DEPARTMENT OF THE INTERIOR

MONOGRAPHS

OF THE

UNITED STATES GEOLOGICAL SURVEY

VOLUME XXX

WASHINGTON
GOVERNMENT PRINTING OFFICE
1898

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

FOSSIL MEDUSÆ

BY

CHARLES DOOLITTLE WALCOTT

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PREFACE.

In a collection of fossils obtained by Dr. Cooper Curtice in the Coosa Valley of Alabama during the summer of 1886 there were a number of siliceous nodules embedding fragments of trilobites and brachiopods of the Middle Cambrian fauna. A few had a radiate-lobed appearance that suggested the sea-urchin, while a few others had what appeared to be a starfish flattened out on the nodule. Large collections were subsequently made by a local collector, Mr. Henry Bufford, but it was not until 1893 that I felt sure that the so-called "star-cobbles" contained fossil medusæ. When I came to the conclusion that this was the case, I began an investigation of the subject, but owing to pressure of administrative duties, the work was frequently interrupted. It was continued, however, in a desultory way until the winter of 1895, when it was pushed to completion. In the course of the investigation I found it necessary to make comparisons with other fossil forms, and having assembled material from the Cambrian strata of Sweden and the Jurassic of Bavaria, I decided to enlarge the scope of the work so as to embrace all fossil medusæ.

In the course of my investigations I frequently consulted with Prof. W. K. Brooks, of Johns Hopkins University, Baltimore, Maryland, and am indebted to him for references to rare publications relating to the subject of the medusæ. The assembling of the literature pertaining to the Jurassic medusæ was the work of Mr. George H. Girty, of the United States Geological Survey; and Mr. Charles Schuchert, of the United States National Museum, aided me in securing material from the Jurassic of Europe. In the endeavor to obtain evidence of the presence of fossil medusæ at different geologic horizons in Europe, I corresponded with and received assistance from Dr. H. B. Geinitz, of Dresden, and Dr. Wilhelm Pabst, of Gotha, Saxony; Dr. Karl Zittel and Dr. J. F. Pompeckj, of Munich, Bavaria; Dr. H. Pohlig, of Bonn, Germany; and Dr. F. A. Bather, of London, England.

FOSSIL MEDUSÆ.

By Charles D. Walcott.

INTRODUCTION.

The occurrence of impressions of medusæ on the Jurassic lithographic limestones of Solenhofen has long been known and is referred to in nearly all comprehensive works on paleontology. In 1881 Dr. Nathorst called attention to certain problematic fossils from the Lower Cambrian rocks of Sweden, which he regarded as casts of the impressions of the lower side of medusæ that had been left on the soft mud by the tide or had been thrown up by the waves; others were thought to be casts of the gastric cavity of a medusa having a large mouth opening and a large gastric cavity. In 1891 I called attention to the Lower Cambrian *Dactyloidites asteroides*, suggesting that it might be the impression of the mouth and gastric cavity of a medusa. In the last four years I have studied, during short intervals of time taken from administrative work, large collections of medusæ from the Middle Cambrian rocks of the Coosa Valley, Alabama. The original plan was to incorporate the results in a monograph on the Middle Cambrian fauna; but now that the study has included the Lower Cambrian and Jurassic types, it seems advisable to publish a separate memoir on the subject of fossil medusæ, in order to place before students a full review of the subject.

The Middle Cambrian medusæ will first be described, and then, in order, the Lower Cambrian of the United States and of Sweden and Bohemia, and the Jurassic of Bavaria.

The known geologic and geographic range of fossil medusæ is shown in the following table:

Table showing the known geologic and geographic range of fossil medusæ.

Jurassic	Bavaria.
Permian	Saxony.
Cambrian	Middle Cambrian: Northern Alabama, U. S. A. Lower Cambrian: New York, U. S. A.; Lugnås, Sweden; Esthonia, Russia; Bohemia.

List of species occurring at each horizon:

Jurassic		Semæostomites zitteli. Eulithota fasciculata. Acraspedites antiquus. Rhizostomites admirandus. Rhizostomites lithographicus. Leptobrachites trigonobrachius. Medusina deperdita. Medusina quadrata. Medusina bicincta. Medusina staurophora. Medusina circularis. Medusina porpitina.
Permian		Medusina atava.
Cambrian	Middle.	Brooksella alternata. Brooksella confusa. Laotira cambria.
	Lower.	Dactyloidites asteroides. Medusina costata. Medusina princeps. Medusina radiata.

There is also to be considered the possibility that the Ordovician species *Bythotrephis (?) radiata* Nich., from the Skiddaw slates, and *Discophyllum peltatum* Hall, from the Lorraine formation, are the remains of medusæ.

Of the evolution of the medusæ, the fossil forms give little positive information. According to Haeckel, the Discomedusæ were among the latest to develop of the Acraspeda. Geologically, their representatives appear in the

Jurassic, and still earlier, in the Middle and probably in the Lower Cambrian. The conclusion is that the acraspedote medusæ were mainly differentiated in early Cambrian if not in pre-Cambrian time. It is evident that we yet have much to learn of the medusiform ancestors of the Hydrozoa.

FOSSIL MEDUSÆ OF THE MIDDLE CAMBRIAN TERRANE.

As related in the Preface, a collection of fossils from the Coosa Valley, Alabama, made in the summer of 1886, contained a number of semicherty nodules, some of which had fragments of trilobites and brachiopods of the Middle Cambrian fauna attached to and buried in them; others had a radiate-lobed appearance that suggested the sea-urchin, while a few of the flat nodules had a fossil spread out on them that resembled a star-fish. Large collections were made during the succeeding years, but it was not until 1893 that I felt assured that the so-called "star-cobbles" were fossil medusæ. There are now more than 9,000 specimens in the collections of the United States Geological Survey. These afford ample material for the study of two types[1] that may be referred to the Discomedusæ.

MODE OF OCCURRENCE.

The shale containing the fossils breaks down into clay on exposure to moisture, heat, and cold, and the siliceous nodules weather out from it and are found in large numbers on the surface and along the drainage channels. Fragments of trilobites, etc., occur in the shale, and are attached to and embedded in many of the nodules, and, more rarely, attached to specimens of the medusæ. The fossils common to the shale and nodules are:

Laotira cambria Walcott.
Acrotreta.
Lingulella.
Scenella.
Stenotheca.
Hyolithes.
Ptychoparia antiquata Salter.
Ptychoparia. 3 sp. (?)
Olenoides curticei Walcott.

Of the nodules, about one-quarter show more or less of fossil medusæ. A few of the larger flat nodules have several medusæ attached to each, but usually a single individual forms the entire nodule, or serves as the nucleus for a nodule that may vary in form and size from all its fellows. It is rare to find two that agree in all respects.

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[1] A notice of these appeared in the Proceedings of the United States National Museum, Vol. XVIII, 1896, pp. 611–614.

CONDITION AND MANNER OF PRESERVATION.

In physical appearance the nodules that weather out of the shale are externally of a dull-yellow or ocher color, and, when unaltered, of a dark color inside. Many of the nodules are slightly calcareous, and when the calcareous matter has been dissolved and oxide of iron developed, there remains a red, yellow, or dark, siliceous, ironstone-like nodule. In these nearly all traces of the medusæ, except the outer form, are lost. The body of the medusa is usually preserved in the sections as a dark-gray or black mass, often with many oolitic-like grains, with the filling of the umbrella beneath the body and arms of a lavender or yellowish-lavender color. (See Pls. IV and XXIII.)

An examination of the character and habits of some of the Discomedusæ shows that, from their mode of occurrence, the Middle Cambrian fossil medusæ appear to have had something of the same habits as the recent Polyclonia and Cassiopea in living on a firm, muddy bottom in large numbers. The associated fossils indicate no great depth of water; and that the habitat of the medusæ was not far from shore is proved by the character of the sediments. The latter, we know, were deposited in the Appalachian sea[1] in an area where calcareous and argillaceous muds and alternating beds of sand were accumulating. These conditions were favorable to the more or less rapid burial of the medusæ that were resting on the bottom or floating in the water.

The endoderm of the recent medusæ, Polyclonia and Cassiopea, is tough and strong, and I obtained a very good cast in plaster of a small alcoholic specimen in which the general form and oral arms are fairly well shown.

Prof. Louis Agassiz states that *Aurelia flavidula*, after the spawning period, is often seen in large numbers floating upon the water. There has been a thickening of the tissues by an increased deposition of animal substance. The disk of the animal has become thin and almost leathery, and it is more elastic, though at the same time more brittle, than it was before. The tentacles are for the most part gone, as well as the eyes, and this decomposition of the margins extends so far that even the marginal tube and parts of the anastomoses have disappeared. The fringes along

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[1] The North American continent during Cambrian time: Twelfth Ann. Rept. U. S. Geol. Survey, Part I, 1891, p. 536.

the margins of the oral appendages gradually drop off, and with them parts of the arms themselves, especially toward the extremities, which become blunt. Professor Agassiz says "the manner in which stranded medusæ are sometimes covered in hot, dry, and windy days by floating sand and molded in it, explains the possibility of acalephs in the fossil state. The few specimens found in the fine-grained limestones of Solenhofen were probably preserved in this way."[1]

In the fall of 1893 I observed great numbers of specimens of Aurelia that had been thrown up onto the sand of the New Jersey beach, in the condition described by Professor Agassiz. They collapsed, however, after a few hours' exposure to the sun and wind.

While experimenting, in 1895, with some living specimens of *Aurelia flavidula* in the Indian River, on the coast of Florida, a large specimen was thrown into the quiet, shallow water at my feet, where it remained for some little time, when I observed that it was lying on its back and that the arms had dried and shrunken in the bright sunlight, and the body had swollen so that the genital openings and the mouth were completely lost. On picking up the medusa, I found it to be firm and hard, and when tossed on the wharf it did not break or tear. The shrunken arms were tough, and it required considerable force to pull them apart. This condition might possibly explain how a medusa, when killed by being overwhelmed by a sudden incursion of muddy sediment into the water in which it was living, might retain its shape a sufficient length of time to have the sediment settle closely about it and its cavities and to solidify, so as to make a mold of its exterior form.

I found no difficulty in securing plaster casts of Aurelia. A bed of soft plaster was prepared and a living medusa taken directly from the water and laid thereon and at once covered by pouring a thin mixture of plaster over it so as to completely bury it in the mass. When the plaster had set, the water in both plaster and medusa was removed by evaporation and an opening made into the cast. It was then found that the plaster had penetrated the genital openings and cavities and the mouth and gastric cavity (so far as the latter was open), and that the cast showed the details of the form of the animal in a very beautiful manner. Photographs of some of the casts are shown on Pls. XXX and XXXI.

[1] Contributions to the Natural History of the United States of America, Vol. IV, 1862, p. 63.

It may be urged that the plaster sets very quickly, and that sediment deposited in the sea would require so much time for its consolidation that an organism as delicate as a medusa would be decomposed and crushed. In this connection I wish to record an observation made at the inlet west of Noyes Point, Rhode Island, which indicates that sediments may consolidate and harden very rapidly under favorable conditions. A deposit, formed of fine sand and silt, hardened to such an extent during the time that elapsed between its deposition by the outflowing tide and the return of the tide that it was broken up by the waves of the latter so as to form a brecciated layer, the fragments of which remained, often with sharp edges, after the ebb of the tide on the following morning. That sediments may set and harden quickly under water is known to those who have waded or dredged in shallow waters in protected bays and inlets.

Mr. H. Archer notes, in the following words, the mode of occurrence of a species that is referred to *Polyclonia frondosa* by Prof. Alexander Agassiz:

A few years ago I was quartered for some time at Port Royal, Jamaica, and in the channels between the mangroves I observed what I at first thought were Actiniæ of large size on the muddy bottom, in about 8 feet of water. They were very numerous. I stirred one up with the boat hook, and was surprised to find it was a medusa turned upside down. On being disturbed it lazily contracted its umbrella in the usual manner and settled down again in the mud as before. The species was about a foot in diameter of umbrella, and dirty white in color. I never saw them swimming in the mangrove creeks, though I was frequently out in a boat, and they were at all times common on the bottom, lying as described. Some time afterwards I saw what seemed to be the same species at St. Georges Bay, a small island about 10 miles from Belize, Honduras. It was lying in the same position on the mud amongst the mangroves, in about 4 feet of water. I poked several up with a stick, and they slowly swam for a short distance and again settled down on their umbrellas. I believe it to be really the habit of the species to lie on its back, as it were, and it is interesting to find another kind in the East acting similarly. Mangrove swamps are extensive in the vicinity of Singapore, but I have not noticed any medusæ here in that position, possibly because there is a considerable tide which leaves the mud bare at low water.[1]

Professor Agassiz, in commenting on Mr. Archer's note, said:

The medusa mentioned by Mr. Archer in Nature, Vol. XXIV, p. 307, is undoubtedly *Polyclonia frondosa* Ag., figured in the Contributions to the Natural History of the United States. This medusa was already known to Pallas, who described alcoholic specimens sent him from the West Indies by Drury. It is stated by Agassiz to be quite common along the Florida Keys. I have myself observed it in great abun-

[1] Nature, Vol. XXIV, 1881, p. 307.

dance at the Tortugas, in the moat of Fort Jefferson, and in the mud flats to the north of Key West. They occur there in from 3 to 6 feet of water, the disk resting upon the bottom, the tentacles turned upwards; the disk pulsates slowly while they are at rest. Their habits when disturbed are well described by Mr. Archer. The young sometimes swim near the surface, and are far more active than larger specimens. When kept in confinement they also creep slowly over the ground by means of their tentacles, or, raising themselves sometimes edgeways against the sides of the dishes, remain stationary for a considerable time. The resemblance of Polyclonia, when at rest upon the bottom, to large Actiniæ with fringed tentacular lobes, such as Phythactis, is very striking. The peculiar habits of Polyclonia were noticed by Mertens in a species named by Brandt *P. Mertensii* in 1838, and found at the Carolines.[1]

Prof. W. K. Brooks informs me that both Polyclonia and Cassiopea occur in abundance near Port Royal, Jamaica, and that there is no way of telling which genus Mr. Archer observed, as their habits are almost identical, and they occur in similar localities.

The mode of occurrence of the fossil medusæ in the Middle Cambrian (p. 3) suggests at once the habit of living on a muddy bottom in great numbers. The same is also true of the Lower Cambrian forms from the roofing slates of eastern New York. It is only by their having some such habit that I can account for the preservation of the medusæ in such great numbers and in such condition as they are found in the shales of northern Alabama.

The conditions most favorable to the preservation of a medusa of the character of Polyclonia and Cassiopea, and consequently the Middle Cambrian species, appear to be rapid burial and consolidation of the sediment, not by exposure between tides, but entirely beneath the water. If the medusa were buried in such a sediment its watery contents would not be drained off and produce a collapse before the sediment that penetrated into the interior and settled about the exterior had time to harden. There is no a priori reason why the external form and the radial, intestinal, and other interior canals should not be preserved under such favorable conditions. Not one in a hundred of the fossil specimens, however, show traces of any structure within the body, and, so far as known at present, the particularly favorable conditions required, even for this partial preservation of the structure of the medusæ in a fossil state, were confined during geologic time to the vicinity of the spot in the Cambrian sea that is now occupied by the township of Cedar Bluff, Cherokee County, Alabama.

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[1] Nature, Vol. XXIV, 1881, p 509.

RELATION TO OTHER FOSSIL MEDUSÆ.

Since the publication of the notes on the Lower Cambrian medusæ, in 1891,[1] much more has been learned respecting the Middle Cambrian forms; and it now appears to be possible to establish a family relation between the Lower Cambrian *Dactyloidites asteroides* and the Middle Cambrian genera, Brooksella and Laotira. The specimens of Dactyloidites are usually pressed out flat in the laminæ of the slates, only a thin film remaining as a dark stain on the slate. (See Pl. XXVI.) In one instance some fine sand was mixed with the argillaceous mud, and on a single large slab a few specimens are a little convex. One of the best of these is shown by fig. 2 of Pl. XXIV. It is a beautiful specimen, in which the interior radial canals are indicated within an inner portion of the lobes, which is separated from the dark surrounding slate by a semitranslucent outer part of the lobes that strongly resembles the sarcode of a recent medusa. Fig. 1 of Pl. XXV is another somewhat convex specimen, but it does not show any traces of the interior structure. With the exception of fig. 2 of Pl. XXIV, all the specimens of Dactyloidites are very much compressed and distorted. For comparison with *Laotira cambria*, compare fig. *e* of Pl. XXVI with fig. 5 of Pl. XXII; fig. *d* of Pl. XXVI with fig. 6 of Pl. VI; fig. 1 of Pl. XXV with fig. 10 of Pl. V; and fig. 2 of Pl. XXIV with fig. 2 of Pl. XXI.

The foregoing comparisons, and many others that can be made with the abundant material in the collections, establish the relation between the Middle Cambrian genera and Dactyloidites. Of the two genera, Brooksella appears to be nearer the latter than does Laotira.

To the Lower Cambrian species of Sweden there is little apparent similarity outside of their ordinal or subordinal relationship in belonging to the Discomedusæ. This applies to *Medusina costata* and *M. princeps*. The position of *M. radiata* is much more doubtful.

The well-identified Jurassic species are referred by Dr. Ammon to the Discomedusæ and the suborders Semostomæ and Rhizostomæ. Except that the Middle Cambrian species may possibly belong to the Rhizostomæ, and that three of the Jurassic are referred to the same, there appears to be no opportunity for further detailed comparison. The transverse vertical section

[1] Fauna of the Lower Cambrian or Olenellus zone: Tenth Ann. Rept. U. S. Geol. Survey, pp. 587, 605, 606.

of Brandt's restoration of Rhizostomites (text fig. 18, A, p. 80) is strikingly similar to that of *Brooksella alternata* (text fig. 1, below), but the similarity is one of an ordinal or subordinal character.

RELATION TO LIVING MEDUSÆ.

It is not to be supposed that the Cambrian medusæ were similar to any living species, genus, or family. The great time interval and the changes that have taken place in the associated fauna lead us to look for only slight resemblance to the living forms.

Nothing is known of the genitalia or sense organs of the Middle Cambrian fossil medusæ. The general form of Brooksella is depressed discoidal, and the stomach is surrounded by radial canals. These characters enable us to place it in the Discomedusæ, while the closed mouth and oral arms suggest the Rhizostomæ. The accompanying diagrammatic restoration of a vertical section of *Brooksella alternata* (text fig. 1), when compared with the vertical section of *Cannorhiza connexa* (text fig. 3, p. 11), illustrates the ordinal relationship between them, and one is almost inclined to refer the Cambrian species to the Rhizostomæ, and thus place them in the same family. The lack of knowledge of many critical features of the fossil form compels its reference to a distinct family. Among the living species, *Archirhiza primordialis* is considered by Dr. Haeckel to be the simplest and most primitive form of all the known Rhizostomæ.[1] The disk-shaped umbrella; simple, undivided, almost cylindrical oral arms; individual marginal lobes; simple form of canal system, all suggest the Middle Cambrian type much more closely than any other recent form. To enable the student to make direct comparisons, the view of the lower side of the medusa is reproduced from Haeckel (text fig. 2, p. 10).[2] The canal system is more complex than in Brooksella; and there are other marked differences. It is instructive,

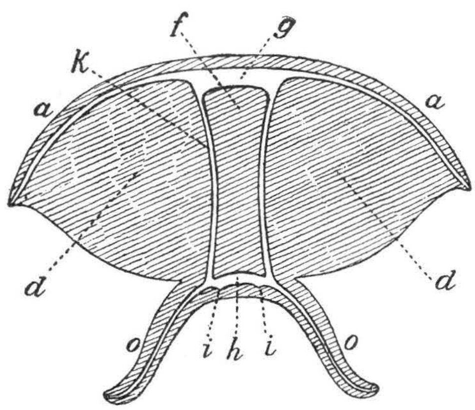

FIG. 1.—*Brooksella alternata.* Central vertical section. For description of figure, see text fig. 4, p. 28.

[1] System der Medusen, 1880, p. 565.
[2] System der Medusen, Atlas, 1879, fig. 2 of Pl. XXXVI.

however, to compare the lobed margin with that of figs. 7, 7a of Pl. XVII. The four oral arms of Brooksella are not known to have been subdivided (see Pl. II, figs. 8, 8a); nor is there any trace in the fossils of a system of sucking pores, corresponding to the sucking frill on the axial side of the arms of Archirhiza. That such sucking pores existed is highly probable.

The transverse section of the recent *Cannorhiza connexa* Haeckel is of value in interpreting the structure of Brooksella. The section shows the main radial canals extending from the central stomach to the margin, pillar canals,

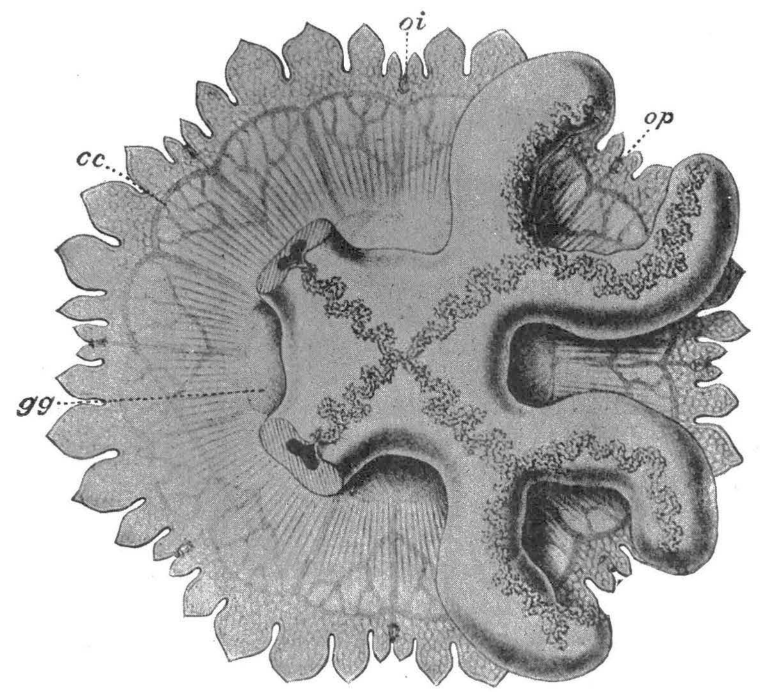

FIG. 2.—*Archirhiza primordialis* Haeckel. View from below; twice the natural size. The two paired arms of the left half are cut away. In the center of the arm disk the regular cross of the mouth seam is visible, the four branches of which fork at the ends of the brachial trunks. *op*, perradial sensory button; *oi*, interradial sensory button; *cc*, ring canal.

arm pillars, buccal stomach, oral arms, brachial canals, and sucking mouths. In the fossil forms (Pl. II, fig. 8b) the oral arms, brachial canals, base and pillar canals, radial canals, and central stomach are more or less clearly shown. These are all general features, but taken in connection with the character of the umbrella, they serve to classify the Brooksellidæ under the Discomedusæ, but not to establish their family relation with any of the living families.

The living forms of medusæ that resemble Brooksella and Laotira most clearly in their habits appear to be Polyclonia and Cassiopea (pp. 6, 7).

Beyond the appearance of the surface of many of the complex, irregular forms of *Laotira cambria*, which suggests the anastomosing base of some of the hydroids (*Campanularia johnstonia*[1]), there do not appear to be any points of comparison between the Middle Cambrian forms and the hydroids.

LITHOLOGIC CHARACTERS OF THE SILICEOUS NODULES.

A thin section from a nodule containing fragments of the trilobite *Olenoides curticei*, when examined under the microscope, shows that the space once occupied by the test is now filled by quartz crystals, grown

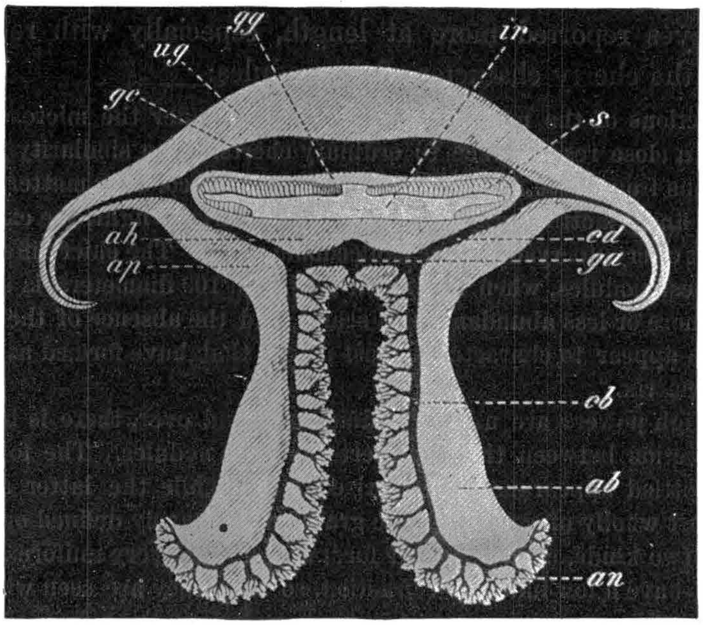

FIG. 3.—*Cannorhiza connexa* Haeckel. Adradial section. *ug*, gelatinous umbrella; *gc*, central stomach; *gg*, bottom of the central stomach (gastrogenital membrane, with the genitalia, *s*); *ir*, subgenital porticus; *ah*, brachiferous plate; *ap*, arm pillars; *cd*, pillar canals; *ga*, buccal stomach; *ab*, oral arms (adradial); *cb*, brachial canals; *an*, funnel frills (sucking mouths).

from the matrix toward the center of the spaces. Lines of opaque particles indicate the former presence of the test. The sections of the trilobite tests are well defined, and the quartz crystals are much larger than those in the body of the nodule.

At my request, Prof. Joseph P. Iddings and Dr. C. Willard Hayes both studied the microscopic characters of the nodules, and they arrived at essentially the same conclusion in regard to them.

[1] A Monograph of the Gymnoblastic or Tubularian Hydroids, by George James Allman (a publication of the Ray Society), Part I, 1871, p. 23, fig. 2.

Professor Iddings states his conclusions briefly in these words:

The siliceous nodules consist of a mixture of granular quartz in allotriomorphic grains, occasional flakes of muscovite-mica, and a small amount of calcite in minute particles, numerous gas pores, and some coloring matter, probably carbonaceous. In one section there was a considerable amount of minute crystals, with very pronounced pleochroism, blue, purplish, and colorless, which is undoubtedly dumortierite, basic silicate of aluminum.

Of the shale in which the nodule occurs, he says that a thin section shows very fine scales of mica in each micro-cryptocrystalline matrix, the only knowledge of which that we have is from chemical analysis.

Dr. Hayes reported more at length, especially with relation to the question of the cherty character of the nodules:

Thin sections of the nodules, when examined under the microscope with low powers, show a close resemblance to ordinary cherts. The similarity is particularly close in sections from those nodules which are free from coloring matter, as iron oxide. They have a finely mottled-gray appearance in polarized light, the extinction being similar to that of cryptocrystalline or chalcedonic silica. The chief difference between cherts and these nodules, when magnified less than 100 diameters, is the presence in the latter of more or less abundant mica scales, and the absence of the rhombohedral cavities which appear to characterize most cherts that have formed as concretions in a calcareous matrix.

When high powers are used, 400 diameters and over, there is in every case a marked distinction between the true cherts and the nodules. The former show the same gray-mottled appearance in polarized light, while the latter are seen to be made up almost wholly of extremely fine grains with sharply defined outlines. These grains are of two kinds, although their form and size are very uniform. The first are colorless and have a low index of refraction, so that they are seen with difficulty in ordinary light. They come out prominently in polarized light, having sharp extinction and sometimes bright polarization colors. It seems quite probable that these are extremely fine grains of original detrital quartz.

The second kind of grains have a high single refraction and contain some coloring matter, so that they stand out prominently in ordinary light. They have very little, if any, double refraction, so that they remain practically black between crossed nicols. These grains are probably a hydrous silicate of alumina—that is, clay.

The color of the nodules is due chiefly to hydrated iron oxide. They contain also some carbonaceous matter, in extremely fine dust-like grains, and also some very small opaque cubes or octahedrons, probably pyrite or magnetite. They also contain more or less detrital mica scales, as mentioned above. If they contain amorphous silica, it is an inconsiderable amount.

In most cases no concentric structure, due to true concretionary growth by the deposition of successive shells about a nucleus, appears either in polished sections of the nodules or under the microscope. In some cases the nodules are clearly stratified;

the lamellæ, marked by abundant parallel mica scales, pass directly through the nodule. In these the nodule is apparently due to the silicification of a portion of the stratified mud, which originally differed but slightly, if at all, from that which formed the mass of the surrounding shales.

MODE OF OCCURRENCE OF THE SILICEOUS NODULES.

The description of the mode of occurrence of the siliceous nodules is based largely on notes prepared by Dr. C. Willard Hayes, who mapped the areal geology of the region and studied the rocks with great care. I made a hurried trip to the region in which the nodules occur, in company with Dr. Cooper Curtice and Mr. S. W. McCallie, of the Geological Survey of Alabama, in the summer of 1895.

The shale from which the "cobbles" or siliceous nodules were derived is finely laminated, greenish, yellowish, or gray at the surface, and generally bluish-black below drainage. They are found in several narrow bands, extending northeast and southwest, near the center of the Coosa Valley. These alternate with other bands of brown argillaceous shales and bands of interbedded shale and limestone. Although the evidence is far from conclusive, it appears probable that the cobble beds belong in the highest, the limestones in the intermediate, and the brown shales in the lowest division of the Coosa Valley formations. If this is the case, the cobble beds correspond with beds of greenish micaceous sandstone along the southeastern side of the valley. In some places these sandy beds can be traced directly into the cobbles through all intermediate gradations. The sandstone beds become thinner, the grains finer, and the silicification less uniform, resulting at first in thin plates slightly more resistant than the mass of the shale, then broad, thin lenses, and finally the flat ellipsoidal cobbles. Also, the cobble beds probably correspond with the shales on the northwest side of the valley, which carry thin plates of limestone and calcareous nodules, the latter closely resembling the siliceous nodules in which the medusæ are found. They vary considerably in the amount of calcareous matter which they contain, from nearly pure to highly siliceous limestone. The silica appears to be original and not secondary, due to replacement since the rock solidified.

If the above correlation is correct, there is a marked change in the composition of contemporaneous deposits from southeast to northwest—from silicified micaceous sandstone, through argillo-siliceous shales containing siliceous nodules to argillo-calcareous shales containing calcareo-siliceous nodules Owing to the folding and fracturing of the strata, it is impossible to prove that the sandstones, siliceous nodules, and calcareo-siliceous nodules were deposited at the same identical horizon or formed in the same period of time This is probable, but in the absence of an unbroken stratum and a similar fauna it can not be proved.

The shale is hard and compact in its unweathered portions.

CHEMICAL CHARACTER OF THE NODULES AND SHALE.

Partial analyses, by Dr. H. M. Stokes, of the Geological Survey, of the dark inner portion and the red outer portion of one of the fossil medusæ (nodules) give the following results:

Analyses of portions of a fossil medusa.

	Dark inner portion.	Red outer portion.
SiO_2	88.33	85.13
Al_2O_3	4.45	5.15
Fe_2O_3	trace	3.53
$CaCO_3$	*a* 3.91	*b* 3.40
	96.69	97.21

a Pure CO_2 1.72. *b* Pure CO_2 1.50.

The following analysis of the shale, by Dr. Stokes, shows that the mud or sediment in which the medusæ were buried was highly siliceous:

Analysis of the Coosa shale.

	Per cent.		Per cent.
SiO_2	55.02	SrO	trace
TiO_2	.65	CaO	1.60
P_2O_5	.06	MgO	2.32
CO_2	.83	K_2O	3.19
SO_3	.02	Na_2O	.81
Cl	trace	Li_2O	.03
Al_2O_3	21.02	Carbonaceous matter	*b* .32
Fe_2O_3	5	H_2O below 110°	2.44
FeO	*a* 1.54	H_2O above 110°	*c* 5.65
MnO	trace		100.54
BaO	.04		

a FeO approximate only, owing to presence of organic matter.
b Represents only the carbon of the organic matter.
c Includes water from oxidation of organic matter.

SILICIFICATION.

To the biologist the suggestion of silicified medusæ is a violent attack upon his previous conceptions of such organisms and the possibilities of their preservation as fossils in any other manner than as faint impressions on fine limestone, sandstone, or shale. The fact is, however, that they occur in a silicified condition, and we now have to consider how this may have come about.

If the views expressed in the foregoing section on the "Condition and manner of preservation" (pp. 4–7) are correct, the Middle Cambrian medusæ under consideration lived in relatively shallow water, not far from the shore line. It is also inferred that they were quickly overwhelmed and buried in a siliceous mud that was subsequently consolidated to form a siliceous shale. There are certain features, however, connected with the external appearance of the nodules which strongly indicate that they were exposed for some time near to or directly on the bed of the sea. The former is more probable, as it is difficult to give any explanation of the preservation and silicification of an organism like a medusa on the bed of the sea. Nature performs so much of her chemical work in the consolidating mud or ooze just below the surface, that this has been aptly called the "chemical laboratory of the sea." The external features referred to are the presence of casts of annelid trails, entire trilobites, brachiopods and pteropods (Pl. XV, figs. 1 and 5; Pl. XVI, figs. 6, 7, 8) attached to the outer surface of the nodule, and medusæ like those represented by figs. 7 and 8 of Pl. XVII, figs. 3 and 5 of Pl. XXI, and figs. 2, 3, 5, and 6 of Pl. XXII. In many instances the medusa is entirely buried in the nodule; in others partially, and often only a small amount of matter was deposited between the lobes and about the oral arms.

The mode of occurrence of the tests of trilobites, usually in fragments but often entire, suggests the formation of a nodule about a fragment, or a mass of fragments, resting on or embedded in the ooze. That the nodules did not reach a larger size than 20^{cm} in diameter is probably owing to the rapid deposition of mud on and over them,[1] or to the consolidation and hardening of the sediment in which they were forming before the silicifying solution could build up a larger nodule.

[1] I have observed masses of fossils and calcareous matter in the Niagara calcareous shales of Waldron, Indiana, some of which were several feet (2 meters or more) in diameter and a foot or two (one-half meter or more) in thickness.

The inference that the nodule remained for some time in a relatively plastic condition is proved by the presence, in several hundred sections, of fine annelid borings that penetrate the nodules in all directions, cutting through medusæ and matrix alike (Pl. XXIII, figs. 10 and 11). This occurs whether the specimen of medusa is a cast of its outer mold or of its body, appendages, and interior parts. The casts of the borings are filled with material differing from the surrounding matrix in color and composition, and often it has dissolved and left minute openings. Many nodules have vertical borings (Scolithus-like) passing through them. Sometimes there is a hole or filling from bottom to top, and often only surface markings remain, as shown by fig. 8 of Pl. XVI.

Were the nodules calcareous or siliceous as they were originally formed? To the student of the processes of mineralization or fossilization of organisms the view is at once suggested that the nodules were at first calcareous and that the calcite was subsequently replaced by siliceous matter brought in by silicifying solutions. Just how the medusæ were calcified and preserved it is difficult to understand. If they were as firm of substance as the recent Discomedusæ, Polyclonia and Cassiopea, and were buried in mud that set quickly, a very good mold might result. The animal matter would have to be replaced rapidly by the calcite if the interior canals, etc., were to retain their true relations to the umbrella lobes and other parts. If, however, all of the interior parts were destroyed the mold might be filled in by calcite and a cast of the exterior form of the medusa result. Among the fossil medusæ many specimens preserve the interior canals, but such is not the case in a majority of specimens. Hundreds occur in which there is not a trace of any of the interior parts (Pl. XXIII, fig. 9). If the original mineralization was by calcite the replacement by silica, deposited from infiltrating silicifying solutions, could take place at any time after the deposition of the calcareous matter. Usually such replacement occurs long after the embedding sediment is hardened into rock. If the silicification was by replacement of calcite, we must assume that the radial and other canals were filled and preserved at the time of the deposition of the calcite, also the numerous annelid borings that must have also existed in the medusa, and the surrounding material that gave shape to the nodule. Such a theory is scarcely tenable with any of the specimens showing the interior canals of the medusæ or the borings of annelids.

The analysis of the shale shows only a trace of calcareous matter and 53 per cent of silica. The nodules are almost wholly siliceous, the calcite occurring as microscopic points embedded in the siliceous matter. An analysis of a portion of a nodule, within the body of a medusa, shows 88.33 per cent of silica and 3.91 per cent of calcite. If the sediment which now forms the shale buried the medusæ in it, the process of mineralization must have gone on within the highly siliceous mud. If the sediment set quickly it is possible that the form of the medusa was preserved, and that the silica was deposited directly from the alkaline silicates precipitated in connection with the presence of organic matter. This would account for the formation of the siliceous nodules without the intervention of calcite and the secondary replacement by silica. The process of silicification might then have taken place in the manner suggested, and, when this had once begun, additional deposits might have been made so as to form a nodule or concretion about the medusa. From the presence of a large number of nodules in which there are few traces of medusæ, or any other organic forms, it appears that nodules of siliceous matter were also formed independently of the presence of the medusæ.

In the case of the medusæ preserving the interior canals, it is probable that the canals and internal cavities of the medusa were filled at once, to a greater or less extent, by the soft siliceous ooze or mud. As the animal matter decomposed, the ooze gradually took its place, and then began the silicification of the sediment that resulted in the formation of the cast of the medusa, and of the nodules by the extension of the silicification into the surrounding sediment. Either before or while this was going on, the annelids bored their way through the medusa and the surrounding matrix. This appears to be the most probable explanation of the preservation of the medusæ and the formation of the nodules.

SOURCE OF THE SILICA.

The silica that forms so large a portion of the shale is probably derived from the original detrital quartz, which occurs in microscopic grains, and from that deposited in the sediment from the solution of siliceous organisms that were buried in the mud or were present on the bed of the sea. The soluble silica undoubtedly furnished some of the silica that formed many of the nodules. It may be urged that the silica was deposited directly from the sea water without the intervention of any organic agency. In answer to this suggestion, and also to show the drift of opinion in relation to the origin of the silica forming the flints of the Cretaceous, I will quote the opinions and conclusions of several authors.

In a contribution to the physical history of the Cretaceous flints,[1] Dr. Wallich arrived at the following conclusions:

> 1. That the silica of the flints is derived mainly from the sponge beds and sponge fields which exist in immense profusion over the areas occupied by the globigerine or calcareous "ooze." 2. That the deep-sea sponges, with their environment of protoplasmic matter, constitute by far the most important and essential factors in the production and stratification of the flints. 3. That whereas nearly the whole of the carbonate of lime, derived partly from Foraminifera and other organisms that have lived and died at the bottom, and partly from such as have subsided to the bottom only after death, goes to build up the calcareous stratum, nearly the whole of the silica, whether derived from the deep-sea sponges or from surface Protozoa, goes to form the flints. 4. That the sponges are the only really important contributors to the flint formation that live and die at the sea bed. 5. That the flints are just as much an organic product as the Chalk itself. 6. That the stratification of the flint is the immediate result of all sessile protozoan life being confined to the superficial layer of the muddy deposits. 7. That the substance which received the name of "Bathybius," and was declared to be an independent living Moneron is in reality sponge protoplasm. 8. That no valid lithological distinction exists between the chalk and the calcareous mud of the Atlantic; and pro tanto, therefore, the calcareous mud may be and in all probability is a continuation of *the* Chalk formation.

Dr. Sorby, in discussing these conclusions of Wallich's, stated[2] that he—

> had formerly studied this subject and come to the conclusion that, though deep-sea mud differs from chalk in many important particulars, yet still it was sufficiently related to warrant a comparison. Since the remains of siliceous organisms are absent from the chalk, but flint present, whilst in the deep-sea mud siliceous organisms are abundant and flints absent, probably the material of the flints had been to a greater or less extent derived from these organisms. Much, however, remains to be learned.

Prof. W. J. Sollas, in his article on the flint nodules of the Trimmingham chalk,[3] in commenting on this argument, considers that it is not an analogy, but is in reality nothing less than a statement of fact. He then proceeds to prove that the Trimmingham flints have not only sponge spicules intimately associated with them in great numbers, but that the spicules afford clear proof of the previous existence of a great mass of spicules of

[1] Quart. Jour. Geol. Soc. London, Vol. XXXVI, 1880, p. 90.
[2] Loc. cit., p. 91.
[3] Annals Mag. Nat. Hist., 5th series, Vol. VI, 1860, p. 438.

which those preserved are but a remnant. He describes the accumulation of sponge spicules and their solution, and summarizes on the latter as follows:[1]

1. Fossil sponge spicules are frequently eroded externally, and their axial canals enlarged internally; 2, all flesh spicules, necessarily once present, have entirely disappeared; 3, in many chalk flints Ventriculite and Lithistid skeletons occur, perfectly preserved as to form, but not as solid network, merely as empty casts; 4, the skeletons of many fossil sponges have exchanged a siliceous for a calcareous composition.

The mode of solution of the spicules is one of great interest in this connection, and Professor Sollas quotes Julian, where he suggests that the humus acids produced during the submarine decomposition of organic matter may have been the agents which accomplished the solution. He says: "This may very possibly have been the case, though possibly the water at the sea bottom may, even without the assistance of these substances, have been a sufficiently powerful solvent."

In reference to the redeposition of silica, Professor Sollas considers that there are three different modes by which the deposition may have been effected: First, simple deposition; second, deposition as pseudomorph after carbonate of lime; and third, deposition in combination with bases, forming silicates. Under the first, he describes deposition by simple crystallization of quartz from siliceous solution, which disposes of the view that the presence of an organic nidus is necessary. The deposition of silica as a pseudomorph after carbonate of lime he considers to be the method of formation of flint and chert. Some of the Trimmingham flints consist within of ordinary flint, black, translucent, and compact, but exteriorly simply of ordinary chalk, with a few siliceous remains scattered through it. Between these two he found every intermediate stage of silicification. He says:[2]

Passing from the chalk to the flint, one finds first the coccoliths, foraminifers, and other calcareous constituents of the chalk converted into silex, the siliceous pseudomorphs retaining all the details of their original form down to the delicate striæ on some of the foraminiferal tests; from the mixture of chalk material and its siliceous pseudomorphs, we proceed nearer the flint and reach a porous superficial layer, formed by the cementation of the siliceous pseudomorphs together into a siliceous network; the side of this network next the flint enters half immersed into it, as it were; a step further and we reach the flint itself, the siliceous pseudomorphs being

[1] Annals Mag. Nat. Hist., 5th series, Vol. VI, 1860, p. 443. [2] Loc. cit., p. 447.

now completely involved and no more distinguishable from one another in the common "fusionment" than the separate snow crystals of a mass of snow which has been frozen by infiltrating water into ice.

As to the deposition of silica in combination as a silicate, Professor Sollas sees no difficulty in the supposition that the dissolved silica derived from siliceous organisms should combine with the impurities present in the surrounding sediment, and so give rise to glauconitic deposits; thus, with such matters as iron oxide, alumina, and potash, the silica is supposed to combine, while carbonate of lime merely replaces.

In discussing the quantity of available silica in the waters of different regions, Messrs. Murray and Renard[1] state that silica was always found whenever specially looked for. The analyses, when arranged into a maximum set of determinations, show one part of silica in 9,000 to 8,200 parts of sea water. When carefully filtered the average proportion from pure sea water is one part of silica in 250,000 parts of sea water. This appears to be almost constant in purely oceanic waters, coast waters, and in many river waters. The amount of soluble silica in sea water is thus so small that these authors consider it impossible that this is the exclusive source of the silica. They consider the probability of the pelagic organisms which secrete silica obtaining it from the hydrated silicate of alumina or clay held in suspension as well as the silica held in solution.[2] This might explain the fact that these organisms abound in brackish waters and waters of low salinity and low temperature, where the clay is more abundant than in the warmest and saltest waters of the ocean.

In the case of siliceous sponges, which are rooted for the most part in the oozes and clays, Messrs. Murray and Renard think that the silica of their skeletons may be derived from the silica in solution in sea water, or from the colloid silica set free during the decomposition of the feldspathic rock fragments and minerals in the deposits.

In an article on beds of sponge remains in the Lower and Upper Greensand of the south of England, Dr. Hinde gives an interesting account of the mode of occurrence of the cherts in England, Germany, France, and Belgium.[3] In the discussion of the mineral conditions of the sponge remains and the beds derived from them, Dr. Hinde states that no fossil

[1] Rept. Voyage H. M. S. *Challenger;* Deep-Sea Deposits, 1891, pp. 286–288.

[2] See also Murray and Irvine, On silica and the siliceous remains of organisms in modern seas: Proc. Royal Soc. Edinburgh, Vol. XVIII, 1891, pp. 246–250.

[3] Philos. Trans. Royal Soc. London, vol. 176, 1886, pp. 403–448.

sponge is yet known in which the spicular skeleton retains its original transparent hyaline condition; the silica in all now presents numerous gradations between the amorphous, or colloid, and the crystalline state.[1] It also frequently occurs that the silica has been partially or entirely dissolved and replaced by calcite, glauconite, or other minerals, or entirely removed, leaving the empty cast of the spicule.[2]

The existence of hexactinellid sponges in the Middle Cambrian sea is proved by the presence of casts of characteristic spicules on the exterior of a few nodules, and in one instance a nodule appears to have had many of the spicules as a nucleus. It is very probable that these few spicules are all that remains of an extensive growth of siliceous sponges, the great mass of the spicules of which disappeared by solution prior to the consolidation of the sediment.

RELATION TO THE SPONGES.

Early in my study of the Middle Cambrian fossils now referred to the Medusæ, the question came up whether they were not a peculiar form of siliceous sponge. The same question has also been suggested by others when first looking at the specimens. After the preliminary study the material was laid aside for nearly two years before the final examination was made. In both the conclusion was that the fossils are the remains of medusæ. The points of resemblance to the sponges are found in making comparison of the exterior form with *Hallirhoa costata* Lamx.[3] and *Brachiospongia digitata* Owen,[4] and of the interior canals with those of *B. digitata.* The resemblances, however, are of a superficial character.

An examination of a large number of thin sections has failed to show any traces of spiculæ. But this is not conclusive, as the spicules, if present, might have been destroyed in the process of mineralization. In addition to the form and organization of the medusæ, the most conclusive evidence to my mind that the forms under consideration are not sponges is the presence of compressed specimens in the shale where only a slightly carbonaceous film remains, as shown by fig. 7 of Pl. VIII and the Lower Cam-

[1] I find that the term "colloid" is used by chemists for gelatinous silicate, and by Dr. Hinde and others for the opaline or amorphous silicate. I think that it should be limited to the former use, and the term "opaline" used when reference is made to the spiculæ of sponges and to the siliceous shells of diatoms, etc.

[2] Loc. cit., p. 425.

[3] Cat. Fossil Sponges, 1883, Pl. XIV.

[4] As figured by Beecher; Mem. Peabody Museum of Yale Univerity, Vol. II, Part I, 1889, Pls. I–III.

brian forms seen on Pls. XXIV–XXVIII. The occurrence of such forms as those shown on Pls. I–VIII in the same shale with a compressed specimen like fig. 7 of Pl. VIII is scarcely conceivable if they were siliceous or calcareous sponges. Nearly all of the Lower Cambrian specimens are thin films of slightly carbonaceous matter between the laminæ of the slate. Annelid trails and burrows in the same slates are usually compressed to a thin film, but often they are preserved so as to show a round or oval transverse section. Only in a few rare instances have the fossils referred to the Medusæ shown any convexity. When this occurs, as in fig. 2 of Pl. XXIV, and in fig. 1 of Pl. XXV, it suggests a partially compressed medusa. Fig. 7 of Pl. VIII could not have been compressed after the mud was hardened into rock, as the fragments of trilobites and brachiopods in the shale show no evidence of any considerable amount of compression. A few nodules of chert associated with the Medusæ cherts have large, well-preserved casts of spicules of a hexactinellid sponge (Protospongia?) attached to their outer surface, and in one instance buried in the body of the nodule.

I have called attention to the possibility of the Middle Cambrian forms being referred to the Spongiozoa in order to anticipate such suggestion and to explain that it has been considered as one of the possibilities in determining the character of the remarkable fossils now under consideration.

DESCRIPTION OF GENERA AND SPECIES.

Order SCYPHOMEDUSÆ (ACRASPEDA).

Suborder DISCOMEDUSÆ.

Family BROOKSELLIDÆ.

Genera .. { BROOKSELLA. LAOTIRA. DACTYLOIDITES.

Genus BROOKSELLA Walcott.

Brooksella Walcott, 1896. Proc. U. S. Nat. Mus., Vol. XVIII (1895), p. 611.

Discomedusæ with a lobate umbrella, 6, 7, to 12 or more lobes; without tentacles and without (?) central oral opening; with a simple radial canal in each lobe of the umbrella and each interradial lobe, when the latter are present. Oral plate quadripartite, with four oral arms starting out from it, but whether these branch or not is not known. A second type of oral arms may be represented by the interradial lobes. Type, *Brooksella alternata.*

BROOKSELLA ALTERNATA Walcott.

Pls. I–IV.

Broksella alternata Walcott, 1896. Proc. U. S. Nat. Mus., Vol. XVIII (1895), p. 612, Pl. XXXI, figs. 1–5.

The variation is so great in this species that a brief specific diagnosis is of little value. For the purpose of special description the external form and parts will first be considered and then what is known of the "gastro-vascular" system. The average size of the specimens thus far collected is about 4^{cm}. A few individuals reach 5^{cm}, and a number occur below 2^{cm} in diameter, but none less than 1^{cm}.

Umbrella.—The general form of the umbrella as preserved in the fossil state varies from subspherical to a somewhat depressed convex disk. Following Haeckel, the dorsal surface will be called the *exumbrella;* the ventral surface, the *subumbrella;* the central section of the umbrella inclosing the stomach and oral organs, the *umbrella disk;* and the peripheral section, or umbrella margin, the *umbrella corona.* The least compressed specimen is illustrated by figs. 4, 4a, 4b of Pl. I. These give the impression that the medusa, when living and floating in the water, was nearly spherical, with the exception of a flattening of the dorsal pole; this, however, is probably misleading, as these specimens presumably represent the umbrella when contracted, the expanded condition being seen in such specimens as those shown in figs. 1 and 2 of Pl. I, figs. 1, 1a of Pl. III, etc. In the latter the radial ribs of the subumbrella would be drawn up, but not, normally, as far as in fig. 3a of Pl. I.

Exumbrella.—The form and character of the exumbrella vary, owing to (1) original form and (2) condition of preservation.

1. In its original form the lobation was more or less clearly defined and varied. Individuals of nearly the same size have from 6 to 12 lobes; in some the lobation starts from the center of the umbrella, and the surface of the lobes is on the general surface plane (Pl. I, figs. 1 and 3), while in others a secondary system of lobes appears from beneath the upper lobes and gives great irregularity to the surface. (Pl. I, figs. 7 and 8; Pl. II, figs. 5 and 6.)

2. The influence of the condition of preservation is readily seen in the form of the umbrella in distorted and broken specimens, but it is not so easily determined with relation to the presence or absence of the gelatinous matter that is so prominent in the umbrella of recent species of the Acraspeda. In some individuals it appears to be present (Pl. I, figs. 1, 2, 3, 4), while in others the firm, supporting ectoderm appears to have shrunk so as to leave only a skeleton form of the umbrella (Pl. I, fig. 7; Pl. II, figs. 5 and 6). Frequently the medusa is completely embedded in the siliceous matter of the nodule, and it is only by cutting sections that its form can be observed. The embedding may be entire (Pl. IV, figs. 10, 11, 13) or partial (Pl. III, figs. 2, 9; Pl. IV, figs. 1, 3, 5, 8).

The lobation of the umbrella is rarely, if ever, lost; it is the dominant character in all the specimens, and extends from or near the center to the margin and forms the lobate marginal border (Pl. I, figs. 1, 2, 4), which is often deeply indented (Pl. III, figs. 1, 5, 6). The lobes vary in number from 6 to 20, or more, and in form from broad, slightly rounded to narrow and strongly rounded. There is no regular sequence of 6, 8, 12, etc.; on the contrary, the irregular numbers 5 and 7 are largely represented (Pl. I, figs. 4 and 5; Pl. III, fig. 1), and 6 and 8 are abundant. The sinus between the lobes may be merely a depressed line (Pl. I, figs. 1, 2, 3), or it may cut through to the base, leaving only the central portion of the lobes attached to the umbrella disk (Pl. 1, figs. 5, 7, 8; Pl. III, figs. 3, 5, and 6), or it may be irregular, varying in size and arrangement (Pl. I, figs. 7 and 8; Pl. II, fig. 5). In the former instances the umbrella is symmetrical and relatively smooth, while in the latter the surface is broken by the normal series and a secondary series of lobes that may be represented in an individual by a single narrow lobe projecting from between and beneath two of the upper lobes (Pl. I, fig. 6, *x*), or by a much larger number, as seen in Pl. II, fig. 1, where eight project from beneath the upper series. The variation in the latter group is considerable and is not reducible to any serial tabulation.

The more regularly lobed individuals may be taken as the first type of the species (Pl. I, figs. 1, 2, 3, 4), and the irregularly lobed as a variety (Pl. I, figs. 6 and 7; Pl. II, figs. 1 and 3). So many gradations occur between the two extremes (fig. 4 of Pl. I, and fig. 1 of Pl. II), that I do not find it practicable to distinguish two species or even varieties. The passage from the typical forms (Pl. I, figs. 1 to 4) to the variety represented by figs.

5, 6, and 7 of Pl. I and fig. 1 of Pl. II is unbroken. It is partially represented by figs. 1, 2, 3, 4, 6, 7, and 8 of Pl. I and figs. 1 and 7 of Pl. II.

