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New York State Museum Bulletin

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No. 189

ALBANY, N. Y.

SEPTEMBER 1, 1916

The University of the State of New York

New York State Museum

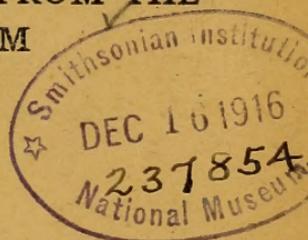
JOHN M. CLARKE, Director

PALEONTOLOGIC CONTRIBUTIONS FROM THE NEW YORK STATE MUSEUM

BY

RUDOLF RUEDEMANN

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ALBANY

THE UNIVERSITY OF THE STATE OF NEW YORK

1916

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The University of the State of New York
Department of Science, February 18, 1916

Dr John H. Finley
President of the University

SIR:

I beg to transmit to you herewith and to recommend for publication as a bulletin of the State Museum, the accompanying manuscript entitled "*Paleontologic Contributions from the New York State Museum,*" with necessary plates of illustrations. This treatise has been prepared by Dr Rudolf Ruedemann, assistant state paleontologist.

Very respectfully
JOHN M. CLARKE
Director

THE UNIVERSITY OF THE STATE OF NEW YORK
OFFICE OF THE PRESIDENT

Approved for publication this 19th day of February 1916

A handwritten signature in dark ink, appearing to read "John H. Finley". The signature is written in a cursive style with a prominent flourish at the end.

President of the University

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JOHN M. CLARKE, Director

PALEONTOLOGIC CONTRIBUTIONS FROM THE NEW YORK STATE MUSEUM

BY

RUDOLF RUEDEMANN

I

ACCOUNT OF SOME NEW OR LITTLE-KNOWN SPECIES OF FOSSILS, MOSTLY FROM PALEOZOIC ROCKS OF NEW YORK

The assembling and arranging of material for exhibition in the new State Museum has brought together a number of specimens which represent species either new to science or to the State, or which exhibit features hitherto not observed. It has been thought an opportune occasion to publish these together, although they are derived from very diverse groups and horizons. The quantity of the new material is so great that we are in this report able to present only a first instalment. For this we have mainly selected material which exhibits structures that more precisely fix the taxonomic position of the species; and further material, as the fossils of the Bertie waterlime other than eurypterids, because of its temporary interest in the discussion of the habitat of the eurypterids. Much new material of Ordovician cephalopods has been left out of consideration because the author intends to describe this in a separate paper.

Dr P. E. Raymond was so kind as to describe for us a new *Ceraurus* from the Chazy rocks which was sent to him at his request. His note is appended to this paper.

Favosites turbinatus Billings*Plate 1, figures 1-7*

The purpose of this note is to describe an exceptionally perfect specimen of this coral from the Onondaga limestone of western New York. The specimen, which is a young colony, is remarkable for several features, the most important of which is the covering of most of the corallum with opercula. The opercula are sub-circular plates which overlap each other like the tiles of a roof from above downward. Their surface is flat or low convex, mostly smooth or showing an obscure concentric structure due to the building up of the opercula of gradually widening layers. The center shows frequently a low knob in mature opercula, while the younger ones possess in its place a depression, or in the smallest ones even a perforation. It appears from this structure that, as Rominger has stated,¹ the young opercula were provided with a central opening which finally was closed by a solid nodular piece. Some opercula show the structure reproduced in figure 6. Here a distinctly concentric annular structure with a central depression is revealed after the last, outer smooth layer has been scaled off. This indicates that the last stage was not only the filling of the depression but also the covering of the operculum with a final smooth layer. Toward the upper younger portion of the corallum the opercula become smaller and on the top they apparently were, for the most part, absent. They are therefore a more or less gerontic feature of the corallites, and at the lower, older portion they overlap so tightly that the corallites may there have been closed definitely. At the base they have coalesced into a solid mass so that the different opercula can hardly be distinguished. They thus effectually sealed that part of the corallum which gradually sank into the mud as the growing corallum grew heavier.

Where the operculum is broken out, a low conical calyxlike depression is seen, which contains from 12 to 16 radial ridges, resembling septa. They are most distinct in the smaller calyces where they reach to the bottom, while in the older corallites they are mostly reduced to the knoblike outer terminations which again in many corallites are continued outward beyond the crest of the calyx into rapidly tapering low ridges sometimes even upon the next operculum below. The undersides of the opercula are furnished with short peripheral ridges and grooves which fit into the

¹C. Rominger. Geological Survey of Michigan, v. 3, pt 1. Geology, pt 2. Paleontology — Corals, p. 26. 1876.

terminal knobs of the calyxes, thus providing a safely hinged covering for the corallites.

Hand in hand with the tightening of the covers in the gerontic stage of the corallites goes the thickening of the walls and the development of tabulae. While, therefore, in sections the lower, older corallites are all filled with calcite, partly primary wall thickening and partly secondary filling of the remaining cavities, the habitation chambers of the upper corallites are filled with brown calcareous mud.

In looking into the shallow calyxlike depressions, in view of the deep chambers of the younger portion of the corallum, one is inclined to consider these only as the casts of the opercula upon the secondary filling of the chambers. This assumption is disproved by the presence of calyxes with small, still perforated, opercula (see fig. 7) in the upper, younger zones of the corallum, and further by the central cavity extending downward from the calyx.

It would thus seem that when the corallum was in the vigorous growing stage the corallites had rather deep open chambers now filled with brown mud; that later these lumina became partly partitioned off by tabulae and partly filled by calcite, leaving only the small, upper space which finally was sealed with the death of the polyp by the closely fitting operculum.

These different conditions of the corallites explain also the fact that in most specimens of *F. turbinatus* the top, which was not covered by opercula, is either weathered away, leaving a depression, as described by Rominger, or is so closely attached to the matrix that it can not be separated from it, as in the specimen here described.

In this connection, we have before us also a specimen of *Ischadites squamifer* Hall which not only exhibits on the side that was protected by the matrix, the surface with the rectangular imbricating plates, such as were figured by Conrad (Annual Report of Geological Survey, 1841) and Hall (Palaeontology of New York, v. 6, pl. 24, figs. 1 and 2, 1887), but also shows on the weathered side the interior structure as reproduced in text figure 1. This agrees very well with that observed by Rauff (Abhandlungen k. bayer. Akademie, II Cl. Bd. 17, 1892, pl. 7, fig. 1) of *Ischadites murchisoni*



Fig. 1 *Ischadites squamifer* Hall. Portion of interior structure. x5-
Devonian (New Scotland beds),
Clarksville, N. Y.

Eichwald. It shows distinctly the impressions of what Rauff terms the proximal arms of the meromes or skeletal elements which are directed toward the apex.

Plumalina plumaria Hall

The State Museum contains a large collection of splendid material of *Plumalina plumaria* Hall from the Ithaca beds at Ithaca. This fossil is with its long pinnate branches not only one of the most striking forms of the Portage fauna, but also one of the most puzzling of that remarkable association, which has afforded to the paleontologist so many peculiar and interesting organisms.

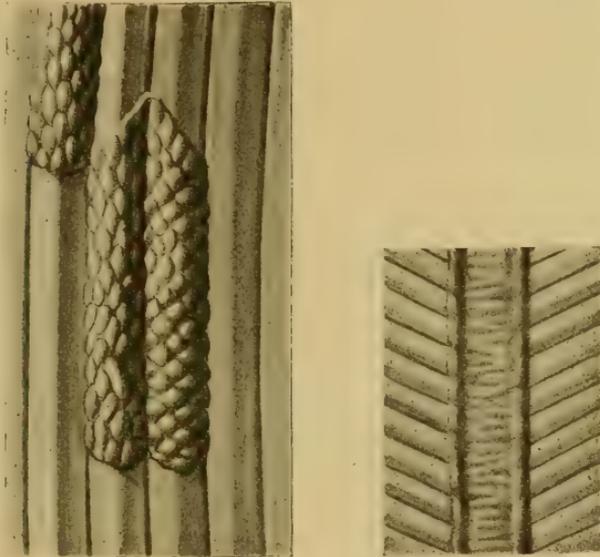
Plumalina plumaria was first described by Hall as a graptolite (Can. Nat. and Geol., 3:175. 1858). Dawson (Quarterly Jour. Geol. Soc., 18:314. 1862) subsequently described this New York fossil as a plant, referring it to *Lycopodites vanuxemi*, and *P. plumaria* is still cited among the plants in Miller's "North American Geology and Palaeontology," 1889, page 134. Hall in his "Graptolites of the Quebec Group" (Figures and Descriptions of Canadian Organic Remains, decade II, 1865), his last and most complete work on graptolites, does not cite *Plumalina* any more, probably in consequence of Sir William's publication. In 1878, however, in the 30th Annual Report of the New York State Museum of Natural History, page 255, plate 4, the same author returned to the investigation of that fossil, giving a plate of excellent figures. He mentions that since the first description of the genotype other forms have come under his observation, until at least six species are known. Of these he says:

In all the species observed, the usual form is that of a simple frond, or hydrocaulus, with narrow, linear pinnulae diverging from each side, essentially in the same plane, and more or less ascending. Rare examples are bifurcating or otherwise branching, and the specimen shown on plate 4, figure 1, is the most remarkable example of this kind observed. Although usually occurring singly, it is evident from the figure given in the Report of the Fourth Geological District, as well as from other specimens known, that they may grow in tufts. No evidence of fertile cells or hydrothecae has been seen, and no distinct serration of the pinnulae can be made out in the specimens examined. From certain appearances upon some specimens, I infer that the pinnulae were cylindrical, and probably tubular, their present appearance being due to extreme compression.

From the general aspect of these fossils, they appear to be

referable to the family Plumularidae, and their forms and mode of growth may be compared with some species of Plumularia and Aglaophenia.

We see from this description that Hall in his last paper on the subject referred his species to the Plumularidae (order Campanulariae of the Hydrozoa). He also considered the graptolites, like most authors of his time, as related to the Sertularidae and Plumularidae. We shall now present evidence indicating that *Plumalina plumaria* is possibly an early representative of the



2

3

Fig. 2, 3 *Plumalina plumaria* Hall. 2 Enlargement (x 10) of surface with portion of outer granular rind preserved. 3 Enlargement x 5) of wrinkled axis

order Alcyonaria (class Anthozoa) and comparable to such Gorgonidae as *Primnoa* with which it also has a striking exterior resemblance. The absence of any distinct thecae or cells forbids placing it with the graptolites or with the sertularians or plumularians. On the other hand, we have found pinnules (see text fig. 2) which distinctly show their composition of an inner solid carbonaceous (horny) axis and an outer granular rind. Likewise the stems exhibit an inner, irregularly wrinkled axis (see text fig. 3) which is surrounded by an exterior rind. Neither the axis nor the rind show any traces of fibrous or other composite structure.

It is therefore to be assumed that we have before us only the central axis of the organism, which was surrounded by the polypiferous fleshy parts. This central axis was, judging from its carbonaceous character, of horny or chitinoid substance. The outer granular rind is preserved only in rare instances. This, on account of the preservation of the fossil in a sandy shale, where every trace of calcite of all shells is leached out; and also the fact that mollusks and brachiopods are preserved only as molds would indicate that the rind probably was originally of a calcareous nature. We have then a central horny axis surrounded by a calcareous, or possibly also chitinous, skeleton which in its turn is enveloped by the polypiferous sarcode. This is the structure found in numerous Alcyonarians, notably the Gorgonidae. This structure, combined with the fact that the habit of *Plumalina* is more similar to that of the Gorgonidae than to that of any other Coelenterata, permits the reference of *Plumalina* to the order Alcyonaria as conclusively as fossil material will allow it; for it is still always to be remembered that we lack the polyps themselves and have not the least indication of their shape; that hence the soft parts might place the fossils in an entirely different taxonomic position and show *Plumalina* to have been an extinct, very aberrant branch of another class or order of the Coelenterata. This alternative view would, however, obviously leave *Plumalina* a greater puzzle than before, and moreover, not serve the purposes of paleontologic taxonomy, which is to indicate the nearest relationship to living organisms as far as it can be elaborated.

The Museum collection contains large slabs with thick structureless stems of this species which show that the stem branched repeatedly and irregularly. Some stems show an irregular transverse wrinkling of the inner axis as if this body had been able to shrink to some extent (see text fig. 3). The pinnulae were apparently not articulated for fragments of them of various lengths are seen attached to the stem, while when articulated they would all have come off at the articulation point. The "pinnules" are mostly squarish in section through pressure and frequently show a groove in the middle on the upper and under sides from partial collapse, indicating that they were not very solid.

Mr David White informed me some years ago that in his opinion *Plumalina plumaria* can not be a plant, while on the other hand, Doctor Van Name, the zoologist of the State Museum, after studying the structure here figured, considered it well comparable to that of the Alcyonarians.

Inocaulis lesquereuxi (Grote and Pitt)*Plate 4, figures 1-4*

There had been on exhibition in the State Museum for many years a fine slab from the Bertie waterlime at Buffalo which bore the label "Hydroid?." This reference was due to the fact that the long, straight bandlike branches of this fossil, which otherwise would be considered as a seaweed, are densely covered with fine tubercles in some places and fine pores in others. For this reason the specimen has also been considered as a seaweed covered with a bryozoan. An occasional closer inspection of the specimen showed that in the basal portion the branches are composed of a twisted mass of long, fine carbonaceous (chitinous?) fibers, that also in the upper portion such patches of fibers are discernible and that the tubercles are the casts of the pores, so that the entire surface of the organism appears covered with pores. Along the edges, however, the terminal straight portions of the tubes or fibers are preserved in many places and are seen to project as a dense corona of processes perpendicular to the surface (see pl. 4, figs. 2 and 4).

This structure suggests that the fossil is a graptolite related to the group represented by *Inocaulis*, *Palaeodictyota* etc. A fossil from the Bertie waterlime of Buffalo, identical in general aspect with our specimen, has been described by Grote and Pitt (Bul. Buffalo Soc. Nat. Sci., 3:88. 1876) and later figured by Pohlman (*op. cit.*, 4:19. 1881) as a seaweed under the name *Buthotrephis lesquereuxi*. Superintendent Howland of the museum of the Buffalo Society was so kind as to send me both Grote and Pitt's and Pohlman's types, as well as two other specimens. All these show the identical porous surface and fibrous structure of the branches in many places. We should therefore have no hesitation in referring this organism to the graptolites if it were not for the fact that its closest relatives, the species of *Buthotrephis* from the Eurypterid beds at Kokomo, have been considered as algae by no less an authority than Mr David White.¹

It is now perfectly legitimate that in the view of the paleobotanist the vegetal features of the fossils should stand out most strongly, while in that of the invertebrate paleontologist those suggestive of a reference to a class of the animal kingdom would be most prominent. While with fossils of such a negative character as *Buthotrephis lesquereuxi* a positive conclusion may

¹ David White. Two new species of algae of the genus *Buthotrephis* from the Upper Silurian of Indiana. Proc. U. S. Nat. Mus., 24: 265. 1902.

not be reached at once, the accumulation of facts will finally clear up their true nature. We can do no better than to refer the reader to the elaborate and thorough discussion of the possible nature of the three species of *Buthotrephis* (*op. cit.*, p. 268-70), stating merely

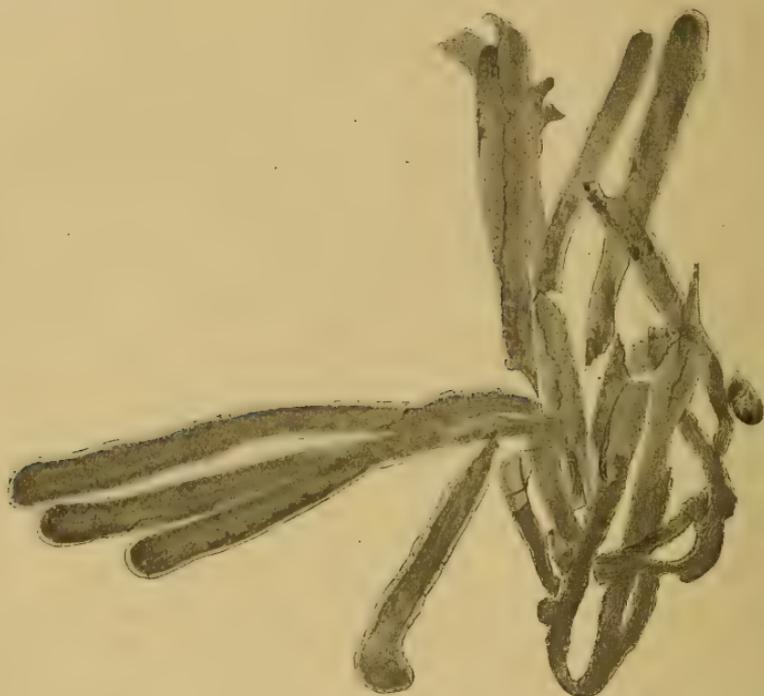


Fig. 4 *Inocaulis lesquereuxi* (Grote & Pitt). Type specimen (No. $\frac{11460}{E975}$ of Museum Buffalo Soc. Nat. Sci.) $\times \frac{1}{2}$

that the author rejects the view held by many paleontologists that the fossils were sponges and arrives at the conclusion that, while the reference of the forms from the Eurypterid beds to the algae can not be conclusively demonstrated, since neither the histology nor the fructification is known, yet he believes them to be such, mainly on account of the following three circumstances which point toward a place for these types among the marine algae: (*a*) the marine habitat; (*b*) the typically algaloid form of development and growth; and (*c*) the aspect of the residue. It is specially pointed out that the *Codium* group of the Siphonous Chlorophyceae (green algae) contains types, which would seem calculated, under favorable circumstances of fossilization, to present characters of form, aspect, and carbonaceous texture similar to and perhaps essentially the same as those of *Buthotrephis*. While this author considers a reference of the three species of *Buthotrephis* to the sponges as

unwarranted, in the absence of distinctive sponge characters, he, on the other hand, suggests (p. 270) that certain of the organisms generally though doubtfully ranged with the graptolites might be more at home among the algae, pointing to the similarity in the texture of the Kokomo forms with some of the species of *Inocaulis*.

It is possible to approach the same fossils from the study of graptolites and arrive, as the present writer has actually done, at the belief that they are graptolites of the group of *Inocaulis* which Mr White would be inclined to take over into the algae. The points which in this view are considered as of greatest importance are that while these bodies indeed are in general habitus extremely similar to algae, they are connected by an uninterrupted series of stages with the species of *Inocaulis* and *Acanthograptus* occurring in the Niagaran of Hamilton, Ontario, and elsewhere, that lead again distinctly to *Dictyonema* and other undoubted graptolites. Some of these species, as *Inocaulis vegetabilis*,¹ *I. ramulosus* (*ibid.* p. 50), *diffusus* (*ibid.* p. 53) and *plumulosus* Hall,² are indeed of strongly algal aspect, nevertheless they occur not only associated with undoubted graptolites, but exhibit the same strong carbonaceous residue as the graptolites, and the same filamentous composition. The latter is, as we have pointed out in *I. plumosa*, a true dendroid graptolite structure. Wiman³ has even succeeded in etching a species of *Inocaulis* (*Inocaulis musciformis*) out of limestone, and demonstrating its identity of structure and of the thecal composition with that of *Dictyonema*. It is true a like filamentous structure is found in the very similar green alga *Codium*, but aside from the fact that it is quite doubtful that the unicellular filaments composing that alga would be able to furnish the strong threads or tubes seen in *Inocaulis lesquereuxi*, it is in our view conclusive that the filaments of *I. lesquereuxi* all terminate in pores on the surface of the fossil, and therefore presumably represent actual tubes. We have reproduced in plate 4, figures 1, 2 and 4, these apertural portions of the thecal tubes, that as a rule are perpendicular to the surface of the rhabdosome, and a comparison of this structure with that described of *I. plumosa* by the writer will show their essential identity.

¹ See Ray S. Bassler: "Dendroid Graptolites of the Niagaran Dolomites of Hamilton, Ontario." U. S. Nat. Mus. Bul. 65, pl. 5, fig. 1. 1909.

² See Ruedemann, R. "Graptolites of New York," pt 2, N. Y. State Mus. Mem. 11, pl. 7, figs. 1 and 2. 1908.

³ Wiman, Carl. Über die Borkholmer Schicht im Mittelbaltischen Silurgebiet. Bul. of the Geol. Inst. of Upsala, no. 10. v. 5, pt 2. 1900.

The three species of *Buthotrephis* from the *Eurypterus* beds appear to us as the final stage of the development which the sessile graptolites of the order *Dendroidea* were taking in the Clinton-Niagara stages and which is most distinctly expressed in the genera *Palaeodictyota* of our Clinton and the strange graptolite fauna from the Niagaran dolomites at Hamilton, Ontario. In that fauna there have been described by Gurley and Bassler species of as strangely algal aspect as our *Buthotrephis* unhesitatingly as graptolites because of their association and of the fact that wherever the stipes were sufficiently well preserved they exhibited a distinct graptolite structure. The marine conditions under which these dolomites were deposited and these graptolites existed were to all appearances similar, though not nearly so pronounced as those under which the eurypterids flourished, and it is a fair conclusion that the three species of *Buthotrephis* represent the extreme adaptation to these lagoon conditions. This finds its strongest expression in the broad expansion (in the compressed condition, see below) of the stipes and the resulting algal aspect.

While we thus fully recognize the distinct algal habitus of *Inocaulis lesquereuxi* and consider it still possible that it may prove an alga, we see, on the other hand, in the absence of any observed fructifications, its composition of fine tubes emptying on the surface, and its connection with true graptolites by preceding gradational stages fair evidence for its graptolite nature.

Inocaulis lesquereuxi consists of numerous long, cylindrical erect rhabdosomes or polyparies (about 20 cm long and 7 to 10 mm wide), which originate to the number of about 8 to 10 from a common base, are sparingly dichotomous (mostly undivided, bifurcating once, or twice at the most), gradually widening toward the apex, which is well rounded, somewhat club-shaped; polyparies straight or slightly undulating, consisting of ropelike, twisted, thin tubes which open perpendicularly to the general surface in circular pores that are densely crowded (about five in 1 mm linear) and separated by intervals not larger than their own diameters. The width of the tubes is but one-twentieth mm.

Remarks. The rhabdosomes of this graptolite are so completely flattened that they at first glance suggest a ribbonlike shape. The absence of twisted rhabdosomes, however, as well as the indication of a bursting of the cylinders along the edges and the crowding of the pores near the edges in other branches, indicate that the rhabdosomes were cylindrical in shape, as the twisted mass of tubules opening on the entire surface would require.

We reproduce here the type of Grote & Pitt, our specimen which shows the base, and a third specimen from the Buffalo Museum which shows the occasional undulating character of the branches. The specimen figured by Pohlman is very imperfect and consists only of a few dichotomous basal portions. Pohlman's figure (Bul. Buffalo Soc. Nat. Sci., 4:19, text fig. 6. 1881) is misleading since it represents the acute broken upper edges of the rhabdosomes as natural terminations.

Inocaulis kirki nov.

Description. Rhabdosome small (length of type specimen, 19 mm), bushlike, consisting of numerous rigid, rapidly bifurcating branches; the angle of bifurcation acute so that the branches appear densely bushy. Width of branches, .4 to .8 mm; bifurcations about 3 mm apart. Surface of branches smooth or longitudinally striated, pores very minute.

Horizon and locality. Trenton limestone, Balsam lake, Victoria county, Ontario.

Remarks. This type and other graptolite material from the Trenton limestone of northern Ontario was presented to the Museum by Dr Edwin Kirk of Washington, D. C. This other material consists of bundles



Fig. 5, 6 *Inocaulis kirki* nov. 5 Basal portion of specimen, natural size. Holotype. 6 Enlargement (x 18) of distal part of rhabdosome

of long bandlike striated branches of the exact width and aspect of those of the type of *Inocaulis kirki*, with the difference, however, that they lack dichotomies (see text figure 6). The facts, however, that between these long bands are seen fragments of the branching type and that the branches of the type specimen are clearly broken at their ends, indicate that the type is only the basal part of a graptolite rhabdosome where rapid branching took place and that more distally the branches became long, undivided and more or less fluctuous. In the habit of the rhabdosomes, the species is then comparable to *Dendrograptus fluitans* Rued. and *Strophograptus trichomanes* Rued., two Deep Kill graptolites.

Airograptus (Dictyonema) furciferus Ruedemann

Prof. E. S. Moore of State College, Pa., in 1913 sent some material of a new graptolite that he had found in the Beekmantown rocks of Spring Creek, near Bellefonte, Center county, Pa. The

writer identified the material at the time with *Dictyonema furciferum*, a species described by him¹ from the lowest beds of the Deep Kill section. Later Prof. Thomas C. Brown sent a slab with still better specimens from the same locality, but labeled as *Callograptus grabau* Hahn.

As *D. furciferum*, occurring at the Deep kill in the upper Tetragraptus and lower Didymograptus bifidus zone, is well suited for a correlation of the bed holding this single graptolite in the important and well-known Bellefonte section with the graptolite horizons at the Deep kill, the writer has taken special pains to compare the material and descriptions of *D. furciferum* and *Callograptus grabau*. The very careful description of *C. grabau* by the lamented Dr F. F. Hahn² leaves no doubt that the *C. grabau* is a synonym of *D. furciferum*, the measurements agreeing completely. The number of thecae in 10 mm shows a discrepancy in so far as 16 of them are recorded for *D. furciferum* and 19 to 21 for the other species. The first figure proves to be an average for mature branches in both the Deep kill and Bellefonte specimens, the higher figure being reached only in the proximal portion or the early nepiastic stage, which, as is apparent from Doctor Hahn's description, was alone available to him. This fact and the further circumstance that the lithographed original drawing of *D. furciferum* is poor, are fully competent to explain the failure to identify the Pennsylvania form with the Deep kill species.

D. furciferum has received its name from the remarkable bifurcate terminations of the apertural processes which grasp the opposite branch (see Ruedemann, *op. cit.*, text fig. 28, at lower end). Doctor Hahn's material did not show this feature, as it is to be observed only with difficulty unless the branches have been torn apart. The specimens received from Bellefonte, however, show this character much better than could be figured from the type of *D. furciferum*. For this reason there are added here two camera-drawings of detached branches which show the various

¹ Graptolites of New York, pt 1, p. 606. 1904.

² Dr Felix F. Hahn. On the Dictyonema-Fauna of Navy Island, N. B. Annals of the N. Y. Academy of Sciences: 22: 142. 1912. Doctor Hahn was killed early in the European War before Nancy. In him geology and paleontology have suffered a grievous loss. The excellent paper here cited, as well as several publications on Jurassic fossils and Alpine tectonics, prove him to have been a keen and philosophic investigator who could not have failed to achieve an eminent position in his chosen field.

aspects of the apertural processes. Frequently the two prongs are pressed one upon the other and many of the processes appear therefore simply club-shaped; others, however, show distinctly the fork, and in others again the fork, in being torn from the branch to which it was attached, seems either to have taken with it a piece of periderm and thus appears peltate (see text fig. 7) or it had actually broadened into an irregular attachment disk. This seems of interest inasmuch as Wiman has described a species of *Dictyonema* with exactly such terminal prongs, as *D. cervicorne*, and another with irregular patches at the ends of the filamentous apertural process as *D. peltatum*. It is possible that our earlier species leads to this whole group of aberrant types, represented by *D. cervicorne*, *peltatum*, *tuberosum* and *cavernosum*.

Hahn in his genealogic chart of the Dendroidea, considers his *Callograptus grabaui* (= *Dictyonema furciferum*) as leading from *D. flabelliforme* var. *ruedemanni* to *Dendrograptus fluitans*. From present evidence it appears that it rather leads from *D. flabelliforme* to the aberrant group mentioned above, which in Hahn's chart is given an isolated position.

Hahn referred his species to *Callograptus*, comparing it with *C. salteri* and *C. compactus*. The reason for this reference appears from his statement that "very seldom one or the other of these apertural processes reaches the neighboring branch, joining it like a dissepiment. While well-preserved material shows that as a fact all apertural processes reach the neighboring branch, whereby a network identical in aspect with that of *Dictyonema* arises, Hahn is nevertheless right in seeing in this form not a typical *Dictyonema*, for there the branches are regularly connected by true dissepiments instead of apertural processes. In *Callograptus*, by Hall's definition, the branches are sometimes distantly and irregularly united by transverse dissepiments. The species here discussed

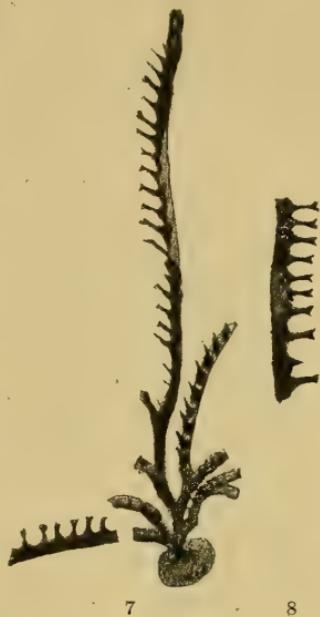


Fig. 7, 8 *Airograptus furciferus* (Ruedemann). 7 Fragmentary rhabdosome with apertural processes (x 4). 8 Fragment of another specimen. (x 4)

shows no traces of true dissepiments and differs from *Callograptus* by its projecting thecal apertures. It is obvious that *Dictyonema furciferum* forms, together with the Swedish species mentioned above, a well-defined group which, in consideration of the generally conceded collective or polyphyletic nature of the genus *Dictyonema* and the resulting necessity of dividing this genus into its components, should be recognized as a separate generic unit. We propose for it the name

Airograptus

(Etym. *αἰρέω* to grasp, *γράφω* to write)

The genus is characterized by flabelliform or shrublike rhabdosomes, projecting thecae of the general type of *Dictyonema*, but whose apertural processes are developed into furcate or peltate terminations that attach themselves to the neighboring branch. True dissepiments are absent or rare. Genotype: *Airograptus furciferus* (Ruedemann). Here also belong *A. tuberosus*, *cervicornis*, *peltatus*, *cavernosus* (Wiman).

The chief interest attaching to this species is that regarding its geologic age, for it has been found on one hand in the long Deep Kill section of graptolite horizons and in the other in the Bellefonte section of Pennsylvania which is the most complete Beekmantown section in the Appalachian region. It should therefore permit the correlation of at least one graptolite horizon with one of the formations of the Bellefonte section. The latter has been described by Ulrich in the Revision of the Paleozoic Systems, page 627. We learn there that the total thickness of the Canadian in this section is 4232 feet, the formations distinguished being, from the base upward: the Stonehenge limestone, the Nittany dolomite, the Axeman limestone and the Bellefonte dolomite. Hahn, on the authority of Victor Ziegler, reports that the graptolites were obtained "2000 feet from the bottom of the limestone series which is referred by Collie to the Beekmantown," which would bring the graptolite horizon near the top of the Nittany or the base of the Axeman. Prof. Thomas C. Brown has kindly informed the writer that the graptolite horizon is located near the top of the Nittany formation. Ulrich states (*op. cit.* p. 660) that "pending further study, it may be said that the Fort Cassin fauna seems to be represented in the Axeman limestone and in the upper part of the Nittany dolomite by *Syntrophia lateralis*, *Raphistoma compressum*, *Trochonema exile*, *Maclurea affinis*, *Bathyrurus caudatus* and *Ribeiria compressa*."

It is therefore for the present a fair conclusion that the horizon bearing the *Dictyonema furciferum* corresponds roughly to the Fort Cassin beds which are in D of the New York Beekmantown section.

The writer had recorded the occurrence of *D. furciferum* from graptolite bed 2 (*Tetragraptus* zone) and bed 3 (lowest of zone with *Didymograptus bifidus*). The type specimen is from the former, where on the same slab the common forms of that zone, together with a type of *Tetragraptus fruticosus* are seen. The specimens from the following zone are very fragmentary and not so safe for a correlation. The inference would thus be proper that the upper part of the *Tetragraptus* horizon and possibly the lower one of the *Didymograptus-bifidus* horizon, may approximately correspond in age to the Fort Cassin beds or the upper part of D (D_4).¹

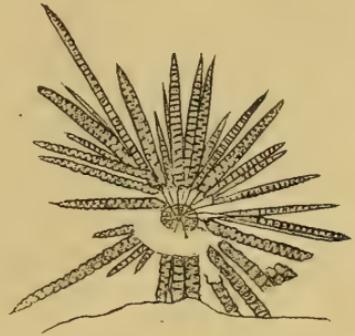


Fig. 9 *Climacograptus parvus* Hall. Synrhabdosome, or entire colonial stock. Natural size

Climacograptus parvus Hall

The writer has before² described entire colonial stocks (synrhabdosomes) of the genera *Diplograptus* (*D. incisus*, *euglyphus* var. *pygmaeus*), *Glossograptus* (*G. quadrimucronatus* and varieties) and *Lasiograptus* (*L. eucharis* and *mucronatus*). It was shown³ that

¹ Since this note was written, the *Bibliographic Index of American Ordovician and Silurian Fossils* by Dr Ray S. Bassler has been published, and in this welcome publication *Dictyonema furciferum* is placed into the base of the Stonehenge at Bellefonte, Pa., as Doctor Bassler writes me, on information furnished by Doctor Ulrich. This would make the horizon with *Tetragraptus* as old as the Tribes Hill limestone or the base of the Beekmantown (part of division B, A, now being correlated with the Little Falls dolomite, which is Ozarkian in age). On the other hand, Doctor Raymond has meanwhile (in *The Succession of Faunas at Levis, P. Q.*, in *Amer. Jour. Science*, v. 38, 1914, p. 529) recorded the same species from the horizon with *Diplograptus dentatus* at Quebec. This identification, if correct, would give the species such a long range as to make it useless for purposes of correlation.

² N. Y. State Mus. Mem. 11, pt 2. 1908.

³ R. Ruedemann. Annual Rep't N. Y. State Geol. 1894, p. 219 f.

each composite member or "stipe" of such a colonial stock grows from a separate sicula and therefore corresponds to the whole colony or rhabdosome of the earlier graptolites, the *Axonolipa*. It was to be surmised that also the other genera of the *Axonophora* form like synrhabdosomes. We are now able to prove this for the important genus *Climacograptus*, Mr Edwin Stein of the New York State Museum having found a synrhabdosome of the common graptolite *C. parvus* of the Normanskill shale at the well-known type locality of that formation, Kenwood on the Normanskill. About forty rhabdosomes of very different age and size radiate from the center of a small disk that is obscured by the confused mass of thin stems of the rhabdosomes. The diameter of the colonial stock is 45 to 50 mm.

**Note on *Paropsonema cryptophya* Clarke, and
Discophyllum peltatum Hall**

Plate 1, figure 8; plate 2

In Bulletin 39 of the New York State Museum, page 172 (1900), Doctor Clarke very fully described a fossil from the Portage beds at Naples which is by all means at once the most striking and the most puzzling of all the peculiar forms that the Portage beds of western New York have afforded. After Mr Luther succeeded in collecting a small series of these large disklike bodies, specimens and drawings were sent to a number of prominent zoologists and paleontologists for suggestions, without, however, bringing forth more than rather vague views that they were not distinctly referable to any recent class of organisms, Prof. E. Haeckel being perhaps the most decided in comparing them to the Medusae. The present writer, though much interested in these striking fossils, was likewise unable to find any clue to their true nature. Doctor Clarke finally inclined to the view that they might be extremely aberrant echinoids, although Doctor Jackson and others declined definitely to corroborate this view. So the species was referred to the echinoids although it was stated that "the characters of this singular fossil are so unusual and so different from structures presented by the fossil and recent Echinodermata that it would be venturesome to make further suggestions as to the probable affinities of the organism."

The material available at the time showed the organism to have consisted of a flat, elliptic disk, one side of which exhibits three concentric cycles of radial bands looking like knotted cords, separated

by smooth smaller bands. These intervening bands bifurcate at the boundaries of the second and third cycles. The radial bands bear a regular succession of horizontal rows of pores, the whole suggesting ambulacral areas. The other side, which was considered the underside, shows only irregularly radial folds and wrinkles.

It is stated in the description that no trace of the substance of plates was found; in fact there is no trace of the original substance of the bodies preserved, only the casts of the exterior surface, which are separated by sandy matrices.

Some years after the publication of the description of the problematicum, an interesting note by Theodor Fuchs: *Ueber Paropsonema cryptophysa¹ und deren Stellung im System*, was printed in the *Centralblatt für Mineralogie*, etc., *Jahrg.* 1905, no. 12, p. 357. The well-known Austrian paleontologist offers the interesting suggestion that Paropsonema may have been the float or pneumatophore of a siphonophore related to Porpita. He writes: "Porpita, which is found floating in all warm seas on the surface and sometimes appears in immense multitudes in the gulf stream, consists generally of a flat gelatinous or chitinous disk, which serves as float, and to the underside of which the various types of polyps are attached, of which the colony consists."

In Agassiz's paper on the Porpitiidae and Velellidae (Mem. Mus. Comp. Zool., v. 8, pt 2, 1883), is given the following brief description of the float of Porpita:

If one views the float of a Porpita from above, one sees a large number of concentric circles, which are crossed by a system of radial lines, which with the concentric circles produce a most regular meshwork. In studying the interior structure of the disk, one finds it to present a great similarity to the structure of an orbitolid foraminifer. One finds a central sphaeroidal chamber, surrounded by eight wedge-shaped chambers. These are surrounded by smaller chambers, arranged strictly geometrically in numerous concentric circles. The chambers, which belong to the same cycle, are completely shut off from the adjoining cycles, but connected with each other, since the lateral partitions are not complete, but only in the form of projecting folds.

All these chambers contain air and are connected with the atmosphere by fine pores that on the surface are arranged in radial rows. Since every pore is situated on a ridgelike prominence of the disk, radial ridges with pores are formed on the surface.

If one views the underside of the disk, one finds a large number of radially arranged, well-shaped folds, which increase in number toward the periphery through fission or intercalation of new folds and which carry the various single polyps.

¹ Misprint for cryptophya.

Comparing this description with that given above of *Paropsonema*, one must concede that the basal plan of structure is in both cases the same, as far as one can judge at present.

Doctor Fuchs adds:

Should my view prove the truth, then herewith, as far as I know, the existence of fossil siphonophores related to *Porpita* has been demonstrated for the first time.

Since these two papers were published, several new specimens have reached the State Museum. Two of these exhibit features not seen in the earlier collections and have an interesting bearing on the probable taxonomic position of *Paropsonema*. The smaller (see pl. I, fig. 8) was obtained by Mr D. D. Luther at the same horizon as the other specimens, but farther west, on West hill near Naples; the larger one, which retains the surface sculpture more perfectly than any other yet collected, was found by one of the students of Professor Chadwick in the Portage beds of Johnson's glen, Canandaigua lake, N. Y., which is several miles to the north of the original locality of the fossil.

The characters worthy of description are the following: While the earlier specimens were flat disks, the two specimens here figured, as well as a third large specimen not figured, present the first cycle as a more or less prominent ring, in the third specimen even as a spherical segment. The central circular area is depressed and in the smallest specimen it is broken out, while the first cycle of radial bands is faintly present and flattened on one side, on the opposite (upper side in the drawing) the outer layer is broken away and below it club-shaped, outwardly widening welts are seen, which are separated by narrow depressions. In the larger specimen also the rays of the second and third cycles appear as broad welts upon the disk, which can be broken off and then display impressions of the concentric lines corresponding to those on the upper side of the rays and interrupted by the smooth bands.

It seems to us that one has to infer from the appearance of the projecting cycles of rays that they may well have been air chambers, that in the flat specimens they were emptied or collapsed before entombment, while in these three they became filled with sediment. In the smaller specimen we probably see an interior cast of the first cycle of chambers, with the original partitions indicated by the flat interspaces and narrow furrows. In the second and third cycles the rays in the larger specimen appear now as separate bodies and from the presence of the concentric lines on their undersides it

appears possible that they were divided into many small air chambers as in *Porpita*, these lines being the chamber walls. These concentric chamber walls would seem to have been lacking in the first cycle from the appearance of the cast of the first cycle in the smaller specimen, yet the same specimen shows on the compressed

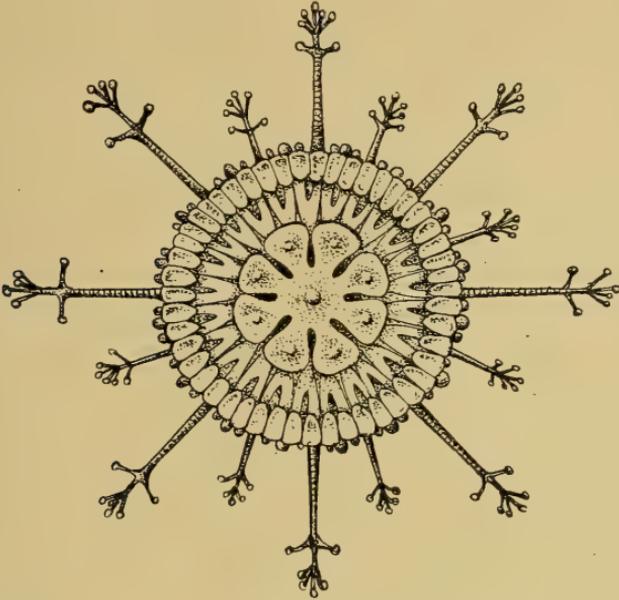


Fig. 10 *Porpita* sp. Young specimen, with the eight primary chambers, ($\times 44$). Recent, coast of Florida. Copy from Alexander Agassiz

lower side (in the figure) the concentric lines also over this region. On the other hand, it is quite apparent from a comparison of the early growth-stages of *Porpita*, figured by Agassiz (*op. cit.*, pl. 9, 1-4; see also text fig. 10) with *Paropsonema cryptophya* that they, with their first cycle of club-shaped chambers and the two to three cycles of successive chambers, each set of which is alternating with the preceding, give a picture entirely alike to that of *Paropsonema*, with the exception of the concentric rows of pores upon the chambers of the latter. The larger specimen shows a distinctly outlined small circle, about 4 mm in diameter in the center, from which fine lines radiate. This may correspond to the central spheroidal chamber of the float of *Porpita*.

A further specimen brought into the Museum since the former publication is rolled up like a withered leaf or the cover of a cigar. Also the smaller specimen, here figured, is partly infolded from the edges, and Doctor Clarke has also figured several specimens in this

condition. It is therefore obvious that these bodies were lacking in stiffness and like the floats of the *Verellas* along our coast, when thrown upon the shore, were liable to roll up, to dry and shrink. I think this proves their former gelatinous nature.

Taken as a whole, the new features shown in these specimens would appear to favor the suggestion advanced by Fuchs, although there are still facts, such as the lack of correlation between the outer concentric lines and the inner chambers in the first cycle of the smaller specimen, that are not readily explained by reference to *Porpita*.

Doctor Clarke has already directed attention to the very noteworthy resemblance between the young specimen of *Paropsonema*, figured by him, and the *Discophyllum peltatum* Hall, a fossil from the "Hudson River" shales (probably Snake Hill shale) at Troy, N. Y., which has been refigured by Walcott in his monograph on the fossil *Medusae*. A comparison of Walcott's second specimen with the specimens of *Paropsonema* here figured, brings out some further striking resemblances, as the presence of narrow radiating ridges between the rays, suggestive of partition walls. These are especially well shown in the second cycle of the larger *Paropsonema*. Likewise, in the second specimen of *Discophyllum* the central half of the disk is slightly but distinctly projecting above the outer half, similarly as in the two specimens of *Paropsonema* here figured. The concentric system of lines in the *Discophyllum* and the young *Paropsonema* here figured are exactly identical, and there seems to us little doubt that the two are closely related organisms belonging to the same class, whatever that may be.

In this connection we wish to describe, merely in order to direct attention to it, a problematicum that possibly is also referable to the *Coelenterata*.

***Plectodiscus molestus* nov.**

Plate 3, figure 1

Diagnosis. Elliptic depressed convex disk, 105 mm wide and 123 mm long and 7 mm high, rising rather abruptly along the margin and flat in the middle portion. From the surface of the disk project low, outwardly directed knots which are arranged somewhat obscurely in three or four cycles, the knots of the successive cycles alternating. The surface of the disk is raised into numerous concentric folds or wrinkles which are finest near the margin and become successively broader and less distinct toward the center.

They pass over the knots and appear drawn together on them. The knots are about 17 to 20 mm apart and about 7 wrinkles are counted in 10 mm.

Horizon and locality. Portage (Ithaca) beds near Ithaca, N. Y., from a quarry one-quarter of a mile southeast of the fairground.

Remarks. The fossil is preserved as an impression only and the figure is taken from a paris-plaster cast, in order to obtain the presumable exterior view. The other side was not obtained. The specimen lies on a bedding plane in a gray sandstone and projects with the surface shown above or below the plane. The margin is not perfect and it is obvious that the disk extended a little farther out. The knots are filled with the gray sandstone matrix, and on breaking this away one finds that there is no test substance but only a colored surface left. In several places the casts of the knots give the impression, by the drawing together of the folds and the presence of an apical spot where the matrix when broken away will furnish no surface, of a contracted aperture or opening of some kind.

While at first glance this specimen might suggest the basal epitheca of a coral, perhaps of a compound tetracoral with rootlets, or of a Favosites, the Ithaca beds, as all Portage beds, are notably free from corals, and moreover the specimen itself leaves no doubt that there was no thick calcareous test that would have been dissolved out. There is little doubt that this was a gelatinous or chitinous body leaving nothing but the colored surface and an interior filling with matrix, very much like the *Paropsonema*. The specimen further has all the appearance of a body shrunken and wrinkled before entombment. It is therefore quite possible that we have before us an organism related to *Paropsonema* and exhibiting its lower surface, especially since the fossil comes from the same formation (Portage) though of another province (Ithaca) than the Naples form, *Paropsonema*; and also the suggestion of Doctor Van Name, the zoologist of the State Museum, that the specimen is the remains of a compound soft coral and the knots are closed and contracted apertures of polyps, has much to commend itself.

***Pleurocystites squamosus* (Billings)**

mut. *matutina* nov.

Plate 5, figures 1-4

The main purpose of this note is to record the occurrence in the rocks of New York of a highly aberrant genus of cystids, hitherto reported in America only from Canada and Kentucky. The speci-

mens were obtained by the writer in the very low horizon of Trenton limestone at Glens Falls which has been termed the Glens Falls limestone and is below the base of the outcropping Trenton at Trenton Falls. The species is there associated with the algae *Callithamnopsis delicatula* and *Corematocladus densa*¹ and other peculiar fossils. Billings² described four species of *Pleurocystites* from the Trenton limestone at Ottawa and one from the lower part of the Trenton limestone at Montreal. Jaekel in his monumental *Stammesgeschichte der Pelmatozoen* has reduced the five species to two and one variety.