Subumbrella.—The subumbrella, exclusive of the oral disk and its appendages, varies to nearly as great a degree as the exumbrella. Strong ridges or ribs radiate from the center to each of the principal lobes of the exumbrella; and sometimes the lobes separate above, so that there is little more than the central umbrella disk with a series of attached plates, like broad spokes in a wheel (Pl. I, figs. 5, 5a; Pl. III, figs. 5 and 6).

In addition to the main radial ribs that connect the principal lobes of the exumbrella with the body of the umbrella disk or axis, there is a varying number of secondary, minor ribs that are connected with the smaller secondary lobes (interumbrella) that project from between the principal lobes and the radial subumbrella ribs. In fig. 6 of Pl. III the 8 regular radial ribs are present that correspond to the 8 lobes of the exumbrella. Three of the ribs are represented by their broken bases next to the central axis. In fig. 4 of Pl. I there are 7 exumbrella lobes and one extra rib (*a*) that was attached to the interlobe. At *x* (fig. 4a of Pl. I) an interumbrella lobe appears that is not attached to the central axis by a subumbrella rib. The rib *b* is broken down at the axis, but its point of attachment is indicated. In fig. 8a of Pl. I 6 radial ribs unite at the base of the central axis and 3 are attached above (*x*, *x*, *x*). The corresponding exumbrella lobes are shown at *x*, *x*, *x*, fig. 8. Transverse sections of such lobes are shown in figs. 1, 6, and 14 of Pl. IV.

Interumbrella.—The interlobes are attached to the central axis, between the plane of the exumbrella and subumbrella lobes. A good illustration is shown by fig. 5 of Pl. III. In this, one of the interlobes does not appear to have any connecting subumbrella rib. A disconnected interumbrella lobe with its included radial canal, corresponding to the radial canal in each of the exumbrella lobes, may be attached to the umbrella disk or axis nearly on the plane of the dorsal surface of the exumbrella, *x*, *x*, *x* (Pl. I, fig. 7), or at any point along down the axis to the base of the oral disk (Pl. II, figs. 2, 3, 4b). This results in a very complex structure, and instead of a simple symmetrical medusa, an irregularly lobed body results, with round, appendage-like lobes projecting out in various directions from the central disk or axis (Pl. II, figs. 2–5). In connection with the rounded, radial ribs of the subumbrella, such forms appear at first to be a different species, when compared with such regular forms as are represented by figs. 1 and 3 of Pl. I. The larger proportion of the specimens possessing the latter characters are flattened on the lower side so as to form a compressed disk, but a few specimens retain some of the original fullness and have a transverse spheroidal outline.

Umbrella corona.—The line of the corona furrow is suggested by the ring about the central disk (Pl. I, figs. 1, 2, and 3). It is quite probable that this is correct, as the sutures between the exumbrella lobes cut back to the disk in nearly all, if not all, the specimens (Pl. I, figs 1, 2, 3; Pl. III, figs. 1, 1a, 5, 6). The ring is not always present, but it usually is in the more perfect specimens, where the distinct exumbrella lobation does not continue to the center of the disk.

The umbrella margin is deeply lobed, following the rim of the exumbrella lobes. In such specimens as are represented by fig. 5 of Pl. II and figs. 3, 6, etc., of Pl. III, it could have been little more than the irregular rim of the various exumbrella and interumbrella lobes. The presence of organs of sense on the margin is not known from the fossil specimens. It is only by the relations of the species to the recent Discomedusæ that we may assume that they were present. Haeckel says:[1]

> The umbrella margin is the most important part of the neurodermal system in all medusæ, both morphologically and physiologically, as in it the most important animal organs—organs of sense, nerves, and muscles—attain their highest development. The central part of the nervous system and the tentacles especially are always originally situated in the umbrella margin. The umbrella margin is also of great importance for classification, as it is chiefly on it that the variations of formation appear which lead to the distinction of genera and species. In fact, the distinction and nomenclature of the two principal divisions of the class Medusæ, of the two sections Craspedota and Acraspeda, are taken from the umbrella margin, which presents important and striking diversities in the two sections. The "velum" is characteristic of the former, the "lobe corona" of the latter.

In *Brooksella alternata* and associated medusæ no tentacles have been observed. Organs of sense, touch, smell, vision, and hearing probably existed. We can imagine the existence of sense clubs from analogy with recent Discomedusæ, but they are not preserved in the fossil state. All such organs appear to have been destroyed in the process of fossilization.

Gastrovascular system.—In all medusæ the gastrovascular system or intestinal system is divided first of all into two principal sections, a central and a peripheral part. For

[1] Report on the deep-sea medusæ: Voyage of H. M. S. *Challenger;* Zoology, Vol. IV, 1882, p. xlii.

brevity we shall term the former the principal intestine and the latter the coronal intestine. The central or principal intestine ("gaster principalis, axogaster") is simple and undivided; its axis is at the same time the principal axis of the whole body; the umbrella cone (or center of the gelatinous umbrella disk) lies at its aboral pole; the oral opening at the oral pole. The peripheral or coronal intestine ("gaster corouaris, perogaster"), on the other hand, is always divided by radial septa (or cathamma) into four or more radial cavities (pouches or canals). The ideal circular or polygonal boundary line between the principal intestine and the coronal intestine is consequently defined by the proximal ends of the septa or cathamma; the gastral openings ("ostra gastralia") lie between them. These narrow or wider fissures are the only openings by which the central or principal intestine communicates with the divisions of the radially divided coronal intestine.[1]

The central or principal intestine of the medusæ is rarely perfectly simple; it is usually divided more or less distinctly into two or three sections or chambers, lying one above the other in the principal axis of the body. The lowest of these is the œsophagus or buccal stomach ("gaster buccalis"), which contains the oral opening at the oral pole of the principal axis. The middle chamber is the principal cavity or central stomach ("gaster centralis"). The third or uppermost section is the peduncle tube or basal stomach ("gaster basalis"), which ends cæcally at the aboral pole of the principal axis. The central stomach communicates with the basal stomach—below by the palatine opening ("porta palatina"); above by the pyloric opening ("porta pylorica"). Besides these, there are usually gastral openings ("ostia gastralis"), in the lateral walls of the stomach, by which the latter communicates with the radial chambers of the coronal intestine. All three stomachs are well developed in many medusæ of both sections (namely, Anthomedusæ and Peromedusæ); the uppermost (basal) stomach has, however, usually undergone retrograde formation. In the majority of medusæ the buccal stomach is the longest, the central stomach the broadest of the three chambers, whilst the basal stomach is the smallest, or has disappeared.[2]

The actual and theoretical information concerning the gastrovascular system of this species that I have thus far secured is illustrated by text figs. 4, 5, 6, and 7 (pp. 28, 29). The general form of fig. 4 is restored from specimens like those represented by figs. 1–4 of Pl. I; the radial canals, figs. 1, 3, 4 of Pl. III; oral arms, figs. 8, 8a of Pl. II; central and buccal stomach, figs. 8b of Pl. II, 1 and 4 of Pl. III, and 9, 10, 11 of Pl. IV. It is not possible, owing to the condition of preservation of the inner parts of the medusæ, to determine the shape and size of the central intestinal tube or stomach. That it was not simple in the typical form is fairly well shown by the natural section, fig. 8b of Pl. II. In the restoration (text figs. 4 and 5) the central stomach may have been relatively broad in some specimens (figs.

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[1] Haeckel, loc. cit., p. xlviii, par. 99.
[2] Haeckel, loc. cit., p. lxxv, par. 109.

1–3 of Pl. I), but in the great majority it could only have been very narrow and deep. Whether it was more than a simple tube, uniting the radial exumbrella canals and the oral canals, is doubtful. In such specimens as those represented by figs. 4, 4a, 4b, 8, 8a of Pl. I, there is little space for any central divisions of the intestinal canal. Such a space is represented, however, in text figs. 6 and 7, as it is improbable that a simple intestinal canal existed in such forms and the divided canal in others, like text fig. 4.

In the fossils the central axis or disk is usually distorted by compression and penetrated through and through by fine annelid borings. The presence of the central stomach is suggested by the frequent collapse of the central disk immediately above its normal place (Pl. I, fig. 2); over forty individuals before me show this with marked distinctness. The central stomach is clearly indicated in fig. 4 of Pl. III, where the radial intestine of the exumbrella lobes passes into it. This is also shown in the transverse sections (Pl. IV, figs. 7, 8, 9) and in vertical sections (Pl. IV, figs. 10, 11). The buccal stomach is indicated by fig. 8b of Pl. II.

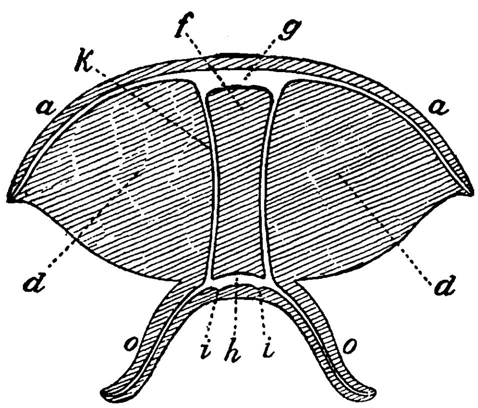

FIG. 4.—*Brooksella alternata.* Diagrammatic central vertical section through the umbrella lobes.

a, exumbrella lobes, with radial canals; *d*, section of umbrella lobes; *o*, oral arms, with interior canal; *f*, undifferentiated central axis that in the living animal was probably the seat of the genitalia, etc., as in some recent forms (see text fig. 3, p. 11); *g*, position of the central stomach; *h*, position of the buccal stomach; *i*, points extending downward in the stomach that suggest a former opening to a central mouth; *k*, axial canals, corresponding to the pillar canals of text fig. 3, p. 11.

Coronal intestine.—By this term Haeckel includes the entire peripheral gastrovascular system of medusæ which surrounds the central or principal intestine and communicates with it by the gastral opening. He considers that in the Acraspeda the typical and original arrangement was four wide perradial pouches, which begin at the circumference of the central stomach and run in the subumbrella toward the umbrella margin, where they are united by a coronal canal.

This typical quadripartite pouch corona of the Scyphomedusæ has been developed from the simple gastral space of their ancestors, the Scyphopolyps, by the four interradial tæniola of the latter being laid together and fused at four points (of equal height), or in four streaks, by their upper dorsal parts and lower ventral parts. In this way four small interradial nodes or narrow ridges are originated, which form incomplete septa between four wide perradial pouches.[1]

[1] Haeckel, loc. cit., p. lxxxix, par. 126.

In the form under consideration the coronal intestine is confined, so far as we know at present, to the simple, direct, radial canals extending from the central disk to the margin of each exumbrella and interumbrella lobe. These canals are large in proportion to the size of the lobes (see Pl. II, figs. 6 and 7; Pl. III, figs. 3 and 4; Pl. IV, figs. 7, 8, 9, 10a, 11a, 13) and are not branched. There is no trace of a connecting coronal intestine, and it is probable that the canals terminated in a minute excreting opening at the margin of the exumbrella, as similar canals do in Aurelia, although in the latter a coronal canal exists.

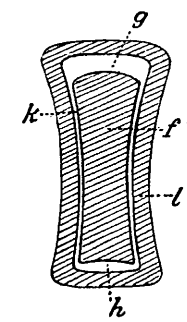

FIG. 5.—*Brooksella alternata.* Diagrammatic central vertical section through the central axis between the radiating lobes.

The description of the lettering is to be found under text fig. 4 (p. 28), with the exception of that of the letter *l*, which refers to that portion of the umbrella between the free lobes and exterior to the pillar canals.

Genitalia.—No traces of the reproductive system have been observed.

Oral opening, plate, and arms.—No traces of an oral opening have been seen. In a number of specimens, where the oral plate and arms have been removed prior to the fossilization of the animal, a circular depression is seen at the base of the central axis (Pl. I, fig. 3a, *x'*). This was probably the location of the mouth at an early stage in the evolution of this species and the development of the individual, but with the development of the oral plate and arms it was covered over.

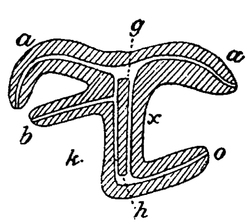

FIG. 6.—*Brooksella alternata.* Diagrammatic vertical section after figs. 4, 4a, 4b of Pl. I, so as to cut between the subumbrella lobes. Interior restored.

a, exumbrella lobes, with radial canals; *b*, interlobe, with interior canal; *k*, axial or pillar canals; *o*, oral arm, with interior canal; *x*, central axis.

The presence of a *typical* oral plate and arms was for a long time in doubt; upwards of 1,500 specimens had been collected before one was found in which they were preserved, and this specimen is thus far unique (Pl. II, figs. 8, 8a, 8b). The medusa was crushed obliquely down and the exumbrella lobes turned inward, the oral plate and arms being pushed to one side of the center.

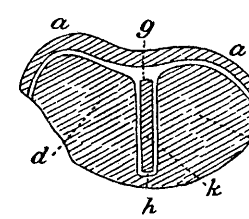

FIG. 7.—*Brooksella alternata.* Diagrammatic vertical median section of same specimen as text fig. 6, so as to cut through the subumbrella and exumbrella lobes and the central axis. The radial canals and central stomach (or intestinal tube) are drawn in from information partly obtained from other specimens.

The oral plate is formed by the union of the four arms at the center (Pl. II, figs. 8, 8a). Each arm is broken off about 1^{cm} from the center; the sections of the terminal portions have an average diameter of 5^{mm} by a depth of 7^{mm}; the opening of the brachial canal is plainly shown in each, and in a vertical cross-section (Pl. II, fig. 8b) the canals of two of the arms arch upward and then gently downward, meeting in the center; at the highest point of each the base of the pillar canals (*c c*) is still preserved. The size of the canals, and also of the arms, has probably been enlarged during the mineralization of the original specimen. The upper surface of the oral arms and plate and the lobes of the subumbrella have been so closely pressed together that there is not any distinct line of demarcation between them. A difference in the color of the rock suggests the presence of a central stomach that has been pressed out laterally, but, unfortunately, is not sufficiently well defined to prove its character, or that it is what it appears to represent.

The free interradial lobes or arms, attached to the central axis beneath or between the umbrella lobes, may have served the purpose of oral arms. This appears to have been the case in *Brooksella confusa*, where there is no evidence of the presence of oral arms of the Discomedusæ type.

Surface.—What may have been the surface of the exumbrella and subumbrella of a large number of specimens has a slight rugosity given to it by semi-inosculating, irregular, raised and depressed lines extending from the center toward the margin (Pl. I, fig. 1). This occurs usually in the more perfect specimens; many others do not show it, but in these there is reason to think that the original surface has been worn off, or that it is obscured by a siliceous deposit.

BROOKSELLA CONFUSA Walcott.

Pl. III, figs. 11, 12, 12a, 12b, 13.

Brooksella confusa Walcott, 1896. Proc. U. S. Nat. Mus., Vol. XVIII (1895), pp. 612–613, Pl. XXXI, figs. 7, 7*a*, 7*b*.

In the external form and appearance of the exumbrella this species is similar to *B. alternata*, but it differs materially in the arrangement of the lobes of the subumbrella. This is shown by comparing figs. 3a, 8a, and 9a of Pl. I and fig. 1a of Pl. II (the subumbrella surface of *B. alternata*) with figs. 11, 12b, and 13 of Pl. III (the same surface of *B. confusa*). In the former the lobes unite at the center and preserve the true radiate structure from a central axis. In the latter (*B. confusa*) the lobes do not join at the center, but have a tendency to form an irregular union near that point (fig. 13), or a double center (figs. 11, 12b).

The interumbrella lobes of *B. confusa* vary greatly in number and position. In fig. 11 (of Pl. III) few are seen, but in figs. 12, 12a, 12b, and 13 they are numerous. In fig: 13 they extend down so far on the central axis that they appear one on the other in a confused pile. It seems to be owing to the great development of the more or less irregular interlobes that the peculiar arrangement of the ventral surface is produced.

The gastrovascular system of the umbrella, so far as known, does not differ from that of *B. alternata*, but the oral openings and arms must vary materially. There does not appear to be a true central oral opening; and a careful study of the specimens leads to the view that the hollow, free interlobes and basal lobes or arms served as the oral arms and conveyed food direct to the intestine or stomach in the central axis. If this view is correct, the free interlobes of *B. alternata* served the same purpose in addition to the true oral arms of that species.

Genus LAOTIRA Walcott.

Laotira Walcott, 1896. Proc. U. S. Nat. Mus., Vol. XVIII (1895), p. 613.

Discomedusæ with a lobate umbrella, 4, 5, 6, 7, to 12 or more lobes in the simple forms, and with a large number in the compound forms; without tentacles and without central oral openings in the adult; with a simple radial canal in each lobe of the umbrella and in the interradial lobes attached to the central axes, when the latter are present; oral arms represented by interradial lobes attached to the central axis and to the subumbrella lobes; reproduction sexual or by fission. Type, *Laotira cambria.*

The genus Laotira differs from Brooksella very strongly in most of the specimens. In the simple forms it approaches Brooksella in general appearance, but there is a fairly constant variation, as may be seen by comparing the types of Brooksella, as illustrated on Pls. I and II, and the simple forms of Laotira, as illustrated on Pls. V, VI, and XVIII. There is, however, a strong resemblance between the oral arms of fig. 3a of Pl. I and those of fig. 1a, 2, and 3c of Pl. XVIII. The complex forms of Laotira differ widely from any known forms of Brooksella, with the exception of the subumbrella surface of *Brooksella confusa.* This species, when viewed from below, appears to be an intermediate form between the two genera. Its exumbrella surface, however, is so clearly of the type of Brooksella that I have referred it to the latter genus.

LAOTIRA CAMBRIA Walcott.

Pls. V–XIX, XXI–XXIII.

Laotira cambria Walcott, 1896. Proc. U. S. Nat. Mus., Vol. XVIII (1895), p. 613, Pl. XXXII, figs. 1–8.

The description of this species will follow in arrangement that of *Brooksella alternata.* Its variations, however, are greater, and the descriptions will be divided into, first, the simple forms, and second, the compound forms. Individuals vary in size from 1.5 cm to 8 cm in diameter, the average size of the simple forms being about 5 cm.

Umbrella.—The general form of the simple type is subspherical to depressed-convex, and that of the compound type varies from nearly circular, semiglobular forms to irregularly transverse, flattened disks. The simple type is illustrated by figs. 1, 4, 7, 10, and 11 of Pl. V, and the compound type by fig. 6 of Pl. VIII, 7 and 7a of Pl. IX, 6 and 6a of Pl. X, and 3 of Pl. XI. The lobation of the exumbrella varies from the simple four-lobed variety (Pl. V, figs. 1, 4, and 10), through the series represented by figs. 7, 9, and 11 of Pl. V; 1, 2, 4, 5a, 7, and 8 of Pl. VI; 2 and 4 of Pl. VII; 2 of Pl. VIII; 3, 4, 6, and 7 of Pl. IX, and 2 and 3 of Pl. XI, to the compound type shown in Pl. XII, figs. 1, 2, and 3. The variation in form and arrangement of the lobes is also shown by the same series of figures. As in the case of *Brooksella alternata*, the form varies with the condition of preservation. In figs. 5 and 10 of Pl. V the original form is obscured by a deposition of siliceous matter over the original body of the medusa. This is not a rare occurrence, as about 10 per cent. of the specimens exhibit more or less of it. In a large number of individuals the firm ectoderm preserved the original outlines, and, with the exception of the flattening as the result of collapse after death, the original plumpness and rotundity of the lobes are preserved.

The subumbrella varies more than the exumbrella. Figs. 1 and 11a of Pl. V, 1a and 2a of Pl. VI, and 1a and 7 of Pl. VII, illustrate the regular, simple type; but in fig. 1 of Pl. X the almost simple type of the exumbrella, like fig. 1 of Pl. V, has a complex subumbrella. The same is also well shown by figs. 1 and 1a of Pl. XI. The progressive variation of the complexity of the subumbrella is exhibited by fig. 1 of Pl. V, 1a of Pl. VII; 3a, 5a, 6a, and 7a of Pl. IX; 4, 6, and 7 of Pl. X; 1a and 2a of Pl. XI, and 2a of Pl. XII. The series of figures illustrate the variations much better than they can be described in detail; but attention will be called to a few points: In the simple forms (Pl. V, figs. 1 and 11; Pl. VI, figs. 4a and 7a, etc.), the subumbrella lobes radiate from the central axis to the exumbrella lobes, as in *Brooksella alternata;* but with the introduction of a tendency to irregularity in the arrangement of the subumbrella lobes at the center, all order and system is soon lost. The exumbrella lobes of fig. 3, Pl. IX, are systematically arranged about the center; but the subumbrella lobes show a slightly transverse arrangement, so that they do not meet at a common center; this is carried further in figs. 5, 6, and 7 of Pl. IX, and 5 of Pl. X, until a distinctly bilateral arrangement is developed. In many individuals there is no regularity (Pl. XI, figs. 1a and 2a, etc.), and in the extreme forms (Pl. XIII, figs. 5 and 6), there is an irregular network of subumbrella lobes and oral arms.

Umbrella corona.—The corona furrow has not been recognized in any individual that could with certainty be referred to this species. The umbrella margin of the simple forms is not sufficiently well preserved to show any organs of sense, and there is no defined margin in the complex forms. No tentacles have been observed.

Gastrovascular system.—In the simple forms the radiating canals of the exumbrella lobes appear as in *Brooksella alternata*, and they unite at the center of the central axis (Pl. XVII, fig. 6; Pl. XXI, fig. 2; canals and central chamber). The termination of the radial canals is shown in figs. 2 and 6 of Pl. V, 1 and 3 of Pl. VI, and 3a, 3c, and 4a of Pl. XVIII, and their course in the exumbrella lobes by fig. 7 of Pl. VIII and fig. 2 of Pl. XXI and in the transverse sections on Pl. XXIII, figs. 1, 3. In the complex forms the irregularity of the exumbrella lobes influences the interior canals (Pl. XVII, fig. 3a), and even, in some cases, where the exterior is nearly symmetrical the interior shows irregularity in the arrangement of the canals (Pl. XXIII, fig. 7). Often the canals are not so well preserved in the more complex forms, but a careful examination usually shows traces of them, and in worn specimens they are sometimes clearly shown. The only specimen preserving the radial exumbrella canals, flattened in the shale, is but a film in which the canals are traced by dark, iron-stained bands about 1^{mm} wide (Pl. VIII, fig. 7). The medusa is completely pressed out in an oval form 4^{cm} by 7^{cm} in diameter. The 30 to 34 radial canals terminate at a central area, 11^{mm} by 17^{mm} in diameter, that corresponds to the central stomach, as shown by figs. 6 of Pl. XVII, 2 of Pl. XXI, and 1 and 3 of Pl. XXIII. This central area is outlined at the margin by dark material which is similar to that of the radial canals, but which does not extend over the central parts. It is not possible to distinguish any canals that might be referred to the oral arms. The number of canals is from 30 to 34, and exceeds that of any of the silicified specimens. Fig. 8 of Pl. VIII has 20 lobes indicated, and there may have been attached to the central axis others that are now concealed.

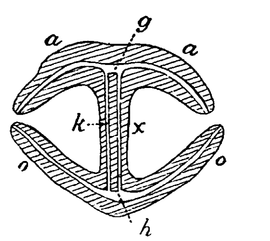

FIG. 8.—*Laotira cambria*. Diagrammatic vertical section of the specimen represented by figs. 4, 4a, and 4b of Pl. XVIII. The general form only is taken from the specimen. The interior canals are restored from sections of other specimens, such as those represented by figs. 1, 3, and 4 of Pl. XXIII.

a, exumbrella lobes with radial canals; *k*, axial or pillar canals; *o*, upturned oral arms with interior canals; *x*, central axis; *g*, central stomach; *h*, buccal stomach.

The interior canal system of the simple complex form of this species is shown by the transverse horizontal sections illustrated in fig. 3a of Pl. XVII and fig. 7 of Pl. XXIII. It is unfortunate that we have no good vertical sections showing the entire canal system in the more complex forms, such as are figured on Pls. XII and XIV. There is sufficient, however, in fig. 5 of Pl. XII and fig. 3 of Pl. XIV, and many similar specimens, to prove the existence of a canal in each one of the lobes of the exumbrella and in the free lobes of the subumbrella, and frequently in the inosculating lobes of the subumbrella.

One of the simplest types is represented by text fig. 8, in which the canals of the exumbrella radiate from the center and there is a simple axis connecting with the radiating oral arms beneath.

In a more complex individual, in which the central axis seems to have disappeared and only the transverse canal of the subumbrella lobe is present, the gastro-vascular system appears to be represented by canals in the subumbrella oral arms or lobes and by the canal system extending through the exumbrella lobe or lobes. This is shown diagrammatically by text fig. 9.

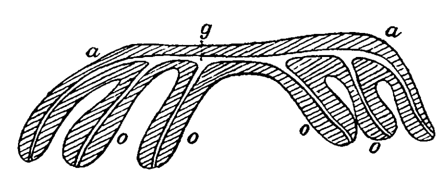

FIG. 9.—*Laotira cambria*. Transverse section of a complex specimen of the type of figs. 3, 3a, 5, and 5a of Pl. XIII.

a, upper or exumbrella lobes; *o*, oral arms with interior canal; *g*, interior canal corresponding to the upper central stomach in Brooksella and the simple form of Laotira.

A still more complex canal system is hypothetically shown by text fig. 10. In this there is the broad exumbrella surface with its canal system and the oral or subumbrella lobes showing the combination of characteristics found in text figs. 8 and 9. Text fig. 10 is, in fact, a transverse vertical section of three or four individuals united by the exumbrella surface.

The system of canals of the exumbrella is shown by text figs. 11 and 12 (pp. 36, 37). We are not dependent upon the assumption that such canals exist in the complex forms, as they have been exposed by weathering in numerous specimens, one of which is illustrated by fig. 5 of Pl. XII. I think it is fair to assume that lobes or arms of the character of those illustrated in text fig. 10 are attached below the various centers of text fig. 11.

Fig. 1 of Pl. XII illustrates the subumbrella surface of a specimen in which the subumbrella lobes are united in three centers which can not be distinguished upon the upper or exumbrella surface, owing partly to its being obscured by attached material. From the number of large lobes indicated on the exumbrella surface, and from analogy with other specimens, it is probable that the two surfaces were as unlike as those of the specimen represented by figs. 2 and 2a of Pl. XII. The special point to which attention needs to be called is the fact that nearly all, if not all, of

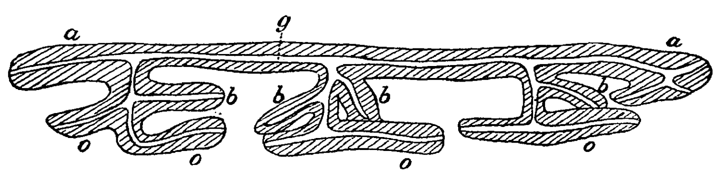

FIG. 10.—*Laotira cambria*. Diagrammatic transverse section of a complex form, such as is represented by fig. 2 of Pl. XIII.

a, upper or exumbrella lobes; *b*, interlobes with canal corresponding to the interlobe "*b*" of text fig. 6 (p. 29); *o*, oral arms or lobes with interior canal; *g*, same as in fig. 9.

the lobes of the subumbrella surface of this specimen are united, as shown in the figure. The presence of canals in such lobes is shown in a number of specimens, and apparently we have in this an example in which the canal system is confined almost entirely to the fixed portions, and there is practically little, if any, representation of the free oral arms or lobes so characteristic of many other specimens.

Figs. 2 and 2a of Pl. XII illustrate a relatively simple form of exumbrella with a complex subumbrella. The canal system of the exumbrella and subumbrella is diagrammatically represented by text fig. 13, p. 37. The canal system of the exumbrella is shown by heavy dark lines on the exumbrella lobes, and the subumbrella canals are represented by dotted lines. Of the canals connecting these two systems of canals we have no knowledge, as none of the specimens of which transverse sections have been made illustrate this feature. This is owing probably to the compression of nearly all specimens of a complex type which have been studied, or to the nonpreservation of the interior canals in the fossil state.

Oral opening and arms.—No central oral opening has been seen. It is highly probable that one did exist in the simple, regular forms of the young, but not even a trace has been seen of a depression at the base of the central axis; usually there is no trace of mouth, regular oral arms, or oral plate.

FIG. 11.—*Laotira cambria.* Hypothetical canal system of the exumbrella of fig. 1 of Pl. XIV. The canals are drawn in from other specimens in which they are exposed by weathering.

There is, however, a group of specimens that present characters indicating an unusual development of the oral arms in the simple type. My first impression was that two individuals were pressed together at their ventral surface, but as more and better specimens were collected, this finally gave way to the view that what had been considered as a second individual was the oral arms turned upward and interlocked with the exumbrella lobes, in the extreme examples. This view was strengthened by the finding of specimens in which the group of oral arms formed was much smaller than the exumbrella, as shown by figs. 1a and 2 of Pl. XVIII. The simplest type of these arms is shown by fig. 3a (*x*, *x*, *x*) of Pl. IX and figs. 1a (*x*, *x*) and 2a (*x*, *x*) of Pl. XVII, where the arms are rounded, not flattened like those of figs. 1a and 2 of Pl. XVIII. The interior canals are clearly shown (*x*, *x*, *x*) in the former, and the arms of 1a, Pl. XVII, appear to merge into and form a part of the exumbrella. This may arise from the coalescing through pressure of the arms and the subumbrella surface out to the margin of the exumbrella. The lobes or arms of all these have a canal running from their termination inward toward the center, which is apparently similar to that of the exumbrella lobes. This is still more marked in figs. 3a, 3b, and 4a of Pl. XVIII, where there is every appearance of two individuals locked together. In figs. 3, 3a, 3b, and 3c of Pl. XVIII, the lower side is formed of simple lobes or arms; and the exumbrella is one of the first stages of the complex type. After long study of 22 specimens showing these features in a marked degree, I have no other interpretation of them than that they are infolded oral arms. This view is strengthened by figs. 5 and 5a of Pl. X, where a relatively simple complex type of exumbrella has a complex subumbrella with several oral arms (*x*, *x*, fig. 5a) that, considered individually, differ but little from the oral arms of figs. 3 and 4 of Pl. XVIII. The more complex type is shown by fig. 5a of Pl. XIII. The exumbrella (fig. 5) is highly irregular, but its irregularity is increased on the subumbrella side by the infolding of the exumbrella lobes and the presence of the irregular oral arms. This is still

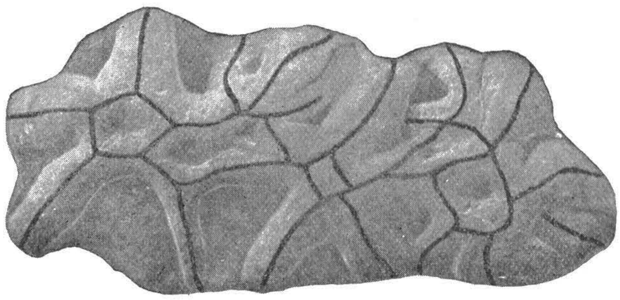

FIG. 12.—*Laotira cambria.* Restoration of the canal system of the subumbrella of the specimen illustrated by fig. 1 of Pl. XII.

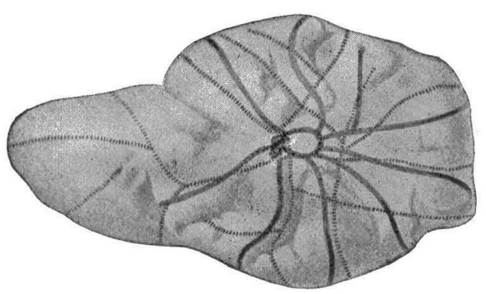

FIG. 13.—*Laotira cambria.* Theoretical diagram of the canal system of the exumbrella and subumbrella lobes of the specimen illustrated by figs. 2, 2a of Pl. XII.

more finely exhibited by fig. 6 of Pl. XIII, and the more flattened individual represented by fig. 5 of Pl. XII. The lower surface of fig. 1 of Pl. XIII is, unfortunately, not sufficiently well preserved to be illustrated. It was a combination of the characters seen in figs. 5 and 6a of Pl. XII. Fig. 1 of Pl. XXI is a portion of the lower surface of a large complex individual of the type represented by fig. 6 of Pl. XII. The variety of form of the complex type is almost endless. This is owing to the original variation and to the incidents of the embedding and preservation of organic remains so liable to be distorted by pressure and their own weight.

The presence of axial oral arms, such as occur in *Brooksella alternata*, is of rare occurrence in *Laotira cambria*. It is fairly well shown in figs. 3 and 3a of Pl. VIII, where several arms project out between the exumbrella and subumbrella.

Oral plate.—The oral plate may be formed in the simple types by the union of the oral arms at the center (as in Brooksella), but in the complex forms no true plate can be said to exist.

Circulation.—The circulation of the complex forms may have been by the intaking of food through the oral pores or tubes of the various irregular, individual, or combined oral lobes of the lower surface of the organism, followed by its passage through the irregular interior canals and final expulsion through the exterior openings of the exumbrella canals. Such would be anticipated to be the case if we should begin with the simple, regular forms, and trace the structure as it gradually becomes more and more complicated.

Reproduction.—No traces of the reproductive system have been observed in Brooksella, and none in Laotira except what appears to be a process of fission. No true sexual organs have been recognized. Reproduction by fission is indicated by the specimens represented on Pl. XIX, figs. 2 and 3. In these, two otherwise entire, simple individuals are held together by a single lobe, the severing of which would set them free. Fig. 1 of that plate illustrates a more complete union of two, and fig. 1 of Pl. XIII of three or more. In fig. 6 of Pl. XII there is a general appearance of looseness that might give rise to the view that a portion would have soon separated as a distinct individual. The same is also true of the double form, shown by fig. 3 of Pl. XII.

Reproduction by lateral fission is of rare occurrence among the recent medusæ. Kölliker describes an instance among the Discomedusæ—in the fission of *Stomobrachium mirabile* (probably a young form of *Mesonema cærulescens*). He states that the stomach divides first, and that simple animals were seen in which this organ was folded and completely divided. Then a furrow began to appear on the disk above the involution of the stomach, that sank deeper and deeper until complete fission resulted. These animals also divide at right angles to the first division.[1]

Kölliker's observations appear to have received little attention, and they were not sustained by other discoveries until those of Davidoff and, after him, those of Dr. Arnold Lang were made. Dr. Lang published a memoir on *Gastroblasta raffaeli* in 1886.[2] He states that almost every individual possessed more than one stomach, and a changing number of tentacles and radial canals. Not a single example showed a true radiating arrangement of organs. A large individual had nine stomachs and a large number of tentacles and radiating canals; of the latter some were connected with the stomachs and others were closed centripetal canals penetrating a longer or shorter distance into the subumbrella, toward the middle of the body. New stomachs were developed on some of the centripetal canals. Fission begins by the doubling of the peripheral pustules (which inclose the otoliths); then the canal uniting the two oldest stomachs is absorbed, and the canal systems of the two stomachs are connected only through the exterior ring canal. Then on the rim of the disk, at the double pustule, an invagination begins, which penetrates deeper and deeper until it meets another similar but smaller incision which started from the opposite side. When this is accomplished the medusa is divided into two individuals.

The fission described by Kölliker and Davidoff occurred in true radiating medusæ; but *G. raffaeli* is an irregular form in the adult, resulting from fission in a very young stage of the medusa, which was a true radiating form. This is Lang's interpretation, based on the results obtained by Davidoff. To illustrate Lang's observations a number of figures have been copied from his memoir and reproduced on Pls. XIX and XX.

Prof. W. K. Brooks showed me a sketch of a specimen of *Platypyxis foliata* McChesney, which he studied at Beaufort, North Carolina, in which there were two stomachs and mouths, very much like those of *Gastroblasta raffaeli*. He suggested that it and Dr. Lang's species might be identical.

Professor Brooks has called my attention to the results of a study by

[1] Zeitschr. für wiss. Zoologie, 1853, p. 235.
[2] Jenaische Zeitschr., Vol. XIX, part 4, pp. 735-763.

Dr. Robert P. Bigelow on the development of *Cassiopea xamachana.*[1] He states that it exhibited a phase of budding and fission that might aid in the better understanding of the fossil forms. I wrote to Dr. Bigelow, and he very kindly sent me his notes and original drawings for examination. These show that in the scyphostoma larvæ the process of budding is carried on by the formation of a swelling on one side of the calyx just above where it tapers into the stem. The swelling increases in size, becoming hemispherical and then elongating. As it elongates a constriction appears close to the body of the scyphostoma; the constriction deepens as the bud alters its shape, so as to cut off the lumen of the bud from the digestive cavity of the scyphostoma, leaving a pear-shaped body attached to the scyphostoma by a very slender neck of jelly covered by the ectoderm. Sometimes a second bud starts in exactly the same place as the first before the latter drops off. As soon as it is free the bud becomes a planula-like, free, swimming larva. The point of interest in relation to the growth and subsequent dropping off of the bud is the fission-like process by which it secures its freedom from the parent larva. It is not fission in the sense of fission in *Gastroblasta raffaeli*, but it is suggestive of a type of fission that may be represented in Cambrian medusæ by the growth and cutting off of portions of the body of the medusa, as illustrated by *Laotira cambria.*

In speaking of fission among the hydroids, Dr. Allman states that, while budding constitutes a highly characteristic and all but universal phenomenon among the Hydroida, multiplication by spontaneous fission occurs, although it is rare and exceptional. He mentions an instance described by Kölliker, and describes one that came under his own immediate observation. It occurred in a campanularian hydroid, *Schizocladium ramosum.*[2] Stating the peculiarities of the species, he says that it is a profusely branched form, and that besides the ramuli which support the hydranths, others are developed in abundance from all parts of the hydrocaulus. These commence just like the ordinary ramuli, as offshoots from the hydrocaulus, and consist as usual of a continuation of the cœnosarc by a chitinous perisarc. Unlike the ordinary branchlets, however, they never carry a hydranth. After the entire ramulus has attained some length

[1] Professor Brooks thinks that this species may be identical with the *Cassiopea frondosa* which was somewhat imperfectly described by Agassiz.

[2] A Monograph of the Gymnoblastic or Tubularian Hydroids, by George James Allman (a pubilcation of the Ray Society), Part I, 1871, p. 151.

the contained cœnosarc continues to elongate itself until it ruptures the delicate pellicle of chitine which closes the extremity of the ramulus. It then extends itself, quite naked, into the surrounding water, and a constriction takes place at some distance below its distal extremity in the parts still covered by the chitinous perisarc. The constriction rapidly deepens and ultimately cuts off a piece, which slips entirely out of the perisarcal tube and becomes a free zooid, while the surface of disseveration soon heals over and the axial cavity of the free frustule becomes as completely closed as at the opposite end.

In tracing the further history of the frustule, it was found that this never directly develops a mouth or becomes transformed into a hydranth. After a time a bud springs from its side, and it is from this bud alone that the first hydranth of the new colony is developed.[1]

I have mentioned this type of fission on account of the rarity of reproduction by that process among the Hydroida. It departs quite widely from the mode of fission described by Dr. Lang, and is not, I think, comparable with that which takes place in *Laotira cambria.*

FOSSIL MEDUSÆ OF THE LOWER CAMBRIAN TERRANE OF EASTERN NEW YORK.

The manner of occurrence and the mode of preservation of the one species found at this horizon in America are stated in the discussion of the relations of the Middle Cambrian fossil medusæ to those of the Lower Cambrian (p. 8) and in the following description of the species:

Genus DACTYLOIDITES Hall.

DACTYLOIDITES ASTEROIDES Fitch.

Pls. XXIV to XXVIII.

Buthotrephis ? asteroides Fitch, 1850. Trans. New York State Agric. Soc., Vol. IX, for 1849, p. 863.

Dactyloidites bulbosus Hall, 1886. Thirty-ninth Ann. Rept. Trustees State Mus. Nat. Hist. New York, for 1885, p. 160; pl. 11, figs. 1, 2.

Dactyloidites asteroides Walcott, 1891. Tenth Ann. Rept. U. S. Geol. Survey, Part I, p. 605; fig. 61, p. 606; Pl. LVII; Pl. LVIII, figs. 1, 1*a*.

The description and figure of this species by Dr. Asa Fitch are very incomplete, but they are sufficient for the identification of the species in

[1] Loc. cit., pp. 152, 153.

the collections from the Lower Cambrian slates of Middle Granville, New York. Dr. Fitch does not mention the name of the village in which the quarry was located at which the specimen was found. Knowing that he visited North Granville frequently, that the quarries there are west of the village, that at about that time (1849) slabs of slate were quarried at the Middle Granville quarries and used in the sidewalks of the village, and that those slabs still show numerous specimens of *Dactyloidites asteroides*, I think we are warranted in concluding that the type specimens were from that locality. Dr. Fitch describes and figures the species as follows:

Buthotrephis (?) *asteroides*, new species. This has been observed only upon a single slab now standing in the quarry in the west part of the village. On this slab, in fifteen or twenty places, faint discolorations occur, the outlines of which are accurately represented in the annexed figure. Neither the axillæ nor the terminations of the branches are distinct; enough, however, is seen to show that this is a relic very different from any that has hitherto been noticed, and so well characterized that the figure here given will enable any one to recognize it.

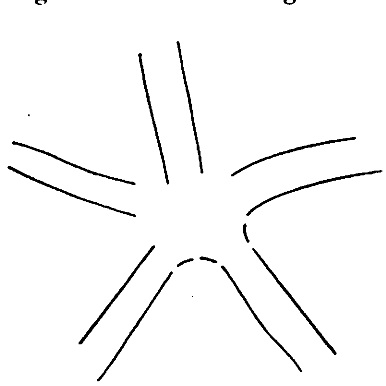
FIG. 14.—Bythotrephis (?) asteroides.

The specimens studied and described by Prof. James Hall were taken from the sidewalks in the village of Middle Granville, where the slabs of slate had been lying for many years. He identified the fossils as plant remains, and described them as follows:

The smallest specimen measures 70^{mm} across, and shows six ovate peripheral expansions, with short stalks, radiating from a small central disk. The larger specimen has a diameter of nearly 130^{mm}, and differs from the preceding not only in size, but in the length of the foot stalks of the leaf-like expansions, which are from 10 to 20^{mm} long.

The peripheral expansions or bodies preserve more carbonaceous matter than the stalks or the central disk, and would appear to indicate that they were of firmer (possibly chitinous) texture and contained more organic matter.

The distal ends of the expansions show a dark spot surrounded by light and dark concentric bands, such as would be preserved if the body had been a bulb open at the end, or contained a large vesicle.

It is difficult to determine the true biological position of these obscure specimens. They differ in their mode of growth from the compound fronds of graptolites, such as Graptolithus, Retiograptus, Loganograptus, or Phyllograptus, in having six rays to the frond, while in those genera the multiplication of the branches is by regular dichotomy or is four rayed as in Phyllograptus.

Associated with these organisms are fragments of other organisms which have all the appearance of undoubted plant remains (described as *Fucoides flexuosa* by Emmons), and from the absence of characteristic graptolites in the shales it would seem to warrant the conclusion that these radiate specimens are not of graptolitic origin, but are referable to the sponges or possibly the marine algæ.

The name *Dactyloidites bulbosus* is proposed for these fossils.

The material studied by Professor Hall, although abundant, was poorly preserved. Only a dark stain remained on the slate, and of the original form nothing but the radiate arrangement of the lobes. The carbonaceous matter referred to is shown as a very thin coating in a few instances, but usually it is a dark coloration on the smooth surface of the slate. When subjected to a high degree of heat it is burned off and only a faint trace of the impression is left on the slate, as a slightly darker, smooth spot. The annelid trails and what may have been a simple form of alga often show more of the carbonaceous matter than the impressions of the medusæ. It is probable that the mud contained more or less carbonaceous matter that was segregated in the annelid burrows and trails. The animal matter in the body of the medusæ may have produced the trace now found on their impressions. The presence of the dark, carbonaceous matter is well shown in fig. 1 of Pl. XXIV, fig. 2 of Pl. XXV, figs. 1, 5, and 6 of Pl. XXVII, and fig. 5 of Pl. XXVIII.

The reference of this fossil to the marine algæ, by Dr. Fitch, was the most natural one to make in view of the form of the specimens and the presence of some carbonaceous matter. Professor Hall considered that the forms were referable to the sponges or, possibly, the marine algæ. My first tentative opinion was that they suggested the impression of the mouth and gastric cavity of a species of medusa.[1] Subsequent study of the fossil medusæ of the Middle Cambrian led to the view that it was the body of a discomedusan, flattened in the slate, and not the cast of the interior. The reasons for this view are based on the direct comparison of a large series of specimens from the slate quarries at Middle Granville and the Middle Cambrian forms from Alabama. Reference to this comparison is made in speaking of the relations of Brooksella and Laotira to other fossil medusæ (p. 8).

[1] Tenth Ann. Rept. U. S. Geol. Survey, Part I, 1891, p. 606.

Before any direct comparisons between *D. asteroides* and *Laotira cambria* are made, attention is called to the fact that nearly all the specimens of the former species are crushed flat in the slate and that those of *L. cambria* are usually convex. A few specimens are flattened on the chert nodules and afford the means of comparison of specimens preserved under nearly the same conditions with reference to their compression and distortion.

Fig. *e* of Pl. XXVI has seven lobes, one of which is pressed out broadly at the outer end. Fig. 5 of Pl. XXII has six lobes, one of which is similarly expanded. The general appearance of the two specimens is similar. In Fig. 6 of Pl. XXII the lobes, where not broken off, are flattened and pressed out at the outer portion, somewhat as in fig. *b* of Pl. XXVI. The lobes of fig. 6 of Pl. VI are more convex than those of fig. *d* of Pl. XXVI, but the general form is the same. Of the four-lobed specimens, fig. 1 of Pl. XXV may be compared with fig. 10 of Pl. V, and of the five-lobed, fig. 2 of Pl. XXIV with fig. 2 of Pl. XXI. Of the specimens indicating reproduction by fission, compare fig. 2 of Pl. XXV with fig. 2 of Pl. XIX. When comparison is made between some of the examples of the two species they appear to be generically identical, but a series of specimens shows a looseness of structure in *D. asteroides* (as in fig. 1 of Pl. XXIV, fig. 3 of Pl. XXV, fig. *c* of Pl. XXVI) that is not met with in *L. cambria* or *B. alternata.* The range of variation in the number of lobes is also much less—4 to 7.

Our knowledge of the details of this genus and species is too limited for a clear generic and specific description. Of the genus it may be said that it is a discomedusan with a lobate umbrella, 4 to 7 or more lobes; without tentacles and without (?) central oral opening in the adult; with a central radial canal in each lobe, which enters a central stomach. This applies to such forms as those illustrated by fig. 2 of Pl. XXIV, fig. 1 of Pl. XXV, and figs. *b*, *d*, and *e* of Pl. XXVI. There are other forms (fig. 1 of Pl. XXIV, fig. 3 of Pl. XXV, figs. *c* and *e* of Pl. XXVI, etc.) that preserve more or less of the subumbrella surface, and from them we learn that the subumbrella lobes were narrow and united at the center, as in many examples of *Laotira cambria* (figs. 1a and 2a of Pl. VII, fig. 3a of Pl. IX). It is to be remembered that the Lower Cambrian specimens are compressed and flattened between the laminæ of the slate. With this in mind we can understand how the forms illustrated by fig. 3 of Pl. XXV and fig. 6 of Pl.

XXVII were given their present outlines. A medusa resting on its back on the bottom and covered with a deposit of fine mud would be pressed out, and as the pressure increased there would be a tendency to rupture it. In the examples cited, and in fig. 1 of Pl. XXIV and fig. *a* of Pl. XXVI, the rupture appears to have been in the exumbrella, and the broad ends of the exumbrella lobes were left attached to the narrow subumbrella lobes so as to give them the appearance of having had a bulb attached to their outer end. The fact that the exumbrella lobes have a central canal accounts for the traces of openings in the broad terminations of the radiating lobes in fig. 1 of Pl. XXIV and fig. 6 of Pl. XXVII. In fig. 1 of Pl. XXIV it appears as though each of the entire exumbrella lobes had been drawn or pressed out and flattened. An example of the drawing out of the subumbrella lobes in one of the flint nodules from the Middle Cambrian is shown by fig. 2 of Pl. XXII, and of the flattening of the outer portion of the exumbrella lobes while attached to their subumbrella lobes, by figs. 5 and 6 of Pl. XXII. This is also shown for *Brooksella alternata* by figs. 1 and 1a of Pl. III, and many other specimens in the collection. It may readily be conceived that the flattening of a specimen, like that shown by fig. 3a of Pl. IX, would give a series of narrow, radiating lobes with broad, spatulate outer ends. In fig. 5 of Pl. XXVIII the entire medusa is flattened to a film that spreads out on the slate in strong contrast with the narrow lobes of fig. 3 of Pl. XXV. The interpretation is that the broader exumbrella lobes were pressed out to form the lighter or thinner portion, and the narrow subumbrella lobes to form the thicker, dark parts of the radiating lobes.

Whether *D. asteroides* was reproduced by fission is not determined. It is very strongly suggested by the specimen illustrated by fig. 2 of Pl. XXV, where there appear to be two individuals connected only by a single lobe—much as in the example of *Laotira cambria*, fig. 2 of Pl. XIX.

The specimens illustrated on Pls. XXIV–XXVIII are considered to be the best examples of the species in the collection. There are many specimens compressed and distorted in various ways, as would be the case if a comparatively soft body, like a medusa of the rhizostomean type, were compressed between laminæ of mud. From the condition of preservation of this species it seems probable that the medusæ were either less firm in structure, and hence offered less resistance to pressure, or more macerated or decomposed prior to final burial in the mud, than the Middle Cambrian Brooksella and Laotira.

In addition to the large number of specimens obtained on the slabs of slate in the sidewalks of Middle Granville, I collected a series of fine specimens from the greenish-colored roofing slate at the middle Penrhyn quarry, just west of the upper end of the village. At this quarry the cleavage of the slate is coincident with the bedding. The vertical range of the medusæ is through a band of slate about 6 feet thick that occurs in the face of the quarry, about 50 feet above the lowest bed quarried. It is only when this portion of the quarry is being worked that specimens can be obtained. Through the courtesy of the superintendent in charge, Mr. Edward Willis, of New York, I was notified at the time the quarrymen were taking down a new cut that passed through the medusa bed.

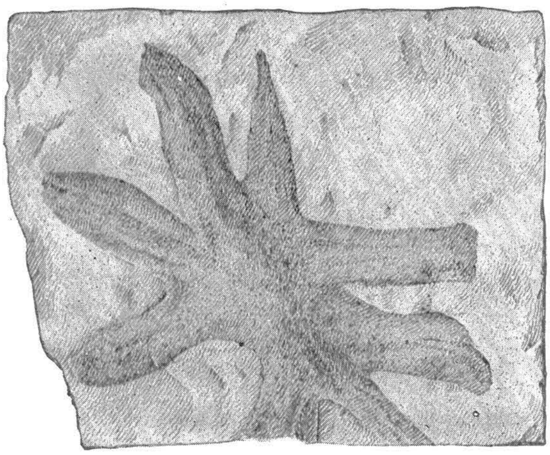

FIG. 15.—*Dactyloidites asteroides* from Parker's quarry, Georgia, Vermont.

The gregarious habit of this species is shown by the occurrence of 42 specimens on the surface of a slab of slate 37 by 62 inches, 19 on a slab 26 by 49 inches, and 11 on a slab 27 by 38 inches.

Formation and locality.—Lower Cambrian; Penrhyn quarry, Middle Granville, Washington County, New York.

Dactyloidites asteroides in Vermont.

I recently received from Mr. G. E. Edson, of St. Albans, Vermont, an impression of a star-like fossil which he found at Parker's quarry, Georgia, Vermont, in the coarse Olenellus shales. He calls attention to its resemblance to *Dactyloidites asteroides*, and I am inclined to think that this identification is correct. The impression is quite clearly defined on the somewhat rough, arenaceous shale, and the interior canals are clearly shown in three of the lobes. The specimen is represented in text fig. 15.

FOSSIL MEDUSÆ OF THE LOWER CAMBRIAN TERRANES OF SWEDEN AND BOHEMIA.

The interpretation of the fossils from the Lower Cambrian beds of Lugnås has been a subject of dispute among European paleontologists. *Medusina radiata* is first referred by Linnarsson to the sponges; but this view was abandoned by him later, after the appearance of Dr. Nathorst's paper, in which it was referred to the medusæ. *Medusina princeps* was referred by Dr. Torell to the corals; but this view was not accepted by those most familiar with this class of fossils, although Dr. Ammon had at a later date (1886) mentioned it and was inclined to place both *M. favosa* (*M. princeps*) and *M. radiata* in another division of the Cœlenterata.[1] He says:

> We do not regard it as possible that animals of such delicate constitution as the Æquoridæ could produce such sharp impressions in sandy deposits, and on no account is one justified, in view of the known material, in believing that in Cambrian time the class of Medusæ was already differentiated into its two chief divisions, Acraspeda and Craspedota.

To this Dr. Nathorst replies by referring Dr. Ammon to raindrop impressions on sand and also to artificial impressions of recent medusæ figured in his memoir.[2]

I think that the objection raised by Dr. Ammon, that the Æquoridæ could not produce such sharp impressions in sandy deposits, arises from a misunderstanding. The impressions were made in a very fine silt or clay, and sand was washed into those impressions, producing the fossils described by Dr. Nathorst. As found in nature, there is a thin bed of shale on which rests a layer of sandstone or sandy shale, on the lower side of which the impression is found; or, if the fossil is free, it is formed of a fine sand and clay that was washed into the impression made on the soft clay which now forms the shale. Since the recent developments as to the extent of the differentiation of the Cambrian fauna, I do not think that strong objection could be made to the probable occurrence of the two chief divisions of the medusæ in Cambrian time.

Dr. Ammon claimed that *Medusina* (*lindströmi*) *costata* could not be a

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[1] Ueber neue Examplare von jurassischen Medusen: Abhandl. Math.-phys. Classe Königl. bayerischen Akad. der Wiss., Vol. XV, 1886, pp. 160–161.

[2] Ueber cambrische Medusen: Zeitschr. Deutsch. geol. Gesell., Berlin, 1884, Vol. XXXVI, pp. 177–179.

medusa on account of its pentameral symmetry. Replying to this, Dr. Nathorst stated that he had studied the recent forms, *Aurelia aurita* and *Cyanea capillata*, in large numbers, and found in the latter five-sided as well as four-sided symmetry. It is more rare in *A. aurita*, though both three-sided and five-sided symmetries exist, in addition to the usual tetrameral symmetry.[1]

From the evidence adduced by Dr. Nathorst, and from a comparative study of both the fossil and the recent forms, I am led to regard the Swedish Lower Cambrian fossils as evidences of the presence of medusæ in the Lower Cambrian seas of Sweden.

It may be doubtful whether Dr. Nathorst's interpretation of Eophyton, as made up of trails produced on mud by medusæ, is correct, but it is quite probable that in some instances they have originated as he suggests. As regards others, however, I think there is little doubt that they owe their origin to the trailing of algæ over the bottom. On this account I have inserted a description (pp. 59–65), rather freely illustrated, of the fossil forms that have been referred to Eophyton.

In an article on "Illustrations of the fauna of the St. John group, No. V," Mr. G. F. Matthew quotes the descriptions of *Medusina princeps*, *M. radiata*, and *M. costata* from Linnarsson. He also describes five forms of what he considers to be trails or the imprints of tentacles of medusæ, under the generic name of *Medusichnites*.[2]

Through the courtesy of Mr. Matthew, I have examined the original specimens, and I find that, with possibly the exception of fig. 1 of his Pl. XIII, all of the varieties of Medusichnites might much better be referred to markings of inorganic origin. I have seen large areas of Lower Cambrian shales in Rensselaer County, New York, covered with markings like those shown by his fig. 4 of Pl. XII and fig. 1 of Pl. XIII. These were studied in connection with the investigation of medusa-like trails, and the conclusion reached was that they could not have had such an origin.

In order that the student may have the means of comparison, I have introduced photographs of some of the typical specimens described by Mr. Matthew. (See Pl. XLVI.)

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[1] Loc. cit., p. 177.
[2] Trans. Royal Soc. Canada, Vol. VIII, 1890, sec. 4, pp. 143–146, Pls. XII, XIII, fig. 1.

DESCRIPTION OF GENERA AND SPECIES.

Genus MEDUSINA Walcott.

Medusites Germar, 1826. Geogn. Deutschland, Vol. IV, 1826, p. 108, Pl. 1*a*, figs. 8–10.
Medusites Haeckel, 1865. Zeitschr. für wiss. Zoologie, Vol. XV, p. 513.

The genus Medusites was proposed by Professor Germar for some problematic fossils that were referred to Lumbricaria by Dr. Goldfuss.[1] This appears to be a correct reference, judging from Germar's figures. Medusites is, therefore, a synonym of Lumbricaria; and Medusina is proposed as a generic term to include all species of fossil medusæ whose generic characters can not be determined.

MEDUSINA COSTATA Torell (sp.).

Pl. XXIX, figs. 1, 2, 3a–b.

Spatangopsis costata Torell, 1870. Lunds Universitets Års-Skrift, 1869, No. VIII, p. 11.
Agelacrinus ? lindströmi Linnarsson, 1871. Kongl. svensk. Vet.-Akad. Handl., vol. 9, No. 7, p. 11, Pl. I, figs. 6–9; Pl. II, figs. 10–14.
Medusites lindströmi Nathorst, 1881. Kongl. svensk. Vet.-Akad. Handl., vol. 19, No. 1, p. 25, Pl. IV, figs. 1–10; Pl. V, figs. 1–4.
Medusites lindströmi Schmidt, 1888. Mém. Acad. imp. sci. St. Pétersbourg, 7th series, Vol. XXXVI, No. 2, p. 27, Pl. II, figs. 34, 35.
Medusites costatus Matthew, 1890. Trans. Royal Soc. Canada, Vol. VIII, Sec. IV, p. 142.
Medusites lindströmi Walcott, 1891. Tenth Ann. Rept. U. S. Geol. Survey, Part I, Pl. LVI, figs. 1, 1*a–c*.

Original description:

Infra globosa, supra obtuse conica, costis 5 acutis, ex apice excentrico radiantibus, prope marginem desinentibus. In parte inferiore cujusque areæ intercostalis eminentia fere semiglobosa costas non attingens. Alt. circiter 30^{mm}, lat. 32^{mm}, speciminis depressi prope 50^{mm}.

Locus: In saxo arenaceo formationis cambricæ ad Lugnås et Timmerdala in monte Billingen, Vestrogothiæ.

Dr. Torell referred the species with doubt to the Echinodermata. Dr. Linnarsson referred it tentatively to the genus Agelacrinus, and described it in part as follows:

These echinoderms are among the most remarkable of the fossils of the Eophyton sandstone. They vary greatly in form and size. No part of the shell is ever found

[1] Petrefacta Germaniæ, 1826–33, Vol. I, p. 222.

preserved, and the casts do not even show any trace of its sculpture. We are also left in the dark in regard to the position and nature of the organs most important for classification, such as the mouth, the anus, etc. Such being the case, it is impossible to determine with certainty their place in the system, and their relation to each other, all the more because in many cases it can not be decided to what extent the differences are to be attributed to the changes to which the casts were subjected after their first formation. Such changes readily occurred before the mass hardened by reason of pressure or other external agencies, which is rendered evident by the fact that most of the specimens are more or less oblique. Nevertheless, these fossils are of great interest as the oldest representatives thus far known of their class, and for that reason I deemed it incumbent on me to give a description of them, however unsatisfactory it necessarily must be. For the reasons given above, their affinities can not be made out with any degree of accuracy. Professor Loven is inclined to regard them as Cystideæ, perhaps related to Agelacrinus, and accordingly I have provisionally given the above name to the form which seems most constant. Its outline is either circular or more or less distinctly five- or four-sided, with the corners rounded off. One side is of low conical form, sometimes nearly hemispherical. It bears four or five radiating ribs, which proceed from the point and extend to near the edge. There they are nearly always broken; it is found, however, that they had prolongations which extended beyond the edge and formed free arms. A few specimens, which are attached to sandstone plates, and one of which is represented in fig. 10, show long, narrow arms; still, the specimens are so indistinct that it can not be made out with certainty whether they belong to this species. The opposite side for the most part appears nearly even, with a slight circular depression in the middle. In one specimen (figs. 8, 9) it has an altogether peculiar structure, bearing on the periphery five oval, strongly marked elevations, each of which corresponds to one of the radiating ribs on the other side. If these are imagined absent, the form will be the usual one.

Agelacrinus (?) *lindströmi* was found by me at Lugnås only, and even there not in special abundance. Usually, however, several specimens are found together. They are often embedded in clay slate, so that they can be detached. To be able to explain this fact, taken together with their nature as casts, it must be assumed that they are not altogether complete. Some part of the animal must have risen above the clay mud, so that after its dissolution an opening was left through which sand, when it began to be deposited, might enter, and one is led to think that the sandstone tube, which gradually filled up this opening and connected the casts with the sandstone stratum formed above the clay bed containing the casts, was broken off. On the specimen collected, however, no trace of such a break can be discovered. Even when I found them still embedded in the clay slate nothing touching this subject could ever be made out, for the clay slate was always in such condition that when the casts were loosened from it it crumbled to pieces, together with the small cavities filled with sandstone, in form of arms and the like, connected with the casts. A more accurate investigation of the structure of the animal must, therefore, be left to the future, together with the explanation of the remarkable difference in the structure of one side in the casts, which probably is due not to differences in the animal itself, but to differences in the manner in which the casts were produced.

Another form (figs. 11–14) has more the appearance of a sea star, but is perhaps related to the preceding. It has mostly four, but sometimes five arms, which vary in form and size, but ordinarily agree in this, that one side is nearly flat, while the other is strongly convex or more or less distinctly keeled. This form is found at Lugnås under the same circumstances as the preceding. For the present it would be improper to designate it by a special name, because the limits of the species can not be defined.

These two forms are the most prominent among the echinoderms of the Eophyton sandstone, and the others may possibly be referable to them as accidental variations, due to the mode of fossilization. A detailed description of the latter without figures would afford but little information, and may, therefore, be for the present postponed. The feature which besides their age renders these fossils most remarkable is the alternation between four- and five-parting.

Dr. Nathorst's study resulted in an entirely different interpretation of the zoological relations of the species. His description is as follows:

A species belonging to the acraspedote medusæ, in which either four- or five-partition prevails. Gastric cavity pyramidal, with four-sided, roundly five-sided or round base, sharply defined grooves on the sides; from the middle of the lower side of the umbrella there projects downward into the gastric cavity a small round spike. The genital apertures between the arms communicating with the gastric cavity. Mouth opening pyramidal, four- or five-edged; arms, at least in young specimens, with longitudinal open grooves, not branched (?). Presumably long tentacles. * * *

Of course I had great hesitation in referring all these forms to only one species, and I must insist expressly that I do not mean thereby to say that they do not comprise several. The latter seems even more probable, but the agreement in the organization of the parts that are here preserved, though possibly belonging to widely differing medusæ, does not allow this question to be settled with certainty. There might be a better chance for arriving at a decision if we had definite data regarding the occurrence of the various specimens in the rocks, and on the respective upper or lower sides of the strata. At present, on the contrary, more regard must be had to the difficulty of drawing definite boundary lines between the various forms, and so forth.

How great is the difficulty really met with in the attempt to define the number of species may best be understood if we imagine some tons of medusæ of various kinds, but not rhizostomids, cast up on a beach and leaving impressions of their mouth openings. * * * Now, as it seems not quite impossible to refer the various forms to one common type, I judged best, at least for the present, not to separate them, so much the more as various differences may be due solely to phenomena of concretion and other causes. From a theoretic standpoint, it might seem most reasonable to assume the contrary, for seeing that a perfectly typical acraspedote medusa is found, there is good reason for expecting more. The main point, of course, is that the presence of acraspedote medusæ in Cambrian time can in any case be affirmed with perfect certainty. * * * The various forms under which *Medusites lindströmi* occurs may properly be classified as follows:

(*a*) Imprint of lower side:

(1) Shows only irregular impressions of tentacles[1] (?).

(2) Like (1), but has besides in the middle a pyramidal filling of the mouth opening, at times also with filled-up genital apertures; imprint of tentacles (?) often lacking. [See fig. 1, Pl. XXIX, of this memoir.]

(3) Like (2), but corner of pyramid continues outward in the filling of the arm grooves.

(4) Imprint of arms or filling of their grooves, either four- or five-parted, at times with imprint of genital apertures.

(5) Filling of arm grooves (in a five-parted specimen), together with imprint of the whole mass of the body.

(*b*) Closed casts of gastric cavity:

(6) Pyramidal or hemispheric, free, four- or five-parted, with base four-parted or roundly five parted or round, sides bounded by four or five sharp edges, and sides between them either flat, convex, or concave, at times with projecting parts, corresponding to the filled-up genital apertures.

Here may properly be mentioned a circumstance which harmonizes very well with the reference of those fossils to Medusæ, and gives external confirmation to the correctness of such reference—that is, the great difference in size among the various specimens. While the smallest specimens have a base of only about 12^{mm}, the diameter of the largest is at times 60^{mm}. This is precisely what is seen in medusæ, the greatest differences being found in various individuals of the same swarm.

(7) A free biconvex cross, composed as it were of two halves laid one on the other. It is uncertain to which of the two principal groups this form should be referred. If it is really the filling of a gastric cavity, it must no doubt be derived from a special species. Otherwise, it would be the filled-up grooves of the arms, together with a mass accumulated by means of concretion, a theory which seems to be contradicted by the little round impression in the middle. It is to be hoped that further discoveries will settle this question, as well as the question whether *Medusites lindströmi* comprises only one or several species.

No. 2 of class *a* is illustrated by fig. 1 of Pl. XXIX, and the close casts of the gastric cavity (class *b*) by the figures of Pls. XXVIII and XXIX. The former is considered by Dr. Nathorst to be the cast of the lower surface of the medusa, the central pyramid and four radiating ridges being the cast of the opening of the mouth.

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[1] This impression, as in form 3, at times extends to the mouth pyramid, and the question might thus be asked whether it might not rather be regarded as derived from mouth curtains or sex curtains. On the other hand, however, the tentacles might have accidentally been bent toward the center.

In a letter received from Dr. Nathorst, dated February 19, 1892, he says that "as to *Medusites lindströmi*, it has now been proved with certainty that it is a true medusa, a specimen having been found showing the impression of the genital hollows." A pencil sketch accompanied the note. More recently a sketch of the specimen was published,[1] and I have had a copy made, as shown by fig. 1 of Pl. XXX. The mouth is at M, the genital hollows at G, G, G, G, and the radiating imprints between the latter and the outer margin.

Among some specimens of this species received from the Geological Survey of Sweden, I find one that shows very clearly the casts of four hollows in the roof of the gastric cavity; also, as rounded protuberances between the four raised angles, the genital sacs, *g*, *g*, *g*, *g*, of Pl. XXVIII, figs. 3a, 3b. The roof hollows are shown in a five-lobed specimen by Dr. Linnarsson (loc. cit., fig. 9 of Pl. I). The casts of the genital sacs were noted by Messrs. Torell and Linnarsson, and Dr. Nathorst describes them in detail. He compares casts that he had made of the lower surface of *Aurelia aurita* with the casts from the Lower Cambrian at Lugnås, and his illustrations show a remarkable resemblance between them. On Pls. XXX and XXXI, I have reproduced photographs of casts in soft plaster which I made of the lower surface of *Aurelia flavidula*, in order to furnish the student with the means for a direct comparison of the casts of the recent and fossil forms. The cast of the lower side of Aurelia (figs. 2 and 3 of Pl. XXX) shows the quadripartite pyramid formed by the cast of the mouth opening; also the outline of the genital sacs. This may be compared with the cast of *Medusina costata*, fig. 1 of Pl. XXX. The cast of the uncompressed genital sacs of the fossil medusa is shown by *g*, *g*, *g*, *g*, of figs. 3a, 3b of Pl. XXVIII.

Dr. F. Schmidt describes the occurrence of a specimen of this species in Esthonia, one of the Baltic provinces of Russia, as follows:

> Up to the present only a single specimen of this form is on hand, which agrees perfectly with the specimens from the Eophyton sandstone of Sweden. The specimen is five-rayed, and rises into a regular five-sided pyramid with raised, obtuse ribs. The lower side is arched, with a flat depression in the middle. It shows most agreement with Linnarsson's F. 8.
>
> The height of the specimen is 40^{mm}, the largest horizontal diameter 53^{mm}.

[1] Sveriges geologi, af A. G. Nathorst, Stockholm. (No date.) Received by Library of U. S. Geological Survey in 1895.

The piece was washed out on the shore of Ontika, in Esthonia; was found at the foot of the Glint, and donated to the Reval provincial museum by Baron Hermann Toll-Kuckers. Judging by the rock, it belongs evidently to the sandy layers intercalated in the upper blue clay, in which the Cruzianas and Fraenas of the Eophyton sandstone were also found. Further finds may be expected.[1]

I fully agree with Mr. Matthew, that the original name given by Torell, *costata*, should be retained for this species.

MEDUSINA PRINCEPS Torell (sp.).

Pl. XXVIII, fig. 1.

Protolyellia princeps Torell, 1870. Lunds Universitets Årks-Skrift, 1869, No. VIII, p. 10.

Astylospongia radiata Linnarsson (ex parte?), 1871. Kongl. svensk. Vet.-Akad. Handl., vol. 9, No. 7, p. 13, Pl. II, fig. 15.

Medusites favosus Nathorst, 1881. Kongl. svensk. Vet.-Akad. Handl., vol. 19, No. 1, p. 25, Pl. V, figs. 5 and 6?

Medusites princeps Matthew, 1890. Trans. Royal Soc. Canada, Vol. VIII, Sec. IV, p. 140.

The original description is as follows:

Obicularis, pileo fungi similis, margine distincto; superficies superior convexa interdum impressione media, calcibus nullis insigni; inferior plano-convexa medio pedunculo brevi affixa et calcybus polygonis obliquis complanatis, ut in *Alveolite*.

Diam. calycum, 1–2^{mm}; diam. speciminis maximi, 72^{mm}; crassitudo, 20^{mm}.

Locus: In saxo formationis cambricæ ad Lugnås, Vestrogothiæ.

In the remarks following the description the species is compared with Archæocyathus Billings, to show that it has no affinities with it or the sponges, and that its relations are with the genera Lyellia and Alveolites of the corals.

Dr. Nathorst points out the differences between Dr. Torell's species, *P. princeps* and *M. radiata*, and describes the former as a new species, *Medusites favosus*, as follows:

A species probably belonging to the acraspedote medusæ, family Cyaneidæ, with circular gastric cavity, whose roof (or bottom), bounded by the umbrella, is divided into irregularly polygonal fields by small furrows. Diameter of gastric cavity generally about 35–40^{mm}, though specimens are found both smaller and twice as large.

Dr. Nathorst says (in a footnote) that the specific name *princeps* can hardly be retained, considering the present view of the nature of the fossil.

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[1] Mém. Acad. imp. sci. St. Pétersbourg, 7th series, Vol. XXXVI, No. 2, 1888, p. 27.

In this I can not agree with him. Dr. Torell's name has priority; his description is sufficient to identify the species, and under the prevailing rules of nomenclature it should be retained. And I find that Mr. Matthew is of the same opinion. To change all specific names that are not strictly descriptive or appropriate would lead to endless confusion and to more or less injustice to authors.

Dr. Nathorst points out the differences between *M. radiata* and *Protolyellia princeps*, calling attention to Dr. Linnarsson's having probably described two forms under *Astylospongia radiata*.[1] For the form with a round circumference, a region in the middle without structure, and having elevations resembling strings of pearls radiating toward the center, the name *radiata* is retained. The other form, Dr. Torell's *P. princeps*, is also round, strongly convex on one side, slightly convex on the other; the surface of the latter has a structure of irregular cells or spaces, formed by sharp elevations anastomosing with each other, that lack the string-of-pearls appearance of *M. radiata*. This structure is generally absent from a more or less well-defined central space, which is usually raised above the cellular part.

Dr. Nathorst states that the floor of the gastric cavity of *Cyanea capillata* is circular and divided by deep furrows into polygonal spaces; and the casts show polygonal cells surrounded by sharp edges. From this resemblance, which he fully discusses, he refers the fossil form to the acraspedote medusæ and the family Cyaneidæ.

I have before me several good specimens of *M. princeps*, received from Dr. G. Lindström and from the Geological Survey of Sweden, that show the characters described. As yet I do not know of any similar forms from American Cambrian rocks.

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[1] Kongl. svensk. Vet.-Akad. Handl., Vol. XIX, No. 1, p. 20.

MEDUSINA RADIATA Linnarsson (sp.).

Pl. XXVIII, fig. 2.

Astylospongia radiata Linnarsson, 1871. Kongl. svensk. Vet.-Akad. Handl., vol. 9, No. 7, p. 13, Pl. II, figs. 15, 16.

Medusites radiatus Nathorst, 1881. Kongl. svensk. Vet.-Akad. Handl., vol. 19, No. 1, p. 25, Pl. VI, figs. 1, 2.

Medusites radiatus Matthew, 1890. Trans. Royal Soc. Canada, Vol. VIII, Sec. IV, p. 141.

Medusites radiatus Walcott, 1891. Tenth Ann. Rept. U. S. Geol. Survey, Part I, Pl. LVI, figs. 2, *2a*.

Medusites cf. radiatus Pompeckj, 1896. Die fauna des Cambrium von Tejřovic und Skrej in Böhmen. Jahrbuch K.-k. geol. Reichsanstalt, vol. 45, parts 2 and 3, p. 501, pl. 14, fig. 3.

The original description is printed in Swedish and the volume containing it is accessible to but few students; therefore a translation is given:

A disk-shaped sponge, varying to hemispherical, with nearly regular circular periphery. The diameter is generally between 40^{mm} and 50^{mm}, but sometimes both larger and smaller specimens are found. Fig. 15[1] represents one of the largest, with a diameter of 60^{mm}, fig. 16[1], one of the smallest. The lower side is generally almost hemispherical, and this seems to be its natural form, but sometimes it is found nearly flat, probably owing to pressure. It always appears smooth, without any trace of structure. No attachment surface is ever visible, and hence, supposing that this is really the lower side, the sponge must have been free. The upper side, near the periphery, is generally almost level. At times it is so all over, but ordinarily it rises gradually inward until it is interrupted by a circular opening the diameter of which is about equal to half the diameter of the whole sponge. This opening probably led down to a funnel- or cup-shaped depression, which, however, is at present always filled with rock mass, so that its structure can not be observed. Between the opening and the periphery of the sponge there run numerous narrow, radiating ridges. When the upper surface is level, they are nearly straight, simple, or in the form of strings of pearls. When the upper surface is raised, they appear more irregular, curling and anastomosing, while the string-of pearls appearance becomes more and more smoothed out, a difference which, however, should not induce the establishment of several species, since transition forms are not wanting. Perhaps the upper side of the sponge was covered with a kind of epidermis. On some stone slabs there is seen the upper surface of some specimens, in all of them level and ornamented with regular, radiating, string-of-pearl lines. Small lamellæ of that surface occasionally come off, and their lower side is found ornamented in the same way as the upper, leaving under them an impression consisting of radiating depressed lines with dot-like depressions.

[1] Figs. 3 and 2 of Pl. XXVIII of this monograph.

Thus these lamellæ seem to be the remnants of a coating which the sponge possessed, whereas the fossil for the rest is perhaps a mere cast. In their consistency they hardly differ from the ordinary sandstone mass. One might rather expect to find, in agreement with the usual conditions, that such an epidermis existed on the lower side of the sponge. It is therefore not impossible that the side which I have described as the upper may really be the lower, although on that supposition the mode of formation of the fossil would be more difficult to explain. The opening which interrupts the ornamentation would in that case be the surface of attachment, and the sponge would thus have been attached. I have found no specimen in situ, and thus no conclusion can be drawn from the natural position of the fossil. No structure can be distinguished in the interior. Thus the generic position remains uncertain, even if it be assumed that the hemispherical side was the lower, and that therefore the sponge was free. The species usually differs considerably from the typical species of the genus Astylospongia, but it seems still more difficult to unite it with any other of the genera above described. In all probability it ought rather to form a genus by itself, but to establish such a genus now would be of little advantage, since no definite generic characters can be given.

This species is not uncommon at Lugnås. At times specimens are found lying altogether loose. They have been embedded in clay slate which was detached by weathering. Others remain fixed in the sandstone slabs, and in such case ordinarily form groups. At Stola I found a stone slab densely studded with individuals of this species. A loose specimen I received from Mösseberg.

Dr. Linnarsson's reference of the species to the Spongiæ was, as noted by Dr. Nathorst, opposed by M. Barrande, Prof. G. Lindström, and Dr. Ferd. Roemer, and was finally given up by Dr. Linnarsson.[1]

Dr. Nathorst, in his memoir of the Cambrian medusæ, described this species as follows:

A species probably belonging to the craspedote medusæ, family Æquoridæ, with disk-like umbrella 40^{mm} to 60^{mm} in diameter; wide mouth, like that of Æquorea or Mesonema, taking up about half the transverse section of the body; radial canals many, probably 130 to 150, single (or sometimes branching toward the edge); gonads with string-of-pearls appearance all along the under side of the radial canals.

The species is illustrated by a reproduction of photographs of a large, finely preserved specimen and a small slab retaining the impression of the lower side of several individuals. These certainly appear to be different from the form described as *Medusites favosus;* and it appears that Dr. Linnarsson illustrated two species as the type of *M. radiata.* His fig. 16 corresponds to the described type; and fig. 15 is the form taken by Dr. Nathorst

[1] Kongl. svensk. Vet.-Akad. Handl., Vol. XIX, No. 1, p. 6.

as the type of his *Medusites favosus* = Dr. Torell's *Protolyellia princeps*. This has been noticed under the description of that species (p. 55.)

I have reviewed Dr. Nathorst's comparisons, and think that they are very suggestive. My knowledge of living medusæ is so limited, however, that any opinion I might give would have little weight. I hope that some naturalist will take up the subject anew and make an extended series of experiments, so that the basis for the comparison of the fossil and living forms may be greatly extended, and Dr. Nathorst's conclusion be thus strengthened or modified, as the case may be.

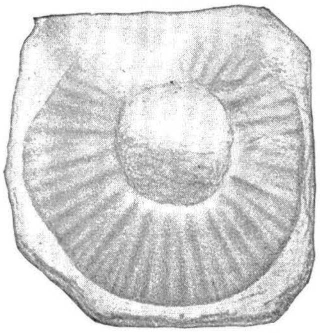

FIG. 16.—Reproduction of the type figure of *Medusina radiata?* of Bohemia. Pompeckj.

Through the kindness of Dr. Karl Zittel, I recently received a cast of a Medusites found at Tejřovic, Bohemia, in the Middle Cambrian beds. The form was described and illustrated by Dr. J. F. Pompeckj,[1] whose description is as follows:

The impression figured (the only one) agrees in a general way with the figures given by Nathorst, loc. cit. fig. 1. Some differences forbid the direct identification of the present form with the Swedish form. The string-of-pearls shape of radii, already noted by Linnarsson, can not be observed, and the number of radii in the Bohemian specimen is less than in Linnarsson's species. On the outer edge I estimate in the present specimen about 75 to 80 radii, while Nathorst counted almost twice that number in *Medusites radiatus*. The intervals between the radii are larger in our species. The forking of the radii is analogous to that in the specimens figured by Nathorst, loc. cit., fig. 1.

The specimen was found at a locality near Tejřovic, on the left border of the Beraun River, in a gray-brown sandstone. The following species of the Middle Cambrian fauna are associated with it:

Paradoxides rugulosus Corda.
Paradoxides spinosus Boeck, sp.
Paradoxides rotundatus Barr.
Agraulus ceticephalus Barr., sp.
Agraulus spinosus Jahn, sp.
Agnostus nudus Barr.
Conocoryphe sulzeri Schloth., sp.
Conocoryphe (Cten.) coronata Barr., sp.
Ptychoparia striata Emmr., sp.
Ptychoparia (Con.) emmrichi Barr., sp.
Ellipsocephalus germari Barr.
Orthis romingeri Barr.
Stromatocystites pentangularis Pompeckj.
Lichenoides priscus Barr.
Mitrocistites, sp.

[1] Die fauna des Cambrium von Tejřovic und Skrej in Böhmen, von. J. F. Pompeckj: Jahrbuch K.-k. geol. Reichsanstalt, vol. 45, parts 2 and 3, 1896, p. 501, pl. 14, fig. 3.

Genus EOPHYTON Torell.

Pls. XXXII–XXXVIII.

Eophyton Torell, 1868. Lunds Universitets Års-Skrift, 1867, No. XIII, pp. 36–38, Pl. II, fig. 3; Pl. III, figs. 1–3.

Eophyton Linnarsson, 1869. Öfversigt k. Vet.-Akad. Förhandl., No. 3, pp. 345–352, Pl. VII, figs. 3, 4; Pl. VIII; Pl. IX. Idem, 1869. Geol. Mag., Vol. VI., pp. 399–403, Pl. XI, figs. 3, 4; Pl. XII; Pl. XIII. Idem 1869. Reprint of the English translation, Stockholm, pp. 9–13, Pl. VII, figs. 3, 4; Pl. VIII; Pl. IX.

Eophyton Nicholson, 1869. Geol. Mag., Vol. VI, p. 497, Pl. XVIII, fig. C.

Eophyton Torell 1870. Lunds Universitets, Års-Skrift, 1869, No. VIII, p. 8.

Eophyton Dawson, 1870. Canadian Naturalist, 2d series, Vol. V., pp. 20–22.

Eophyton Linnarsson, 1871. Kongl. svensk. Vet.-Akad. Handl., Vol. IX, No. 7, pp. 16–18.

Eophyton Dawson, 1873. Am. Jour. Sci., 3d series, Vol. V, p. 20.

Eophyton Nathorst, 1874. Öfversigt k. Vet.-Akad. Förhandl., 1873, No. 9, pp. 26–46.

Eophyton Billings, 1874. Geol. Nat. Hist. Survey Canada; Pal. Fossils, Vol. II, Part I, pp. 65–66.

Eophyton Dames, 1875. Zeitschr. Deutsch. geol. Gesell., Vol. XXVII, pp. 244–245.

Eophyton Nathorst, 1881. Kongl. svensk. Vet.-Akad. Handl., Vol. XVIII, No. 7, pp. 44–46, 97–99, Pl. X, fig. 6. Idem, 1881. Loc. cit., Vol. XIX, No. 1, pp. 28–30.

Eophyton Saporta et Marion, 1881. L'Évolution du règne végétal; Cryptogames, pp. 82–83, fig. 22.

Eophyton Saporta, 1882. A propos des algues fossiles, Paris, p. 63, Pl. VIII, fig. 6.

Eophyton James (J. F.), 1891. Bull. Geol. Soc. Am., Vol. III, p. 40.

Dr. Torell's original description of Eophyton, under the designation "*Eophyton linnæanum*," is accompanied by several illustrations which clearly show the characters of the species. He considered Eophyton to be a plant impression, having an affinity with the monocotyledons.[1] He also suggested an affinity with Cordaites, on account of the resemblance to what he considered to be leaves of the latter. Dr. Linnarsson[2] adopts Dr. Torell's view, although questioning the interpretation of the parts which the latter referred to as leaves. He regards them as portions of stems, and finally concludes that great uncertainty remains as to the place that Eophyton occupies in the natural system. He says, however, that "it hardly can be doubted that it is of a far higher organization than any plant hitherto known from the oldest deposits." He considers it probable that the plant,

[1] Loc. cit., p. 37. [2] Loc. cit., reprint of English translation, pp. 11–12.

immersed in water, made impressions in the mud upon its bottom, and that after the plant itself had been dissolved the impressions filled with sand. Several fine illustrations accompany Dr. Linnarsson's paper.

In 1871 Dr. Linnarsson published a description of *Eophyton linnæanum* and *E. torelli*, stating that he had collected a large number of fine specimens, but that they threw no new light upon the nature of the fossil. In his description he says:

> The conjecture which I previously put forth regarding the mode of formation of the fossil has now been fully confirmed, since I had occasion to see it in its natural position. It always occurs on the lower side of the sandstone slabs, and if one succeeds in detaching a piece of the underlying clay-slate without crumbling it, he will find on it the corresponding impression, or the form in which the cast was made. In the depressed lines, which here correspond to the raised ridges on the fossil itself, there is often seen a row of fine depressed dots.

In 1874 Dr. Nathorst, in an essay on some supposed fossil plants, stated that Eophyton must be regarded as a track of some kind, and that tracks agreeing with it are formed on the present seashores by plants driven about in the water. He made experiments and obtained striations on coarse sand and also on fine clay, and on the latter reproduced the relief of the trails by taking casts with fine plaster. He found, on comparison, that Eophyton agreed with the artificially made trails in the minutest details. In his classical essay on traces of some invertebrate animals, etc., and their paleontologic significance, a full description of the mode of occurrence of Eophyton is given, with the statement that it occurs under the same forms from the Cambrian at least up to the Trias, and that all the forms under which it occurs are found on the seashores at the present time. He says, further, that it is evident that similar tracks might be produced by animals, supposing those animals to have fringed appendages that trail over the bottom. "The branching arms of *Cyanea capillata*, on experimentation, gave rise to Eophyton that could not be distinguished from those produced by plants." In closing his remarks, Dr. Nathorst states that his interpretation is fully supported by Linnarsson's observations.[1] Casts in plaster of two trails made by fine algæ, and also a fragment of Eophyton, are illustrated to show that they are essentially identical.

In an essay on Impressions of Medusæ in the Cambrian Strata of Sweden, Dr. Nathorst refers to having pointed out that Eophyton may

[1] Öfversigt k. Vet.-Akad. Förhandl. 1873, No. 9, 1874, p. 44.

possibly owe its presence to the arms or tentacles of medusæ. He found in the collection of the National Museum at Stockholm a block of rock from Lugnås which he thought showed that "*Medusites favosus*, at least in this case, gave rise to Eophyton." "Besides the ordinary form of Eophyton," he says, "there is found another which can be said to be thread-like, and several such threads often run side by side on the surface of the strata for some distance. It is quite possible that this may be due to the tentacles of medusæ. At any rate, I noticed at Kristianburg that when *Cyanea capillata* descends to the bottom it allows its tentacles, or part of them, to trail on the bottom." Dr. Nathorst also calls attention to the great resemblance existing between *Spiroscolex spiralis* and the tentacles of several medusæ. His theory of this resemblance, as here given, is very interesting and is worthy of careful consideration and experimentation with a view to proving or disproving its soundness.

Sir William Dawson was convinced that Eophyton could not be a plant, but markings of the nature of Rabdichnites, which he defined as straight or slightly curved marks usually striated or grooved longitudinally, and either single or in pairs. He considered that the marks owed their origin to furrows produced by trailing pointed objects over the mud.[1]

Dr. Dames identified Eophyton from the Trias by comparing typical specimens from Lugnås with those found in the "Bunter Sandstein." He agreed with Dr. Nathorst's view that Eophyton is a trail, and not a fossil alga.[2]

Dr. Rauff considers that Eophyton may be of purely mechanical origin.[3] He studied a specimen from Lugnås by cutting thin sections and observing the arrangement of the sandstone. His work is very suggestive, and explains many of the so-called trails and algæ I have met with in studying the evidences of life in the Lower Paleozoic rocks. I do not think, however, that the specimens illustrated by Dr. Linnarsson, or those in this memoir (Pls. XXXII–XXXVIII), are of mechanical origin.

Count Saporta discusses three suppositions in regard to the nature of Eophyton:

1. Tracks of animals, viz, trilobites.
2. Trails of medusæ, etc.
3. Plant remains.

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[1] Am. Jour. Sci., 3d series, Vol. V, 1873, p. 20.
[2] Loc. cit., 1875, p. 245.
[3] Neues Jahrbuch für Min., Geol. und Pal., 1891, Vol. II, pp. 100–101.

1. Against the first he urges the multiplicity of the striæ, their clearness, their strictly rectilinear direction, but more especially the fact that they not only touch but intermingle in such a way that one passes above or beneath the other; this he claims could not occur with simple tracks.

2. Against their being trails made by medusæ, or algæ being dragged over the surface, he adduces the facts that they extend in so many different directions, are so clear, and are often in the shape of veritable cylinders. It is, further, incomprehensible that the Cambrian should have the monopoly of such effects. Lastly, the objection offered in the former case, that the trails intermingle, holds good here.

3. On the supposition that these are plant remains, all the above facts are perfectly natural. The striæ, he says, are not nerves, but superficial longitudinal ridges, not without analogy in Bilobites and Taonurus. He thinks that the markings may be both trails and impressions, the well-defined and solid ones being impressions, the others trails of fragments swept about on the sea bottom.

In reply to Nathorst, that these never occur with vegetable remains, Saporta describes *Eophyton bleicheri* n. s. from the environs of Vailhan, which agrees with Eophyton in every way, yet shows dark discoloration due to plant substance.[1]

In an earlier paper Messrs. Saporta and Marion said: [2]

> It appears impossible to admit Nathorst's explanation and not to recognize in the remains described by Torell a vegetable organism similar to others passed in review, though different in genus, yet beyond doubt belonging to the same family. There are shreds, detached fragments, preserved in demirelief and occupying the under surface of Silurian slabs in the greatest disorder. Some of these tatters are flat, ribbon-like, others have a cylindrical form, often appearing lacerate; all having their surface furrowed by numerous longitudinal striæ, parallel and regularly disposed. Chance alone could not have produced a similar arrangement, no more than the relief visible in certain of the fragments.

Whether Dr. Nathorst is correct in interpreting Eophyton as made up of trails produced on fine sand or mud by medusæ may possibly be open to question; but it is true, as he states, that such forms occur from the Cambrian to the Trias, and to my mind it is quite probable that in some instances they may have originated as he suggests. As regards others,

[1] À propos des algues fossiles, Paris, 1882, p. 63.
[2] L'Évolution du règne végétal; Cryptogames, 1881, p. 83.

however, I think there is little doubt that they owe their origin to the trailing of algæ over the bottom, especially in shallow water when the tide was running out. I recently made a study of the trails produced by algæ on the flats of the inlet west of Noyes Point, Rhode Island, and was surprised at the close resemblance of those trails to the fossil trails. When the tide was running out trails many feet in length were made in direct lines, without a bend or interruption, by the drifting algæ. At other times, when from the action of the wind or any local obstruction the current was deviated, the most irregular and erratic trails frequently resulted. These observations have led me to fully concur with Dr. Nathorst, that Eophyton and many of the supposed fossil algæ are casts of trails made by both vegetable and animal organisms.

In order to place before American students illustrations of Eophyton, I have figured (on Pls. XXXII and XXXV–XXXVIII) specimens of the genus from the type locality at Lugnås, and also specimens of Eophyton and somewhat similar markings from the Cambrian rocks of various parts of the United States.

The most Eophyton-like trail is that from the St. Croix sandstone of Eau Claire, Wisconsin (Pl. XXXV, fig. 3). It differs in being larger and shorter; but this is probably an accident of origin, and not necessarily a genetic difference. On Pl. XXXVIII the broad, strongly striated trail suggests the sweeping over the mud of the tentacles of a large medusa. Another specimen from the same layers is shown by fig. 2 of Pl. XXXVII. These occur in the lower side of a thin layer of Middle Cambrian (Tonto) sandstone in the Grand Canyon of the Colorado, Arizona. Another peculiar marking, that may have been produced by the same agency, is shown by figs. 1 and 2 of Pl. XXXV.

Dr. Nathorst has suggested that certain delicate linear markings may have been made by the trailing tentacles of a medusa. Some of these from American localities are shown on Pls. XXXVI and XXXVII. They may have been so produced; but a comparison with photographs which I took the past season of trails made by drifting algæ shows that the latter are also competent to produce such markings (Pl. XXXVI, figs. 1, 2). So far as known, no traces of medusæ have been observed in association with the trails or markings illustrated, or with any known to me from American rocks.

The principal species that have been referred to Eophyton are:

EOPHYTON LINNÆANUM Torell.

Pl. XXXII, figs. 1 and 2.

Eophyton linnæanum Torell, 1868. Lunds Universitets Års-Skrift, 1867, No. XIII, pp. 36–38, Pl. II, fig. 3; Pl. III, figs. 1–3.
Eophyton linnæanum Linnarsson, 1869. Öfversigt k. Vet.-Akad. Förhandl., No. 3, pp. 345–351, Pl. VII, figs. 3, 4; Pl. VIII. Idem, 1869. Geol. Mag., Vol. VI, pp. 399–407, Pls. XI, figs. 3, 4; Pl. XII. Idem, 1869. Reprint of the English translation, Stockholm, pp. 9–12, Pl. VII, figs. 3, 4; Pl. VIII.
Eophyton linnæanum Torell, 1870. Lunds Universitets Års-Skrift, 1869, No. VIII, p. 8.

EOPHYTON TORELLI Linnarsson.

Pl. XXXII, fig. 3, 3a.

Eophyton torelli Linnarsson, 1869. Öfversigt k. Vet.-Akad. Förhandl., No. 3, pp. 351–352, Pl. IX. Idem, 1869. Geol. Mag., Vol. VI, pp. 402–403, Pl. XIII. Idem, 1869. Reprint of the English translation, Stockholm, pp. 12–13, Pl. XIII.
Eophyton torelli Torell, 1870. Lunds Universitets Års-Skrift, 1869, No. VIII, p. 8.

EOPHYTON JUKESI Billings.

Eophyton jukesi Billings, 1874. Geol. Nat. Hist. Survey Canada; Pal. Fossils, Vol. II, Part I, p. 66.

Professor Billings doubtfully identifies *E. linnæanum*, and describes *E. jukesi* as a new species, on account of the greater size of the stems.

EOPHYTON (?) EXPLANATUM Hicks.

Eophyton (?) explanatum Hicks, 1869. Geol. Mag., Vol. VI, p. 535, Pl. XX, fig. 1.

Dr. Hicks referred this species, with doubt, to Eophyton, and it has since (according to Dr. Nathorst) been referred to the sponges.[1]

EOPHYTON (?) PALMATUM Nicholson.

Eophyton (?) palmatum Nicholson, 1869. Geol. Mag., Vol. VI, p. 497, Pl. XVIII, fig. C.

It is doubtful whether this form should be referred to Eophyton. It occurs in the Skiddaw slates (Ordovician).

[1] Nathorst, 1881: Kongl. svensk. Vet.-Akad. Handl., Vol. XVIII, No. 7, p. 46.

EOPHYTON MORIERERI Saporta and Marion.

Eophyton morierei Saporta and Marion, 1881. L'Évolution du règne végétal; Cryptogames, Paris, fig. 21B.

The figure given of the species shows it to be much like *Eophyton bleicheri* Saporta. It does not appear to be a true Eophyton.

EOPHYTON BLEICHERI Saporta.

Eophyton bleicheri Saporta, 1882. À propos des algues fossiles, Paris, p. 66, Pl. VIII, fig. 6.

This form may be Eophyton, but the illustration does not convey the same impression as the true Eophyton of the Lower Cambrian. It is from the Silurian sandstone of Hérault, in the suburbs of Vailhan.

EOPHYTON DISPAR James.

Eophyton dispar James (J. F.), 1891. Bull. Geol. Soc. Am., Vol. III, p. 40, fig. 14.

This is an Eophyton-like trail from the Cincinnati formation of Ohio.

EOPHYTON SAPORTANUM Crié.

Eophyton saportanum Crié, 1881, in Saporta and Marion, l'Évolution du règne végétal; Cryptogames, Paris, p. 83, note.

This species is mentioned in the above reference, but it is neither described nor figured. I have been unable to find other mention of it.

FOSSIL MEDUSÆ FROM THE JURASSIC AND THE PERMIAN.

THE JURASSIC.

The fossil medusæ of the Jurassic are preserved as impressions, with the corresponding casts, on the surface of the fine lithographic slates of Bavaria. Their appearance and mode of occurrence suggest that the medusæ were left by the retreating tide on a soft, clayey bottom, the weight of the medusa forcing it slightly down into the mud or ooze. With the evaporation of the watery content of the tissues the part of the animal substance that was preserved formed a thin film in the impression, which served as the plane of division between the impression and the material that filled it on the return of the tide. The conditions for the preservation of the medusæ in the lithographic slates were more favorable than were those of early Cambrian time at Lugnås, Sweden. The sediment was much finer, and hence better calculated to preserve delicate impressions. And other favorable conditions must have been present, such as a tidal flat on which the medusæ could be left by the receding tide and additional sediment of a fine character be deposited on the return of the tide. Thus far this combination of favorable conditions appears to have been present only in the Bavarian and Swedish localities.

When looking up the literature of the Jurassic fossil medusæ, I found that it was quite widely scattered and most of it inaccessible to American students.

The first fossil described as a fossil medusa was found near Lexington, Kentucky, and named by Rafinesque *Trianisites cliffordi.*[1] It has been suggested that the fossil should be referred to the Algæ. It certainly does not appear to be a medusa.

According to Dr. Alexander Brandt, the first printed notice of a real fossil medusa seems to date back to 1835, when F. S. Leuckart[2] noted the existence of a fossil medusa from the Solenhofen slates. This was the specimen examined subsequently by Louis Agassiz. In 1845 Frischmann exhibited a specimen before the meeting of German naturalists at Nuremberg.[3] The same specimen is referred to later by Eichwald,[4] who regarded it as a Scutella. He subsequently produced it at a convention at Regensburg, where Beyrich saw it and described it under the name *Acalepha deperdita.*[5] In 1857 Professor Agassiz mentioned in his essay on "Classification" that "Acalepha had been found in the Jurassic limestone of Solenhofen."[6] In 1860 he wrote that thirty-three years previously his attention had been attracted by two slabs of limestone slate from Solenhofen, in the museum of the Grand Duke of Baden, upon which a perfect impression of a discophorous acaleph and its cast was shown.[7] In 1865 Professor Haeckel gave a

[1] Am. Jour. Sci., Vol. III, 1821, pp. 285–287, Pl. I.

[2] Ueber die Verbreitung der uebriggebliebenen Reste einer vorweltlichen Schöpfung. Freiberg, 1835, p. 12.

[3] Brandt, Ueber fossile Medusen: Mém. Acad. imp. sci., St. Pétersbourg, 7th series, Vol. XVI, No. 11, p. 1; Mélanges biolog. tirés du Bull. de l'Acad. St. Pétersbourg, Vol. VIII, p. 170.

[4] Das herzogliche leuchtenbergische Museum zu Eichstaedt: Augsb. Allg. Zeitung, 1846, No. 218, p. 1740.

[5] Zeitschr. Deutsch. geol. Gesell., Vol. I, 1849, pp. 437–439.

[6] Contributions to the Natural History of the United States of America, Vol. I, 1857, pp. 24, 306.

[7] Loc. cit., Vol. III, 1860, p. 125.

description of two fossil medusæ, one of which was Beyrich's *Acalepha deperdita*, which afterwards proved to be specifically identical with the specimen mentioned by Agassiz. He also described *Medusites antiquus*, and referred Beyrich's species to Medusites, placing, however, the two species under the genera Craspedonites (*C. deperditus*) and Acraspedites (*A. antiquus*).[1]

Dr. Haeckel, in 1866, described two additional species from the Solenhofen slates, referring them to the family Rhizostomæ. The two species *Rhizostomites admirandus* and *R. lithographicus* are illustrated by two very good plates.[2] This was followed, in 1870, by the description of several new genera and species. These include: *Palægina gigantea*, *Leptobrachites trigonobrachius*, *Eulithota fasciculata*, *Medusites quadratus*, *M. bicinctus*, *M. staurophorus*, *M. circularis*, and *M. porpitinus*. He also described *Rhizostomites admirandus* H., *R. lithographicus* H., *Acraspedites antiquus* H., and *Trachynemites deperditus* H.[3] In 1871 Dr. Brandt published a memoir of *Rhizostomites admirandus*, *R. lithographicus*, and *Leptobrachites trigonobrachius*, illustrating the species and giving restorations of the two rhizostomes.[4] In the same year he published an historical review of fossil medusæ literature and a discussion of *Acalepha deperdita* Beyrich.[5]

Dr. Haeckel returned to the study of the fossil medusæ again in 1874, and described two new species of Discomedusæ under the names *Hexarhizites insignis* H. and *Semæostomites zitteli* H.[6]

In 1886 Dr. Ludwig von Ammon published a memoir[7] in which he reviewed the work of his predecessors on the fossil medusæ and gave the results of his own studies on some new material from the Jurassic rocks of Bavaria. *Hexarhizites insignis* H. is considered to be a synonym of *Rhizostomites lithographicus*, and *Leptobrachites trigonobrachius* as possibly a laterally crushed form of the same species. *Leptobrachites giganteus* H. is said to

[1] Ueber fossile Medusen: Zeitschr. für wiss. Zoologie, Vol. XV, 1865, pp. 504–514, Pl. XXXIX.

[2] Neues Jahrbuch für Min., Geol. und Pal., 1866, pp. 257–292, Pls. V, VI.

[3] Ueber die fossilen Medusen der Jura-Zeit: Zeitschr. für wiss. Zoologie, Vol. XIX, 1869, pp. 538–562, Pls. XL–XLII.

[4] Ueber fossile Medusen: Mém. Acad. imp. sci. St. Pétersbourg, 7th series, Vol. XVI, No. 11, 1871, pp. 1–28, Pls. I, II.

[5] Nachträgliche Bemerkungen ueber fossile Medusen: Mélanges biolog. tirés du Bull. de l'Acad. St. Pétersbourg, Vol. VIII, 1871, pp. 168–180.

[6] Ueber eine sechszählige fossile Rhizostomee, etc.: Jenaische Zeitschr., Vol. VIII, 1874, pp. 308–330, Pls. X, XI.

[7] Ueber neue Exemplare von jurassischen Medusen: Abhandl. Math.-phys. Classe Königl. bayerischen Akad. Wiss., Vol. XV, 1886, pp. 105–168, Pls. I–V.

represent the circumference of the head and the arms of a cephalopod. Important observations were made on the classification of the Jurassic medusæ that will be referred to again.

ORIGIN OF THE IMPRESSIONS OF MEDUSÆ.

Dr. Haeckel advanced the view that the impressions were secondary and not direçt. Dr. Brandt, on the contrary, regards them as direct impressions, and in this Dr. von Ammon agrees with him. Dr. Brandt thinks that on account of the low specific gravity and the well-known physical constitution of medusæ, it is very improbable that one should become embedded and petrified on the bottom of the high sea. The Jurassic fossil medusæ therefore belong to stranded individuals. They did not lie on their side, as *Leptobrachites trigonobrachius* did, but were spread out on their under or oral surface. The fluid calcareous slime filled the under surface of the oral disk and the umbrella almost completely. The small quantity of air or water which might in the process have become caught under the medusa-bell would become forced into the most excavated zone of the umbrella, and there have occasioned the existence of the so-called smooth ring through which the impressions are interrupted. Through the oval apertures the limy ooze forced its way into the four genital cavities. Although the latter must have been collapsed by reason of the hypothetical position of the medusæ, the intrusive mass succeeded in taking impressions of the covers of the genital cavities, the saddle-shaped plats. That these last appear as raised positions on the mid-field is sure indication for the interpretation of the fossils as impressions in the narrower sense of the word. The cœlenteric central cavity remained unfilled, except, perhaps, as shown in the fossils by a few irregular attached pieces of limestone, where the ooze may have pressed in here and there, either through a slight rupture or through a still open portion of the mouth. Concerning the structure of the floor of the central cavity, therefore, no information could, under these circumstances, reach us.

Only by the mode of fossilization just described is it explicable that no impressions of the oral arms exist, namely, that they could very well lie under the surface of the slab, inside it, and there have left their impressions. Against the probable objection that at least the basal portions of the arms must have left traces, the following reply can be made: In view of the slight material consistency of the medusa body, the arm bases may find sufficient expression in the capillary division area, which is present between the point of projection of the arms and the irregular accretions which are situated at the periphery and which represent the tentacles. If it is asked why it was not possible, then, for the arms to be thrown up laterally and so impressed upon the fossil, it can be replied that the arms may have been quite short, or even, as is so often the case among Rhizostomidæ of the present day, broken off during life.

It is evident that the counter impression could be formed only when the umbrella and oral disk had dried up or decayed away, and the impression had had time to become hard.[1]

CLASSIFICATION.

Dr Haeckel's classification is scattered through his publications on the fossil medusæ and is mentioned in connection with the descriptions of the species. Dr. von Ammon studied the various genera and species very thoroughly, and I shall follow his classification in this memoir. He creates for the reception of the Jurassic rhizostomites the extinct family Lithorhizostomeæ. It approaches on the one hand the Rhizostomidæ, through the subgenital opercula and the muscular system, and on the other the Crambessidæ, through the families Colostylidæ and Leptobrachidæ, on account of the broad, short arm disk and the hypothetically long, thin arms.

The similarity of the Jurassic Rhizostomæ to the Crambessidæ, clearly enough expressed in the structure of the body, especially the mouth disk, is noteworthy, in so far as the latter are the most aberrant of all living families of medusæ.

In view of the circumstances mentioned, it seems justifiable to consider the Jurassic rhizostomites as generalized types whose characters are to-day divided among the different families of medusæ.[2]

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[1] Brandt, Ueber fossile Medusen: Mém. Acad. imp. sci. St. Pétersbourg, 7th series, Vol. XVI, No. 11, pp. 13, 14.

[2] Ueber neue Examplare von jurassischen Medusen: Abhandl. Math.-phys. Classe Königl. bayerischen Akad. Wiss., Vol. XV, 1886, p. 165.

Dr. Ammon's[1] classification of the fossil medusæ from the Jurassic is as follows:

CRASPEDOTÆ Gegenbaur. (Not yet proved beyond doubt to exist fossil.)
ACRASPEDÆ Gegenbaur.
Order DISCOMEDUSÆ Haeckel.
1. Suborder CANNOSTOMÆ Haeckel. (Not known.)
2. Suborder SEMOSTOMÆ L. Agassiz.
Family *Lithosemæidæ* Haeckel. (Fossil.)
(1) Semæostomites zitteli Haeckel.
Family *Eulithotidæ* Haeckel. (Fossil.)
(2) Eulithota fasciculata Haeckel.
Family (?) *Pelagidæ* Gegenbaur.
(3) Acraspedites antiquus Haeckel.
3. Suborder RHIZOSTOMÆ Cuvier.
Family *Lithorhizostomeæ* v. Ammon. (Fossil.)
(4) Rhizostomites admirandus Haeckel.
(5) Rhizostomites lithographicus Haeckel.
Hexarhizites insignis is only the six-rayed form of *Rhizostomites lithographicus*. It may belong to the same family or to the family of the Crambessidæ (Subfamily Leptobrachidæ).
(6) Leptobrachites trigonobrachius Haeckel.

MEDUSÆ OF UNCERTAIN POSITION.

(7) Medusites deperditus Beyrich.
(8) Medusites quadratus Haeckel.
(9) Medusites bicinctus Haeckel.
(10) Medusites staurophorus Haeckel.
(11) Medusites circularis Haeckel.
(12) Medusites porpitinus Haeckel.

DESCRIPTION OF GENERA AND SPECIES.

Suborder SEMOSTOMÆ L. Agassiz.

Family LITHOSEMÆIDÆ Haeckel.

Genus SEMÆOSTOMITES Haeckel.

SEMÆOSTOMITES ZITTELI Haeckel.