While Billings saw the principal differential characters of his species in the sculpturing of the plates and the form of the pectinated rhombs, Jaekel, for phylogenetic reasons, lays the main emphasis on the relative size of the plates of the anal side. By a combination of these criteria he distinguishes the groups of (1) *Pleurocystites filitextus* Billings, with *P. elegans* Billings as a synonym, and the *exornata* Billings as a variety, and (2) *P. squamosus* Billings with *P. robustus* as a synonym and the variety *anticostiensis* Billings (from the Richmond beds of Anticosti).

P. filitextus is defined by this author as having radially striated thecal plates and the upper pectinated rhombs long; rather large anal plates (about seventy) and stem joints with relatively smooth collars.

P. squamosus has the thecal plates almost wholly sculptured by concentric lines; the anal plates small (about five hundred); the pectinated rhombs short and the stem joints longitudinally striated.

Applying these criteria to our form, of which we have seven specimens, we find that it has prevailingly the character of *P. squamosus*, that is, the small anal plates, the longitudinally striated stem joints and the thecal plates, mostly marked by concentric lines. Alongside of these features our type exhibits, however, also in two specimens very well-developed radial striae, and above all the pectinated rhombs are long and narrow throughout. This form would, hence, to some extent, appear to combine the

¹ Ruedemann. Some Marine Algae from the Trenton Limestone of New York. N. Y. State Mus. Bul. 133, p. 194. 1909.

² Billings. On the Cystidae of the Lower Silurian Rocks of Canada. Geol. Surv. of Canada. Fig. & Descr. of Canadian Org. Remains, decade III, p. 46ff. 1858.

features of both groups, with a prevailing leaning toward *P. squamosus*. This, combined with its earlier appearance in the lowest Trenton beds, indicates that it stands nearer the common ancestor than either *P. filitextus* or *P. squamosus*.

It forms a most interesting counterpart of *P. filitextus* mut. *exornata* which has all the features of a *filitextus*, but the pectinated rhombs short. Thus these two earlier mutations bridge, to a considerable extent, the gap between the two Trenton species of *Pleurocystites*.¹

The variety *anticostiensis* is described by Jaekel as alike to *P. squamosus*, excepting the long pectinated rhombs, and would therefore be identical with *matutina*. It is, however, not from the Trenton as assumed by Jaekel, but from the late Ordovician or early Silurian of Anticosti, and judging from Billings's description and figure its pectinated rhombs are short as in *P. squamosus*.² It is therefore probably a later derivative of *P. squamosus*.

Clarkeaster gen. nov.

Professor Schuchert³ has referred a Devonian starfish, described by Clarke and Swartz as *Palaeaster clarki*, to *Mesopalaeaster* with doubt because the disk skeleton was not preserved, and stated that it is very probable that when this feature is known the form will be seen to belong to a new genus. We have before us, besides the species mentioned, another closely related form, *C. perspinosus*, which shows the characters of these species to be such as to require their recognition under a new generic term. Only one abactinal disk is sufficiently well preserved to allow a fair analysis of the plates. This shows a rather large central plate which is surrounded by a ring of ten (eight of which are counted and two indicated by the interspaces) small plates; this in turn is surrounded by one of ten larger plates of fairly equal size with adjoining, very small, accessory plates. Outside of this follows the ring of five

¹Dr Percy E. Raymond, in a letter of October 13, 1915, has kindly informed the writer that *P. squamosus* and *P. filitextus* occur in what he has called the cystid bed of the *Prasopora* zone, that is, in the true Trenton, while the mut. *exornata* comes from the Glens Falls limestone at Montreal, is hence of the same age as *matutina* and both these mutations are distinctly older than the typical *P. filitextus* and *P. squamosus*.

²Billings states that the outline of the rhombs is as in *P. robustus*.

³Schuchert, Charles. Revision of Paleozoic Stelleroidea, with special reference to North America. Smithsonian Institution, Bul. 88, p. 98, 1915.

large plates with long spines and five intercalated smaller plates. In *Mesopalaeaster* there is a first ring of seven pieces and a second of fourteen pieces, outside of which the ring of proximal radials and supramarginals is seen as in *Clarkeaster*. In the rays the main difference rests in the intercalation of the pairs of accessory plates between the radial plates. There are two interbrachial marginals in each interbrachial area, while *Mesopalaeaster* has but one. The actinal side is as in *Mesopalaeaster*.

Genoholotype. *C. perspinosus* nov.

Remarks. Of the two species belonging to *Clarkeaster*, namely, *C. perspinosus* and *C. clarki*, the latter shows the more primitive characters (see under *C. perspinosus*). Both species representing the genus appear as a later development of the *Mesopalaeasterinae* Schuchert. In the extreme development of the spines a gerontic feature of this race may possibly be seen. They certainly surpass in this feature any of our Paleozoic starfishes.

***Clarkeaster perspinosus* nov.**

Plate 5, figures 5 and 6; plate 6, figure 1; plate 7, figures 1 and 2

Description. Rays long, slender, tapering regularly proximally and narrow, whiplike distally. Disk comparatively large. Interbrachial areas distinct.

The abactinal side of the disk is most strikingly marked by a ring of ten plates, five of which, the basal plates of the radial columns, are of very large size and produced into large thick spines that diverge outwardly. Alternating with these are five much smaller plates, the basal plates of the supramarginal columns which apparently bore no spines. The disk plates within this ring are small and not all seen. They contain apparently a ring of ten plates adjoining the large ring and a central disk plate, and between these very small accessory plates. The interbrachial area of the disk is occupied by small accessory plates and two large marginal plates which extend into blunt, thick, oblique spines. The arrangement of the plates on the abactinal side of the rays is very striking. Radial ossicles (which are elongate, subquadrangular or subelliptical) alternate with a pair of subcircular accessory plates each. The supramarginal plates are large, wedge-shaped, adjoining the accessory plates with their narrow ends and leaving deep subtriangular interspaces between them. Outside of the round margins of the supramarginals are the crescent-shaped upper portions of the inframarginals which bear long, slender, articulated spines. Also the first three radials

and supramarginal ossicles are furnished with thick, short inarticulate spines.

Madreporite small, depressed, inside and between two marginal ossicles, marked by indistinctly concentric ridges.

The actinal area shows broad, ambulacral grooves. The ambulacral plates are opposite or but very slightly alternate, subquadrangular, with a high transverse carina. The podial openings are large. The adambulacral plates equal in number the ambulacral plates; are small; rectangular, or pentagonal, where they adjoin the

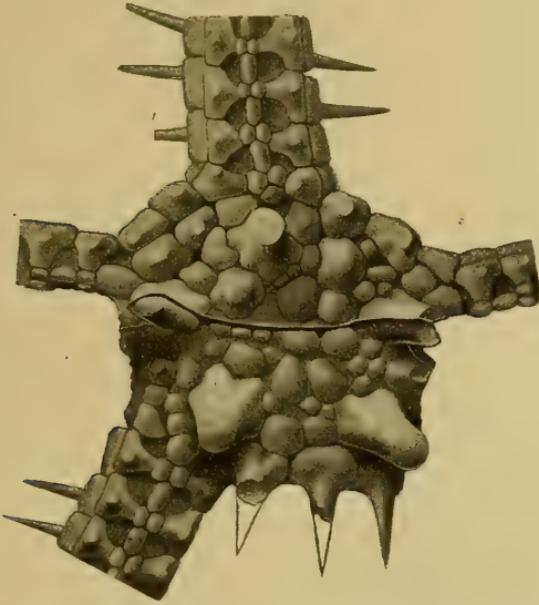


Fig. 11 *Clarkeaster perspinosus* nov.
Abactinal disk area and base of arm of cotype
(figured pl. 7, fig. 1). (x 2½)

suture of two inframarginal plates. The latter form the most conspicuous column, are large, rounded quadrangular to oval in outline, about one of them corresponding to two adambulacral plates. They bear on their outer edge long spines. The ossicles of the oral armature belong to the adambulacral column, are small and obtusely bent so as to form a Y-shaped piece. The interbrachial area is occupied by one large quadratic axillary interbrachial which bears a long central spine. Also the first two inframarginals have large central spines.

Measurements. Length of ray ($R=32$ mm), radius of disk ($r=6$ mm), basal width of ray (outside of disk) ≈ 5 mm.

Horizon and locality. Chemung beds, Avoca, Steuben county, N. Y.

Remarks. We have before us parts of five specimens, two of which show the abactinal side, the others the actinal side. This species is most similar to *Acanthaster clarki* (Clarke & Swartz) from the Jennings formation (Chemung member) of Oakland, Md. The latter species has a much more convex disk, the basal radial and supramarginal plates are of less unequal size and the accessory ambital plates in the interbrachial areas are absent; the radial plates are less elongate and the accessory plates are of very minute size. The supramarginal plates are not so distinctly wedge-shaped but rounded quadrangular, leaving not any or but small depressions between them. The inframarginal plates do not appear as marginal crescent-shaped pieces. All the plates of the rays are much more convex and the rays were narrower and thicker. On the actinal surface the ambulacral grooves are narrower and shallower, the ambulacral plates do not show the pronounced transversal ridges, the inframarginal plates are broader and shorter and no long central spines are seen. As *A. clarki* is only known in one small specimen, it may appear possible that our species represents but the mature types of *A. clarki*. We have, however, two specimens of the size of the type of that species which exhibit the adult characters of *A. perspinosus*, both on the actinal and abactinal sides. As it is, *A. clarki* bears in all its features a more primitive and hence younger character than *A. perspinosus*, although of approximately the same geologic age. *Devonaster chemungensis* Schuchert, from the Chemung of Central Pennsylvania, is a larger form which is known only from the actinal side and bears in its general outline a considerable resemblance to *A. perspinosus*, but is distinguished by the broad form of the supramarginal plates, which, however, distally become like those of our species. The inframarginal plates lack in *Devonaster chemungensis* all indication of the marginal articulated spines so prominent in *A. perspinosus*. The axillary interbrachial and the proximal inframarginal plates bear centrally large spines in *D. chemungensis*; in *A. perspinosus* only the axillary interbrachial and the first two inframarginals show large central spines in the larger specimen, while in the smaller one no such spines or spine bases are noticeable. The difference in the development of the spines in the two species could therefore be considered as one of individual age within the same species. From the evidence available we consider it possible that also *Devonaster chemungensis* belongs in this genus.

Devonaster eucharis (Hall)

Plate 8, figures 1 and 2; plate 9, figures 1-6

This species has been very elaborately described and beautifully figured by Hall in the 20th Report of the New York State Museum. Additional observations have been made by Cole, Schöndorf, Clarke and Schuchert, so that the species appears to be known to the least details of its ossicles. The wonderful find of hundreds of specimens of this hitherto rare species in the Hamilton sandstone at Saugerties, however, still permits us to add a few observations, especially regarding the growth stages.

From the detailed study of our material we have nothing to add to the description of the species, as brought up to date and corrected by Schuchert in his excellent Revision of the Paleozoic Stellerioidea.¹ It is, however, apparent that Hall's description and those of his successors, which are based mostly on the casts of his types, are taken from specimens that are not only larger by one-quarter to one-third than those from Saugerties which all possess a fairly uniform size, but which also exhibit when compared with the latter, certain differential features attributable to greater individual age. We therefore believe that either the Saugerties specimens should be described as a new variety of more youthful aspect, since on account of their fairly uniform size they would seem to have reached maturity — if one will not assume that they represent a wandering swarm of individuals of a certain adolescent growth stage — or that they should be considered as representing the real mature type of *Devonaster eucharis*, and Hall's types as gerontic individuals. We prefer the latter view in the present state of our knowledge because it avoids the giving of a new name, although in view of the remarkable fact that not any of the many Saugerties specimens comes near the size of the few specimens available to Hall, it is quite possible that we have *de facto* two varieties of different size and stage of phylogenetic development before us. However that may be, we will point out only the differences and by comparison with a few very young specimens also obtained at Saugerties, ascertain the changes attributable to individual growth.

The principal difference is seen in the development of the accessory plates on the abactinal (dorsal) side. In Hall's type the abactinal central area is filled with a pavement of minute accessory plates or granules. "In the center of the disk is a plate somewhat

¹ Schuchert. *Op. cit.* p. 98.

more prominent than those surrounding it, and just inside of the adjoining proximal supramarginals is a small but distinct plate interradiial in position" (Schuchert). In the Saugerties specimens the number of accessory plates in this area is easily but half that of Hall's types and since the accessory plates are also relatively smaller the central plate and the ring of five plates in this area are very much more prominent. In a young specimen (length of ray but 12 mm) this central plate and the surrounding ring of five plates, have already the size of those in the mature and gerontic specimens, and since there are but very few small accessory plates between them, they are nearly in contact. Outside of this ring there follows almost immediately a closed ring of ten equal, subcircular adjoining plates. We have here, therefore, a condition of the disk corresponding to that of the Lower Devonian Spaniaster; but we have a still smaller specimen and this leaves no doubt that originally the disk had no accessory plates at all. The central plate and the ring of small plates which in the mature disk are hardly distinguishable from the accessory plates and have been counted with them, are hence primary plates and homologous to the centrodorsals and the "underbasals" respectively. The next ring of ten plates consists of the proximal radial plates and the interradiial plates. That these are yet in contact, subcircular and equal in shape, is also a primitive character. It seems therefore that we have in these young still the primary skeleton of the Phanerozoian type, namely, the centrodorsal, a first ring of five primordial radials, and a second ring of ten plates, five of which are the second radials, and five interradiial pieces, the primordial supramarginals. This primitive skeleton is still seen in the Ordovician starfish, Hudsonaster, where, however, also accessory pieces have already been inserted between the centro-dorsal and the first ring of primary radials.

The abactinal side of the arms has also an entirely different aspect in the gerontic types from those obtained at Saugerties. In the former the radials and supramarginals are floating, so to say, in a mass of minute accessory plates which fill all interspaces. In the Saugerties specimens only small groups of minute accessory plates are developed in the corners where two adambulacrals and supramarginals come in contact in the proximal portion of the rays. They are so little prominent that they were at first overlooked. In a few cases they unite to a thin line between the adambulacrals and supramarginals in the proximal portion of the arms. Nevertheless they appear so early that already in the half-grown individuals single accessory plates are seen in the proximal corners (see plate

9, figure 2). The ambital accessory plates in the outer interradial disk areas between the arms are so strongly developed in Hall's types that they form a very marked weblike structure (not well brought out in Hall's figure) between the arms (see plate 8, figure 1). In the material from Saugerties only the largest specimens exhibit a few accessory plates in the interradial spaces which are easily overlooked.

On the actinal (ambulacral) side of the specimens the differences between Hall's types and the mature Saugerties specimens are not quite so striking. The number of plates is smaller; there are only about thirty-two adambulacrals against thirty-eight to forty in the type of the species and about twenty against twenty-seven to twenty-eight inframarginals. The ambulacral grooves which are slightly petaloid in the gerontic individuals, are straight in the young and mature specimens from Saugerties; and the difference in size between the adambulacrals and inframarginals is not nearly so large as in Hall's type, for the reason that while the adambulacrals are in both of the same size, the inframarginals have grown much broader in the old individuals. On that account they also show more distinctly along the edges of arms on the abactinal side than they do in the Saugerties material, for the supramarginals have not grown correspondingly in width.

All these differences between the mature specimens of Saugerties and the supposed gerontic type of the species produce such marked differences in general habit that the two could be well considered as at least belonging to different varieties, if not species, were it not for the fact that the still younger stages show that the differences are all of ontogenetic development. As it is, the specimens from Saugerties resemble much more those of Spaniaster, both in the actinal and abactinal aspects, than those of the gerontic Devonaster.

Besides the many mature individuals of *D. eucharis*, the material from Saugerties contains also several very young individuals, one with a radius of but 4 mm. These furnish some facts which are probably of more than ontogenetic interest. We have already mentioned above the different structure of the abactinal disk and the absence of accessory plates in the abactinal disk and arms. These plates are quite clearly only a later acquisition and are in line with the general tendency of all progressive asterids of the Phanerozoia to get away from the solid caselike primary skeleton. Schuchert (*op. cit.*, p. 32) describes this tendency as follows: "The change lies mainly in the increasing number of the

ossicles, relative decrease in the size of the plates, introduction of many new series of accessory pieces, absorption and removal of others, with a marked general tendency to break up the stiff and ponderous inherited skeleton into one of small pieces, thus affording greater flexibility and greater podial strength through the endless duplication of ambulacral parts."

In the half-grown (adolescent) individuals (see pl. 9, fig. 2) the most characteristic features are, on both the actinal and abactinal sides, the fairly uniform size of the columns of ossicles at corresponding distances from the center, while in the mature, and still more so in the gerontic stage, great differences develop in the size of the adambulacral and inframarginal and a less marked differentiation in that of the radial and supramarginal plates of the arms. The primary plates of the disk remain entirely behind, as shown above, and sink almost to the size of accessory granules. The proximal radials and proximal axillary (proximal supra-marginals) plates are all circular, knoblike in shape and remain so throughout, although figured as oval bodies by Hall and later authors. They contrast thereby with the following oval plates in the columns. Further, all the plates are much more convex or thick in the younger stages than in the mature and gerontic and the arms correspondingly higher and thicker. This is also a character clearly shown in the primitive *Hudsonaster* and of probable phylogenetic importance.

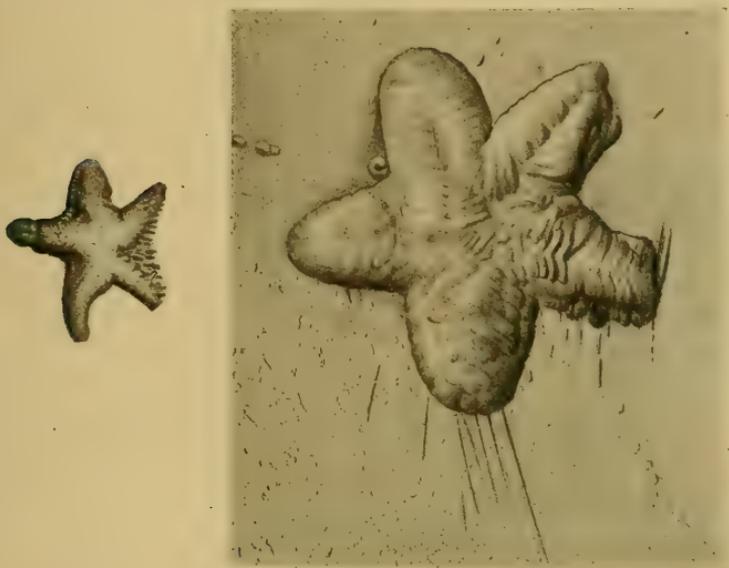
On the actinal side the axillary interbrachial plates have retained their original circular shape, as is well shown in Hall's figure (see also plate 8, figure 2 and plate 9, figure 3). The inframarginals are throughout of convex subquadratic instead of long rectangular shape, as in the later growth stages; where, however, this stage is retained near the ends of the arms. The plates of the oral armature are apparently as in the older individuals.

The smallest specimen available (radius 4 mm) shows a still greater uniformity in the size of the plates.

A few abnormal specimens deserve separate notice. Two of these have but four, another has six arms. The former show all plates in tetrameral arrangement, and one ray has therefore been completely suppressed; in the latter, however, which is seen from the actinal side, only five plates of the oral armature and a corresponding number of axillaries can be counted, and two arms are irregularly coalescent at their bases as if they originated from one arm that was torn off, a case sometimes observed in recent specimens.

Promopalaeaster (?) sp.

The State Museum contains a slab of Clinton sandstone from Clinton, N. Y., once taken by Doctor Clarke from a culvert near Utica, that bears the impressions of two starfishes. Although the specimens are not sufficiently well preserved for description or even generic determination, they are so peculiar in their characters that it seems appropriate to record the occurrence of such an interesting form in the Clinton beds.



12

13

Fig. 12, 13 *Promopalaeaster (?)* sp. Two specimens, natural size.

The slab is obviously the cast of a bottom surface with many trails such as are extremely common in the Clinton sandstone. Also the larger starfish shows distinctly the trail of two of its arms and the impressions of the spines of one of them. The larger specimen is of plump form with short, broad rays and large disk, formed by the bases of the rays. The entire surface is covered with a dense mass of spines, so that no structure can be discerned save a median furrow in one of the rays, corresponding to the position of an ambulacrum.

The smaller specimen has a similar outline, but more slender rays and apparently less-developed spines.

The larger specimen is, in outline and the covering by spines, comparable to certain species of *Promopalaeaster*, p. e. *P. dyeri*

(Meek), which are composed of a multitude of small ossicles each bearing a spine.

The form described as *Heliophycus stelliforme* by Miller and Dyer from the "Hudson River Group" (Maysville) of Ohio, judging from the figures,¹ is exactly like our species and may possibly also be the impression of a multispinose starfish.

Lepidasterella Schuchert

This interesting genus is based on a specimen of *Lepidasterella babcocki* Schuchert, the genoholotype, from the Upper Devonian near Ithaca. The State Museum contains two specimens from the Cashaqua shale of the Portage in Hunt's quarry at Interlaken, N. Y., also mentioned by Professor Schuchert (*op. cit.*, p. 161), which are more perfect than the holotype of the species and therefore permit to add a few data to the knowledge of this extremely striking and as yet very imperfectly known starfish.

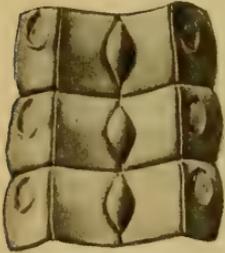


Fig. 14 *Lepidasterella babcocki* Schuchert. Portion of abactinal side of ray. $\times 5$

One of the Museum specimens was figured by Doctor Clarke in the Report of the Director of the Science Division for 1905, opposite page 36, being referred there to the nearest related genus, namely, *Helianthaster*. While the holotype is a natural mold of the abactinal side in sandstone, this specimen retains the abactinal surface itself. As the figure clearly shows, the plates of the radial and of the supramarginal columns stand out clearly as tumid projections. Nevertheless their sutures can not be made out, because the surface is covered by a granular test (see pl. X, fig. 6). There is little doubt that this represents a skin that was originally present in the specimen covering the entire abactinal and an unknown portion of the actinal skeleton. Such a granular exterior skin has also been observed by Schöndorf in *Helianthaster rhenanus*²

Another interesting feature not shown by the genoholotype but clearly exhibited in our specimens, is the remarkable development of the interbrachial disk areas. While Schuchert states that there appear to be no ambital areas as the inframarginals of adjoining

¹ Contributions to Palaeontology, no. 2, p. 2. 1878.

² Palaeontographica, 36:218f. 1899-1900.

rays meet and the disk begins at their junction, our two specimens show that interbrachial ambital areas are developed to nearly half the length of the rays. They are formed by a skin that is alate to the rays for some distance, giving the interbrachial areas a web-fingered appearance. The margin is strengthened by marginal ambital plates. This feature is also exactly as in *Helianthaster*.

The abactinal area was apparently also covered by a skin in which were embedded numerous subpolygonal to circular plates which are still found scattered over the abactinal disk area of one of the specimens.

***Lepidasterella gyalum* (Clarke)**

Plate 10, figure 5

Through the praiseworthy generosity of Prof. H. P. Cushing, the State Museum has received the counterpart of a beautiful slab with three specimens of a multibrachious starfish, the other side of which is in Cornell University. It is from the Portage near Ithaca, N. Y. This remarkable species was described by Doctor Clarke¹ as *Helianthaster gyalum*. In his revision of the Paleozoic Stelleroidea, Professor Schuchert has placed this species, with some doubt, with *Palaeosolaster*, which belongs in the order *Cryptozonia*, while *Helianthaster* is a *Phanerozonian*, stating:

That *P. (?) gyalum* can not be referred to *Helianthaster* is therefore seen in the different position of the madreporite, the greater number of rays, the wider ambulacral furrow and the improbability of its having three columns of abactinal ray plates in place of an integument bristling with spines. All of these differences are in harmony with *Palaeosolaster*. Further, if *P. (?) gyalum* had interbrachial intramarginals as does *Helianthaster*, they should show somewhere on these five (three) specimens, all of which preserve the actinal side. While these differences may not appear to be great, they make of *Helianthaster* a *phanerozonian* and of *Palaeosolaster* a *cryptozonian*.

A closer study of our slab by means of numerous plasticene impressions, has shown that two of the specimens show their abactinal side, and only the third the actinal side. Peculiarly enough, the two former specimens retain the oral armature and its powerful frame, which is very misleading but happens also in other forms, where the body of the starfish was thin and the frame heavy so that it became pressed through and is then seen on the

¹N. Y. State Mus. Bul. 121, p. 63. 1908.

abactinal side with its abactinal aspect.¹ These abactinal or dorsal sides of the rays exhibit now a composition of three columns of plates (see text fig. 15), one of smaller median radials and two columns of supramarginal plates, outside of which the narrow margins of the inframarginals are seen. In *Palaeosolaster* the abactinal side is formed by an integument bristling with spines. This difference indicates already that this species can in no case be a *Palaeosolaster* or even belong to the *Palaeosolasteridae*, but the evidence of the marginal plates proves also that it is a phaneronian. The structure and aspect of the abactinal side of the rays is identical with that of *Lepidasterella* Schuchert, which is a *Helianthaster* with twenty-four instead of thirteen arms. Since the species under discussion has also twenty-four rays and *Lepidasterella* is known only from its abactinal side, there are no facts available by which this species could be separated from that genus. There is, however, corroborative evidence seen in the presence of an alate disk integument extending between the rays, exactly as we have described it here of *Lepidasterella babcoki*, and this integument is likewise furnished with a column of small ambital marginals. It follows from this observation that *L. gyalum* actually possessed interbrachial inframarginals, a fact doubted by Schuchert who had not seen the specimens.

The one feature which still seems to militate against a reference of our species to the *Lepidasteridae* is the position of the madreporite, which is very close to the mouth and actinal according to Schuchert's view. The single specimen which exhibits the madreporite shows the abactinal side of the rays, and we believe therefore that also the madreporite was abactinal. Furthermore the madreporite interrupts the series of the oral ossicles, which means that these must have been under it, or, in other words, on the other side of the creature. The madreporite was hence on the abactinal side. While in the *Palaeosolasteridae* the madreporite is typically on the actinal side, it is in the *Lepidasteridae* only known of *Helianthaster*, where it is "marginal, large, more actinal than abactinal." Since the alate interbrachial integument of the disk is quite close to the oral frame (see pl. X, fig. 5) it is obvious that also the madreporite of *L. gyalum*, on the abactinal side, was marginal in its position.

¹ See, for instance, *Medusaster rhenanus* Stürtz, *Palaeontographica*, v. 36, pl. 31, fig. 35; *Echinasterias spinosus* Stürtz, *Verh. naturh. Ver. der preuss. Rheinl.* v. 56, pl. 3, figs. 5 and 6, and many others in *Palaeontographica*, v. 32.

It thus becomes highly probable that the two types from the Ithaca beds which Doctor Clarke had united under *Helianthaster gyalum*, are congeneric, one, *L. babcocki*, being the genoholotype of the genus, the other, *L. gyalum*, a somewhat smaller vicarious form. As far as the abactinal side of the

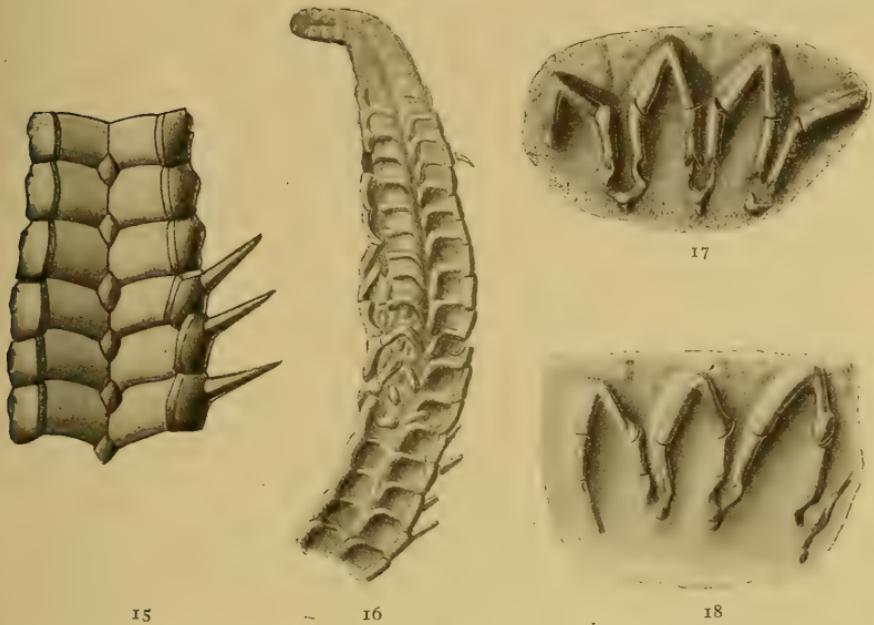


Fig. 15-18 *Lepidasterella gyalum* (Clarke). 15 Portion of abactinal side of ray, drawn from gutta-percha squeeze. (x 5) 16 Actinal view of ray (x 3) drawn from gutta-percha squeeze, shows a suture between ambulacrals in middle of right side. 17, 18 Portions of the oral frame, with syngnaths. (x 3)

rays, which alone is available for comparison, is concerned, the two species differ mainly in their size and the relatively stouter and shorter form of the rays in the genoholotype.

If our contention, that the smaller form, *gyalum*, is also a *Lepidasterella*, is true, then we also have here the actinal side of that genus, hitherto unknown (see text fig. 16). The arrangement and form of the actinal plates is very different from that of *Lepidaster*, but identical with that of *Helianthaster* as figured by Stürtz (*Palaeontographica*, v. 36, pl. 26, fig. 14a). It exhibits a median furrow, on both sides of which rise rectangularly bent, hooklike crests that delimit square areas, in the distal, outer corners of which relatively small pores or depressions can be seen. These crests and the pores are opposite each other, indicating that the ambulacrals were also opposite. The margin of the arm is

formed by narrow, slightly curved plates. As to the determination of these plates there is still considerable doubt. Stürtz (*op. cit.*) considered the pores as the podial pores and the marginal plates as the adambulacrals, thus making the whole width of the ray the ambulacral groove. Schöndorf¹ uses the same terminology, but states that the description of this starfish needs a thorough revision. Schuchert (*op. cit.*, p. 159) considers the median groove as the ambulacral groove, the ambulacral plates as not seen, the adjoining plates as adambulacral plates and the marginal plates as inframarginals. Our material is hardly preserved well enough to decide this question, and however it may be answered, the fact remains that the arrangement is exactly alike in *Helianthaster rhenanus* and *Lepidasterella gyalum*.

The oral armature is splendidly preserved in one specimen of *L. gyalum*. It is there seen to consist of a powerful frame, each arch or "jaw" of which consists of four strong ossicles, two long uprights and two shorter joists. The bases of the uprights hold the small sygnaths (see text figs. 16 and 17).

Lepidasterina gen. nov.

The genus *Lepidaster* Forbes has thirteen arms; *Lepidasterella*, proposed by Schuchert, has essentially the same structure as *Lepidaster*, but twenty-four rays. The State Museum contains still another multiradiate starfish of the same family with eight rays. For this the name *Lepidasterina* is proposed. Like *Lepidaster* and *Lepidasterella* it is based only on one species. It differs from these genera and *Helianthaster*, which also belongs in the *Lepidasteridae*, principally in the number of the rays, and further in the very small size of its disk and the long slender form of the rays. The structure of the rays, however, if we understand this genus correctly, is that of *Lepidaster* and *Lepidasterella*. Corresponding to the more slender form of the rays, the plates are also distinctly more elongate. This is especially true of the adambulacral plates which are not short, transversal as in *Lepidaster*, but long, somewhat dumb-bell-shaped, being thickened at the sutures. The inframarginals are somewhat wider. The adambulacral plates are opposite, as in the other genera, in one specimen and alternating in the other, thereby indicating that also the ambulacral plates which have not been seen were very variable in their relative position.

¹ Fr. Schöndorf. Die fossilen Seesterne Nassaus. Jahrb. des Nass. Vereins für Naturk. in Wiesbaden. 62 Jahrg., p. 35. 1909.

On the abactinal side the radial plates form a continuous column of narrow, elongate plates, as in *Lepidasterella*; and also the supra-marginal plates which alternate with them are as in that genus. The upper edges of the inframarginals form a narrow marginal fringe of the rays.

The preservation of the specimens which are interior molds, has left us in doubt, especially in regard to our correct understanding of the ventral or actinal structure, and we consider it possible that this genus may some day prove to have an entirely different taxonomic position.

Genoholotype and only species. *Lepidasterina gracilis* nov.

***Lepidasterina gracilis* nov.**

Plate 10, figures 1-4

Description. Rays eight to nine, long and slender. Length of ray in one specimen 48 mm and basal width 2.5 mm; length in the other specimen 21 mm and width 2 mm. Disk very small and only formed by the bases of the rays; its radius about 10 mm.

The actinal side of the rays shows in no case the ambulacrals, the ambulacral groove being very narrow; the adambulacral plates are slender, elongate ossicles with straight margin on the inner and slightly concave margins on the outer side, where they are slightly widened toward the extremities. They may be alternate or opposite in different specimens. The inframarginal plates which alternate with them are of similar shape, subrectangular, as seen from below, with slightly concave longer margins. They bear a long spine on the lateral margin and exhibit spine-bases on the underside near the distal suture. The ossicles of the oral armature appear to have been slender, V-shaped. The abactinal side of the disk is not well preserved but seems to have been very spinous. The rays show a median column of narrow, subelliptic radials, flanked on either side, without interruption by any accessory plates, by the supra-marginal plates that are subquadratic in outline, quite tumid of form and bear spines on the outer distal angle. The upper portions of the inframarginals form an outer fringe of narrow ossicles.

Horizon and locality. Lower Chemung beds at Avoca, Steuben county, N. Y.

Remarks. The material consists of only two specimens, neither of which is especially well preserved. The smaller shows distinctly

eight rays, but the larger may have possessed nine. The number of the rays may therefore have been somewhat variable or rather increased somewhat with growth, as it still does today in multi-radiate forms. While *Lepidaster* with thirteen rays is a Silurian type, *Helianthaster*, *Lepidasterella* and *Lepidasterina* are Devonian forms, *Helianthaster* with fourteen to sixteen rays early Devonian, and *Lepidasterella* and *Lepidasterina* late Devonian. *Lepidasterina* has less rays than any of the others and contrasts especially with *Lepidasterella*, which has more than the preceding genera. While, therefore, an increase in the number of rays seems to have taken place in one direction, a decrease seems to have led to *Lepidasterina*. If, as has been suggested, the increase in the number of arms has been principally to permit to gain a stronger hold on the food and on the rocks, then *Lepidasterina* would appear to have made up for the smaller number by increased relative length of the rays in comparison with the size of the disk. It is just the opposite in relative size of rays and disk to *Lepidasterella*.

***Ptilonaster princeps* Hall**

Plate 20, figure 1

The genus *Ptilonaster*, with its genoholotype *P. princeps*, is based on a single specimen from the "Chemung group at Cortlandville," (now Cortland), N. Y., which is now in the American Museum of Natural History. The specimen consists, according to Hall's statement, of the impression of the greater part of one ray, with parts of two others, and intervening portions of the disk. The State Museum contains original wax and plaster casts and replicas of the ray, figured by Hall. These show that the original drawing of the species (20th Ann. Rep't, N. Y. State Museum of Nat. Hist., pl. 9, fig. 9, 1867) is a diagrammatic one, intended to indicate the outlines of the ossicles as understood by Hall. Based on the original description and this figure, the genus has always remained problematic in regard to its taxonomic position, and authors, as Gregory and Schuchert, have been satisfied with leaving the genus next to *Eugaster* where Hall had placed it. If we, with the same incomplete material as was available to Hall, venture to suggest a different position for this genus, it is mainly because we have before us other genera still more similar to *Ptilonaster* and not known at the time of the creation of the genus.

As Hall gives but the diagrammatic drawing of the ossicles which fails to record the actual aspect of the actinal side, we reproduce here the wax cast of the type from which the original drawing

was made. It is seen at once that this is entirely different from *Eugasterella* (see pl. XVII, fig. 3), but identical in aspect with *Lepidasterella*, as here described of *L. gyalum* (see pl. X, fig. 5). We find the same median furrow formed by the sharply rectangular bent ridges, proceeding from the narrow marginal

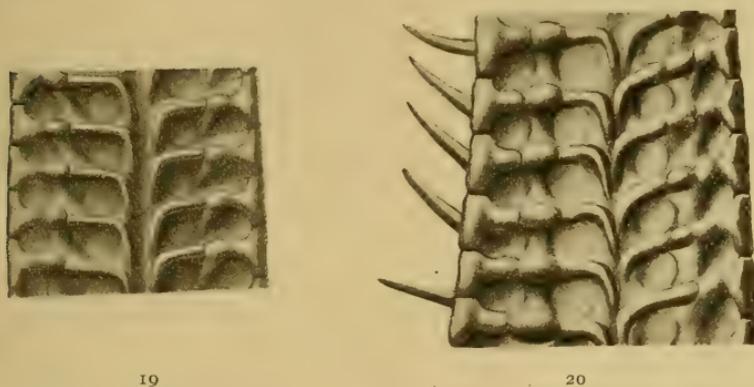


Fig. 19, 20 *Ptilonaster princeps* Hall. Proximal and distal portions of the ray of holotype. Figure 19 x 3; figure 20 x 5.

plates, and the pores or depressions within the spaces delimited by the hooklike ridges. It was stated under the description of *Lepidasterella gyalum*, that in the similar and closely related *Helianthaster* the authorities still disagree as to whether the median furrow is the ambulacral furrow or the ambulacrum itself, and correspondingly whether the adjoining plates are the ambulacra or the adambulacra. From the presence of the transverse hooklike ridges, the longitudinal bars of which serve for the attachment of the transverse ventral muscles, and the identity of the structure of the actinal side with that of such primitive Asteroidea as *Uranaster* where identical ridges mark the ambulacral plates, we infer that also here we have before us a median ambulacral channel, two columns of ambulacra with ridges and two columns of adambulacra.

While in the proximal portion of the ray it would seem impossible to discern more than two columns of plates whose separating suture is inside of the knobs upon the crests, the distal younger portion of the rays suggests a further division of the crest by a suture.

The fragments of the disk show this to have been highly alate, furnished with a marginal row of plates and the interbranchial divisions forming so acute an angle that the starfish had probably a greater number of rays. Combining the fact that the aspect and

probable composition of the actinal part of the rays are identical with those of *Lepidasterella* and *Helianthaster*, with the evidence from the visible interbrachial portion of the disk, we can not escape the inference that *Ptilonaster* probably belonged to the *Lepidasteridae* and may prove with better material to have been a large *Lepidasterella* or a *Helianthaster*.

It is also significant in this connection that the type specimen while reported to have come from the Chemung group, is from the vicinity of Cortland where the rocks were considered in the earlier days of the Survey to be of Chemung age, but are now referred to the Ithaca beds of the Portage group, which has also furnished our species of *Lepidasterella*.

***Urasterella ruthveni* (Forbes) mut. *arisaigensis* nov.**

Plate 11, figures 5 and 6; plate 12, figure 3

Description. Disk small, without interbrachial areas, rays slender, very slightly widening in first proximal third, then regularly tapering. R (length of ray), 14 mm; radius of disk, 2 mm. Abactinal area of disk with distinct central large plate, from which five ridges radiate along the median lines of the rays. These ridges consist of the radial plates, their bases being formed by the five basal radials. The next or second proximal radials of the column are flanked by the basal marginal plates. The abactinal side of the rays has a very characteristic and pretty aspect. The median line is occupied by a crest formed by the radials which are a little more tumid and larger than the remaining plates. The radials, as well as all the other plates, are subquadratic in outline, forming a very close pavement. They are flanked on either side by three columns at the base and two columns near the tip. Of these, those next to the radials are smaller than the outer columns; they are the supramarginals. The third column, or second of the ambitals, reaches only to the middle of the rays. The interbrachial area is occupied by a single interbrachial marginal plate, on either side of which is located a minute plate in regular quincunx position with the adjoining ambitals, indicating that these may be the beginnings of other columns of ambital ossicles. All ossicles of the abactinal side of the rays are arranged in very regular quincunx and are all furnished with the unarticulated rods characteristic of the genus.

The actinal side exhibits rather narrow ambulacral grooves at the bottom of which can be seen distinctly opposite, wedge-shaped

ambulacrals that leave space for large podial pores and meet in a well-defined, straight, ambulacrual channel or gutter. The adambulacrals are typically coin-shaped, the narrow ridges are somewhat obliquely directed forward and inward and separated by furrows about as wide as the ridges. The ossicles number about twenty in 10 mm, and there are about thirty in a column. The first three adambulacrals diminish in size to the basal plate, which with the neighboring one bears a very minute triangular syngnath or mouth angle plate. The adambulacrals also bore two or three spines or rods each.

Horizon and locality. Arisaig series (Silurian) at mouth of Stonehouse brook, Nova Scotia.

Remarks. We have two specimens of this *Urasterella* before us, one showing the actinal and the other the abactinal side. Both were collected by Doctor Clarke. The actinal side agrees in its outline, size, number and character of adambulacrual ossicles in a certain space with the figures published of *U. ruthveni* (Forbes) from the Upper Ludlow rocks near Kendal, Westmoreland, England. This species, the genotype of *Urasterella*, is not well known and its abactinal side has not yet been described. Positive identification is therefore at present impossible. As, however, the Arisaig series has so many forms in common with the European Silurian, it is highly probable that this Arisaig type is conspecific with the English form. The Arisaig series has been shown by Schuchert and Twenhofel to represent a period of time in Europe between the lower Llandovery and the Ludlow. As the English species comes from the Upper Ludlow, it is very probable that our species represents an earlier mutation and a direct identification would be liable to mislead.

Urasterella lutheri sp. nov.

Plate 13, figures 2-6; plate 14, figures 1-4

Description. Disk relatively small, about one-fourth the size of the animal, rays of very flexible appearance, fairly long and robust. Abactinal disk area covered by a great number of very small, irregularly stellate ossicles without regular arrangement that are separated by deep intervals; many (or all?) of these bore a central rod or mucro; on the rays the abactinal side is composed for the most part of four-rayed stellate ossicles that are distinctly arranged in columns, seven to nine of which can be counted on the mature part. The rays of the ossicles touch only at their tips, thus leaving

wide interspaces and giving the surface a meshy appearance. Of the nine columns, the mesial one (radials) and adjoining ones are smaller than those near the margin, save the marginal ones themselves which are also small. These ossicles also bore central mucros in the median columns and rods in the marginal ones. The ambital columns are not distinguishable in character from the supramarginal ones in the mature portion of the rays.

The actinal side is characterized by the very wide lanceolate ambulacral grooves, at the bottom of which the very long, narrow, arm-bone-shaped ambulacrals are seen. Their inner ends are more thickened than the outer and their straight edges form, with those of the column directly opposite, a very distinct straight ambulacral channel. It appears that the ambulacrals originally were steeply inclined toward each other. The podial pores were between the ambulacrals. The adambulacral plates show the coin-shaped form and arrangement characteristic of the genus and the granulose actinal surface. They are closely arranged, each adambulacral directly opposite and corresponding to an ambulacral plate. There may have been about forty in a complete column. No inframarginals have been noticed, the marginal column being formed by small disk-shaped ambitals that bear a central rod. The orals are small triangular ossicles that belong to the column of the adambulacral plates. In the interbrachial area a single subpentagonal marginal plate is seen.

Horizon and locality. West Hill flags, about 150 feet above Grimes sandstone (Portage beds), Deyo Basin, 2 miles south of Naples, N. Y.

Remarks. This species is based besides fragments and young individuals on four mature specimens; two of these show the actinal and the other two the abactinal side. The species is in both views widely different from the other Devonian congeners; on the abactinal side by the great mass of very small stellate plates which give the very flexuous rays and disk a strangely granular aspect; on the abactinal side by the wide ambulacral grooves filled with long, narrow, striplike ambulacrals. The rays which originally were probably higher than wide appear now too wide in several of the specimens, the abactinal portion having been flattened out and pressed over on both sides of the actinal sides.

We also figure here the abactinal view of a young specimen (pl. XIV, fig. 1). It shows a curiously intricate mass of star-shaped and wedge-shaped ossicles apparently without any regular arrangement. The actinal view of another young specimen proves the

adambulacrals to have been more closely arranged, broader and thicker disks; and also the ambitals and ambulacrals appear to have been relatively thicker.

Urasterella stella nov.

Plate 12, figures 1 and 2; plate 13, figure 1

Description. Rays short, rapidly tapering and angularly convex abactinally. Disk formed only by the united bases of the arms. The ossicles of the disk are all spinose, small, granular, indistinctly arranged in three or four concentric circles. Those of the rays are arranged extremely regularly in columns in quincunx, giving the surface a striking similarity to a knitted texture. The crest of the ray is formed by a single column, the radial plates, which are a little longer than the other ossicles. The sides are formed by three columns each of equal subquadrangular plates, the column adjoining the radial plates on either side not reaching to the tips of the rays. All ossicles of the rays are furnished each with one long unarticulated spine or rod. These fail to appear in the squeezes from which the photographs are taken except on the lowest column where they are directed horizontally. The madreporite has not been found. The actinal side shows very broad ambulacral grooves with subrectangular ambulacral plates and relatively small podial openings, excavated at the forward exterior angle. The adambulacral plates are narrow, coin-shaped, arranged on edge, the columns terminating in the ossicles of the oral armature, which, so far as discernible, are small and subtriangular in shape. The adambulacral plates are flanked on either side by a row of small semielliptic ambitals bearing short, stout central rods.

Measurements. The radius of the rays (R) is 10.5 mm long, that of the disk (r) about 2.5 mm, and the rays are about 2.3 mm wide at their base.

Horizon and locality. The specimens were collected by Mr D. D. Luther in the Middle Grimes sandstone (Portage group), about 3½ miles northeast of Naples, near William Harrington's residence.

Remarks. The material consists of one specimen showing the abactinal side and another retaining both the actinal and abactinal sides in the specimen and counterpart. This species is distinguished from the Chemung type of *Urasterella* by the shorter, stouter rays, smaller number of columns on the abactinal side, and on the actinal side, in the shape of the ambulacral and adambulacral plates, which are narrower.

Urasterella schucherti nov.

Plate 11, figures 3 and 4; plate 12, figures 4 and 5

Description. Disk small, formed by the united bases of rays. Rays long, slender, tapering very slowly and very convex on abactinal side.

Abactinal area of disk shows one larger central plate surrounded by irregularly distributed small, tumid plates. Madreporite, if properly recognized, a small depressed plate with granular surface, situated between the basal supramarginals. Plates on rays distinctly arranged in columns and in quincunx. Three columns of very convex, spinose plates, the radial and supramarginal plates, which are flanked on either side by four columns of smaller plates, the ambital plates, which bear the erect nonarticulate rods characteristic of the genus. Along the edges the spines of the lower ambitals are seen.

On the actinal side the ray shows wide, shallow, ambulacral grooves, bluntly wedge-shaped ambulacral ossicles which are in one column slightly advanced beyond those of the others and overlap slightly in the medial furrow. The podial openings seem to be narrow and situated between the attenuated ends of the ambulacrals. The adambulacral plates are rather thick disk-shaped, arranged on edge, numbering fifty or more in each column and corresponding in number to the ambulacrals. The adambulacrals continue in somewhat diminished size to the oral armature pieces which are blunt, with short, stout, subrectangular ossicles. Outside of the adambulacrals a column of small onion-shaped ambital ossicles is seen, which bear long unarticulated rods, the inframarginal plates being absent in the mature specimen.

Measurements. The length of a ray from the center (R) is 23 mm, the radius of the disk (r) about 2.5 mm, the basal width of a ray 3.1 mm.

Horizon and locality. Chemung beds, Kirkwood, Broome county, N. Y.

Remarks. We have two specimens of this species from Kirkwood before us, one showing the actinal, the other the abactinal side. This is the only Upper Devonian *Urasterella* as yet described; *U. asperula* (Roemer) from the Lower Devonian of Germany and *U. montana* (Stschurowsky) from the Upper Carbonic of Russia are the nearest in age. In aspect and structure it is hardly different from the Ordovician and Silurian forms and is especially similar to the Trenton species *U. pulchella*.

Urasterella sp. nov.*Plate 13, figures 7 and 8*

Professor Schuchert records the presence of a large, slender rayed species in the Ithaca beds of the neighborhood of Ithaca, of which, however, so little actinal detail is preserved that only the presence of the species could be indicated. The State Museum contains another like specimen, collected by the writer in the Ithaca beds at Messengerville, Cortland county, N. Y. Unfortunately this specimen also shows only the abactinal side since the counterpart of the specimen could not be found. The R (radius of ray) of this species was from 45 to 50 mm long. The ray shows in the median line a more or less interrupted row of somewhat elongate small ossicles, the radial plates; on either side of this, larger rhombic plates are seen; outside of these two rows of large rhombic plates and along the edge smaller disk-shaped plates with rods. All the radial, supramarginal and ambital plates are spinose or bore rods after the fashion of the other species of *Urasterella*. In one place along the edge the impressions of long, slender, flattened and longitudinally grooved spines can be observed protruding from the actinal side. These have been described by Schuchert from *U. grandis* (Meek) and considered as probable paxillae attached to the articulate spines of the adambulacrals.

The little that is known of this species leaves no doubt that it is quite different from the *U. stella* of the Naples beds, both in relative size and the character of the ossicles of the abactinal region of the rays.

Palaeosolaster roemeri (Clarke)¹

This species, proposed by Doctor Clarke in New York State Museum Bulletin 121, page 64, plate 11, is based on a magnificently preserved specimen from the Bundenbach slate of the Rhenish Devonian. The genus is represented by only one other species, *P. gregoryi* Stürtz, also existent in but one specimen.

The species had originally been referred to *Helianthaster* which is distinguished from *Palaeosolaster* mainly in the number of the rays; and its differences from the supposed congeners were pointed out. In general aspect *P. roemeri* is so similar, though much larger, to the genotype as to suggest identity; we therefore desire heré to point out the specific differences between the two.

The proportions between the free parts of the rays and the disk, as well as the relative width and length of the rays and the mouth,

¹ By John M. Clarke.

are the same. The madreporite, however, which is oval and striate as in the genotype, is smaller by one-sixth although the specimen is larger by one-third. The ambulacral plates are distinctly opposite, while in the specimen of *P. gregoryi* they are apparently alternating, probably owing to oblique shoving of the entire starfish. The plates themselves are alike in outline in both species; they have a spoon-shaped crest which in *P. roemeri* is narrower and lacks the distinct widening at the inner end and is more sharply bent, thus resembling a single right angle. The adambulacral plates are smaller and less prominent than in the genotype. The ambulacral groove which is very narrow in *P. gregoryi* is distinctly wider in the other species. The spines which form a dense covering in both species are for the main part simple and not compound as in *P. gregoryi*, especially so on the disk.

***Stenaster salteri* (Billings)**

Plate II, figures 1 and 2

The State Museum contains a slab of Trenton limestone from Kirkfield, Ontario, which bears two beautifully preserved specimens of *Stenaster salteri* (Billings) that reveal some structures hitherto not recognized.

The two specimens present the abactinal or dorsal view, lately so well figured and described by Spencer¹ for *Stenaster obtusus*. The abactinal arm-view of *Stenaster salteri* not having been figured as yet, we give here that side in plate XI, figures 1 and 2. It is essentially alike as in *S. obtusus*, the British Ordovician representative of our species.

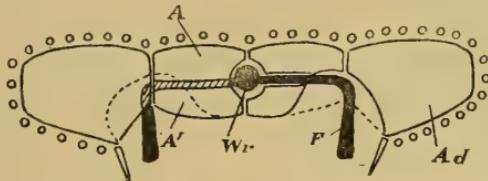
The new characters which are recognizable in our two specimens are the presence of a dorsal integument and an interradian disk. Schuchert had already observed interbranchial areas in a specimen of *S. salteri* regarding which he states (*op. cit.*, p. 166):

In the University of Toronto there is a specimen that in every way, except one, has the characters of *Stenaster salteri*. It was found associated with many other individuals at Kirkfield. It differs from its associates in having what appears to be a distinct disk, rather large, with concave sides, filling in the spaces between the rays. One looks in vain, however, for plates or spines, as the interbranchial areas are nothing more than an amorphous mass of calcium carbonate. These areas are very distinct and stand out

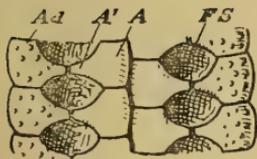
¹ W. K. Spencer. A Monograph of the British Palaeozoic Asterozoa. Pt. I. Palaeontographical Society 1913 (1914), pl. 1, fig. 7.

prominently, but because they do not reveal any plated or spiniferous structure the writer regards them as false characters, produced during the permineralization of the specimen. This conclusion is further supported by the fact that otherwise the characters are those of *S. salteri*.

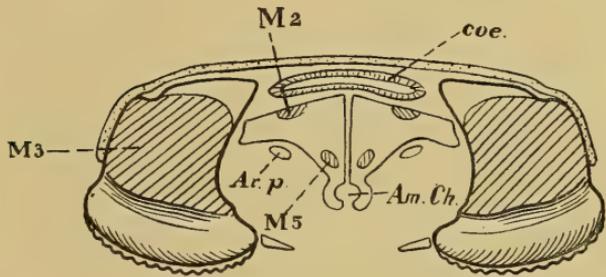
The regular outline and development of these interbrachial areas in both specimens suggest already that they are more than accidental features. This suspicion is strengthened by the fact that



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22



23

Fig. 21, 22, 23 Diagrams illustrating structure of Auluroidea. 21 Transverse section of ray, after Schöndorf: *A*, ambulacral ossicle, *Ad*, adambulacral ossicle; *Wr.*, interskeletal radial water vessel; *F*, podia, on left the canal passes through the plate, on right, the plate is dissected down to the canal. 22 Ventral arm structure of auluroid, after Schöndorf: *A*, Ambulacralia; *A'*, ventral extensions of ambulacralia; *Ad*, adambulacralia; *FS*, podial cavities. 23 Diagrammatic section of ray of *Stenaster obtusus* (Forbes) from Spencer, showing dorsal integument, protecting coelom (*coe.*): *AmCh*, ambulacral channel; *M*, muscles

they correspond exactly to the narrow basal portions of the petaloid arms (see pl. XI, fig. 1), thus giving them the necessary support. They resemble in this regard the interbrachial areas of the later auluroids with petaloid arms, notably of the species of *Encrinaster*. Positive proof, however, is furnished of the actual fossil nature of the interbrachial areas by their continuation into a dorsal integument of the starfish. This was fully present in both specimens, but was unfortunately worked away by the writer in one of them before its nature and importance were recognized.

The integument, on the dorsal side of the disk, in the inter-brachial areas and on the rays, consists of a rather thick calcareous layer, which rises to a broad node or apex in the center of the starfish, above the wide oral cavity. It exhibits a very fine sculpturing, consisting of granules which are arranged in very regular radiating lines. These are separated by intervals little wider than their diameter. In the section these granules appear as rods and there is little doubt that they are original calcifications of the integument.

It is in this connection interesting to note that Spencer has shown that the genus *Stenaster*, hitherto classified with the Asteroidea, is really a very primitive "ophiuroid" and belongs to the subclass Auluroidea of the Stelleroidea. Schöndorf, who first clearly recognized the composition of the rays in this class, of one layer of ossicles only, gave the diagrammatic section of a ray, here reproduced in text figure 21. Spencer has furnished in his paper (*op. cit.*, p. 23) the improved diagrammatic section, here reproduced in text figure 23, which shows a thick dorsal integument covering the coelom. He states, however, (p. 25) of this integument, that it had "few or no calcifications." He assumes its former existence on theoretical grounds. As our specimens indicate, it must have been well calcified in *S. salteri* which species thus verifies Spencer's conclusion as to the section of this remarkable stelleroid, which on the one hand is still very close to the primitive Asterozoa and on the other leads already to the Ophiuroidea.

The specimen reproduced in plate XI, figure 1, exhibits near the center, but nearer to the upper right interradius than indicated in the figure, an elliptic prominence with a central depressed smooth area. This node is clearly the center of the dorsal sculpture and therefore not a fortuitous feature. The central depressed area contains an elongate perforation which may be accidental, but which, situated as it is, can not help but being quite suggestive of an original opening. It is possible that *Stenaster*, which although an auluroid, still exhibits various primitive stelleroid features, may also have retained the anal opening. The latter, though undoubtedly present in the Paleozoic starfishes, has never yet been clearly observed (see Schuchert, *op. cit.*, p. 39). In recent starfishes it is reduced to a minute pore or entirely absent, as it is also in the Ophiuroidea. In the primitive starfishes, owing to their descent from the Edrioasteroidea¹ the anal opening, which migrated from the actinal to the abactinal side, should be distinctly recognizable.

¹ See Bather, F. A. Studies in Edrioasteroidea, 1915.

Eugasterella Schuchert

The genus *Eugasterella* was formerly known as *Eugaster* Hall. This name being preoccupied by an orthopterous insect, has been changed to *Eugasterella*. It is thus far represented only by the genotype, *E. logani* Hall from Hamilton, N. Y.; a second, Rochester shale type, *E. concinnus*, that was referred by Ringueberg to the genus, does not belong here according to Schuchert.

We have before us the genoholotype of *Eugasterella*, *E. logani*, which is in the New York State Museum, as well as several new species. Since *E. logani* is based on a single specimen, all discussion of the species, as well as of the genus *Eugaster-Eugasterella*, has concededly been based on Hall's accurate description and diagrammatic figure in the 20th Annual Report of the New York State Museum of Natural History.

There is no doubt that Hall, on the whole, saw the outlines of the ambulacral and adambulacral ossicles (see pl. 17, fig. 3) quite correctly. He describes the ambulacral ossicles as subquadrate; this should be qualified into subheptagonal, since, on the inner side the ambulacral gutter forms a zigzag line, thereby producing an obtuse angle of that side of the ambulacral; and on the outer side the middle of the ossicle is produced into a short truncate process for contact with the corresponding adambulacral, thereby producing two more corners. The adambulacrals are elongate, hammer-head-shaped ossicles with a strong curved to rectangular crest that gives them a crescent-shaped appearance when seen from the actinal side. There are no conclusive marginal spines in the type specimen, although Hall has figured such.

We furnish here in figures 3 and 4, plate 17, two drawings of the actinal side of the genoholotype to bring out more distinctly the sculpture of the ambulacral furrow. The outlines of the ambulacral plates are not drawn in, because they are not sufficiently distinct. The close similarity or practical identity in the appearance of the ambulacral furrows of this genus with that of *Encrinaster*, will at once be apparent when the two are compared, and *Encrinaster roemeri* Schöndorf and *E. arnoldi* Goldfuss could as well be referred to the present genus. We would therefore feel inclined to unite *Eugasterella* with *Encrinaster*, if it were not for the fact that we have two new species of *Eugasterella* before us which emphasize the differences in habitus between the

genotypes of *Eugasterella* and *Encrinaster* to such an extent that it seems to serve the purposes of taxonomy best to keep the two groups of species distinct. These new species are *Eugasterella bicatenulata* and *E. aranea*. As a group they may be said to differ from typical *Encrinaster* in lacking the distinct petaloid form of the rays, these being much more slender and relatively longer; and also to lack the marginal plates of the disk. *E. aranea* forms the extreme of the series of species. In it the ambulacral ossicles, as seen from the abactinal side, are relatively long prismatic plates. Since these ossicles, as well as the semiprismatic adambulacrals, are elongate and relatively high, the arms are not broad and flat as in *Encrinaster*, but narrow and of semicircular section and become whiplike toward the end.

Eugasterella bicatenulata nov.

Plate 14, figure 5; plate 16, figures 5-7

The Grimes sandstone (Portage group) near Naples, N. Y., has furnished beautifully sharp molds of the actinal side of a starfish that proves to be a Portage representative of the interesting genus *Eugasterella*.

Description. Starfish of medium size. Disk relatively large ($r = 11.5$ mm); with concave margins; rays slender, slightly petaloid, about 36 mm long and 4 mm at the widest part, which is at about one-third of its length.

The ambulacrum is wide, with a slightly zigzag-shaped ambulacral gutter. The ambulacral plates, as seen from the actinal side, are boot-shaped with a very thick, short "foot" and a distinct "heel." The adambulacrals, in their ventrally projecting part, are thick and very high, rising much above the floor of the ambulacrum. They are but slightly curved and extend with their sharply truncated outer extremities beyond the next ossicles, thus forming a distinctly offset series. The proximal end bends hook-like down to the contact with the ambulacral. The projecting truncated distal extremity bears a spine. There are about thirty ambulacrals in a ray and ten in the space of 10 mm. The abactinal side is not now known.

The syngnaths are small, sharply V-shaped and attached to the adambulacral column. The disk is covered with small irregular plates embedded in the granulose integument.

Eugasterella aranea nov.

Plate 15, figure 1; plate 16, figures 1-4

Description. Rays five, slender, of semicircular section, of stiff appearance, distal third whiplike and more flexible. Disk not extending to quite one-fourth of length of rays, with straight or slightly convex margins and well-developed interbrachial areas.

Ambulacral ossicles elongate cylindrical, as seen from the abactinal side, with beveled edges; on the actinal side they show the characteristic bootlike projection with a deeply indented "foot" and the outer extremity of the process bent inward; the entire aspect of the ambulacral groove being very much as in *E. logani*; with the differences, however, that the ambulacrals are much more slender, the bootlike crests relatively longer (about twice) and the podial cavities not large and subquadratic but obliquely elongate. Likewise the adambulacrals are, while in arrangement and shape alike to those of *Eugasterella logani*, more slender and connected with the ambulacral crests by shorter processes. As seen from the abactinal side, the adambulacral plates are distinctly semicircular to semitubular.

The oral skeleton has been seen only from the dorsal or abactinal side. It is strong and apparently carries small thick syngnaths. The outer margin of the disk is straight or even convex, and the disk is covered with a pavement of small irregular plates, embedded in the integument. The margin does not exhibit larger marginal plates. The surface of the disk plates and integument is finely granulose. The integument is also seen to extend over the entire abactinal side of one ray (see pl. 15).

Horizon and locality. The specimen was collected by Mr E. E. Davis of Norwich in a cut of the Lehigh Valley Railroad near Park Station, N. Y., from the Wiscoy shale (Upper Portage with Naples beds fauna).

Remarks. This is probably the most interesting of our Devonian auluroids, since it has developed the ophiuroid aspect in its slender, flexible rays and distinct disk to a greater extent than any other American auluroid. Nevertheless its structure is still that of a true auluroid, and it shows no traces of a development of ventral shields such as the Devonian genus *Klasmura* here described (p. 62) already possessed, or of dorsal shields; and the ambulacral furrow with its median ambulacral gutter and podial cavities is still fully exposed. It is, however, remarkable how completely the

adambulacrals are able to close above the ambulacral grooves in the distal portions of the rays, suggesting a tendency toward an envelopment of the grooves.

Encrinaster Haeckel

The genus *Encrinaster* is represented in the Lower Devonian of Germany by seven species and one variety; a species from the Caradoc of Great Britain has been referred here, but is considered as doubtful by Schuchert (*op. cit.*, p. 245). In America, *E. pontis*, lately described by Doctor Clarke from the Lower Devonian of Ponta Grossa and Jaguarahyva, Brazil, belongs here properly, as also a species from the Silurian of the Argentine Republic, also here described. The species described below as *E. pusillus* is from the Chemung beds.

Encrinaster pusillus nov.

Plate 17, figures 1 and 2

The collections made by Mr Butts from the Chemung about Elmira (Station O4, southeast of Elmira), contain a minute starfish that exhibits characters widely distinguishing it from its asteroid associates in the Chemung and Portage formations, and placing it, in our view, in the genus *Encrinaster*, formerly *Aspidosoma*, so well known from the Lower Devonian of Germany. The most important of these characters are the petaloid form of the rays and the structure of the actinal side of the rays. The rays are not so broadly petaloid as in some of the typical species, but they compare in that feature well with such species as *Encrinaster schmidti* and the common *E. tischbeinianus*, and they are sharply set off from the disk, thereby indicating that the body cavity did not extend from the disk into the rays as in the Asteroidea. The most important structure indicating that this starfish belongs to the subclass Auluroidea, which are Paleozoic brittle-stars, is reproduced in plate XVII, figure 2. It shows in some rays the cast of the median canal from which short side branches diverge that end in round nodes, the casts of depressions. This structure is characteristic of the Auluroidea, as described by Schöndorf.¹ It consists of the median interskeletal water vessel,

¹Friedrich Schöndorf, Paläozoische Seesterne Deutschlands. II. Die Aspidosomatiden des deutschen Unterdevon. *Palaeontographica*, v. 57, p. 37, 1910. See also Schuchert, Charles, Revision of Paleozoic Stelleroidea, with special reference to North American Asteroidea. *Smiths. Inst., Bul.* 88, p. 213. 1915.

which lying between the ambulacralia is usually hidden from view, but here exposed where the ambulacral plates are partly broken away. There also the side branches are seen which lead through the ambulacrals to the circular depressions, seen in the casts as nodes, which served for the ampullae or for these and the podial insertions (see text fig. 21).

Under water the picture is entirely different. Here the casts of the canals and the depressions are obliterated and the outlines of the system of plates, as well as the disk, become distinctly visible (see pl. XVII, fig. 1). One sees there four columns of plates in the ray, namely, the alternating columns of smaller subrectangular plates, the ambulacrals; and two marginal columns of slightly larger, somewhat transversely oblong plates, the adambulacrals. As Schöndorf has shown, the ray of the Auluroids consists only of four columns of plates, which form the actinal and abactinal sides. It is hence the entire plate system of the brittle-star visible under water.

The oral area is clearly seen. The syngnaths appear as small, hooklike slightly converging or almost parallel slits (molds) in the rock. The remainder of the oral skeleton can not be made out.

The madreporite has not been observed. The disk is distinctly seen only under water. It appears then as a dark stain. Where best preserved it possesses a concave margin and is slightly alate on the rays. Marginal plates could not be distinguished, the margins being all more or less torn.

The rays are 9+ mm long, the radius of the disk is about 3 mm. There are about twelve plates in each column.

In its general outline, notably the blunt extremities of the rays, the small size of the organism and the relatively small disk, this species is most similar to *Encrinaster* (*Aspidosoma*) *schmidti* Schöndorf from the Lower Devonian Siegener beds of Germany.

Hallaster, Squamaster

Plate 19; plate 20, figure 2

The Paleozoic rocks of this State have furnished several monotypic genera which, being based on a single species and sometimes on a single specimen, have remained imperfectly known to this day. Two closely related genera of this group are Hallaster Stürtz and Squamaster Ringueberg. The former was proposed for Hall's species *Protaster forbesi* from the Coeymans limestone of the Helderbergian series and the other for a species

from the Rochester shale. Of the latter the Museum, through the liberality of Mr Frank Springer, possesses the genoholotype, and of the former it contains a number of specimens which exhibit features not shown in the two type specimens.

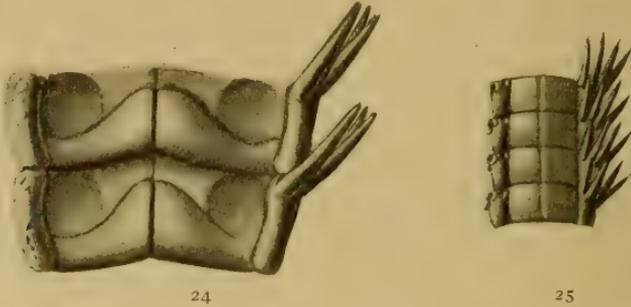


Fig. 24, 25 *Hallaster forbesi* (Hall). 24 Diagrammatic view of actinal side of ray (x 5). 25 Abactinal side of ray (x 5), spines on left broken away

James Hall has quite correctly figured the outline of the actinal aspect of the ray of *Hallaster* in the 20th Museum Report, 1867, plate 9, figure 6. A later diagram, giving the sutures between the ambulacrals and adambulacrals more correctly is furnished by Schuchert in the Revision of the Paleozoic Stelleroidea, page 255, figure 31. The abactinal side of the ray was correctly described by Stürtz¹ but has not yet been figured. The oral or mouth angle plates are short and stout and directly attached to the column of the adambulacrals, while small ambulacral plates seem to continue between them. It is, however, quite possible and even apparent that this condition is due to a contraction of the mouth parts.

The disk is distinctly pentagonal in the two best preserved specimens and the rays are so arranged that the angles of the pentagon lie between the rays. The abactinal side of the disk exhibits tumid, coarse, irregular plates and many blunt, articulated spines like those on the rays. On the latter they are arranged in series of three to five along the distal edges of the adambulacrals. They are mostly blunt, rod-shaped or even slightly club-shaped as figured by Hall, with a distinct broad articulating base.

As the published drawings give only an inadequate idea of the strange ophiuroid aspect of this ancient auluroid, we have reproduced a restoration of the abactinal side in plate 19.

¹Stürtz, N. Jahrb. für Min. etc., 2, 150. 1886.

An interesting feature of the genotype *H. forbesi* is that the majority of the specimens in the Museum show relatively short, somewhat abruptly terminating rays, which, however, do not exhibit any distinct fractures, but terminate in rounded stumps. There were, however, several rays observed which attain a length at least greater by one-half, and which taper to a thin, very flexible whiplike portion. It is therefore probable that the rays were rather fragile, without possessing, however, the faculty of rejuvenation.

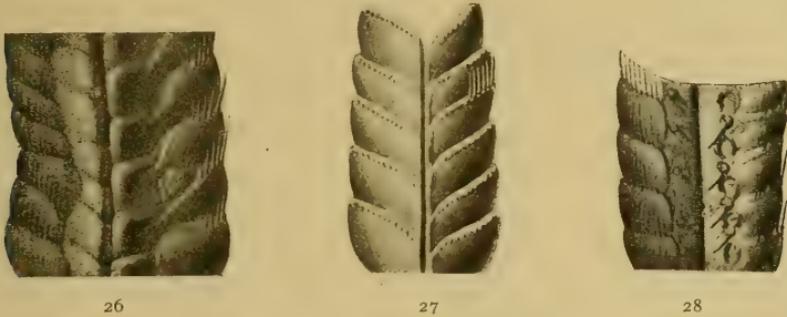


Fig. 26, 27, 28 *Squamaster echinatus* (Ringueberg). 26, 27 Proximal and distal portions of abactinal side of ray (x 5). 28 Portion of actinal side (x 5)

The genus *Squamaster* has essentially the same structure as *Hallaster*, in its rays at least. Its adambulacrals, which also bear series of spines along the distal edges, are so nearly semitubular that they leave only a relatively narrow ambulacral groove on the actinal side; and on the abactinal side, at least in the distal half, come almost into contact. As in *Hallaster* they overlap with their distal ends upon the next plates and widen correspondingly in that direction. Their surface where not covered by the spines is finely reticulate. The spines are thin and bristlelike, not thick or even club-shaped as in *Hallaster*. The ambulacrals are opposite, the podial pore or depression is in the outer distal corner, thus giving the plate a boot shape, with a proximal wing or foot that surrounds the pore. They lack entirely the highly projecting node along the ambulacral channel, with its lateral expansions, seen in *Hallaster*, but instead show an oblique naillike projection proximally of the podial opening. On the abactinal side they meet along a sharp groove with raised edges.

The disk is in the type and only specimen folded upon itself and thus not favorable for study. What appear to have been the mouth frames are strongly keeled, V-shaped, elongate ossicles.

The similarity in general habit of the arms and in the series of spines, between this genus and the Devonian *Eoluidia* of Europe is most striking; and we consider it quite probable that the actual structure of *Squamaster* is more like that of *Eoluidia* than the somewhat unfavorable preservation of the type specimen would permit to demonstrate.

Klasmura gen. nov.

Etym. *κλάσμα*, fragment, *ὄψα* tail, starfish

The term *Klasmura* is here proposed for a group of Auluroids, of the order Streptophiuræ, which is represented in our material by two species. These furnish the following diagnosis:

Description. Disk small. Rays five, long, narrow, tapering very gradually, extremely brittle, actinally flat, abactinally rounded or keeled. Dorsal plates subquadrangular, with a median furrow and distal spout-shaped processes, or ears to which are attached the crossbars of the flat side plates. On the latter ride long wedge-shaped or club-shaped hollow spines.

The ambulacrals, which are opposite, are fused but still plainly showing the median line of fusion. They are boot-shaped, consisting of a long central body and a proximal "footlike" process, which extends to the side plates. They are covered by a median row of elliptical ventral plates.

Rays covered entirely by integument that bears dense masses of small unarticulate spines. On the abactinal side the integument is closed; on the actinal is shown a median series of slits, corresponding to the ambulacral furrow.

Oral frame very heavy, apparently with smaller spoon-shaped or divided ossicles in the angles between the oral frames and jaws.

Genotype. *K. mirabilis* Ruedemann.

Remarks. The presence of the ventral plates and the union of the ambulacral ossicles to vertebral ossicles, as well as the absence of a well-developed buccal shield brings this genus into the family Eoluidiidae Gregory. This family, which comprises the most advanced of the Devonian Auluroidea, or Stellerioidea in general, is represented by three genera, namely, *Eoluidia* Stürtz, *Eospondylus* and *Miospondylus* Gregory. Of the first two of these, *Klasmura* is distinguished by the shape of the ambulacral and ventral ossicles, as well as of the lateral shield, although in general habitus it most resembles *Eospondylus* (*Ophiurella* Stürtz). The form of the boot-shaped vertebral ossicles and of the oval to elliptical ventral

or under arm plates, it has in common with *Miospondylus* (represented by *Ophiura rhenana*¹ Stürtz). Sollas and Sollas² who have restudied the type and only known specimen of that species state that these underarm plates are seen only in one arm which has undergone rotation and that "near the disc where the rotation undergone is less, the underarm plates are clearly paired." They consider, therefore, their real nature as problematic. From the identity in shape between the underarm plates of *Miospondylus* as figured by Stürtz and those of our species, we believe that these structures are really present in *Miospondylus* as figured by Stürtz. It is stated by Sollas and Sollas regarding *Miospondylus rhenanus*, that "curious jointed structures, looking like jointed and flattened spines, are present on the lateral aspect of the arms and are named by Stürtz side shields." We consider it probable from this statement and Stürtz's figure 2, that *Miospondylus* had similar wedge-shaped lateral spines as our genus. As in *Klasmura*, so also in *Miospondylus* most parts were originally covered by a heavily armed integument. The differences between *Miospondylus* and *Klasmura*, undoubtedly closely related genera, consist in the presence of jawplates, reported as absent in *Miospondylus* by Gregory, and of the spoonlike structures in the interangles of the oral frames in our genus. Also the absence of dorsal plates, recorded by Stürtz, though still doubtful on account of the unfavorable preservation of the dorsal side, and the presence of "dorsal plates" (or projecting parts of the vertebral ossicles) in *Klasmura* may constitute a difference, for, if present in *Miospondylus* and forming a median prominent ridge, they would probably have become apparent on one of the rays. No traces of a relatively large disk, such as is figured of *Miospondylus*, have as yet been observed in *Klasmura*, but it is possible that this failed of preservation. We believe, that the lateral series of long wedge-shaped, hollow spines with their saddle-shaped interlocking bases will, in time, be found to constitute a character distinguishing *Klasmura* from the other genera of the Eoluidiidae;

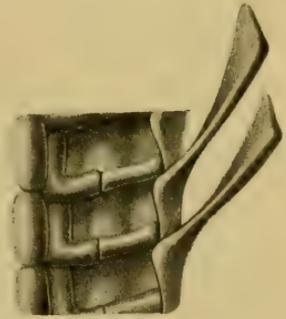


Fig. 29 *Klasmura mirabilis* nov. Diagrammatic view of right half of portion of actinal side of ray, showing ventral plates at left

¹ See Verhandl. naturh. Vereins der preuss. Rheinlande, v. 50, p. 29, pl. I, figs. 1-3. 1893.

² Philosophical Trans. Roy. Soc. of London, ser. B, v. 202, p. 226. 1911-12.

and consider that, in view of these differences, it would be misleading to unite the form here described with *Miospondylus*, especially until the characters of that genus still in doubt have been cleared up.

***Klasmura mirabilis* nov.**

Plates 20-22; plate 23, figures 1-7

The Naples beds (West Hill flags) of the Deyo Basin near Naples have afforded to Mr D. Dana Luther, an abundance of ray fragments of an auluroid, besides numerous crinoids and several species of a *Urasterella*. This Devonian ancestor of the brittlestar was so brittle that, though we counted hundreds of rays and fragments of rays, there were only two disks found, one with no rays left and the other with but two fragmentary rays remaining.

Description. Specimens small, largest ray (fragmentary) observed, 41 mm long and 3 mm wide; disk circular, small (one 4.5, the other 6 mm in diameter). Rays slender, flexuous and extremely brittle; flat or slightly concave on the actinal side and with a median crest bordered by flatter margins on the abactinal side. Dorsal plates (dorsal sides of thickened ambulacrals) occupying about one-half of width of ray; separated by median groove with fine central suture; somewhat bifurcated at distal end; the outer prong developing into a longer spoutlike process. Ambulacral ossicles elongate, boot-shaped, the "shaft" straight and about as long as the "foot" or longer (see pl. 22, fig. 1); about thirteen to fifteen in 10 mm in the proximal portion of rays. The variable aspect of the ambulacrals in the specimens (see pl. 22, fig. 5, 8; pl. 23, fig. 3) shows that they were on the ventral side distinctly fused, leaving but a slight depression in the median line (pl. 23, fig. 3). The ambulacral canal was well inside. On the lower surface, also the foot or wing and the "body" of the ambulacrals were separated by distinct grooves (see pl. 22, fig. 5), giving the impression that these ossicles consisted of two bars, a longitudinal and a transverse one. The median furrow is covered by a series of oval, thick (conical) ossicles, the *ventral plates*, which are broadest distally and not in contact with each other, leaving small interspaces (see pl. 22, fig. 8; pl. 23, fig. 4). They are mostly lost (pl. 22, figs. 5, 6 etc.) exposing the suture of the vertebral ossicles or even the ambulacral channel, where the ray is slightly weathered (see pl. 22, fig. 6).

The side plate consists of a flat subquadrangular body, bearing a prominent crossbar which connects with the wing of the adjoining

ambulacral and thereby delimits the subquadrangular lateral depression in which the ambulacral pore and the podial cup are found. To each column of side plates are attached a series of large, wedge-shaped spines, whose bases are widened laterally and saddle-shaped, riding on the side plates; and at the same time extended into a process proximally (see pl. 22, fig. 3; pl. 23, fig. 5) by which they interlock. The spines were concave or flat on the proximal side and somewhat convex on the other. Their distal portion was apparently hollow (see pl. 22, fig. 5; pl. 23, fig. 6) the distal extremity truncate with indications of a cuplike depression in some specimens. Both the base and the end of the spines are furnished with dense masses of fine club-shaped bristles or spines, apparently paxillae (see pl. 22, fig. 1; pl. 23, figs. 1, 6, 7). The lateral spines reach 3 to 4 mm in length, the secondary spines, 1 to 2 mm. The abactinal area of the disk is covered by irregular larger plates (see pl. 22, fig. 2). The oral armature consists of heavy arched frames, bearing apparently thick teeth. The details of the armature are not clearly recognized, owing to the circumstance that the ossicles were only seen from the dorsal side.

The disk and both actinal and abactinal sides of the rays are covered by a thick integument (see pl. 22, figs. 7 and 8; pl. 23, fig. 2) which on the abactinal side is densely set with nonarticulate spines (see pl. 23, fig. 1). On the ventral side the integument leaves in the median line a series of slits open with thickened margins (see pl. 22, figs. 7 and 8) and what may have been rows of pores (podial pores?) or spine-bases. The bases of the large lateral spines were apparently also covered by this integument (see pl. 22, fig. 7).

Horizon and locality. Naples beds (West Hill flags), gully of Italy Hollow, Yates county, N. Y. and Deyo Basin near Naples, N. Y.

Remarks. The material of this species consists of five drawers, all taken from two adjoining layers. The species must have been very abundant at the site for we counted over twenty fragmentary rays on one slab not one-half of a square foot in size; but owing to its remarkable brittleness it is impossible to obtain entire specimens. Many of the broken rays are rolled up into circles. The strange aspect of the rays is due to the strong rows of lateral spines and the spinous integument. The dense bundles of large paxillae on the ends of the spines must have still increased the peculiar aspect of the form (see restoration, plate 21). A similar integument is also known from other auluroids, as is evident from Stürtz's work on the Bundenbach Stelleroidea.

Klasmura clavigera sp. nov.*Plate 23, figures 8 and 9*

The collection of starfishes secured by Mr D. D. Luther from the West Hill flags (Gardeau beds of the Portage group) at Deyo Basin, south of Naples, contains a ray and a fragment of another that exhibit so striking characters that it is safe to describe their species from them; for, on one hand, the species can always easily be recognized from the characters known at present, and on the other, the rays expose their oral side so that the genus also can be determined with certainty.

This starfish was a small form. The ray which is fairly complete is about 15 mm long and but 1 mm wide at the widest part, and each column contains more than forty (about forty-two) ossicles; the ray is very slender, narrow at its base, then widening gradually to twice its initial width at about one-third its length,



Fig. 30 *Klasmura clavigera* nov. Disagrammatic view of portion of actinal side of ray; ventral plates lacking

and then again tapering to the very slender distal extremity. The ambulacra are opposite, short, boot-shaped with relatively short, pointed "foot," or wing; the opposite ossicles apparently closely united and separated by a very narrow ambulacral channel or furrow. They number thirty in 10 mm. The adambulacra are in the more complete ray seen only in their outer projecting edges, while in the fragment (see pl. 23, fig. 8) they are distinctly recognizable as rather broad transverse plates,

which are opposite to the ambulacra, and with them surround the podial openings, situated between the distal portions of the ossicles. The outer edges of the adambulacra are distinctly elevated; their margin is produced outward a little below the distal transverse suture and there bears a long, strongly clavate forwardly directed spine with saddle-shaped basis.

The characters by which this form is most distinctly marked are the boot-shaped form and opposite position of the ambulacral plates and the corresponding opposite position of the adambulacra or side plates; and finally the clavate shape of the spines. The form and opposite arrangement of the ossicles suggest relationship to *Hallaſter forbesi* (Hall), but the form of the side plates with their saddle-shaped interlocked spines refers the species distinctly to *Klasmura*; although we have seen neither the ventral

plates nor spinose integument nor dorsal plates. From the genotype, *K. mirabilis*, this form is distinguished by its much smaller dimensions, the ray being but one-third as wide and the ambulacral ossicles numbering twice as many (thirty in 10 mm) as in *K. mirabilis*.

Lingula semina nov.

Plate 24, figures 5 and 6

Description. Shell small, flat, widest in middle, elongate-elliptical; one-half times longer than wide; anterior and posterior extremities subequally and acutely rounded; posterior somewhat more acute than the anterior; lateral margins nearly parallel and but slightly curved. Surface flat; projecting at beak, whence a widening low ridge extends anteriorly and fades out toward the middle. Brachial valve relatively wider and its posterior margin more obtuse. Exfoliated pedicle valves show a broad median longitudinal depression (septum or progressive muscle-scar) that extends nearly the full length of the valve; and alongside of this in the posterior region the faint depressions of the progressive lateral muscle-scars (see pl. 24, fig. 5). Shell thin, light colored, phosphatic-calcareous, with little carbonaceous matter; surface finely striated. The pedicle valve measures about 9 mm in length and 5 mm in width.

Horizon and locality. Pittsford shale, Pittsford, Monroe county, N. Y.

Remarks. This pretty little *Lingula* covers some surfaces of the shale and also of the waterlime bands in wonderful profusion. With its light yellow color and elongate-elliptical shape it greatly resembles melon or cucumber seeds. *L. semina* resembles *L. vicina* in outline and size but differs distinctly in being flat and is relatively longer and narrower. Nevertheless the two are similar enough to suggest that the younger might be a derivative or mutation of the earlier Pittsford form, which returned after the uncongenial conditions of the Salina sea had changed.

Lingula testatrix nov.

Plate 24, figures 7 and 8

Description. Valves of median to small size, of oblong outline, two-thirds as wide as long at the widest place, which is near the anterior margin. The latter straight or but little convex, abruptly

curving into the lateral margins which, in the pedicle valve, are converging and little curved; the posterior margin is, in the pedicle valve, acutely rounded. The brachial valve approaches an ellipse in outline, the anterior and posterior margins are subequally rounded, and the lateral margins subparallel. Both valves are flat, the pedicle valve with a low elevation that begins at the apex, broadens rapidly and merges into the general surface about the center of the valve. The brachial valve is more evenly rounded in the posterior half; the anterior half is also quite flat. The pedicle valve shows indications of a low septum extending halfway to the margin, the brachial valve one reaching two-thirds the length of the valve. The growth-lines are fine, unequal and little prominent.

Measurements. Length 12 mm, width 8 mm.

Horizon and locality. Bertie waterlime, Litchfield, N. Y.

Remarks. This species is rather common in the Eurypterus beds about Litchfield. We have nine specimens in the space of 3 square inches. It has also been cited as *L. rectilatera* Hall¹ from the Bertie waterlime at Buffalo. The latter species is, however, a type of the New Scotland limestone and while similar, differs distinctly by its squarish posterior end. The occurrence of our species in the Eurypterus beds of the Bertie waterlime together with other marine forms testifies to the marine sedimentation of the beds, hence its name.

Lingula vicina nov.

Plate 24, figures 11 and 12

Description. Shell small, elongate-elliptical, high, two-thirds as wide as long, widest at beginning of the anterior third. Anterior margin well rounded, lateral margins converging in the posterior half, slightly convex, posterior margin acutely rounded. Brachial valve relatively broader and less acute posteriorly. Valves high for a *Lingula*, with a broad median ridge extending two-thirds of the length of the valve. Septum on pedicle valve broad, traceable nearly the full length of the valve, that of the brachial valve narrower and shorter. Growth-lines very fine, distinctly bunched in varices, giving the shell a more coarsely striated appearance.

Measurements. Average size 9 by 5.5 mm; the largest specimen observed measures 10 by 6 mm.

¹I. P. Bishop, Geology of Erie County, N. Y. 49th Rep't N. Y. State Geol. for 1895, p. 341. 1898.

Horizon and locality. Lowest Bertie waterlime at Farmer's Mills, near Utica. It is there associated with *Eusarcus vaningeni* and *Orbiculoidea molina*. Both brachiopods are extremely abundant on the slabs before us, demonstrating that the beds where the peculiar *Eusarcus vaningeni* occurs are undoubtedly of marine origin.

Remarks. *Lingula vicina* is readily distinguished from *L. testatrix* which occurs higher up in the Bertie waterlime at Litchfield, by its smaller size, rounded anterior extremity and greater height of shell.

***Lingula subtrigona* nov.**

Plate 24, figures 9 and 10

Description. Shell of medium size; very flat; of broadly subtriangular outline; length and width equal; greatest width one-third of length from anterior margin. Shell obtusely angular in posterior half with straight margins and rounded apex; well rounded in anterior half where lateral and anterior margins form a broad, semioval curve. Pedicle valve with slightly elevated broad beak, which is a little forward of posterior margin and from it a low elevation extends halfway to the anterior margin. The brachial valve is entirely flat. The cardinal region shows a faint pedicle groove only on the inside. The surface is remarkable for the wide, flat, fairly smooth interspaces, with very faint growth-lines, between sharply elevated, filiform varices. Where the shell is exfoliated, radiating lines are seen.

Horizon and locality. Manlius limestone on Frontenac island near Union Springs. According to Mr Luther's label, the specimens are from the "waterlimes below horizon of blue limestone on Frontenac island, from farm of John Wooley, east of road from Union Springs to Cross Roads Station, 3 miles south of latter."

Remarks. We have only two specimens of this *Lingula*, which is at once distinguished from the congeners in both the Manlius and Bertie waterlimes by its broad, subtriangular shape and the character of the surface sculpture. It is, however, very similar to the *L. perovata* Hall, from the Clinton beds.

***Lingulasma* (?) *elongatum* nov.**

The writer has, in New York State Museum Bulletin 162, pages 41 and 42, recorded from the Schenectady beds — a shaly development of the Trenton limestone in the lower Mohawk and middle

Hudson valley—a very varied fauna of some thirty species, the most striking elements of which are new eurypterids (nine species). There were also some mollusks and half a dozen species of brachiopods. To the latter we refer the peculiar and rather puzzling fossil here described, for it resembles most nearly the internal mold of the pedicle valve of a *Lingulasma*. Its posterior portion is unfortunately broken.

Description. The valve is elongate linguiform in outline, widest in the posterior third and somewhat contracted anteriorly of the middle. The platform is distinctly shown. Its central part appears



Fig. 31 *Lingulasma*
(?) *elongatum* nov.
Holotype. Natural size

in the mold as a broad pentagonal shield, which in the middle is divided by the low, broad, rounded septum that extends to the anterior third of the valve. Along the anterior margin of the platform a triangular space is depressed or beveled, indicating that this part of the platform was slightly elevated above the remainder. The lateral muscular scars are distinctly set off along both lateral margins of the platform and beyond this is a convex rim, the mold of the concave margin of the valve. The anterior part of the mold exhibits a flat margin, probably the impression of the thick valve, which, like all calcareous shells in shale,

has been completely dissolved away, leaving only a tenuous carbonaceous film. The anterior half of the mold is uniformly convex, with the exception of a faint depressed transversal band, probably due to the gerontic thickening of the shell.

The valve is about 33 mm wide in the contracted part and about 39 mm in the widest. Its length, so far as preserved, is 52 mm.

Horizon and locality. Schenectady beds at the Dettbarn quarry near Schenectady, N. Y.

Remarks. From its two congeners, *Lingulasma schucherti* Ulrich and *L. galenaense* Winchell & Schuchert, our species is readily distinguished by its more elongate form, larger size, posterior widening and the peculiar shape of the anterior part of the platform.

Orbiculoidea molina nov.

Plate 24, figures 1-4

Description. Valves small, subcircular, flat. Apex of pedicle valve at center or anteriorly (to one-fourth of radius) of it, little prominent; surface sloping fairly uniformly to all sides, though in most specimens through pressure the valve has been flattened and the apex forms a small prominent knob, projected forward. The pedicle slit extends from apex to margin, is depressed and marked with radial lines, when seen from the outside; from the inside it appears as a fusiform semiconical prominence. The brachial valve (probably larger) has the same outline and elevation as the lower valve; the apex is in most specimens somewhat nearer to the anterior margin. The surface shows fine concentric growth-lines which toward the margin become increasingly lamellose, coarser and irregular in size.

Measurements. Largest diameter of brachial valve observed, 7.7 mm; of a pedicle valve, 7 mm in longitudinal direction and 6 mm transversely.

Horizon and locality. Lowest Bertie waterlime (probably of Pittsford age) at Farmer's Mills near Utica, in association with *Lingula alta* and *Eusarcus vaningeni*.

Remarks. While this small orbiculoid brachiopod has been found only in the horizon with *Eusarcus vaningeni* at Farmer's Mills, it is there as abundant as the *Lingula*; there were counted seven specimens in the space of a square inch. On the same slab in the space of a square foot remains of three *Eusarci* were scattered.

Hall described as *O. vanuxemi* a form from the "Waterlime group" which may have come from the Bertie waterlime, but more probably is derived from the Manlius limestone or another formation of the Helderberg group. At any rate our species differs from it in its smaller size and relatively smaller elevation and the lack of the radiating lines. It is, however, quite similar to *O. numulus* Hall and Clarke, a Manlius type, in outline and elevation. The latter form differs in being larger, having coarser striae and a deeper and shorter pedicle groove in the exterior aspect.

The writer has also seen in the Museum of the Buffalo Society of Natural Sciences a large *Orbiculoidea*, from the Bertie waterlime, as yet undescribed but already cited in several fossil lists as *Orbiculoidea* sp.

Dinobolus canadensis (Billings)*Plate 24, figures 13 and 14*

The Watertown limestone of the Black River group at Watertown, N. Y., has furnished us a well-preserved mold of the brachial valve of a *Dinobolus* that is identical with *D. canadensis* (Billings). It possesses the characteristic subpentagonal outline and oblong platform with anteriorly produced septum. The crescents are but faintly developed. The specimen is smaller than the mature types figured by Billings, though agreeing in that particular with one of his figures. On account of this smaller size, a comparison with *D. (?) parvus* (Whitfield) from the Galena of Wisconsin and Minnesota might suggest itself, but that form as figured by Schuchert (*Paleontology of Minnesota*, v. 3, pt 1, p. 356. 1895) has a broader and more circular outline and lacks the distinct crescents. *D. canadensis*, according to Billings, occurs abundantly in the Black River beds at Pauquette Rapids in lower Canada, but has not been as yet recorded from the Black River beds of New York.