Pl. XXXIX, fig. 1.

Semæostomites zitteli Haeckel, 1874. Jenaische Zeitschr., Vol. VIII, pp. 323–329, Pl. XI.
Semæostomites zitteli Hæckel, 1880. System der Medusen, p. 647.
Semæostomites zitteli Ammon, 1886. Abhandl. Math.-phys. Classe Königl. bayerischen Akad. Wiss., Vol. XV, p. 157.

[1] Abhandl. Math.-phys. Classe Königl. bayerischen Akad. Wiss., Vol. XV, 1886, pp. 157–158.

Dr. Haeckel characterizes this species as follows:[1]

Medusa disk circular, 80^{mm} in diameter; mouth surrounded by 4 feeding arms, which are about 80^{mm} long and 10^{mm} broad; stomach cavity with 4 (radial) three-cornered pouches of 10^{mm} to 12^{mm} diameter; between the latter, 4 (interradial) elliptical genital pouches of 8^{mm} to 10^{mm} diameter; 16 (unbranched?) radial canals (4 perradial, 4 interradial, and 8 adradial); a rim canal; 16 marginal bodies (?). Umbrella rim

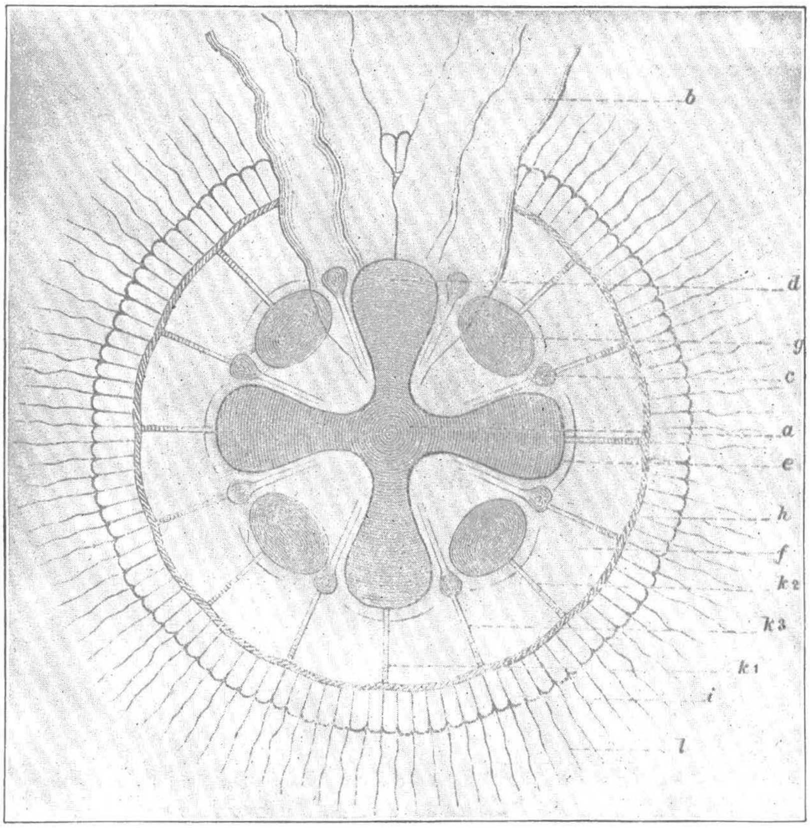

FIG. 17.—Restoration of Semæostomites zitteli. Natural size. (After Haeckel.)
a, gastral cavity and mouth opening; *b*, oral arms; *c*, adradial papillæ; *d*, gastral pouch; *e*, circular mound on the periphery of the stomach pouch and genital pouch; *f*, the smooth zone; *g*, genital pouch; *h*, ring canal; *i*, marginal lobe; *k*, radial canals (k_1, perradial; k_2, interradial; k_3, adradial); *l*, marginal tentacles.

split up into 120 to 128 narrow marginal lobes, between which arise an equal number of marginal tentacles 30^{mm} long.

The following notes are from an abstract of Dr. Haeckel's remarks on the species:[2]

Even a superficial examination of this fossil shows that it represents one of the higher medusæ of the order of the Semostomæ. It is an acraspedote or phanerocarpous medusa, with a central mouth opening, 4 feeding arms, and numerous marginal lobes.

[1] Jenaische Zeitschr., Vol. VIII, 1874, p. 329. [2] Loc. cit., pp. 323–329.

As in Hexarhizites, there are three zones which can be distinguished—an inner or genital zone; a median, smooth zone, and an external marginal zone.

The mid-field shows a strong, bowl-shaped excavation, which plainly corresponds to the gastral cavity. Its periphery is circular, but appears to be octagonal with rounded corners, if one regards as its boundary points the points of contact of the genital pouches and the stomach pouches. In the central part of the mid-field, where it is most depressed, is the central mouth opening, surrounded by four oral arms which are thrown outward to one side, over the edge of the umbrella.

Arms appear as convex rolls, considerably elevated. They do not reach the edge of the slab, but only about as far as the marginal tentacles.

In the peripheral portion of the bowl-shaped mid-field arise eight radial ridges of about 2^{mm} width, which gradually ascend from within outward until they reach the steep peripheral descent of the genital zone, and here end in the form of eight convex knots or papillæ. These papillæ are the most elevated portion of the fossil, and should therefore correspond to the thickest portion of the medusa disk. Each papilla has about the shape of a three-sided pyramid with a blunt point. By a more exact inspection of the mid-field and the adjacent genital zone, one is convinced that the eight areas (of the shape of an isosceles triangle) which are dissected by the eight radial ridges are alternately different. Four wide triangles alternate with four narrower. The latter are only very slightly narrower, but in their peripheral portion appear round, pit-like depressions, rather sharply defined, which are lacking in the areas alternating with these, and which without doubt are to be interpreted as genital cavities. The four narrower areas are interradial; the four broader ones alternating with them are, on the contrary, perradial, and, because of their concave nature, are to be regarded as gastral pouches.

That the four broader areas which alternate with the genital fields are truly correspondent to gastral pouches can not be doubted; while their peripheral rim is sharply defined by a convex curved line, and the middle part appears strongly excavated, their central end passes without interruption in the deep middle portion of the mid-field, into the stomach cavity.

In the peripheral portion of the smooth zone there are poorly defined wrinkles which form fragments of concentric flutings, and are to be referred to the ring muscles of the subumbrella. Besides this, almost no especial structure is recognizable on the smooth zone. However, in certain lights, several very fine, straight, radial lines can be seen which persist through the whole width of the smooth zone and indicate radial canals.

Since the families of this group are especially distinguished by means of the different character of the radial canals, and since just upon this very detail of character no satisfactory degree of certainty can be attained, we will leave the question of its family relationship open here. It almost seems, however, that it can not be joined with any one of the known families. If this supposition proves correct, our fossil group can be called Lithosemæa, and the related family Lithosemæidæ.

Family EULITHOTIDÆ Haeckel.

Genus EULITHOTA Haeckel.

EULITHOTA FASCICULATA Haeckel.

Pl. XLV, figs. 3, 4.

Eulithota fasciculata Haeckel, 1869. Zeitschr. für wiss. Zoologie, Vol. XIX, pp. 549–553, 559, Pl. XLII, figs. 1, 2.

Eulithota fasciculata Haeckel, 1880. System der Medusen, p. 647.

Eulithota fasciculata Ammon, 1886. Abhandl. Math.-phys. Classe Königl. bayerischen Akad. Wiss., Vol. XV, p. 157.

Dr. Haeckel's descriptive remarks are essentially as follows:[1]

The impression of this medusa shows the animal lying on its oral side, and the depth and distinctness of its outline bear witness to the considerable cartilaginous consistency of the gelatinous mass. By a careful inspection it is shown that the peripheral outline of the disk takes on almost the form of a regular octagon, while at equal intervals lie eight pit-like depressions of an irregular form, directed radially. These eight marginal pits have evidently been produced by some especially thick and firm portion of the body rim, and probably by those well-known sense organs distinguished by the name of "rand-koerper" (marginal bodies), while the filaments streaming out from them were probably formed by marginal tentacles. It is necessary to believe that the latter belong to the hard and fast category of marginal tentacles whose axis is supported by a central cartilaginous band, for tentacles of the other class, which represent a thin-walled, hollow cylinder, could hardly, under the most favorable circumstances, leave behind so sharp and distinct an impression. There is in favor of this hypothesis the somewhat hard and stiff position of the tentacles of our fossil, which is exactly as in the cartilage tentacles described by me. The umbrella rim of our Eulithota appears to be supplied with tentacles only at the eight prominent places where are the hollows of the "rand-koerper," or sense organs, and, in fact, they form a tuft which was probably fastened immediately beneath the base of the sense organ. Only four tentacles can be clearly and unquestionably made out in each bunch, but probably their number was much more considerable.

Arising from the octagonal periphery of the disk rim are 16 equal crescent-shaped depressions, directed inward, and terminating outwardly in a smooth, sharply defined convex curve. These can be nothing else than the 16 lobes of the deeply indented umbrella rim. That they project convexly inward instead of outward is easily explained by supposing that the disk of our medusa (as in many still living forms) had its greatest diameter, not at the disk margin at the mouth of the umbrella cavity, but some distance above the rim. Accordingly, the umbrella cavity must have been wider above its orifice than at it. The indentation between any two marginal lobes is very deep.

Centrally from the infolded lobes of the disk rim there follows, in our impression, a rather strongly prominent ring which presents no especial structural features. It

[1] Zeitschr. für wiss. Zoologie, Vol. XIX, 1869, pp. 549–552.

seems to correspond to that thinnest portion of the disk which lies outside of the genital ring, between it and the disk rim, which is thickened by the reversed marginal lobes.

Farther inward follows a thinner ring, which I designate a genital ring because I believe that I recognize with certainty sexual organs in it. In a favorable light seven contiguous crescentic facets can be recognized on one-half of the disk within the ring. They are directed with the convex side inward, the concave outward, and seem to repeat the wreath of marginal lobes, which are almost twice as large. Their number, in all probability, amounted to 16, and there seems to be no other possibility than to regard them as sex organs, as they agree exactly in form and position with like organs in other acraspedote medusæ. The great number of these sex organs, together with their continuity and contiguity, may appear remarkable, since the Acraspedæ usually possess only 4 or 8 genital glands. In this particular our medusa draws nearer to the craspedote forms, in which often a continuous ring is formed by a large number of tangent genital organs. In any case this conspicuous circumstance appears sufficiently important, according to the general custom ruling in the systematic study of medusæ, to consider our fossil as a representative of a new family among Acraspedæ.

From the notch between each two genital glands, radially to the corresponding peripheral notch, runs a straight line which can not be otherwise interpreted than as a radial canal.

In the central circular field, which is inclosed by the genital ring, we would expect to find the mouth and its surrounding mouth arms. However, the visible portions of this area are so obscure, and the drawing of their boundary lines is so faint and confused, that we should prefer not to give any definite opinion upon it. The only figures which are somewhat clear are two sausage-shaped mounds lying near each other on the periphery of the central field. In any case, the oral arms must have been quite short, or otherwise one at least would project out over the genital ring.

As a résumé we have 8 eyes, 8 bunches of tentacles, 16 genital glands, 16 radial arms, and probably 4 simple oral arms. On the other hand, nothing definite has been determined regarding the form of the mouth, of the stomach, and of the system for procuring food which radiates from it. It is, therefore, not possible to determine sharply the whole generic character of our medusa. This much can be deduced from the form of the well-developed marginal lobes and their sufficiently recognizable structure, that it belongs to that division of the higher medusæ which Eschscholtz called Phanerocarpæ, and Gegenbaur, Acraspedæ. In any case, it must belong to that great group with a simple mouth and 4 (or 8) oral arms which Agassiz assembled together as Semostomæ and compared with Rhizostomæ.

After a somewhat full comparison with the forms of the Semostomæ, Dr. Haeckel concludes with these remarks:

Under these circumstances we can not enroll our medusa with the Sthenonidæ, which stands the nearest among living medusæ, but must regard it as the representative of an especial, extinct semostomous family, which we call Eulithotidæ and characterize in the following manner: Tentacles grouped in bunches, 8 eyes, disk rim lobed, 16 sex glands.

Family (?) PELAGIDÆ Gegenbaur.

Genus ACRASPEDITES Haeckel.

ACRASPEDITES ANTIQUUS Haeckel.

Pl. XLIV, fig. 2.

Medusites antiquus Haeckel, 1865. Zeitschr. für wiss. Zoologie, Vol. XV, pp. 509–513, Pl. XXXIX, fig. 2.

Acraspedites antiquus Haeckel, 1869. Zeitschr. für wiss. Zoologie, Vol. XIX, p. 559.

Acraspedites antiquus Haeckel, 1880. System der Medusen, p. 647.

Acraspedites antiquus Ammon, 1886. Abhandl. Math.-phys. Classe Königl. bayerischen Akad. Wiss., Vol. XV, p. 157.

Dr. Haeckel states that little besides the "topography" of the specimen is preserved. An acraspedote or phanerocarpous medusa.

This is shown by the apparent structure of the genitalia. In *M. antiquus* I regard as such the lobe-like projections of the inner indented circle, which, as in all acraspedotes, lie between the radial canals. In *M. deperditus*, on the other hand, the genitalia appear in the gentle spindle-shaped swellings in the middle of the radial canals, the direct enlargement of which they produce, as with all craspedotes.

I inclined to put *M. antiquus* with the Pelagidæ because of the simple, unbranched radial canals, which, together with the marginal lobes, are 8 in number. If, however, the radial canals were branched, the minor forks not being preserved, this form would probably have to be placed with the Aurelidæ or Cyanidæ.

M. deperditus probably goes with the Trachynemidæ, and bears a strong resemblance to Rhopalonema. Both have eight equally strongly developed radial canals, somewhat swollen in the middle. I believe that I can support this opinion also by the fact that in Rhopalonema I find every radial canal accompanied and supported by a double band of cartilage in streaks of greater consistency, which in any case would tend to leave behind a distinct impression. The gelatinous mass of the umbrella also, as well with the Trachynemidæ as with the nearly related Æginidæ, is distinguished by an almost cartilaginous consistency, which renders them better adapted for preservation in a fossil condition than most other medusæ. One is then almost inclined to regard the broad ring which surrounds the circle canal as the flat, expanded, and pressed velum, which in the family of the Trachynemidæ is strikingly thick and strongly developed. Probably, however, here, as in *M. antiquus*, it is better to refer this ring to the thickness of the gelatinous mantle itself, which, of necessity in the case of an animal spread out flat and lying on the sea bottom, spread symmetrically during its gradual entombment, while the whole body was slowly and symmetrically compressed in the direction of the principal axis. In the case of *M. antiquus*, in which the ring surrounding the circle canal (and also the actual rim of the umbrella cavity, though much less broad) appears much more distinctly impressed, is this conclusion all the more safe, since a velum is universally among the Acraspedæ only occasionally developed. That the fossil *Medusites deperditus* (of 70^{mm} diameter) is much larger than any living Trachynemidæ, at least any yet known (4^{mm}–8^{mm} the maximum and only in a few cases, a few even below 1^{mm} in diameter), constitutes no argument against placing the former in this family, since in the nearest related group of the Geryonidæ the greatest variation in size exists (1–3^{mm} to 50–60^{mm} in diameter).[1]

Suborder RHIZOSTOMÆ Cuvier.

Family LITHORHIZOSTOMEÆ Ammon.

Genus RHIZOSTOMITES Haeckel.

RHIZOSTOMITES ADMIRANDUS Haeckel.

Pl. XL; Pl. XLII, fig. 2.

Rhizostomites admirandus Haeckel, 1866. Neues Jahrbuch für Min., Geol. und Pal., pp. 261–282, Pl. V.

Rhizostomites admirandus Haeckel, 1869. Zeitschr. für wiss. Zoologie, Vol. XIX, p. 557.

Rhizostomites admirandus Brandt, 1871. Mém. Acad. imp. sci., St. Pétersbourg, 7th series, Vol. XVI, No. 11, pp. 1–18, Pl. I, figs. 1–4.

Rhizostomites admirandus Haeckel, 1880. System der Medusen, p. 647.

Rhizostomites admirandus Ammon, 1886. Abhandl. Math.-phys. Classe Königl. bayerischen Akad. Wiss., Vol. XV, pp. 123–130; 158, 163–165, Pl. I, fig. 1; Pl. V.

Dr. Haeckel's original diagnosis of the species is as follows:[2]

Medusa disk of 4 decimeters diameter. In the center 4 short and strong radial major arms (branches of the gastral trunk, whose undivided base is 60^{mm} long and 34^{mm} broad), and which are connate for the length of 20^{mm} in the middle of the inferior surface of the disk. (Probably each of the four principal arms was subdivided into two simple, short secondary arms.) Genital cavities 4, interradial between the basal portions of the 4 principal arms. The 4 sex organs are crescent-shaped elevations, 120^{mm} long and 15^{mm} broad, located on the periphery of the pouch-shaped genital cavities. A peripheral zone of the disk, of 70^{mm} breadth, with strongly developed ring muscles of the subumbrella. Rim of the disk contracted at intervals so as to form 8 indentations (4 radial and 4 interradial), separated one from another by equal intervals, and thus forming 8 flat lobes (with probably 8 sense organs in the 8 incisions). Besides these 8 deep incisions in the umbrella margin, 120 other flatter radial incisions, by which the latter is divided into 128 lobes of 22^{mm} length and 9^{mm} breadth.

Dr. Haeckel gave a diagrammatic restoration of the under side of this species, and also a vertical meridian section of the impression on the lithographic limestone and of the medusa body, restored according to the impression.

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[1] Zeitschr. für wiss. Zoologie, Vol. XV, 1865, pp. 511–512.

[2] Neues Jahrbuch für Min., Geol. und Pal., 1866, p. 282.

This species and the following, *R. lithographicus*, were referred to the Rhizostomidæ because they have the center of the mid-field occupied by a regular and sharp cross-shaped figure, which is referable to the connate bases of the feeding arms, which are so characteristic of the rhizostomes. The complete lack of marginal tentacles, together with the division of the umbrella rim into numerous lobes, is also suggestive. The absence of the median spaces observed between the outer and inner ring of *Acraspedites antiquus* shows that the greatest diameter of the disk in *R. admirandus* and *R. lithographicus* was at the rim, as in the case of most of the Rhizostomidæ.

It is especially noteworthy that small examples of *R. admirandus* have the same number of marginal lobes (as nearly as can be ascertained) as the largest specimens.

The sharp and characteristic structure of the mid-field is explained completely and naturally on the supposition that the mouth opening is lacking, and that the four regular, equal rims of the cruciform furrow (*a–c*), which meet at right angles in the center, are the seam-like boundaries between the four connate bases of the four great feeding arms, which in rhizostomes hang down from the middle of the under surface of the disk, where in other medusæ the mouth is situated.

The four convex isosceles triangles are interpreted as the basal portions of the four great arms or so-called branches of the gastral trunk which hang down from the center of the umbrella cavity and correspond to the four mouth arms of other Acraspedæ.

At the periphery of the mid-field each principal arm or trunk appears to bifurcate, so that eight arms start from the periphery of the mid-field. Whether the eight arms which result in this way branch again, it is not possible to follow up, since the outlines, which in the case of the four arms are so sharp in the mid-field, gradually disappear toward the exterior and are lost in the confused, irregular lines and depressions of the first concentric ring. However, this is probably not the case. Furthermore, the unbroken periphery of the concentric ring indicates that no arms overlie it, and that, within, the eight arms were both simple and short.

Of the four concentric rings which surround the mid-field, the first or deep ring (*n*) corresponds without doubt to the four genital cavities. This is shown as well by its position as by the irregular nature of its upper surface, and finally by its suggestive depression. Since this ring is the deepest portion of the whole impression, the medusa disk must here have been the thinnest, and this, in fact, corresponds completely to the circumstance that in many acraspedote medusæ that portion of the disk in which the genital cavities lie is the thinnest portion of the umbrella.

The second or four-part ring (*p*) can be regarded with great probability as the genitalia themselves, or a part of them. In fact, in some rhizostomes the sex organs lie on the outer periphery of the pouch-shaped genital cavities, in the form of elongated cylindrical rolls, which are concave toward the center. Each of the four crescentic mounds is, then, to be regarded as a reproductive organ. The peculiar furrowed character of their upper surface tallies with this interpretation. The fine furrows on it do not go to form connected concentric rings, as do the regular circular furrows of the outer (muscle) ring (*u*), and can not therefore be referred to the ring muscles of the subumbrella. On the contrary, they are short, much broken, unequally separated one from the other, and for the most part bifurcate terminally and run out into several gradually disappearing and diverging delicate furrows. These furrows can very well be referred to the irregular furrows which exist between the superficial folds of the fourfold elevation formed by the genitalia in the Rhizostomidæ and other acraspedote medusæ.

The third or smooth ring can be nothing else than that portion of the gelatinous disk which immediately surrounds the genital cavity, and, in fact, forms its outer wall. The completely even and smooth surface of this ring corresponds to the simple nature of this portion of the umbrella, in which no especial structures are visible, and where even the ring muscles of the subumbrella, which characterize the fourth ring in so marked a manner, are lacking. Very important, too, is the negative circumstance that neither the smooth ring nor the two rings inclosing it are pierced and interrupted in a radial direction by the prolongations of the radial arms. It can be concluded from this that these were proportionally short and thick, similar to those in the living Stomolophus; even were they as long as in Rhizostoma and in most other Rhizostomidæ, they need not necessarily have overlain merely the inner ring (whose irregular figure they condition), but also the three outer rings.

Beyond all doubt the 35 to 40 fine and concentric circular mounds which project as low, three-cornered, prismatic ribs over the surface of the rings and leave the same number of deep and sharp furrows between them, are to be referred to the muscle rings of the subumbrella, which, in many Rhizostomidæ, as well as in many other Acraspedæ (especially Cyaneidæ), project in the form of strong, almost furrow-shaped muscle rings over the under surface of the subumbrella. The muscular rings begin in the outer portion of the smooth ring, become the strongest in the inner third of the furrowed ring, and from there gradually fade away, so that the periphery of the disk could only be contracted by comparatively weak ring muscles. The peripheral lobes amount to 128 in the circuit of the entire disk. The very large number of these marginal lobes, which are characteristic of the Acraspedæ, fits in especially with the character of the Rhizostomidæ, which are distinguished from the rest of the medusæ by the especially large number of these. The entire absence of all appendages to the disk rim also speaks in a strong, negative manner for the rhizostomide nature of the medusæ. As a last form-character of the umbrella rim, likewise excellently fitting our interpretation, can be offered the large, flat marginal lobes, which are indicated on the under side of the impression by the strong radial indentations (y_3) and the interradial indentations (x). Both these invaginations, of which there must have been eight in the whole disk edge, were surely deep incisions in which the four radial and four interradial sense organs resided.[1]

Dr. Haeckel next discusses the systematic position of this species, and refers it to the family Rhizostomidæ

In his review of the fossil medusæ of the Jura, Dr. Haeckel[2] states

[1] Neues Jahrbuch für Min., Geol. und Pal., 1866, pp. 273–280.

[2] Zeitschr. für wiss. Zoologie. Vol. XIX, 1869, p. 557.

that his interpretation of this species as a rhizostome was correct, as his study of the living *Crambessa tagi* had given him renewed assurance of the correctness of the reference. He says:

> The oral under surface of the disk's center, or, more exactly, of the umbrella stalk or oral disk, from whose periphery the four pairs of arms arise, shows in *Crambessa tagi* the same markings as in *R. admirandus*, namely, a central mouth cross surrounded by eight isosceles triangular areas. However, the significance which I gave to these fields in Rhizostomites must be somewhat modified, for, as Crambessa plainly shows, the four major, convex isosceles triangles which touch in the center are not radial, but interradial. On the other hand, the four smaller, concave isosceles triangles whose points converge with the ends of the limbs of the mouth-cross are not interradial, but radial (more accurately, perradial).

NOTES ON THE OBSERVATIONS OF DR. BRANDT[1] AND DR. AMMON ON RHIZOSTOMITES AND THE TWO SPECIES REFERRED TO IT.

Dr. Brandt studied the material described by Dr. Haeckel and arrived at the conclusion that *Rhizostomites admirandus* and *R. lithographicus* were identical, the latter being only a younger specimen, as was suggested by Dr. Haeckel in his remarks on the species. This resulted from his observations on the number of the marginal lobes, the width of the marginal zone, and the arrangement of the oral cross. Dr. Brandt believes that Dr. Haeckel was in error in his observations on the four crescentic mounds forming the crescent ring. Dr. Haeckel regards these as representing the genital pouches, but Dr. Brandt maintains that they are adventitious and without structural significance. He locates the genital arms in four radially located, depressed, elliptical figures, which Dr. Haeckel failed to observe.

The fact that Dr. Haeckel regarded the fossils as secondary impressions, while Dr. Brandt believes them to be direct impressions, affords a basis for a definite interpretation of many of the future observations.

Dr. Brandt calls attention to the fact that the configuration of the mid-field in *R. lithographicus* corresponds remarkably with that of Crambessa and must have the same significance. This is possible only on the theory that the fossil is a direct impression. He is also inclined to believe that Rhizostomites possessed, even at maturity, a mouth which was not closed by the growing together of the margins; in which event it would represent an intermediate form between the two acraspedote families.

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[1] Ueber fossile Medusen: Mém. Acad. imp. sci. St. Pétersbourg, 7th series, Vol. XVI, No. 11, pp. 1-18, Pl. I, fig. 1, 4.

Dr. Brandt defines the genus Rhizostomites as follows:

Disk as large as 0.4 meter, with 128 marginal lobes, without marginal tentacles; oral trunk rudimentary, usually the form of the oral disk, surrounded by eight arms. Genital cavities, 4. Cœlenteric central cavity simple, with sphero-quadratic roof. Mouth opening late, perhaps never completely obliterated, cruciform, with 8 branches. Locality, Eichstädt. Original in Royal Geological Museum at Dresden.

Dr. Brandt gives a diagrammatic restoration of Rhizostomites, accompanied by a representation of one of the stages passed through in the

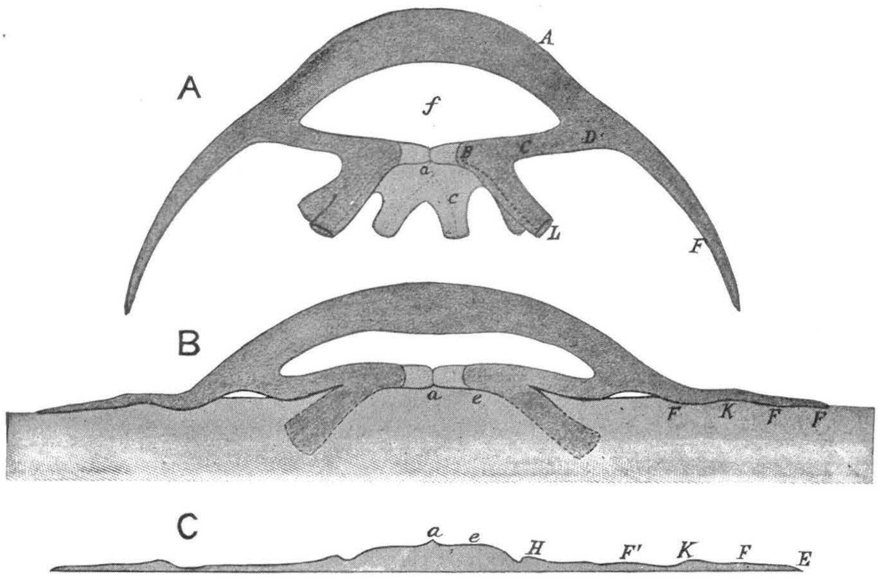

FIG. 18.—Restoration of Rhizostomites. (After Brandt.)

A. Diagrammatic vertical section of Rhizostomites in the direction of a main ray (R_1, fig. 19). The dimensions of this section correspond as accurately as possible to fig. 19; on account of the curvature it appears to be drawn on a smaller scale. The dome of the umbrella and the cut-off mouth arms that are shown are restorations. The curvature of the whole umbrella and the width of the central cavity are also hypothetic.

B. The fossil of a rhizostomite supposed to be in course of production.

C. Approximate section of the impression of a large specimen of *Rhizostomites admirandus*.

(For explanation of lettering, see under fig. 19, opposite.)

course of production of the fossil and by a section of the fossil impression, as well as a view of the restoration from below. These are here reproduced (figs. 18, 19).

Dr. Ammon admits the similarity between *R. admirandus* and *R. lithographicus*, but in view of the fact that no intermediate forms have been discovered he recommends that both species be retained, and gives the following distinctive characters of each: In *R. admirandus* the furrowed zone is a little wider than in *R. lithographicus;* the circular ridges in the furrowed zone are more numerous, and they are equally distributed, which

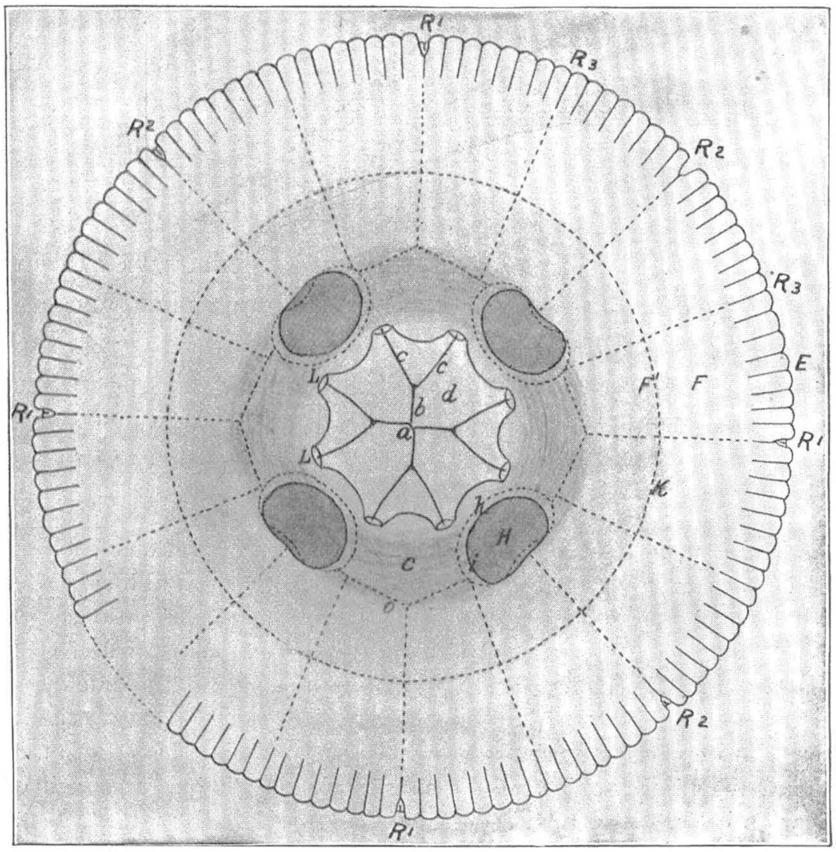

FIG. 19.—Restoration of Rhizostomites, seen from below, after Brandt. The relative dimensions were taken into account so far as possible. For the purpose of more accurate topographic orientation, there were drawn at the edge of the umbrella, besides the 128 edge lobes, also the 16 rays in which the radial canals terminated, in analogy with living forms. For the same reason also the position of 8 marginal bodies and of the circular canal was hypothetically indicated. In the middle of the drawing the peduncles, and the mouth disk produced by their blending, were introduced. The mouth disk sends out 8 arms, which have been drawn as if cut off at their base. On the mouth disk lies the mouth cross, whose secondary arms continue on the oral edges of the arms. Dotted lines indicate the lids of the genital cavities, and of the cœlenteric central cavity.

A. Dome of the disk (umbrella).
B. Mouth disk (stem).
C. Its peduncles, or roots.
D. Base of the peduncles.
E. Edge of disk.
F, F^1. Peripheral zone of disk (umbrella).
H. Kidney-shaped plates (lids of the genital cavities).
L. Mouth arms.
R^1. Four main rays.
R^2. Four intermediate rays.
R^3. Eight rays of lower rank.
a. Center of mouth disk and central mouth rudiment.
b. Primary arms of the mouth cross.
c. Secondary arms of the same.
d, *e*. Isosceles triangles with the mouth cross.
f. Cœlenteric central cavity.
h. Boundary of the kidney-shaped plates (lids of the genital cavities) and in part of the central cavity.
i. Oval windows (entrances to the genital cavities).

is not the case in *R. lithographicus*. *R. lithographicus* also has a broader smooth zone than *R. admirandus* and on the radiating seams forming the 8-armed oral cross numerous crinkled appendages appear in place that look like tufts. In *R. admirandus* these fringes are shorter and more scanty, and the species also seems to be of larger form.[1]

After a careful study of the type specimen of *Hexarhizites insignis*,[2] Dr. Ammon concludes that it agrees in all essential particulars with *R. admirandus* and *R. lithographicus*. It possesses the oral subgenital lids, and, aside from its hexameral symmetry, it has no points of difference. He is also inclined to consider it possible that *Leptobrachites trigonobrachius* is the same form, crushed laterally, as that which produced the oral impressions in *R. admirandus* and *R. lithographicus*. His description of the genus Rhizostomites is as follows (p. 155):

Umbrella large, up to 400^{mm} in diameter, round, with indications of 4 or 8 principal lobes. Umbrella rim subdivided into a large number of marginal lobes. Besides the somewhat larger lobes, smaller ones can be distinguished. Indentations of the rim for marginal sense organs. Circle canal situated in the external third of the umbrella surface. Sixteen radial canals. Subumbrella with strong muscular expression. A powerful ring muscle. Between the oral disk and the muscle zone on the inner side, a strong circular depression, perhaps with the structural significance of an inner ring canal. Four subgenital cavities. Four subgenital opercula on the margin of the not especially wide ostia. Broad but short brachial trunks. Broad, strong arm disk, hollowed out below. Cruciform mouth seam on the oral surface of the arm disk. Arms of the mouth cross with crinkled appendages. Arms long and thin, probably with tassel-shaped tuft on the lower end. Locality, Solenhofen and Eichstadt lithographic slates, stage of *Ammonites* (*Oppelia*) *steraspis*.

Dr. Ammon has no doubt about the correctness of the reference of *Rhizostomites admirandus* and *R. lithographicus* to the Rhizostomidæ. He thinks that the fossil forms under discussion probably possessed long, simple, unbranched arms. The evidence for this rests upon the facts (1) that if the arms were fleshy, manifold, and much branched, the fossils, which are largely gastral impressions, would not be so clearly impressed and their lines so unbroken and undisturbed; (2) the specimen of *Leptobrachites trigonobrachius*, which has long, simple arms terminating in a bristly spatulation, can be regarded as only a lateral impression of *Rhizos-*

[1] Ueber neue Exemplare von jurassischen Medusen: Abhandl. Math.-phys. Classe Königl. bayerischen Akad. Wiss., Vol. XV, pp. 123–130, 158, 163–165, Pl. I, fig. 2; Pl. V.

[2] Loc. cit., pp. 134–137.

tomites admirandus or *R. lithographicus;* (3) in a specimen of *R. lithographicus* there is a long furrow originating near the center and extending irregularly over the disk, terminating in an expansion, which can be interpreted as the impression of an arm, like the arms of *Leptobrachites trigonobrachius.* He considers that these characters indicate an affinity with the Crambessidæ. Analogies with the latter are also shown in the arm disk, which in most Crambessidæ is said to be a large, thick, gelatinous sheet of a quadrate form (seldom octagonal), on the under side of which is the characteristic crumpled seam of the cruciform mouth. There are also subgenital opercula, and there can be readily presupposed the existence of four subgenital cavities instead of the single central cavity situated on the ventral floor, as in the Crambessidæ. Dr. Ammon considers that this view could be maintained even if the oval figures, which otherwise would be referred directly to the cavity, should be taken for the impression of gonads.

This structure of four subgenital cavities and four subgenital opercula speaks, on the other hand, for a relationship with the Pilemidæ, in which every thickening of the rim of the ostium (subgenital lid) is shown in the clearest form; likewise the muscle rim by which, in this family, the firm, hard substance of the gelatinous disk is indicated. The seam of the cruciform mouth, on the under side of the thick, strong oval, can have the same structure in the Pilemidæ as in the Crambessidæ; but there are here present strong, heavy, bushy arms which can not have existed in the Jurassic rhizostomites. The fossil forms thus seem to stand midway between the Pilemidæ and Crambessidæ, the Tetrademnia and the Monodemnia, and to represent a peculiar extinct family of the rhizostomous medusæ.

RHIZOSTOMITES LITHOGRAPHICUS Haeckel.

Pl. XLI, fig. 1; Pl. XLII, figs. 1, 2.

Rhizostomites (?) lithographicus Haeckel, 1866. Neues Jahrbuch für Min., Geol. und Pal., pp. 282–286, Pl. VI.

Rhizostomites (?) lithographicus Haeckel, 1869. Zeitschr. für wiss. Zoologie, Vol. XIX, p. 558.

Rhizostomites (?) lithographicus Brandt, 1871. Mém. Acad. imp. sci., St. Pétersbourg, 7th series, Vol. XVI, No. 11, pp. 3–13, Pl. I, fig. 2.

Rhizostomites (?) lithographicus Haeckel, 1880. System der Medusen, p. 647.

Rhizostomites (?) lithographicus Ammon, 1886. Abhandl. Math.-phys. Classe Königl. bayerischen Akad. Wiss., Vol. XV, pp. 108–122, 158, 161–162, Pl. I; Pl. III, fig. 1; Pl. III; Pl. IV, fig. 3.

In comparing this species with *R. admirandus*, Dr. Haeckel says:[1]

At first sight the disk of *Rhizostomites lithographicus* is nearly like that of *R. admirandus*, especially in the structure of a strongly convex, octagonal mid-field, which is surrounded concentrically by several ring fields. The mid-field is not, as in *R. admirandus*, divided by two bifurcating lines crossing at right angles in the center into four alternating pairs of convex and concave isosceles triangles; at least, a structure corresponding to this can not with certainty be made out. On the other hand, the mid-field is divided by eight radial lines into eight triangular fields, but these eight areas appear to be pretty nearly of a size, so that alternately large and small triangles can not be distinguished. Nor are the equal legs of the eight alternating isosceles triangles bent. They are, on the contrary, almost straight lines.

The inner or deep ring of *R. lithographicus* is traversed by furrows, ribs, elevations, and depressions according to no system which can be recognized.

Of the four-part ring, which in *R. admirandus*, in the form of four crescentic rolls meeting in four points, surrounds the inner or deep ring, there is no trace. They appear to be lost in the outer portion of the inner ring.

The middle or smooth ring, which here immediately surrounds the deep ring, appears as a quite smooth, narrow band, everywhere of equal breadth, which, as well on its outer as its inner margin (*g*), is sharply differentiated from both inclosing rings.

The furrowed ring, here as in *R. admirandus*, is traversed by numerous fine, concentric furrows, which, however, are shallower and somewhat blunter than in the latter. One can count only 20 instead of 40 in the breadth of the ring.

The external portion of the furrowed ring is, in *R. lithographicus*, essentially distinguished from that of *Rhizostomites admirandus*, in that the radial furrows, which in the latter are so plainly impressed and divide the rim into such distinct lobes, in the former are recognized only as quite weak and shallow notches in the disk edge. The number of short lobes which they form may have amounted to about 112 in an uninjured specimen, since there appear to be 28 of them to one quadrant. Besides these small marginal lobes four larger, principal lobes seem to be indicated by four deeper indentations, in which the sense organs probably lay.

The inadequate definition of the mid-field, and especially of its center, which admits of no certain conclusions as to the structure of the gastro-vascular system of the medusa (*R. lithographicus*), renders it impossible to determine with certainty the significance of the various structures and the affinities of the form itself. The four intersecting central lines, which are so sharply impressed in *R. admirandus*, indicating the undoubted rhizostomous nature of the specimen, are here lacking or are indeterminable. On the other hand, the eight radial furrows, which divide the mid-field into eight triangular areas, seem to have been connected in the center. Also, the simple, large, individual and smooth mid-field, which is so plainly expressed in *Medusites antiquus* and *M. deperditus*, and represents beyond a doubt the mouth and gastral cavity, is lacking. Under these circumstances, it is most probable that *R. lithographicus*, too, is a rhizostome; that it lacks a central mouth, and that, instead,

[1] Neues Jahrbuch für Min., Geol. und Pal., Vol. VI, 1866, pp. 286–288.

numerous openings existed on the strong arms which hung down from the center of the inferior surface of the disk. Such arms, which were connate at their bases, appear to have been in the present case 8.

As concerns the three concentric ring fields which surround the mid-field in *R. lithographicus*, the first or innermost of these, which we have here called the deep ring, on account of its strong depression, can be here likewise interpreted as the genital field, since in it, without doubt, the genital cavities were located, and in them the sex organs. It is, however, not possible to pick out clear and certain forms from the unintelligible confusion of fine lines and furrows which traverse the whole deep ring; and, especially, of the sickle-shaped genital mounds, which in *R. admirandus* combine to form the four-fold ring, there is no trace.

The smooth ring (*s*) is similar in every way to the smooth ring of *R. admirandus*.

The furrowed ring.—The number of ring muscles of the subumbrella is only half as great (20) in *R. lithographicus* as in *R. admirandus*. The eight greater indentations of the disk rim, four radial (*y*) and four interradial (*x*), in which the rim bodies were situated and by which eight bow-shaped lobes were formed, are likewise less distinct here than in *R. admirandus*. Further, these are made up of smaller lobes (*z*), which are formed by short radial furrows in the rim, and whose number may be reckoned at about 112.

On the whole, we can maintain that *R. lithographicus* is an acraspedote (discophorous) or higher medusa, and very probably belongs to the suborder of the Rhizostomæ, but are not in position to determine definitely its family, although it is probably of the Rhizostomidæ.

It was Dr. Haeckel's original purpose to refer all species of fossil medusæ to the genus Medusites, or, in case they could be referred to one of the two principal divisions of the medusæ, he proposed to use Acraspedites or Craspedonites. This was made with the belief that zoologists would never be in position to determine accurately the family of fossil medusæ. The discovery, however, of *R. admirandus* proved that he was mistaken; so he proposed Rhizostomites to receive the new forms, stating at the same time that if anyone was unwilling to accept his conclusions and evidence, the fossils might be placed in the genus Acraspedites or even Medusites.

In his review of the fossil medusæ of the Jura, in 1869,[1] Dr. Haeckel states that perhaps this species is only a young example of *R. admirandus*, or, it may be, a quite different rhizostome. The eight three-cornered arching arms of the mid-field, which were interpreted in the original description as the basal portions of eight powerful arms, are perhaps with greater probability to be regarded, as in *R. admirandus*, as four arm bases with four genital cavities alternating with them.

[1] Zeitschr. für wiss. Zoologie, Vol. XIX, 1869, p. 558.

Genus HEXARHIZITES Haeckel.

HEXARHIZITES INSIGNIS Haeckel.

Pl. XLIII, fig. 1.

Hexarhizites insignis Haeckel, 1874. Jenaische Zeitschr., Vol. VIII, pp. 312–323, Pl. X.
Hexarhizites insignis Haeckel, 1880. System der Medusen, p. 647.
Hexarhizites insignis Ammon, 1886. Abhandl. Math.-phys. Classe Königl. bayerischen Akad. Wiss., Vol. XV, pp. 134–137, 158.

Dr. Haeckel defines the genus *Hexarhizites* as follows:[1]

Medusa disk made up of 6 antimeres, which group themselves symmetrically on both sides of the central mouth seam. The transverse 2-lipped mouth opening (almost?) completely grown together in the middle of a regular 12-sided, concave mouth disk, which is formed by the bases of 6 strong, forking, connate mouth arms. The 12 arm branches short, without further bifurcation. Six interradial genital pouches, over the entrance to which a centripetal subgenital lid projects. Twelve radial canals; at the end of these, 12 marginal sense organs. No marginal tentacles. Umbrella rim split up into numerous lobes.

Character of Hexarhizites insignis.—Umbrella circular (27^{cm} in diameter), with a regular 12-sided mouth disk on the oral side, whose diameter measures a third of the former (9^{cm}). Mouth disk formed by the basal portion of 6 short, broad oral arms grown together, which later divide up into two forks. The seams of union of the oral arms unite in the center of the mouth disk to form a 12-rayed figure, composed of 6 small perradial and 6 larger interradial areas, whose boundaries (the "seams of union") project as sharp ridges. The oral seam forms a transverse fissure, upon which two interradial areas abut. On either side of this the remaining ten areas are so arranged that the regular 6-rayed form of the medusa passes over into the amphithect-symmetrical form. On the periphery of every interradial area is a genital pouch, shaped like an isosceles triangle with a base 6^{cm} long, over the entrance to which an arched subgenital flap projects radially inward, 4^{cm} distant from the center. The smooth zone, 3^{cm} wide, which surrounds this genital zone is separated from the marginal zone (likewise 3^{cm} broad) by a circular ring canal 21^{cm} in diameter. Sharply impressed ring muscles on the oral surface of the marginal zone; 144 shallow lobes on the umbrella edge; 12 marginal bodies or sense organs; 12 radial canals.

As in *Rhizostomites admirandus*, we distinguish in the Hexarhizites disk a central circular mid-field and several concentric zones, which surround it in a circle. Even when viewed from above three such rings or disk zones can be distinguished, the outer of which is designated the marginal zone or muscle zone, the median as the smooth zone or smooth ring, and the inner, the one which incloses the middle field, as the genital zone.

The mid-field (g–g_6) is a regular 12-sided, flat depression, and is a counter proof of the flat, excavated oral disk of the medusa. The margin of the mid-field passes over

[1] Jenaische Zeitschr., Vol. VIII, 1874, pp. 312, 314–315.

without a sharp boundary into the genital zone, in which lie the six genital organs. The genital zone sinks gradually toward the exterior and is separated from the smooth zone by a circular furrow which is sometimes sharp and sometimes obscure. The latter (smooth zone) lies a little deeper and represents a slightly elevated plateau. It declines externally quite suddenly and steeply into the muscle zone or marginal zone, which lies much deeper, and, like a moat, as it were, divides the entire inner convex portion of the impression from the surrounding, more elevated portion of the shaly slab.

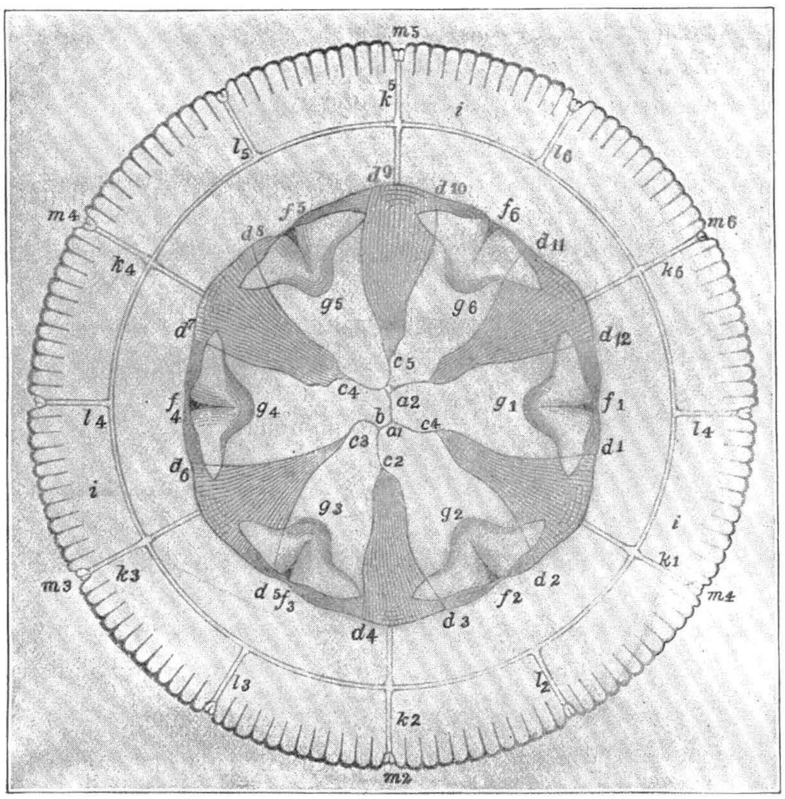

FIG. 20.—*Hexarhizites insignis.* *a*, a_2, mouth seam (a_2, remains of mouth opening?); *b*, lateral branch of the mouth seam; c_1–c_6, bifurcation points of the perradial seam at the base of the 6 oral arms; d_1, d_{12}, the limbs of this bifurcation, by which the oral disk falls into 6 pairs of three-cornered areas. The smaller perradial fields are hatched; the larger (alternating with them) interradial fields are white. In the peripheral portions of the latter the triangular genital pouches are visible, over whose inner entrance a subgenital operculum (*g*) is arched, while a radial furrow (*f*) can be seen in the middle of their basal periphery. *i*, ring canal; *k*, perradial canal; *l*, interradial canal. The marginal bodies (*m*) are shown at the end of this radial canal. The rim is split up into 144 marginal lobes.

When we compare the mid-field of *Hexarhizites insignis* with that of *Rhizostomites admirandus*, we are convinced that the sharp projecting outline of the mid-field in both impressions must have the same significance. The 12 triangular areas of Hexarhizites, alternating in pairs, correspond in configuration and position completely with the 8 alternating triangles of the oral disk of Rhizostomites.

Dr. Ammon studied the specimen described by Dr. Haeckel, and found the oral subgenital lids referred to under *Rhizostomites admirandus* and

R. lithographicus, and concluded that, apart from the hexameral symmetry, it agreed in all essential particulars with those species. He calls attention to the great number of anomalies existing among recent medusæ, and suggests the advisability of calling *H. insignis* a synonym of *R. admirandus.*

Genus LEPTOBRACHITES Haeckel.

LEPTOBRACHITES TRIGONOBRACHIUS Haeckel.

Leptobrachites trigonobrachius Haeckel, 1869. Zeitschr. für wiss. Zoologie, Vol. XIX, pp. 544–548, 558, Pl. XLI.

Leptobrachites trigonobrachius Leuckart, 1870. Jahresberichten ueber Acalephæ: Archiv. für Naturgesch., Wiegmann, Vol. II, p. 280.

Pelagiopsis leuckarti Brandt, 1871. Mém. Acad. imp. sci. St. Pétersbourg, 7th series, Vol. XVI, No. 11, pp. 18–26, Pl. II.

Leptobrachites trigonobrachius Haeckel, 1880. System der Medusen, p. 647.

Leptobrachites trigonobrachius Ammon, 1886. Abhandl. Math.-phys. Classe Königl. bayerischen Akad. Wiss., Vol. XV, p. 158.

Dr. Haeckel's description and remarks, freely translated and condensed, are as follows:[1]

The only clearly recognizable portions of this medusa are 8 three-cornered, slender, oral arms, and a portion of the lobed umbrella rim, as well as the peripheral contour of the whole disk and a genital gland.

The disk of the living animal probably possessed a tolerably high bell, and the consistency of the gelatinous substance seems to have been inconsiderable. There appear to have been 48 marginal lobes in all, though only 16 are discernible on even a very careful inspection.

The deep indentations in the margin, for the sense organs, which were found in other fossil medusæ, are not to be distinctly seen here, though probably present. Marginal tentacles appear to have been entirely lacking.

The oral arms, the best-preserved portions of the entire organism, are 8 in number and very slender. At their base they are only slightly enlarged, and toward the end they are only slightly tapering. Through the middle of each arm, throughout its entire length, runs a sharp, strongly projecting keel, on both sides of which the surface of the arms declines toward the limiting contour, in the shape of oblique planes. Plainly, this appearance indicates a three-sided prismatic form for the arms, as is common to many rhizostomes. The arms seem, conformably to their slenderness, to have been very flexible. The structure of the terminal portion of the arms appears to be very important, especially in connection with the determination of the systematic position of the medusa. The outer or under (distal) portion of the arms is not simply pointed, or rounded off, but terminates in a lancet-shaped body, 24^{mm} long.

Owing to poor preservation, no certain conclusions can be drawn as to the structure of the umbrella, the relation and form of the arm bases, or the mouth and

[1] Zeitschr. für wiss. Zoologie, Vol. XIX, 1869, pp. 545–547.

stomach. On the other hand, one can recognize with moderate certainty the quadrant of a mound-shaped ring lying on the upper left-hand portion of the disk center. It appears as a crescent-shaped body, everywhere 10^{mm} broad, whose two rounded ends are about 60^{mm} apart. It is almost absolutely certain that this is a sexual gland. This is indicated by its characteristic position and also by its crescentic shape, which, as in many acraspedotes, is rounded off at both ends. Another gland, beginning near the end of the first, shows that there was a complete genital ring.

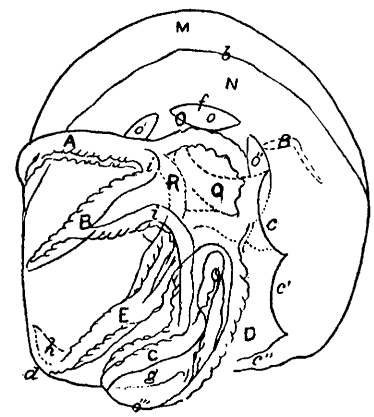

FIG. 21.—Contour drawing of *Leptobrachites trigonobrachius*, reduced and restored. (After Brandt.)

A, *B*, *C*, *E*, four distinctly recognizable mouth arms; *D*, problematic fifth arm; *M*, expression of the thickness of the umbrella; *N*, lower surface of the umbrella; *O*, ring zone, with the entrances into the genital cavities; *P*, place of transition of the umbrella into the stem; *Q*, wall of the stem; *R*, transition of the stem into the bases of the mouth arms; *a*, boundary of the outside surface of the umbrella; *b*, boundary of the inner surface of the umbrella; *c*, *c'*, *c''*, *c'''*, marginal lobes; *f*, outline of the cœlenteric central cavity; *i*, lips of the mouth and side plates of the mouth arms; *o*, *o'*, *o''*, entrances into the genital cavities.