Protospira minuta nov.*Plate 25, figures 1 and 2*

Description. Shell minute, spiral, turreted, slender, solid, consisting of about five or six volutions. Whorls gently convex, sutures moderately deep; body whorl not larger than the others. Aperture crescent-shaped, through a lobelike extended outer lip. Inner lip formed by the penultimate volution. Surface with few slightly sigmoidal growth-lines, which are deepest in the sutural grooves. Length of shell 6.5 mm.

Horizon and locality. Hoyt (Ozarkian) limestone, Hoyt quarry, town of Greenfield, Saratoga county, N. Y.

Remarks. This remarkable, small gastropod was found by the author in one specimen in the oolitic limestone of the Hoyt quarry. It is there associated with other peculiar gastropods, namely, *Triblidium cornutaforme* (Walcott), *Pelagiella minutissima* and *hoyti* (Walcott) and *Matherella saratogensis* (Walcott). It is needless to say that all these Cambric gastropods are minute and extremely primitive forms. Yet they exhibit already the different types of convolution observed in their descendants, *Pelagiella* being coiled in one plane, *Matherella* in a low, broad, sinistral spiral, and *Protospira* in a high, turreted, dextral spiral.

In general aspect our species is comparable to certain types of *Loxonema*, as *L. murrayanum* Salter (Canadian Organic Remains, decade 1, p. 31, 1859), but aside from the fact that true *Loxonema* may not occur below the Silurian, that genus typically possesses a shallow apertural canal which is absent in our primitive form. There is no trace of a slit in the aperture or of a slit-band on the whorls. This excludes it from the *Murchisonias* to which it bears some resemblance. The lobelike extension of the outer lip is a peculiar character which, however, is not above suspicion since only one specimen is available and this feature may be due to an accident of preservation. A similar though less developed lobe is figured by Barrande of the Devonian *Scollionostoma bohemicum* (Syst. Sil. de la Boh., v. 4, pt 1, pl. 60, fig. 31) and thickened outer margins of the aperture are characteristic of the *Volutidae*, as *Marginella*, *Mitra*, *Athleta* etc. At any rate, this little Cambrian gastropod is not referable to any of the genera of the Ordovician, as far as we are aware.

Diaphorostoma sp.

A very large *Diaphorostoma* occurs in the Bertie waterlime of Litchfield, N. Y., in association with *Eurypterus remipes*. The material, however, is not sufficient for a specific diagnosis.



Fig. 32 *Diaphorostoma* sp. Fragment of volution. Bertie waterlime, Litchfield, N. Y.

Hormotoma gregaria nov.

Plate 25, figures 3 and 4

Description. Small, moderately slender shells, of five to eight volutions. Apical angle rather wide. Volutions rounded, less convex above than below, with a slight angulation. Sutures simple, deep. Slit-band rarely observable on the exfoliated, compressed specimens, rather wide, bounded by two fine raised lines. Growth-lines fine, apparently slightly convex forward between suture and slit-band and curving forward in a concave line below the slit-band. Aperture rounded, about as wide as high, a little produced below. Inner lip not distinctly observed.

Measurements. Length of shell 9 to 16 mm. Apical angle about 23° .

Horizon and locality. In the lower Bertie waterlime, 5 feet above gypsum bed, at Sweet Quarry, Marcellus, N. Y., associated with *Eurypterus remipes* and *Lingula testatrix*.

Remarks. This small gastropod appears in densely crowded flocks on the otherwise barren bedding planes of the waterlime. It is similar to *Hormotoma minuta* Hall, a type from the Manlius limestone of New York and the lower Monroe of Michigan, but is somewhat larger, less slender and possesses more rounded volutions.

***Pterinea poststriata* nov.**

Plate 25, figures 5-7

Description. Strongly inequivalve. The left valve highly convex, the right depressed convex to nearly flat. Very inequilateral, strongly oblique. Anterior height by one-half smaller than posterior height. Beak about one-fourth of length of valve from anterior extremity, prominent and projecting beyond hinge line in left valve, depressed and not projecting beyond hinge line in right valve. Cardinal margin straight and extending nearly the whole length of the valve, anterior ear small, narrow, anterior extremity rounded. Anterior margin slightly arcuate, curving obliquely to well-rounded basal margin. Posterior margin very obliquely truncate, strongly curved. Umbonal ridge high and distinct on left valve, its highest part about one-third of its length from the beak, vanishing toward the postero-basal margin. On the right valve only a low, broad umbonal ridge extends halfway toward the postero-basal margin; the rest of the valve is flat. Mesial sulcus undefined. Surface with rather coarse growth-lines and concentric varices and fine radiating lines on the posterior half, extending over the posterior wing and to the crest of the umbonal ridge or a little beyond. Anterior muscle impression about half the size of the posterior.

Measurements. Largest specimen 33 mm long, posterior height 24+ (about 30 mm), anterior height 15.5 mm, thickness about 4 mm. Most specimens are smaller. A well-preserved right valve measures 23 mm in length, 16 mm in posterior height, 11 mm in anterior height.

Horizon and locality. Pittsford shale at Pittsford, N. Y., in both the shale and the waterlime bands where it occurs abundantly.

This species has been compared by Sarle (Rep't N. Y. State Pal. for 1902, p. 1085, 1903) with *P. emacerata* of the Rochester shale but is stated by him to be a little more rhomboid and convex.

It has also finer longitudinal striae which do not extend to the anterior portion of the valve and the extremity of its posterior wing is not produced but truncated.

Ctenodonta ? salinensis nov.

Plate 25, figures 8 and 9

Description. Shell small, inequilateral, moderately elongate-ovate, the length surpassing the height by one-half, quite flat. Beak widely obtuse, projecting a little beyond hinge line, far forward (about one-third of length from anterior extremity). Dorsal line convex, sloping downward from beak to the narrowly rounded posterior extremity. Anterior end considerably wider than the posterior, and anterior margin more fully rounded. Ventral margin but gently convex. An obscure umbonal ridge with its shoulder close to the dorsal margin, is traceable nearly to the posterior margin. Above it a narrow impressed strip is seen along the dorsal margin. The surface is flat, sloping from the umbonal ridge fairly evenly to the ventral and anterior margins. Fine growth-lines with a few coarser ones are observable on the whole surface. The hinge and the muscle impressions have not been observed.

Measurements. Length of average shell 12.5 mm, height 8 mm, thickness about 1 mm.

Horizon and locality. Salina beds at Bull's quarry, town of Lenox, Madison county.

Remarks. The sole interest in this insignificant little pelecypod consists in its occurrence in the Salina beds close to the gypsum beds. The Salina beds, where the salt-pan conditions that began in the Pittsford shale and waterlime reached their climax and led to the deposition of the well-known salt and gypsum deposits of the State of New York, appear to the collector as absolutely barren of fossils. It is true, Prof. James Hall¹ described in 1851 eight small marine fossils from the "Onondaga Salt Group" of Wayne county. Mr C. A. Hartnagel, however, states that these were obtained from a Guelph boulder in the Salina belt. As a matter of fact they are Guelph species. *Ctenodonta ? salinensis*, however, is a true Salina species. It must have locally been quite common, for we have before us, on a slab measuring 3 by 4 inches, some eighteen specimens. Mr Hartnagel states that he has also

¹ Pal. of New York, 2:340. 151.

observed a *Leperditia* in the Salina beds, and wormtubes and tracks are seen on the other side of the slab with *C. salinensis*. These are the only signs of organic life in the Salina beds of which I am aware, and even this little life seems out of place considering the conditions indicated by the repetition of salt and gypsum beds, hopper-crystals etc. Still, even today organic life in the shape of a few small pelecypods persists in the chain of "shotts," lakes in the south of Tunis and Algiers, some of which are so intensely saline that caravans pass over the salt crusts covering them.

The species here described is, from its general outline, probably a *Ctenodonta* and similar to representatives of that genus in the preceding Niagaran group and the later Cobleskill limestone.

***Orthoceras vicinus* nov.**

Plate 25, figure 10

Description. Slender orthoceracone of medium to large size; rate of expansion 10 mm in 130 mm of length. Septa closely arranged, four in 10 mm, where the conch is about 20 mm wide. Camerae shallow, nine times as wide as deep. Living chamber long. Aperture not observed. Siphuncle small, centren, segments cylindrical, apparently empty. Surface sculpture not known.

Horizon and locality. Bertie waterlime, 5 feet above gypsum in Sweet Plaster quarry at Marcellus, N. Y.

Remarks. This simple *Orthoceras* is mainly interesting on account of its occurrence in the Bertie waterlime in association with the eurypterids. From this it derives its name. The slow rate of growth, suggested by the slender form and very shallow camerae, is perhaps an indication of little favorable conditions for the growth of these typically marine creatures. The close arrangement of the septa is the most striking feature of the species.

***Gomphoceras osculum* nov.**

Plate 27, figures 10 and 11

Description. Small cyrtoceracone, of slight curvature, but very rapid expansion, the greatest width of the living chamber (15.5 mm) being almost one-half of the length of the conch (28 mm). Section oval, contracting slightly more toward the inner (ventral) side; major axis about twice as long as minor. Living chamber nearly half the size of the conch (16 mm), about as wide (at the aperture) as long, strongly convex on exterior side, slightly

convex or nearly straight on the inner margin. Aperture slightly contracted, apertural margin raised a little on outer side; the hyponomic sinus produced spoutlike and distinctly set off. Camerae shallow and crowded; about eight times as wide as deep. Siphuncle exogastric, small (about 1 mm wide), nummuloidal.

Horizon and locality. The label is "Salina under the bridge at Morganville, N. Y." Mr C. A. Hartnagel considers this bed as belonging to the Cobleskill.

Remarks. We have a small slab with three specimens before us, one of which shows gerontic features in the thickening of the apertural margin, indicating that it was a small species. The most remarkable feature is the spoutlike protruding hyponomic sinus, while the brachial area seems to be but little contracted. Like hyponomic sinuses have been figured by Barrande of species of *Phragmoceras* (for example, *bolli*) and *Hexameroceras* (for example, *pollens*, *panderi*). The siphuncle is exogastric, excluding reference to *Phragmoceras* to which the species otherwise would seem to be related by the character of the hyponomic area.

Phragmoceras accola nov.

Plate 26, figures 1-5

Description. Conch of large size for *Phragmoceras*; a compressed cyrtoceracone, that is, but slightly curved; expanding very rapidly. Section, as far as recognizable in the compressed condition, a long oval, wider on the dorsal (external) side and possibly somewhat angular on the inner side. Living chamber broadly subquadrangular, one-fifth wider than long, longer on the dorsal side by about one-eighth, the basal suture nearly straight transverse, the dorsal margin slightly convex, the ventral margin projecting in the proximal two-thirds, the distal third drawn out into a spoutlike hyponomic sinus. The apertural margin projecting slightly forward in middle. The aperture was apparently much contracted in the middle, leaving a relatively small subcircular or elliptic opening (brachial area) at the external side and a long, narrow, hyponomic sinus at the ventral side. Sutures fairly straight transversal, or but slightly curved forward in the middle in earlier portion of conch. They are closely arranged, the depth of the camerae being about one-eighth of the width or less. The siphuncle has not been observed in the type specimen.

Horizon and locality. Bertie waterlime at Schooley's farm, Crane's Corners, town of Litchfield, Herkimer county, N. Y.

Sections which probably belong to this species have also been collected in the lowest Bertie at Crossroads near Union Springs, N. Y.

Measurements. The entire length of the specimen is 135 mm, that of the living chamber 79 mm, its width in the middle about 103 mm. Sutures in middle of mature portion of conch about 8 mm apart.

Remarks. This rather incompletely preserved specimen has been described chiefly on account of its interesting occurrence in the Eurypterus beds of the Bertie waterlime. It is there associated on the same slab with *E. remipes*.

The specimen is a gerontic individual, as shown by the remarkable crowding of the septa behind the living chamber. From the fragments of the septate portion of the conch, and especially from the rather strong divergence of the sutures, it can be inferred that the conch was typically breviconic and expanded very rapidly.

The form of the living chamber invites comparison with *Phragmoceras nestor* Hall, *P. ellipticum* Whitfield, that of the curvature of the conch with *P. hoyi* Whitfield and *P. angustum* Newell, all from the western Niagaran, and also with *P. hector* Billings from the Guelph. From the first-named species it is distinguished by the larger size and the greater length of the living chamber along the ventral margin. It is also to be noted that the latter margin is concave in *P. nestor* and bulging outward in *P. accola*. All these differences could be attributed to differences in age, for *P. nestor* could be well considered as a younger individual of *P. accola*, were it not that the drawing of the type¹ showed also an extremely shallow last chamber indicating old age. *P. ellipticum* has a living chamber which, while attaining the size and general outline of that of *P. accola*, possesses straight or, according to Kindle's figure,² even a concave inner margin. *P. hoyi* has a curvature very much like our species and the younger specimens of *P. accola* may well have resembled it, but its living chamber is relatively longer, and *P. angustum*, as described by Kindle, has also an elongate living chamber and its sutures are also much more and differently curved.

¹ James Hall. Account of Some New or Little Known Species of Fossils from Rocks of the Age of the Niagara Group. 20th N. Y. State Mus. Rep't, 1867, p. 348, fig. 7.

² E. M. Kindle. The Stratigraphy and Paleontology of the Niagara of Northern Indiana. 28th Annual Rep't Dep't of Geol. and Natural Resources of Indiana, 1903, pl. 19, fig. 5.

We have referred this species to *Phragmoceras*. The term *Phragmoceras* has been used rather loosely for *breviconic*, curved compressed shells with contracted apertures and protracted hyponomic sinus. The genus as restricted by Hyatt comprises, however, only species with an undivided brachial aperture. That our species possessed such a one, is shown by the specimen reproduced in plate 26, figure 3.

While plate XXVI, figure 1, is to be considered as the holotype of the species, we figure with this species several fragments of smaller specimens from the type locality. One, plate XXVI, figure 4, may well be a younger individual of that form, from the shape of the living chamber. Corresponding to its growth stage the aperture is still wide open. Plate XXVI, figures 2 and 5, are two septa showing the sections at the corresponding growth stages and the position of the siphuncle; the last figured specimen retains a segment of the siphuncle which is nummuloidal. There are still other specimens indicating that this species is common enough in the waterlime beds of Litchfield to be considered as having been an associate of the eurypterids in the fauna of the Bertie waterlime sea, as indicated by the specific name given this interesting form.

***Hexameroceras microstoma* nov.**

Plate 27, figures 2-9

Description. Conch a small arcuate *brevicone*; transverse section broadly oval with little difference (one-tenth) in major and minor diameters; greatest width nine-tenths of the thickness and situated halfway between dorsal and ventral sides or slightly toward dorsal side; siphuncle ventral, submarginal.

Living chamber long for a *Hexameroceras* (about six-sevenths of thickness), strongly curved on dorsal side, with less convex margin on inner, ventral side. Aperture but slightly sloping from brachial area to hyponomic area. Lateral sinuses of brachial area decreasing in size from first to third; third pair very small. Hyponomic area consisting of narrow slit, occupying about half of aperture and oval ventral opening whose edges project spoutlike.

Camerae shallow, depth about one-tenth of greatest width. Sutures fairly straight transverse, with a low, narrow saddle on the ventral side and a broad, low saddle on the dorsal side. Septa shallow, their depth about equaling that of the camerae.

The surface sculpture has not been observed.

Measurements. Largest (a gerontic) specimen (living chamber and six chambers) measures 39.5 mm in length, its living chamber

26.5 mm, an average specimen (living chamber and four camerae) is 35 mm long, its living chamber is 23.5 mm high and 24.1 mm thick; the sutures are 3 mm apart; the siphuncle is 2.5 mm wide; the two diameters of the section measure 13.5 mm and 15 mm respectively. In another specimen the living chamber is 22.5 mm long and 19.5 mm thick.

Horizon and locality. Lockport (Guelph) limestone. Niagara Falls.

Remarks. All American species of *Hexameroceras* have been obtained in the Niagaran; *H. herzeri* Hall and Whitfield in that of Ohio, *H. delphicolum* and *cacabiforme* Newell in Indiana. *H. microstoma* is readily distinguished from the first of these western species by the horizontal course of the hyponomic area of the aperture, which in *herzeri* slopes rather steeply downward. Also the living chamber of that form is relatively much shorter. Both *H. delphicolum* and *H. cacabiforme* are larger types with relatively shorter living chambers. *H. delphicolum* differs also in having strongly curved suture lines; in *cacabiforme*, which is characterized by its very short living chamber, the rest of the conch is unknown.

The geologic distribution of the genus *Hexameroceras* is of especial interest. The whole series of the family Trimeroceratidae Hyatt, namely, *Mandaloceras*, *Hemiphragmoceras*, *Trimeroceras*, *Tetrameroceras*, *Pentameroceras*, *Hexameroceras*, *Septameroceras* and *Octameroceras*, form a sudden outburst of peculiar aberrant breviconic cephalopods with strongly contracted apertures and highly differentiated brachial and hyponomic areas. They are entirely restricted to the Middle Silurian, the Bohemian types all occurring in stage E and the American species (as those of *Hexameroceras* named above, *Trimeroceras gilberti* Kindle and *Trimeroceras wabashense* Newell, the *Septameroceras septoris* Hall, *Pentameroceras mirum* (Barrande) Newell and a *Septameroceras* from the Pittsford shale) being all restricted to the Niagaran, with the exception of the specimen from the Pittsford shale which immediately follows the Niagaran. They represent, therefore, a typical aberrant group of very rapid development through stages with increase of the number of arms and of corresponding sinuses in the aperture from 2 to 8; and equally rapid extinction. It would be likewise interesting if one could trace the external influences, if there were such, that led to the rapid development of this group.

Septameroceras (?) sp.*Plate 27, figure 1*

Among the fossils cited from the Pittsford shale and intercalated dolomite layers by Mr Sarle¹ is a "pentalabiate Gomphoceras." The specimen to which Mr Sarle obviously had reference is here figured merely to establish the occurrence of cephalopods of the Septameroceras or Pentameroceras type in that formation. The dorsal margin of the brachial area is not sufficiently well preserved to indicate whether it was concave or also provided with lobes. Apparently there were two small lobes there, making the form transitional between Pentameroceras and Septameroceras.

Protonympha marcellensis nov.*Plate 29, figure 6*

Prof. Charles S. Prosser found in a concretion in the Marcellus shale on the south side of Bennett hill, 1½ miles southeast of Clarksville, the fossil here described. It consists of a curved, flattened, lanceolate body which is composed of about forty-eight segments that decrease in size toward the pointed extremity of the fossil. The segments are annular and separated by a distinct linear depression. On the concave margin scales that closely overlap posteriorly and correspond to the annulations in number are seen. Near the blunt extremity of the fossil they are lacking, probably only through an accident of preservation or a twisting of the body. Where the scales are broken away, darker, circular, clearly outlined scars with a central depression are observed. The opposite margin is entirely unbroken and without appendages. At the blunt end the segmentation terminates abruptly and the extremity itself is formed by an elongate semioval body, on both sides of which are observed falcate appendages that are directed opposite to the scales on the segments. Posteriorly there extends from this terminal body a distinct rounded ridge along the median line for about one-fourth of the length of the fossil, where it abruptly changes into a shallow, median depression. Over the segments there are scattered many irregularly curved filiform markings suggestive of setae.

The taxonomic position of this puzzling fossil will probably not be conclusively determined until more material is obtained. We have

¹ Rep't N. Y. State Pal. for 1902, p. 1085. 1903.

only the mold and cast of a single specimen before us. The first impression which it gives is that of a badly flattened column of plates of one of the Paleozoic barnacles with a long series of overlapping plates as in *Lepidocoleus*. On closer study it becomes evident, however, that the main part of the body is simply segmented without overlapping plates, while on one side there is attached to the segments a series of overlapping scales, under an angle different from that of the annular segments. These scales overlap in a different direction from the plates of a *Lepidocoleus*, that is, outward, and the surface of our fossil lacks entirely the characteristic surface sculpture of the plates of the *Lepidocoleidae*. On the other hand, the segmented surface exhibits a great number of setae, directed backward, and the blunt end is formed by an oval plate. We believe that this structure can be properly referred to the chaetopod described by Doctor Clarke as *Protonympha*¹ from the Portage group at Naples, N. Y., by assuming that our specimen is resting on its side and therefore shows on the left (dorsal) side the elytra or dorsal scales and along the median line the setae while the right (ventral) side is smooth. The body was then probably cylindrical instead of flat as in the type species of *Protonympha*. The blunt extremity is apparently the head, the body being twisted so that the ventral side of the head is shown. This view is supported by the disappearance of the elytra toward the head because they are turned to the under (dorsal) side of the fossil. On both sides of the head and the segments behind it are seen falcate appendages suggesting the jaws and bristles of such rapacious *Polychaeta* as *Nereis*. Whether the scales correspond to the elytra of such polychaetous annelids as the subfamilies *Hermionina* and *Polynoina* embrace, we are not prepared to say, especially for the reason that they seem not to be alternating on the right and left sides of consecutive segments as in the recent worms. On the other hand the circular scars on the segments recall very strongly the attachment places of the elytra as seen in the recent *Polychaeta*. Likewise, the lateral setae are a distinct character, finding its recent duplication in the same annelids. The jaws of the head again suggest relationship to other *Polychaeta*, notably the nereids. It is therefore probable that this Paleozoic worm is not in close taxonomic relationship to any of the recent orders of the *Polychaeta* but represents an early synthetic or aberrant, entirely extinct type.

¹ John M. Clarke. Some Devonian Worms. Rep't N. Y. State Pal. for 1902, p. 1234. 1903.

Serpulites McLeay, **Sphenothallus** Hall, **Enchostoma** Miller & Gurley, **Conularia** Ruedemann and **Torrellella** Holm.

The shales of the Paleozoic formations afford from time to time quantities of long, flat-tubular bodies with thick tests of dark brown to black glistening color and transversal wrinkling or growth-lines. These bodies are especially common in the Canajoharie beds at Menands and in the Utica shale at many localities, but they have also been observed in the Clinton and in the Devonian and Carboniferous shales and limestones. A characteristic feature of most of these wormlike tubes is that the margins appear as two thick, solid welts.

From considerable material that has accumulated in our museum it would appear that these fossils have been described under different names, according to the distance of the fragments of the often extremely long tubes from the proximal point. The proximal portions which are distinguished by an adhesion disk have been described by Hall as *Sphenothallus angustifolius*¹ under the supposition that they were plants. The distal portions with parallel thickened margins have been figured and described by Murchison² and referred to the worms as *Serpulites longissimus* and *dispar*. In 1893 Gerhard Holm³ erected for similar fossils the genus *Torrellella* and the family *Torellellidae*, which he places alongside the *Conularidae*. He characterizes the genus as follows:

The shell strongly compressed, with elliptical transverse section, very slowly tapering, sometimes almost tubuliform, but with the apex acute, irregularly curved in two planes, or straight. The two sides perfectly alike, so that a dorsal or a ventral side can not be distinguished. The surface of the shell with generally feeble, straight lines of growth only, so that the aperture has also been straight. The shell, as to its chemical composition, mostly of calcium phosphate, as to color, gray-violet, or brownish, or even black, resembling the shell of *Conularia*. Septa wanting. Small and narrow species.

Holm describes two species, *T. laevigata* from the Lower Cambrian, and *T. taenia* from the Ordovician. The latter is of especial interest to us as it explains the marginal welts in our compressed material, which from Holm's sections (see text fig. 33),

¹ Pal. of New York, 1:261. 1847.

² Sil. Syst., p. 700, t. 5, fig. 1; ib. Siluria, 4 ed., t. 16, fig. 1.

³ Sveriges Kambrisk-Siluriska Hyolithidae och Conularidae, in Sver. Geol. Unders. Ser. C. Affh. och upps. No. 112, p. 146.

obtained from uncompressed material, appear as lateral thickenings at the points of strongest curvature of a test with a broad elliptical section.

In 1896, Miller and Gurley¹ erected the genus *Enchostoma* for the same kind of phosphatic-calcareous, smooth, elongate, flexible tubes with varying sections, citing a species from the Chouteau group, and Girty has lately² figured as *Enchostoma* sp. a form from the Wewoka formation of Oklahoma, that distinctly shows the lateral welts or "ribs."



Fig. 33
Torel-
lella.
D-a-
gram-
matic
cross
section
of tube,
to show
late al
thicken-
ings.
(From
Holm)

At about the same time, the writer³ referred the curved, flattened, cuneiform bodies, known as *Sphenothallus angustifolius* Hall, to *Conularia gracilis* Hall, describing their adhesion disks and growth stages.

With the accumulation of more material it becomes increasingly clearer that while the relationship of *Sphenothallus* and *Conularia* is close, both in general form and the phosphatic-calcareous substance of the test, it is necessary to keep the two distinct. We shall later show that *Conularia gracilis* forms in certain characters a connecting link between the two genera.

We are now in a position to show that the bodies with adhesion disks (*Sphenothallus*) are the bases of the tubular bodies which often attain extreme length and are known as *Serpulites*. There are several species described below, one of which (*S. gracilis*, pl. 28, figs. 6 and 7) exhibits chitinoid rods or setae back of the aperture of the tube, such as would be found at the head of chaetopodous worms.

It is mainly for this reason that the oldest of the generic terms, *Serpulites*, with *S. longissimus* Murchison, as defined by Murchison, is preferable to all later terms, even if it would not have the right of priority. Murchison's definition of the genus and his figure of *S. longissimus*, as well as Salter's figure of *S. dispar* (in Sedgwick and McCoy, *British Palaeozoic Rocks and Fossils*, 1855, pl. 1D, figs. 11 and 12), bring out very distinctly the characteristic features of the genus, notably the thickened lateral margins and the transverse wrinkled upper and under

¹ Illinois State Mus. Nat. Hist. Bul. 11, p. 29.

² U. S. Geol. Surv. Bul. 544. 1915.

³ The Discovery of a Sessile *Conularia*. 15th Rep't State Geol. for 1895, p. 701. 1897.

surfaces. The British author here cited defines the genus as follows: Tube smooth, arched, slightly calcareous, glossy; having two small, longitudinal tubes at opposite points of the circumference, stronger than the rest of the shell, and prolonged at the posterior end. Type *S. longissimus*.

It is apparent that the small longitudinal tubes "at opposite points of the circumference" are identical with the thickenings of the extremities of the elliptical section observed by Holm and the marginal welts so distinct in our compressed specimens. That the substance of the test was phosphatic calcareous with a chitinoid admixture in most species is shown by the strong gloss and the brownish color of the tests, as well as by their good preservation in shales where all calcite has been leached out. By comparing the observations of Murchison, Hall, Holm and the writer, we may derive the following more complete diagnosis of *Serpulites*:

Tubes of elliptical transverse section, very slowly tapering, irregularly curved in two planes, or straight. The two sides perfectly alike, so that a dorsal or ventral side can not be distinguished. Tubes mostly thickened or strengthened at the two extremities of the broad ellipse; growing from small adhesion disks by which they are attached to foreign bodies. The shell, as to its chemical composition, mostly of calcium phosphate, as to color, gray violet, or brownish, or even black, resembling the shell of *Conularia*. Septa wanting. Chitinoid setae sometimes observed within the tube near the aperture.

Of the seven species cited by Miller (*op. cit.*, p. 521) from the Paleozoic rocks of North America, we are sure that only two belong to this genus, namely, *Serpulites splendens* Billings from the Chazy rocks and *S. dissolutus* Billings from the Trenton limestones. The other species (described by Hall and Dawson) do not seem to have the typical characters cited here for the genus.

The similarity in the surface sculpture and substance of the test between *Serpulites angustifolius* (Hall) and *Conularia gracilis* led us to unite the two species which are associated in the Dolgeville shale in the paper cited before. While this is no longer admissible, the fact remains that the points of contact between the two are so many that if *Serpulites* can be shown to have been the tube of an annelid, the probability that also *Conularia* may belong with the Annulata becomes very great. It is therefore worth while to survey briefly the relations of *Conularia* to *Serpulites*. The surface sculpture of *Conularia* consists

typically of transverse lines with short connecting cross-wrinkles which may develop into longitudinal lines. *Conularia gracilis* from the upper Trenton shales, which already in its slightly curved, slender form is very suggestive of relationship to *Serpulites*, as represented by *S. (Sphenothallus) angustifolius*, shows how this *Conularia*-sculpture can be readily derived from that of *Serpulites*. Its sculpture consists mainly of "sharply undulating transverse striae" (Hall), which well compare with the growth-lines or transverse wrinkles of *Serpulites*, and it can be readily seen how the acute points of the angular wrinkles may develop into the longitudinal lines. A further very important connecting character is the composition of the tests in both *Conularia* and *Serpulites*, of phosphate of calcium and chitinous substance. *Serpulites* is typically sessile; that also *Conularia* was sessile, at least at times, is no more doubted. Besides the early stages of *Conularia gracilis* showing fixation, Miss Slater has also described a sessile *Conularia*¹ and the writer has seen in the collection of Mr Frederick Braun of Brooklyn a large slab with a number of large *Conularias* from the western Carboniferous, all of which are sessile, forming a radiating group. Most *Conularias*, however, detached themselves later and must have become free-swimming. If we finally add that the two marginal thickenings of *Serpulites* are in structure comparable to the thickened grooves of *Conularia*, it will be seen that there are enough data to suggest that *Conularia* may well be a further peculiar development of an annelid of the structure of *Serpulites*, perhaps largely adapted to swimming.

The following species of *Serpulites* are before the writer :

1 *Serpulites interrogans* nov.

Plate 29, figures 1 and 2

The oldest *Serpulites* before us was collected by the writer in the lowest zone of the Deep Kill graptolite shale (*Tetragraptus* zone) and is of Beekmantown age. The tubes are small, about 20 mm long, slender and slowly expanding (from .5 mm to 1.7 mm+ in length of 20 mm), strongly curved, smooth, very glossy, with filiform marginal thickening and distinct, cup-shaped basal organs of attachment.

¹Ida L. Slater. A Monograph of British *Conulariae*. Pal. Soc. vol. for 1907. It is interesting that the authoress figures a number of cup-shaped bodies, recalling those of *Serpulites*, about the center of the sessile *C. tenuis*.

2 *Serpulites lumbricoides* nov.

Plate 29, figure 3

Tube very gradually tapering to a width of 2.5 mm or more; of very broadly elliptic section. Surface shows regular straight transverse impressed lines, along which the test overlaps slightly forward, giving it a segmented appearance; and irregular wrinkles. Both the lines and wrinkles do not extend upon the lateral thickenings. Test very glossy and yellowish to black in color, the specimen resembling much the dried test of an angleworm.

This species differs from *S. dissolutus* in its much smaller rate of growth (1 in 25 as against about 1 in 14 in the other species) and the greater width attained, for our specimen appears from its slow rate of growth to have nearly attained its mature condition. It grows from a width of 1.7 mm to one of 2.5 mm in a length of 20 mm.

Horizon and locality. Trenton limestone at Trenton Falls.

3 *Serpulites angustifolius* (Hall)

This species with its adhesion disks has been fully described by Hall and the writer in the publications cited before. It is especially characterized by its rapid expansion. It has been found in the upper Canajoharie shale about Dolgeville and in the Mohawk valley attached in great numbers to cephalopod and gastropod shells. It does not seem to have grown to very great length, the longest specimen observed measuring about 40 mm. Its rate of expansion is from an initial width of 1 mm to 6+ mm in the length given.

4 *Serpulites crassimarginalis* nov.

Plate 29, figures 4 and 4a

Large, transverse, elliptic cone of very gradual expansion attaining a length of 95 mm, and a width of 6 mm. The marginal welts are very thick (1.3 mm wide); the basal disk apparently small. The smaller rate of expansion and the thick marginal welts are the principal characters distinguishing this species from *Serpulites angustifolius*.

This species occurs in the Utica shale at Holland Patent, N. Y., and other localities.

5 *Serpulites gracilis* nov.

Plate 28, figures 5-8

Cones extremely slender, attaining a length of 70 mm but a width of only 2.3 mm. Test thin and marginal welts distinct only in the proximal portion. Basal disk small.

This is the species which has afforded in three specimens the chitinoid setae within the apertures of the tubes. It was of a gregarious habit, for in one instance three specimens with their disks in contact are attached to one small fragment, and in another (pl. 28, fig. 5) a dozen specimens are counted upon a small pile of debris of brachiopod and cephalopod shells, which in the soft mud formed a base for attachment.

The species occurs in the upper Canajoharie (Dolgeville) shale at Dolgeville and the Utica shale at Holland Patent.

6 *Serpulites magnus* nov.

Plate 28, figures 1 and 2

During the construction of sewers in the village of Menands north of Albany some years ago, several blocks of much contorted Canajoharie shale were obtained by Doctor Clarke which are literally filled with extremely glossy thick tubes of the structure of *Serpulites*. The tubes are quite uniformly 7 to 8 mm wide and since none of the specimens show any trace of tapering to either end they must have been of considerable length; they are all fragments limited by the size of the blocks (70 mm *in maximo*). The marginal welt is very thick (1.5 mm wide) and appears frequently in the middle line of the flattened specimens as a carinate ridge. The test is mostly smooth, but exhibits in some cases regular transverse lines with smaller connecting longitudinal wrinkles. It is possible that the appearance of perforation of the rock in all directions is due to the contorted condition of the rock, as for the most part the specimens follow the bedding planes of the shale.

This species must have borne some resemblance to *S. dissolutus* Billings from the Trenton of Ottawa, etc., which attained a like width, but judging from the original description, tapered more rapidly and was altogether shorter.

7 *Serpulites tener* nov.

Plate 28, figures 3 and 4

A fragment of a *Serpulites*-tube 46 mm long and 1 to 2 mm wide attests the occurrence of the genus in the Hamilton shales. It comes from the top layers of a bluestone quarry near Clarksville, N. Y., on the road between Mud Hollow and Reidville.

The marginal welt is well developed, the test very thick and smooth and furnished with deep, regular, elliptic depressions on the median line. The fragment shows no tapering toward either end and the species must have been an extremely slender and long one.

8 *Serpulites longus* nov.*Plate 29, figure 5*

A long narrow tube (about 120 mm long and uniformly about 2.7 mm wide) with thick marginal welts, smooth, flat surface and purplish-brown phosphate of calcium test is before us from the Keokuk beds at Crawfordsville, Ind. It is described in this place because it shows the range of *Serpulites*, in the restricted sense here used, into the Carboniferous era. The three species (*S. hortonensis*, *S. annulatus* and *S. inelegans*) described and figured by Dawson in *Acadian Geology*, 1878, page 312, from the Carboniferous, do not belong here.

The writer has also seen typical *Serpulites* from the Clinton shales but they are at present not available.

Agraulos cushingi nov.*Plate 30, figures 1-4*

Agraulos sp. nov. Cushing & Ruedemann. N. Y. State Mus. Bul. 169, p. 38.

Description. Cranidium small, subquadrangular in outline, forming a uniformly convex calotte. The frontal margin is very long, strongly curved and reaching back at its ends to one-fourth of the length of the cranidium. The suture line passes first slightly inward, then backward along the eye lobe, and reaches the posterior margin on a line a little inward of its anterior extremity. The glabella is very broad, about half as wide as the cranidium, and very flat, hardly, if at all, projecting above the cheeks, trapezoidal in outline, extending two-thirds the length of the cranidium. The glabellar furrows are straight and slightly converging forward, deepest posteriorly and in mature exfoliated specimens fading into the cranidial surface. In young specimens the frontal end is seen to be squarish. The occipital groove is discernible only on the glabella, where it sets off a depressed, flat occipital ring. The free cheeks or other parts of the body have not been recognized.

Horizon and locality. Theresa (Ozarkian) dolomite in cut of Adirondack Railroad northwest of Saratoga. For a description of the section where this form occurs, see New York State Museum Bulletin 169, pages 36-37. It is there associated with *Ptychoparia matheri* Walcott, *Agraulos* cf. *newtonensis* Weller and *Lingulella* (*Lingulepis*) *acuminata* (Conrad).

Remarks. We have three cranidia of this strange type which, representing different growth-stages, have all been figured. No trilobite has as yet been described from the Upper Cambrian which would invite close comparison with this species. It differs from its congeners strikingly in the broad, anteriorly well-rounded, convex cranidium and the obscure glabella. Doctor Walcott, to whom the specimens were sent, informs us that he has a very closely related, if not identical form in the upper beds of the St Croix sandstone of Wisconsin.

The fossil-bearing layer was discovered and the specimens were collected by Prof. H. P. Cushing, to whom the form is dedicated.

***Amphilichas conifrons* nov.**

Plate 30, figures 5-8

Description. Glabella convex, broadly trapezoidal in outline, about twice as broad as long, projecting medially. Length 23 mm, width about 45+ mm. Median lobe trapezoidal in outline, its posterior margin about twice as long as the frontal, very prominent, culminating a little forward of the middle, the apex about 20 mm above the base of the glabella, bent sharply downward in front. The lateral slopes are straight or a little incurved; the posterior slope is gently convex with a suggestion of a ridge. The area of the posterior angles is slightly convex. The first pair of glabellar furrows is sigmoidal, narrow, but fairly deep, the posterior portion more strongly curved and extending into the neck furrow. The first lateral lobe is subquadrangular, wider in front, sloping fairly evenly laterally and with the greater portion bent forward; the second lobe is, as far as preserved, but a narrow strip, apparently broadening at the anterior extremity. The second glabellar furrow is also bent slightly sigmoidal and shallower than the first. The neck furrow is narrow, nearly straight in the middle and curving abruptly forward at the ends. The surface of the glabella is furnished with small tubercles and bases of spines which are largest at the apex of the middle lobe. In working out the latter many of the spines were seen to be bent in part and diverging in various directions, as illustrated in the profile view, plate 30, figure 7.

The pygidium of *Amphilichas* here described was collected at the same locality and, judging from the rock, possibly in the same bed. It differs from that of the only Trenton congener, *A. trentonensis* Hall, and may therefore properly be referred to *A. conifrons*. It is broadly semielliptic in outline, a little contracted in front, about 25 mm long, 30 mm wide in front and 36 mm in its

widest part. The axis is broad (10 mm) and prominent in its anterior half, contracted and tapering and flat in its posterior half. It bulges in the middle where the contraction of the margins begins. The first annulation is partly broken, but apparently reached transversally across; the second groove is convex and angular backward and does not extend to the lateral grooves. The pleura are nearly flat, sloping a little outward; they are hooklike, curved backward, terminating apparently in rather blunt lobes. The four anterior pleura are each subdivided by a secondary short groove that extends about one-third the length of the pleuron. The surface is ornamented with small tubercles and bears the bases of many spines which are especially large in the last pair of pleura.

Notes. This species differs from *A. trentonensis* Hall in the entirely different outline of the middle lobe of the glabella, which in the former is widest behind, and in the latter broadens forward. In this character *A. conifrons* diverges somewhat from the typical *Amphilichas*. Also the pygidium of the Trenton congener is different, mainly in possessing a longer axis and straight transversal annulations.

While the pygidium of our species is very similar to that of the smaller *A. minganensis* from the Chazy beds, the glabellas differ in the outlines of the middle lobe, as mentioned before. Considering the variability of the lichads, the forms are still sufficiently similar to make it possible that both are genetically directly connected, especially since the more stable pygidia are so much alike.

The writer is not aware of any European species of *Lichas* to which our type approaches, and it also differs considerably from the congeners and the genotype of *Amphilichas* in the posterior widening of the middle lobe of the glabella and the forward position of the side lobes. In the shape of the middle lobe, and notably also its convexity, and the side lobes, it bears, however a general resemblance to *Lichas* (*Metopias*) *hübneri*¹ Eichwald, and it is conceivable that a similar species of *Metopias* might lead, through an extension of the first pair of glabellar furrows, to our *Amphilichas*. This is the more probable since Raymond² has observed that in the young of *Amphilichas*

¹ See Fr. Schmidt: Revision der ostbaltischen Trilobiten. Abtheilung 2, 1885, pl. 1, figs. 13-14, in Mem. de l'Acad. Imp. des Sciences de St Pétersbourg, 7 ser., t. 23, no. 1.

² Percy E. Raymond: Notes on Ordovician Trilobites IV. Annals of the Carnegie Museum, v. 7, no. 1, p. 73. 1910.

minganensis the glabellar furrows likewise do not extend back to the neck-ring. Raymond does not recognize the genus *Metopias* which originally was created by Eichwald, subsequently abandoned by the same author, but revived by Schmidt (*op. cit.*, p. 30) for just such species with strongly forward bulging glabella and glabellar furrows that fail to reach the occipital groove. Reed has shown that in *Amphilichas* the side lobes are the fused second, third and fourth glabellar furrows and that the glabellar furrows are the first pair prolonged by the uniting of the inner ends of all three pairs of furrows. It is for this reason obvious that *Metopias* represents an earlier stage of development of *Amphilichas*, as also suggested by Raymond's observation in the young of *A. minganensis*. If the *Metopias* character of the glabellar furrow, then, proves to represent a genetic stage of development of *Amphilichas*, also represented in the ontogeny of *Amphilichas*, it is worthy of recognition as determining a generic group.

Horizon and locality. Both the glabella and pygidium came from the Rust collection and were collected in the Trenton limestone at Trenton Falls.

Ceratiocaris (Limnocaris) salina nov.

Plate 33, figures 1-5

Description. Carapace-valves small, pod-shaped, about three times as long as wide, widest at the anterior third whence each valve contracts rapidly to the acutely pointed or mucronate anterodorsal margin and gradually to the posterior margin which is subrectangularly truncated with rounded corners. The dorsal margin is nearly straight to the anterior extremity which is slightly contracted. The ventral and anterior margins are furnished with a filiform raised border, the dorsal margin apparently with a flat, vertical hinge-border and the posterior margin with a frill-like thin extension. The eye tubercle is very large and prominent and situated well forward. No surface markings have been observed on the specimens, which are mostly internal casts. The rostrum is also relatively large and apple-seed shaped in outline. The abdomen is notably small and protruding in the specimens only with the telson. Not more than five segments have been observed, the ultimate being a little larger than the others. The telson is short and blunt and the two shorter cercopods closely adhere to it in all the specimens.

Measurements. Length of specimens 6 to 8 mm, width of same 2 to 3 mm.

Horizon and locality. Pittsford shale, Pittsford, N. Y.

Observations. The specimens, ten in all, were collected by Prof. George H. Chadwick and Mrs C. S. Phelps in the gray Salina shale, underlain by green and red shale in the bank of the Erie canal, just west of the Pittsford bridge. They are small and completely flattened out, but notable for their very favorable preservation in the very fine-grained shale, retaining features but rarely seen in specimens of *Ceratiocaris*. This is especially true of the rostrum which is seen in no less than four specimens, while Rupert Jones and Woodward could figure in their Monograph of the British Palaeozoic Phyllozoa, where many species of *Ceratiocaris* are described, but one imperfect rostrum of a large species. Likewise the abdomen and telson retained in three of the ten specimens are by no means often seen in *Ceratiocaris*.

All the specimens figured show a distinctly outlined, rather large, smooth, elevated area near the front which we have considered an eye spot, although we believe it possible that it may be an attachment area of an adductor muscle. *Ceratiocaris* does not possess an eye spot or tubercle and Woodward separated *Emmelezoe* from *Ceratiocaris* partly for this reason. Doctor Clarke has already described a very large carapace of *Ceratiocaris* from the black Pittsford shales¹ and there tentatively proposed the subgenus *Limnocaris* for valves with eye spots but otherwise like *Ceratiocaris*, his species *C. praecedens* being such a form. The type before us would also be referable to this subgenus, but it exhibits still other features not known in typical species of *Ceratiocaris*, namely, the posterior fringe and the short abdomen which is quite surely composed of less segments than are found in *Ceratiocaris*. It is therefore possible that this peculiar and interesting little crustacean will in time be made to represent still another subgroup of *Ceratiocaris*.

The *Ceratiocaris praecedens*, also occurring in the Pittsford shale, is not only much larger, but differs also in its relatively wider valve, which is widest in the middle and in the obliquely and sinuously truncated posterior extremity of the valve.

C. (Limnocaris) salina is associated in the gray shale bed with ostracods of the *Isochilina* type and fragments of *Emmelezoe*.

¹ Rep't N. Y. State Pal. for 1900, p. 92. 1901.

Spathiocaris emersoni Clarke*Plate 31, figures 7 and 8*

Since this species was described in *Palaeontology of New York*, volume 7, page 199, larger and more perfect specimens have been observed by Mr Luther in the Portage (Naples) beds at Naples, N. Y. The most remarkable feature of these specimens is their much greater elongation than that shown by the earlier stages and especially the strong bending downward or the lateral compression of the sides instead of the vertical compression which all fossils have normally suffered in these undisturbed beds. This lateral compression which is uniform in all these larger specimens, would seem to indicate either an original, highly convex form of the conchiolinous valves or their connection with a body that shrank after death bringing the two anterior wings or angles close together. A cartilaginous substance would supply the required medium for such a shrinking process (see p. 101).

These specimens differ markedly from the strange valve figured with *S. emersoni* on plate 35, figure 13, (*Pal. N. Y.*, v. 7), which latter possesses a much broadened flat posterior fold or extension, and a very shallow anterior notch. If this unique specimen, which is in the State Museum, is not an entirely abnormal individual of *S. emersoni*, it represents a widely different form. Aside from the posterior lobe it is also quite distinct from the large specimens of *S. emersoni* before us, both in outline, being relatively much broader, and in the shallow frontal notch with sigmoidally curved margins. The separation of the median lobe with diverging margins it has in common with Woodward's genus *Pholadocaris*. We therefore venture to separate it from *S. emersoni* as *Pholadocaris lutheri* sp. nov.

Spathiocaris lata nov.*Plate 31, figure 6*

Description. Valve semielliptic in outline; its length five-sixths of its greatest width which is near the anterior margin; anterior notch forming a very obtuse angle. Surface depressed convex, the apex about one-quarter of length posteriorly of the anterior margin; posterior slope flat, lateral slope declining more steeply to the antero-lateral angles. The surface sculpture consists of coarse concentric folds which carry a system of concentric lines so fine that they are not visible to the naked eye. Behind the point of

the anterior angle a small, smooth, semicircular convex area is set off by a groove, from which short, branching, carbonaceous lines radiate on the mould of the interior. From the sides of these areas proceed two transverse grooves halfway to the antero-lateral angles.

Horizon and locality. Chemung beds, Cotton farm, 1 mile north of Avoca, Steuben county, N. Y.