The affinities of this medusa are not known with certainty, since we can learn nothing of its whole gastrovascular system, the form of the mouth, of the stomach, of the radial canals, etc. It can be asserted, however, that it belongs to the higher medusæ, the acraspedote or phanerocarpous medusæ. Proofs of this exist in the marginal lobes and the oral arms. Of the two groups which Agassiz distinguishes in this division, the Rhizostomæ and the Semostomæ, our fossil medusa probably belongs to the former. This can be deduced with great certainty from the number and structure of the arms, in spite of the fact that the characteristic polystomy and the lack of a central mouth, by which the Rhizostomæ are distinguished from all other medusæ, are not to be recognized in the obscure impression in question. Most of the rhizostomes possess 8 similar oral arms of a three-sided prismatic form, while a similar number and structure of the arms very seldom exists among the semostomes. Furthermore, if our fossil medusa had possessed marginal tentacles, one would expect to find at least some trace of them between the lobes of the margin. But this is not the case. Since these structures are characteristically absent from the rhizostomes, while among the semostomes they are developed in greater or less numbers, the balance of evidence seems to be in favor of placing *L. trigonobrachius* with the rhizostomes. Furthermore, it can be concluded, by a process of exclusion, that it stands among the Leptobrachidæ.

Leuckart, in reviewing Haeckel's diagnosis of this species, states that he has examined the types and can not discern the characters of a rhizostomide, nor the 8 arms, and that he favors the views expressed in the forthcoming work of Brandt.

Dr. Brandt's observations on *L trigonobrachius* are so at variance with those of Dr. Haeckel that he has felt it necessary to propose for the species, as interpreted by himself, the new name *Pelagiopsis leuckarti.* He states that instead of 48 marginal lobes and 8 feeding arms, which Haeckel described, he found only 10 lobes and 5 arms. The view, therefore, that the fossil is a rhizostomide is erroneous, since it possesses a wide mouth surrounded by a number of channel-shaped arms. Its most striking peculiarity consists in the pentameral symmetry of the organism, there being 5 mouth arms and genital cavities and 10 marginal lobes. In its general structure it may be compared with Pelagio, although it has no traces of marginal tentacles. Dr. Brandt is in doubt, however, about the true relations of this fossil, as he can not vouch for the existence of the 5 arms and genital cavities and the 15 marginal lobes.

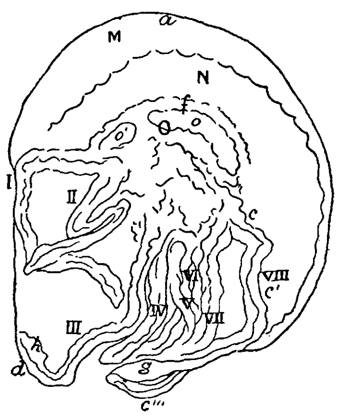

FIG. 22.—Contour drawing of the same fossil (fig. 21) according to Haeckel's restoration, reduced, and, owing to reduction, reversed (right and left interchanged).
I-VIII. Mouth arms.

Dr. Ammon agrees with Dr. Brandt as to the facts observed, but not at all as to his conclusions, and he even considered that *L. trigonobrachius* is a laterally crushed specimen of the same species shown by the oral impressions in *R. admirandus* and *R. lithographicus.*

The interpretations of this species as made by Haeckel and Brandt, respectively, are shown in the two accompanying diagrammatic figures (figs. 21, 22).

The illustrations of the specimens of this species by Haeckel and Brandt are so obscure that I think their reproduction here would not be of sufficient service to the student to warrant the attempt.

LEPTOBRACHITES GIGANTEA Haeckel.

Palægina gigantea Haeckel, 1869. Zeitschr. für wiss. Zoologie, Vol. XIX, pp. 540–544, 559, Pl. XL.

Leptobrachites gigantea Haeckel, 1880. System der Medusen, p. 647.

Leptobrachites gigantea Ammon, 1886. Abhandl. Math.-phys. Classe Königl. bayerischen Akad. Wiss., Vol. XV, p. 158.

Dr. Ammon states that *L. gigantea* should, without doubt, be struck from the list of the medusæ, as it represents the circumference of the head and the arms of a cephalopod. The shell of the animal is also found on the same slab of limestone with the impression of the head and arms.

The second group of species described by Dr. Haeckel includes those whose systematic position can not be further determined. They are grouped under the genus *Medusina*. All are illustrated, with the exception of *M. circularis*.

Genus MEDUSINA[1] Walcott.

MEDUSINA DEPERDITA Beyrich (sp.).

Pl. XLIV, fig. 1.

Acalepha deperdita Beyrich, 1849. Zeitschr. Deutsch. geol. Gesell., Vol. I, pp. 437–439.
Medusites deperditus Haeckel, 1865. Zeitschr. für wiss. Zoologie, Vol. XV, pp. 506–508, Pl. XXXIX, fig. 1.
Trachynemites deperditus Haeckel, 1869. Zeitschr. für wiss. Zoologie, Vol. XIX, p. 560.
Medusites deperditus Leuckart, 1870. Jahresber. ueber Acalephæ: Archiv. für Naturgesch., Wiegmann, Vol. II, p. 280.
Acalepha deperdita Brandt, 1871. Mélanges biolog. tirés du Bull. de l'Acad. St. Pétersbourg, Vol. VIII, pp. 71–180.
Medusites deperditus Haeckel, 1880. System der Medusen, p. 647.
Medusites deperditus Ammon, 1886. Abhandl. Math.-phys. Classe Königl. bayerischen Akad. Wiss., Vol. XV, p. 158.

The original description by Beyrich is brief, and calls attention to the occurrence of the fossil in the lithographic slates. It was followed, in 1869, by Dr. Haeckel's historical notes and elaborate description of the mode of occurrence of the fossil medusæ of the Jurassic. Dr. Haeckel again speaks of the species as the first described, and as the only one of which he had more than one similar impression. From the peculiar stiffness and regularity of form in all the impressions, his conviction was strengthened that this medusa belongs to the family Trachynemidæ.

All that was known of this species by Dr. Haeckel is shown in the figure (Pl. XLIV, fig. 1) and in the accompanying description. Leuckart examined the specimens of *M. deperditus*, and concluded that the eight ridges, interpreted by Haeckel as radial canals, are arranged in pairs, and hence their significance is doubtful.

Dr. Brandt studied a plaster cast of the Carlsruhe specimen (fig. 23, p. 92) and found it to differ from the figure given by Haeckel. He considers that there is no doubt of the specific identity with *Acalepha deperdita*. He regards the rosette (which Haeckel appears to have overlooked) as the

[1] See p. 49.

essential part of the mid-field, and the radial and circular furrows as only bounding it. The zone *u* is not a velum, but the protuberance (Ausguss) of the umbrella surface. The outer parts are due to the thickness of the disk, which first formed a projection, then a fold. The projection would explain the existence of the furrow *p;* the fold, partly filled with mud, that of the ridge *s*.

The "rosette" is a branched stomach. In view of this character, this species appears to be related to the craspedote family of the Æquoridæ (Æginia, Cunina, Eurybia), which have 8 broad gastral branches, and also

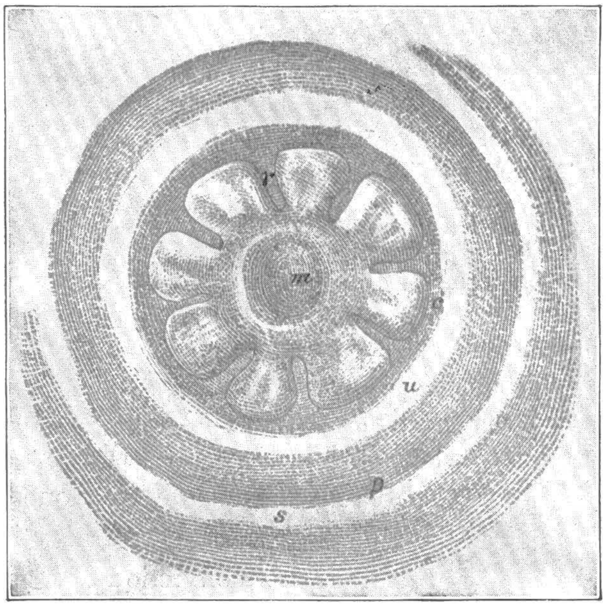

FIG. 23.—*Medusina deperdita.* Reproduced from Dr. Brandt's figure, which he describes as follows:

s, a sharp and distinct peripheral ridge, of a circular shape; *p*, circular furrow; *u*, ring zone; *c*, inner furrow; *m*, depressed mid-field; *r*, radial extension of the furrow *c*. The lobes of the rosette are of two sizes, alternately large and small. The larger lobes show slight excavations at their periphery as if it were the beginning of fission. *m* is the cœlenteric cavity. The eight lobes of the rosette are only additional pouches of the central cavity. *u* is the projection of the umbrella disk; not a velum.

In order to comprehend the details of the peripheral portions of the impression from their origin, one can perhaps imagine that the umbrella rim was thrown inward (orally), so that it formed first a circular projection and later an outward fold. The projection then would explain the existence of the furrow *p*, and the fold filled with ooze the existence of the ridge *s*.

lack an oral trunk and tentacles, which appear to be lacking in *Acalepha deperdita* also. However, the latter can not with certainty be referred to the Æquoridæ, for in the recent form the gastral ramifications are long, not short, and, furthermore, are all equal, while in *A. deperdita* they are alternately large and small.

The characteristic features of the species are as follows: A form without an oral trunk and arms, with a round mouth, and likewise 8 round pouches radiating from a central cavity. In all these characters there is seen an agreement with the Æquoridæ.

Under this definition the term Trachymenites loses its applicability to this species, and Brandt suggests returning to the original name of *Acalepha deperdita* Beyrich.

In the table of fossil medusæ published in 1880, Haeckel drops Trachymenites and refers the species to the general generic term Medusites.

MEDUSINA QUADRATA Haeckel.

Pl. XLV, fig. 1.

Medusites quadratus Haeckel, 1869. Zeitschr. für wiss. Zoologie, Vol. XIX, pp. 553, 560, Pl. XLII, fig. 4.

Medusites quadratus Haeckel, 1880. System der Medusen, p. 648.

Medusites quadratus Ammon, 1886. Abhandl. Math.-phys. Classe Königl. bayerischen Akad. Wiss., Vol. XV, p. 158.

The outline of this fossil is not round, as in all other fossil medusæ, but forms a square with rounded corners. The body is surrounded by a very thick ring which, especially in the middle of each side, rolls up into a strong mound. This subcircular marginal mound shuts in a quadratic field of about 52^{mm} on a side. This is split up into four smaller areas, which, however, can be seen only in a favorable light. At least one can discern two faintly defined mounds which run parallel to the four sides of the square disk, meeting in the middle at right angles.

If one dared hazard an opinion upon the very indistinct and obscure markings of the impression, the four legs of the central cross (r) would appear to indicate four radial canals, which radiated from the four corners of the central stomach. The circular furrow which connects their external ends would represent the rim canal, and the strong elevation surrounding it the thickness of the gelatinous disk. From the form relations, even if they are correctly interpreted, no conclusion can be drawn as to the systematic position of the medusa. Even the square outline discloses nothing definite; for under certain circumstances living medusæ, even of very different families, take on a quadrate form, owing to a contraction of the radial muscles which accompany the radial canals (Staurophora among the Thaumatidæ, and Tiara among the Oceanidæ), while sometimes the circumference of the gelatine disk remains fixed in a shape approaching quadrate.[1]

[1] Zeitschr. für wiss. Zoologie, Vol. XIX, 1869, p. 554.

MEDUSINA BICINCTA Haeckel.

Pl. XLV, fig. 2.

Medusites bicinctus Haeckel, 1869. Zeitschr. für wiss. Zoologie, Vol. XIX, pp. 554–555, 561, Pl. XLII, fig. 3.

Medusites bicinctus Haeckel, 1880. System der Medusen, p. 648.

Medusites bicinctus Ammon, 1886. Abhandl. Math.-phys. Classe Königl. bayerischen Akad. Wiss., Vol. XV, p. 158.

The impression of this medusa is very weak and only with difficulty can the outlines be distinguished of a central cruciform figure surrounded by two circular zones. At first sight this form appears to be an example of *Medusites* (*Trachynemites*) *deperditus*, but by a more careful inspection essential differences become apparent. In the first place, the external circular zone is not simple, but double, and, secondly, the eight radial lines of the mid-field lie at alternately unequal intervals.

The interpretation of this very obscure configuration is difficult and uncertain. The external of the two peripheral rings (*u*) is probably to be referred to the thickness of the gelatinous disk; the inner (*c*) either to a very broad ring canal or to a strong velum. The four narrower of the eight three-cornered facets of the mid-field (*r*) are probably to be interpreted as four radial canals, widening toward the periphery, the four broader ones as interradial areas.[1]

MEDUSINA STAUROPHORA Haeckel.

Pl. XLII, fig. 3.

Medusites staurophorus Haeckel, 1869. Zeitschr. für wiss. Zoologie, Vol. XIX, pp. 555–556, 561, Pl. XLII, fig. 6.

Medusites staurophorus Haeckel, 1880. System der Medusen, p. 648.

Medusites staurophorus Ammon, 1886. Abhandl. Math.-phys. Classe Königl. bayerischen Akad. Wiss., Vol. XV, p. 158.

The outline of the disk of this medusa is so faint as to be scarcely discernible. It appears to form a circle with a diameter of 50^{mm}; 6^{mm} from this runs another concentric circle, just as indistinct. This peripheral zone is probably to be referred to the thickness of the umbrella mass. There is no trace of a ring canal. On the other hand, there is in the middle of the disk a sharply defined cross, composed of two thick mounds intersecting at right angles. In the middle of each mound runs a radial furrow or channel, which gradually enlarges on approaching the center. In the midfield the furrows of the four radial mounds, or cross-quadrants, unite to form a small, flat, funnel-shaped excavation. This is in any case to be referred to the gastral cavity, and the four crossing furrows to the four radial canals passing outward from the stomach. The thickness of the prominent ridges leads to the conclusion that the walls of the radial canals (especially toward the center of the disk) were solid and thick, perhaps supported by cartilage, as in many trachynemids. A conclusion as to the systematic position of this medusa can not be formed, on account of the very deficient impression.[2]

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[1] Zeitschr. für wiss. Zoologie, Vol. XIX, 1869, pp. 554–555.

[2] Loc. cit., pp. 555–556.

MEDUSINA CIRCULARIS Haeckel.

Medusites circularis Haeckel, 1869. Zeitschr. für wiss. Zoologie, Vol. XIX, pp. 556, 561.
Medusites circularis Haeckel, 1880. System der Medusen, p. 648.
Medusites circularis Ammon, 1886. Abhandl. Math.-phys. Classe Königl. bayerischen Akad. Wiss., Vol. XV, p. 158.

This is only a medusa impression, in which nothing can be recognized besides a sharply defined outline.

MEDUSINA PORPITINA Haeckel.

Pl. XLIV, fig. 3.

Medusites porpitinus Haeckel, 1869. Zeitschr. für wiss. Zoologie, Vol. XIX, pp. 556, 561, Pl. XLII, fig. 5.
Medusites porpitinus Haeckel, 1880. System der Medusen, p. 648.
Medusites porpitinus Ammon, 1886. Abhandl. Math.-phys. Classe Königl. bayerischen Akad. Wiss., Vol. XV, p. 158.

The very fine-grained slab shows a quite regular circle, which, by the dark, greenish-black coloring of the whole disk surface, stands out strongly against the yellow-white stone.

The dark zone is circumscribed by a bright one, which shows on one side a rather wide dark contour. Inside the dark mid-field can be seen several obscure concentric circles. No radial markings are shown. The exceptionally clear and sharp definition of the circles, in connection with the dark coloring and the corresponding size, leads to the supposition that here possibly are the impressions of a fossil Porpita.[1]

THE PERMIAN.

Genus MEDUSINA Walcott.

MEDUSINA ATAVA Pohlig.

Medusites atavus Pohlig, 1892. Altpermische Saurierfährten, Fische und Medusen. Festschrift zum siebenzigsten Geburtstage Rudolf Leuckarts; Leipzig, p. 64, Pl. VII, figs. 2 and 5, 1 fig. in text.

The accompanying figure (fig. 24, p. 96) shows Dr. Pohlig's restoration of this species, as perfect as he could make it from the material at hand. He states that it is possible to distinguish in the impressions of the medusæ the narrow inner and broad outer ring fields and, in one specimen, traces of concentric muscular bands. In the mid-field there is shown, in a somewhat indistinct manner, the characteristic tetrameral symmetry of the medusæ. It is concluded that nothing can be determined as to the exact systematic position of the form, except that it does not appear possible to refer it to

[1] Zeitschr. für wiss. Zoologie, Vol. XIX, 1869, p. 556.

the Rhizostomæ. The figures in the plate show quite clearly the general form of the parts described by Dr. Pohlig, and I have received, through the courtesy of Dr. Wilhelm Pabst, of the Herzogliches Museum at Gotha, a photograph of a slab containing a number of impressions of the same character. Dr. Pabst also calls my attention to a photograph of a slab from the Upper Rothliegende of Thüringen, from Tambach in the Duchy of Gotha, containing some impressions which Dr. H. Potonié has designated *Sponginopsis dyadika*

A specimen of this species kindly supplied for study by Dr. Pabst shows a smooth outer zone and a confused, apparently lobate central portion. The peripheral boundary of this specimen is quite distinctly double.

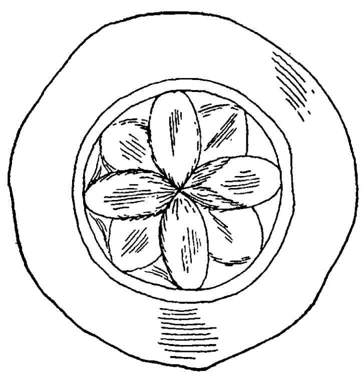

FIG. 24.—Restoration of *Medusina atava*. (After Pohlig.)

MEDUSINA ? sp. undet.

Through the courtesy of Dr. H. B. Geinitz, I have received a cast of a form that has been tentatively referred by him to Medusites. It occurs in the Bunter Sandstein of the Upper Trias near Grotenleite (or Crotenleeide), between Gössnitz and Meerane. The cast indicates an impression such as might be made by the body of a medusa, but, as Dr. Geinitz says in his letter, the remains are too indistinct to warrant any definite statement regarding them, except that they show some resemblance to forms like "*Medusites lindströmi*."

INCERTÆ SEDIS.

It is possible that imprints or casts of fossil medusæ have been described and figured by authors who have not recognized their true characters. Two have come to my notice, to which I wish to call attention as being worthy of further investigation. One of them is described and illustrated by Dr. H. A. Nicholson as *Buthotrephis (?) radiata*. It is a peculiar radiate fossil from the Skiddaw slates (Ordovician), that suggests the imprint of a medusa; and it seems desirable to have the specimens studied from this point of view. The figures[1] recall the appearance of some of the medusæ and trails on the

[1] On the occurrence of plants in the Skiddaw slates: Geol. Mag., Vol. VI, 1869, Pl. XVIII, figs. A. B. and D.

Lower Cambrian slates of Middle Granville, New York. The second is *Discophyllum peltatum* Hall, from the "Hudson River group" of New York.[1] (See p. 101.)

CRETACEOUS.

Reports of the discovery of fossil medusæ in flint nodules derived from the Cretaceous have been made from time to time since Dr. Kner described *Medusites cretaceus* in 1866. This species is noticed by Brandt, Haeckel, and Ammon. In 1871 Dr. Brandt proposed *Medusites helgolandicus* for a second species, and in 1886 Dr. Ammon described a third species as *Medusites latilobatus*.

Through the courtesy of Dr. C. Gottsche, I have had an opportunity to examine a collection of the so-called fossil medusæ belonging to the Natural History Museum at Hamburg. In the letter transmitting the specimens, under date of January 23, 1896, Dr. Gottsche states that he is convinced that the fossils have nothing to do with medusæ; that the specimen from Langenhorn shows on the under surface the undoubted stalk of a siliceous sponge, which led him to suspect that the fossils are Camerospongia-like bodies. On the receipt of the specimens from Dr. Gottsche, I had thin sections cut from one of them, and found it to be a true siliceous sponge belonging to the Lithistida.

All three of the species described from the Cretaceous flints appear to belong to the same group and should be referred to the Spongiæ. As they have, however, been described as fossil medusæ, a description of them will be given; also the figure of *Medusites latilobatus* (fig. 25, p. 99), and an illustration of the spicular structure cut from a specimen of *M. latilobatus* (fig. 26, p. 100).

Genus MEDUSITES Germar.

MEDUSITES CRETACEUS Kner.

Medusites cretaceus Kner, 1866. Sitzungsber. K. Akad. Wiss. Wien., Math.-naturwiss. Classe, Vol. LII, Part I, pp. 480–482.

Medusites cretaceus Brandt, 1871. Mém. Acad. imp. sci. St. Pétersbourg, 7th series, Vol. XVI, No. 11, p. 2.

Medusites cretaceus Haeckel, 1880. System der Medusen, p. 647.

Medusites cretaceus Ammon, 1886. Abhandl. Math.-phys. Classe Köngl. bayerischen Akad. Wiss., Vol. XV, p. 158.

[1] Paleontology of New York, Vol. I, p. 277, pl. 75, fig. 3.

Dr. Kner's description of this species is essentially as follows:

In a fragment of a flint nodule, such as exist in great numbers in the chalk of Niszniow (in Galicia, Stanislaw chalk). The piece of flint shows on one fractured surface (*a*) the dorsal and upon the other (*b*) the oral side of the medusa. The many-lobed and notched margin of the disk refers this genus to the acraspedote acalephs, particularly for the reason that in the angles of the indentation, roundish, point-like bodies can be recognized here and there under the disk, which are distinguished by a different coloring from the rest of the margin, which resembles a dried orange peel, as well as by their opacity. The number of these conjectural marginal bodies or ocelli, however, can not be determined precisely; I was able to recognize only a few of them in the entire circumference. Then, too, the unequal thickness of the flint and its shaly fracture hinder the medusæ from shining through.

The finer structure of the margin shows under the lobes as a fine-celled or meshed one, and the radii lying between, which proceed from the indentations, may have led into a ring canal. This structure can hardly be made apparent by drawing.

On the oral side some very indistinct arms glimmer through the mass, which I believe to have surrounded the mouth to the number of four. Their outline and length can not be given, since they are much contorted and deeply buried in the flint.

So little information concerning the arms, tentacles, and sexual organs is vouchsafed by the specimen that I was the more rejoiced at the sight of the muscular bands which, as in many living medusæ, are distributed concentrically in a parallel position on the ventral side. Since from the drawing the size, form, and number of the marginal lobes, as well as the coloration still retained, which resembles that of many living medusæ, are shown, a further description would be unnecessary; all the more as no finer details can be added. Moreover, I refrain from the attempt to determine its genus, since too many essential organs are lacking on the oral side. Still, it will probably find place in the family of the Pelagidæ, and may, therefore, for the time being, be designated *Medusites cretaceus*, in order to express at least the formation to which it belongs.

This species has been noticed by Drs. Brandt, Haeckel, and Ammon. Dr. Brandt suggests that it ought to be assigned to the family Pelagidæ, and it is so referred by Dr. Ammon.

The original figure of this species by Kner shows so little of what he describes that I have not thought it worth reproducing.

Dr. Zittel mentions other impressions from the Cretaceous flints, in his text-book.[1] "Fine imprints of medusæ, but not yet accurately examined, in flint nodules of the Upper Cretaceous, are found as Pleistocene drift near Hamburg, and in Galicia indistinct impressions in flint of the Cretaceous of that region have been described by Kner." Dr. Ammon describes the disk-like bodies under the name of *Medusites latilobatus*.

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[1] Handb. der Pal., Vol. I; Paleozool., p. 306.

MEDUSITES LATILOBATUS Ammon.

Medusites latilobatus Ammon, 1886. Abhandl. Math.-phys. Classe Königl. bayerischen Akad. Wiss., Vol. XV, p. 159, figure in text.

This species is based on a somewhat indistinct specimen preserved on a flint pebble found in the diluvium near Hamburg. The pebble is thought to have been derived from the Upper Cretaceous. All that is known of the species is shown in the accompanying figure. (See p. 97.)

FIG. 25.—*Medusites* (?) *latilobatus*. Copy of Dr. Ammon's illustration of the type specimen.

MEDUSITES HELGOLANDICUS Brandt.

Medusites helgolandicus Brandt, 1871. Mém. Acad. imp. sci. St. Pétersbourg, 7th series, Vol. XVI, No. 11, p. 2.

Medusites helgolandicus Haeckel, 1880. System der Medusen, p. 647.

This specific name appears to have been based on the report of the discovery of specimens in Helgoland that were subsequently lost.

Genus MEDUSICHNITES Matthew.

In an article on "Illustrations of the Fauna of the St. John Group, No. V," Mr. G. F. Matthew reprints the description of *Medusites princeps*, *M. radiata*, and *M. costata*, as given by Linnarsson. He also describes, under the generic name Medusichnites,[1] what he considers to be trails and imprints of tentacles of medusæ. Five forms are figured.

Through the courtesy of Mr. Matthew, I have been enabled to examine the original specimens, and I find that, with possibly the exception of fig. 1 of his Pl. XIII, all of the varieties of Medusichnites may be referred to

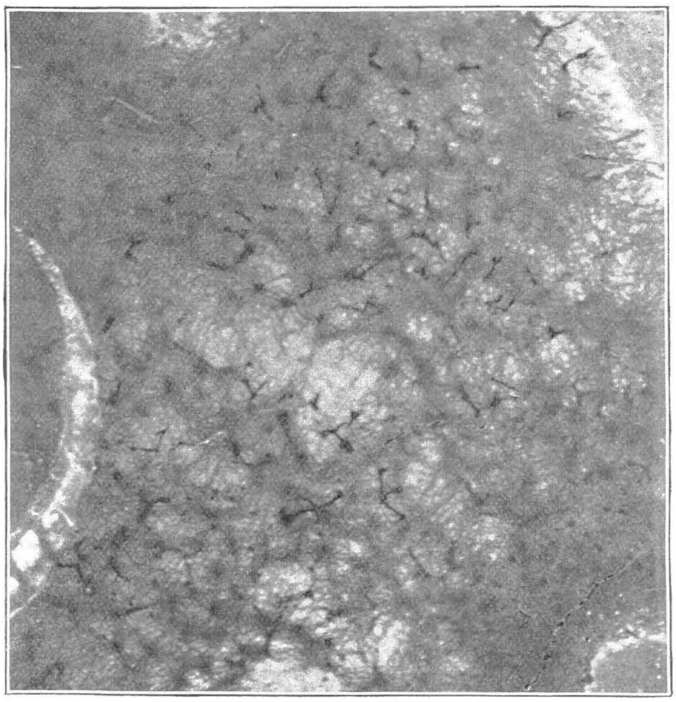


FIG. 26.—*Medusites* (?) *latilobatus*. Enlarged section of a slice cut from a typical specimen of this species.

markings of inorganic origin. I have seen large surfaces of Lower Cambrian shale in Rensselaer County, New York, covered with markings like those shown by fig. 4 of Pl. XII and fig. 1 of Pl. XIII. These were studied in connection with the investigation of medusa-like trails, and the conclusion was reached that they could not have had such an origin.

In order that the student may have the means of comparison with Eophyton, etc., I have introduced photographs (on Pl. XLVI) of some of the typical specimens described by Mr. Matthew.

[1] Trans. Royal Soc. Canada, Vol. VIII, 1891, Sec. IV, pp. 143-146.

Genus DISCOPHYLLUM Hall.

DISCOPHYLLUM PELTATUM Hall.

Pl. XLVII, figs. 1 and 2.

Discophyllum peltatum Hall, 1847, Pal. N Y., Vol. I, p. 277, Pl. LXXV, fig. 3.

Body consisting of a somewhat circular, flattened expansion, composed mainly of radiating fibers, which enlarge as they recede from the center, and terminate in a thickened border.

This fossil appears to have consisted originally of a semihard circular or oval body, with firmer rays, reaching nearly or quite to the margin. The body becomes thicker and apparently harder toward the margin, and the rays are nearly concealed in its substance. This disk may have been attached by a smaller stipe, proceeding from the lower side, some obscure evidence of such an appendage existing.

Two specimens of this peculiar fossil have been found, one in 1822 and the other a few years since, showing that it is an exceedingly rare form. It is quite unlike any other fossil known in our older strata.

Position and locality.—This species occurs in the partially metamorphic arenaceous shales of the Hudson River group, near the nail factory, below Troy, where the only known specimens have been found. (Cabinet of Troy Lyceum; cabinet of Professor Cook.)

Observations.—Through the courtesy of Prof. J. M. Clarke, I have had an opportunity of studying the type specimens described by Professor Hall. There is little to add to his description, except to note the presence of fine, concentric, undulating lines that cross both the rays and the interspaces between. There is also indicated on the larger or broken specimen, fig. 2 of Pl. XLVII, a ring surrounding an area about 2^{cm} in diameter. The rays, however, cross the ring to the center. This may be the result of the compression of the specimen, so as to bring the opposite side down to a point opposite an aperture of which the ring is the margin, or the ring may be simply a stage in the growth of the specimen.

It is exceedingly difficult to determine whether *D. peltatum* is the impression of a medusa. There is no a priori reason why a gelatinous disk should not leave such an impression in the very fine arenaceous silt which now forms the slightly gritty layers embedded in the shales carrying the graptolitic fauna referred to the Trenton terrane. If *D. peltatum* be considered to be the cast of the impression of a medusa, it might be grouped with *Medusina princeps* as an acraspedote medusa. In order to present to the student all the information available, a plate illustrating the two type specimens is introduced (Pl. XLVII).

PLATES.

PLATE I.

PLATE I.

BROOKSELLA ALTERNATA (p. 23).

FIG. 1. View of an exumbrella with 6 lobes and a depression over the central stomach.

FIG. 2. An exumbrella with 8 lobes and with a much larger central depression than that of fig. 1.

FIG. 3. An exumbrella with 9 lobes and preserving a trace of the corona furrow in the ring about the central disk.

FIG. 3a. View of the under or subumbrella side of fig. 3. The narrow subumbrella lobes are well shown, and also what appear to be oral arms, *x*, *x*. These oral arms appear to be of the same type as those of *Laotira cambria*, as shown by figs. 1a, 2, and 3c of Pl. XVIII. A slight circular depression at the center (*x'*) may possibly indicate the position of the primitive oral aperture, or the depression beneath the buccal stomach.

FIG. 4. Exumbrella view of an unusually rotund specimen. A projecting interradial lobe or arm is shown at *x*.

FIG. 4a. Subumbrella view of fig. 4. An interradial lobe or arm is shown at *x*, and a broken subumbrella lobe at *b*. The lobe at *a* apparently did not connect with the exumbrella. It appears to have been an interumbrella lobe or arm that was attached at the same general plane as the subumbrella lobes.

FIG. 4b. Side view of fig. 4, showing the lobes described in figs. 4 and 4a.

FIG. 5. View of an exumbrella with 5 lobes which are continued into the subumbrella lobes.

FIG. 5a. Side view of the same.

FIG. 6. An exumbrella with 7 main lobes and 2 smaller ones (*x*, *x*). The lobes are much narrower than those of figs. 1 and 5, and their lower portion has been worn away so as to expose the radial canals that extend from the central disk through each of the exumbrella lobes.

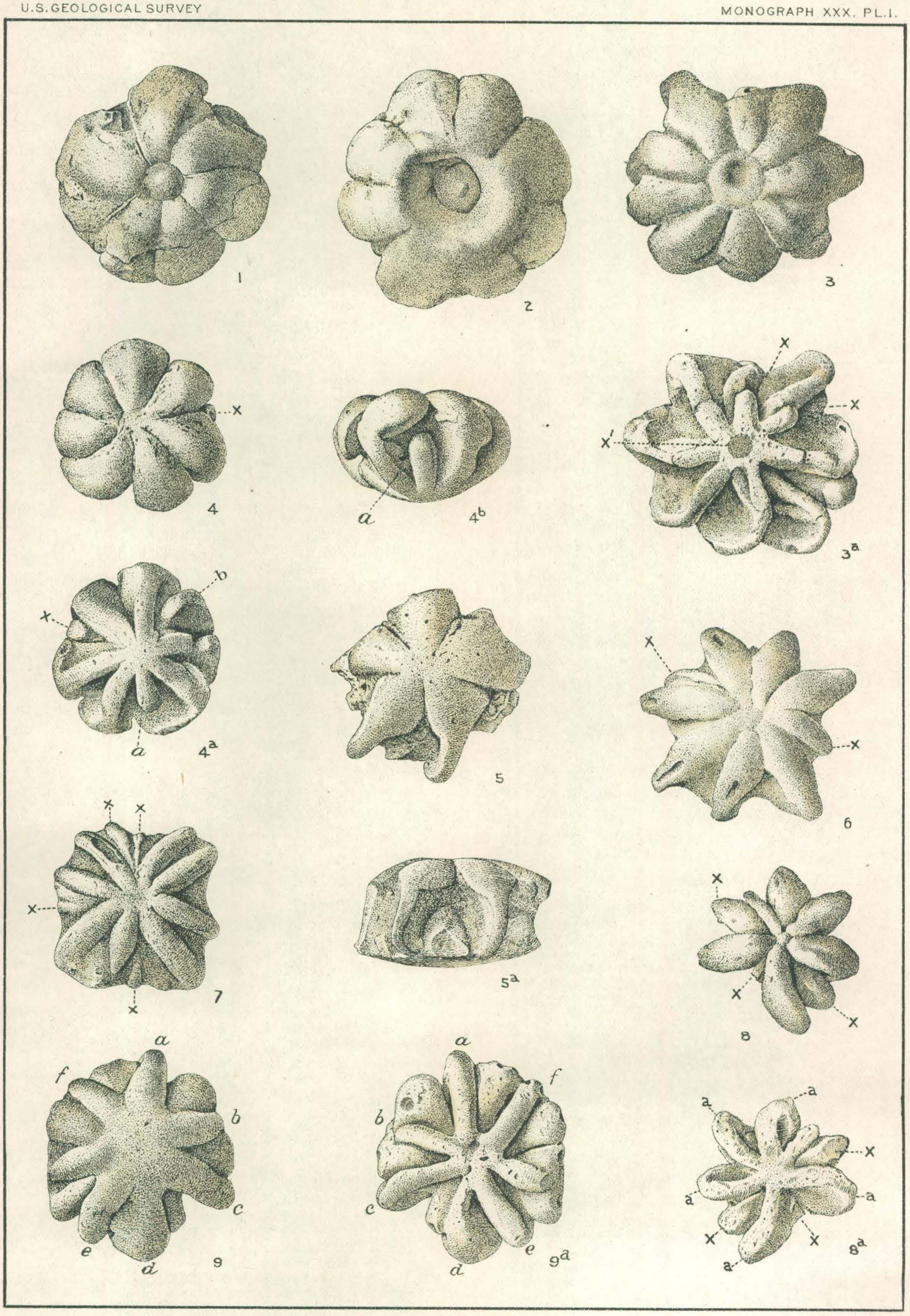
FIG. 7. An exumbrella with 8 narrow lobes and 4 smaller interumbrella lobes (*x*, *x*, *x*, *x*).

FIG. 8. An exumbrella showing lobes of various width and several interumbrella lobes (*x*, *x*, *x*).

FIG. 8a. View of the subumbrella of fig. 8. The lower sides of the interumbrella lobes of fig. 8 are indicated by *x*, *x*, *x*. The exumbrella lobes proper (*a*, *a*, *a*) merge into the 5 narrow subumbrella lobes which meet at the center.

FIG. 9. An exumbrella in which the interumbrella lobes are a much more prominent feature than in fig. 8. The specimen appears as though an individual was resting upon and clasping one beneath. The exumbrella lobes (*a* to *f*), however, merge into the subumbrella lobes *a* to *f* of fig. 9a.

FIG. 9a. View of the subumbrella of fig. 9.



BROOKSELLA

PLATE II.

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PLATE II.

BROOKSELLA ALTERNATA (p. 23).

FIG. 1. An exumbrella showing a more complicated system of lobes than those shown in figs. 8 or 9 of Pl. I.

FIG. 1a. View of the flattened surface of the subumbrella of fig. 1.

FIG. 2. An exumbrella in which the lobes are more distinct than in fig. 1. Numerous interumbrella lobes are shown projecting from beneath the exumbrella lobes.

FIG. 3. An exumbrella in which it appears as though a narrow-lobed exumbrella, like that of fig. 7, Pl. I, had been superimposed upon a wide-lobed exumbrella, like that of fig. 1, Pl. I.

FIGS. 4, 4a, 4b. An irregularly lobed exumbrella which has the appearance of two narrow-lobed exumbrellas placed one upon the other, very much as one starfish would close down upon another. The side view of this specimen (fig. 4b) and the subumbrella (fig. 4a) show that the irregular exumbrella lobes join the subumbrella lobes, and that there is but one individual.

FIG. 5. Exumbrella having very narrow, rounded lobes, the surface of which is slightly roughened by semi-inosculating, irregular, raised and depressed lines.

FIG. 5a. Side view of fig. 5.

FIG. 6. Narrow-lobed exumbrella showing the radial canals.

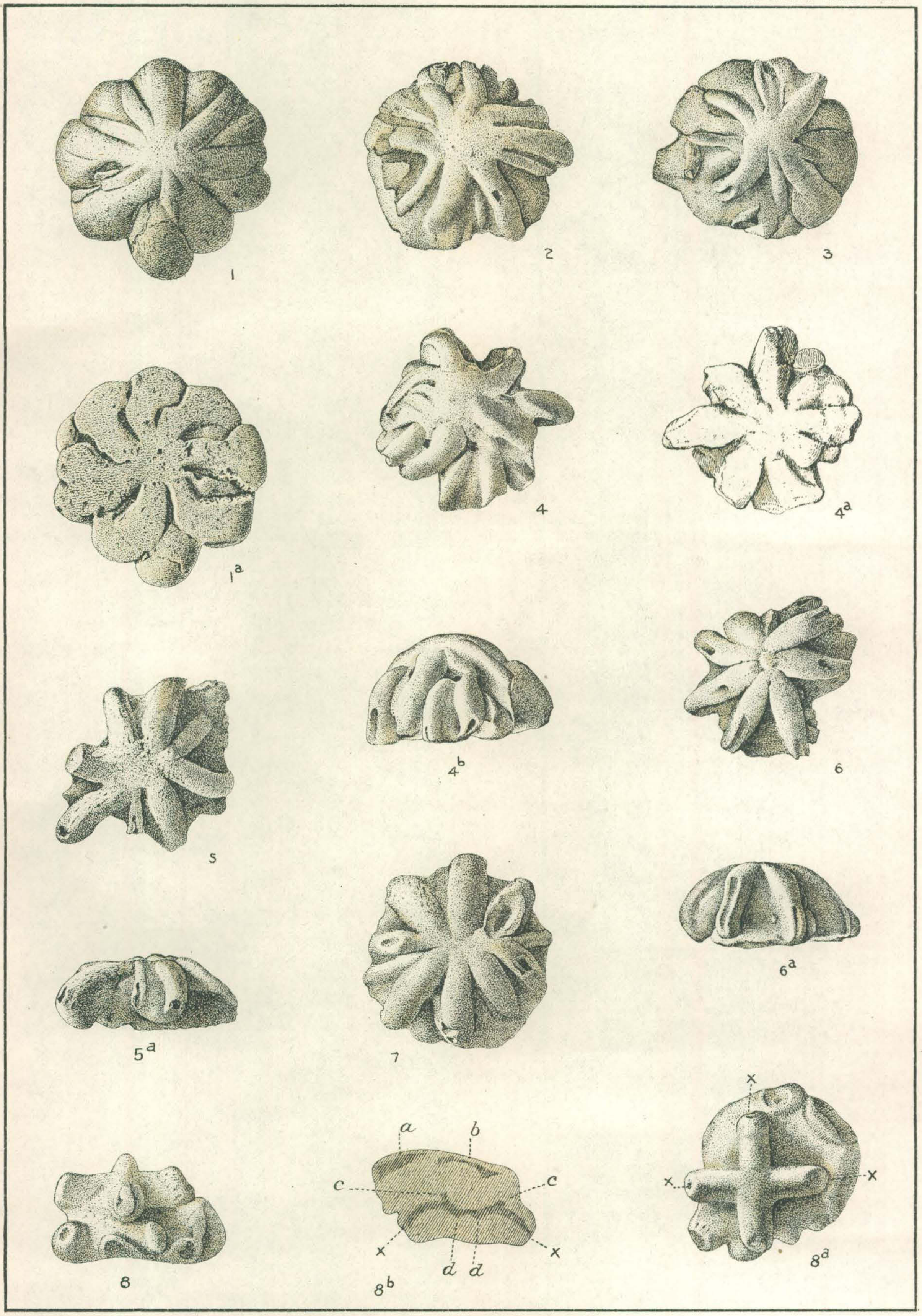
FIG. 6a. Side view of fig. 6.

FIG. 7. An exumbrella in which the surface of the lobes is roughened in the same manner as shown in fig. 5.

FIG. 8. Side view of an individual preserving 4 oral arms.

FIG. 8a. Dorsal view of fig. 8. The canals of the oral arms are shown at *x*, *x*, *x*.

FIG. 8b. Transverse section of fig. 8, showing the section of the canals and the oral arms at *x*, *x*, a radial canal of the exumbrella lobe at *a*, a trace of the central stomach (?) at *b*, and the lower portion of the pillar canals at *c*. The points at *d*, *d* may indicate the direction of the primitive oral aperture.



BROOKSELLA

PLATE III.

PLATE III.

BROOKSELLA ALTERNATA (p. 23).

FIG. 1. Outline of an exumbrella, the central portion of which has been worn away so as to expose the radial canals (*x*, *x*, *x*), and the central cavity at *a*.

FIG. 1a. View of the flattened subumbrella surface of fig. 1, showing the narrow lobes and 2 interradial arms.

FIG. 2. Outline of the subumbrella surface of a compressed individual in which the openings of the radial canals of the exumbrella are unusually large.

FIG. 3. View of a worn specimen showing the radial canals of the exumbrella lobes.

FIG. 4. Specimen showing the radial canals and central cavity even more distinctly than in figs. 1 and 3.

FIG. 5. Side view of a broken specimen resting on the ventral surface, showing sections of the umbrella and interradial lobes.

FIG. 6. View of the subumbrella of a very narrow-lobed individual. Sections of the lobe are shown at *x*, *x*.

FIG. 7. A 7-lobed individual resting upon an individual having 12 or more lobes.

FIG. 8. Specimen dissected by weathering so as to show some of the interradial arms united to the central axis, the extension of the upper lobes being shown at *x*, *x*, *x*, *x*.

FIG. 9. A crushed specimen that may belong to this species.

FIG. 10. A specimen preserving what appears to be an unusual form of an exumbrella lobe (*x*). It resembles one of the interradial lobes.

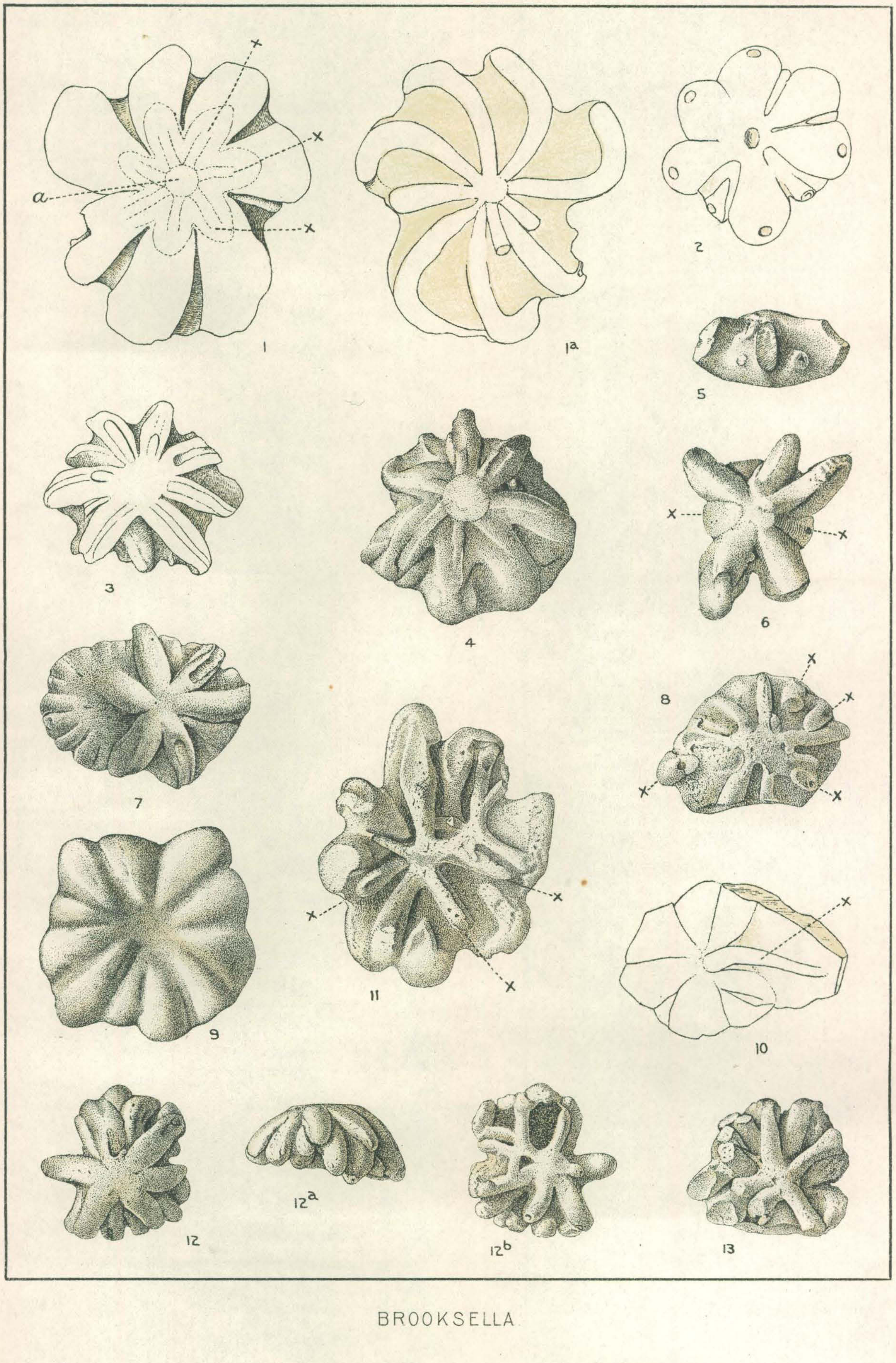
BROOKSELLA CONFUSA (p. 30).

FIG. 11. Subumbrella surface of a specimen the exumbrella of which is much like that of fig. 3 of Pl. I. The relations of the various lobes are shown in the figure, and the free interradial or oral lobes at *x*, *x*, *x*.

FIGS. 12, 12a. View of the exumbrella and several of the interradial lobes. The relations of the two sets of lobes are shown in the side view, fig. 12.

FIG. 12b. Subumbrella surface of fig. 12, showing essentially the same arrangement as fig. 11.

FIG. 13. Subumbrella view of an individual in which the interradial lobes are numerous and the subumbrella lobes somewhat more regular than in figs. 11 and 12b.



BROOKSELLA.

PLATE IV.

PLATE IV.

BROOKSELLA ALTERNATA (p. 23).

FIGS. 1, 2, 3, 4, 5. Transverse sections showing in natural colors the various forms of the lobes, and the color of the inclosing matrix.

FIG. 6. Transverse sections of an individual in which various interradial lobes are cut across.

FIGS. 7, 8, 9. Transverse sections in which the radial canals of the exumbrella lobes and the central stomach of the umbrella disk are preserved. This is particularly well shown in fig. 9.

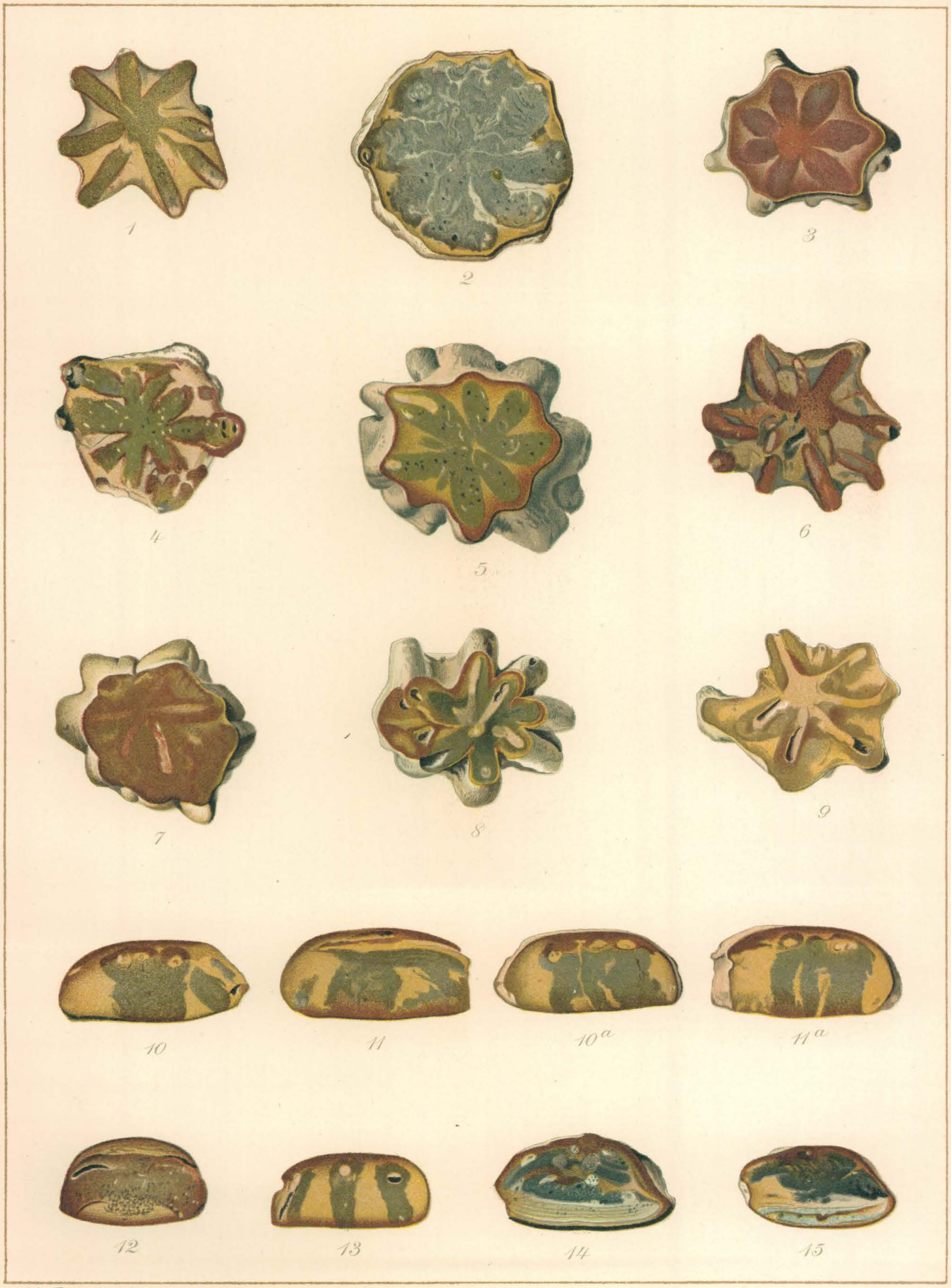
FIGS. 10, 10a, 11, 11a. Vertical sections in which the radial canals and the lobes of the umbrella are shown. Figs. 10 and 11 show the umbrella disk; 10, toward the margin; and 11, nearer the center. In figs. 10a and 11a the openings of the radial canals and the sections of the umbrella lobes are clearly shown.

FIG. 12. Vertical section through the center of another individual which cuts through the depth of the umbrella lobes on each side. The umbrella disk is outlined below and the radial canals above.

FIG. 13. Section showing same essential features as fig. 10a.

FIG. 14. Vertical section cutting across several interradial lobes or arms.

FIG. 15. Vertical central section showing traces of the umbrella disk.



J. L. RIDGWAY DEL.

BROOKSELLA

PLATE V.

PLATE V.

LAOTIRA CAMBRIA (p. 32).

FIG. 1. Subumbrella surface of an individual with 4 lobes.

FIG. 2. Subumbrella surface of an individual with 4 lobes. The radial canal openings of the exumbrella lobes are shown at x, x.

FIG. 3. A distorted specimen which has apparently 3 lobes. Owing to the great variation in the size of the lobes, it is probable that it is imperfect, the fourth lobe having been turned under and merged by pressure into the larger lobe.

FIG. 4. Subumbrella view of a small individual with 4 lobes.

FIG. 5. A 5-lobed specimen, the outlines of which have been obscured by the siliceous matter deposited about it.

FIG. 6. Exumbrella surface of a specimen with 6 lobes.

FIG. 7. A common form of the exumbrella with 5 lobes.

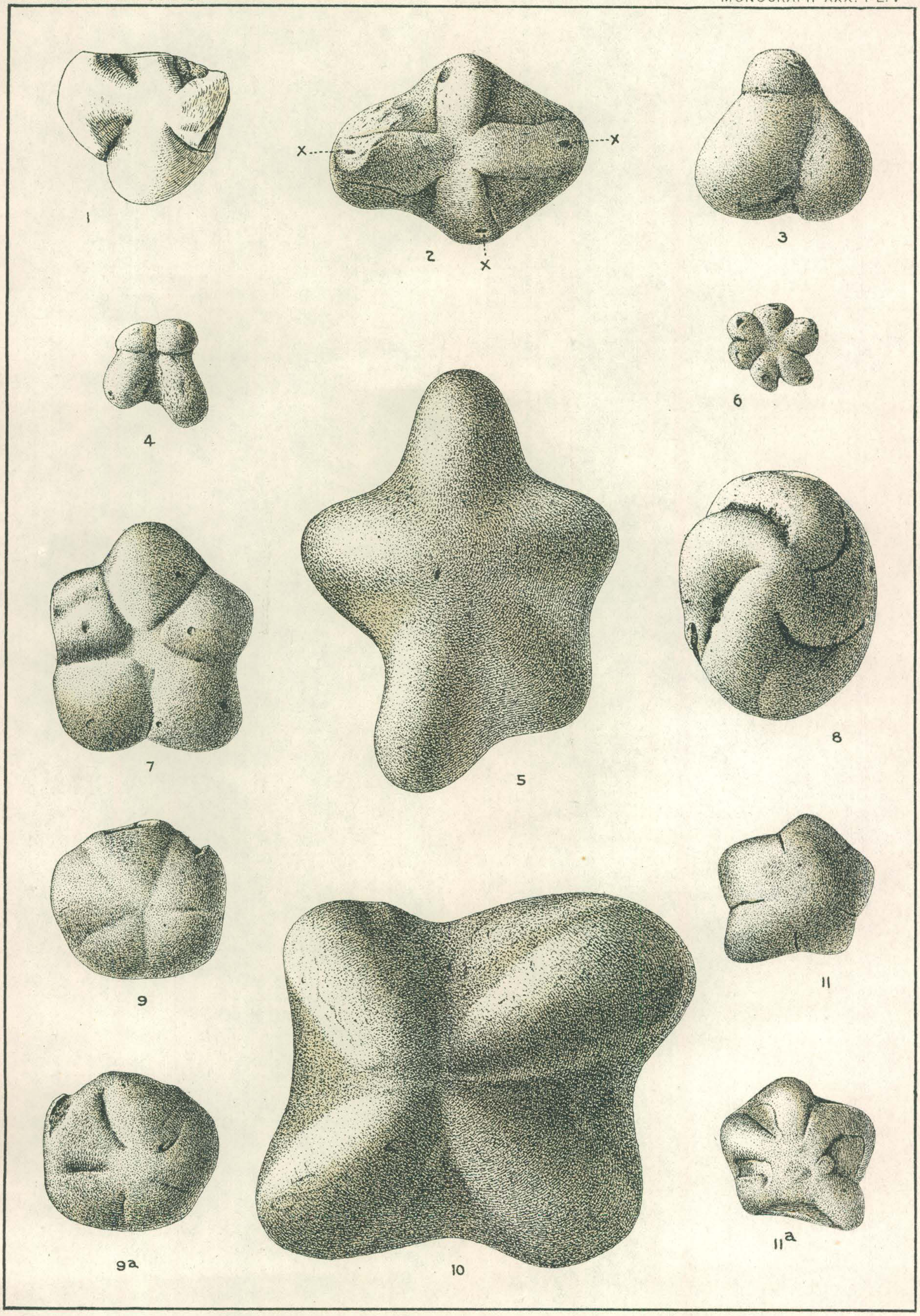
FIG. 8 A specimen in which the 5 lobes are compressed so as to give them a spiral appearance.

FIGS. 9, 9a. Exumbrella and subumbrella surface of a rotund specimen.

FIG. 10. A large, 4-lobed individual, which is very much obscured by the siliceous matter deposited about it.

FIGS. 11, 11a. Exumbrella and subumbrella view of a 5-lobed individual preserving some of the characteristics of *Brooksella alternata*, as shown in Pl. I, figs. 4, 4a.

Most of the specimens represented on this plate are more or less obscured by the siliceous matter deposited about them. The extent of this deposition is shown in the transverse sections on Pl. XXIII.



LAOTIRA

PLATE VI.

PLATE VI.

Laotira cambria (p. 32).

Fig. 1. View of a somewhat flattened exumbrella.

Fig. 1a. Subumbrella view of fig. 1, showing the exumbrella lobes slightly twisted.

Fig. 1b. Lateral view of figs. 1, 1a, showing convexity of the subumbrella and its lobes.

Fig. 2, 2a, 2b. Upper, lower, and side view of an individual in which the subumbrella is flattened and the exumbrella is strongly convexed. This is in direct contrast with figs. 1, 1a, 1b.

Fig. 3. The subumbrella side of a 7-lobed individual in which the lobes are almost entirely concealed by the deposit of siliceous matter about them.

Figs. 4, 4a. Upper and lower view of a specimen in which the exumbrella and subumbrella correspond very closely.

Fig. 5. View of the subumbrella of a small, somewhat worn specimen showing 9 lobes and 1 interradial lobe or arm (x).

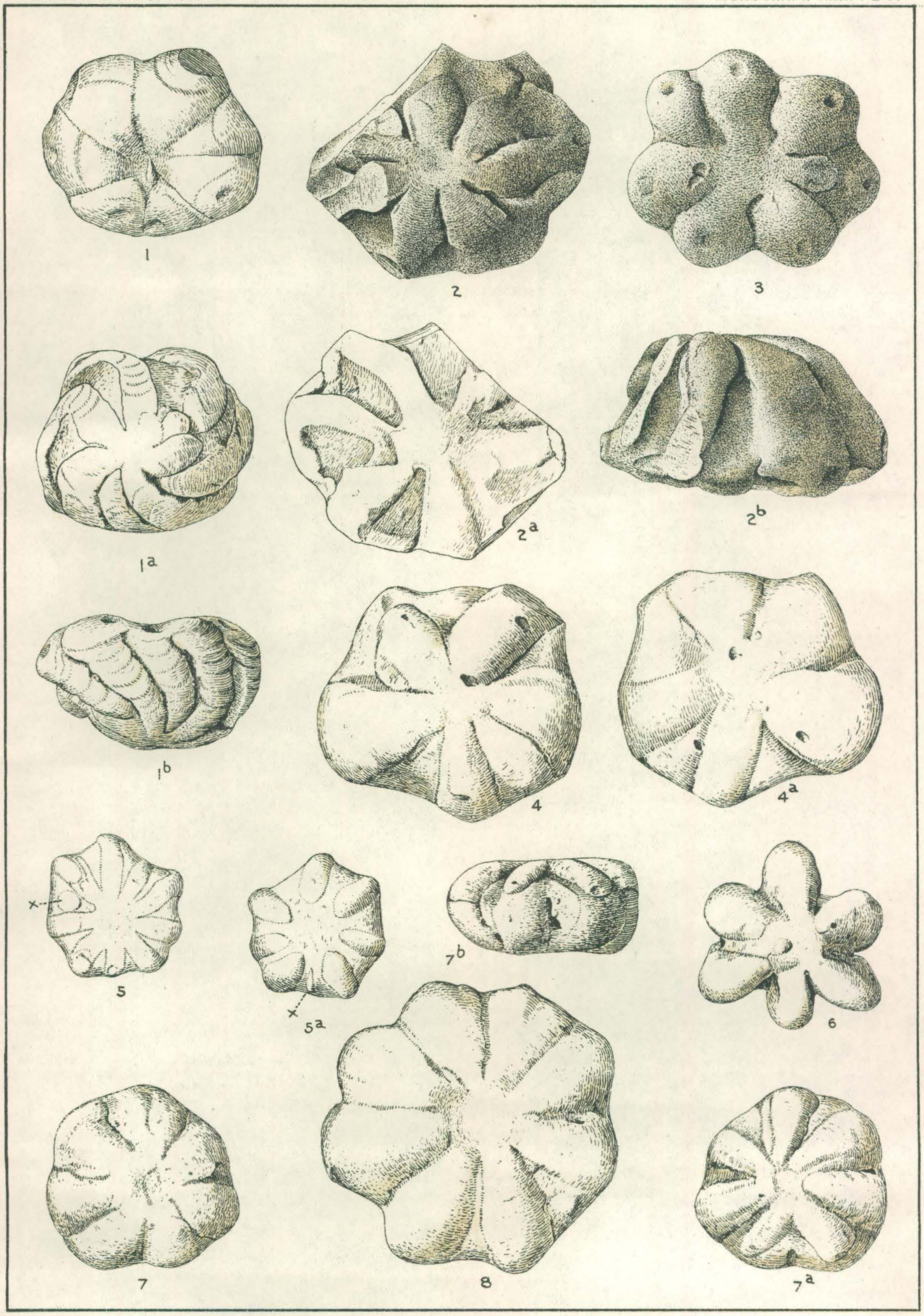
Fig. 5a. Exumbrella view of fig. 5, showing 7 lobes, two of the lobes shown in fig. 5 not appearing on the upper surface, excepting one which appears as little more than a line at x.

Fig. 6. A somewhat common form in the collections, which has very narrow lobes that have been more or less concealed by a deposit of siliceous matter.

Figs. 7, 7a. Exumbrella and subumbrella surfaces of a somewhat compressed specimen.

Fig. 7b. Side view of fig. 7, in which the specimen appears to be resting on the exumbrella surface, but, owing to the deposit of siliceous matter, it is not possible to say which is the upper or lower side.

Fig. 8. Exumbrella of a specimen having 8 rather wide lobes. This may be compared with fig. 1 of Pl. I.



LAOTIRA

PLATE VII.

PLATE VII.

LAOTIRA CAMBRIA (p. 32).

FIG. 1. View of the exumbrella of an individual in which there is a departure from the radial arrangement of the lobes shown in the specimen illustrated on Pls. V and VI, the short lobes *aa* being an added feature. They correspond to the subumbrella lobes *aa*, fig. 1a.

FIG. 1a. Subumbrella side of fig. 1. In this it will be noticed that the arrangement of the lobes near the center gives a slightly transverse central portion.

FIG. 2. View of an exumbrella in which the lobes have been slightly upturned by lateral compression.

FIG. 2a. Subumbrella side of fig. 1. The lobes are narrow and do not meet around a center, the tendency to a transverse arrangement being greater than in fig. 1a.

FIG. 3. Subumbrella surface of a small specimen in which the lobes are turned in toward the center.

FIG. 4. Exumbrella view of a rounded, somewhat melon-shaped specimen.

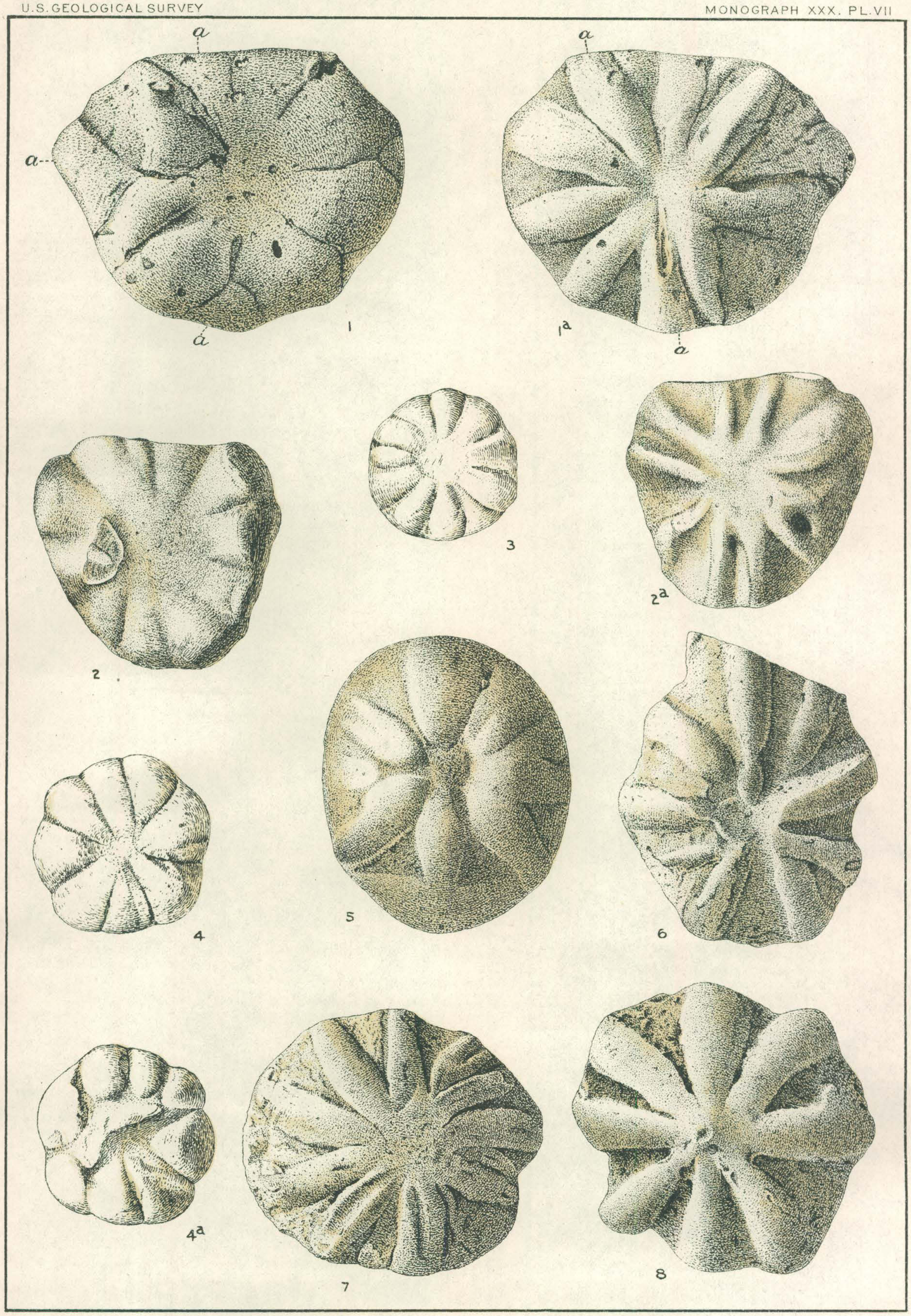
FIG. 4a. Subumbrella surface of fig. 4, in which the lobes are turned inward, very much as in fig. 3.

FIG. 5. View of an individual illustrating the mode of occurrence of a large number of specimens. They appear to be the upper portion of a flattened concretion, the siliceous matter having been deposited between the lobes and over the subumbrella surface so as to conceal it, and often over much of the exumbrella surface.

FIG. 6. Subumbrella view of a specimen in which the lobes are very strongly defined. It may be compared with fig. 1a.

FIG. 7. A specimen preserved in the same manner as fig. 5, but which has been worn by weathering so as to expose the radiating canals of the exumbrella lobes.

FIG. 8. A specimen in which it is difficult to decide whether it is the exumbrella or subumbrella surface that is preserved. It is apparently the exumbrella.



LAOTIRA

PLATE VIII.

PLATE VIII.

LAOTIRA CAMBRIA (p. 32).

FIG. 1. View of an exumbrella with 12 narrow lobes. The arrangement of the lobes shows a slight tendency to irregularity.

FIG. 2, 2a. View of the exumbrella and subumbrella sides of a specimen having many lobes, in which the tendency to an irregularity of arrangement is greater than in figs. 1a and 2a of Pl. VII.

FIG. 3, 3a. Side views of a specimen in which the exumbrella lobe is flattened out and the subumbrella and interradial lobes are clearly defined.

FIG. 4. Exumbrella view of a somewhat distorted individual with 5 regular lobes and 3 projecting, irregular, interradial lobes.

FIG. 5. Exumbrella view of a specimen with 6 broad lobes.

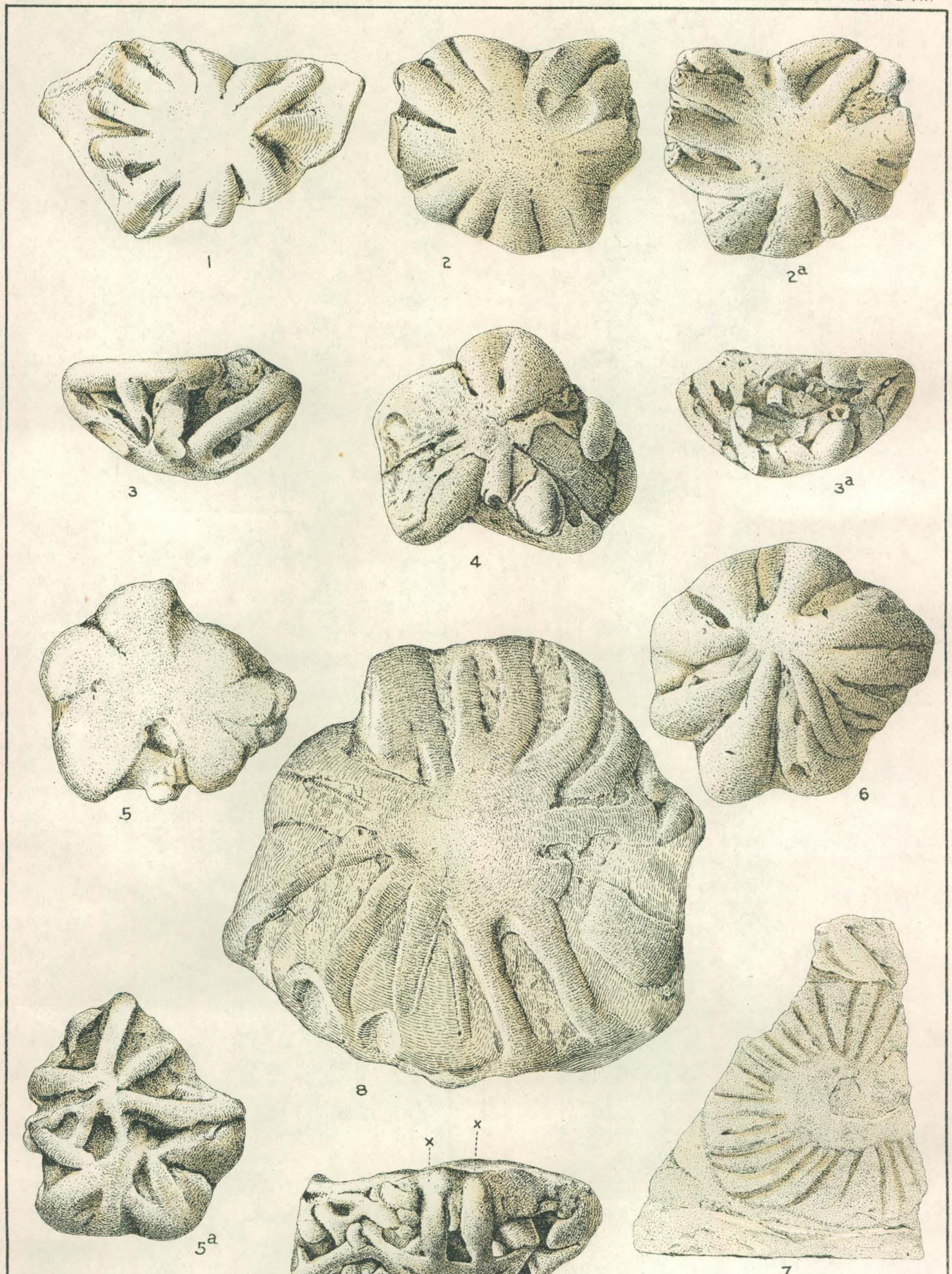
FIG. 5a. Subumbrella view of fig. 5, showing a complex system of lobes, somewhat like that of fig. 5a of Pl. X and fig. 3 of Pl. XIII.

FIG. 6. Exumbrella view of a specimen in which the irregularity of the lobes is strongly marked.

FIG. 7. A specimen, flattened out in the shale, in which the radial exumbrella canals appear as narrow, dark, iron-stained bands; the mass of the medusa leaving but a film which is scarcely perceptible on the shale.

FIG. 8. Subumbrella surface of a large individual in which the irregularity of the arrangement of the lobes is much more marked than in figs. 1a and 2a of Pl. VII.

FIG. 9. Partial side and subumbrella view of fig. 6, Pl. XIII. The lobes *x*, *x* correspond to the lobes *x*, *x* of the latter figure.



LAOTIRA

PLATE IX.

PLATE IX.

LAOTIRA CAMBRIA (p. 32).

FIG. 1. View of an exumbrella in which the lobes are but slightly indicated.

FIG. 1a. Subumbrella view of fig. 1, showing a tendency to irregularity, which is indicated in a somewhat different type by fig. 6 of Pl. VIII.

FIG. 2. Subumbrella view of a very rotund specimen, which, though obscured by adhered siliceous matter, shows a slightly transverse arrangement.

FIG. 3. A well-preserved individual having 5 principal exumbrella lobes and 2 small interradial lobes.

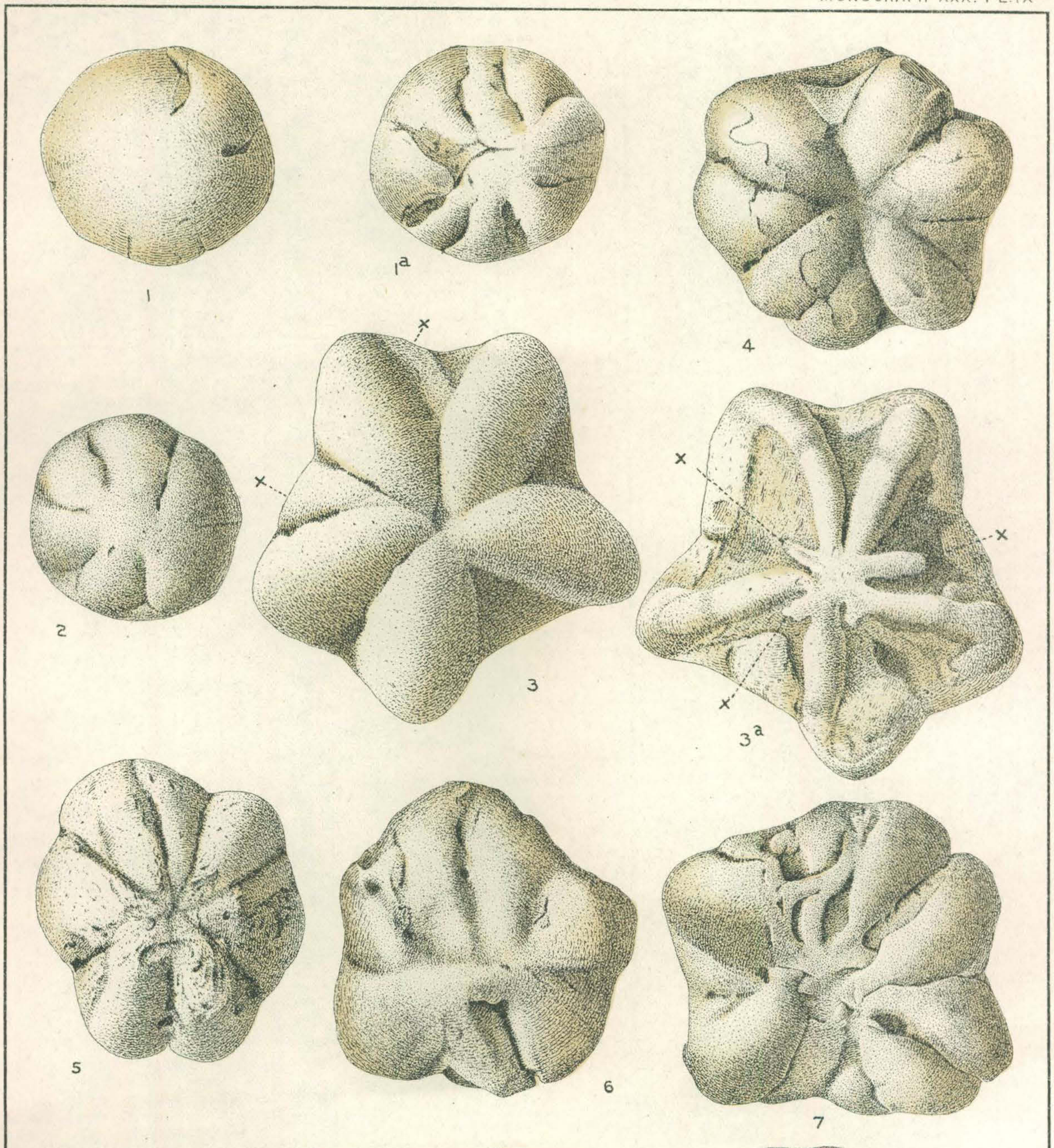
FIG. 3a. Subumbrella view of fig. 3. The subumbrella lobes are strongly defined. An irregularity of the meeting of the lobes at the center is shown, which is carried still further in figs. 5a, 6a, and 7a.

FIG. 4. Exumbrella view of a more rotund specimen than fig. 3.

FIGS. 5, 5a. Exumbrella and subumbrella views of an individual in which the bilateral arrangement of the subumbrella surface is indicated, but not so strongly as in fig. 6a.

FIGS. 6, 6a. Exumbrella and subumbrella views of a specimen in which the bilateral arrangement of the lobes is strongly marked.

FIGS. 7, 7a. Exumbrella and subumbrella views of umbrella lobes still more irregularly arranged than in figs. 5 or 6.



LAOTIRA

PLATE X.

PLATE X.

LAOTIRA CAMBRIA (p. 32.)

FIGS. 1, 1a. A specimen having well-defined exumbrella lobes that may be compared with figs. 1 and 10 of Pl. V. It differs in the introduction of some small irregular lobes. This difference is further shown in the subumbrella surface represented by fig. 1a.

FIG. 2. Subumbrella surface having 4 principal lobes and several small, indistinct lobes.

FIG. 3. Same type as fig. 2, with more robust lobes, and a large interradial lobe, *x*.

FIG. 4. Small specimen with slightly irregular subumbrella lobes.

FIG. 5. Exumbrella surface of an irregular character.

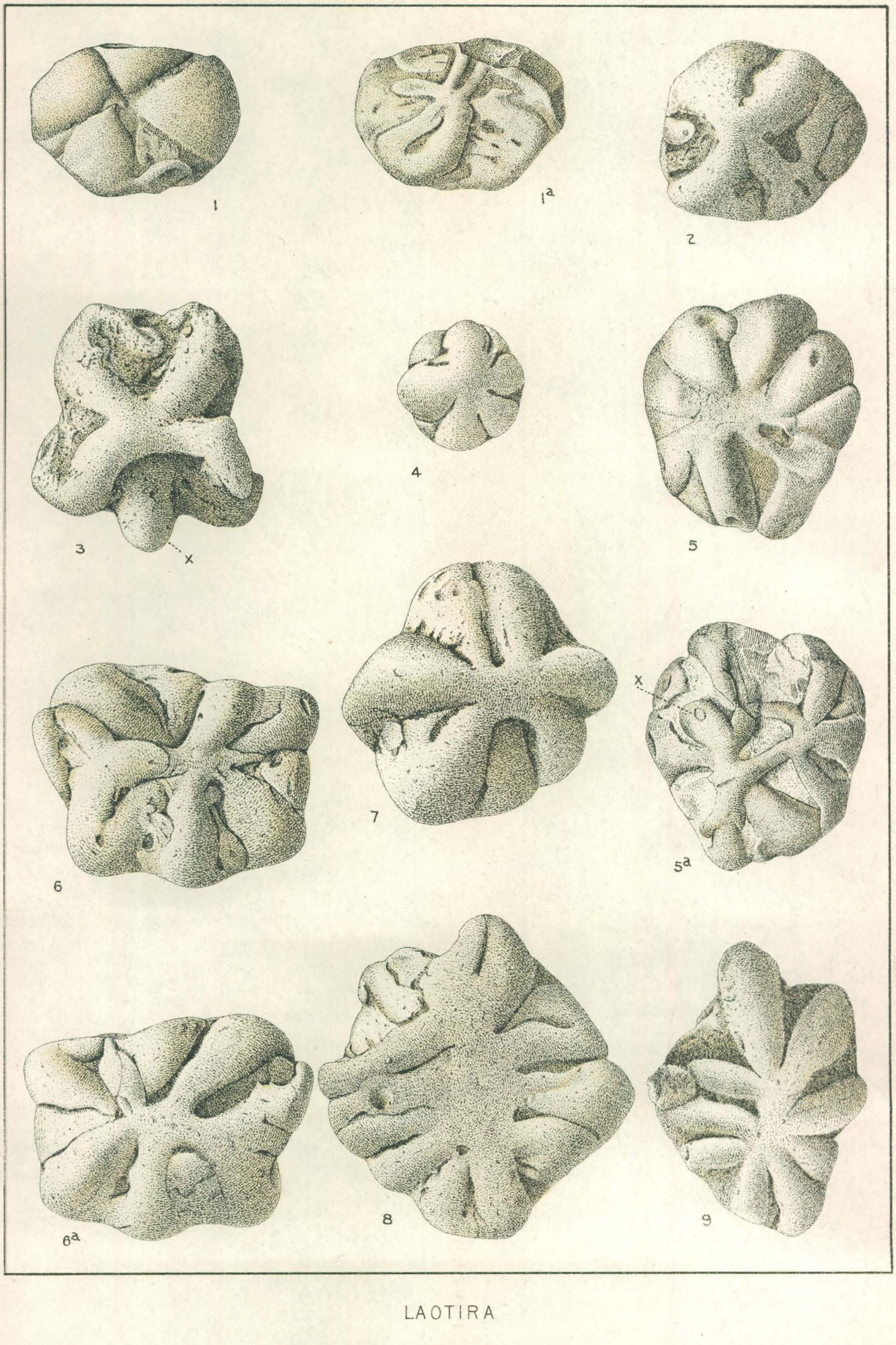
FIG. 5a. Subumbrella surface of fig. 5, in which the tendency to a transverse arrangement, shown in figs. 5a and 6a of Pl. IX, is developed into two centers connected by a transverse lobe. One of the oral arms is shown at *x*.

FIGS. 6, 6a. Exumbrella and subumbrella surfaces of a specimen in which the two surfaces correspond quite closely in arrangement.

FIG. 7. A strongly convex subumbrella surface.

FIG. 8. Subumbrella surface in which the lobes are arranged along a transverse, irregular central lobe.

FIG. 9. Exumbrella or subumbrella surface; probably the former, showing the transverse arrangement of the lobes.



LAOTIRA

PLATE XI.

PLATE XI.

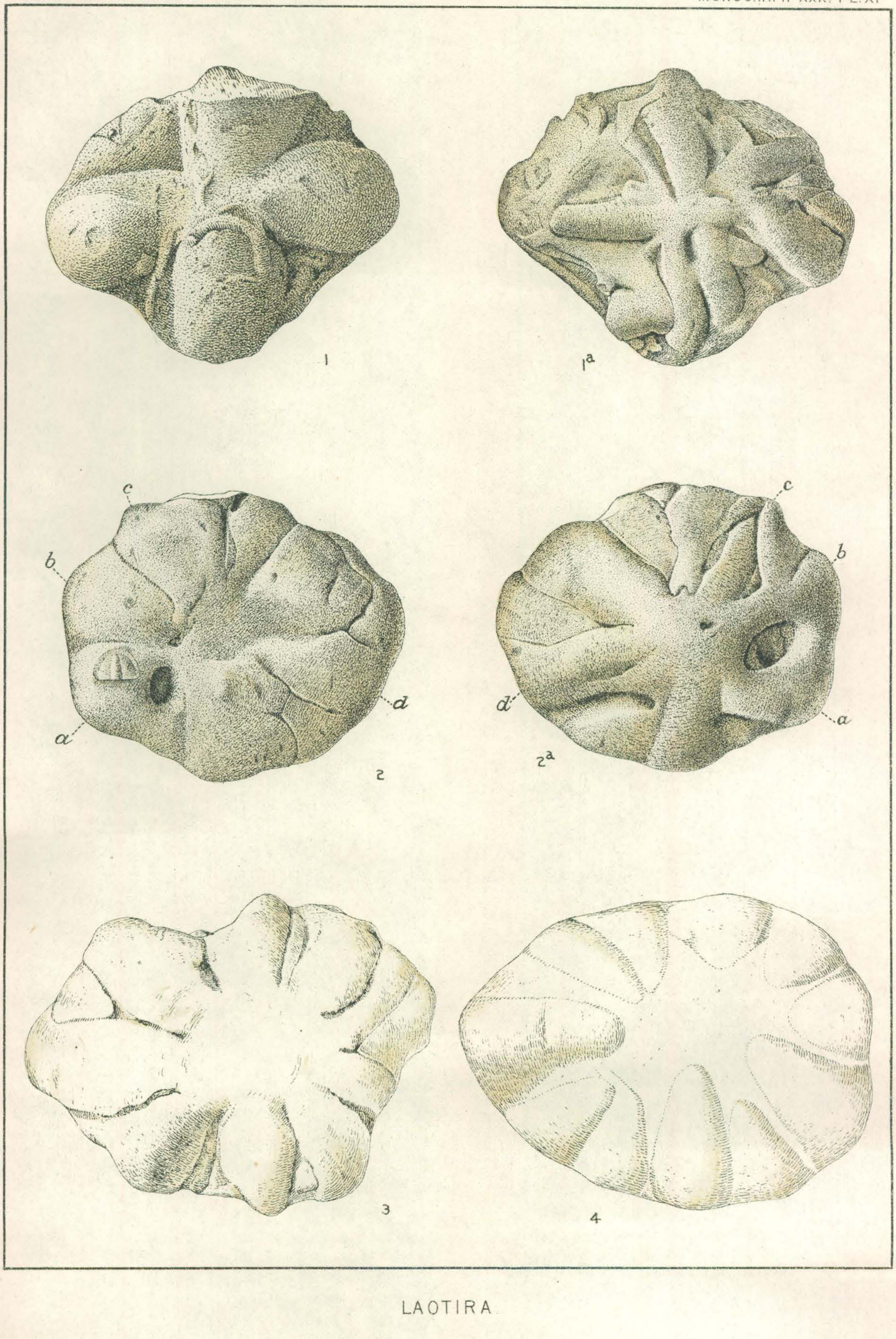
LAOTIRA CAMBRIA (p. 32).

FIGS. 1, 1a. Exumbrella view of a 4-lobed specimen that is fairly regular. The irregularly lobed subumbrella surface, fig. 1*a*, should be compared with the regularly lobed subumbrella surface of fig. 1 of Pl. V. The transition between the latter and the former is shown by various figures on Pls. IX and X.

FIGS. 2, 2a. Fig. 2 is of the exumbrella surface, in which there are 6 strongly defined lobes and several minor lobes. The exumbrella lobes *a*, *b*, *c*, *d* correspond to the subumbrella lobes *a*, *b*, *c*, *d* of fig. 2a.

FIG. 3. Exumbrella view of a large specimen in which are 7 principal lobes and several minor lobes.

FIG. 4. Subumbrella view of a specimen in which the lobes are inturned very much as in the similar forms illustrated by figs. 3 and 4a of Pl. VII.



LAOTIRA

PLATE XII.

PLATE XII.

LAOTIRA CAMBRIA (p. 32).

FIG. 1. Exumbrella surface of an elongate complex specimen in which 3 centers are developed.

FIGS. 2, 2a. Exumbrella and subumbrella surfaces of a specimen in which a tendency to fission is developing on the left side.

FIG. 3. Exumbrella surface of a complex specimen in which there is a tendency to fission of a portion of the left side.

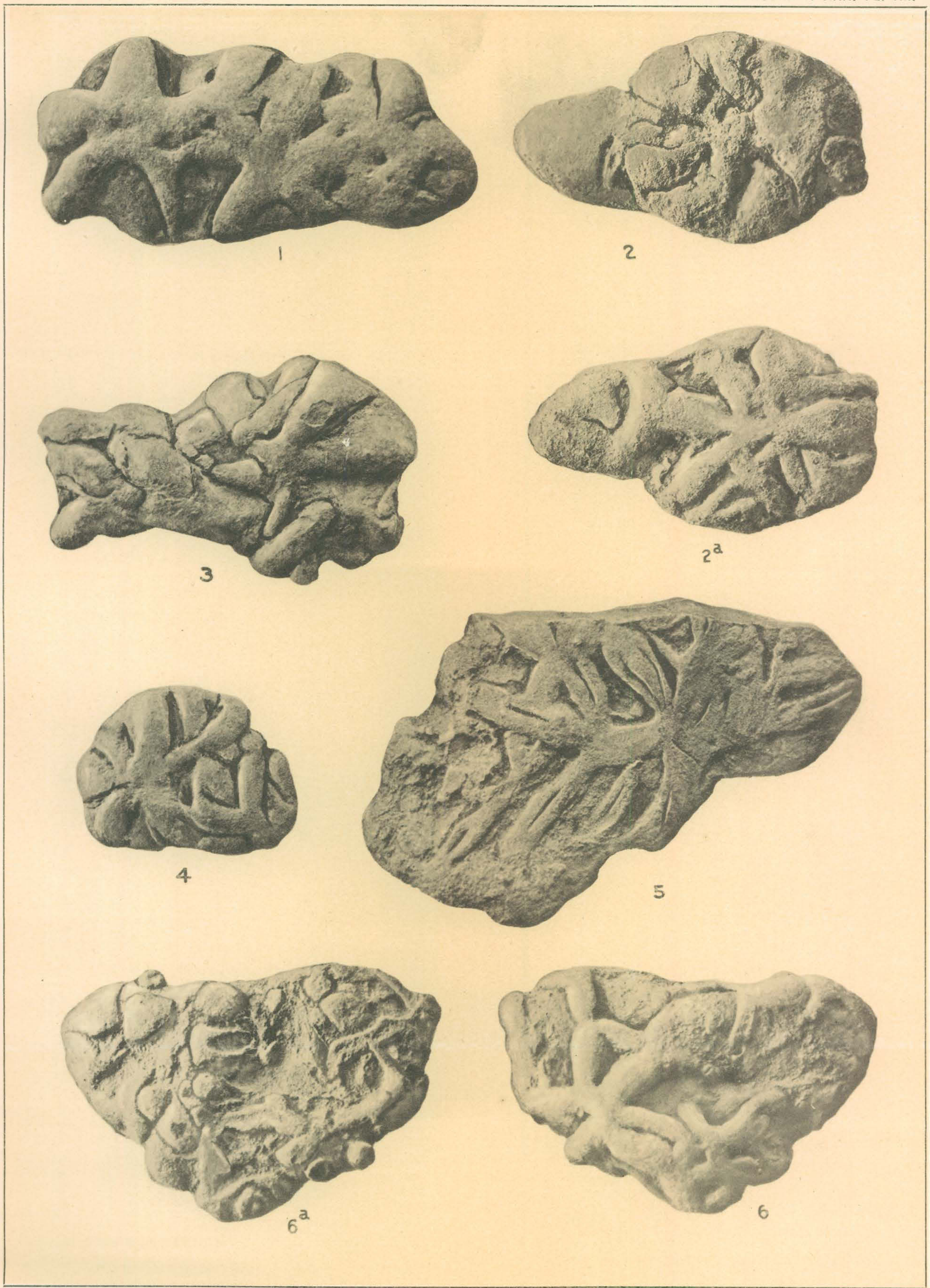
FIG. 4. Exumbrella surface of a small complex specimen with 3 centers, from which lobes radiate to the margin and to the opposing centers. A larger specimen of the same type is shown by fig. 1 of Pl. XIII.

FIG. 5 Worn section of a complex specimen of the type of fig. 9 of Pl. X. Traces of canals are shown in some of the lobes.

FIG. 6. Exumbrella surface with a portion of the lobes in strong relief.

FIG. 6a. Subumbrella surface of fig. 6, showing terminations of some of the oral arms and lobes of the exumbrella surface.

All figures natural size and reproduced from photographs.



LAOTIRA.

PLATE XIII.

PLATE XIII.

LAOTIRA CAMBRIA (p. 32).

FIG. 1. Exumbrella surface of a specimen in which 3 centers are distinctly developed.

FIG. 2. Exumbrella surface of a complex specimen with 5 or more centers.

FIG. 3. Exumbrella surface of a specimen having 3 or more centers, the lobes being unusually narrow and strongly marked by fine, irregular, inosculating lines that may represent the original surface.

FIG. 3a. Subumbrella view of fig. 3, showing openings of canals in some of the lobes.

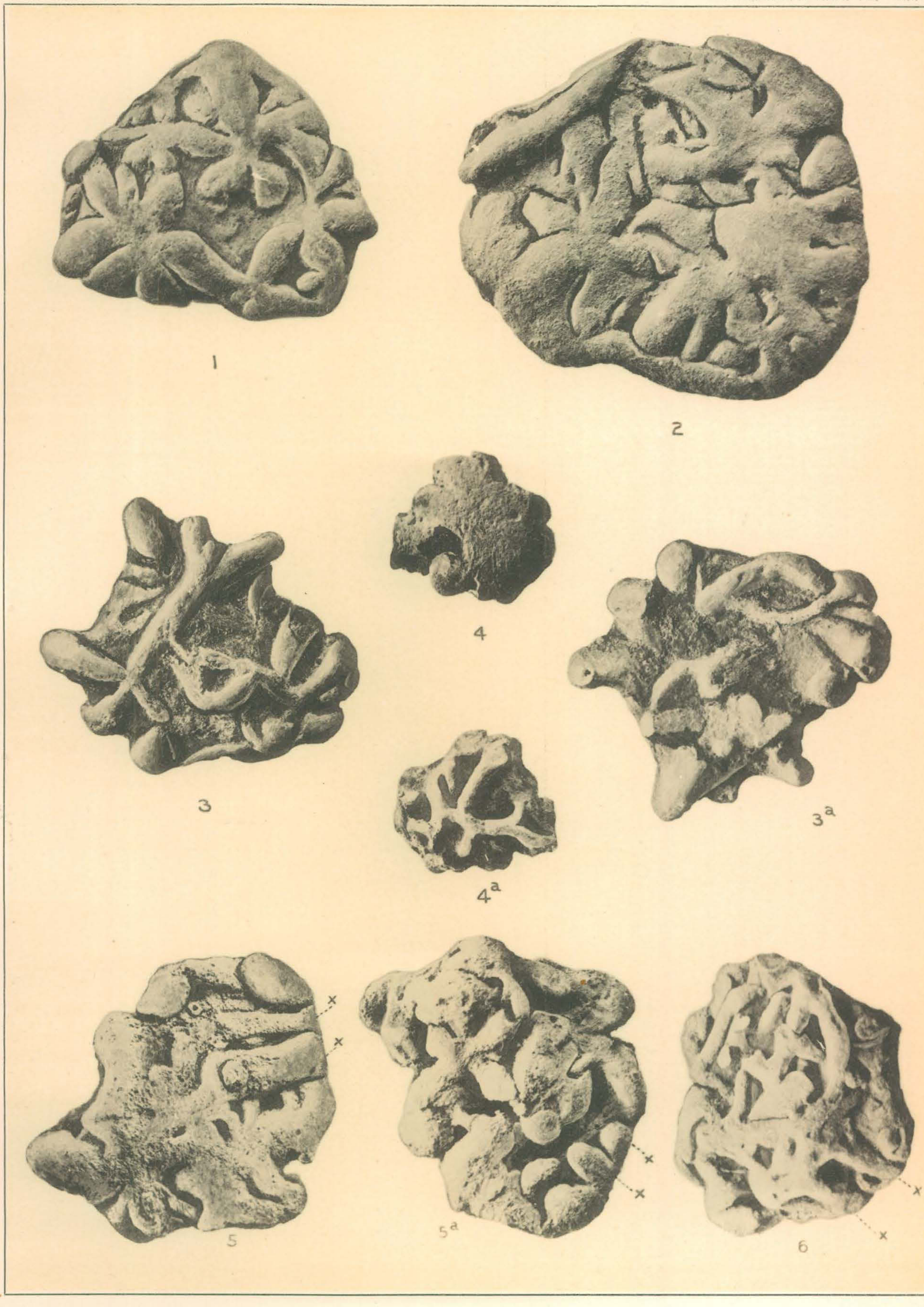
FIGS. 4, 4a. Exumbrella and subumbrella views of a small specimen, the subumbrella surface of which has narrow, irregular lobes. The surface of the lobes is marked much like those of fig. 3.

FIG. 5. Exumbrella view of a complex, irregular specimen with large lobes.

FIG. 5a. Subumbrella view of fig. 5, showing the lobes in strong relief. xx, same as xx of fig. 5.

FIG. 6. Subumbrella view of a complex specimen with narrow lobes in strong relief. The lobes *x*, *x* correspond to the lobes *x*, *x* of the side view of this specimen on Pl. VIII, fig. 9.

All figures natural size and reproduced from photographs.



LAOTIRA.

PLATE XIV.

PLATE XIV.

LAOTIRA CAMBRIA (p. 32).

Fig. 1. Exumbrella surface of an ırregular complex specimen, with 3 or more centers.

Fig. 1a. Lower side of the nodule of fig. 1a, showing irregularly distributed lobes in relief.

Fig. 2. Exumbrella surface of a somewhat more complex specimen than fig. 1. The lobes are in relief on the darker surface of the nodule.

Fig. 3. A still more irregular specimen than fig. 1 or 2. It is probably the subumbrella surface. Two oral arms are shown at *x*, *x*.

All figures natural size and reproduced from photographs.

LAOTIRA.

PLATE XV.

PLATE XV.

PLANOLITES.

FIG. 1. A nodule of chert, with casts of annelid trails or burrows on its surface.

LAOTIRA CAMBRIA (p. 32).

FIG. 2. A specimen of the type of fig. 4, with the lobes in strong relief.

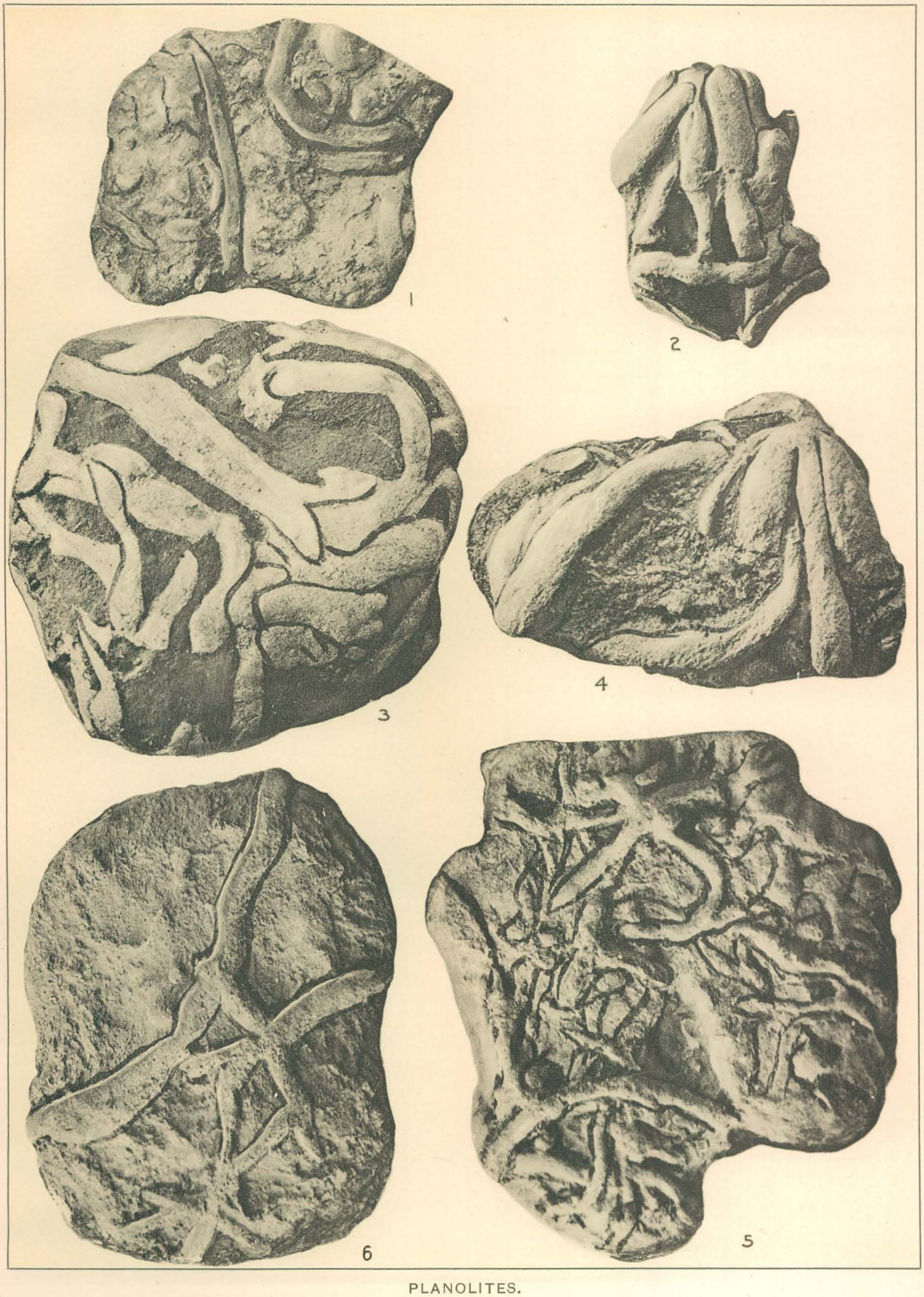
FIG. 3. A specimen of the type of fig. 3 of Pl. XIV. All regularity of structure is lost.

FIG. 4. A distorted specimen, with all the lobes radiating from a common center.

FIG. 5. A nodule, with a combination of casts of annelid trails or burrows and a narrow-lobed medusa.

FIG. 6. A nodule with portion of a complex medusa upon it.

All figures natural size and reproduced from photographs. The outlines of the lobes, etc., were marked with ink before the photographs were made, with the result of giving some of them too much relief in the figures of this plate and of Pls. XXI and XXII.



PLANOLITES.

LAOTIRA.

PLATE XVI.

135

PLATE XVI.

LAOTIRA CAMBRIA (p. 32).

FIG. 1. A distorted specimen in which the subumbrella lobes and oral arms have been drawn out and preserved on the surface of a small nodule.

FIG. 2. Another distorted specimen, somewhat similar to fig. 1.

FIG. 3. A distorted specimen with the lobes spread out on the surface of the nodule.

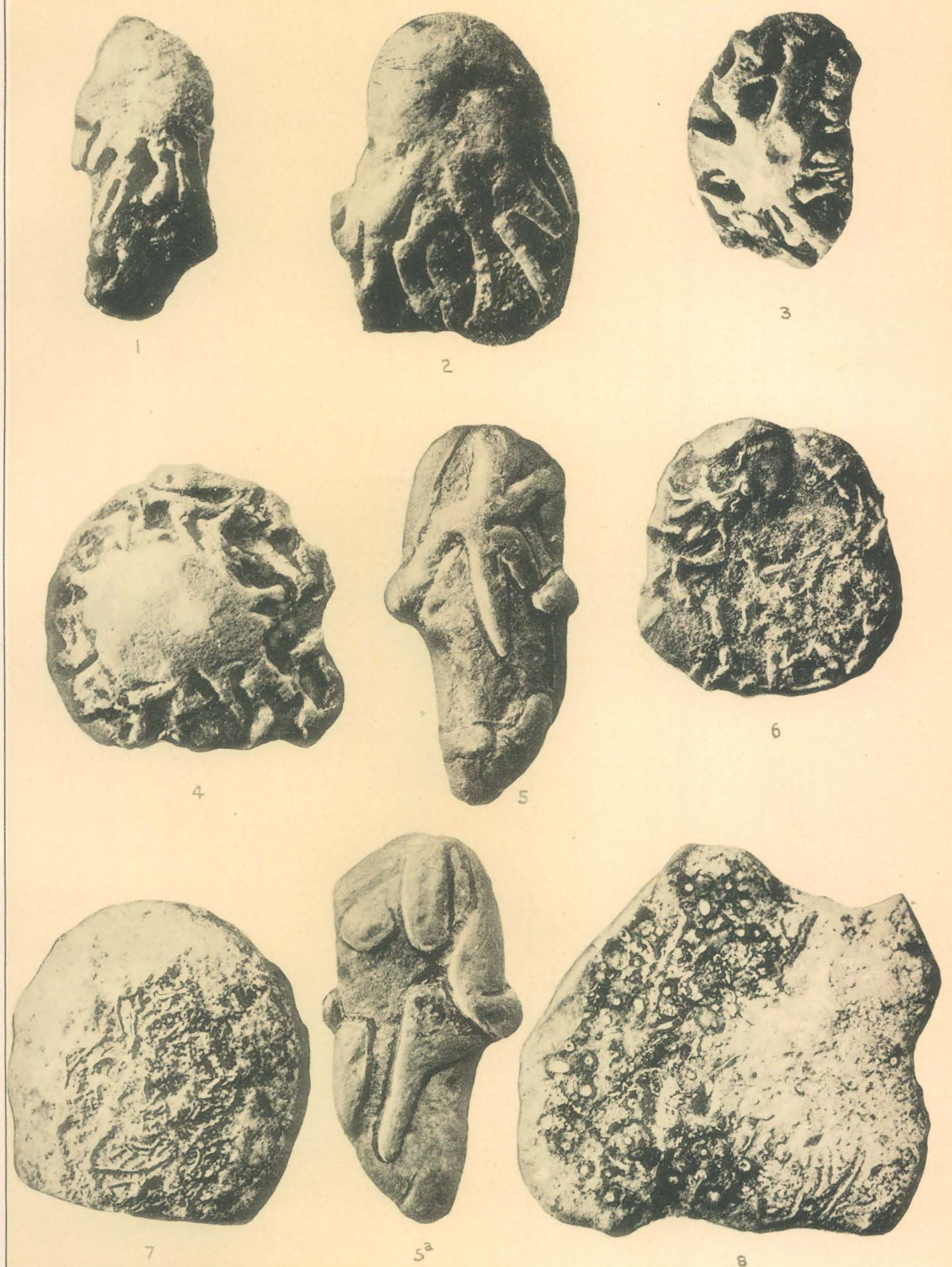
FIG. 4. Same type of specimen as fig. 3.