Remarks. This species is easily distinguished from *S. emersoni* by its broader form and the widely open frontal notch. It corresponds in shape to the earliest growth-stages of *S. emersoni*. The test was so thin that in the fossil state it left little more than a carbonaceous film. The grooves and the radiating carbonaceous lines near the frontal edge are features peculiar to this species. The transverse frontal grooves recall those of the *aptychus* of some ammonites (see text fig. 34).

***Spathiocaris chagrinenensis* nov.**

Plate 31, figure 5

Description. Valve of medium to large size, elongate semi-elliptical, not quite one-fourth longer than wide. Apex situated medially at the anterior margin; from it a smooth, projecting, thickened edge extends toward the anterior angles. The frontal margin, in the compressed condition of the fossil, is slightly emarginate; the basal margin is strongly rounded and narrow, the widest part of the valve being at the front; the lateral margins extend obliquely forward and were slightly sinuous. The concentric growth-lines are rather uniform, closely arranged (8 in 5 mm at the posterior extremity), not very prominent. The exfoliated portions of the valve show extremely delicate longitudinal lines on the middle part of the valve.

Measurements. Length 30 mm, width 26 mm.

Horizon and locality. Chagrín shale (Chemung), Chippewa creek, Breckville, Ohio.

Remarks. The holotype of this species is in the museum of Western Reserve University, Cleveland, Ohio (no. d 600) and was loaned to us, together with the other species of *Spathiocaris*, by Prof. H. P. Cushing.

S. chagrinenensis resembles *S. emersoni* Clarke from the Portage group of New York both in outline and surface characters. It also has the fine median longitudinal lines in common with the latter. The wider angle of the frontal cleft in the Chemung species may furnish a distinguishing character.

Spathiocaris cushingi nov.

Plate 31, figures 3 and 4

Two specimens of supposed *Turrilepas* (?) *newberryi* (Whitfield) from the Cleveland (Olmstead) shale at Cahoon creek, North Dover, Cuyahoga county, Ohio, sent to the State Museum by Prof. H. P. Cushing, represent a new species of *Spathiocaris* of peculiar character.

In the smaller specimen the valve, which is folded upon itself along the median line, is much broader than long, the width being twice the length and the general outline approximately subcircular. The basal margin is but little curved; the lateral margin is slightly drawn in and the antero-lateral angles rounded. The anterior margin is probably straight transversal or very obtusely angular. Aside from the great relative width of the valve, which as in other species of *Spathiocaris* may be only an early ontogenetic feature, the strong concentric lines and a second set of lines that is concentric about the apexes of the antero-lateral angles are the main characters of this species. The second set of lines extends about one-third of the width of the valve on either side, ending abruptly and giving the antero-lateral slope a cancellated sculpture.

The larger specimen, while but little wider, is longer by one-half. This discrepancy is in part due to the loss of the lateral margins in the specimen, which therefore appears too narrow and in outline resembles *S. chagrinsis*. The concentric lines are as strong and regular as in the smaller specimen; the second set of lines, however, is but faintly shown as discontinuous nodes or ridges in the depressions between the concentric striae.

The types are in the geological museum of Western Reserve University. The smaller measures 11 mm in length and about 15 mm in original width at the anterior end; the larger, 16 mm in width and 18 mm in length.

Spathiocaris williamsi nov.

Plate 31, figures 1 and 2

Description. Valve large, broadly subrectangular, somewhat asymmetric, not quite one-fourth wider than long. The apex situated near the anterior margin, to the right of the median line. The basal margin is nearly straight; judging from the concentric growth-lines, it extended about three-fourths the width of the valve, then bent abruptly upward to the gently curved lateral margins.

The anterior edge is not preserved; from the extent of the concentric growth-lines and their sharp curving inward it can be inferred that the anterior margin was, as seen in the compressed condition of the fossil, slightly receding towards the antero-lateral corners, thereby indicating a wide open anterior cleft.

The growth-lines are very coarse, about four in 5 mm at the posterior extremity and six in the same space in the middle. They are bunched by deeper concentric depressions into irregular groups and distinctly overlap outward. They bend rather abruptly forward at the lateral angles, especially in the posterior portion, appearing thus subangular.

Measurements. Length about 32 mm, width about 38 mm.

Horizon and locality. Carboniferous (Waverlyan) Cleveland shale, Mill creek, Newburg, Cleveland, Ohio.

Remarks. The specimen was collected by the late Prof. S. G. Williams and is named in his honor. It is of larger size than the congeners and is readily distinguished by its broad form and coarse lines. The asymmetric shape of the valve is probably due to oblique compression. This is, at least, suggested by the crowding of the growth-lines on the right-hand side and a corresponding exaggerated spacing of the same on the opposite side of the fossil.

We have also referred a small valve, reproduced in plate 31, figure 2, to this species because it agrees in its general outline and the character of the growth-lines very well with the holotype of the species. Also in this valve the apex is slightly out of the median line. Along the anterior margin a depressed area is observable, in which the surface lines are sharply bent inward exactly as in the holotype.

SPATHIOCARIS AND THE DISCINOCARINA

In view of the description of two new species of *Spathiocaris* and the observation of some new features, we venture to touch the much discussed problem of the nature of this interesting genus and of the suborder *Discinocarina* of the crustaceans in general.

Doctor Clarke has in 1902¹ in a chapter on "The organic bodies called *Discinocarid*, *Spathiocaris*, *Cardiocaris*, *Pholadocaris*, etc." furnished a full history of the discussion that has been waged about these problematic crustaceans. It will suffice here to mention that the group of fossils of which *Spathiocaris* is one of the most characteristic representatives are "all thin, chitinous, tenuous, oval, or cordate shields, bearing a deep triangular slit at one end extending back to the apex of the shell, about which the growth-lines are concentric"; further, that they have been considered by some authorities (H. Woodward, Clarke) as crustaceans, by others (as Roemer, de Verneuil, Kayser and Dames) as aptychi of goniatites. The discussion which was carried on in the early nineties by these authors has remained undecided for lack of sufficient evidence either one way or the other. Since that time the question has been but incidentally touched, first by Holzapfel² who discusses the probable nature of *Spathiocaris* after having had access to the material from the Domanik shale in Russia that was originally described by Kayser and de Verneuil as an aptychus. Holzapfel, proceeding on the assumption that the aptychus was an operculum of some goniatite or ammonite, claims that the famous cases of valves of *Cardiocaris* and *Spathiocaris* found within the living chambers of goniatites (*Manticoceras intumescens*) are nonconclusive for the operculum or aptychus-nature of these organisms, since the specimens do not fit the apertures of these living chambers at all and may be there by accident. While it may be true that these bodies could not have been used as opercula, it is still known that aptychi had probably a different function than that of opercula and they could have served another function. There are two views at least differing from that concerning the aptychi as opercula (see below, p. 101). Holzapfel sees further proof of his view in the fact that the goniatites and aptychi

¹ N. Y. State Mus. Bul. 52: Rep't State Pal. for 1901, p. 610. 1902.

² E. Holzapfel. Die Cephalopoden des Domanik im südlichen Timan Mém. du Comité Géol., v. 12, no. 3, p. 48. 1899.

show no relationship in their relative occurrences. We also doubt the conclusiveness of this already much discussed argument, in view of the fact that the aptychi would naturally drop out of the conchs of the goniatites as soon as decay sets in and thus remain at the original habitat of the goniatites, while the conchs, especially the chambers, becoming filled with gas from the decay of the animal would be shifted about either at the bottom or even rise to the surface of the water as those of *Nautilus* are known to do today after death. Holzapfel concludes that the view that *Spathiocaris* has any relation to goniatites is very improbable. On the other hand, from the lack of study on his part, he is not ready to consider them as crustaceans.

The last and most important contribution to this controversy is by Doctor Clarke in the above-cited paper. This author describes *Eunoa accola* from the Deep Kill graptolite shale as a gigantic brachiopod, a form which, if both valves with muscles impressions had not been found, would undoubtedly have been referred to *Discinocaris* Woodward, the most typical genus of the whole group of fossils and whose largest representative (*D. gigantea* Jones and Woodward) also occurs in graptolite shales (the Moffat beds of Scotland). It is therefore inferred that *Discinocaris* may well prove to be a brachiopod instead of a crustacean. Doctor Clarke, after surveying all the evidence, concludes that "in view of all the present evidence, we can not divest ourselves of the belief that there is nevertheless some organic connection between these Devonian bodies and the cephalopods, for, while we lack any further confirmation of the latter than that above given, we have been altogether unable to acquire positive indication of crustacean structure in any of them."

It is in accordance with this view that Doctor Clarke in Zittel-Eastman, volume 1, page 658, refers the genera *Cardiocaris*, *Ellipsocaris*, *Pholadocaris* and *Spathiocaris*, in an addendum to the *Phyllocarida*, with doubt to the crustaceans.

From the specimens of *Spathiocaris* before us, we are enabled to add the following data to the discussion:

The general outlines of the valves of the genera here cited are, as the discussions have shown, by themselves as little conclusive of their position with the crustaceans as with the aptychi of cephalopods and their mode of occurrence is likewise undecisive. It seems, however, that the structure of the valves combined with their outlines is more apt to shed some light upon their nature. All these valves are furnished with lines or ridges concentric about

an umbo that is situated near the anterior margin. Where crustaceans have a similar system of lines they also nearly always display finer markings, especially fine networks of raised lines, either between the ridges, as in *Estheria*, *Emmelezoe*, etc., or on the inside (*Anatifopsis*). This finer sculpture is so characteristic of crustacean valves that one naturally always looks for it as soon as a valve is suspected of being the carapace of a crustacean. No trace of this fine sculpture is observable in any of the *Discinocarina*. The fine longitudinal lines along the median line of *Spathiocaris* are of a different character.

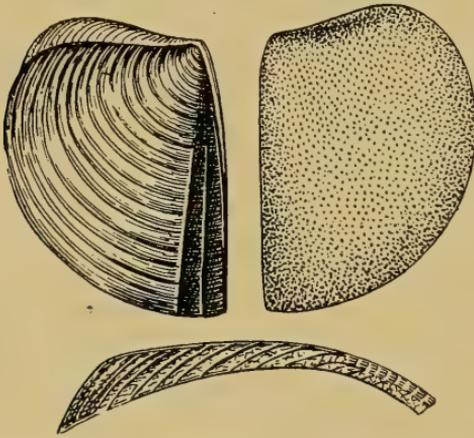


Fig. 34. *Aptychus* of *Aspidoceras*; first figure is a view of the concave interior side, showing the concentric lines; the second figure is a view of the convex ventral side, showing the punctate surface; the third figure is a transverse section below the middle of the first figured specimen and showing the direction of the accretions. (From Steinmann)

the old shell (see text fig. 34); the new shell segments thus pass not inward under the old ones but upward and outward. This, however, is precisely the structure that we also find in *Spathiocaris*, and, as far as the writer is aware, in the other genera under suspicion; in fact in all *Discinocarina* and, judging from the figures, very typically in *Dipterocaris vetustus* and, from inspection, in our species of *Dipterocaris*. It is thereby, however, to be remembered that the mode of accretion described above of the *Discinocarina* is that of the *aptychi*, while these valves have been compared with the *anaptychi*. The *anaptychus* (see Zittel-Eastman, v. 1, p. 545) is, in distinction from the *aptychus*, a single plate which is invariably

Another difference that seems of some significance is seen in the mode of accretion at the edge of the valve or in the direction of the growth segments. In lamellibranchs, brachiopods and crustaceans which grow from an umbo by accretion at the edge of the shell, the new portions are added from the inside of the shell, the new segments therefore pass beneath it and the older growth-lines always overlap the younger ones. In an *aptychus*, however, which is formed within the conch of a cephalopod, the accretion takes place so that the new material is added at the outer edge sloping upward against

carbonaceous and was doubtless horny in the living animal, while the aptychus consists of two thick calcareous plates. The anaptychus is, however, now considered as having been a conchiolinous plate that always was attached to the interior side of the aptychus and which by its elasticity may have fulfilled the function of the ligament of the shell of the lamellibranchs (see Steinmann-Döderlein, *Elemente der Paläontologie*, p. 387. 1890). Since in the Paleozoic rocks no aptychi have been found and the formation of shells generally begins with the conchiolinous deposits which later become more or less calcified, it is quite proper to assume that the Paleozoic goniatites may not yet have had advanced to the calcareous portion of the aptychus structure. It is in this connection worth while to consider the different views on the formation of the aptychus. They have been considered as opercula and as covers of the nidamental gland. The position of the aptychus in the conch, its form and convexity however, as well as the fact that it sometimes has a shrunken appearance, indicate that it is a calcified pair of cartilages, to the inside of which muscles were attached. Its normal position corresponds to that of the base of the funnel of the animal, whose muscles are also in *Nautilus* attached to a noncalcified pair of cartilaginous plates (Steinmann-Döderlein, *op. cit.* p. 388).

If the development of the aptychus started from a cartilaginous body whose interior surface became first conchiolinous, the extreme thinness of the valves of *Spathiocaris* and the other *Discinocarina* is thereby explained, as well as the remarkable flexibility which shows itself in the bending and frequent doubling of the shells upon themselves. Furthermore, the extreme variation in the shape and depth of the anterior notch which varies from a shallow emargination (see *Pal. N. Y.*, v. 7, pl. 35, fig. 13) to a deep cleft (*op. cit.* pl. 35, fig. 15) even in the same species, and which is difficult to explain in a crustacean, and especially the narrow cleft in the posterior portion of *Dipterocaris* which looks strange for a carapace of a crustacean (see *op. cit.* pl. 35, figs. 20-26) are readily accounted for by reference to a partially conchiolinous aptychus. The last-mentioned notch or cleft would indicate the gradual coalescence of the two halves of the funnel, supposed to have been a process of some phylogenetic importance in the cephalopods. Also the peculiar median longitudinal lines upon the valves of *Spathiocaris* and the diverging median lines upon the valves of *Pholadocaris* find their counterpart in similar lines along the median hinge-line of the aptychus halves.

While we are well aware that none of these structural features is fully decisive of the aptychus nature as against the crustacean nature of the valves, they are nevertheless of considerable significance if added to the facts that none of the valves of the genera of the *Discinocarina* has as yet been found with an abdomen of a crustacean and that they all have a shape which is clearly suggestive of an aptychus. If one of the main arguments against their reference to the cephalopods as aptychi was that no true aptychi have been found in the Paleozoic formations then this argument would be much weakened by the probability that the Paleozoic cephalopods had only cartilaginous aptychi or at the best cartilaginous aptychi with a thin conchiolinous inner layer, the anaptychus. These cartilaginous plates, for the attachment of the detractor muscles of the funnel, would naturally also have existed in the Ordovician and Silurian cephalopods and thus account for those earlier anaptychi considered as *Discinocarina*.

Anatifopsis wardelli nov.

Plate 32, figures 1-12

Mr H. C. Wardell, while collecting the Otisville eurypterid material described in New York State Museum Memoir 14, also secured in a bed of greenish shaly sandstone above the eurypterid-bearing strata, about a drawerfull of specimens of a new crustacean. Preparation of this material has brought out the interesting fact that it is an American representative of the cirriped genus *Anatifopsis* of Barrande. The genus as described by Barrande¹ contains four species and is based on detached valves which are somewhat quadrilateral in shape. The main generic character is seen by Barrande in the fact that the plates have the lower part of the base marked out into one or two horizontal segments which are more or less separated from the body of the valve. He also considers as a constant and typical character the fine regular, longitudinal striation of the valves. Our material shows both the characteristic shape of the valves of *Anatifopsis* with the marked-off basal segments (see pl. 32, figs. 1, 2, 5, 6) as also the typical longitudinal striation. As in all cirripeds, the form of the valves is quite variable according to their place in the capitulum or peduncle. This is markedly the case in both the Bohemian and

¹ J. Barrande. Syst. Sil. du Centre de la Bohême, Supplément au v. I, p. 577. 1872.

the American species. Other species have been described from Sweden. Lately Assar Hadding¹ has figured a continuous series of eight valves of *A. ? elongatus* Hadding from the graptolite zone with *Amplexograptus vasae* Tullb. We have a continuous series of four plates (see pl. 32, fig. 7).

The plates of *A. wardelli* are somewhat variable in shape; in general they have the outline of an oblique parallelogram with one short side truncated (pl. 32, figs. 1, 2, 5, 8); others are simply rhomboidal (pl. 32, fig. 9). In the long quadrangular plates the truncated short side is drawn out into a projecting point or apex (see pl. 32, figs. 3, 6, 8). The opposite short side is very oblique and truncate at the dorsal margin (see pl. 32, figs. 2 and 5). The longer plates are quite convex, the largest are fairly semicircular in section and the four sides are in some more or less well rounded, especially also the truncated side. The smaller rhomboidal ones are either nearly flat with a keel on one side (pl. 32, fig. 8) or rooflike (pl. 32, fig. 9). The larger plates have at the truncated end two diverging grooves or sutures (see pl. 32, fig. 2) which in the mold of the interior (pl. 32, fig. 5) appear as ridges and were therefore double grooves on the inside and outside. One of the long sides (dorsal?) was bent rectangularly and possessed a flange. The surface was uniformly ornamented with fine, mostly parallel, but also anastomosing striae (5 in 1 mm) which start from the apex (see pl. 32, fig. 3) and become parallel to the long sides of the plates.

A fragment of the organism, consisting of four plates, was obtained (see pl. 32, fig. 7). This consists of the rhomboidal plates which are hardly overlapping. The rhomboidal plates measure 7 by 7 mm or less, the largest ones of the others reach 26 by 13+ mm in size.

The interior surface of the plates is worthy of special notice. It is covered with an extremely delicate network of chitinous fibers which form polygonal meshes, the points of intersection being thickened. Whether this meshwork was imbedded in a calcareous matrix or exposed free on the inner surface is difficult to decide.

From the great differences in outline, shape and section of the plates we infer that probably the larger and more rounded plates, belonged to the capitulum, while the smaller, rhomboidal ones may have formed the pedicle. The latter were but slightly if at all overlapping, but it can be inferred from the form of the

¹ Assar Hadding. Der mittlere *Dicellograptus*-Schiefer auf Bornholm. Meddelande från Lunds Geologiska Fältklubb, ser. B, no. 8, p. 31. 1913.

larger plates that they must have overlapped considerably with the truncated ends. From the asymmetric shape of the plates and the difference in the two longer margins, it can be seen that there must have been two rows of plates which met in a dorsal and ventral margin. The *Anatifopsis? elongatus* figured by Hadding shows one row of long quadrangular plates which are overlapping with the shorter truncated side and become rapidly shorter at one end. We can conclude from the series of four plates which we possess and the form of our other plates that the surface sculpture runs parallel to the longitudinal axis of the organism and that the plates therefore overlapped also with their shorter side.

Barrande placed his *Anatifopsis* in the cirripedes. Hadding, however, is inclined to refer the body which he found to the Phyllocarida. He states that he had eight specimens with continuous series of plates. "These," he writes, "are of different shape but so arranged that they form a continuous body. Whether this is to be regarded as the abdomen of a phyllocarid or belongs to another animal class, I can not decide yet." We see no reason why our species should not be placed among the cirripedes, provided the plates form a double continuous series, as we have concluded above. It will then belong to the cirripede family *Lepidocoleidae* Clarke (see Zittel-Eastman, Text-book of Palaeontology, second edition, v. 1, p. 743) which is characterized as follows: "Body covered with two vertical columns of overlapping plates, those of one series alternating with those of the other. Terminal or caudal plate axial. Basal or cephalic portion of the body with a ventral curvature. Apexes of the plates on the dorsal margin. No accessory plates." Doctor Clarke has referred three species to this most primitive of the cirripede genera, namely, *Lepidocoleus jamesi* (Hall and Whitfield), a Cincinnati form, *L. sarlei* Clarke, a Niagaran type, and *L. polypetalus*, a Helderbergian species.¹

There is good reason, in our view, why *Anatifopsis*, as represented by the Bohemian and our species, should be placed with *Lepidocoleus* among the *Lepidocoleidae*. Not only is there evidence of the presence of a continuous column of the plates, as in *Lepidocoleus*, but the plates themselves, in their form, in the apex and in the linear surface sculpture are decidedly more similar to

¹ These were described and the genus *Lepidocoleus* fully discussed in *The Structure of Certain Paleozoic Barnacles*, by J. M. Clarke. *The American Geologist*, v. 17, p. 137. 1896.

those of *Lepidocoleus* than to those of any other cirripede genus. Moreover, the reversed symmetry of the plates, while each plate is decidedly unsymmetrical in itself, proves that there must have been double rows of them, exactly as in the *Lepidocoleidae*. The principal difference between *Lepidocoleus* and *Anatifopsis* consists in the fact that in the former the plates of each column are contiguous or overlapping with their longer side, so that with the overlap the column is built up of narrow transverse plates, while in *Anatifopsis* it is composed of plates which overlap or are contiguous with their narrower sides, so that the column consists of narrow longitudinal plates. We have little doubt that, as in *Lepidocoleus*, the apexes of the plates were at the ventral side, where the plates were only in contact and there was a dehiscence for the protrusion of the appendages while on the dorsal edge the plates were interlocked. The grooved edge of a plate, as that figured in plate 32, figure 8, distinctly suggests an interlocking along that edge.

There is some doubt as to the geologic horizon of this species. The specimens were all obtained in the railroad cut north of Otisville, on the eastern slope of the Shawangunk mountain, in a horizon which, according to Mr H. C. Wardell, is above the *Eurypterus*-bearing beds of the Shawangunk grit and which, according to Mr C. A. Hartnagel, belongs to that portion of the Longwood shales that corresponds to the Binnewater beds of the Kingston region.

***Pseudoniscus roosevelti* Clarke**

Plate 33, figures 6 and 7

The eyes of *Pseudoniscus* have for some time been an object of speculation. Nieszkowski,¹ who first described a *Pseudoniscus*, figured a small incision along the edge of the fixed cheek as place for the eye; Eichwald in his *Lethaea rossica* (1860, p. 1445) speaks there of large lunular eyes, and Woodward in his well-known *Monograph of the Merostomata* (pt 4, p. 177, fig. 65) restored the head shield completely with the eyes. This figure, which shows eyes half as long as the carapace, has, on the authority of Woodward, gone into the textbooks (as Nicholson and Lyddeker, "Manual of Palaeontology," v. 1, p. 549, fig. 412, B), although Zittel's *Handbuch der Palaeontologie* (v. 2, p. 642) does not mention the eyes at all.

¹ Zus. z. Monogr. d. Trilob. d. Ostseeprovinz., in Arch. für Naturk. Liv.—, Est.— und Kurl. I. Ser., Bd. II, p. 381, pl. II, fig. 15. 1859.

Fr. Schmidt in his *Crustaceenfauna der Eurypterenschichten in Rootzikhüll auf Oesel*,¹ has redescribed the only *Pseudoniscus* then known and states that he can not see eyes in the incisions observed by Nieszkowski and moreover has found the suture line in a specimen without any opening for the eyes. He adds, however, that he noticed on the right cheek a slight elevation that might be adduced as indicating an eye.

P. roosevelti was the second species described of *Pseudoniscus*. Doctor Clarke made a careful search for eyes. He states (Rep't N. Y. State Pal. for 1900, p. 89): "In all the specimens studied there is no evidence that can be construed as indicating the position or presence of eyes. The more complete specimens show certain wrinkles or ridges concentric to the margin, whose very obscurity might be regarded as veiling the eyes which from analogy one would expect to find in this creature; other shields show irregular swellings which are, in part at least, due to underlying carapaces of *Leperditia*, but the most favorably preserved demonstrate that it would be an error to let any such irregularities pass as an apology for eyes." It is obviously on account of these observations that *Pseudoniscus* in the new edition of Zittel-Eastman, page 777, is stated to be probably eyeless, while in the preceding edition it was considered as having large compound eyes.

The question of the eyes of *P. roosevelti* has been solved by four specimens since brought in from Pittsford; two of these show the eyes distinctly on the inside of the carapace and two others on the outside; one specimen also exhibits the facial sutures passing around the eye. These eyes are, however, in contrast with the supposition of Nieszkowski and Woodward, very small and situated much forward and near the margin (see pl. 33, fig. 6). Since they are small and of lunular outline and situated on the brow of the elevation of the carapace, any flattening or distortion of the carapace is very apt to close or compress them into an insignificant line, a mode of preservation of the eyes often also observed in Otisville shale material of eurypterids. A reinspection of the original material of *P. roosevelti* proves that that is precisely what has happened there. The specimens of *P. clarkii* show the eyes as minute lunular puckers at an exactly corresponding place.

The suture line was already observed by Schmidt on one cheek of *P. aculeatus* (*op. cit.*, pl. I, fig. 49) as a nearly straight or

¹ *Miscellanea Silurica III*, Mem. de l'Acad. Imp. des Sciences de St-Petersb., 7 sér., t. 31, no. 5, p. 40. 1883.

but slightly outward curving line passing backward from the frontal margin. One of our specimens shows a faint black suture line passing in the direction indicated in figure 7, plate 33.

The best preserved of the carapaces of *P. roosevelti* show the anterior projecting point to be strengthened by a trapezoidal prominence (see pl. 33, fig. 6).

An accomplishment, well known among trilobites and other crustaceans but hitherto not observed among Synxiphosurae and other limuloid arachnids, is the power of enrolment. Yet one specimen (pl. 33, fig. 6) has the abdomen distinctly rolled partly under the carapace and the pleura sliding under each other in forward direction in such a way that an accidental post-mortem rolling up seems excluded, especially since the carapace is the best preserved in the collection. Doctor Clarke has already pointed out the many trilobitelike features in this arachnid; the power of enrolment would be another peculiarity, apparently connecting the two. From evidence on the phylogeny of the Merostomata set forth in the monograph of the Eurypterida of New York, it seems probable that these similarities are due to a convergence resulting from similar habits and not to actual relationship.

***Pseudoniscus clarkei* nov.**

Plate 33, figures 8 and 9

In the report of the State Paleontologist for 1900 (p. 89), Doctor Clarke has described as *P. roosevelti* the first representative of this rare and interesting genus of Synxiphosurae before only known from the Silurian of Oesel, Russia. Doctor Clarke had then only the specimens from the Pittsford shale in the collection acquired from Mr Clifton J. Sarle, and one specimen from the Bertie waterlime at Litchfield. Since that time considerable more material has been obtained, partly collected by Mr H. C. Wardell and the writer in the canal bank at Pittsford, and partly in the Bertie waterlime by Mr C. A. Hartnagel. These specimens not only exhibit a number of new features of *P. roosevelti*, but also indicate that the specimens from the Bertie waterlime belong to a different species. Since in the whole *P. roosevelti* is better preserved than the new species, *P. clarkei*, and the former has been elaborately described by Doctor Clarke, we deem it sufficient to note the differences between the two species.

The carapace of *P. clarkei* is relatively longer and narrower than that of *P. roosevelti* (in the former the length is to the

width as 3 : 4; in the latter as $2\frac{1}{2}$: 4), the posterior margin is deeply concave in *P. clarkei*, the genal angles are broad and long; in *P. roosevelti*, however, the posterior margin is nearly straight transverse for the full width of the head shield and the genal angles are short and narrow.¹ The series of crenulations, observed on the posterior margin of *P. roosevelti*, is not seen in *P. clarkei*. The eyes are small, lunular, about one-third of the length of the carapace back and one-fifth the width of the carapace distant from the margin. The carapace and the axis of the abdomen appear, from the wrinkles, to have been higher than those of *P. roosevelti*. The abdomen is not tapering in outline as much as that of the other species and the axis is relatively broader. The pleura appear to be narrower and more curved or sickle-shaped. The telson spine has not been observed.

Echinognathus clevelandi Walcott

We describe under this name some new remains of a eurypterid from the Utica shale which are mainly interesting in indicating a gigantic size for that species.

So far only a walking leg and part of a segment have become known of *E. clevelandi* Walcott. These indicate already a form of fairly large size, easily 1 to 2 feet long. They came from the Utica shale at Holland Patent, N. Y.

In 1913 Dr A. F. Foerste discovered in the same formation at the "Palisades" or "Gulf" at Rome, N. Y., a spine which he recognized as being derived from a eurypterid and was so kind as to present it to the State Museum. This spine, which is not complete at either end and may easily have been longer by one-third, is 112 mm long. It is 7.5 mm wide at the proximal and about 4 mm wide at the other end. It is slightly curved and was obviously sharp-edged on both sides. Its most striking feature is the sculpture which consists of long elliptical scalelike markings arranged in rather indistinct longitudinal series and a row of narrow drop-like scales along the inner margin. These scale-markings are so typically eurypteroid in character that they at once indicated to Doctor Foerste the systematic position of the fossil. There is little

¹ Figure 1 of plate 2 (*op. cit.*) shows on the right side a broad genal angle for *P. roosevelti*, but inspection of the specimen proves that it is somewhat crushed and that the draftsman failed to get the correct line which is like that on the other, left, side. Figure 3 (*ibid.*) is a *P. clarkei* and shows the characteristic posterior margin.

doubt from the shape and curvature of the spine that it is one of the series of spines attached to the underside of the walking legs (see N. Y. State Mus. Mem. 14, pl. 57, fig. 4). If that is the case, then the corresponding leg must have been several feet long and the entire specimen ranked in size with the largest eurypterids known.

The spines on the leg of *Echinognathus clevelandi*, which is the type of the species, are not furnished with scale markings but with longitudinal striae. It is therefore possible that we have here before us another species of *Echinognathus*, but it is also quite possible that the ridges formed by the striae, in mature forms, break up into series of long scales and finally into irregular scales, as we see them on the spine in question. This alternative case is suggested by the shape and the arrangement of the scales.

Another fossil referable, though with more doubt, to *Echinognathus*, is a heart-shaped carbonaceous test, of which we have two specimens, both from the Utica shale at Holland Patent, Oneida county, N. Y. The larger (text fig. 36) one is about 68 mm wide and 64 mm long, broadly heart-shaped with a deep notch in the middle. The other, a slightly smaller specimen, shows evidence of the body having been a rather thick plate. The larger specimen exhibits in several places, as indicated in the figure, irregularly scattered nodes or scalelike markings. From their general outline these bodies, if eurypterid remains, must have been metastomas; and, if such, they indicate an undoubted relationship of *Echinognathus* to *Eusarcus*, for only with the metastoma of that genus can this plate be compared. Clarke and Ruedemann have pointed out in Memoir 14 (p. 58-59) how characteristic the form of the metastoma is of the different genera of the eurypterids. The short, stout walking leg of *Echinognathus* is also well comparable with that of *Eusarcus*, while on the other hand the rows of spines would suggest relationship to *Stylonurus*. When it is remembered, however, that also *Eusarcus scorpionis* and, still more, *E. newlini* have very long curved spines on their walking legs, it is readily conceivable that we see before us in *Echinognathus* an extreme development of this character of *Eusarcus*.

These metastomas would also indicate for the species of *Echinognathus* to which they belong, a size of a meter or more.

There is also a large carbonaceous test (text fig. 37) in the Utica shale material from Holland Patent which, though badly flattened, answers very well for the carapace of a eurypterid, resembling *Eusarcus*. It is trapezoidal in outline, with a broad base and tapering to the narrow frontal side. At the corners of

this side distinct lateral eyes are recognizable, in shape and position corresponding to those of *Eusarcus*. The specimen is somewhat distorted, but still allows the conclusion that the sides were slightly

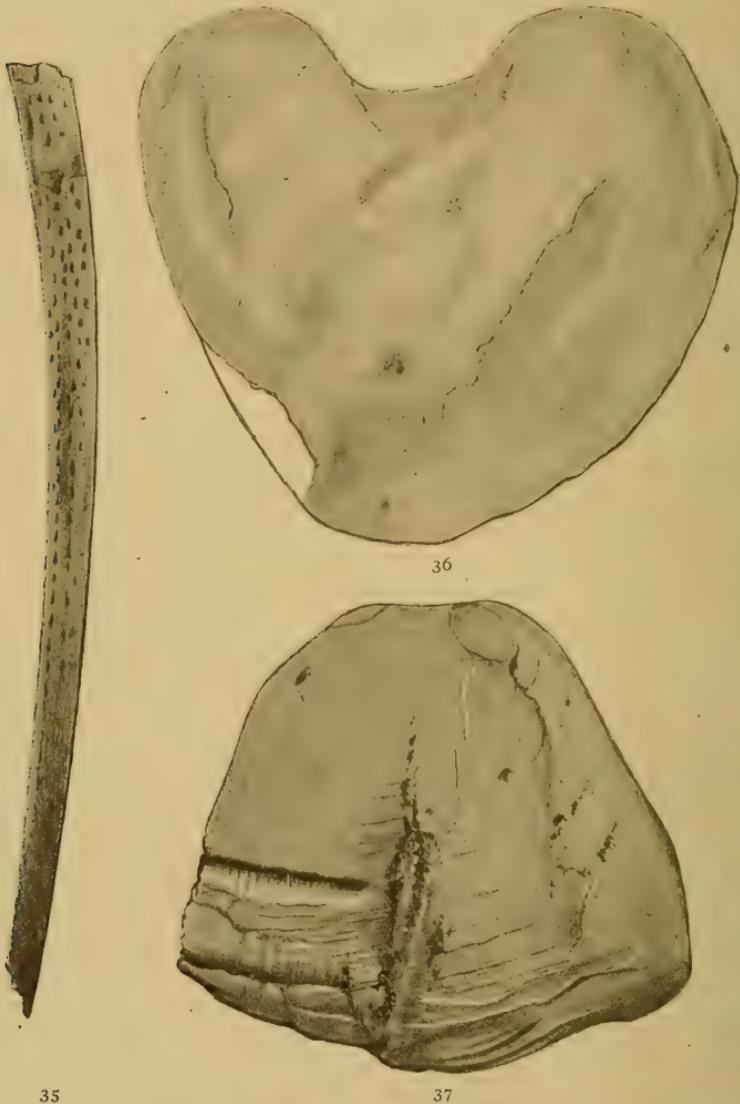


Fig. 35-37 *Echinognathus* cf. *clevelandi* Walcott. 35 Spine, probably of walking leg. 36 Metastoma. 37 Carapace. All natural size

convex and the frontal margin approximately straight; the posterior margin is now strongly convex, but there is evidence in some longitudinal folds of a lateral compression of the carapace which would result in the bulging out of the posterior margin.

The ocellar mound and the scales have been destroyed by the strong flattening of the test.

The eurypterid remains here described and referred to *Echinognathus clevelandi*, all come from the type locality and horizon, namely, the Utica shale at Holland Patent. For this reason and since they all agree in their characters sufficiently to point to a single well-defined eurypterid type, we feel quite certain that they indeed belong to one species or at least to one genus. This genus, *Echinognathus*, would then in the shape of its carapace, metastoma and legs, as well as the peculiar scale-marking, fairly closely agree with *Eusarcus*, with the distinction, however, that the walking legs are furnished with one or several continuous series of articulated spines of extreme length, similarly to the subgenus *Ctenopterus* of *Stylonurus*.

Eusarcus trigonus nov.

Plate 33, figure 10

A collection brought in by Mr C. A. Hartnagel from the Bertie waterlime at Crane's Corners, town of Litchfield, Herkimer county, contains a specimen of *Eusarcus*, the first representative of that interesting genus from the Herkimer pool or colony which is characterized by the well-known *Eurypterus remipes*.¹

The specimen consists of the carapace, preabdomen and the two swimming feet and proves specifically distinct from its congener in the Bertie waterlime, the *E. scorpionis*. Nor could it be considered as a younger stage of that large form, since we have a young *E. scorpionis* of the size of our specimen showing the adult features of *E. scorpionis* (see *op. cit.*, pl. 36, fig. 1). On the other hand, *E. trigonus* exhibits a striking similarity to *E. cicerops* from the Shawangunk grit, differing from the latter only in the size and still more marginal position of the lateral eyes.

Description. Body of small size, distinctly broad and stocky, carapace and abdomen combined of suboval outline. Carapace broadly triangular, one-fourth wider than long. The lateral margins, which are gently and rather uniformly convex, converge to the protruding front. The posterior margin was fairly straight. The lateral eyes are kidney-shaped, very prominent, situated marginal, about one-third the length of the lateral margin of

¹ See N. Y. State Mus. Mem. 14, p. 9. 1912.

the carapace distant from the frontal point. The ocelli are placed on a line connecting the posterior edges of the lateral eyes. The swimming legs are short, about as long as the base of the carapace. It is especially the "paddle" that is relatively shorter and stouter than in other species of *Eusarcus*, while the "arm" is relatively longer and less compact; in other words, the swimming feet of this species approach those of *Eurypterus*. The dorsal plates of the abdomen are broken away and only the interior of the ventral side is shown with a trace of the operculate appendage. The abdomen does not seem to have widened abruptly as in the *E. scorpionis*, but, if at all, more gradually as in *E. cicerops*.

Measurements. The carapace is 16 mm long by 22 mm wide. It is probable from some folds in the test that the carapace is somewhat contracted in antero-posterior direction and was a little less broad. The lateral eyes are about 3 mm long. The abdomen is but 22 mm wide, but clearly not fully preserved.

Remarks. It is a remarkable fact that in distinction from the Buffalo pool and the Shawangunk grit at Otisville, the Herkimer pool has in all the large collections obtained there, afforded but this one specimen of *Eusarcus*. And it is further noteworthy that this species is more closely related to the *E. cicerops* from the Shawangunk beds than to the *E. scorpionis* from the Bertie waterlime. It differs from the latter in the broader outline of the carapace, the position of the lateral eyes farther back along the lateral margin and the position of the ocelli between the lateral eyes as in *E. cicerops*, while in *E. scorpionis* they lie in the middle of the carapace. In the former species we have lately observed that even in the type specimen (see N. Y. State Mus. Mem. 14, pl. 36, fig. 4) there is the snoutlike lobe much more produced than we have figured. It is very much like that of *E. vaningeni*. With the latter species, *E. trigonus* has the position of the ocelli in common, but differs in the position of the lateral eyes, which in *E. vaningeni* lie far within the margin.

The possibility that the specimen could be a *Eurypterus remipes* preserved in an incomplete and deceptive fashion is excluded by the facts that, on one hand, the lateral eyes lie much farther forward than they are found in a carapace of that species with the basal width of our specimen; and, on the other, the ocelli are situated behind the lateral eyes while in *E. remipes* they are found between them.

II

NOTE ON THE HABITAT OF THE EURYPTERIDS

A large portion of the species described in the foregoing notes are fossils from the Salina group (Pittsford shale and Bertie water-lime). These had before been scattered in the collection and neglected, because the eurypterids, synxiphosurans and crustaceans of these formations focused all the attention of paleontologists on their remarkable display. Nevertheless these modest brachiopods, gastropods and pelecypods that are associated with the eurypterids have an importance of their own in aiding us to arrive at a proper conception of the habitat of the eurypterids.

Clarke and Ruedemann in their monograph of the American eurypterids¹ had arrived at the conclusion that the eurypterids were originally marine, but that their climacteric fauna was euryhaline or able to live in both very salt and brackish water and that their later habit throughout the Devonian and Carboniferous led them finally into the fresh water. This view has been challenged by Prof. A. W. Grabau,² who has relegated them into the rivers from earliest to latest Paleozoic time. His evidence rests mainly on the summary of the distribution and occurrence of the eurypterids, furnished for the same paper by Miss M. O'Connell. We have here not the space to enter upon a discussion of his indirect evidence and the attempt to dispute the direct faunal evidence furnished by Clarke and Ruedemann in their memoir. The gist of his argument is simply that the eurypterids are carried by the rivers into the beds where they are found mingled with marine fossils. Where the eurypterid remains themselves occur in great quantities and are promiscuously mixed with graptolites, as in the Normanskill shale, or with graptolites, trilobites, marine gastropods, etc., as in the Schenectady beds, great importance is laid on the fragmentary condition of the eurypterid remains and the conclusion therefrom derived that they are shed exoskeletons which drifted down the rivers to meet the graptolites that were swept up from the sea onto the mud flats. It is true that the exoskeletons of the eurypterids are extremely fragmentary, even in formations where they occur with all their growth stages and the animals were clearly

¹ The Eurypterida of New York. N. Y. State Mus. Mem. 14, 1912.

² Paleozoic Delta Deposits of North America. Geol. Soc. America Bul., v. 24, no. 3, p. 498ff. 1913.

at home, as in the Shawangunk grit and the Bertie waterlime at Litchfield. This is due to the fact that the greater number of specimens are actually shed skins, but shed in the locality itself, and further, as we are quite convinced, to the habit, so clearly observed among the crabs and other crustaceans in the ocean, of eating, with praiseworthy economy, the skins they have shed and further of cutting up and destroying with their pincers all skins and shells that are not any more palatable. In warm seas, where the shore line is alive with crabs, it is on account of these habits of the crabs, impossible to pick up whole exoskeletons. Nevertheless we find in the Bertie waterlime, especially at Buffalo, altogether too large a percentage of splendidly preserved whole exoskeletons of eurypterids which entirely lack the frontal cleft indicating that the skin was shed, to be able to assume that these were drifted into the basin. But Grabau and O'Connell go still further and attempt to make even the fauna of the Bertie waterlime a freshwater fauna.¹ It is in view of this assertion that the writer has brought together the following lists of fossils from the Bertie waterlime and Pittsford shale and waterlime, our two principal eurypterid-horizons of the Silurian.

The Pittsford shale at Pittsford contains besides the eurypterids and crustaceans described therefrom (species of *Eurypterus*, *Pterygotus*, *Hughmilleria*, *Pseudoniscus*, *Emmelezoe*, *Ceratiocaris*):

- Lingula semina* *Ruedemann* cc
- Pterinea poststriata* *Ruedemann* cc
- Leperditia scalaris* *Jones* cc
- Septameroceras* *sp.* rr
- Orthoceras* *sp.* rr

Toward the east this horizon changes into a waterlime rock, which at Farmers Mills contains besides *Eusarcus vaningeni* an abundance of

- Lingula alta* *Ruedemann* cc
- Orbiculoidea molina* *Ruedemann* cc

The Bertie waterlime contains besides the eurypterids, *Pseudoniscus* and *Proscorpius*

- Inocaulis lesquereuxi* (*Grote & Pitt*) r
- Lingula testatrix* *Ruedemann* c
- Diaphorostoma* *sp.* rr
- Hercynella patelliformis* *O'Connell* rr

¹ Marjorie O'Connell. Description of Some Siluric Gastropods. Buffalo Soc. of Natural Sciences Bul., v. XI, no. 1. 1914.

- H. buffaloensis* O'Connell rr
Hormotoma gregaria Ruedemann c
Orthoceras vicinus Ruedemann rr
Phragmoceras accola Ruedemann r

Miss O'Connell (*op. cit.*, p. 100) has inferred from the thin tests of the *Hercynellas* and their association with the eurypterids, ceratiocarids and the "plant" *Buthotrephis lesquerieuxi*, that these *Hercynellas* were not marine animals. The *Buthotrephis* has been proved in this paper to be a good sessile graptolite of the genus *Inocaulis*. It occurs in the waterlime in splendidly preserved colonial stocks, which can not have drifted any distance. The *Lingulas* and *Hormotomas* occur in certain layers in such immense quantities that they are certainly in their proper surroundings where found. The *Diaphorostomas*, *Hercynellas* and specimens of *Orthoceras* are very rare and therefore noncommittal, while of *Phragmoceras accola* we have before us a dozen specimens in various growth-stages suggesting that this cephalopod may well have found the conditions in the Bertie lagoons as congenial as the brachiopods and the eurypterids. At any rate there is not in the whole assemblage of the Bertie waterlime a single genus that could be considered as indicative of a freshwater fauna, and all these marine forms are found on the same slabs with the eurypterids, so that an alternation of marine and freshwater conditions can not be assumed either.

In the Pittsford formation there occur both in shale and waterlime, specimens of a *Lingula* and of a *Pterinea* in great abundance, together with a *Leperditia* and very rare specimens of cephalopods. In the eastern extension of the Pittsford shale *Eusarcus vaningeni* is found on slabs densely crowded with *Lingulas* and *Orbiculoideas*. None of these could be possibly considered as indicative of freshwater conditions. There is hence not a trace of freshwater life in the Silurian eurypterid beds and since the eurypterids themselves are the prevailing element of these faunas, it is clearly a dangerous begging of the question to make them either freshwater animals that were drifted into the marine assemblage, or have the latter with its countless specimens conveniently drift into the freshwater with the waiting eurypterids. As in the Normanskill and especially in the Schenectady beds, and also in the Silurian waterlime, both the eurypterids and the other marine forms are found associated again and again throughout a great thickness of beds; they clearly belong together as members of one fauna, and this fauna was marine.

III

TWO NEW STARFISHES FROM THE SILURIAN OF ARGENTINA

In this paper two new species of starfishes from the Silurian of the Cerro Blanco are described, which were sent by Prof. W. Bodenbender to Doctor Clarke. They are labeled as coming from the Devonian of Jachal (Cerro Blanco)=Quebrada del Aguadida. Prof. E. Kayser in this paper: *Beiträge zur Kenntniss einiger paläozoischer Faunen Süd-Amerikas*,¹ mentions already the occurrence of starfishes at the Cerro Blanco. He states: "At the Cerro Blanco (between the Jachal valley and Iglesia) there are still two more, higher fossil horizons, the *lower* of which is marked by abundant remains of *Lingula subalveata* and *Pholadella radiata*, the *upper* by numerous conularias, starfishes, crinoids, Spirophytons, etc." The beds which carry these starfishes are called the "Conularia sandstones"; they occur only on the west side of the Jachal valley, and are supposed to be of about the same age as the beds with *Vitulina*, etc. on the east side of the same valley (namely, Middle Devonian, see *op. cit.* p. 310). Doctor Clarke² from a close analysis of the species of the Argentina Devonian, has later arrived at the conclusion that there are two distinct groups of fossils, the first of which distinctively represents the Devonian of the Falkland islands and of Ponta Grossa, while the second, to which the starfishes belong, constitutes (1) an assemblage "not known elsewhere in any admitted Devonian fauna, either of the northern or southern hemisphere," and (2) "embraces a series of well-defined Silurian (Upper Silurian) type forms, variant to a noteworthy degree in species but not widely in generic expressions." In the final tabular lists (*op. cit.* p. 351) the fossils of Argentina are arranged by localities and by their print indicated as either of Silurian or Devonian age. The fossils of the Cerro Blanco are about half Silurian and half Devonian; as Silurian elements being cited: *asteroid* (Kayser), *Orthotheses* small, cf. "*arctostriata*" (Kayser), *Clintonella bodenbenderi*, *Brachyprion fascifer*, *Australina*

¹ *Zeitschrift der deutschen geol. Gesellsch.* 49, p. 276. 1897.