FIGS. 5, 5a. Two views of a distorted specimen which represents a number of similar specimens in the collection.

PLANOLITES.

FIGS. 6, 7, 8. Casts of annelid trails or borings on nodules associated with the medusæ. These are introduced to show, in connection with figs. 1 and 5 of Pl. XV, the character of the casts of the annelid trails and borings occurring often on the same nodules with the medusæ.

All figures natural size and reproduced from photographs.



LAOTIRA.
PLANOLITES.

PLATE XVII.

PLATE XVII.

LAOTIRA CAMBRIA (p. 32).

FIGS. 1, 1a. Exumbrella view of an irregularly lobed specimen, the subumbrella side of which (fig. 1a) has 5 strongly marked lobes; three of these show the termination of a canal at *x, x, x*.

FIGS. 2, 2a. A broken specimen, the exumbrella view of which is somewhat similar to fig. 9 of Pl. X. On the subumbrella surface (fig. 2a) there are two oral arms remaining, one of which shows a canal aperture at *x*.

FIGS. 3, 3a. Exumbrella surface of an irregularly lobed individual, the interior canals of which are shown by fig. 3a. The latter view may be compared with fig. 4; also with fig. 7 of Pl. XXIII.

FIG. 4. Natural section of a slightly irregular specimen, preserving seven of the interior radial canals.

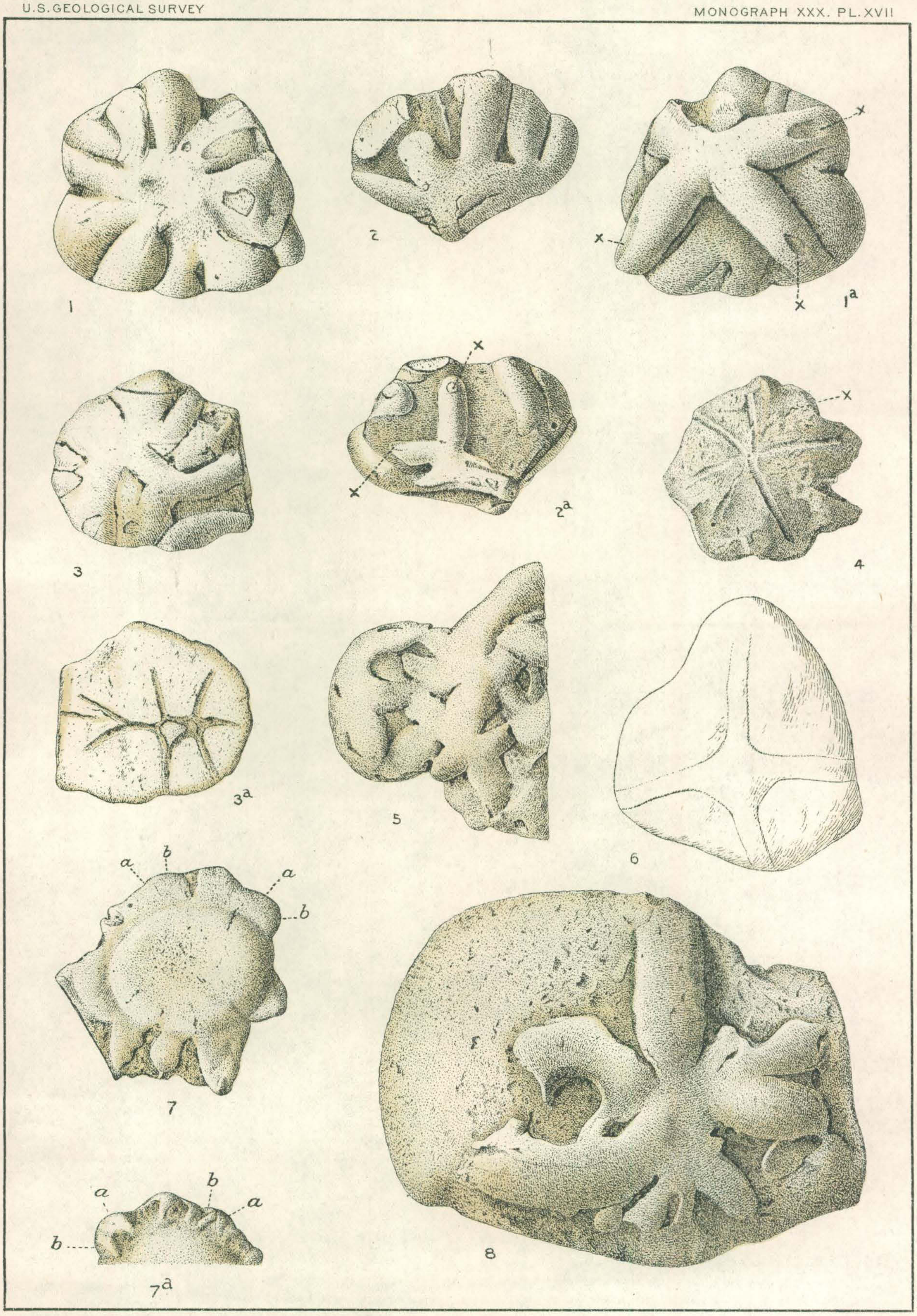
FIG. 5. Portion of a complex specimen in which a constriction has begun that may indicate the origin of another individual by fission.

FIG. 6. Four-lobed individual in which the cast of the 4 radial canals and the central cavity are strongly defined, the size of the canals being greatly increased by a deposit of siliceous matter about their original casts.

FIG. 7. A flattened individual in which the terminations of the lobes are outlined.

FIG. 7a. View of the inturned lobes of the upper portion of fig. 7, the lettering of the lobes of fig. 7a corresponding to the lettering of fig. 7.

FIG. 8. Exumbrella view of an irregularly lobed specimen which is somewhat flattened on the surface of a concretion.



LAOTIRA

PLATE XVIII.

PLATE XVIII.

LAOTIRA CAMBRIA (p. 32).

FIGS. 1, 1a. Exumbrella view of a 5-lobed specimen, the lower side of which (fig. 1a) shows narrow subumbrella lobes that pass beneath 5 broad lobes that are considered to be the oral arms.

FIG. 2. Subumbrella view of a small individual showing the same essential characteristics as fig. 1a.

FIG. 3. Exumbrella surface of a rotund specimen.

FIG. 3a. Side view of fig. 3, showing the interlocking of the exumbrella lobes and the oral arms.

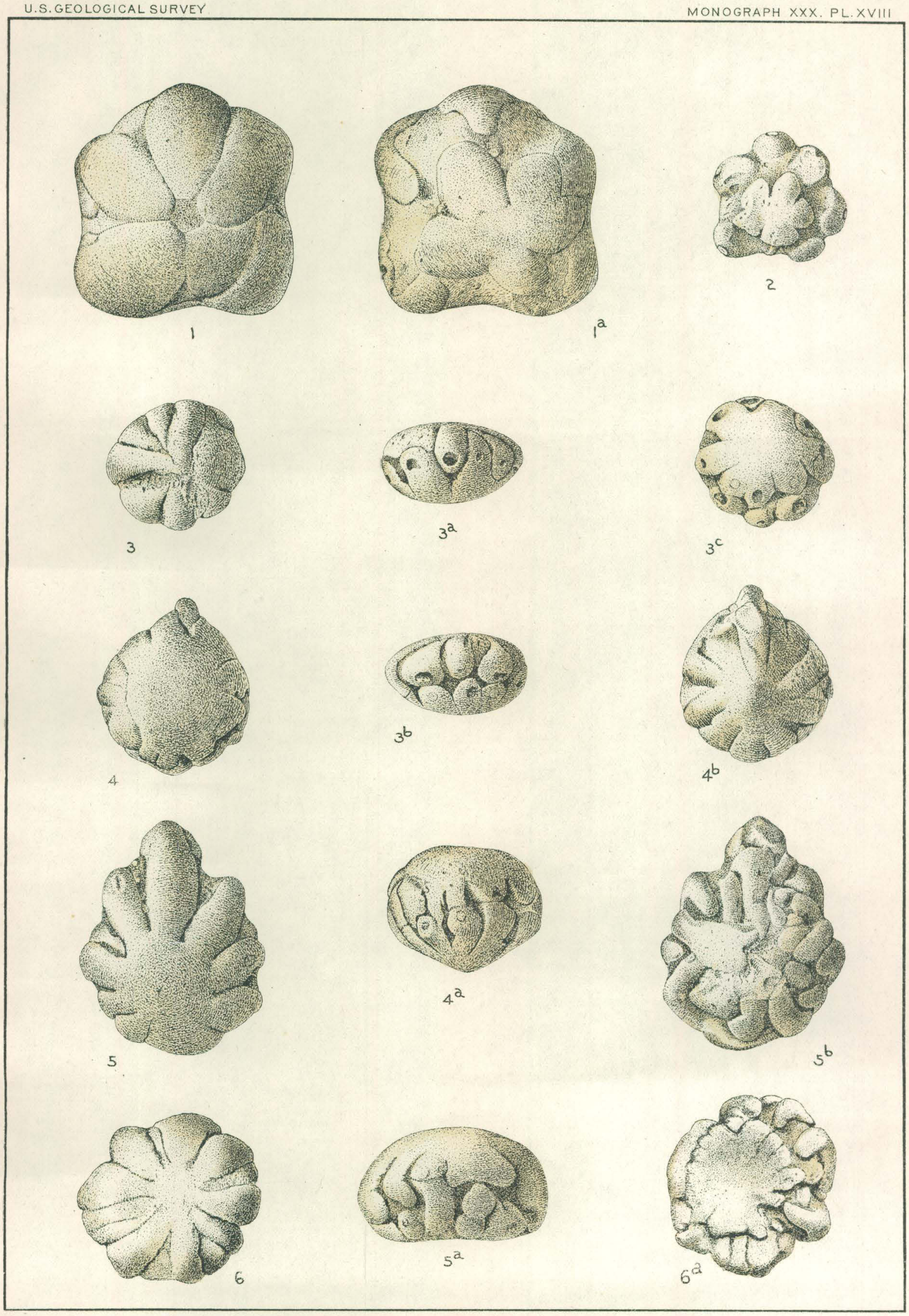
FIG. 3b. Opposite side from fig. 3a, showing the oral arms and exumbrella lobes touching, but not interlocking.

FIG. 3c. Lower surface of fig. 3, showing the oral arms more developed than in figs. 1a and 2.

FIGS. 4, 4a, 4b. Upper, side, and lower views of a rotund specimen, illustrating the same features as figs. 3, 3a, 3b, and 3c.

FIGS. 5, 5a, 5b. Views of a somewhat compressed and distorted specimen in which the exumbrella and subumbrella lobes, interradial lobes, and oral arms are more or less distorted and misplaced.

FIGS. 6, 6a. Exumbrella and subumbrella views of a specimen in which the central oral lobes are more numerous than in figs. 1a and 2.



LAOTIRA

PLATE XIX.

PLATE XIX.

Laotira cambria (p. 32).

Fig. 1. Exumbrella view of a specimen in which the tendency to fission is strongly developed.

Fig. 1a. Subumbrella surface of fig. 1.

Fig. 1b. Side view of fig. 1.

Fig. 2. A worn specimen in which fission has proceeded so far as to leave but one lobe, connecting what are otherwise two individuals.

Figs. 3, 3a. Exumbrella view of a specimen in which fission has proceeded so far that there is apparently but a single lobe uniting the two parts. This is still better shown by the subumbrella surface, fig. 3a.

Gastroblasta raffaeli (p. 39).

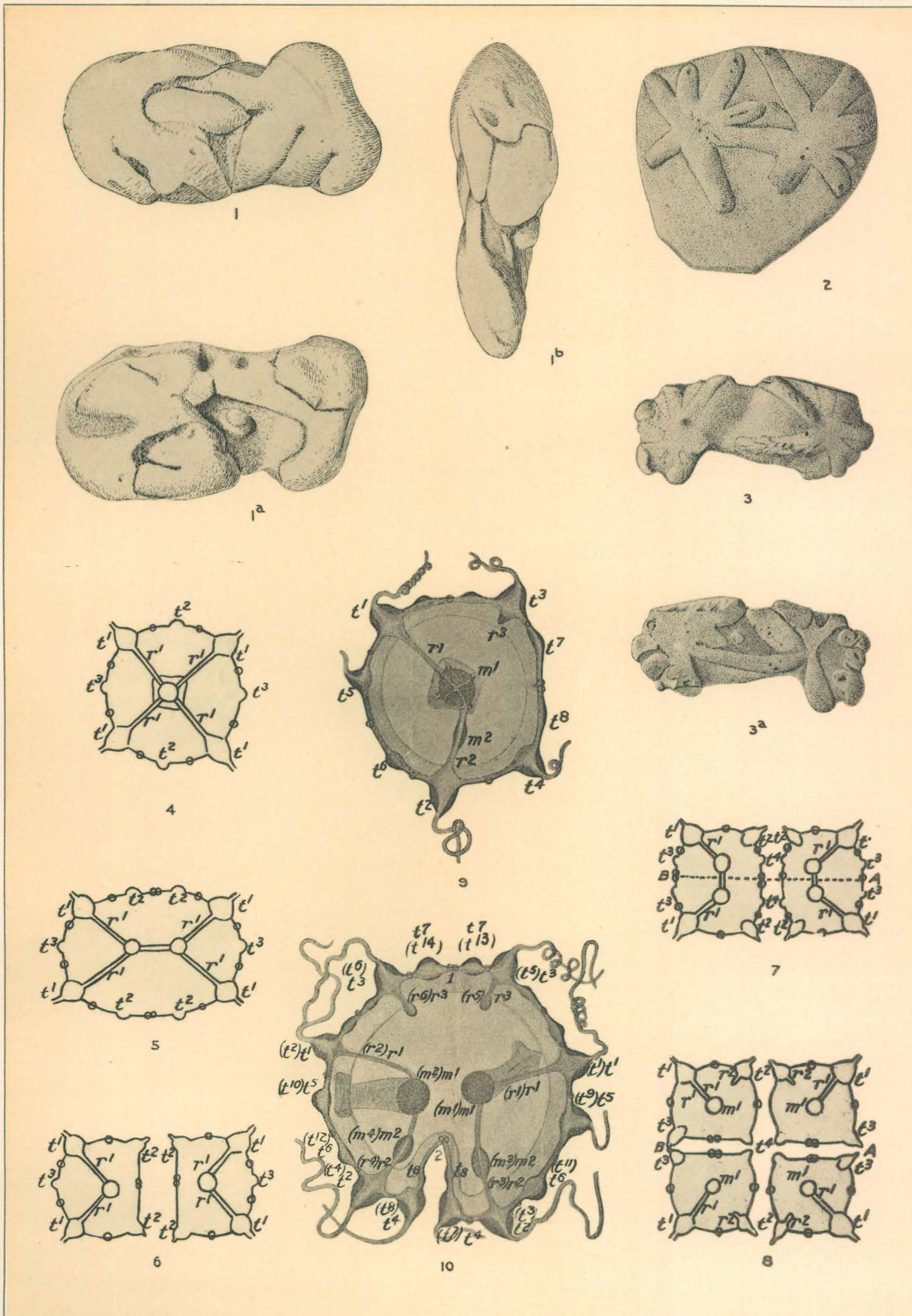
Figs. 4–8. Scheme representing the successive fission of a supposed first radial larval form. (After Lang.)

Fig. 9. A medusa in which the first stages of division are indicated. (After Lang.)

Fig. 10. A different stage of division and binary fission in which two stomachs are developed and the fission is more advanced. (After Lang.)

General meaning of the lettering: *m*, stomach in its inception; *g*, gonads; *t*, tentacles; *r*, radial canals.

The different ages of the gastral cavities, gonads, tentacles, and radial canals are shown by figures, viz: *t*, the oldest tentacle; *t2*, the second-oldest tentacle, etc.; *m*, the oldest stomach, *m2*, the second-oldest stomach, etc.



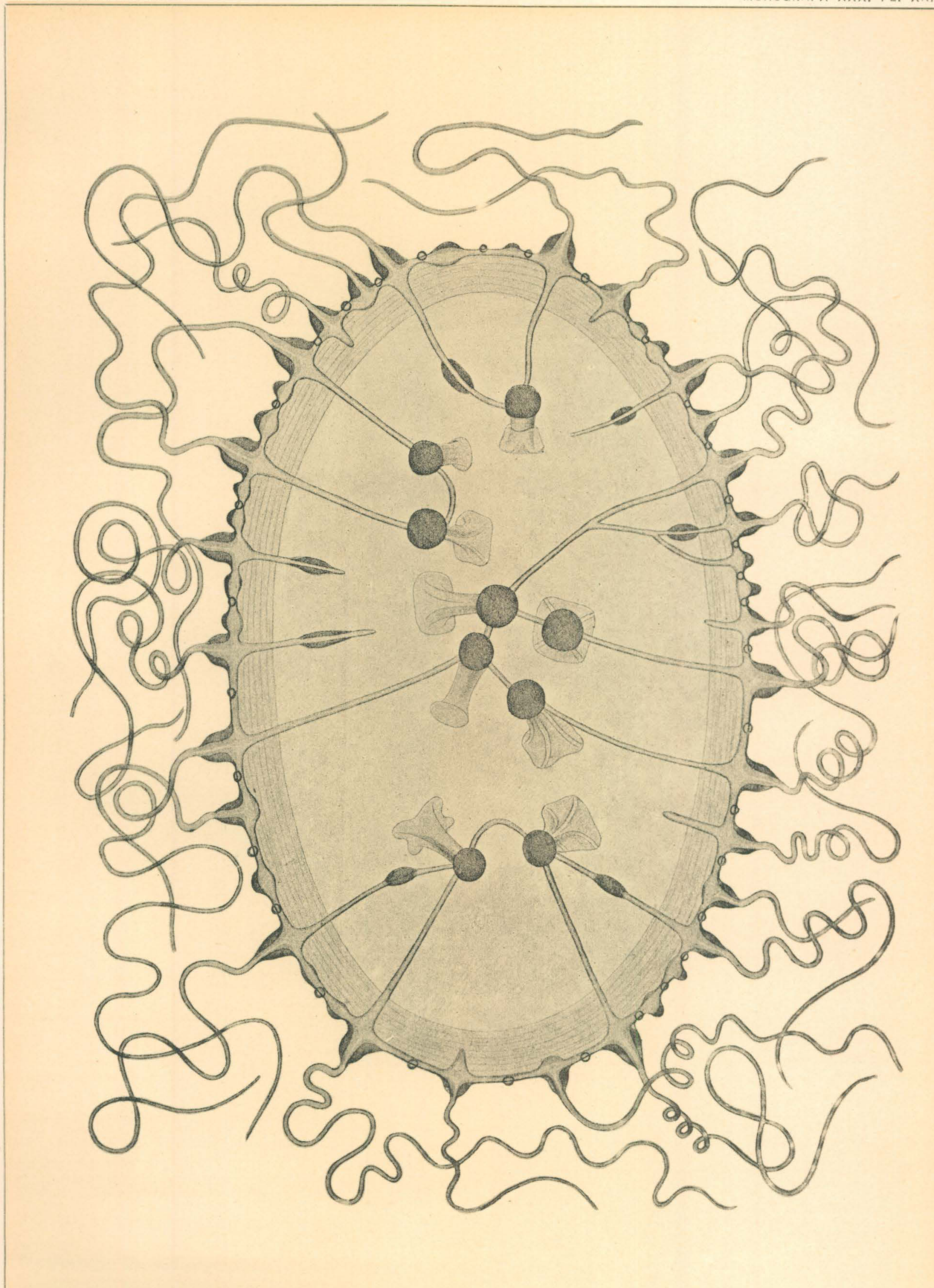
LAOTIRA.
GASTROBLASTA.

PLATE XX.

PLATE XX.

GASTROBLASTA RAFFAELI (p. 39).

FIG. 1. An enlarged view of a large specimen which has 9 developed gastro-pouches, viewed from the exumbrella side. From two sketches of the living animal and a comparison of prepared material. (After Lang.)



GASTROBLASTA

PLATE XXI.

PLATE XXI.

LAOTIRA CAMBRIA (p. 32).

FIG. 1. Fragment of a complex specimen which is weathered out in strong relief on a nodule.

FIG. 2. A 5-lobed individual partially buried in a thin nodule. It has been worn by recent abrasion so as to expose the radial canals and the central stomach.

FIG. 3. A complex specimen that is largely buried in a nodule. It is in strong contrast with fig. 1.

FIGS. 4, 4a. A small distorted specimen in which two of the lobes have been greatly drawn out.

FIG. 5. A thin nodule with three many-lobed medusæ partially embedded in it. This is a characteristic example of a large series of specimens of the same general type.

All figures natural size and reproduced from photographs.

LAOTIRA.

PLATE XXII.

PLATE XXII.

LAOTIRA CAMBRIA (p. 32).

FIG. 1. A large, partially folded, flattened specimen.

FIG. 2. A flattened specimen in which the exumbrella lobes and oral arms have been broken away from the center and drawn out on a line with the exumbrella lobes.

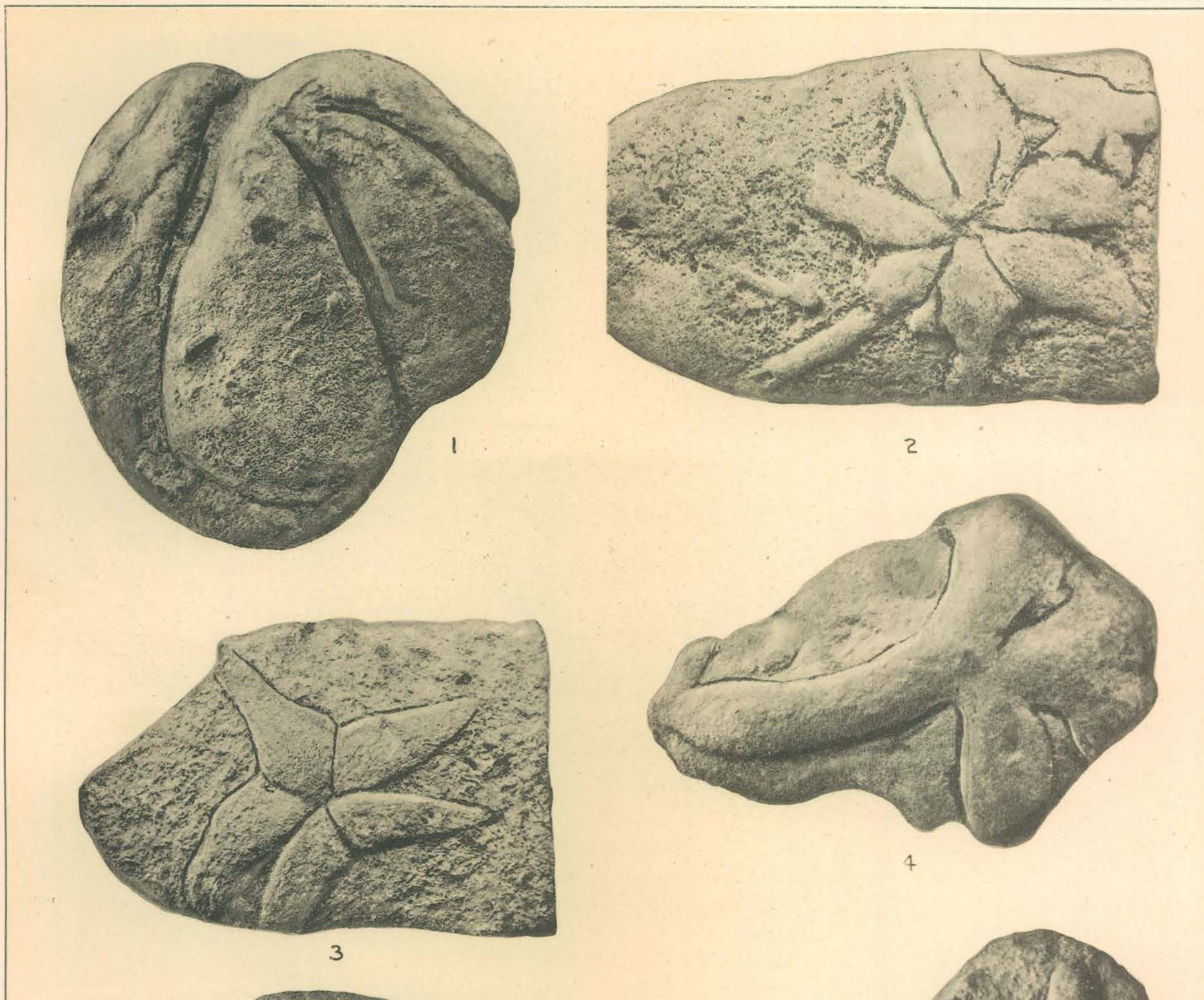
FIG. 3. A specimen flattened and drawn out, but not so much as fig. 2.

FIG. 4. A specimen with distorted exumbrella lobes.

FIGS. 5, 6. Specimens greatly flattened on the surface of flat nodules. Compare with the compressed specimens of *Dactyloidites asteroides* on Pls. XXV and XXVI.

All figures natural size and reproduced from photographs.

All the figures on this plate are of medusæ resting on or partially embedded in siliceous nodules.



LAOTIRA.

PLATE XXIII.

PLATE XXIII.

LAOTIRA CAMBRIA (p. 32).

FIG. 1. Transverse section of a 4-lobed individual, cut so as to show the 4 radial canals of the exumbrella and the central cavity into which they enter. Attention is called to the manner in which the yellow siliceous matter of the matrix is merged into the gray, which represents the substance of the lobes of the medusa.

FIG. 2. Transverse section of a 4-lobed individual in which the lobes have been replaced by the siliceous matter, and nearly all traces of the radial canals obliterated.

FIG. 3. A transverse section of an individual with 6 lobes, in one of which the radial canal is cut across, and seems to connect with the central cavity.

FIG. 4. Central vertical section of a specimen with numerous interradial lobes. Several of these are cut across. Very little is shown of the radial canals or central disk.

FIG. 5. Transverse section of a specimen with narrow lobes. The section of the radial canals is shown in three of them.

FIG. 5a. Vertical section of fig. 5 showing the exumbrella lobe and the distorted axial disk.

FIG. 6. Transverse section of one-half of a specimen with numerous small lobes in which there appears to be traces of a central disk and numerous lobes radiating from it. Several sections of the radial canals are shown near the outer margin.

FIG. 7. Transverse section of an irregularly lobed individual, showing the arrangement of the exumbrella canals. This may be compared with fig. 3a of Pl. XVII.

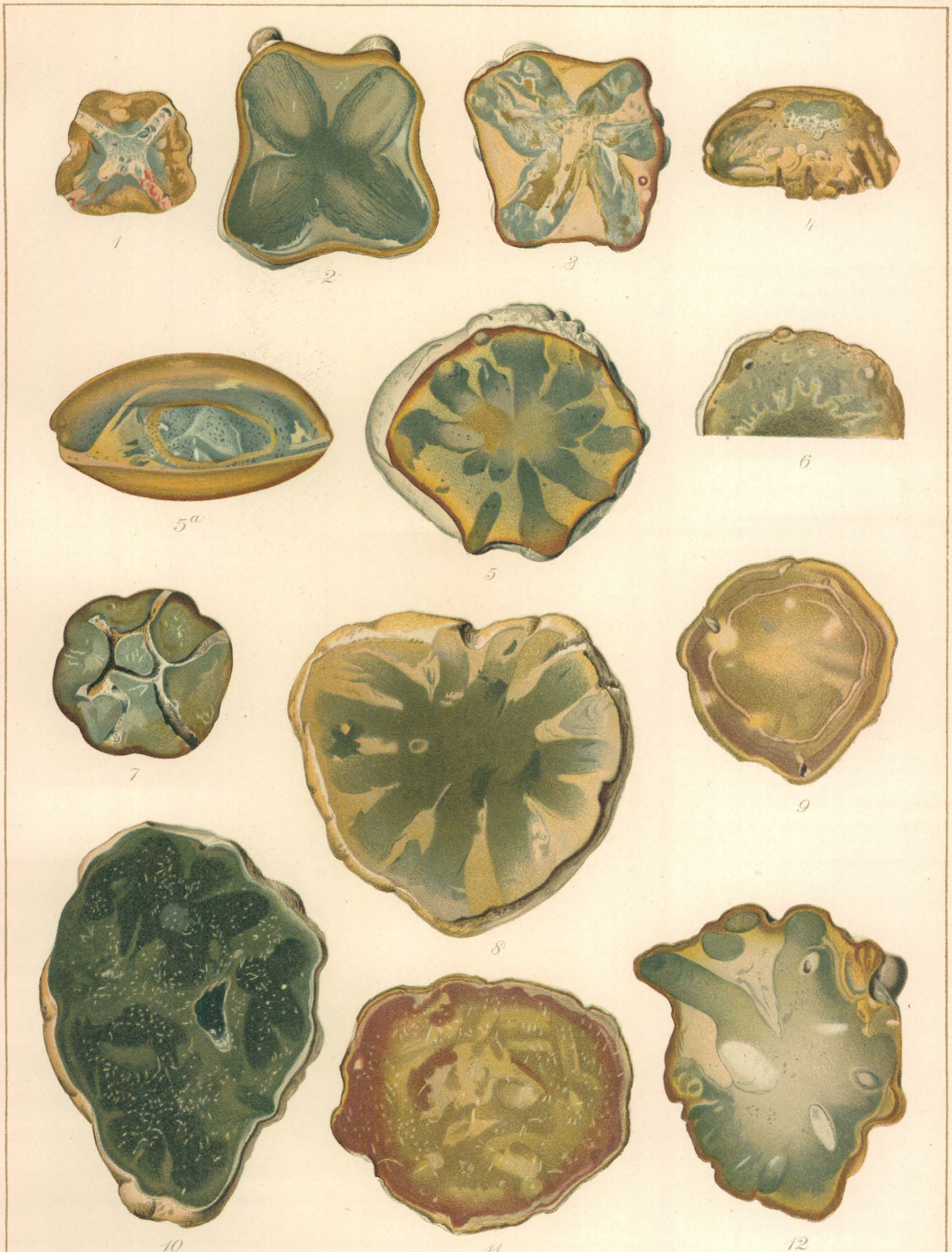
FIG. 8. Transverse section of a large irregularly lobed specimen in which the interior canals are not preserved. This specimen before cutting was of the general form of figs. 1 and 2a of Pl. VIII.

FIG. 9. Transverse section of a specimen in which nearly all traces of the medusa are lost, with the exception of a general outline and the cast of three or four of the radial canals.

FIG. 10. Transverse section of one of the compound forms, such as are illustrated by figs. 3 and 4 of Pl. XII and fig. 1 of Pl. XIII.

FIG. 11. Transverse section of a specimen, such as is represented by fig. 1 of Pl. XIII.

FIG. 12. Transverse section of a specimen which is of the general type of fig. 5 of Pl. XIII.



J. L. RIDGWAY DEL.

LAOTIRA

PLATE XXIV.

PLATE XXIV.

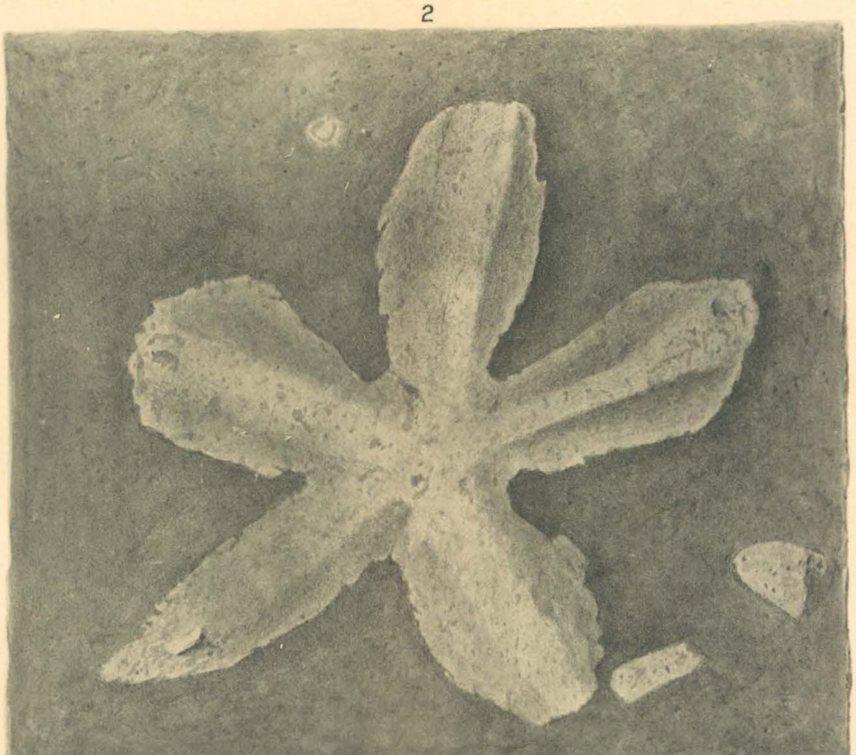
DACTYLOIDITES ASTEROIDES (p. 41).

FIG. 1. A specimen completely flattened in the siliceous slate. The subumbrella lobes appear to be in their natural position, while the exumbrella portion has been pressed out and broken until the original form is lost.

FIG. 2. A specimen preserving a little of its original convexity. The central portion of the disk and lobes was replaced by a little very fine sand, and the exterior is almost translucent. It looks very much like a medusa flattened on the dark slate.

1

2



DACTYLOIDITES.

PLATE XXV.

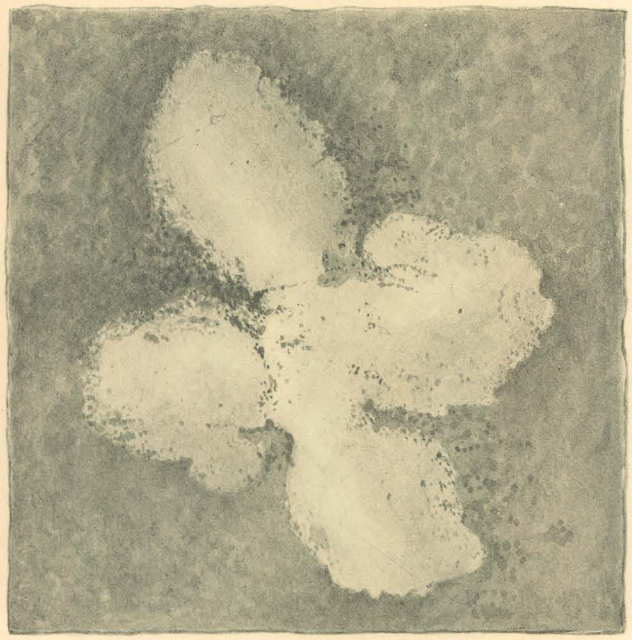
PLATE XXV.

DACTYLOIDITES ASTEROIDES (p. 41).

FIG. 1. A 4-lobed specimen preserving a slight convexity.

FIG. 2. Two small specimens flattened on the slate. It is possible that the two are united by one or two lobes, but this can not be determined positively, as they may be pressed down—the one upon the other.

FIG. 3. A 6-lobed specimen of the type of fig. 1 of Pl. XXIV.



1

2

3

DACTYLOIDITES.

PLATE XXVI.

PLATE XXVI.

DACTYLOIDITES ASTEROIDES (p. 41).

FIG. 1. The fine medusæ illustrated on this plate occur on the surface of a slab of slate (37 by 62 inches) on which there are 42 medusæ and many annelid trails. *a* is a large specimen, and, with *b* and fig. 1 of Pl. XXIV, represents the extreme pressing out of the lobes of the umbrella. This is less in *e* and *c*. The 5-lobed *d* may be compared with fig. 6 of Pl. VI, and *b* and *e* with fig. 5 of Pl. XXII.

DACTYLODITES.

PLATE XXVII.

157

PLATE XXVII.

HELMINTHOIDICHNITES MARINUS.

FIG. 1. A common form of burrow or trail, that occurs on the surface of the slate, associated with the medusæ. It has the appearance of a number of narrow trails made on a broad trail, such as is represented by fig. 2.

FIG. 2. A broad, smooth trail on the surface of the slate.

FIG. 4. Cast of a boring in which the mud was pushed back by the animal that made it.

FIG. 5. Narrow trails as they occur on the surface of the slate.

All of the above occur in the same band of slate with *D. asteroides.*

DACTYLOIDITES ASTEROIDES (p. 41).

FIG. 3. A small specimen showing traces of the central disk.

FIG. 6. A specimen preserving the exumbrella lobes and a peculiar flattening of the subumbrella lobes.

HELMINTHOIDICHNITES.

PLATE XXVIII.

PLATE XXVIII.

MEDUSINA PRINCEPS (p. 54).

FIG. 1. Copy of Linnarsson's second figure of *Medusina radiata*, which Nathorst identified as the species described by Torell.

MEDUSINA RADIATA (p. 56).

FIG. 2. Copy of Linnarsson's original figure. Dr. Nathorst considers this to be a cast of the radial canals of a craspedote medusa belonging to the family Æquoridæ.

MEDUSINA COSTATA (p. 49).

FIG. 3. Side view of a quadripartite specimen showing the radiating ridges and casts of the genital hollows (*g*, *g*). (Collection United States National Museum.)

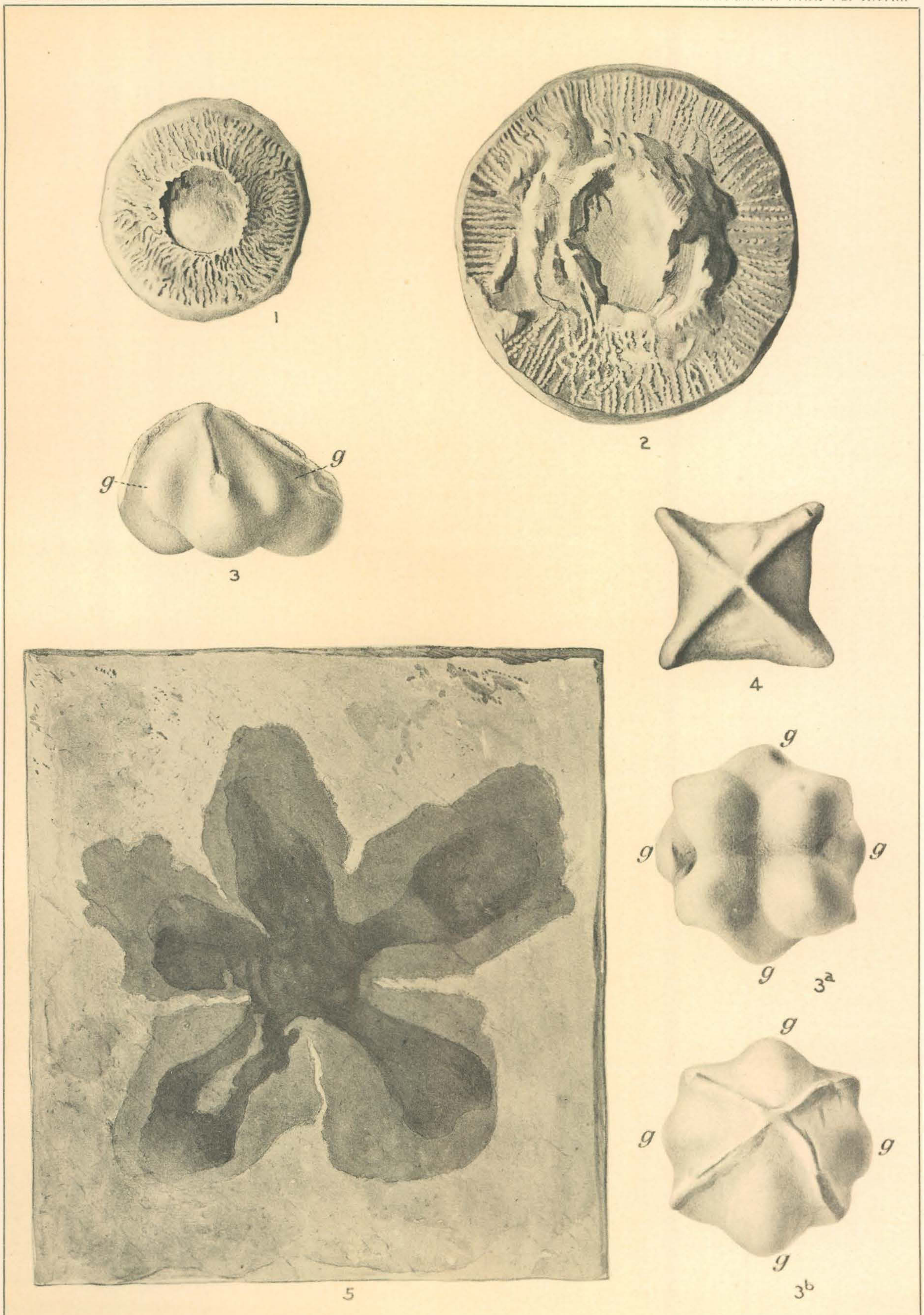
FIG. 3a. Summit view of fig. 3, showing 4 lobes expanding to hollows in the roof of the gastric cavity; also the casts of the genital hollows (*g*, *g*). (Collection United States National Museum.)

FIG. 3b. View of the lower side of fig. 3, showing cast of the 4 radiating ridges and the genital hollows (*g*, *g*). (Collection United States National Museum.)

FIG. 4. View of the under side of a quadripartite specimen. (Collection United States National Museum.)

DACTYLOIDITES ASTEROIDES (p. 41).

FIG. 5. A specimen flattened in the slate. The exumbrella lobes appear to have been pressed out over the subumbrella lobes, the latter appearing as the dark portions of the fossil.



MEDUSINA.

DACTYLOIDITES.

PLATE XXIX.

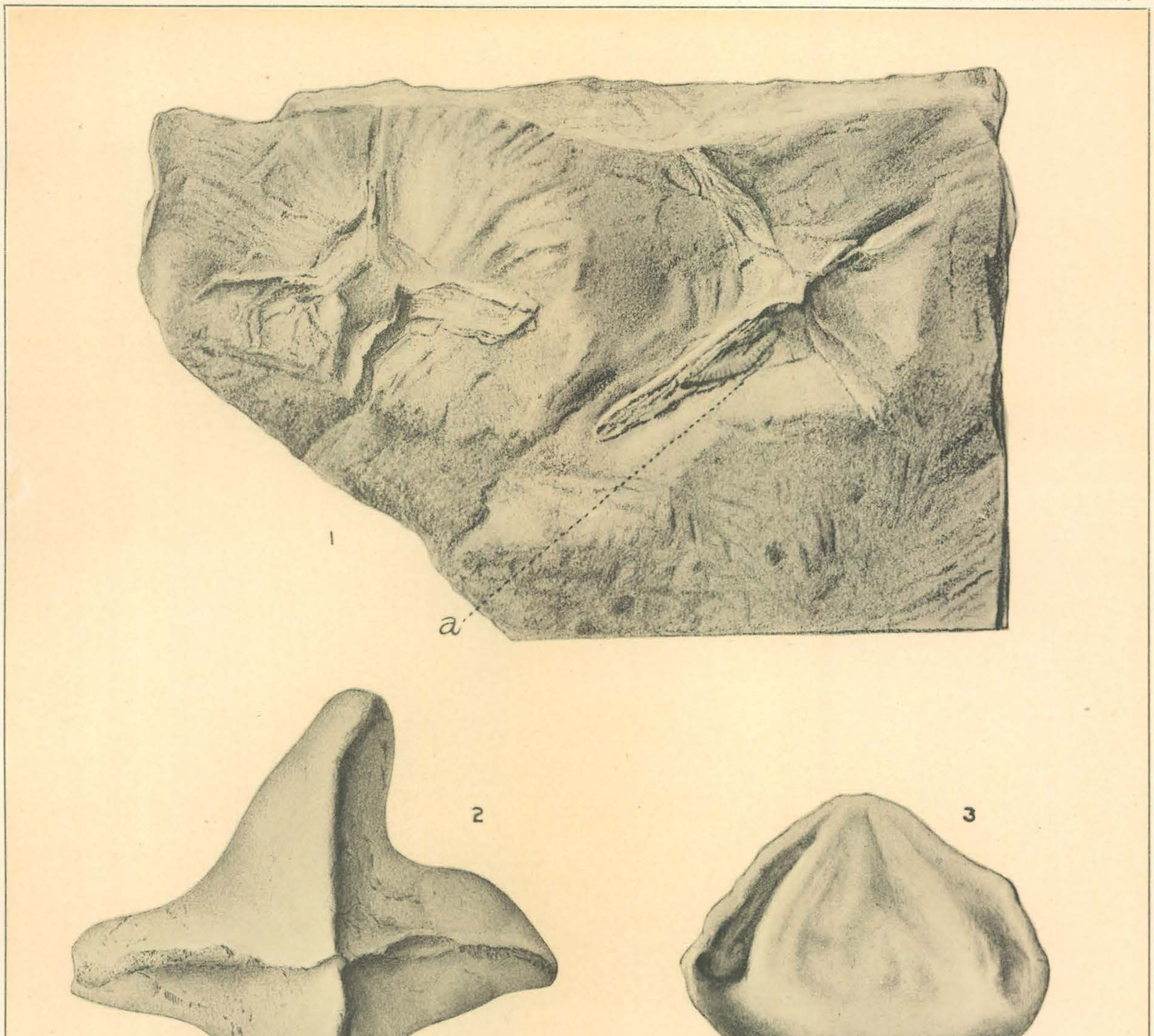
PLATE XXIX.

MEDUSINA COSTATA (p. 49).

FIG. 1. Imprint of lower sides of two specimens on a slab of sandstone, showing the pyramidal cast of the mouth opening and the imprint of the mass of the body. At a the structure indicates the presence of a gonad. (After Nathorst.)

FIG. 2. View of the lower side of a free cast, showing the central pyramid and 4 radiating ridges. This and other specimens of the same character Nathorst considers to be casts of the gastric cavity, the radiating ridges being the casts of the opening of the mouth.

FIGS. 3, 3a, 3b. Side, base, and summit views of a cast of a quinquepartite specimen.



MEDUSINA.

PLATE XXX.

PLATE XXX.

MEDUSINA COSTATA (p. 49).

FIG. 1. Copy of a figure by Nathorst showing an impression of the under side of this species. The mouth (*m*) is clearly defined, and also the impressions of the 4 genital hollows (*g, g, g, g*), and the radiating impression between the latter and the outer margin.

AURELIA FLAVIDULA (p. 5).

FIG. 2. Photograph of a cast in plaster of a portion of a large individual. The cast, which was entire, has been cut away from the side so as to expose the impression of the lower surface of the medusa. The cast of the quadrate mouth, the exterior of the genital sacs and the filling of the interior of three of those sacs, portions of the four arms, and the faint impression made by the radial tubes are beautifully shown.

FIG. 3. Photograph of the cast of a large individual in which the genital sacs are shown on the right by an impression of their exterior and on the left by the cast of the distended interior cavity. The form of the quadrate mouth is clearly shown, and also the cast of the tube that led from the mouth to the genital sac.

A comparison of the fossil impression, fig. 1, with the casts of the recent medusæ, figs. 2 and 3, is suggested.

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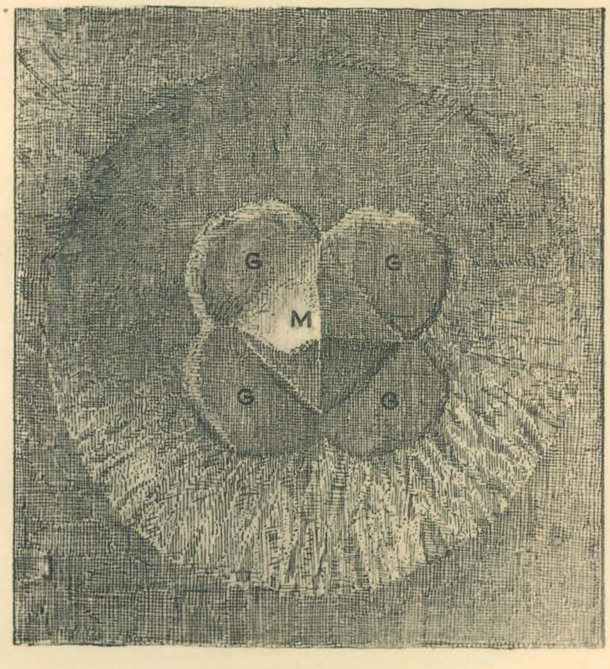
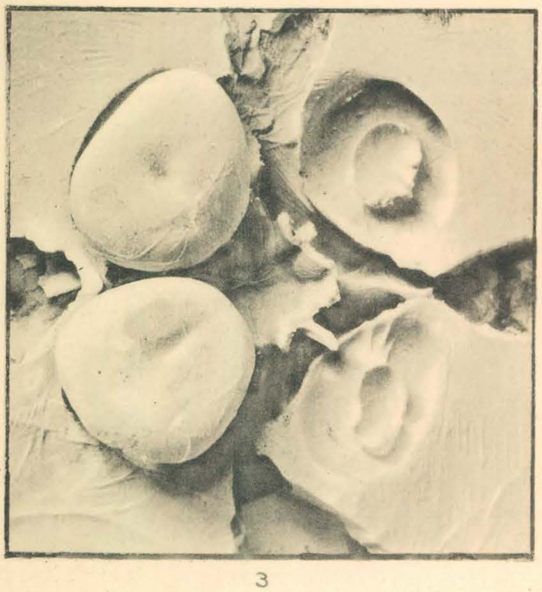




3

MEDUSINA.

PLATE XXXI.

PLATE XXXI.

Aurelia flavidula (p. 5).

Fig. 1. Photograph of a cast in plaster of the under surface of a large specimen of *Aurelia flavidula*. The specimen had been kept in sea water that contained 3 per cent of formaline. It was plump and firm, but the surface contracted and gave the wrinkled appearance shown in the cast. The impressions of the genital sacs are shown, but the casts of the interior of the sacs are all broken away. The arms are imperfectly shown, as the plaster forced itself between them and the body of the medusa.

AURELIA.

PLATE XXXII.

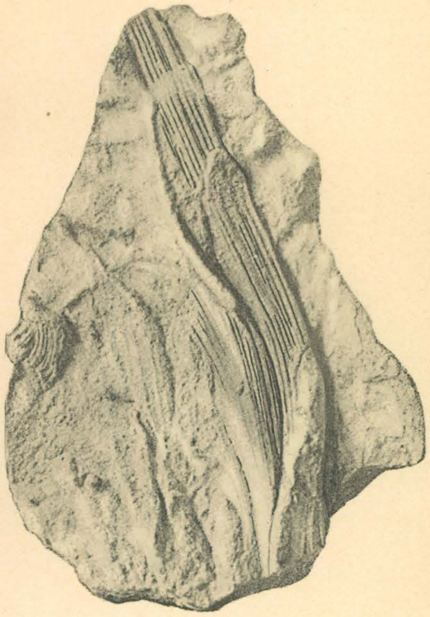
PLATE XXXII.

EOPHYTON LINNÆANUM (p. 64).

FIGS. 1, 2. Reproductions of photographs of two specimens in the collection of the United States National Museum. Fig. 1 illustrates the variety with the very fine striæ, and fig. 2 the variety which appears to show the casts of reed-like stems (*a*, *a*).

EOPHYTON TORELLI (p. 64).

FIGS. 3, 3a, 3b. Reproductions of three of the figures of the type specimens. (After Linnarsson.)



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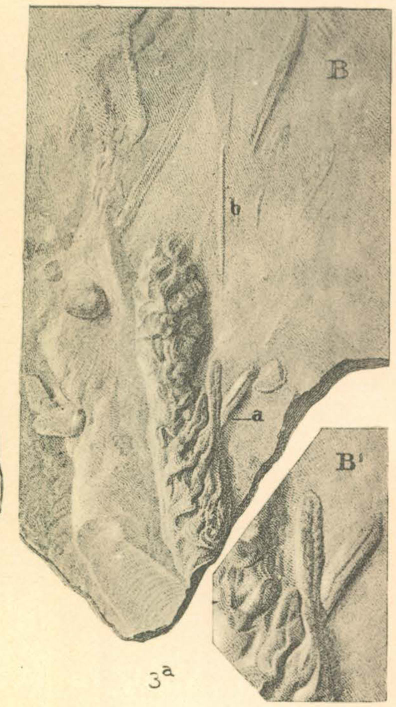

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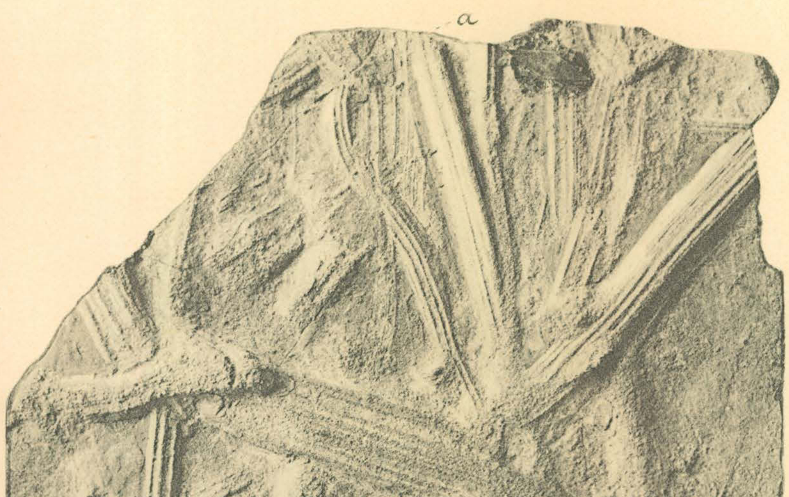

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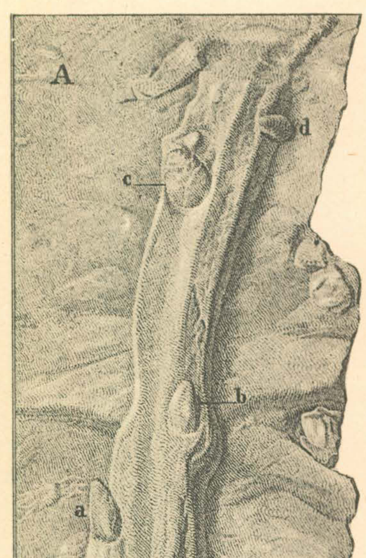


3b

EOPHYTON.

PLATE XXXIII.

PLATE XXXIII.

AURELIA FLAVIDULA (p. 5).

Trails produced by drawing the oral arms of the medusa over the surface of soft plaster, the arms being drawn in about the same manner as they would have been if drifted along by a current in shallow water near the shore.

The resemblance of these trails to those of specimens of Eophyton and other trails that have been referred to Algæ and other fossil plant remains, is very striking. Compare with figures of Pls. XXXII, XXXV.

AURELIA.

PLATE XXXIV.

PLATE XXXIV.

AURELIA FLAVIDULA (p. 5).

Trails produced as indicated for those of Pl. XXXIII.

AURELIA.

PLATE XXXV.

PLATE XXXV.

EOPHYTON (?) (p. 63).

FIGS. 1, 2. Views of casts of trails on the under side of a thin slab of the Middle Cambrian (Tonto) sandstone. (Collection United States National Museum.)

FIG. 3. View of casts of trails on the St. Croix sandstone of Wisconsin. (Collection United States National Museum.)

EOPHYTON.

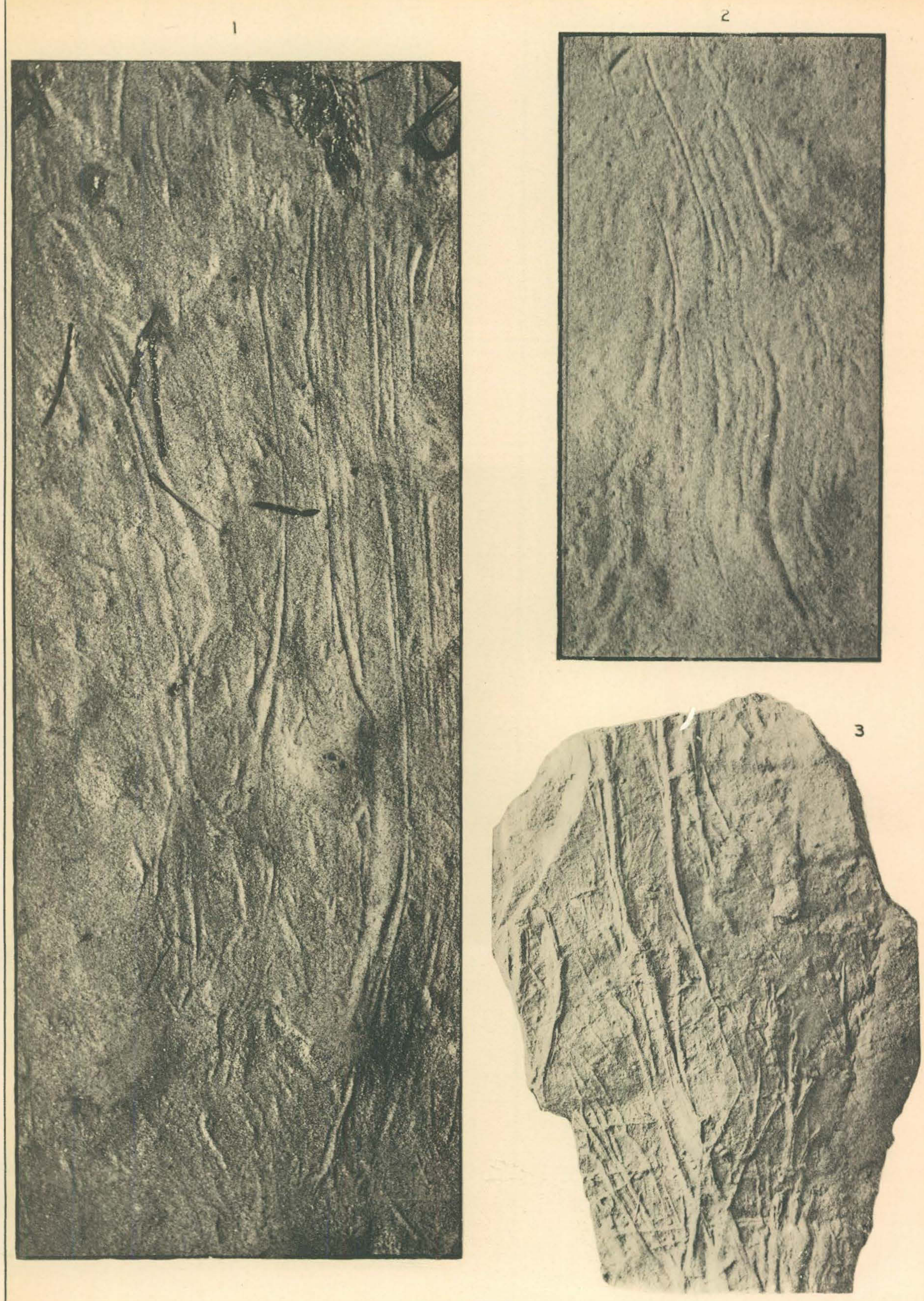
PLATE XXXVI.

PLATE XXXVI.

CASTS OF TRAILS AND MARKINGS (p. 63).

FIGS. 1, 2. Casts of trails made on sand and silt by algæ, drifting with the outflowing tide, at inlet west of Noyes Point, Rhode Island. For comparison with fig. 3 of this plate and figs. 1 and 4 of Pl. XXXVII. (Photograph by C. D. W.)

FIG. 3. Cast of trails on Middle Cambrian sandstone 5 miles southwest of Rogersville, Tennessee. (Collection United States National Museum.)



CASTS OF TRAILS AND MARKINGS.

PLATE XXXVII.

PLATE XXXVII.

CASTS OF TRAILS AND MARKINGS (pp. 62, 63).

FIG. 1. Casts of trails on Middle Cambrian sandstone 4 miles northeast of Rogersville, Tennessee. These trails show an apparent bifurcation, and also a raised margin, indicating an elevated center. This feature is shown by the trails produced by algæ, fig. 1 of Pl. XXXVI. (Collection United States National Museum.)

FIG. 2. Cast of trail having coarse parallel striæ, on the surface of the Middle Cambrian (Tonto) sandstone, Grand Canyon of the Colorado, Arizona. (Collection United States National Museum.)

FIG. 3. Slab of sandstone from same locality as that shown in fig. 1, showing Eophyton-like trails at *a* and *b*. The trail at *a* is coarse, like *a* of fig. 2 of Pl. XXXII. The striæ at *b* are very fine, like those of fig. 1 of Pl. XXXII.

FIG. 4. Cast of fine trails on surface of shaly (Middle Cambrian) sandstone 10 miles east of Knoxville, Tennessee. These striæ are somewhat similar to those illustrated by Nathorst, which he suggested might have been produced by the tentacles of medusæ.

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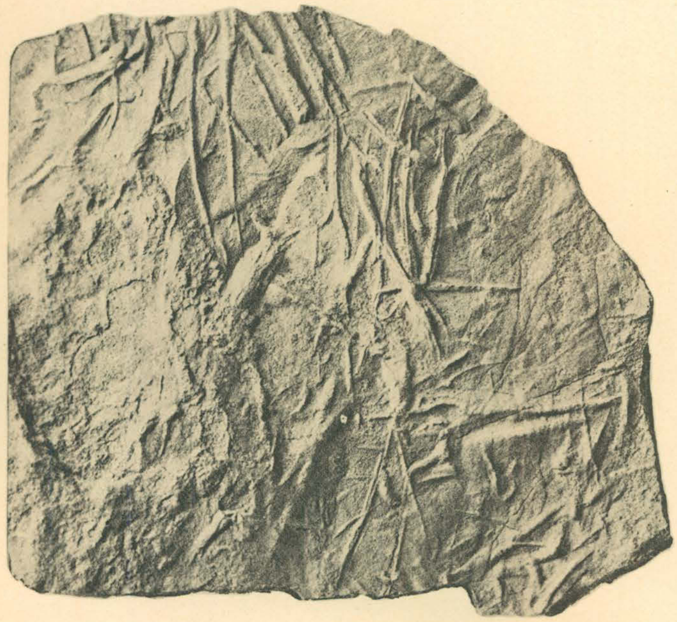

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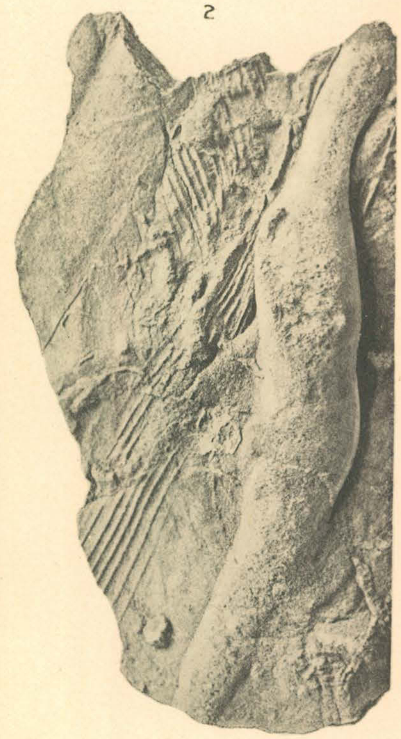

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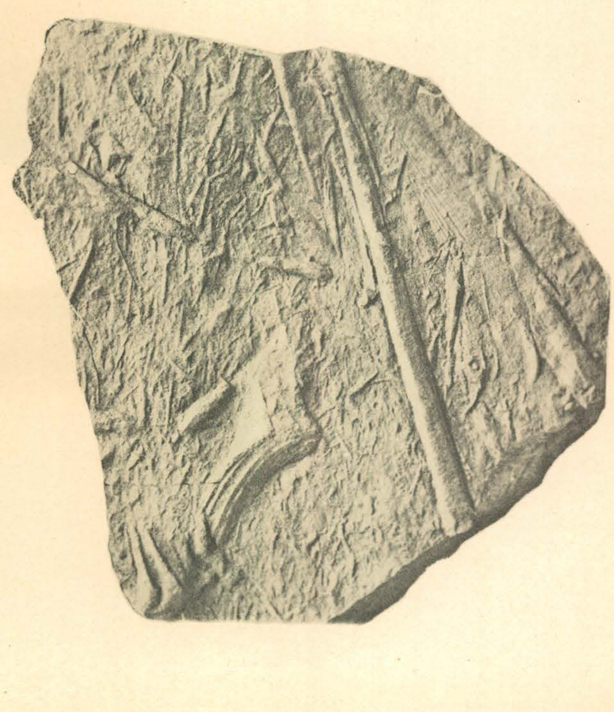


CASTS OF TRAILS AND MARKINGS.

PLATE XXXVIII.

PLATE XXXVIII.

CASTS OF TRAILS AND MARKINGS (p. 63).

FIG. 1. View of a slab of Tonto (Middle Cambrian) sandstone from the Grand Canyon of the Colorado. The principal trail is the large one with coarse, parallel striæ. This strongly suggests the drifting over the surface of the mud of some medusa-like form with numerous trailing tentacles. The strong trail which terminates at *a* is probably the cast of the path of a trilobite walking on the soft bottom. (Collection United States National Museum.)

CAST OF TRAILS AND MARKINGS.

PLATE XXXIX.

PLATE XXXIX.

SEMÆOSTOMITES ZITTELI (p. 70).

Natural size, from a photograph. (After Haeckel.)

a. Gastral cavity.

b_1–b_4. The 4 oral arms.

c_1–c_8. The 3-sided pyramidal adradial papillæ between the external corners of the gastral pouches and the genital pouches.

d_1–d_4. The 4 gastral pouches.

f. The thickened mound-like ring which defines the peripheral boundary of the gastral pouches and the genital pouches.

e. The smooth zone.

g_1–g_4. The 4 genital pouches.

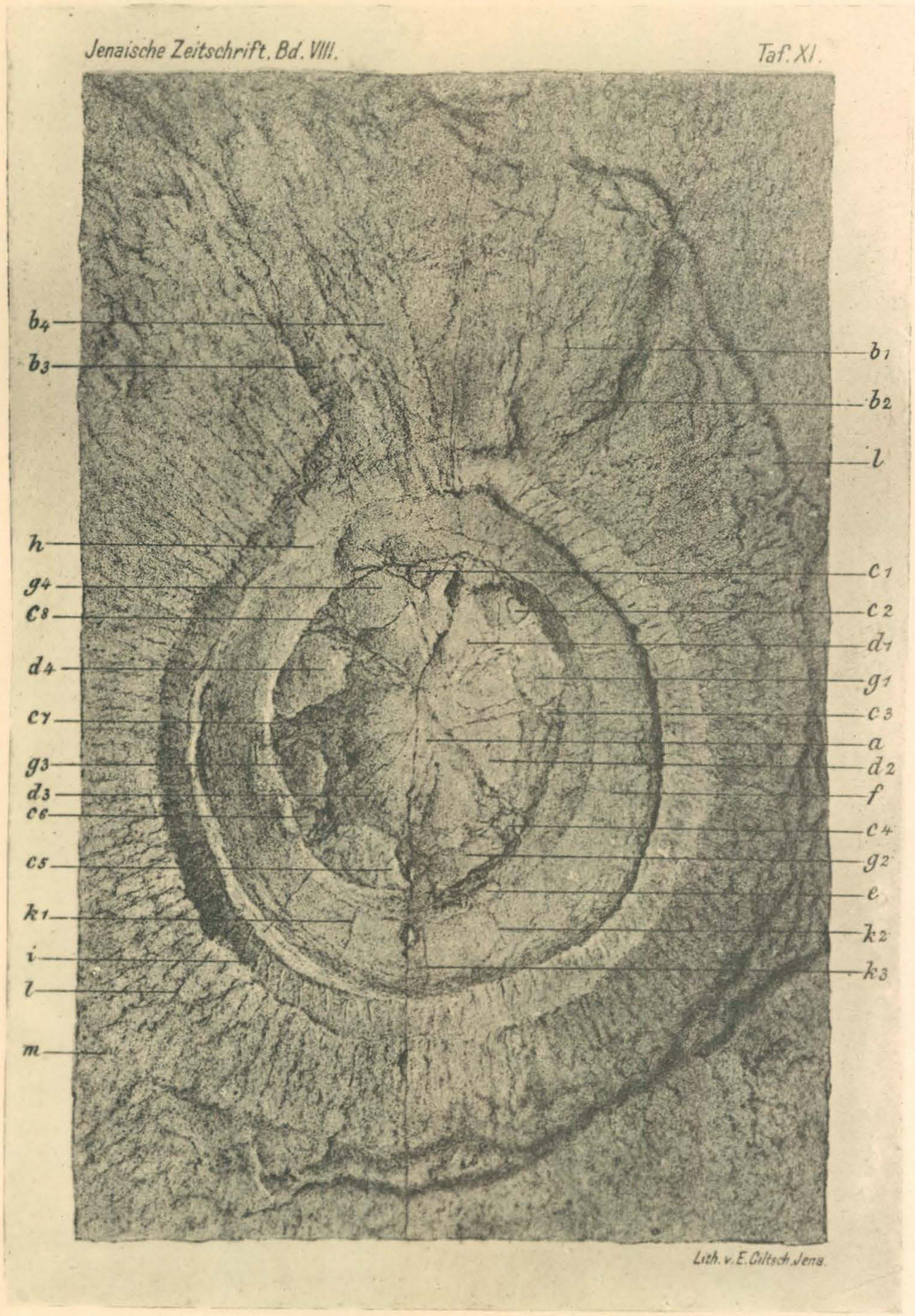
h. The ring canal.

i. The marginal lobes.

k. Radial canals (k_1 perradial canals; k_2 interradial canals; k_3 adradial canals).

l. Marginal tentacles.

m. Periphery of the zone of rays formed by the marginal tentacles.



SEMAEOSTOMITES.

PLATE XL.

PLATE XL.

RHIZOSTOMITES ADMIRANDUS (p. 76).

Photolithograph from the original, natural size. (After Ammon.)

AS. Mouth disk upon which is the cross of the mouth seam.
dp. Perradial areas of the mouth disk.
di. Interradial areas of the same.
HR. Rough or deep ring.
p. Impression of the trunk of a feeding arm.
f. Adradial furrow in the deep ring.
n. Kidney-shaped plate (probably subgenital opercula).
V. Broad marginal border of the same.
GR. Smooth ring.
W. Ring wall.
cc. Boundary between the smooth and the furrowed zone (ring canal).
ci and *ci-o.* Interradial canals.
cp. Perradial canal.
FR. Furrowed ring.
mc. Circular muscle.
l. Marginal lobe.
o. Sinus for sense organ.

RHIZOSTOMITES.

PLATE XLI.

PLATE XLI.

RHIZOSTOMITES LITHOGRAPHICUS (p. 83).

Reproduction of a photograph, one-half natural size, of a specimen from the lithographic limestone of Solenhofen. The original specimen is in the collection of the United States National Museum.

RHIZOSTOMITES.

PLATE XLII.

PLATE XLII.

RHIZOSTOMITES LITHOGRAPHICUS (p. 83).

FIG. 1. Impression of the oral disk. Photograph after the original; natural size. (After Ammon.)

a–a. Rhombic mid-field.
a^1. Primary limb of the cruciform mouth seam.
a^2. Secondary limb of the same (arm seam).
y. Apparent bifurcation of the latter.
dp. Perradial fields of the brachial disk.
di I, *di II*. Interradial areas of the same.
p. Point of departure of the mouth arms.
v and *k*. Limestone accretions.

RHIZOSTOMITES ADMIRANDUS (p. 76).

FIG. 2. Impression of portions of two medusæ. One-third life size. (After Brandt.)

C. Peduncles or roots of mouth disk.
D. Base of the peduncles.
E. Edge of disk.
F, F^1. Peripheral zone of disk (umbrella).
G. "Smooth ring."
H. Kidney-shaped plates, lids of the genital cavities.
a. Center of mouth disk and central mouth rudiment.
b. Primary arms of the mouth cross.
c. Secondary arms of the same.
d, *e*. Isosceles triangles within the mouth cross.
h. Boundary of the kidney-shaped plates (lids of the genital cavities) and in part of the central cavity.
i. Oval apertures, entrances to genital cavities.
K. Circular furrow, perhaps indicating the position of the circular canal.
s. Boundary of middle field.
v, *v'*. Thickenings of the "smooth ring."
o. Position of one of the 8 major constrictions which, Haeckel believed, divided the rim into 8 principal lobes. Brandt considers this only a break in the contour, the broken lobes being impressed upon the smaller specimens of *R. admirandus*, as represented in the figure.

MEDUSINA STAUROPHORA (p. 94).

FIG. 3. (After Haeckel.) See description in text.

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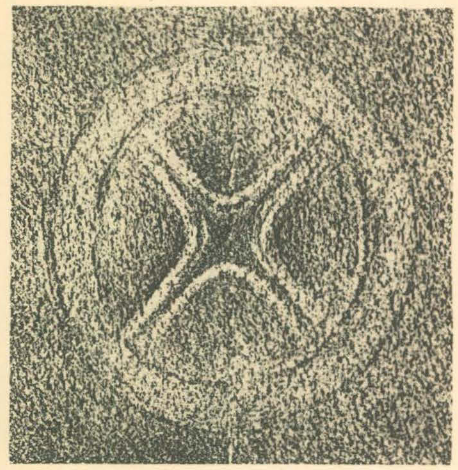

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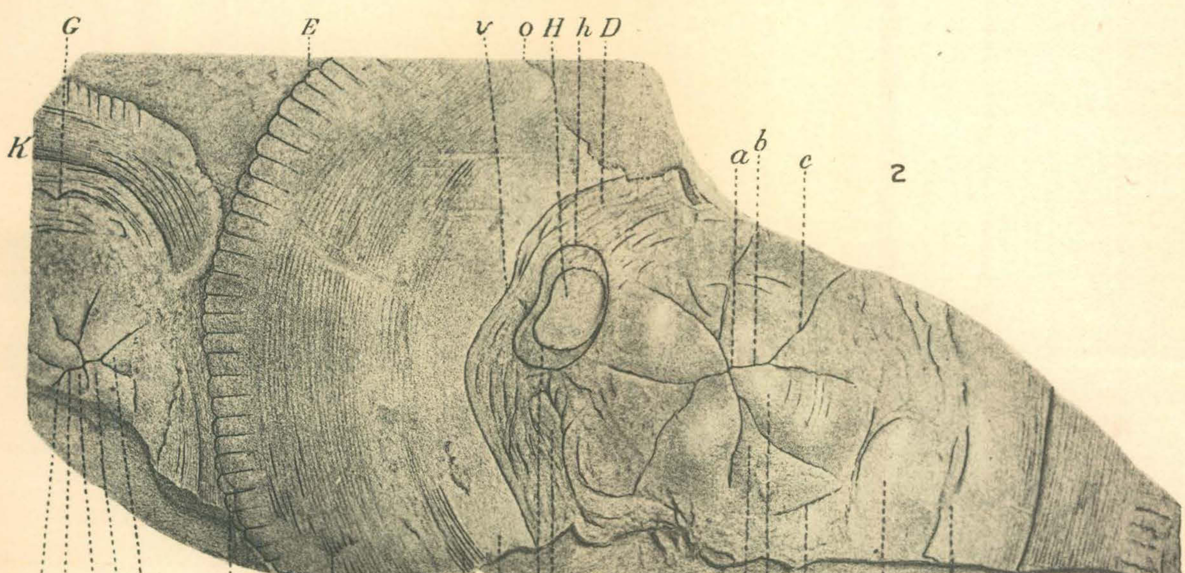

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RHIZOSTOMITES.
MEDUSINA.

PLATE XLIII.

PLATE XLIII.

Hexarhizites insignis (p. 86).

Natural size, from a photograph. (After Haeckel).

a_1, a_2. Mouth seam.

a_1. Three-sided pyramidal point at the end of the mouth seam.

a_2. Open remainder of the mouth orifice, not quite obliterated (?).

b. End of the side limb of the mouth seam a, b.

c_1, c_6. Inner point of the perradial brachial area (point of bifurcation of the 6 arm seams).

d_1, d_{12}. External ends of the 12 branches of the arm seams (corners of the 12-sided mid-field).

e_1, e_{12}. Lateral angles of the 6 three-cornered genital cavities.

f_1, f_6. Convex center of the ground line of the 6 three-cornered genital cavities.

g_1, g_6. Inner periphery or rounded point of the 6 genital cavities (subgenital lids).

h. Periphery of the genital zone.

i. Periphery of the smooth zone (ring canal).

k_1, k_6. Peripheral portion of the 6 perradial canals.

l_1, l_6. Peripheral portion of the 6 interradial canals.

m. Marginal depression for the 6 perradial marginal bodies.

n. Marginal depression for the 6 interradial marginal bodies.

HEXARHIZITES.

PLATE XLIV.

PLATE XLIV.

MEDUSINA DEPERDITA (p. 91).

FIG. 1. Plaster impression of a limestone slab from the lithographic slates of Eichstädt (white Jura coral limestone), with an impression of *Medusina deperdita*. The medusa is drawn to the natural size. (After Haeckel.)

c. Marginal canal (ring canal in the umbrella rim).
g. Expansion in the middle of the radial canal (genitalia?).
m. Mid-field of the medusa impression, corresponding to the stomach and mouth.
p. Periphery of the gelatinous mantle (margin of the impression).
r. Radial canals.
s. Shallow circular furrow in the slab surrounding the impression of the periphery of the mantle.
u. Broader ring about the disk ring (thickness of the gelatin substance of the medusa which has been pressed flat).

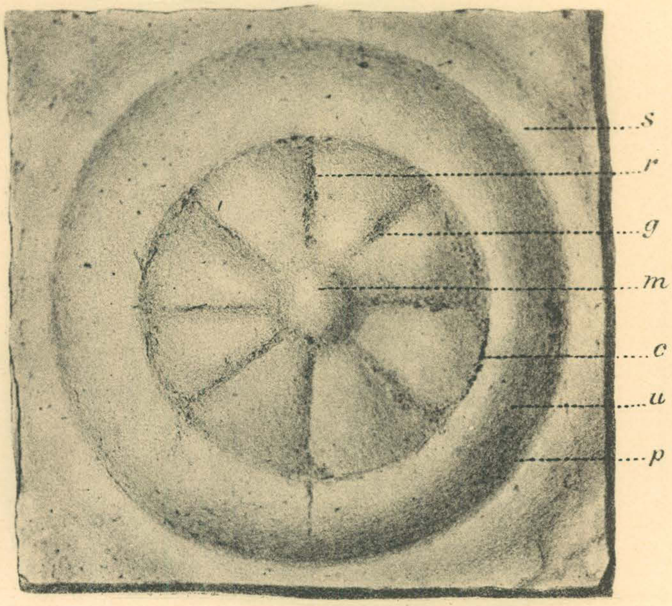
ACRASPEDITES ANTIQUUS (p. 75).

FIG. 2. A limestone slab from the lithographic slates of Eichstädt, with an impression of *Acraspedites antiquus*. The diameter of the figure is in relation to the original as 5 to 7. (After Haeckel.)

c. Marginal canal (ring canal in the umbrella rim).
g. Lobe-shaped elevation, rising from the mid-field, between each two radial canals (genitalia?).
h. Periphery of the genital mounds.
i. Indentation of the umbrella edge, corresponding to the anastomosis of each radial canal into the marginal canal.
m. Mid-field of the medusa impression, corresponding to the stomach and mouth.
p. Periphery of the gelatinous mantle (margin of the impression).
r. Radial canal.
s. Shallow circular furrow in the slab surrounding the impression of the periphery of the mantle.

MEDUSINA PORPITINA (p. 95).

FIG. 3. (After Haeckel.) See description in text.



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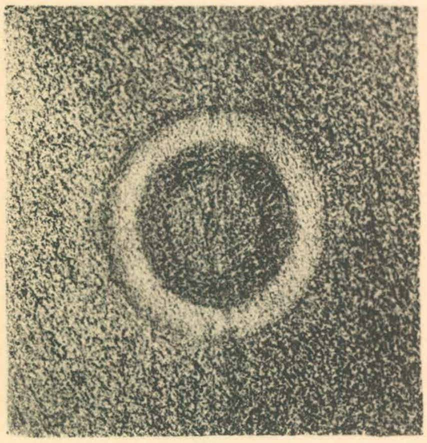

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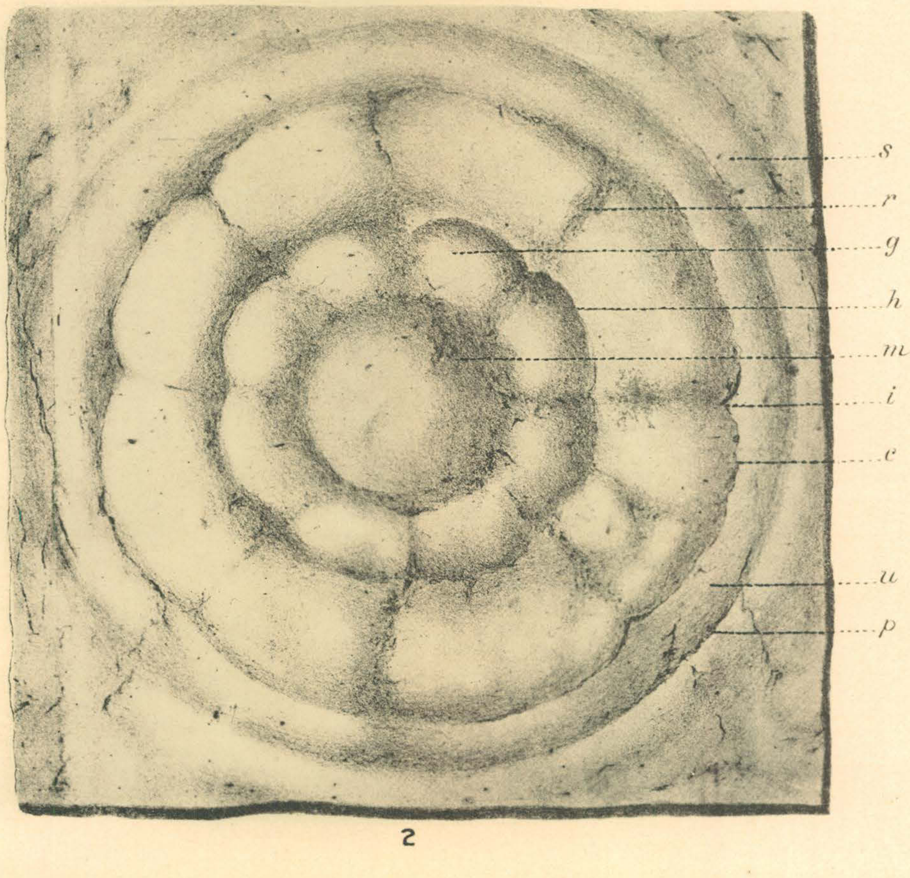

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MEDUSINA
ACRASPEDITES.

PLATE XLV.

PLATE XLV.

MEDUSINA QUADRATA (p. 93).

FIG. 1. (After Haeckel).

m. Mouth area.
r. Radial pouch?
i. Interradial area.
c. Ring canal.
u. Gelatinous disk.

MEDUSINA BICINCTA (p. 94).

FIG. 2. (After Haeckel).

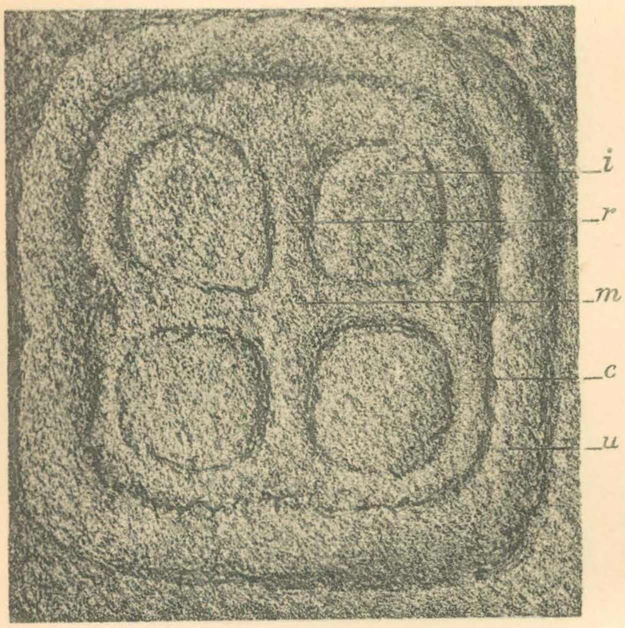
m. Oral field.
r. Radial pouch?
i. Interradial area.
c. Ring canal?
u. Gelatinous disk.

EULITHOTA FASCICULATA (p. 73).

FIG. 3. (After a photograph, Haeckel.) The 16 marginal lobes (*l*) of the umbrella are thrown inward. The 8 incisions of the disk rim in which the eyes (*o*) reside, and from which the fascicles of tentacles arise (*t*), are distinctly prominent on the periphery. The form of the mouth (*m*) and the 4 oral arms (*b*) which surround it, is not clearly discernible. On the other hand, the dextral half of the radial canal (*r*) and the crescentic sexual gland (*g*) are very sharply defined.

FIG. 4. Restoration of this species by Haeckel, after the impression represented by photograph in fig. 3. The 16 lobes of the umbrella margin, which in the impression are withdrawn inward, are here spread out.

m. Mouth.
b. Oral arm.
g. Genital gland.
r. Radial canal.
l. Marginal lobe.
o. Eye.
t. Tentacle fascicle.



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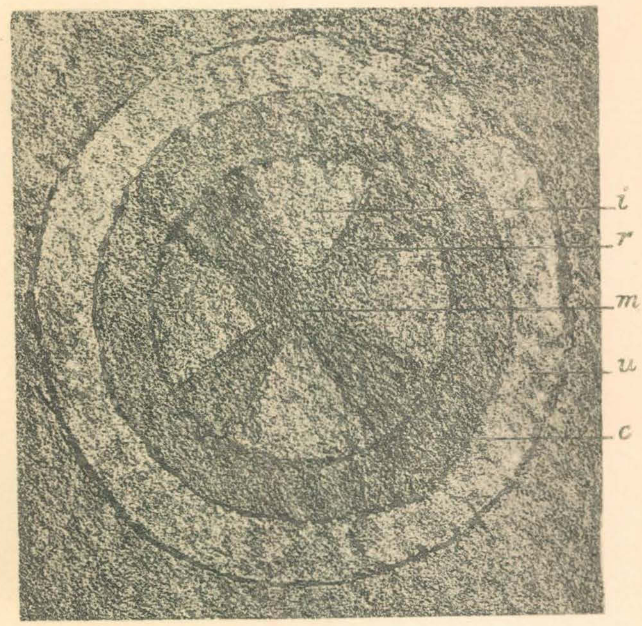

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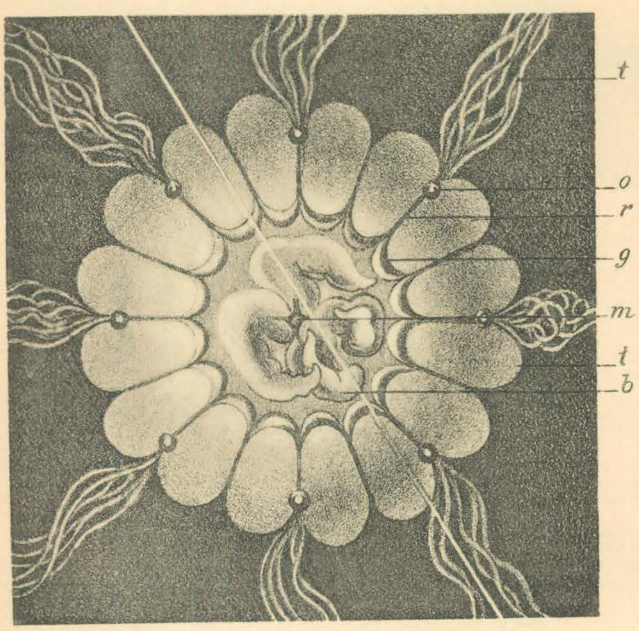

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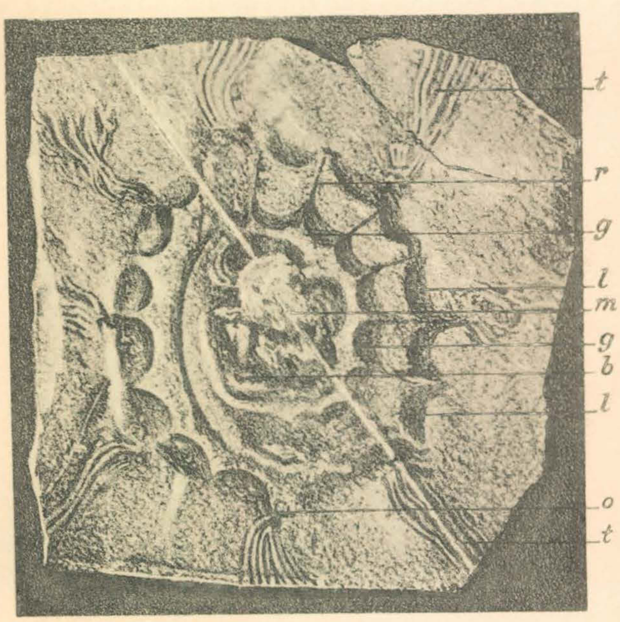

3

MEDUSINA.
EULITHOTA.

PLATE XLVI.

PLATE XLVI.

MEDUSICHNITES (p. 100).

FIG. 1. Photograph, natural size, of a specimen from the Animikie group, Lake Superior. This is the type specimen figured by Matthew, Pl. XII, fig. 3, Trans. Royal Soc. Canada, Vol. VIII, 1891.

FIG. 2. Photograph of specimen, natural size, from the St. John group. This is the type specimen figured by Matthew, Pl. XII, fig. 1, Trans. Royal. Soc. Canada, Vol. VIII, 1891.

FIG. 3. Photograph of specimen, natural size, from the St. John group. This is the type specimen figured by Matthew, Pl. XII, fig. 2, Trans. Royal Soc. Canada, Vol. VIII, 1891.

1

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3

MEDUSICHNITES.

PLATE XLVII.

PLATE XLVII.

DISCOPHYLLUM PELTATUM (p. 101).

FIG. 1. Reproduction of a photograph of the type specimen illustrated by Professor Hall.

FIG. 2. Reproduction of a photograph of the second specimen mentioned by Professor Hall, which shows the concentric striæ much more clearly than does fig. 1. The faintly outlined ring near the center is not shown in the figure.

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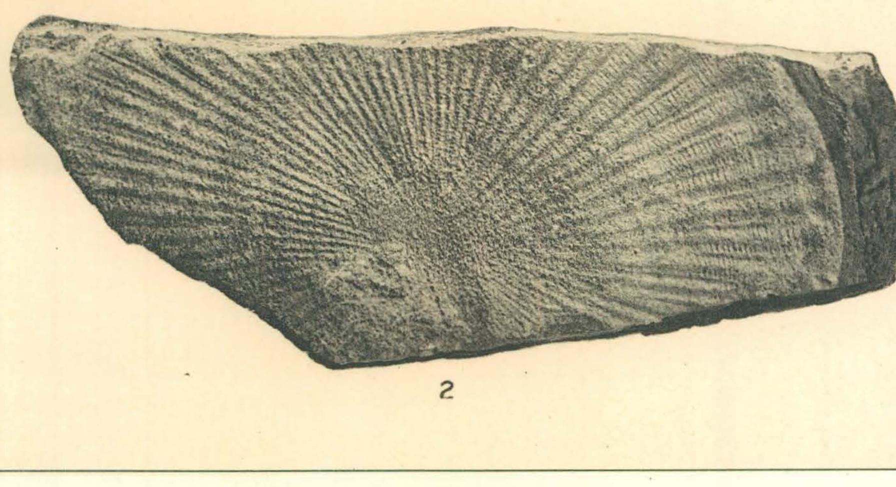

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DISCOPHYLLUM.

INDEX.

○

ADVERTISEMENT.

[Monograph XXX.]

The statute approved March 3, 1879, establishing the United States Geological Survey, contains the following provisions:

"The publications of the Geological Survey shall consist of the annual report of operations, geological and economic maps illustrating the resources and classification of the lands, and reports upon general and economic geology and paleontology. The annual report of operations of the Geological Survey shall accompany the annual report of the Secretary of the Interior. All special memoirs and reports of said Survey shall be issued in uniform quarto series if deemed necessary by the Director, but otherwise in ordinary octavos. Three thousand copies of each shall be published for scientific exchanges and for sale at the price of publication; and all literary and cartographic materials received in exchange shall be the property of the United States and form a part of the library of the organization: And the money resulting from the sale of such publications shall be covered into the Treasury of the United States."

Except in those cases in which an extra number of any special memoir or report has been supplied to the Survey by special resolution of Congress or has been ordered by the Secretary of the Interior, this office has no copies for gratuitous distribution.

ANNUAL REPORTS.

I. First Annual Report of the United States Geological Survey, by Clarence King. 1880. 8°. 79 pp. 1 map.—A preliminary report describing plan of organization and publications.

II. Second Annual Report of the United States Geological Survey, 1880-'81, by J. W. Powell. 1882. 8°. lv, 588 pp. 62 pl. 1 map.

III. Third Annual Report of the United States Geological Survey, 1881-'82, by J. W. Powell. 1883. 8°. xviii, 564 pp. 67 pl. and maps.

IV. Fourth Annual Report of the United States Geological Survey, 1882-'83, by J. W. Powell. 1884. 8°. xxxii, 473 pp. 85 pl. and maps.

V. Fifth Annual Report of the United States Geological Survey, 1883-'84, by J. W. Powell. 1885. 8°. xxxvi, 469 pp. 58 pl. and maps.

VI. Sixth Annual Report of the United States Geological Survey, 1884-'85, by J. W. Powell. 1885. 8°. xxix, 570 pp. 65 pl. and maps.

VII. Seventh Annual Report of the United States Geological Survey, 1885-'86, by J. W. Powell. 1888. 8°. xx, 656 pp. 71 pl. and maps.

VIII. Eighth Annual Report of the United States Geological Survey, 1886-'87, by J. W. Powell. 1889. 8°. 2 pt. xix, 474, xii pp. 53 pl. and maps; 1 p. l. 475-1063 pp. 54-76 pl. and maps.

IX. Ninth Annual Report of the United States Geological Survey, 1887-'88, by J. W. Powell. 1889. 8°. xiii, 717 pp. 88 pl. and maps.

X. Tenth Annual Report of the United States Geological Survey, 1888-'89, by J. W. Powell. 1890. 8°. 2 pt. xv, 774 pp. 98 pl. and maps; viii, 123 pp.

XI. Eleventh Annual Report of the United States Geological Survey, 1889-'90, by J. W. Powell. 1891. 8°. 2 pt. xv, 757 pp. 66 pl. and maps; ix, 351 pp. 30 pl. and maps.

XII. Twelfth Annual Report of the United States Geological Survey, 1890-'91, by J. W. Powell. 1891. 8°. 2 pt. xiii, 675 pp. 53 pl. and maps; xviii, 576 pp. 146 pl. and maps.

XIII. Thirteenth Annual Report of the United States Geological Survey, 1891-'92, by J. W. Powell. 1893. 8°. 3 pt. vii, 240 pp. 2 maps; x, 372 pp. 105 pl. and maps; xi, 486 pp. 77 pl. and maps.

XIV. Fourteenth Annual Report of the United States Geological Survey, 1892-'93, by J. W. Powell. 1893. 8°. 2 pt. vi, 321 pp. 1 pl.; xx, 597 pp. 74 pl. and maps.

XV. Fifteenth Annual Report of the United States Geological Survey, 1893-'94, by J. W. Powell. 1895. 8°. xiv, 755 pp. 48 pl. and maps.

XVI. Sixteenth Annual Report of the United States Geological Survey, 1894-'95, Charles D. Walcott, director. 1895. (Part I, 1886.) 8°. 4 pt. xxii, 910 pp. 117 pl. and maps; xix, 598 pp. 43 pl. and maps; xv, 646 pp. 23 pl.; xix, 735 pp. 6 pl.

XVII. Seventeenth Annual Report of the United States Geological Survey, 1895-'96, Charles D. Walcott, director. 1896. 8°. 3 pts. in 4 vols. xxii, 1076 pp. 67 pl. and maps; xxv, 864 pp. 113 pl. and maps; xxiii, 542 pp. 8 pl. and maps; iii, 543-1058 pp. pls. 9-13.

XVIII. Eighteenth Annual Report of the United States Geological Survey, 1896-'97, Charles D. Walcott, director. 1897. (Parts II and III, 1898.) 5 pts. in 6 vols. 1-440. 4 pl. and maps; (pts. 2 and 3 not yet published;) i-x, 1-756. 102 pl. and maps; i-xii, 1-1400. 1 pl.

MONOGRAPHS.

I. Lake Bonneville, by Grove Karl Gilbert. 1890. 4°. xx, 438 pp. 51 pl. 1 map. Price $1.50.

II. Tertiary History of the Grand Cañon District, with Atlas, by Clarence E. Dutton, Capt., U. S. A. 1882. 4°. xiv, 264 pp. 42 pl. and atlas of 24 sheets folio. Price $10.00.

III. Geology of the Comstock Lode and the Washoe District, with Atlas, by George F. Becker. 1882. 4°. xv, 422 pp. 7 pl. and atlas of 21 sheets folio. Price $11.00.

IV. Comstock Mining and Miners, by Eliot Lord. 1883. 4°. xiv, 451 pp. 3 pl. Price $1.50.

V. The Copper-Bearing Rocks of Lake Superior, by Roland Duer Irving. 1883. 4°. xvi, 464 pp. 15 l. 29 pl. and maps. Price $1.85.

VI. Contributions to the Knowledge of the Older Mesozoic Flora of Virginia, by William Morris Fontaine. 1883. 4°. xi, 144 pp. 54 l. 54 pl. Price $1.05.

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14. New Tests of Certain Pumps and Water-lifts used in Irrigation, by Ozni P. Hood.
15. Operations at River Stations, 1897, Part I.
16. Operations at River Stations, 1897, Part II.

— Water Resources of the Devils Lake region, North Dakota, by Earle J. Babcock.
— Irrigation in the upper portion of San Joaquin Valley, by C. E. Grunsky.
— Irrigation in San Bernardino Valley, by J. B. Lippincott.
— Well Waters of Nebraska, by Edwin H. Barbour.
— Sewage Irrigation in the United States, by Geo. W. Rafter.
— Wells of Indiana, by Frank Leverett.
— Ground Waters and Irrigation, by F. H. King.
— Deep Wells of Ohio, by Edward Orton.
— Water Powers of New England, by Dwight Porter.
— Water Power of New York, by Geo. W. Rafter.
— Average Discharge of Rivers, by F. H. Newell.
— Overflow of Arkansas Valley, by Willard D. Johnson.

TOPOGRAPHIC MAP OF THE UNITED STATES.

When, in 1882, the Geological Survey was directed by law to make a geologic map of the United States there was in existence no suitable topographic map to serve as a base for the geologic map. The preparation of such a topographic map was therefore immediately begun. About one-fifth of the area of the country, excluding Alaska, has now been thus mapped. The map is published in atlas sheets, each sheet representing a small quadrangular district, as explained under the following heading. The separate sheets are sold at 5 cents each when fewer than 100 copies are purchased, but when they are ordered in lots of 100 or more copies, whether of the same sheet or of different sheets, the price is 2 cents each. The mapped areas are widely scattered, nearly every State being represented. More than 800 sheets have been engraved and printed; they are tabulated by States in the Survey's "List of Publications," a pamphlet which may be had on application.

GEOLOGIC ATLAS OF THE UNITED STATES.

The Geologic Atlas of the United States is the final form of publication of the topographic and geologic maps. The atlas is issued in parts, progressively as the surveys are extended, and is designed ultimately to cover the entire country.

Under the plan adopted the entire area of the country is divided into small rectangular districts, bounded by certain meridians and parallels. The unit of survey is also the unit of publication, and the maps and descriptions of each rectangular district are issued as a folio of the Geologic Atlas.

Each folio contains topographic, geologic, economic, and structural maps, together with textual descriptions and explanations, and is designated by the name of a principal town or of a prominent natural feature within the district.

Two forms of issue have been adopted: A *library* edition, bound between heavy paper covers and stitched; and a *field* edition, similarly bound, but unstitched.

Under the law a copy of each folio is sent to certain public libraries and educational institutions. The remainder are sold at 25 cents each, except such as contain an unusual amount of matter, which are priced accordingly. Prepayment is obligatory. The folios ready for distribution are listed below.

No.	Name of sheet.	State.	Limiting meridians.	Limiting parallels.	Area, in square miles.	Price, in cents.
1	Livingston	Montana	110°–111°	45°–46°	3, 354	25
2	Ringgold	Georgia Tennessee	85°–85° 30′	34° 30′–35°	980	25
3	Placerville	California	120° 30′–121°	38° 30′–39°	932	25
4	Kingston	Tennessee	84° 30′–85°	35° 30′–36°	969	25
5	Sacramento	California	121°–121° 30′	38° 30′–39°	932	25
6	Chattanooga	Tennessee	85°–85° 30′	35°–35° 30′	975	25
7	Pikes Peak (out of stock)	Colorado	105°–105° 30′	38° 30′–39°	932	25
8	Sewanee	Tennessee	85° 30′–86°	35°–35° 30′	975	25
9	Anthracite-Crested Butte	Colorado	106° 45′–107° 15′	38° 45′–39°	465	50
10	Harpers Ferry	Virginia West Virginia Maryland	77° 30′–78°	39°–39° 30′	925	25
11	Jackson	California	120° 30′–121°	38°–38° 30′	938	25
12	Estillville	Virginia Kentucky Tennessee	82° 30′–83°	36° 30′–37°	957	25
13	Fredericksburg	Maryland Virginia	77°–77° 30′	38°–38° 30′	938	25
14	Staunton	Virginia West Virginia	79°–79° 30′	38°–38° 30′	938	25
15	Lassen Peak	California	121°–122°	40°–41°	3, 634	25
16	Knoxville	Tennessee North Carolina	83° 30′–84°	35° 30′–36°	925	25
17	Marysville	California	121° 30′–122°	39°–39° 30′	925	25
18	Smartsville	California	121°–121° 30′	39°–39° 30′	925	25
19	Stevenson	Alabama Georgia Tennessee	85° 30′–86°	34° 30′–35°	980	25
20	Cleveland	Tennessee	84° 30′–85°	35°–35° 30′	975	25
21	Pikeville	Tennessee	85°–85° 30′	35° 30′–36°	969	25
22	McMinnville	Tennessee	85° 30′–86°	35° 30′–36°	969	25
23	Nomini	Maryland Virginia	76° 30′–77°	38°–38° 30′	938	25
24	Three Forks	Montana	111°–112°	45°–46°	3, 354	50
25	Loudon	Tennessee	84°–81° 30′	35° 30′–36°	969	25
26	Pocahontas	Virginia West Virginia	81°–81° 30′	37°–37° 30′	951	25
27	Morristown	Tennessee	83°–83° 30′	36°–36° 30′	963	25
28	Piedmont	Virginia Maryland West Virginia	79°–79° 30′	39°–39° 30′	925	25
29	Nevada City: Nevada City. Grass Valley. Banner Hill	California	121° 00′ 25″–121° 03′ 45″ 121° 01′ 35″–121° 05′ 04″ 120° 57′ 05″–121° 00′ 25″	39° 13′ 50″–39° 17′ 16″ 39° 10′ 22″–39° 13′ 50″ 39° 13′ 50″–39° 17′ 16″	11. 65 12. 09 11. 65	50
30	Yellowstone National Park: Gallatin Canyon Shoshone Lake	Wyoming	110°–111°	44°–45°	3, 412	75
31	Pyramid Peak	California	120°–120° 30′	38° 30′–39′	932	25
32	Franklin	Virginia West Virginia	79°–79° 30′	38° 30′–39°	932	25
33	Briceville	Tennessee	84°–84° 30′	36°–36° 30′	963	25
34	Buckhannon	West Virginia	80°–80° 30′	38° 30′–39°	932	25
35	Gadsden	Alabama	86°–86° 30′	34°–34° 30′	986	25
36	Pueblo	Colorado	104° 30′–105°	38°–38° 30′	938	50

STATISTICAL PAPERS.

Mineral Resources of the United States [1882], by Albert Williams, jr. 1883. 8°. xvii, 813 pp. Price 50 cents.

Mineral Resources of the United States, 1883 and 1884, by Albert Williams, jr. 1885. 8°. xiv, 1016 pp. Price 60 cents.

Mineral Resources of the United States, 1885. Division of Mining Statistics and Technology. 1886. 8°. vii, 576 pp. Price 40 cents.

Mineral Resources of the United States, 1886, by David T. Day. 1887. 8°. viii, 813 pp. Price 50 cents.

Mineral Resources of the United States, 1887, by David T. Day. 1888. 8°. vii, 832 pp. Price 50 cents.

Mineral Resources of the United States, 1888, by David T. Day. 1890. 8°. vii, 652 pp. Price 50 cents.

Mineral Resources of the United States, 1889 and 1890, by David T. Day. 1892. 8°. viii, 671 pp. Price 50 cents.

Mineral Resources of the United States, 1891, by David T. Day. 1893. 8°. vii, 630 pp. Price 50 cents.

Mineral Resources of the United States, 1892, by David T. Day. 1893. 8°. vii, 850 pp. Price 50 cents.

Mineral Resources of the United States, 1893, by David T. Day. 1894. 8°. viii, 810 pp. Price 50 cents.

On March 2, 1895, the following provision was included in an act of Congress:

"*Provided*, That hereafter the report of the mineral resources of the United States shall be issued as a part of the report of the Director of the Geological Survey."

In compliance with this legislation, the report Mineral Resources of the United States for the Calendar Year 1894 forms Parts III and IV of the Sixteenth Annual Report of the Survey; Mineral Resources of the United States for the Calendar Year 1895 forms Part III of the Seventeenth Annual Report of the Survey; and Mineral Resources of the United States for the Calendar Year 1896 forms Part V of the Eighteenth Annual Report of the Survey.

The money received from the sale of these publications is deposited in the Treasury, and the Secretary of that Department declines to receive bank checks, drafts, or postage stamps; all remittances, therefore, must be by MONEY ORDER, made payable to the Director of the United States Geological Survey, or in CURRENCY for the exact amount. Correspondence relating to the publications of the Survey should be addressed to

THE DIRECTOR,
UNITED STATES GEOLOGICAL SURVEY,
WASHINGTON, D. C.

WASHINGTON, D. C., *January, 1898.*

LIBRARY CATALOGUE SLIPS.

Series.

United States. *Department of the interior.* (*U. S. geological survey.*)

Department of the interior | — | Monographs | of the | United States geological survey | Volume XXX | [Seal of the department] | Washington | government printing office | 1898

Second title: United States geological survey | Charles D. Walcott, director | — | Fossil medusæ | by | Charles Doolittle Walcott | [Vignette] |

Washington | government printing office | 1898

4°. ix, 201 pp. 47 pl.

Author.

Walcott (Charles Doolittle).

United States geological survey | Charles D. Walcott, director | — | Fossil medusæ | by | Charles Doolittle Walcott | [Vignette] |

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4°. ix, 201 pp. 47 pl.

[UNITED STATES. *Department of the interior.* (*U. S. geological survey.*) Monograph XXX.]

Subject.

United States geological survey | Charles D. Walcott, director | — | Fossil medusæ | by | Charles Doolittle Walcott | [Vignette] |

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