² *Monographias do Serviço geologico e mineralogico do Brasil*, v. 1, 1913, p. 54, 334, 351.

jachalensis. The more recent stratigraphic studies by Stappenbeck of the Argentina Cordilleras have verified the distinction indicated by Clarke.

Of the two species of starfishes here described, one is referred to *Encrinaster*, a genus in Europe practically restricted to the Lower Devonian, if we except a doubtful form from the Caradoc of Great Britain. In America the Lower Devonian of Brazil has furnished one species (*E. pontis* Clarke) and three species are here described from the Devonian of New York, one each from the Hamilton, Portage and Chemung groups. The combined occurrences of the genus in the Lower Devonian of Europe and Brazil would indicate that the genus was well established in Lower Devonian time in the European and South American seas, but arrived in North America not until or lingered there until late Devonian time. Its presence in the Lower Devonian of both Europe and Brazil presupposes of course the possibility of its origin or arrival there in late Silurian time.

The second species is here referred to a new genus, *Argentinaster*. This has distinct relationship to the genera *Hallaster* and *Squamaster*, the first of which is based on a species of earliest Devonian age (Coeymans limestone), the second on a Silurian species. *Argentinaster* may therefore indicate, if an inference based on such slender evidence is altogether admissible, a late Silurian or early Devonian age for the beds in question.

***Encrinaster yachalensis* nov.**

Plate 18, figures 1-5

This *Encrinaster* from the Silurian of Cerro Blanco, Yachal (=Quebrada del Aguadida) in Argentine Republic, collected by Bodenbender, is represented by a single specimen exhibiting the abactinal side. It is remarkable for two features, the very large size of the disk and the very slender appearance of the rays, which, however, is partly due to the fact that the adambulacrals seem to have been rather thin and are poorly preserved. The integument of the disk is fairly granular and its margin is slightly concave. Instead of the single row of marginal plates seen in other species of *Encrinaster*, this species shows a great number of marginal plates, owing to the fact that the marginal row is flanked on the inside by two to three accessory series of plates which do not quite reach the middle of the disk margin. While the large *E. tischbeinianus* (Roemer) shows a few accessory marginal plates

in the corners of the disk, no other species of this genus or any other Devonian auluroid seemed to exhibit a like strong development of the accessory marginal plates. The rays are slender, hardly if at all petaloid in form, but regularly tapering; they probably extended no more than half their length beyond the disk. The specimen shows only the abactinal or dorsal view of the ambulacrals, which are distinctly alternate, subquadrate, half vertebra-shaped with raised distal and proximal margins. Proximally the two columns end in the strong, simple, curved jaws which carry the rather long and slender syngnaths.

The adambulacrals are, as in some other Encrinasters, not seen on the dorsal side within the disk; outside of the latter they could be observed only in one place as thin, obliquely rhomboidal plates that lie opposite the ambulacrals.

Compared with its congeners, this form in its aspect differs from most others by the large disk and narrow, hardly petaloid rays. In the latter feature it compares well with *E. arnoldi* Goldfuss, but it differs from all in the double and threefold columns of marginal disk plates. Its mouth frame is exactly as in the other Encrinasters. With *E. pontis* Clarke, another South American (Devonian) species, from Ponta Grossa, Parana, Brazil, it possesses considerable similarity in the form of the rays and in the shape of the ambulacrals which are exactly alike in the abactinal view, as well as in that of the jaws; but it would seem that *E. pontis*, while altogether a smaller species, had also a relatively much smaller disk (the latter only seen in one specimen) and lacked the strong, or any, development of the marginal plates.

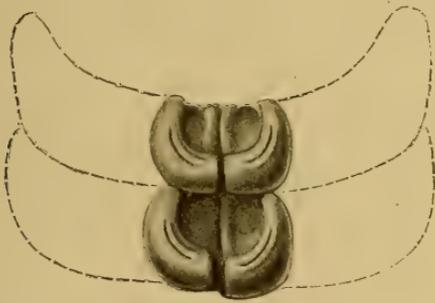
***Argentinaster bodenbenderi* nov.**

Plate 18, figures 6 and 7

The species described in this chapter can not be brought under any known genus of starfish. It is distinctly an Auluroid but has certain characters of the genera Encrinaster, Hallaster and Squamaster without fully agreeing with any of them.

The disk is distinct, with concave margins, and three large distinct marginal plates which belong to the adambulacrals, only the ambulacrals continuing to the mouth. The rays are slender, regularly tapering; on the actinal side they show opposite highly projecting, pipe-bowl-shaped crests, turning the bowls toward each other and in the deep interspaces a distal buttonlike prominence, with the podial pores on either side. The ambulacrals

are transversely subquadrangular in outline with proximal wings curving around the podial openings proximally, as in *Hallaster* and *Taeniaster*. The adambulacrals are, considering the size of the ray, astonishingly strong and large plates; of halfcup shape, imbricating with their distal extremities and extending far up to the abactinal side where they come nearly into contact showing between them the abactinal sides of the ambulacral ossicles which there appear like vertebrae or thick rings with a faint median suture. Along their distal edge they show evidence of fine fragile spines. A column of four of these vertebralike ambulacrals can



38



39

Fig. 38, 39 *Argentinaster bodenbenderi* nov. 38 Ambulacral ossicles, seen from actinal side, the outline of adambulacrals in dotted line. $\times 5$. 39 Abactinal side of one ray, showing the oral frame, the middle column of ambulacrals and the large adambulacrals. $\times 2\frac{1}{2}$

be traced within the disk to the mouth frame. The latter is very heavy, apparently simple and bears the equally blunt, thick syngnaths or mouth angle plates. The surface of the disk integument and of the marginal disk plates was granular, the ray plates were smooth.

Madreporite not seen.

Measurements. Radius of rays 20+mm; radius of disk 5 mm.

Horizon and locality. Silurian of Quebrada del Aguadido (Yachal, Cerro Blanco), Argentine Republic.

The general outline and the presence of the marginal disk plates would suggest a small *Encrinaster*, but the structure of the rays with their opposite ambulacrals that possess proximal wings surrounding the podial pores; and especially the form of the adambulacrals, are characters connecting it with the genera *Hallaster*,

Squamaster et al. of the order Streptophiuræ. It differs from them in the strong development of the marginal disk plates, the presence of the pipe-bowl-shaped crests, which are not observed in any other genus of the Auluroidea, and further in the large size and development of the adambulacrals which almost come in contact on the abactinal side. The fringe of fine spines along the distal extremity is also found in Squamaster and Hallaster, and many other Streptophiuræ.

IV

A NEW CERAURUS FROM THE CHAZY

BY PERCY E. RAYMOND

Several years ago the writer collected the hypostoma of a large *Ceraurus* from the lower part of the Upper Chazy (zone with *Glaphurus pustulatus*) at Cooperville, New York. The hypostoma was much too large to belong to *Ceraurus hudsoni* and so was not described in my first paper on the Chazy trilobites, but a figure found a place in the second paper, in 1910. Recently Doctor Ruedemann was good enough to call my attention to a very large *Ceraurus* which he had collected at the same horizon in the Chazy at Little Monty bay, Chazy, N. Y. Through the kindness of Doctor Ruedemann I am permitted to describe this particularly interesting species.

The specimens in the New York State Museum are five in number, two incomplete cranidia, two free cheeks, one retaining the visual surface of the eye, and an incomplete pygidium.

***Ceraurus ruedemanni* sp. nov.**

Plate 30, figures 9-12

Undetermined hypostoma, Raymond. *Annals Carnegie Museum*, v. 7, no. 1, pl. 19, fig. 22. 1910.

Specific diagnosis. A large *Ceraurus* with somewhat depressed glabella ornamented with small pustules, the axial portion of the glabella isolated from the side lobes by the longitudinal furrows. Pygidium with strongly developed "great" spines and one pair of long spines between the "great" spines, these inner spines being developments of the second segment.

The glabella is roughly rectangular in outline, rather more flattened and more finely pustulose than most species of *Ceraurus*. The outline of the front is not rounded, but shows three straight edges. There is a narrow, slightly pustulose anterior rim separated from the glabella by a narrow, smooth furrow. The width of the glabella expands toward the front, but the axial lobe, which is distinctly isolated from the glabellar lobes by a pair of longitudinal furrows, expands very slightly. The frontal lobe is short and narrowed at the sides. In the middle of the front there is a shallow rounded

indentation, remotely suggesting the rudimentary anterior glabellar furrow of some species of *Pliomerops* or *Heliomera*. The basal lobes are not so nearly square as is usual in *Ceraurus*, the posterior glabellar furrows having an appreciable backward slant. Only a fragment of a fixed cheek is preserved, not enough definitely to locate the position of the eye, which organ would appear, from the outlines of the free cheek, to have been well back and remote from the glabella. In fact, this organ seems to have had about the same position as in *Ceraurus dentatus*. The cheeks are covered with large, rounded pits and small tubercles on the inosculating rounded ridges between the pits. The eye line is prominent and covered with small tubercles.

The hypostoma, known only from the specimen figured by me in 1910, has an oval body portion covered with small tubercles and a wide, smooth border which is incompletely preserved.

The free cheek shows an elevated rounded rim which appears to be smooth, the remainder of the surface being covered with pits which are somewhat smaller than those on the fixed cheeks. The eye is low and large, the lenses, which are small and circular in outline, showing unusually well. No attempt was made to estimate the number.

No segment of the thorax is preserved but the cephalon and pygidium are so characteristically *Ceraurus*-like that there can be no doubt but that the thorax is of the ordinary type for the genus.

The single pygidium is very large and especially wide at the front. The conformation is as usual in *Ceraurus*, there being two greatly developed, elongate spines at the sides, and three rings and a posterior mound on the axial lobe. The unusual feature is the great development of the pleural lobes of the second segment, which form long spines which are prolonged a considerable distance beyond the margin. These spines point almost directly backward, and do not bow outward as do the outer spines. Between these spines of the second segment are two very short spines or denticles, the spines of the third segment of the pygidium, but there is no median spine.

Measurements. The best cranidium is 38 mm long, the glabella 31 mm long, 30 mm wide at the front, and 25 mm wide at the back; the frontal lobe is 12 mm long. The smaller cranidium is 28 mm long. The pygidium is about 45 mm long over all, 16 mm long as measured along the axis. The width at the front is about 36 mm. The great lateral spines appear to have been about 45 mm long, and the second spines are 11 mm long.

These measurements indicate a trilobite even larger than *Ceraurus dentatus*, the largest American *Ceraurus* previously known. An incomplete specimen of that species has an estimated length of about 100 mm, while *C. ruedemanni* should have been about 125 mm long, if it had the same proportion of length of cephalon to length of body that has been observed in *C. dentatus*. This measurement would not include the long pygidial spines, but would be the length along the axial line.

This species has about the same size as *Ceraurus scutiger* Eichwald, the European (Russian) species which it most resembles. The largest specimen of that species has, according to the measurements given by Schmidt, the cephalon 35 mm long; the glabella 26 mm long, and 23 mm wide at the front and 21 mm behind.

Comparison with other species. The presence of two pairs of long spines in the pygidium of this species distinguishes it at once from all other American species of *Ceraurus*. Among European species, there is one which in size and spinose pygidium, very strongly suggests our Chazy form. This is the *Ceraurus scutiger* of Eichwald, from the "Brandschiefer" of the Kuckers formation in Esthonia, Russia. This species was described by Eichwald in 1857 on page 209 of the *Bulletin de la Société des Natur. de Moscou*, and in the same year figured without a name by Nieszkowski in the *Archiv. f. Natur. Livland, Estland u. Kurland*, series I, volume I, plate I, figure 13, plate 3, figure 16. In 1859, Nieszkowski applied the name *Cheirurus spinulosus* to the species and Schmidt has, without right, adopted this name in his "Monograph of the East Baltic Silurian Trilobites" (*Mem. Imp. Acad. Sci. St Pétersbourg*, ser. 7, v. 30, no. 1, p. 147, pl. 6, fig. 16; pl. 7, fig. 6-17; pl. 16, figs. 5, 6. 1881.)

This species is of about the same size as *Ceraurus ruedemanni*, is a true *Ceraurus*, and is in many ways like our Chazy species. The glabella differs in the ornamentation, having rather large tubercles on the posterior portion and being smooth at the anterior end, while the whole of the glabella of *C. ruedemanni* is covered with small tubercles. The glabella of *C. scutiger* does not show the longitudinal furrows isolating the axial lobe. On the pygidium one sees both the greatest similarities and the greatest differences. In *C. scutiger* the pygidium shows three pairs of spines and a short median spine, the pleura of the third as well as the second segment being produced into spines.

The described American species most like this new form is *Ceraurus dentatus* Raymond and Barton (Mus. Comp. Zoology Bul., v. 54, no. 20, p. 534, pl. 1, fig. 2, pl. 2, figs. 4, 5, 1913). In this species both the second and third pairs of spines on the pygidium are represented by denticles which cross the posterior border, the chief difference between the pygidia of the two species being thus the suppression of the second pair of pygidial spines in *C. dentatus*. The glabella of *C. dentatus* is similar in shape to that of the present species, but is somewhat less depressed and has coarser tubercles.

The only other species of *Ceraurus* in the Chazy are *Ceraurus hudsoni* Raymond (Annals Carnegie Mus. v. 3, no. 2, p. 367, pl. 14, fig. 15, 1905), a species known only from specimens of the cephalon, and *C. granulatus* Raymond and Barton, a species with a small cephalon and with granulose rather than pustulose surface (Mus. Comp. Zoology Bul., v. 54, no. 20, p. 536, 1913). The cephalon of *C. hudsoni* is much like that of *Ceraurus pleurexanthemus*, with which species it might have been united at the time of the original description had it not been for the possibility that the pygidium might prove to be of a very different type.

Ceraurus ruedemanni would appear to be a derivative of the Russian *Ceraurus scutigera* by the suppression of the third pair of spines on the pygidium, a shortening of the central spine, and the reduction in size of the pustules of the surface ornamentation. The Kuckers formation, which contains the Russian species, is the second of the formations of C, the formations characterized by Echinospaerites. If we are to judge by comparison of the sections in Russia, Norway, and the eastern United States, the Kuckers is not widely different in age from the Chazy of the Champlain valley.

The species here described is also of especial interest as an example of another link in the chain connecting *Ceraurus pleurexanthemus* and later species of *Ceraurus* with the theoretical *Ceraurus* ancestor. The pygidium of *Ceraurus pleurexanthemus* is small, with a much reduced central portion, and two very long, strong spines at the sides. The posterior margin of the portion between the great spines is often smooth, but as Raymond and Barton have shown, it may be undulating or even show small denticles. Although such a pygidium appears to be highly specialized, the variations in the posterior margin might suggest that it was really a variable form which

might ultimately develop a more instead of a less spinose pygidium. *Ceraurus pleurexanthemus*, as it occurs in the Trenton, holds an intermediate place in the time occupied by the history of the Cheiruridae. Older and more primitive genera like *Pliomera* and some species of *Cyrtometopus* show a pygidium with several pairs of subequal spines, and later species, like some of the Silurian species of *Cheirurus*, also show pygidia with a series of approximately equal spines.

Does the pygidium of *Ceraurus pleurexanthemus* then represent the end of a line in which there is a reduction from a primitive species in which the pygidium has equal spines at the extremities of the pleura of all four segments, or is it in itself a primitive form, from which a many-spined pygidium might be developed?

From the ontogeny of *C. pleurexanthemus* itself we learn nothing. Although specimens only 3 mm long have been studied, they do not differ from the adult.

The pygidium of only one *Ceraurus* from a younger formation than the Trenton is known. That is the *Ceraurus millerianus* Miller and Gurley, of the Cincinnati. In that species the second pair of segments in the pygidium give off blunt spines, so that the posterior margin is undulatory, and thus what slight variation exists is in the direction of the development of spines. The only other indication in this direction is seen in *Cheirurus hydei* Weller (Chicago Acad. of Sci. Bul., 4, p. 2, 1907, page 264), a form which might be considered as a sort of a bridge from *Ceraurus* to *Cheirurus*, as it has the cephalon and thorax of a *Cheirurus* and a *Ceraurus*-like pygidium. From other lines of evidence however, it does not seem probable that this is a primitive but rather a specialized *Cheirurus*.

Turning back to the other hypothetical line connecting *C. pleurexanthemus* with the supposed ancestor, there seems to be somewhat better evidence, though the line is still very incomplete.

As has already been stated, the pygidium of *C. dentatus* is less specialized than that of *C. pleurexanthemus*, as the posterior margin between the great spines has two pairs of short spines and a trace of a median spine. *C. dentatus* is not, however, found in older beds than *C. pleurexanthemus*, but its history is practically contemporaneous with it. *Ceraurus ruedemanni* shows a very decided step back toward the many-spined pygidium, the second pair of spines being strongly developed,

though the third pair are very short and the median spine apparently absent. *Ceraurus scutiger* shows three pairs of spines on the pygidium, and a short median spine, thus making a close approach to the required ancestor, but the great spines are still much longer than the spines between, and the development of the various spines is very unequal.

Horizon and locality. The specimens are from the lower part of the Upper Chazy at Little Monty bay, Chazy, N. Y., and the quarry near the bay at Cooperville, N. Y. The large pygidium may be designated as the holotype and the other figured specimens as paratypes. All were collected by Dr Rudolf Ruedemann and are in the New York State Museum. The hypostoma previously described was collected in the lower part of the Upper Chazy at Cooperville, N. Y.

V

THE PRESENCE OF A MEDIAN EYE IN TRILOBITES¹*Plates 34-30*

The purpose of this paper is to assert the occurrence of median or parietal eyes in the trilobites. We do not know whether the presence of such eyes has been proved before; at any rate, we have been unable to find statements to that end in the literature accessible to us, while on the other hand, none of the recent textbooks and treatises mention the occurrence of such eyes in trilobites, and some, as the excellent Manual of Paleontology by Nicholson and Etheridge, state directly that "trilobites differ from the Merostomata in having no "ocelli" (p. 527). It is true "ocelli" have been mentioned of trilobites, but in every case something else than the median or parietal eyes of the crustaceans, which alone, as a rule, occur as "ocelli," is meant. Thus Woodward has considered as ocelli two pores or funnel-shaped depressions which are found, one on each side of the glabella, in the dorsal furrows mostly alongside the frontal lobe. McCoy thought that these "cephalic pores" might have been the points of origin of a pair of antennae, and Nicholson and Etheridge considered them as the points of origin of deep internal processes of the exoskeleton to which muscles were attached. Whatever their function may have been, they were not ocelli, because these would not be located at the bottom of furrows.²

In his paper on Trinucleus and in his chapter of the Zittel-Eastman textbook (p. 612), Beecher has stated that the visual organs of certain genera, as Harpes and Trinucleus which present from one to three simple elevations or granules on the fixed cheeks at the end of "eye lines," should be correlated with the ocelli of

¹ Paper read before the Paleontological Society of America at the Washington meeting, December 29, 1915.

² We do not claim, however, that they may not have been originally larval ocelli, for in the larvae of insects and other arthropods there occur a pair of frontal ocelli, which, however, in arachnids and crustaceans (phyllo-pods and entomostraca) are highly modified, as two sets of "frontal organs," two paired and one unpaired. In *Limulus* they become the "olfactory organs" (see Patten, no. 13, p. 126) and we consider it quite possible that these pores also had that function in the trilobites.

many crustaceans, "while the ordinary compound eyes on the free cheeks are absent." In their structure these simple eyes of Harpes and Trinucleus may be called ocelli, but they are not homologous to the median or parietal eyes of the crustaceans, as the last clause of Beecher's sentence would indicate, and we consider them as either primitive or atrophied, lateral, compound eyes, agreeing in this regard with Clarke (no. 4) who unites them as simple, particular cases with the schizochroal eyes. Our reasons for this view are:

1 The "ocelli" of Harpes and Trinucleus are situated at the ends of the primitive "eye lines" which, according to Beecher, are found in four-fifths of the Cambrian trilobites. But these Cambrian trilobites show at the end of the eye lines regular compound lateral eyes (as Olenus, for instance) situated along sutures. Hence the "ocelli" of Harpes and of the young Trinucleus are entirely homologous to the compound eyes of the other trilobites, as far as regards their terminal position to the eye lines.

2 The "ocelli" of Harpes show as many as three lenses each, while the median eyes of the crustaceans show no more than two lenses where they are united in the middle of the carapace, or one ocellus for each eye.

3 The "ocelli" of Cryptolithus (Trinucleus) at least can not be homologous to the median eye of the crustaceans because we have found in that genus the true median eye on the glabella (see below), and the facial suture connected with the so-called "ocelli" (see p. 144).

The median eyes which are in this note claimed for the trilobites, appear in the majority of cases as a *single tubercle upon the glabella*, mostly on a line connecting the posterior extremities of the lateral or compound eyes. We first observed these minute tubercles on the glabellas of half or less mature specimens of *Isotelus gigas* (see pl. 34, fig. 6). While the entire integument of this trilobite is smooth, that is, only finely punctate but entirely without any tubercles, there is always seen this single fine tubercle on the posterior portion of the glabella. It is most distinct on the earliest growth-stages and mentioned, and well figured in Raymond's careful "Notes on the Ontogeny of *Isotelus gigas* DeKay" (7, p. 250, fig. 1; pl. 7, figs. 1-3) as a "median tubercle." We then found this tubercle to be a constant feature in many genera (about thirty, see below under 8, p. 138) where as such it had already been recognized by various authors for one or several species in each case, thus by Barrande (no. 1) and by Oehlert (no. 12), for all species of *Cryptolithus* (*Trinucleus*), and

by Schmidt (no. 27) for nearly all Asaphidae. Barrande (*op. cit.*, p. 616) states (translated): "In passing we mention as an interesting fact that in *Trinucleus bucklandi* the eye protuberances which are very marked and constant in young age and during the whole growth of each individual, disappear when it has completed its development. The specimens which we know all agree in showing this feature, while all preserve in all growth-stages another ornamental tubercle of about the same size on the apex of the glabella. Oehlert (no. 12, p. 320) also comments on the fact that the "eye tubercles seem to exist concurrently with a third tubercle which occupies the middle of the frontal lobe." Beecher in his well-known paper on the Structure and Appendages of *Trinucleus* (no. 2) states that a spot or node has been noticed by many observers in the median line of the glabella of that genus and that although its nature has not been demonstrated, it has been considered an ocellus.

Reed (no. 23, p. 446) states regarding the lateral eye spots of immature (*Cryptolithus*) *Trinucleus*, that the visual function of these tubercles in the larval *Trinucleus* has never been demonstrated, and no description of lenses or visual surfaces has ever been published, so far as he knows adding that however the general similarity between the eye line and eye spot of *Harpes* and these structures in the larval *Trinucleus*, is in favor of regarding the latter as organs of sight, and winding up by the suggestive remark: "From the resemblance of the tubercle on the glabella to those on the cheeks, we might probably regard it as possessing likewise a visual function."

After recognizing the constancy of occurrence and corresponding probable functional importance of this tubercle on the glabella, we endeavored to find evidence of its ocular nature. The first effort would naturally be to look for lenses, but it is here to be remembered that the parietal or median eyes of arthropods show a wide range of development. Patten, in his *Evolution of the Vertebrates and Their Kin*, states (no. 13, p. 125) that in the arthropods, we may recognize four types of eyes, namely, paired larval ocelli, parietal eyes, frontal ocelli or stemmata, and the lateral or compound eyes. The larval ocelli are present in the active larvae of most insects and do not concern us here. The frontal eyes or stemmata are in crustaceans modified into other organs (the frontal organs) and here of no concern. Regarding the parietal eye Patten states: "In the crustacea and arachnids, two pairs of ocelli unite to form an unpaired ocellar vesicle, or parietal

eye. . . The parietal eye usually persists through life, and it may be the largest and most important one functionally."

Our observations on the median tubercles in trilobites lead to the conclusion that they represent median eyes in very different stages of development, from mere transparent spots of the test in most genera to fully developed lenses in others. The eye tubercles in *Isotelus gigas* which gradually disappear with advancing ontogenetic development, are hollow and possess obviously no more than a transparent spot on the top of the small tubercle, underlaid by a pigment spot, and may have served only for the recognition of light intensities. This primitive type of parietal eye is alike to the well-recognized eye tubercles of many fossil crustaceans, notably of such ostracods as *Leperditia* or phyllopods as *Ceratiocaris*. The eye tubercles of *Leperditia p. e.* are minute tubercles (see Ulrich, no. 28, p. 635), hardly noticeable, always showing, however, a pit on the inside.¹ While this is probably the prevailing type of the eye tubercles in the Asaphidae, it is not the only one. The excellent preservation of the Paleozoic fossils in the Russian Baltic provinces, shown in the brachiopods of the Cambrian and the justly famous eurypterids of the Silurian, is also manifest in the uncarbonized chitinous exoskeleton of the Ordovician trilobites. We had unfortunately only few specimens at our disposal, namely, examples of *Asaphus expansus* (Linné) and *A. raniceps* Dalman. In one of the former the top of the tubercle is broken off, showing the latter to be hollow; in another the tubercle possessed a transverse flat top, declining forward, which showed two darker spots, arranged transversely. On sectioning this specimen it was found that in these spots the test was slightly thinner and that the opaque matrix there reached closer to the surface causing the darker spots (see pl. 35, fig. 9). In a third, as also in a specimen of *A. raniceps*, the interior cast of the tubercle exhibits a distinctly flat top. In the other specimens of *A. expansus* it is depressed with a well-defined ring (see postea, p. 133).

Schmidt's (no. 27) beautiful photographs of Asaphidae in his "Revision der ostbaltischen silurischen Trilobiten," afford instances of interior casts of eye tubercles where a well-defined pit or pore

¹Deecke (no. 6, p. 116) states that one can make thin sections through the eye tubercles of the *Leperditias* of Gotland, adding (translated): "There the otherwise dark shell is light-colored, but passes in a thinner condition over the tubercle, so that, if eyes were under them, the animals looked through the shell, which happens quite often in crustaceans."

is shown (see pl. 36, figs. 3, 6, 8) that probably contained a lens in *Asaphus laevissimus*,¹ *As. ludibundus* (ibid. pl. 8, fig. 16); *Basilicus kegelensis*,² *Nileus armadillo* (ibid. pl. 8, fig. 13), *Megalaspis acuticauda* var. *typica*.³ In a few of Schmidt's photographs two pits are observable, suggesting the presence of two lenses. This is the case in *Asaphus eichwaldi* (*op. cit.*, Lief. II, p. 41, fig. 28a).

Having noted the peculiar tubercle on the top of the bulgy glabella of *Cryptolithus* (*Trinucleus*) we searched our specimens for evidence of lenses in these. It was found that the numerous shale specimens from the Lorraine beds, which have lost their lime content, exhibit only the exterior surface but afford the significant observation that while in *Cryptolithus* (*Trinucleus*) *tesselatus* the surface of the cheeks and glabella is finely pitted, the top of the tubercle is smooth, exactly as in the eye spots on the cheeks. In the specimens from the Trenton limestone the glabella is usually exfoliated, the test adhering to the matrix. These for the most part give a cast of the interior of the eye tubercle with a well-preserved and regular apical pit. This pit was also found to be finely preserved in a specimen of *C. (T.) bucklandi* (see pl. 34, fig. 5) from the Ordovician of Girvan, Scotland. In this specimen the top of the tubercle is black in contrast to the light buff-colored rock, suggesting that the pigment of the ocellus may be preserved.

In a considerable number of the Trenton limestone specimens, however, the upper portion of the tubercle is glossy, dark and smooth, and therefore so distinctly set off from the surrounding surface which is densely pitted that it appears like a black pearl set in a little mound and can not help suggesting at once the presence of a separate lens (see pl. 34, figs. 2 and 3; pl. 35, figs. 1 and 2). This body is rather strongly conical upward, fairly well defined in outline toward the pitted surface, and when broken out, considerably flatter on the under side. In thin sections (see pl. 35, fig. 2), the lens, in spite of its crystalline aspect, due to its smooth surface, appears to be composed of the same fine-grained brownish lime-mud as the matrix of the rock, but also set off by a distinct carbonaceous line on the under side. It is

¹ See *op. cit.*, Lieferung I, pl. 5, fig. 4.

² See *op. cit.*, Lief. II, pl. 5, figs. 1 and 4.

³ See *op. cit.*, Lief. V, p. 43, fig. 19.

along this line that the lenticular body is apt to break out when pressure is exerted on the tubercle. In thin sections of the overlying crust (see pl. 35, fig. 5), we find that the integument thins to less than one-half its normal thickness above the tubercle,

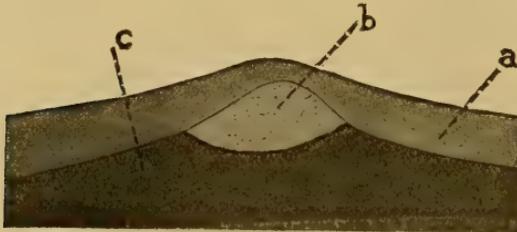


Fig. 40 *Cryptolithus tessellatus* Green. Diagrammatic section through eye tubercle to show relation of integument: *a* (figured on plate 35, figure 5), to the underlying lenticular body, *b* (see plate 35, figures 3, 4); *c*, matrix of the interior of the carapace

wherefore the eye tubercle is quite flat and less distinct where the integument adheres to the mold (Lorraine specimens), while it is more prominent in the molds or interior casts. This proves that the tubercle was not at all an exterior spinelike organ, but essentially an interior organ even where it is most distinct and was therefore early observed as in *Cryptolithus*. It agrees with this nature of an organ situated essentially below the integument, that the parietal eye in the Cambrian trilobites is not visible as a tubercle, and that in the later stages, as in *Cheirurus niagarensis* (see p. 136) it again recedes entirely below the integument.

From the absence of a separate crystalline structure in the lens, and the presence of a carbonaceous division line, we infer that there was no hard chitinous lens that would become a separate center of crystallization in fossilization as in the lateral eyes of the trilobites, but one corresponding to that of the parietal eye of other crustaceans, and especially of the phyllopods, which is a lens-shaped or pear-shaped sac, usually filled with sea water.

In regard to the parietal eye of the phyllopods, Patten (no. 13, p. 144) says: "In the phyllopods, although the parietal eye is often very highly developed, it lies well below the surface, and there is no thickening whatever of the adjacent ectoderm, or of the chiten, to form a lens or vitreous body for them. The frequent absence of a lens or vitreous body, in the otherwise well-developed parietal eye of arthropods, is remarkable since it does not occur in the other types of arthropod ocelli." On page 148 it is added: "The most primitive type of a parietal eye is seen in the nauplii of phyllopods and entomostraca, where the eye is a pear-shaped sac, opening by a median pore or tube on the outer surface of the head." This parietal eye is, nevertheless, according to the same author

(p. 148, *op. cit.*) "an important visual organ until the lateral eyes, which represent a later product, are fully developed. It may then diminish in size and activity, but it rarely, if ever, wholly disappears."

It appears from these citations that the parietal eye structure as seen in *Cryptolithus* is not at all comparable to the larval ocelli of insects or the ocelli of *Limulus*, the eurypterids and arachnids in general, where the chitinous integument thickens into an exterior lens, but that it agrees well with that of the phyllopods and other crustaceans. It is quite probable that the thin black layer at the base of the lenticular body is derived from the pigment of the retina, and that there was but a cavity in front of the retina, filled with either sea water or more probably some body fluid. This cavity, acting as a lens, may have been present under all eye tubercles of trilobites. We have no evidence of a pore that led from it to the exterior in *Cryptolithus tessellatus*, but have before us specimens of *Asaphus expansus* and *Isotelus gigas* that show a pore, probably not accidental.

The cases cited above (p. 131) of casts of the interiors of eye tubercles of *Asaphus expansus*, *raniceps*, *laevis-simus*, *Basilicus kegelensis* and *Nileus armadillo* showing a distinct central pit and surrounding rim are probably indicative of the presence of a similar fluid-filled lens, the interior wall of which produces now the depression. We also have a finely preserved specimen of *Ogygia desiderata* Barrande, exhibiting a finely preserved circular pit on top of the tubercle.

Aside from the direct evidence, from the structures just presented, of the ocular nature of the median tubercle of the glabella, there is so much indirect evidence pointing to a visual function that it alone would seem to be competent to allow a fair conclusion. This evidence rests in the following facts:

1 These tubercles are the sole prominences in the otherwise entirely smooth carapaces of all the many genera of the Asaphidae, in the Trinucleidae and other genera (see below) where they occur. They must therefore have a function that requires prominence for its performance, and they could not serve as spines as they are, as a rule, too small for that purpose, although in a few forms, p. e. *Megalaspis*, they may have degenerated into spines as any other organ is liable to do, and even in that case it is an open question whether the median eye could not have been raised on the top of a spine for better vision, the same as the lateral eyes have in

several trilobites. This is especially probable in the case of hollow, sometimes curved spines on top of the glabella, such as *Ampyx* possesses, and where the animals led a mud-groveling life.

2 The eye tubercles are always situated at the very highest spot of the carapace, either on the apex of the bulging frontal lobe of the glabella as in *Cryptolithus* (*Trinucleus*), or as in *Isotelus* and *Asaphus* where the glabella abruptly bends downward, on the prominent posterior portion between the last lobes. It may have wandered forward and backward, but it is always upon the highest point of the glabella which would be the place of advantage for a median eye. It completely agrees in this regard with the position of the ocelli in the eurypterids.

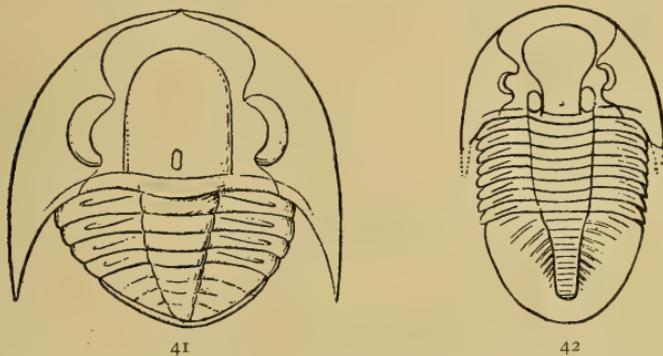
3 The tubercle is generally situated between the posterior portions of the lateral or compound eyes, as in the typical eurypterids. This position seems to us best explained by the fact that the median eye is according to its origin always nearest to the brain, which is, in the phyllopoes and most other crustaceans, situated in the dorsal region of the head, beneath or between the lateral eyes. The median eye is typically, as in *Apus* (the phyllopod that is always referred to in discussions of the taxonomic position of the trilobites), "in immediate contact with the brain."¹ We see for this reason, in the prevailing position of the tubercle between the posterior portion of the lateral eyes, a strong argument for its ocular character.

4 In this connection the observation is also significant that the tubercle is in many cases found at the posterior extremity of a distinct crest, extending backward a short distance upon the glabella. A like crest bearing the ocelli of the median eye, has been observed in *Stylonurus excelsior* by Hall and Clarke (no. 7, pl. 26) and it occurs in other eurypterids. Species which show this feature very well marked are *Asaphus raniceps* (see Schmidt, no. 27. Lief. 2, pl. 2, fig. 2), *Nileus armadillo* (*op. cit.*, Lief. 3, pl. 8, fig. 13), *Illaenus* (*Bumastus*) *barriensis* (*op. cit.*, Lief. 4, pl. 27, fig. 1). It is probable that this crest is an analogon of the "eye line" of the primitive trilobites and, at least in part, marks the path of the nerve leading to the median eye.

Besides the structural features mentioned so far as pointing to an ocular function of the median tubercle, we believe that also the following general considerations support this view.

¹ Parker & Haswell, no. 14, p. 536.

5 As the parietal or median eye in the eurypterids and other arthropods, the tubercle is relatively largest and most prominent in the earliest growth-stages and it becomes less and less prominent in the later stages, apparently (see below) entirely disappearing in many genera. Patten (no. 13, p. 148) says of the parietal eye: "The parietal eye of arthropods is an important visual organ until the lateral eyes, which represent a later product, are fully developed. It may then diminish in size and activity, but it rarely, if ever, wholly disappears." Clarke and Ruedemann (no. 5, p. 117) have shown that in the case of all eurypterids where the



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Fig. 41 *Isotelus gigas* Dek y. A small specimen in the Oygites stage, showing the large tubercle upon the glabella. x 6. (From Raymond)

Fig. 42 *Basilicrus tyrannus* (Murchison). An early asaphid with distinct tubercle. (From Raymond)

earliest growth-stages could be obtained, the ocellar mound or tumescence exhibits a distinct tendency to both larger size and greater prominence in the earlier growth-stages than in the adult. They add: "There is also evidence that the ocelli themselves are relatively larger."

The same significant connection between the ontogenetic stage and the relative development of the tubercle is distinctly shown in the trilobites. The best case available here is that of *Isotelus gigas*, where Raymond (see text fig. 41) has figured and noted the large tubercle on the glabella of the smallest specimen showing the dorsal aspect (3.5 mm long) and pointed out that in this and other features the glabella of the growth-stage is like that of an adult specimen of *Basilicrus*, which is an earlier asaphid (Raymond, no. 21, p. 250). We figure here (see plate 34, figure 6) a specimen of *Isotelus gigas* 40 mm long in which the tubercle is still visible with the naked eye; the same is true of a specimen 65 mm long while in the large specimens found at Trenton Falls nearly a foot long, the tubercle has disappeared altogether. It is

similar in other trilobites, as *Cryptolithus* (*Trinucleus*) *tesselatus*, where Beecher's figure of the protaspis shows a relatively large tubercle compared with that of the mature stage.

6 To the early presence of the tubercle in the individual development of the trilobites just described, corresponds its prevalence in the mature stages of the phylogenetically older and more primitive genera, as far as the differential development of the lateral eyes and the correlated reduction of the median eye has not obliterated the former relation between development of race and median eye. We thus find the median eye much better developed in the genera of the earlier and more primitive orders of the Hypoparia and Opisthoparia than in the third order of trilobites, the Proparia, and the most advanced and phylogenetically and historically late families of this order, the Calymmenidae and Phacopidae, seem to have practically lost the eye tubercle, if not altogether the median eye (see below, p. 137). Expressed in terms of geologic history, we may say that the Ordovician and Silurian trilobites prevailingly possess the parietal eye tubercle while the Devonian forms nearly all lack it.

Also within certain families the same relation of tubercle to phylogenetic age can be observed, as notably in the Asaphidae, where the phylogenetically older genera, as *Asaphus*, *Onchometopus*, *Basilicus*, *Asaphellus*, *Symphysurus* and *Nileus*, retain the tubercle through life, while the younger and more advanced genera, as *Isotelus* and *Megalaspis*, lose it in the mature stage as tubercle.

The case of the gradual disappearance of the eye tubercle in the trilobites is parallel to that in the crustaceans in general, where the highest subclass, the Malacostraca, lacks the median eye as an exterior organ while it prevails in the lowest subclass, the Branchiopoda.

It is to be remarked in regard to the later genera which lack the median eye tubercle, that we are not yet at all sure that they also lack the median eye, for as the median eye wanders inward in the crustaceans and later vertebrates, so it may have done in the later trilobites. Indeed we have direct evidence for this supposition in the gradual disappearance of the eye tubercle in *Isotelus gigas*, leaving but a smooth spot in its place, and in some species where the exoskeleton reveals no longer any trace of a parietal eye, the interior cast exhibits a distinct pit, showing that the organ was still present on the inside of the exoskeleton. We figure in illustration of this (see pl. 34, fig. 9) a glabella of *Cheirurus niagarensis* (Hall) from the Silurian Rochester shale of

New York, with a distinct, deep pit below the exoskeleton in place of the eye tubercle. Other similar cases could be cited. In this final stage the parietal eye of the trilobite may have been like that of the phyllopods.

In view of the facts observed in recent crustaceans, we consider it quite possible that the parietal eye persisted in the trilobites much longer than our present evidence would suggest, in the form of a thin, smooth spot in the glabella.

It is a peculiar phenomenon that the most important Cambrian families, the Conocoryphidae, Mesonacidae, Paradoxidae and Olenidae, do not exhibit a trace of this median tubercle, while in these it should be expected above all. We were at a loss to explain this fact until we observed in several beautifully preserved growth-stages of *Elliptocephala asaphoides* from the Ford collection, that the bulging frontal lobe of the glabella possesses two circular transparent spots, appearing whitish in the black test with a smaller white speck between them, exactly where the young of *Limulus* p.e. shows its ocelli, and we have here also noted two like faint, though distinctly outlined, spots in the test of specimens of *Paradoxides*, as *P. spinosus*. While this matter needs further study with larger and first-class material, we feel justified in expressing the belief that these early Cambrian genera had their median ocelli, like primitive crustaceans, only in form of transparent spots of the test, which in the fossil material are only noticeable in perfectly preserved and but little carbonized exoskeletons.

7 It is a distinct fact pointing to the visual function of the median tubercle that the genera usually considered as blind because of reduced or absent lateral eyes, are apt to show these tubercles most distinctly, as notably *Cryptolithus* (*Trinucleus*) and the related *Dionide* and *Dindymene*, and also *Agnostus*, *Eodiscus* and *Ampyx*. On the other hand, it is apparent that the Phacopid genera *Phacops* and *Dalmanites* with their highly developed, large, lateral eyes, show the least trace of median eyes. In the *Asaphidae*, which have also well-developed lateral eyes and retain the median eye, it is seen that the latter retains its usefulness on account of the vertical position of the visual areas of the lateral eyes that do not allow an upward sweep of the vision.

8 Quite significant as indicating an important function of the tubercle is the fact that it is a constant feature in a great number of genera and species, with otherwise smooth carapaces. We can demonstrate the existence of this tubercle in some thirty odd

genera, cited below, from the figures and descriptions of a limited number of authors whose works are conveniently at hand, and our own observations. There is no doubt that the number of genera and species in which the tubercle could be found is considerably greater, but the list suffices to show the wide distribution of the tubercle on the glabella. A perusal of Schmidt's excellent photographs in his "Revision der baltischen Trilobiten," especially his Lieferungen II and III, will give a clear conception of the regular occurrence of the tubercle in the Asaphidae. The numbers behind the authors refer to the bibliography in this paper. Figures where the tubercles are shown are cited behind the species names.

List of species with median eye tubercles

- Acidaspis*? : *grayae*, Reed, no. 22, pl. 16, fig. 2.
- Aeglina*: *princeps*, Barrande, no. 1, pl. 14, fig. 3; *prisca*, *ibid.*, pl. 5, figs. 1, 2, 4, 5; pl. 8, fig. 5; pl. 14, fig. 1; *rediviva*, *ibid.*, pl. 14, figs. 10, 11; *sulcata*, *ibid.*, pl. 8, fig. 1; *umbonata*, Moberg, no. 11, pl. 3, figs. 1a, 3a.
- Agnostus*: *integer*, Barrande, no. 1, pl. 49, fig. 1; *granulatus*, *ibid.*, pl. 49, figs. 5, 6; *rex*, *ibid.*, pl. 49, figs. 4, 5; *similaris*, *ibid.*, pl. 14, fig. 18; *perrugatus*, *ibid.*, pl. 14, fig. 16. *A. girvanensis* Reed, no. 22, pl. 1, figs. 2, 4; *sidenbladhi*, Moberg and Segerberg, no. 10, pl. 4, figs. 4, 5. Beecher, in diagram of *Agnostus*, Zittel-Eastman Text-book, p. 624, fig. 1281A. *Metagnostus erraticus* Jaekel, no. 8, p. 382, fig. 1. *Paragnostus rex*, *ibid.*, p. 397, fig. 12. *Diplagnostus planicauda*, *ibid.*, p. 3997, fig. 14. *Miagnostus laevigatus*, *ibid.*, p. 401, fig. 21.
- Ampyx*: *hornei*, Reed, no. 22, pl. 3, figs. 8, 9 (see text fig. 44); *obtusus*, Moberg and Segerberg, no. 10, pl. 7, figs. 8, 9.
- Asaphus*: (See Schmidt, no. 27, Lief. 2, p. 6, where the tubercle is figured in all species represented, viz., *A. expansus*, *raniceps*, *cornutus*, *bröggeri*, *eichwaldi*, *delphinus*, *laevissimus* var., *laticauda*, *platyurus*, *latus*, *devexus*, also *A. pachyophthalmus*, *ibid.*, p. 37, fig. 22; *ibid.*, var. *major*, p. 40, fig. 26; *latus*, p. 62, fig. 36; *latus* var. *plautini*, p. 64, fig. 37; *ornatus*, p. 69, fig. 38; *laevissimus*, pl. 5, figs. 1, 4, 5, 8; *ornatus*, pl. 6, figs. 8, 8a; *devexus*, pl. 7, figs. 1, 2; *ludibundus*, pl. 8, figs. 3 (also crest), 15a, 16 (pit). Barrande shows the tubercle in diagrams of *A. expansus*, pl. 2A, fig. 17, *tyrannus*, *ibid.*, fig. 23, also Salter, no. 23, pl. 22, fig. 5, also *A. nobilis*, Schmidt, pl. 31, fig. 1 (concentric rugae), pl. 37, fig. 4. *Asaphus* sp., Reed, no. 22, pt II, pl. 7, fig. 9. Schmidt (no. 27, Lief. 2, p. 8) states that the tubercle is found in *all* species of *Asaphus*.
- Asaphellus*: *monticola* Raymond, no. 17, pl. 14, fig. 4.
- Barrandia*: *crassa*, Barrande, no. 1, pl. 11, fig. 5.

- Basilicus*: *ingens*, Barrande, no. 1, pl. 34, fig. 1 (concentric rugae); *nobilis*, *ibid*, diagrams, fig. 19, also pl. 31, fig. 1 (concentric rugae); *lowrowi*, Schmidt, no. 27, Lief. 3, pl. 4, figs. 1, 2, 3, 9; *kegelensis*, *ibid*, pl. 5, figs. 1, 4; *barrandi*, Raymond, no. 17, pl. 1, figs. 4, 5; *romingeri*, Raymond and Narraway, no. 15, pl. 16, figs. 2, 3. According to Schmidt, all species of *Basilicus* possess the tubercle.
- Bronteus*: *haidingeri* Barrande, no. 1, pl. 46, figs. 32, 34; *angusticeps*, pl. 47, fig. 23; *palifer*, pl. 1, fig. 9, pl. 45, figs. 1, 8; *porosus*, pl. 48, fig. 23.
- Bumastus*: *barriensis*, Salter, no. 26, pl. 27, figs. 1a, 2; *belle-villensis*, Raymond and Narraway, no. 15, pl. 62, fig. 7.
- Ceratopyge*: *forficula*, Moberg and Segerberg, no. 10, pl. 5, figs. 2a, 3; *latelimbata*, *ibid*, pl. 5, fig. 6a.
- Cheirurus*: *niagarensis* shows pit on interior mold in place of tubercle (see pl. 34, fig. 9).
- Cryptolithus* (*Trinucleus* auct.). The common occurrence of the tubercle in *Cryptolithus* has been discussed above (p. 128). Besides the species cited by Oehlert, the tubercle is also figured by Barrande (no. 1) in *C. ornatus*, pl. 2B, fig. 10, pl. 30, figs. 53, 54, 59.
- Cyclopyge*: *armata* Reed, no. 22, pt. II, pl. 7, figs. 53, 54, 59.
- Dindymene*: *frederici augusti*, Barrande, no. 1, pl. 43, fig. 24 (tubercle on internal cast; suppl. pl. 2, fig. 11).
- Dionide*: *formosa*, Barrande, no. 1, pl. 2B, fig. 11, pl. 42, fig. 24; *lapworthi* Reed, no. 22, pt. I, pl. 4, fig. 1; *richardsoni*, pl. 4, fig. 3. We have before us a specimen of *D. formosa* with rudimentary lateral eyes (see p. 145), eye lines and the interior mold of the median eye tubercle which appears as a shallow pit, suggesting that as in *Cryptolithus* the median eye may have possessed a lens.
- Eliptocephala*: *asaphoides*, see p. 137.
- Eodiscus* (*Microdiscus* auct.) *speciosus* (Ford). The author has in the Ford collection specimens which show a distinct parietal eye tubercle and also scars on the cheeks representing the rudimentary lateral eyes.
- Harpides*: Moberg and Segerberg, no. 10, pl. 5, fig. 1.
- Hemigyraspis*: *collieana*, Raymond, no. 17, pl. 14, fig. 11.
- Hysterolenus*: *törnquisti*, Westergard, no. 29, pl. 2, fig. 1.
- Illaenus*: *oriens*, Moberg and Segerberg, no. 10, pl. 7, fig. 2a (with crest); cf. *oculosus*, Reed, no. 22, II, pl. 10, figs. 9, 11. In Museum specimen of *I. oxus* with fine tubercle (see pl. 34, fig. 8).
- Isotelus*: *gigas*, Raymond, no. 19, pl. 1, fig. 1. See also our plate 34, figure 6. Schmidt states that *Isotelus* does not possess the "Nackentuberkel"; it apparently is, as a rule, present only in the immature stages as a tubercle.
- Isoteloides*: *whitfieldi*, Raymond, no. 17, pl. 14, fig. 1; *homalotoides* Raymond and Narraway, no. 15, pl. 16, figs. 10, 11 (see our pl. 36, fig. 1); *angusticaudus*, Raymond, no. 19, pl. 17, fig. 7.
- Megalaspis*: Schmidt (no. 27, Lief. 4, p. 2) states that in *Megalaspis* the tubercle is so small that it is seen with difficulty and his photographs mostly fail to bring it out. It is specially mentioned of *M. larvae* (*ibid*, p. 21), and recognizable in the *acuticauda* var. *typica*, *ibid*, p. 43, fig. 19. In *M. hyorhina* it is developed into a spine.

- Nileus*: *armadillo*, Schmidt, no. 27, Lief. III, pl. 8, fig. 13 (with pit and long crest); *Moberg* and *Segeberg*, no. 10, pl. 6, fig. 1; *perkinsi* Raymond, no. 18, pl. 2, fig. 8 (shows tubercle on interior mould). *N. affinis*, *ibid*, pl. 4, fig. 4.
- Niobe*: Schmidt (no. 27, Lief. III, p. 10) states that the tubercle is present in all representatives of the genus but is very fine. It is well shown in *N. insignis*, *Moberg* and *Segeberg*, no. 10, pl. 6, figs. 6, 10, 11; *laeviceps*, *ibid*, fig. 17.
- Ogygites*: *canadensis*, Raymond, no. 18, pl. 1, fig. 2.
- Onchometopus*: *volborthi* Schmidt, no. 27, Lief. II, p. 82, fig. 48; *obtusus*, Raymond, no. 18, pl. 3, fig. 2; *simplex*, Raymond and *Narraway*, no. 15, pl. 16, fig. 6.
- Phacops*: *fugitivus*, *Barrande*, no. 1, suppl., pl. 9, fig. 2; *browni*, two specimens in Museum from *Damel*, Bohemia, showing small tubercle on posterior top of glabella; *schlotheimi*, specimen in State Museum from *Gerolstein*, Germany, with large tubercle.
- Pseudasaphus*: *globifrons*, Schmidt, no. 27, Lief. III, pl. 7, figs. 2, 3, 4; *testicaudatus*, *ibid*, pl. 1, fig. 1; pl. 2, fig. 3; pl. 3, figs. 1, 10.
- Ptychopyge*: *excavato-zonata*, Schmidt, no. 27, Lief. I, p. 30, fig. 5; *limbata*, *ibid*, p. 31, fig. 6; *larowi*, *ibid*, p. 31, fig. 7; *angustifrons*, Schmidt, no. 27, Lief. III, pl. 5, figs. 4, 7; *truncata*, *ibid*, pl. 6, fig. 5; *pahleni*, *ibid*, pl. 6, figs. 2, 10, 11; *cincta*, *ibid*, pl. 8, figs. 1, 2.
- Remopleurides*: *radians*, specimen in State Museum from *Chodoun*, Bohemia, interior cast with tubercle on center of glabella.
- Salteria*: *primaeva*, *Reed*, no. 22, pt 1, pl. 4, fig. 13.
- Symphysurus*: *convexus*, Raymond, no. 17, pl. 14, fig. 14; (see our pl. 36, fig. 2); *sicardi*, *ibid*, pl. 14, fig. 17; *angustatus*, *Moberg* and *Segeberg*, no. 10, pl. 5, fig. 15.

9 As a last argument in favor of the presence of a median eye in the trilobites, we cite the fact that the trilobites are recognizedly primitive crustaceans, most frequently considered as related to the phyllopo^ds, and that primitive crustaceans, notably the phyllopo^ds and most other branchiopo^ds, possess parietal or median eyes. It is interesting to note in this connection that *Kingsley* (no. 9, p. 34) in a note on the systematic position of the trilobites, states that if the protaspis stage of the trilobites described by *Beecher* is a true nauplius, it should have the median eye, which is never lacking in the nauplius. Against this *Beecher* (*ibid*, p. 40) remarks that the protaspis stages are so minute that even under the most favorable conditions they could not be expected to show such small features as ocelli. We believe that the tubercle figured by *Beecher* in the protaspis stage of *Trinucleus* is the ocellus in question. *Patten* even calmly assumes with complete assurance that the trilobites had median eyes, whether paleontologists found them or not, for

he states (p. 139): "There is no reason to doubt that the trioculate median eye of decapods, copepods, trilobites and merostomes, in structure and development is essentially like that of *Limulus*, scorpions, spiders, *Apus* and *Branchipus*," and again (p. 148): "The parietal eye of vertebrates is homologous with the parietal eye of such arthropods as *Limulus*, scorpions, spiders, phyllopods, copepods, trilobites and merostomes, but not with the frontal stemmata or other ocelli of insects."

When zoologists of standing postulate the presence of median eyes in the trilobites, paleontologists might as well make a serious search for this important organ of crustaceans and adopt the view that normally the trilobites were provided with a distinct parietal eye.

Summary

It is claimed in this paper that most, if not all, trilobites possessed a median or parietal eye on the glabella. In proof of this assertion the following facts are stated:

1 A great number of species, belonging to more than thirty genera, possess a distinct tubercle on the glabella. This tubercle occurs alone in many genera, otherwise smooth, as in the *Asaphidae*, and is hence of functional importance.

2 In certain cases, as in *Cryptolithus tessellatus*, distinct lenticular bodies were recognized; in others, as in *Asaphus expansus*, only a thinner, probably transparent test. Many other species show a distinct pit in interior casts of the tubercle, indicating a lenslike thickening of the top of the tubercle. The median eye therefore probably possessed all the different stages of development seen in other crustaceans.

3 As in the parietal eyes of the crustaceans and the eurypterids, the tubercles are most prominent and distinct in the earlier growth-stages, notably so in *Isotelus gigas*.

4 The tubercle is especially well developed in the so-called blind forms, where the lateral eyes are abortive, as in *Cryptolithus* (*Triarthrus*), *Dionide*, *Ampyx*.

5 The tubercles always appear on the apex on the highest part of the glabella, where their visual function would be most useful.

6 The tubercle is generally situated between the lateral eyes, like the parietal eye in crustaceans and eurypterids, on account of its close connection with the brain.

7 Frequently it forms the posterior termination of a short crest, also as in certain eurypterids (*Stylonurus*) indicating the direction of the nerve.

8 The median eye is borne on a tubercle or mound in the Ordovician and Silurian trilobites, while the tubercle is rarely noticed in the Devonian and in few Cambrian forms. In the Devonian forms, similarly as in many crustaceans and in later growth-stages of some asaphids, the strong development of the lateral eyes may have led to a loss of the parietal eyes. In the Cambrian genera evidence is present to suggest that the parietal eyes consisted only of transparent spots or lenslike thickenings of the exoskeleton, hardly noticeable from the outside.

9 It is *a priori* to be inferred that the trilobites should, as primitive crustaceans, have possessed median or parietal eyes.

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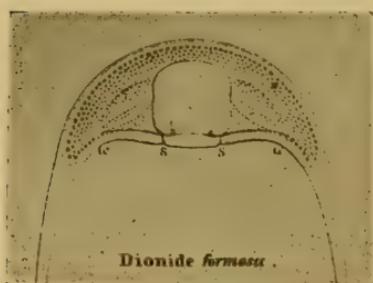
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VI

THE CEPHALIC SUTURE LINES OF CRYPTOLITHUS
(TRINUCLEUS AUCT.)

In the preceding paper on the median eyes of the trilobites it has been stated that the lateral eyes in *Cryptolithus* and *Harpes* appear to have wandered away from the "suture" onto the apexes of the fixed cheeks, thus having attained a position that together with their primitive character, has invited their reference to the median ocelli. This inference presupposes the assumption that the suture



43



44

Fig. 43 *Dionide formosa* Barrande. Cephalon showing median eye tubercle and facial suture. (From Barrande)

Fig. 44 *Ampyx hornei* Reed. Cephalon showing median eye tubercle and facial suture. (From Reed)

is marginal or hypoparous, as claimed by Barrande, Beecher and many others. When the present writer became convinced that the tubercle upon the glabella represents the median or parietal eye, and that therefore the vestigial eyes on the cheeks must be true lateral eyes, he began to look for evidence of this inference. The most important evidence was seen, as stated in the preceding paper, in the eye line extending in the early growth-stages of *Cryptolithus* to the eyes upon the cheeks. Further evidence was found in two distinct suture lines (see pl. 35, fig. 6) extending from the genal angles to the rudimentary eyes, and seen especially well in the shale specimens from the Lorraine beds. On searching the literature it was found that these lines had been noticed and partly figured before, by Salter, McCoy, Barrande (no. 1), Oehlert (no. 7) and Reed (no. 9), but the final consensus of authors with

the exception of Jaekel¹ was that they were not connected with the suture line ("nervures" of Oehlert). Exactly like lines occur in *Dionide*, already well figured by Barrande (see text fig. 43), and *Ampyx hornei*, as figured by Reed (see text fig. 44), all often cited "blind" forms. In a specimen of *Dionide formosa* where the lines reach the lateral furrows, we were able to recognize also probable vestigial eyes in the furrows at the end of the suture lines, appearing as elliptic thickenings of the crust on the inner side of the latter. A figure of *Dionide atra* by Reed (see text fig. 45), in which only one of the lines is given, but is shown cutting the posterior margin and there bounding the limb or "brim,"—to use Bather's better term—is further evidence of the sutural character of these lines. Corroborative evidence of our inference that the cheek lines of *Cryptolithus* are true suture lines extending to the lateral eyes was seen in observations of Richter (no. 10), according to which the marginal suture in *Harpes* is not homologous to the suture of the other trilobites, but a secondary acquisition to allow of molting.

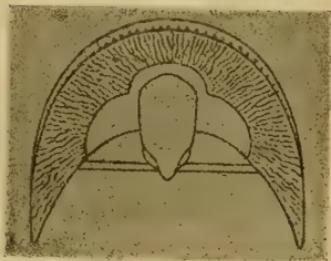


Fig. 45 *Dionide atra* Salter. Diagrammatic restoration of head shield, showing facial suture. (From Reed)

Harpes is not homologous to the suture of the other trilobites, but a secondary acquisition to

After we had reached the conclusion, proceeding from the presence of median eyes on the glabella and the "lateral eye" character of the other eyes on the cheeks, that *Cryptolithus* is not a true Hypoparian trilobite, and written out our notes, most gratifying corroborative evidence reached us in the paper by Swinerton (no. 11) who, on other evidence independently from Richter and the present author, has reached the conclusion that these genera are not Hypoparia, and has altogether dissolved this order and redistributed the families among the Opisthoparia.

Jaekel's view that the free cheeks have coalesced with the fixed cheeks in the Hypoparia and the sutures disappeared, with the

¹ Jaekel with his characteristic astuteness has years ago pointed out in "Über die Agnostiden (no. 6, p. 387) that the absence of eyes and sutures go hand in hand, and that the Trinucleidae, Ampycidae and Harpedidae are not Hypoparia, but that since they show traces of eyes, there were originally also sutures on the cheeks which have disappeared.

lateral eyes, is therefore probably correct, for we find not only traces of the eyes,¹ as he was aware, but also of the suture lines.

In studying our material of *Cryptolithus tessellatus* (*Trinucleus concentricus*) we had occasion to observe still a further suture, which, to our knowledge, has hitherto been neither figured nor described. This is shown in plate 35, figure 7. It is as a rule but very faintly seen where the integument is preserved, but remarkably sharp, as a raised line, on the interior casts of the glabella in the Trenton limestone material. There it has all the characters of a suture. It begins at a small node in front of the median eye tubercle. This minute anterior node (see pl. 35, figs. 1-4, at a), which is connected with the eye tubercle by a narrow crest, often also visible exteriorly, may possibly be another ocellus, either accessory to the first, or representing the second pair of median ocelli occurring originally in crustaceans and arachnids in a much reduced form.

From the anterior tubercle the suture extends over the anterior portion of the frontal lobe of the glabella in two diverging lines to the antero-lateral corners of the glabella, where it recurves abruptly, then following the lateral grooves to near the first glabellar furrows, where it disappears. We have seen this suture in so many specimens that there can be no doubt of its distinct actuality. The area between the lines is often set off from the rest of the glabella in being a little less convex. In front this triangular area is separated from the brim by an abrupt break.

We see in this triangular area the rostral piece or epistoma found in many trilobites in front of the hypostoma and separated from the cephalon by the facial suture. In *Cryptolithus*, we believe, it became incorporated, or rather was drawn up into the glabella by two factors; the exceptional swelling of the frontal lobe of the glabella and the development of the broad brim. Both peculiar characters of the genus are obviously connected with its adaptation to a mud-groveling life, which also led to the loss of the lateral

¹It is worthy of notice in this connection that the State Museum contains specimens of *Eodiscus* (*Microdiscus* auct.) *speciosus*, which also show rudimentary eye tubercles on the cheeks, thereby indicating that also this genus of the Agnostidae had, owing to a special adaptation to living in the bottom mud, its lateral eyes reduced to faint rudiments and therewith lost the facial sutures. The position of the rudimentary eyes indicates that this genus also could not belong to the Hypoparia, and it further corroborates Jaekel's view that the Agnostidae are not very primitive trilobites as generally supposed, but highly specialized types.

eyes. The broad, netlike brim served to support the animal on the soft mud, preventing its complete burial in the latter, and the bulging glabellar lobe was necessary to provide room for the capacious stomach in an animal that gorged itself with the mud to extract the organic matter (see Jaekel, no. 5). As the broad brim extended horizontally all around the head, the rostrum had to be forced backward and up the frontal part of the glabella and the stress upon the frontal lobe from the growing stomach assisted in drawing the rostral piece into its present position.

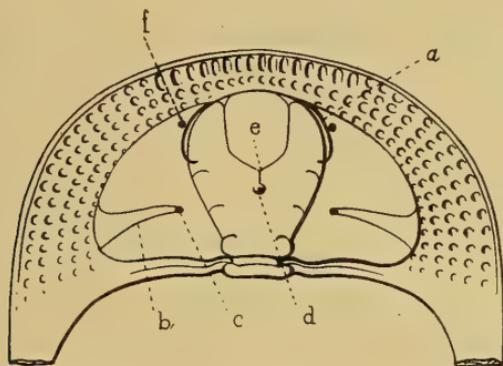


Fig. 46 *Cryptolithus tessellatus*
Green. Diagrammatic restoration of head shield.
a, frontal facial suture; *b*, lateral facial suture;
c, lateral eye tubercle; *d*, median eye tubercle;
e, frontal tubercle; *f*, frontal pores in dorsal
furrow (olfactory organs?)

If this view is correct, we see in the suture line upon the frontal lobe another piece of the facial suture, whose connection with the posterior section of the free cheeks is broken, however. This, we believe, is also due to the gradual expansion of the brim backward, which also forced the anterior of the two suture lines, now leading to the rudimentary lateral eyes more and more backwards, extending the anterior portion of the fixed cheeks continually backward at the expense of the free cheeks. In other words, it appears probable that the free cheeks were originally much broader and extended much farther forward with their anterior margin, passing in front of the glabella, where they cut off a rostral piece. The narrow vestigial free cheek carrying the rudimentary lateral eye is then only a secondary phenomenon due to the excessive broadening of the head. We see in this further evidence of the extreme adaptation of the Trinucleidae from formerly normal Opisthoparia.

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EXPLANATIONS OF PLATES

Plate 1

Favosites turbinatus Billings

Page 8

- 1, 2 Two views of young colony, restored at apex, from section.
Shows the extent of covering by opercula. Natural size.
 - 3 Opercula. Enlarged x 5.
 - 4 Calyxes where opercula are removed. x 5.
 - 5 Section showing open calyxes in the middle and opercula upon them on the left. x 5.
 - 6 Operculum, where the outer smooth layer has been scaled off and the interior structure of the operculum is shown. x 7.
 - 7 Young, still perforated operculum. x 7.
- Devonian: Onondaga limestone, western New York.

Paropsonema cryptophya Clarke

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- 8 Young specimen, preserving interior casts of the first cycle of supposed air chambers. Natural size.
- Devonian: Portage sandstone. West Hill, near Naples, N. Y.
The originals of this plate are in the New York State Museum.

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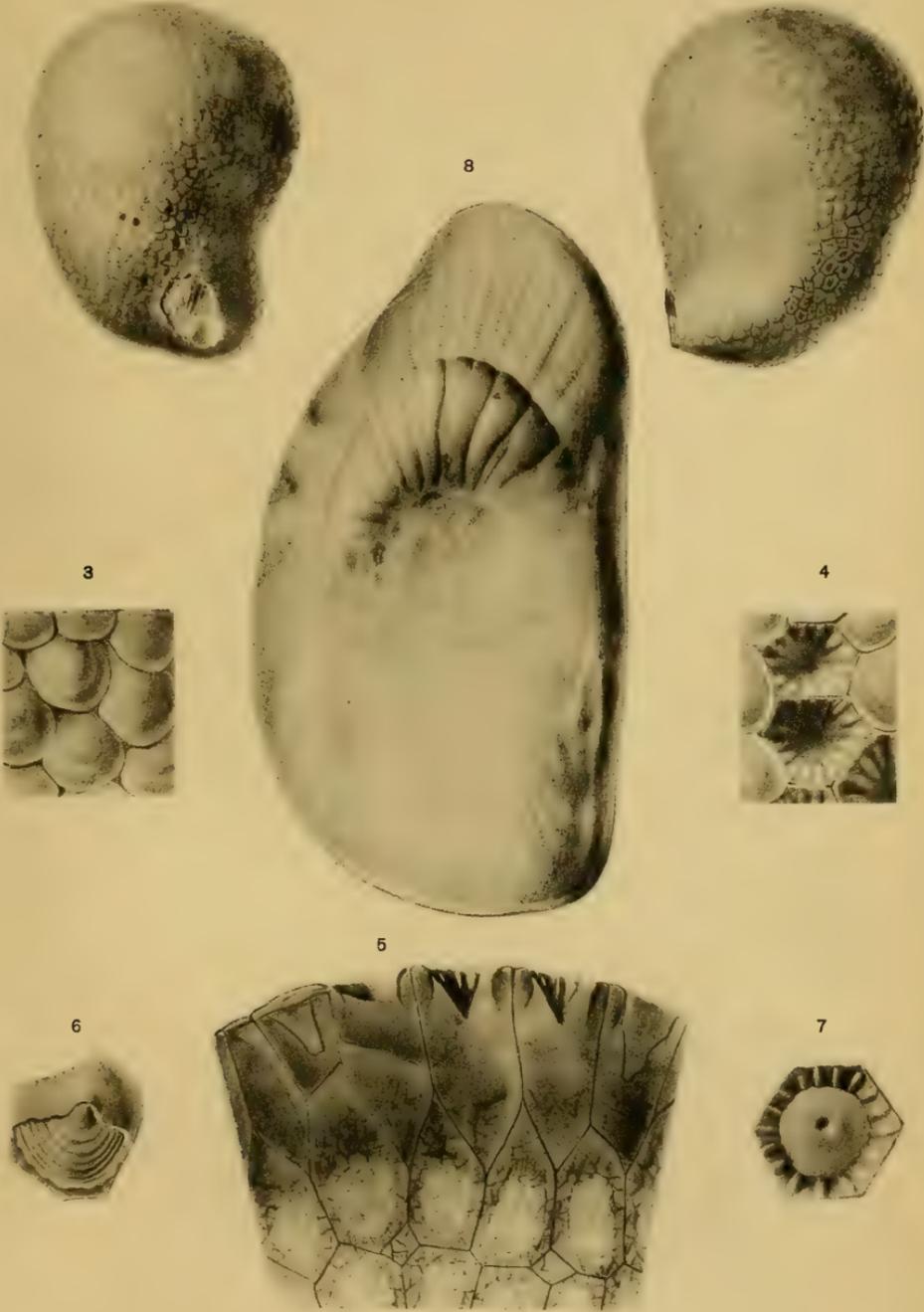


Plate 2

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Paropsonema cryptophya Clarke

Page 22

- 1 Specimen preserving the three cycles of supposed air chambers
their original relief. Natural size.
Devonian: Portage sandstone, Johnson's glen, Canandaigu
lake, N. Y.
Original in New York State Museum.

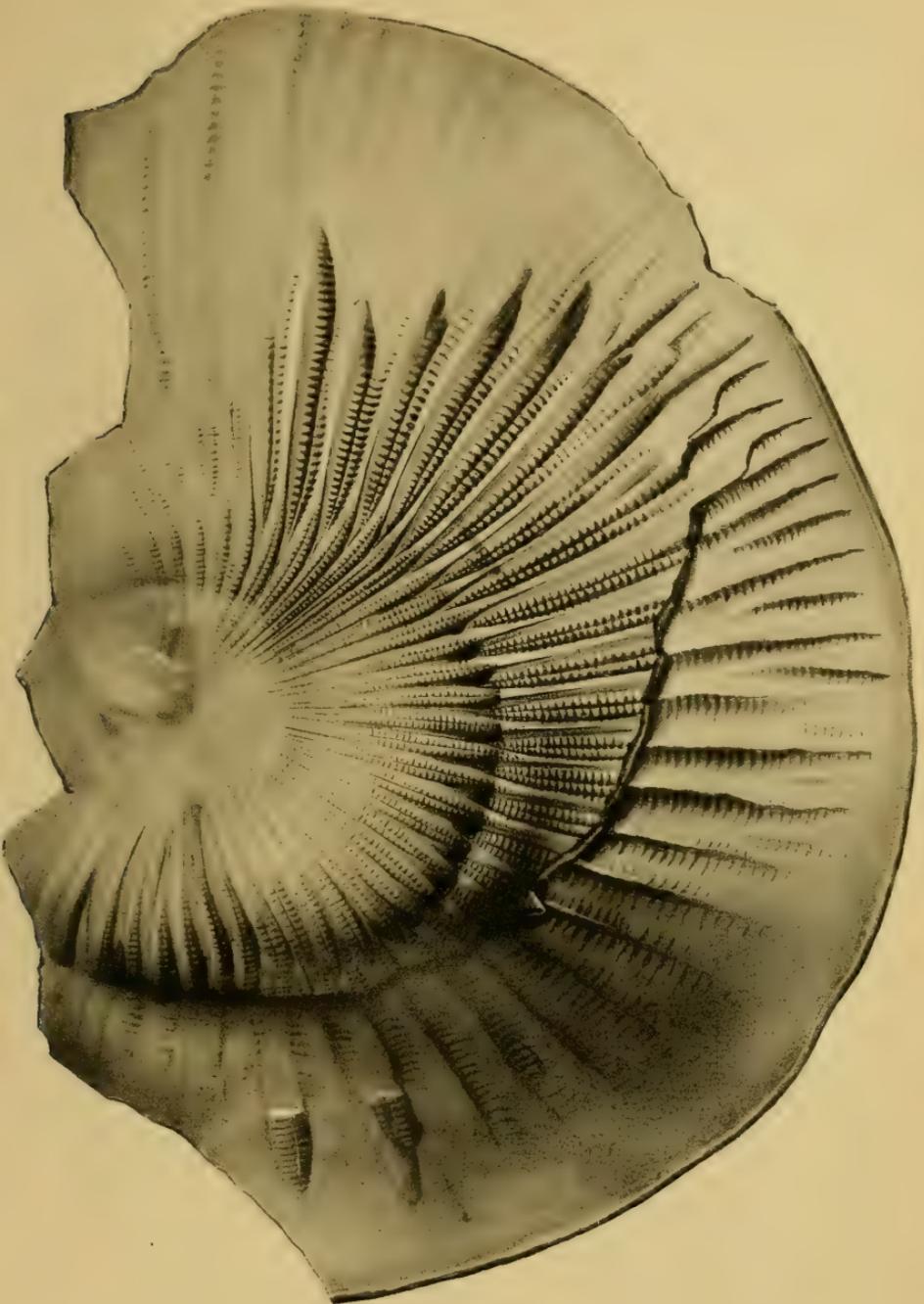


Plate 3

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Plectodiscus molestus nov.

Page 26

1 Natural-size photograph of specimen taken from plaster of par-
cast of original mold (holotype).

Devonian: Portage (Ithaca beds), near Ithaca, N. Y.

Original of figure in New York State Museum.



J. A. Glenn, photo.

Plate 4

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Inocaulis lesquereuxi (Grote & Pitt)

Page 13

- 1 Colonial stock showing mode of branching, rounded terminations of branches and, along edges, projecting thecal tubes. $\times \frac{1}{2}$.
- 2 Colonial stock showing mode of branching, marginal rows of projecting thecal tubes and, at left, branch decomposed into the component thecal tubes. Pohlman's type. $\times \frac{1}{2}$.
- 3 Colonial stock with rather erect, sparsely bifurcating branches, showing the punctate surface and fibrous structure of branches at base. $\times \frac{1}{2}$.
- 4 Extremity of branch of original of figure 1, $\times 6$, to show the punctae of the middle portion of the branch and the marginal tubes.

Silurian: Bertie waterlime, Buffalo, N. Y.

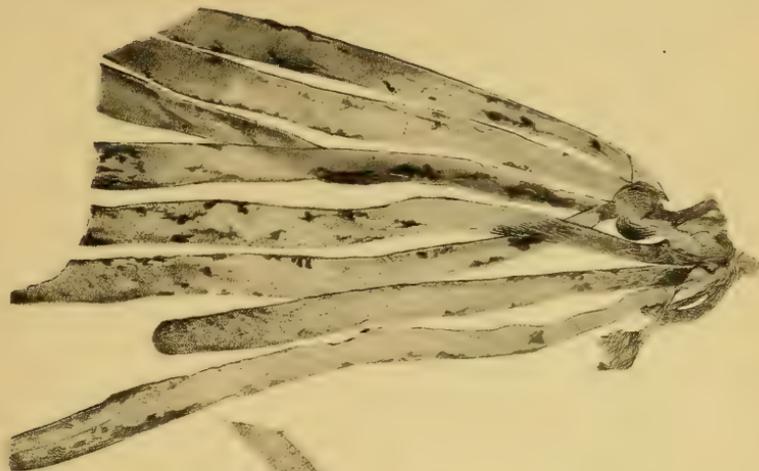
The originals of figures 1, 2 and 4 are in the Museum of the Buffalo Society of Natural Science (nos. $\frac{13299}{E1628}$ and $\frac{13269}{E1598}$); that of figure 3 is in the New York State Museum.



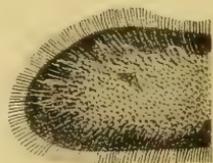
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Plate 5

157

Pleurocystites squamosus (Billings) mut. **matutina** nov.

Page 27

- 1 Specimen (paratype) preserving portion of anal side; the arrangement of the plates is drawn too regular. x 2.
- 2 Specimen (holotype) showing the thecal plates and two pectinated rhombs, the lower one of which is shortened by crushing. x 2.
- 3 Specimen (paratype) showing three pectinated rhombs and portions of the two arms. Natural size.
- 4 Specimen (paratype) preserving two pectinated rhombs and showing the structure of the armlets. The plates are mostly crushed and indistinctly shown. A few plates of the anal side have been forced through a break and are seen on the thecal side. x 2.

Ordovician: Glens Falls limestone, South Glens Falls, N. Y.

Clarkeaster perspinosus nov.

Page 30

(See pl. 6, fig. 1; pl. 7, figs. 1 and 2)

- 5 Portion of actinal or ventral side of ray, showing the ambulacral furrow and ambulacral plates with their crests and podial openings or depressions appearing as faint circles between the crests, the adambulacras plates and the outer series of large inframarginal plates bearing spines. x 5½.
- 6 Portion of actinal or ventral side of ray near tip of ray; the ambulacral groove is closed and only the adambulacral and inframarginal plates are seen. x 5½. Drawing from gutta-percha squeeze of original mold.

Devonian: Chemung beds, Avoca, Steuben county, N. Y.

The originals of all figures are in the New York State Museum

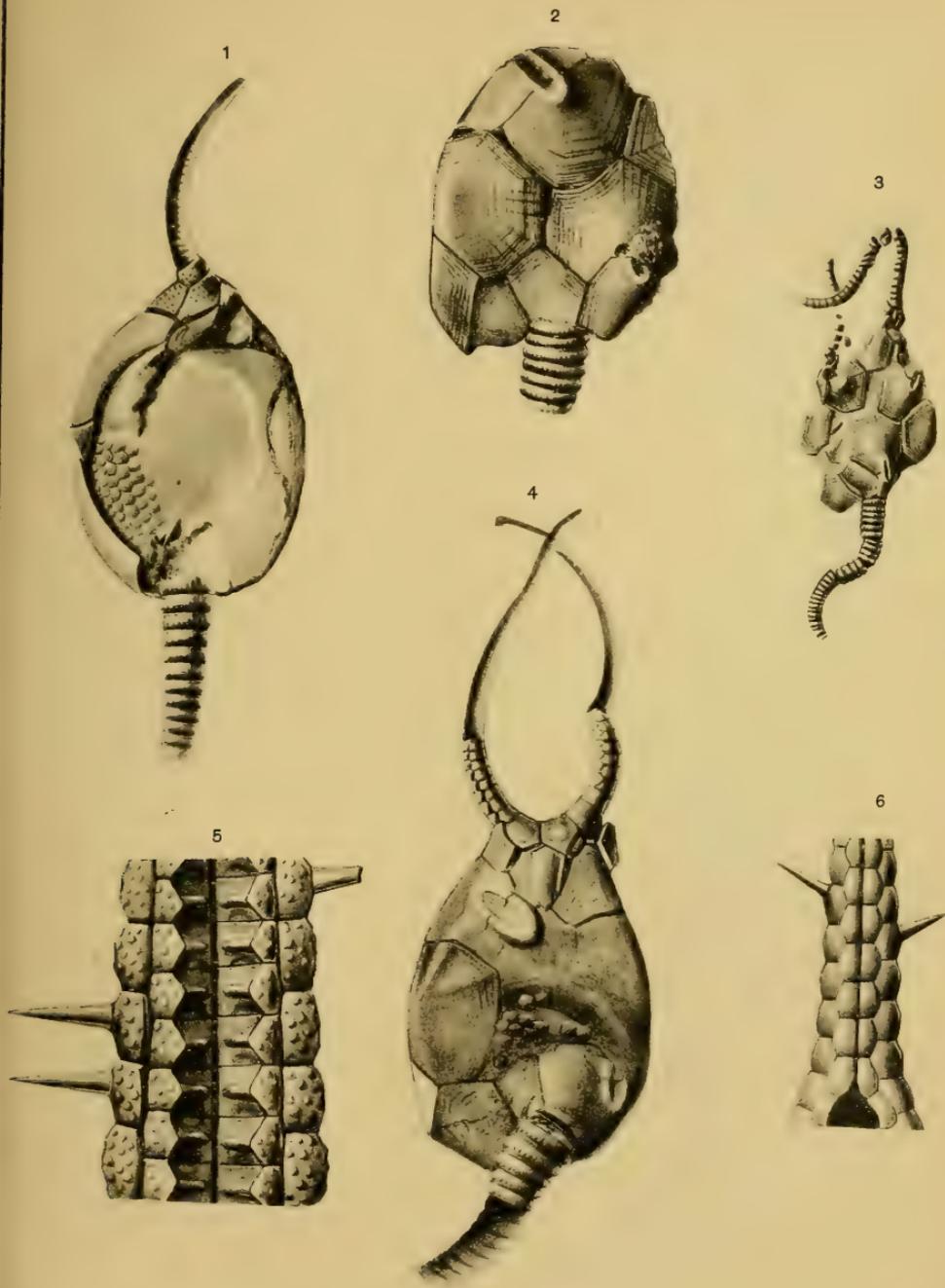


Plate 6

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Clarkeaster perspinosus nov.

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(See pl. 5 and 7)

Restoration of lateral view showing the large spines of the abactinal disk area and the dorsal and lateral rows of spines on the rays. Natural size.

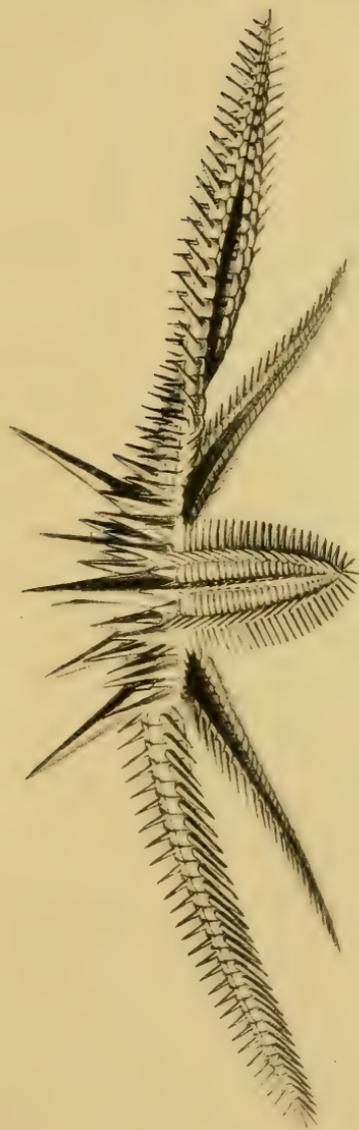


Plate 7

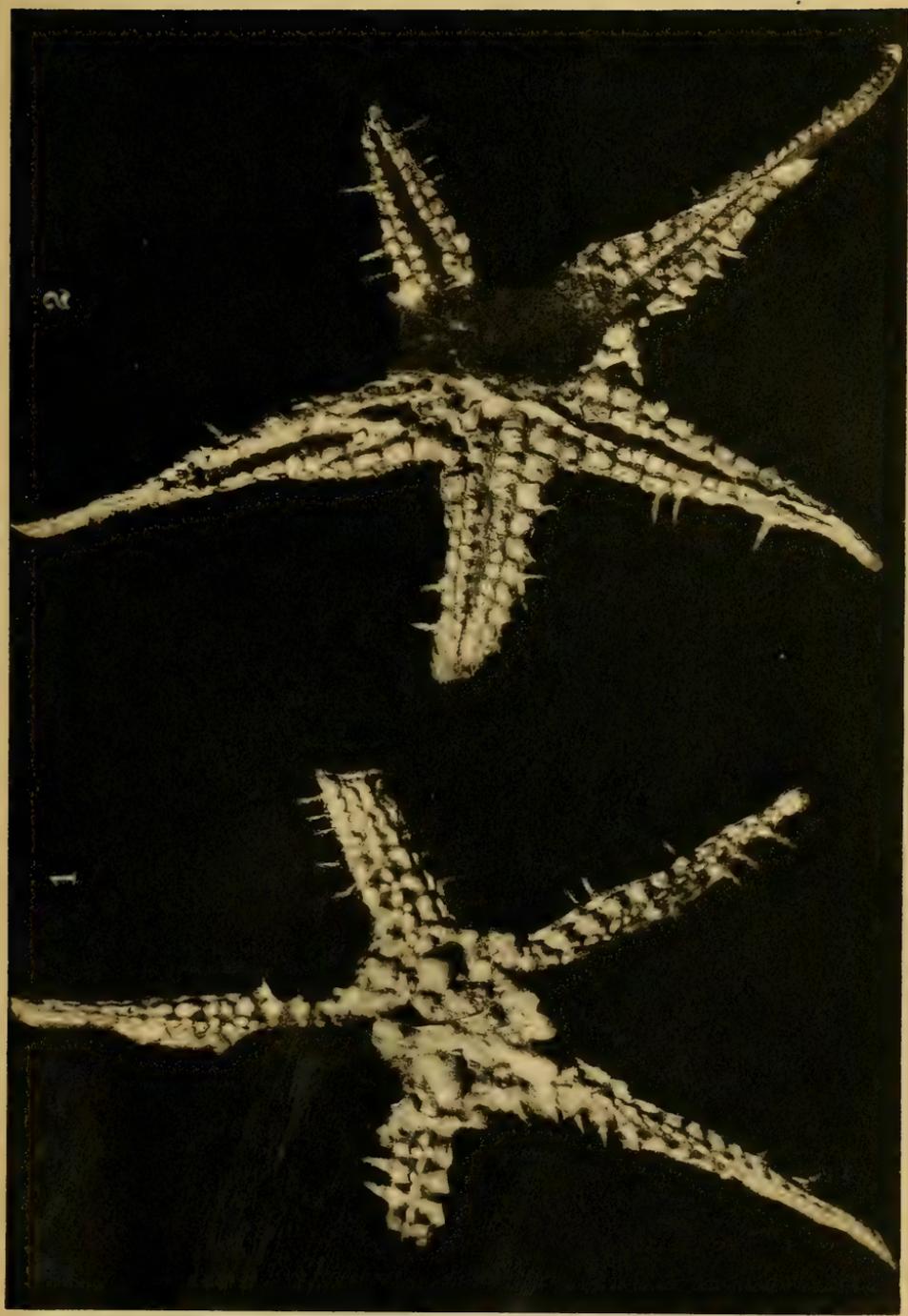
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Clarkeaster perspinosus nov.

Page 30

(See pl. 5 and 6)

- 1 Abactinal or dorsal view of type specimen (holotype), showing only the basal portions of the large spines. Natural size.
 - 2 Actinal or ventral view of paratype. Natural size.
- Devonian: Chemung beds. Avoca, Steuben county, N. Y.
The photographs are made from gutta-percha squeezes, the molds of which are in the New York State Museum.



J. A. Glenn, photo.

Plate 8

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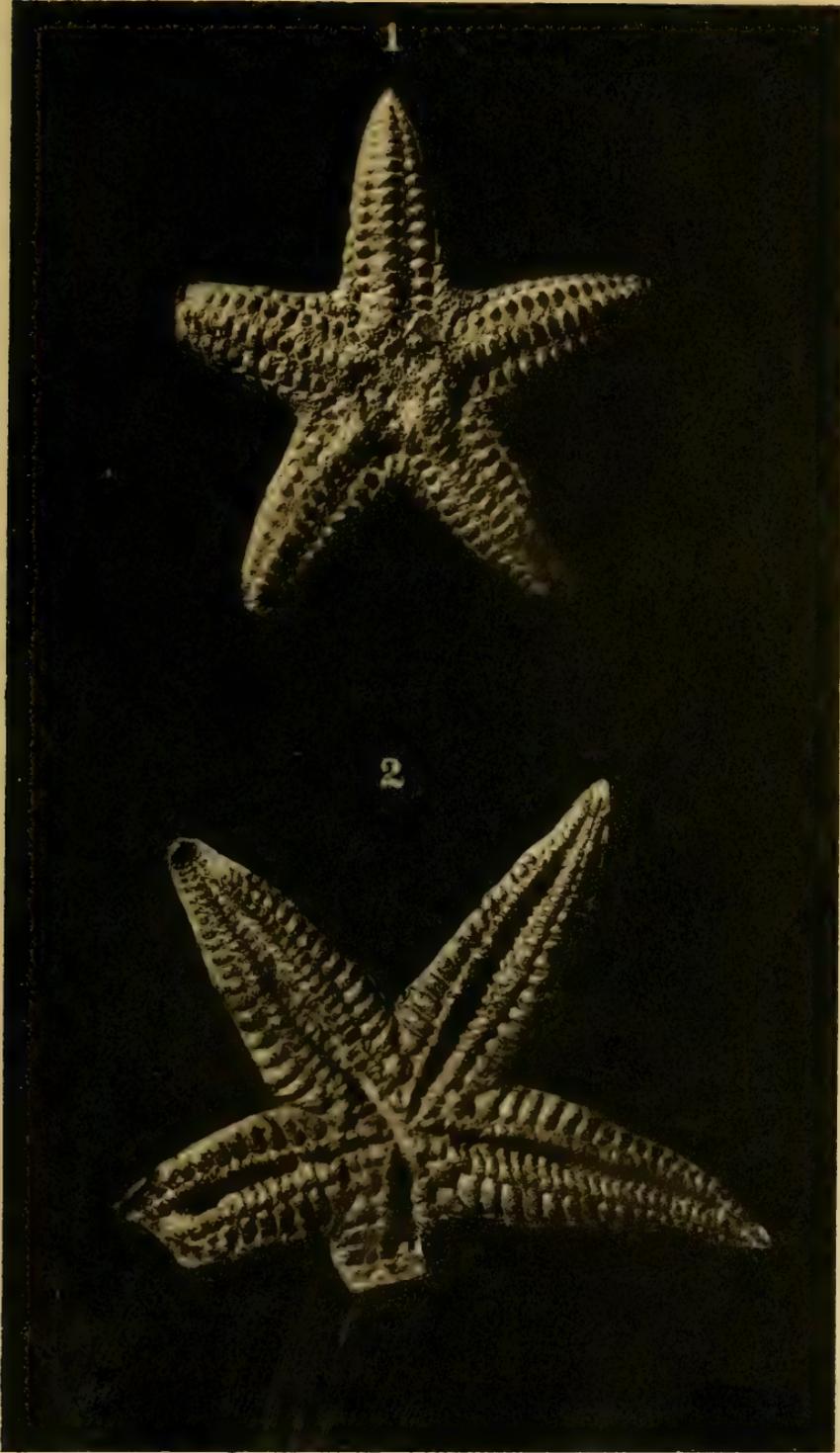
Devonaster eucharis (Hall)

Page 33

(See pl. 9)

- 1 Hall's paratype (20th Mus. Rep't, pl. 9, fig. 3). Abactinal view
From original gutta-percha squeeze. Natural size.
- 2 Hall's paratype (20th Mus. Rep't, pl. 9, fig. 3*). From original
gutta-percha squeeze. Natural size.

Devonian: Hamilton beds. Hamilton and Cooperstown, N. Y.
The photographs are taken from squeezes from which the
original figures were made and which are preserved in the
New York State Museum.



J. A. Glenn, photo.

Plate 9

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Devonaster eucharis (Hall)

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(See plate 8)

- 1 Youngest specimen observed. Abactinal view, x 6, showing early stellate growth-stages of plates and large central plate.
- 2 Early growth-stage, with still distinctive central plate and first ring of five plates of abactinal disk area; a very few accessory plates are seen on the rays. x 5.
- 3 View of oral portion of young specimen. x 5.
- 4 Interior (dorsal) view of ambulacral ossicles (*amb*); *ad*= adambulacrals; *f* is a cast of the interambulacral space. x 5.
- 5 A separate ambulacral ossicle.
- 6 Ambulacral groove of a young specimen, from a gutta-percha squeeze. x 5.

Devonian: Hamilton beds, Saugerties, N. Y.

The originals of the drawings are in the New York State Museum.

The drawings are made from camera outlines.

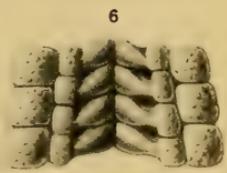
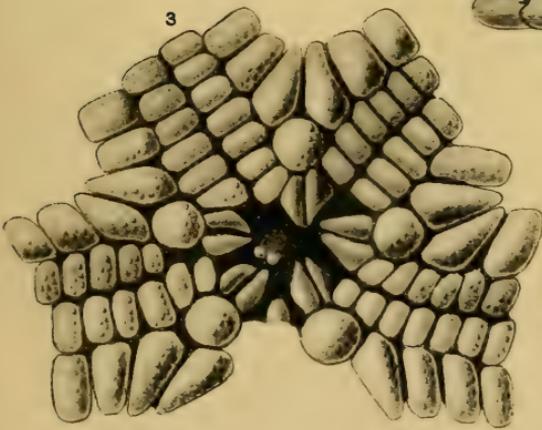
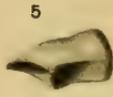
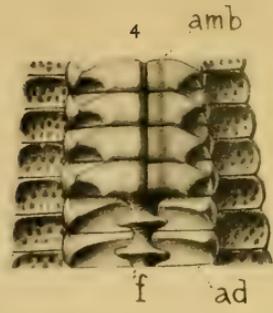
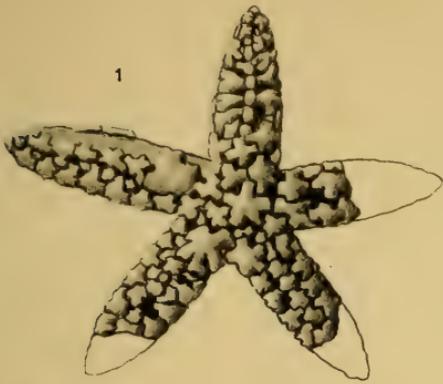


Plate 10

167

Lepidasterina gracilis nov.

Page 43

- 1 Small specimen (holotype), showing six rays preserved and bases of two more. Abactinal view. Natural size.
 - 2 Larger specimen, with eight rays (paratype). Natural size.
 - 3 Oral armature and abactinal view of base of ray. Row of radials and the supramarginals shown as impressions. $\times 5$.
 - 4 Interior mold of actinal (ventral) view of ray, the ambulacral groove closed. $\times 5$.
- Devonian: Lower Chemung beds at Avoca, Steuben county, N. Y.

Lepidasterella gyalum (Clarke)

Page 39

- 5 Portion of type specimen showing the weblike parts of disk between the bases of the rays. Natural size, from gutta-percha squeeze.
- Devonian: Portage beds near Ithaca, N. Y.

Lepidasterella babcocki Schuchert

Page 38

- 6 Portion of specimen drawn to show the median row of radials and the adjoining series of supramarginal columns in the rays, as well as the weblike expansions of the disk and the marginal columns of plates in the disk. Natural size.
 - 7 Further enlargement ($\times 3$) of a disk segment to show more clearly the marginal plates of the disk.
- Devonian: Portage beds (Cashaqua shale) at Interlaken, N. Y. The originals of the figures are in the New York State Museum.

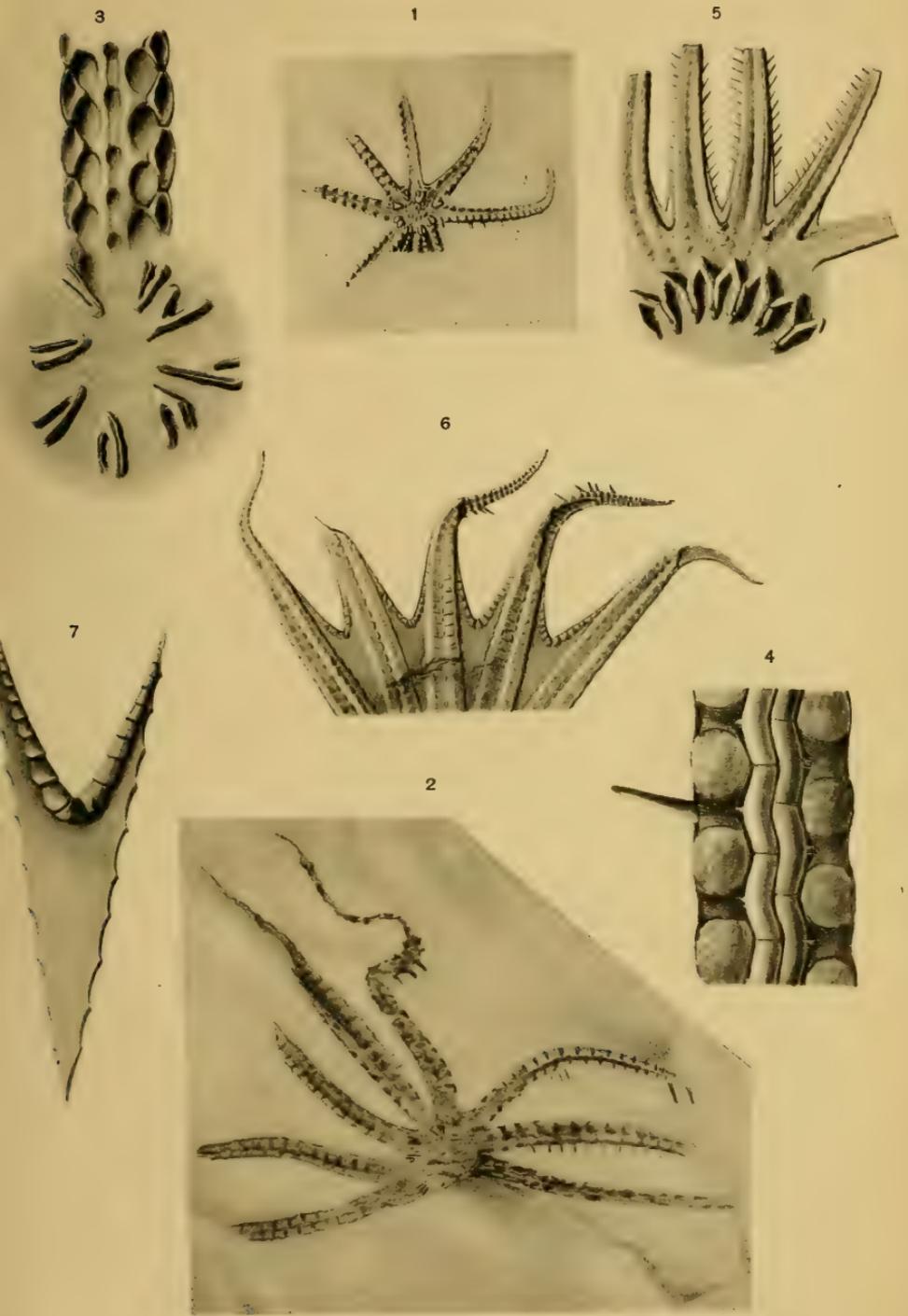


Plate II

169

Stenaster salteri (Billings)

Page 52

- 1 Specimen exhibiting the abactinal or dorsal view and retaining the original integument and the interradian sections of the disk.
x 3.
 - 2 Portion of another specimen showing the dorsal side of the oral armature and of the base of a ray. x 5.
- Ordovician: Trenton limestone, Kirkfield, Ontario, Canada.

Urasterella schucherti nov.

Page 50

(See pl. 12, figs. 4 and 5)

- 3 Actinal view of portion of oral armature and of base of ray, showing the ambulacral groove with the ambulacral plates, and adjoining it the adambulacral plates; and along the margin the small spiniferous ambital plates. x 5.
 - 4 Enlargement of portion of abactinal (dorsal) side of ray, to show the numerous columns of spiniferous plates. x 5.
- Devonian: Chemung beds, Kirkwood, Broome county, N. Y.

Urasterella ruthveni (Forbes) mut. **arisaigensis** nov.

Page 46

(See plate 12, fig. 3)

- 5 Specimen (paratype) exhibiting the actinal (ventral) side with ambulacral furrow and flanking columns of adambulacrals.
x 5.
 - 6 Specimen (paratype) presenting the abactinal (dorsal) view. The outlines of the columns of plates are seen in the distal part of the left upper ray; the remaining surface shows only the bases of the rods projecting from the plates. From gutta-percha squeeze. x 4.
- Silurian: Arisaig series at mouth of Stonehouse brook, Nova Scotia.

The originals of all figures are in the New York State Museum.

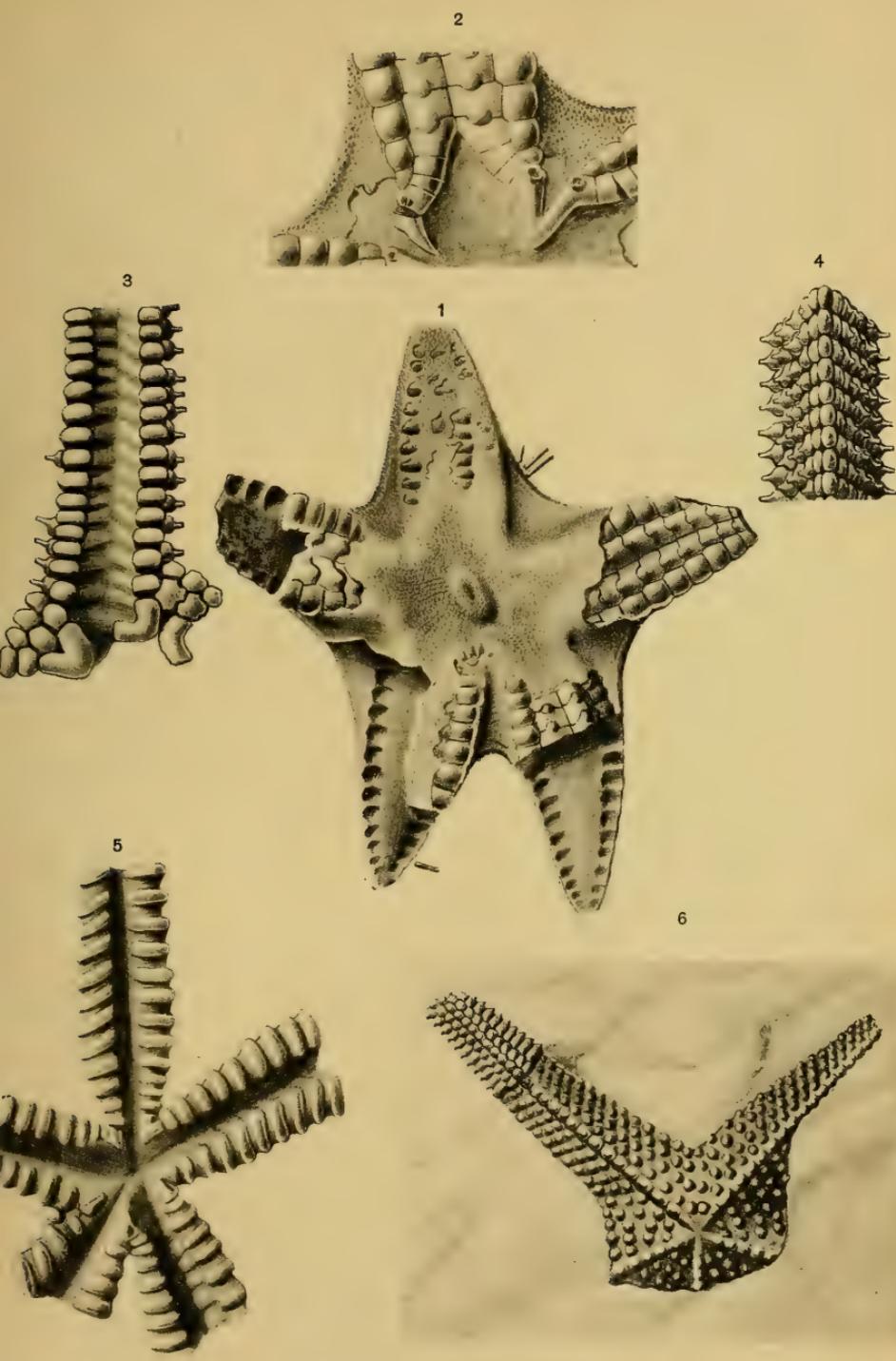


Plate 12

171

Urasterella stella nov.

Page 49

(See pl. 13, fig. 1)

- 1 Type specimen (holotype). Abactinal view. x 2.
 - 2 Paratype. Abactinal view of specimen, retaining the rods of the ambital plates. x 2.
- Devonian: Portage group (Middle Grimes sandstone) 3½ miles northeast of Naples, N. Y.

Urasterella ruthveni (Forbes) mut. arisaigensis nov.

Page 46

(See pl. 13, fig. 1)

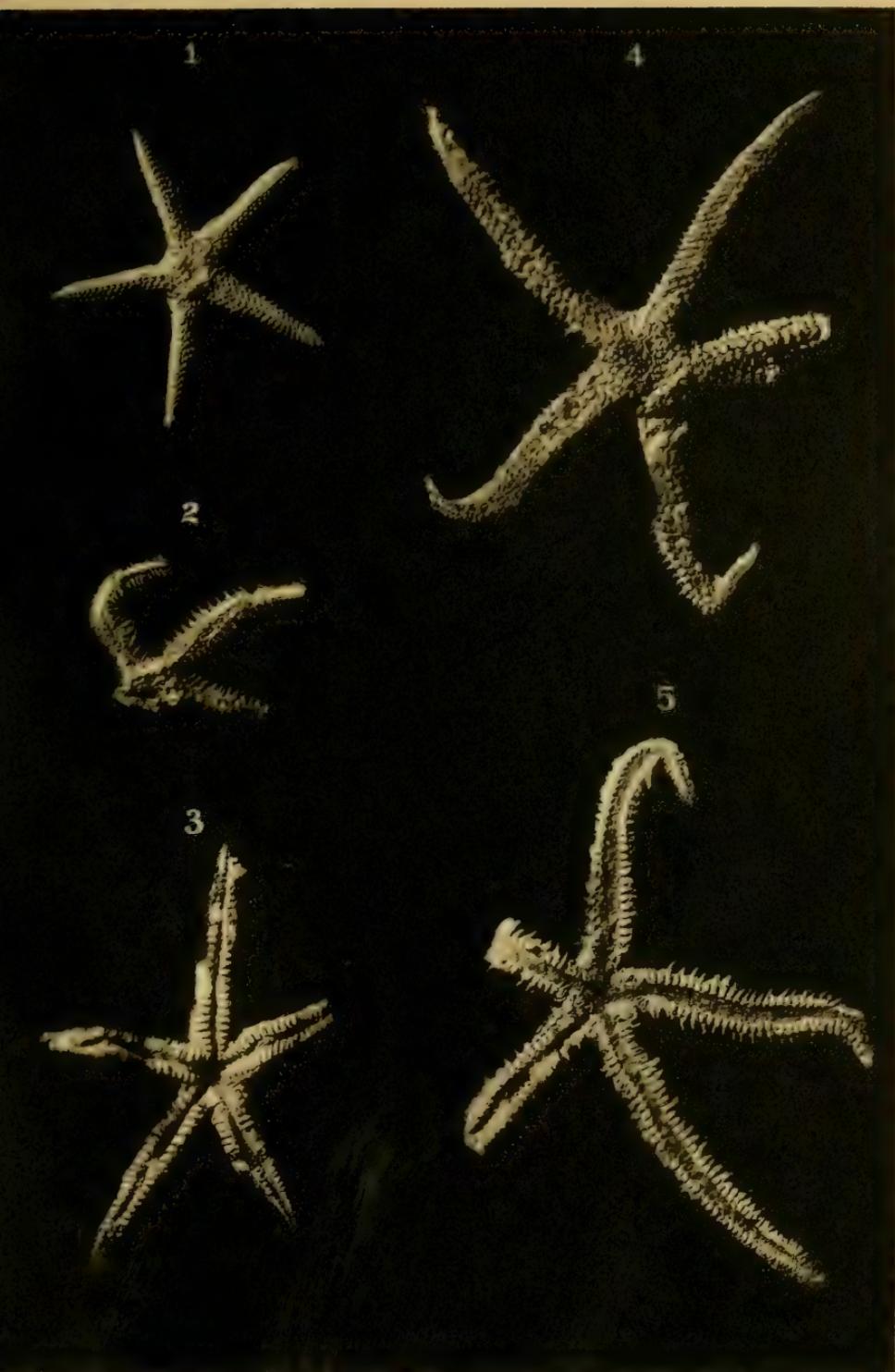
- 3 Specimen (holotype) showing the actinal (ventral) side. x 2.
- Silurian: Arisaig series. Mouth of Stonehouse brook, Nova Scotia.

Urasterella schucherti nov.

Page 50

(See pl. 2, figs. 3 and 4)

- 4 Type specimen (holotype). Abactinal view. From gutta-percha squeeze. x 2.
 - 5 Paratype. Actinal view. x 2.
- Devonian: Chemung beds, Kirkwood, Broome Co., N. Y.
- The photographs are made from gutta-percha squeezes, the molds of which are in the New York State Museum.



A. Glenn, photo.

Plate 13

173

Urasterella stella nov.

Page 49

(See pl. 12, figs. 1 and 2)

- 1 Paratype; exhibits actinal view with wide open ambulacral groove in ray on right-hand side and nearly closed groove on left-hand. x 4.
- Devonian: Portage group (Middle Grimes sandstone), near Naples, N. Y.

Urasterella lutheri nov.

Page 47

(See pl. 14, figs. 1-4)

- 2 Portion of actinal view of ray, showing the wide open ambulacral groove, with its long narrow ambulacral ossicles. The coin-shaped adambulacrals are seen on the left turned over on their flat sides, and one to two columns of stellate or irregular ambitals pressed out from the abactinal side. x 5.
 - 3 Portion of actinal view of ray of other specimen, where the adambulacrals are seen in their normal position. x 5.
 - 4 Portion of abactinal side of ray from margin (base) to median line of ray (top), showing the columns of stellate radials and ambital ossicles. x 5.
 - 5 Portion of actinal side near distal end of ray. The ambulacrals are lost; the adambulacrals are relatively thick and the ambitals more regular. x 5.
 - 6 Portion of actinal view of base of ray and of oral armature. *amb*=ambulacrals; *ad*=adambulacrals; *ax*=axillary; *am*=ambitals; *or*=oral plates. x 5.
- Devonian: Portage beds (West Hill flags), Deyo Basin, near Naples, N. Y.

Urasterella sp.

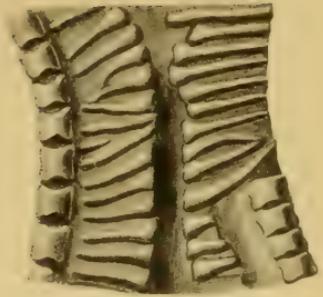
Page 51

- 7 Portion of abactinal view of ray. x 5.
 - 8 Supposed paxillae. x 10.
- Devonian: Ithaca beds, Messengerville, Cortland county, N. Y. The originals are in the New York State Museum. The drawings are made from camera lucida enlargements.

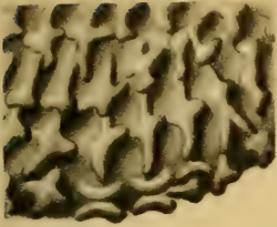
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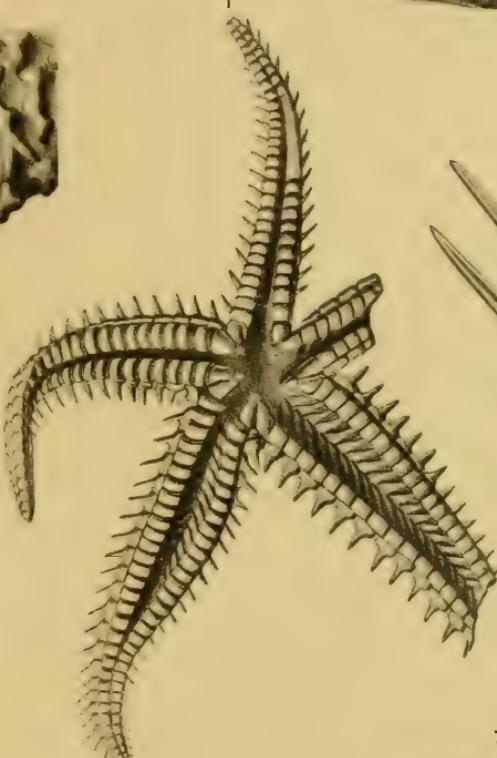
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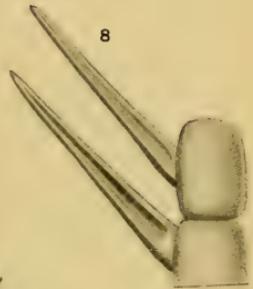
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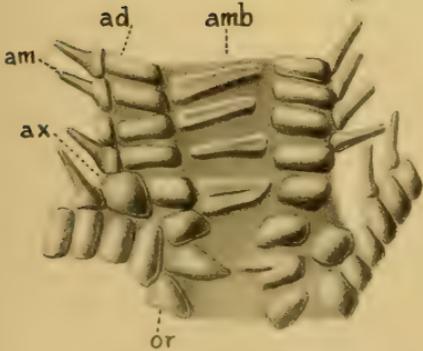
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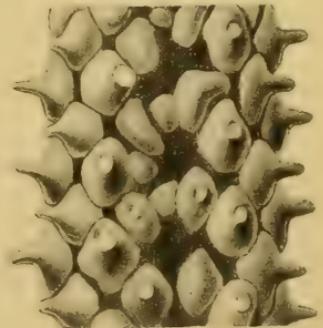


Plate 14

175

Urasterella lutheri nov.

Page 47

(See pl. 13, figs. 2-6)

- 1 Young specimen (paratype). Abactinal view. x 2.
 - 2 Abactinal view of type specimen (holotype). Natural size.
 - 3 Abactinal view of another specimen (paratype). Natural size.
 - 4 Actinal (ventral) view of specimen (paratype). The rays appear unnaturally wide because several columns of lateral ambital ossicles have been pressed downward. Natural size.
- Devonian: Portage beds (West Hill flags), Deyo Basin, near Naples, N. Y.

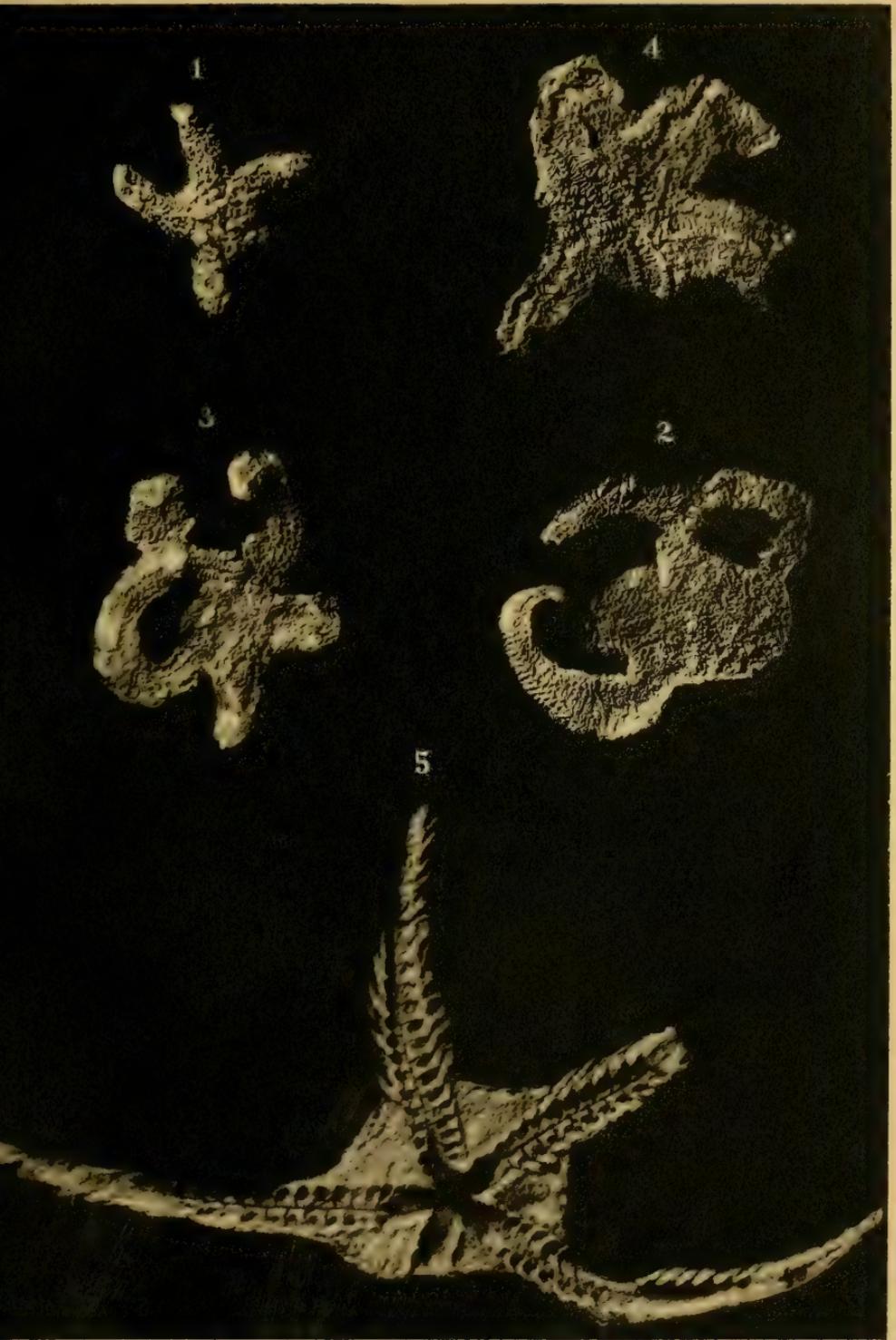
Eugasterella bicatenuata nov.

Page 56

(See pl. 16, figs. 5-7)

- 5 Type specimen (holotype). Actinal view. x 2.
- Devonian: Portage group (Grimes sandstone), near Naples, N. Y.

The photographs are all made from gutta-percha squeezes, the molds of which are in the New York State Museum.



A. Glenn, photo.

Plate 15

177

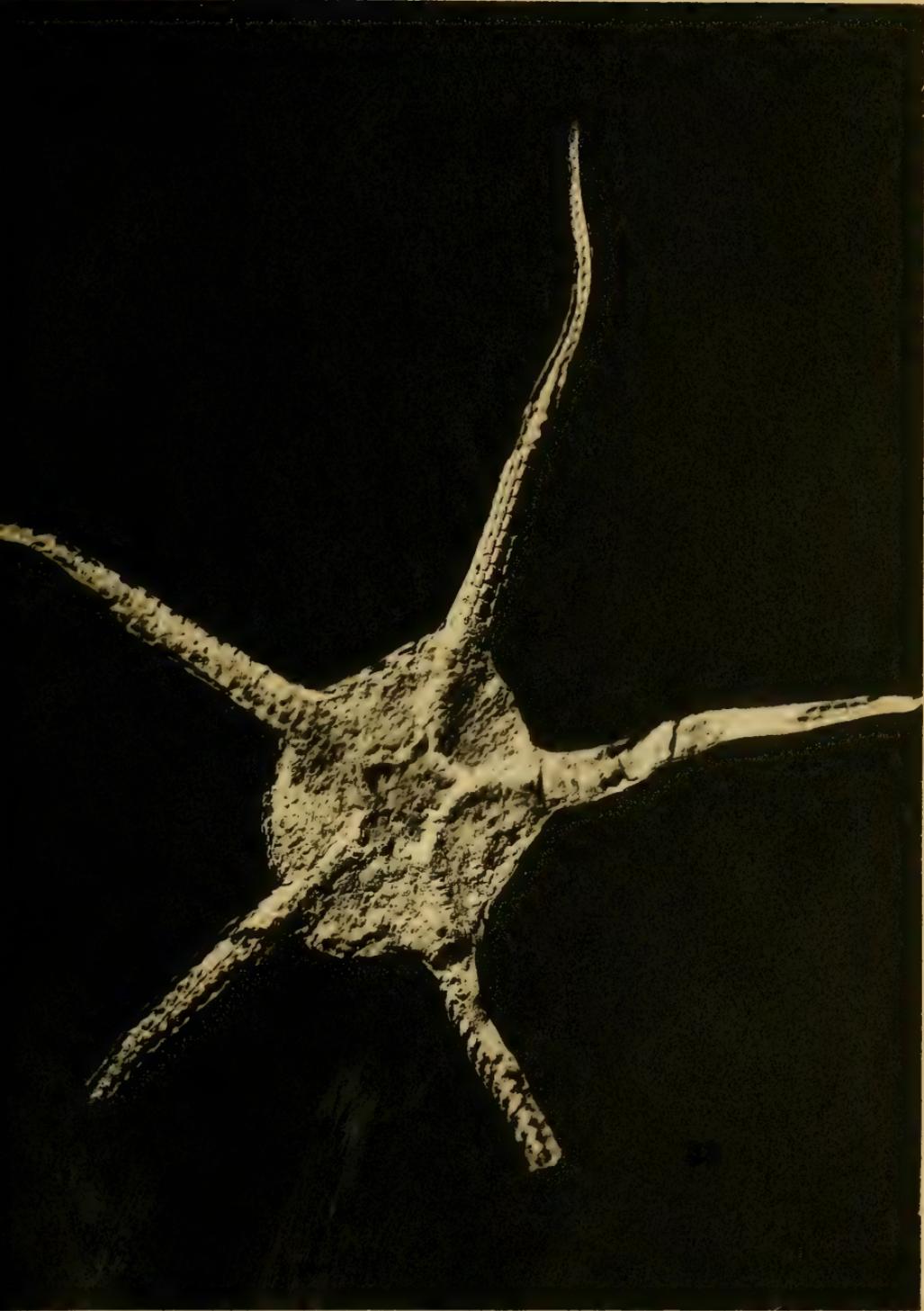
Eugasterella aranea nov.

Page 57

(See pl. 16, figs. 1-4)

- 1 Holotype. Abactinal view. x 2. The upper ray shows the ossicles exposed; the upper left ray shows them covered by the dorsal integument; the lower rays are molds of the actinal (ventral) side. The portion of the abactinal integument over the mouth area has been slightly darkened to bring out more distinctly the mouth frame of which the abactinal side is seen.
Devonian: Upper Portage (Wiscoy) shale, near Park Station, N. Y.

The original is in the New York State Museum.



A. Glenn, photo.

Plate 16

179

Eugasterella aranea nov.

Page 57

(See pl. 15, fig. 1)

- 1 Portion of abactinal view of disk and proximal part of ray, showing the columns of ambulacrals continuing to the oral frame with its small syngnaths; the columns of semitubular adambulacrals; and the scaly covering of the disk. x 5. From gutta-percha squeeze.
 - 2 Actinal view of ray in distal portion, showing the overlapping adambulacrals; ambulacrals not exposed. x 5.
 - 3 Abactinal view of ray near tip, showing very slender ambulacrals and similar adambulacral ossicles. x 5.
 - 4 Actinal view of portion of ray, with ambulacral groove and ambulacral plates well exposed. x 5.
- Devonian: Upper Portage (Wiscoy shale) near Park Station, N. Y.

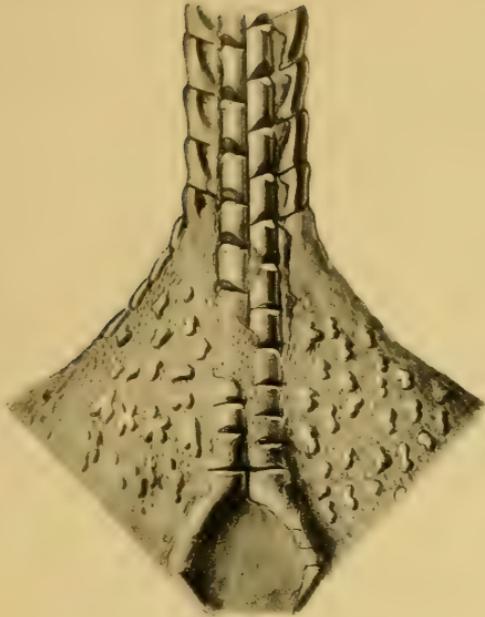
Eugasterella bicatenuolata nov.

Page 56

(See pl. 14, fig. 5)

- 5 Oral portion of actinal side, showing the syngnaths and their relation to the ambulacral and adambulacral columns. x 5. From a gutta-percha squeeze of the type.
 - 6 Actinal view of distal portion of ray, showing the wide ambulacral groove, the alternating ambulacral ossicles and the narrow column of spiniferous adambulacrals. x 5. From a gutta-percha squeeze.
 - 7 Actinal view of a proximal portion of a ray, showing more distinctly the podial pits. x 5. From a gutta-percha squeeze.
- Devonian: Portage (Grimes) sandstone, near Naples, N. Y.
The originals of the figures are in the New York State Museum.
The enlargements are made with the camera lucida.

1



2



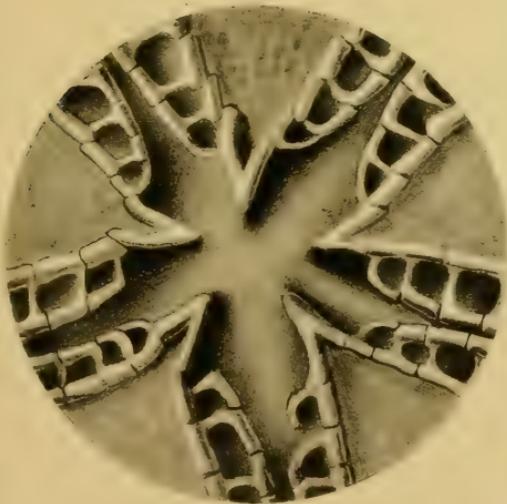
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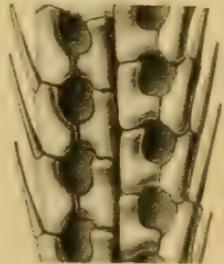


Plate 17

181

Encrinaster pusillus nov.

Page 58

- 1 Portion of type specimen drawn under water and showing the impressions of middle columns of ambulacral plates and two flanking columns of larger adambulacral plates; also the impressions of the oral ossicles and of the disk. x 6.
- 2 The entire type specimen (holotype), x 4. The upper right-hand ray exhibits the casts of the water vessels, namely, — originally situated within the ambulacralia — the median interskeletal canal with short side branches ending in nodes, the casts of depressions which served for the ampullae or for these and the podial insertions. The adambulacral plates do not appear in this drawing since they become distinct only under water.
Devonian: Chemung beds, Elmira, N. Y.

Eugasterella logani (Hall)

Page 55

- 3 Portion of ventral aspect of ray of type specimen to show the form of the ambulacral and adambulacral ossicles. x 5.
- 4 Oral portion of type specimen seen from actinal side. x 5.
- 5 Actinal view near tip of ray of type specimen, showing the ambulacral groove closed by adambulacrals. x 5.
Hamilton beds, Fenner, Madison county, N. Y.

The originals of the figures are in the New York State Museum.
The drawings are made from camera lucida outlines.

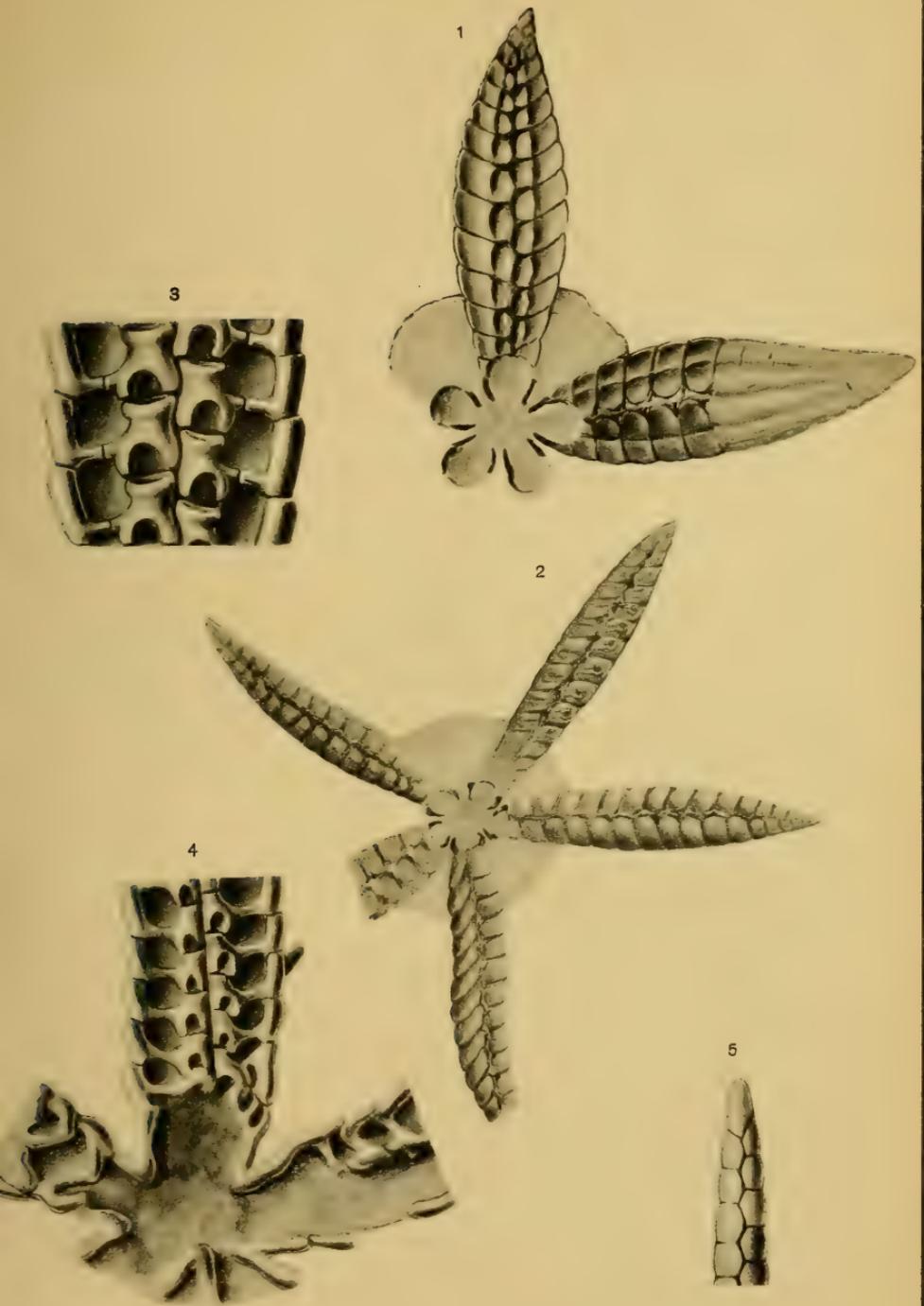


Plate 18

183

Encrinaster yachalensis nov.

Page 117

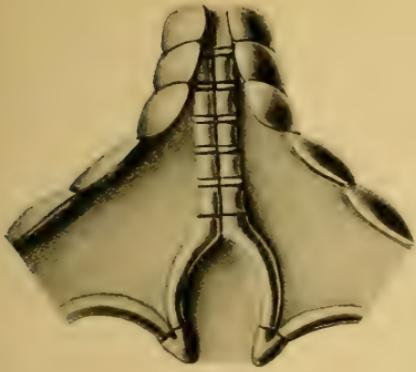
- 1 Holotype. Natural size.
 - 2 Basal part of abactinal view of ray and portion of disk, enlarged x 5, showing the ambulacral ossicles and impressions of the adambulacrals and the numerous accessory marginal plates of the disk.
 - 3 Portion of ray near tip, exhibiting only the ambulacral ossicles in abactinal view. x 5.
 - 4 Portion of oral armature, showing the simple, curved jaw carrying long, slender syngnaths. x 5.
 - 5 Enlargement (x 5) of a small portion of a ray retaining the adambulacrals on right side of figure.
- Silurian of Quebrada del Aguadido, Cerro Blanco, Yachal in Argentine Republic.

Argentinaster bodenbenderi nov.

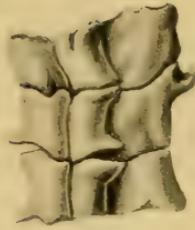
Page 118

- 6 Holotype. Natural size.
 - 7 Diagrammatic restoration of abactinal view of base of ray and oral armature. x 5.
- Silurian of Quebrada del Aguadido, Cerro Blanco, Yachal in Argentine Republic.
- The two holotypes are in the New York State Museum.

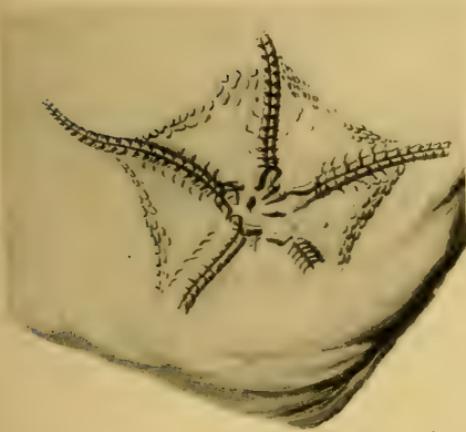
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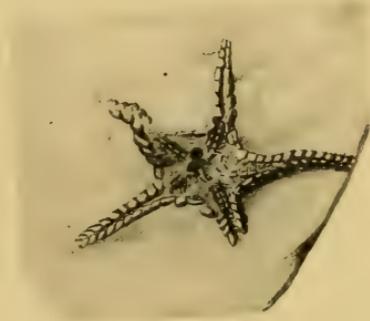
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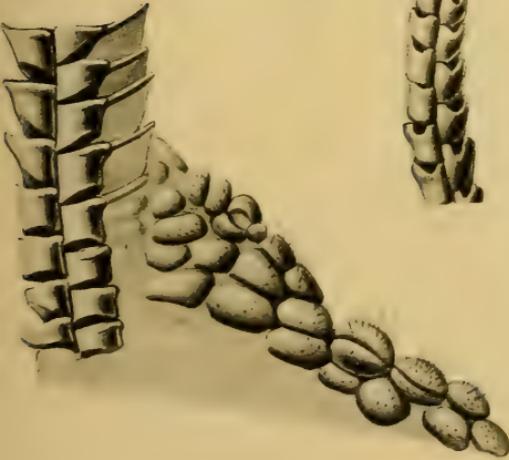
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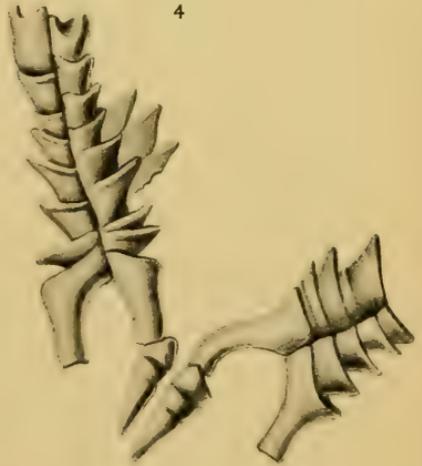


Plate 19

185

Hallaster forbesi (Hall)

Page 59

1 Restoration of abactinal view from specimens in the State Museum. It shows the peculiar shape of the disk which is densely covered with spinules, and the transverse rows of spines upon the adambulacrals. The spinose integument of the disk probably extended upon the abactinal side of the rays but failed of preservation. x 5.

2 Actinal view of disk of another specimen. x 5.

Devonian: Coeymans limestone, Litchfield, Herkimer county, N. Y.

The originals are in the New York State Museum.

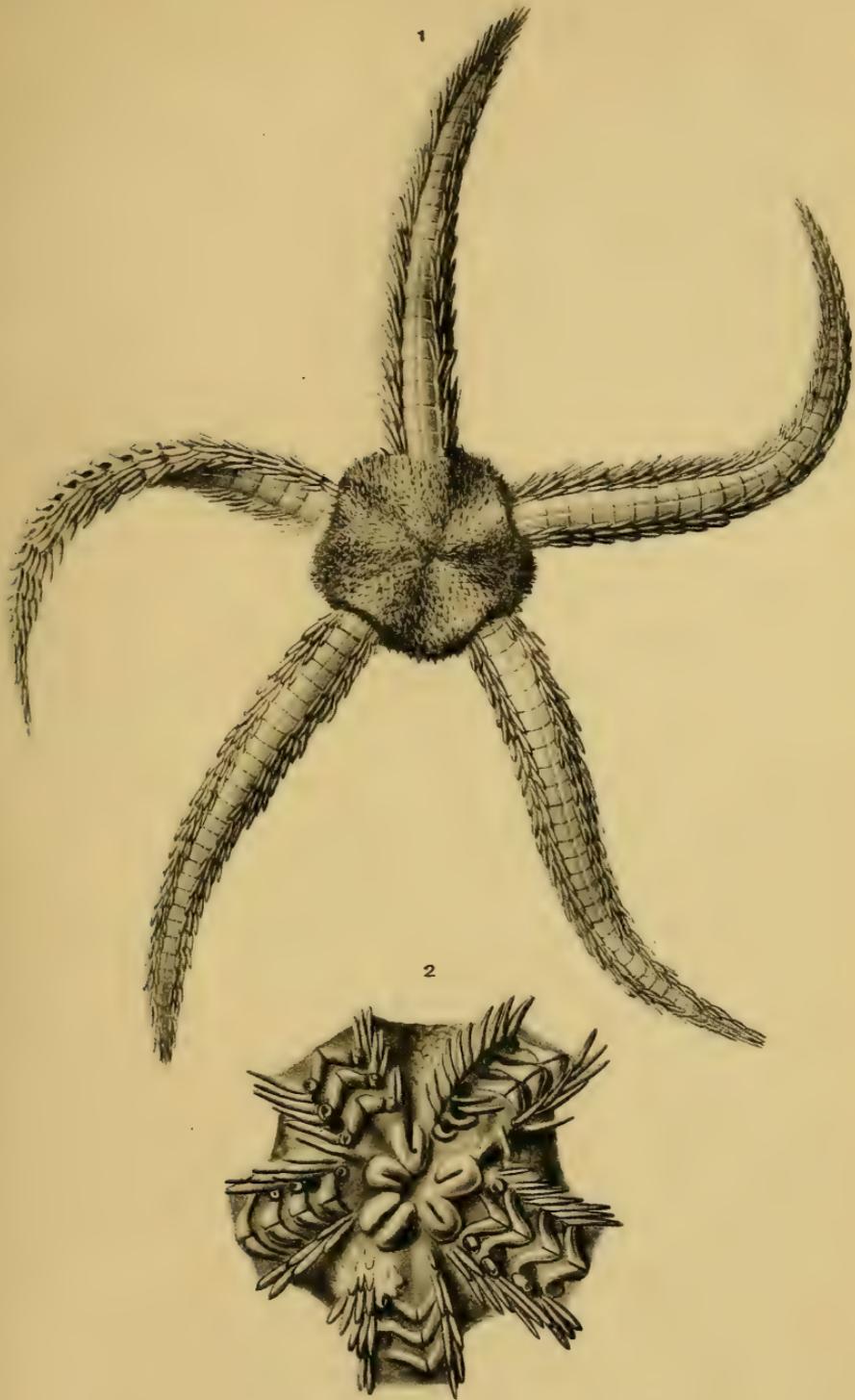


Plate 20

187

Ptilonaster princeps Hall

Page 44

- 1 Holotype, x 2. Photograph of the gutta-percha squeeze from which the original drawing was made. Actinal (ventral) view of a ray.

Devonian: Portage (Ithaca) beds. Cortland, N. Y.

Squamaster echinatus Ringueberg

Page 59

- 2 Holotype. x 2. Specimen folded upon itself and rays exposing the abactinal (dorsal) side.

Silurian: Clinton (Rochester) shale, Lockport, N. Y.

Klasmura mirabilis nov.

Page 64

(See plates 21 and 22)

- 3 Actinal (ventral) view of ray lacking the integument and showing the ambulacral plates, the median row of ventral plates and the lateral spines. x 2.

Devonian: West Hill flags of Naples beds, Deyo Basin, near Naples, N. Y.

The originals of this plate are in the New York State Museum (plastotype of figure 1).

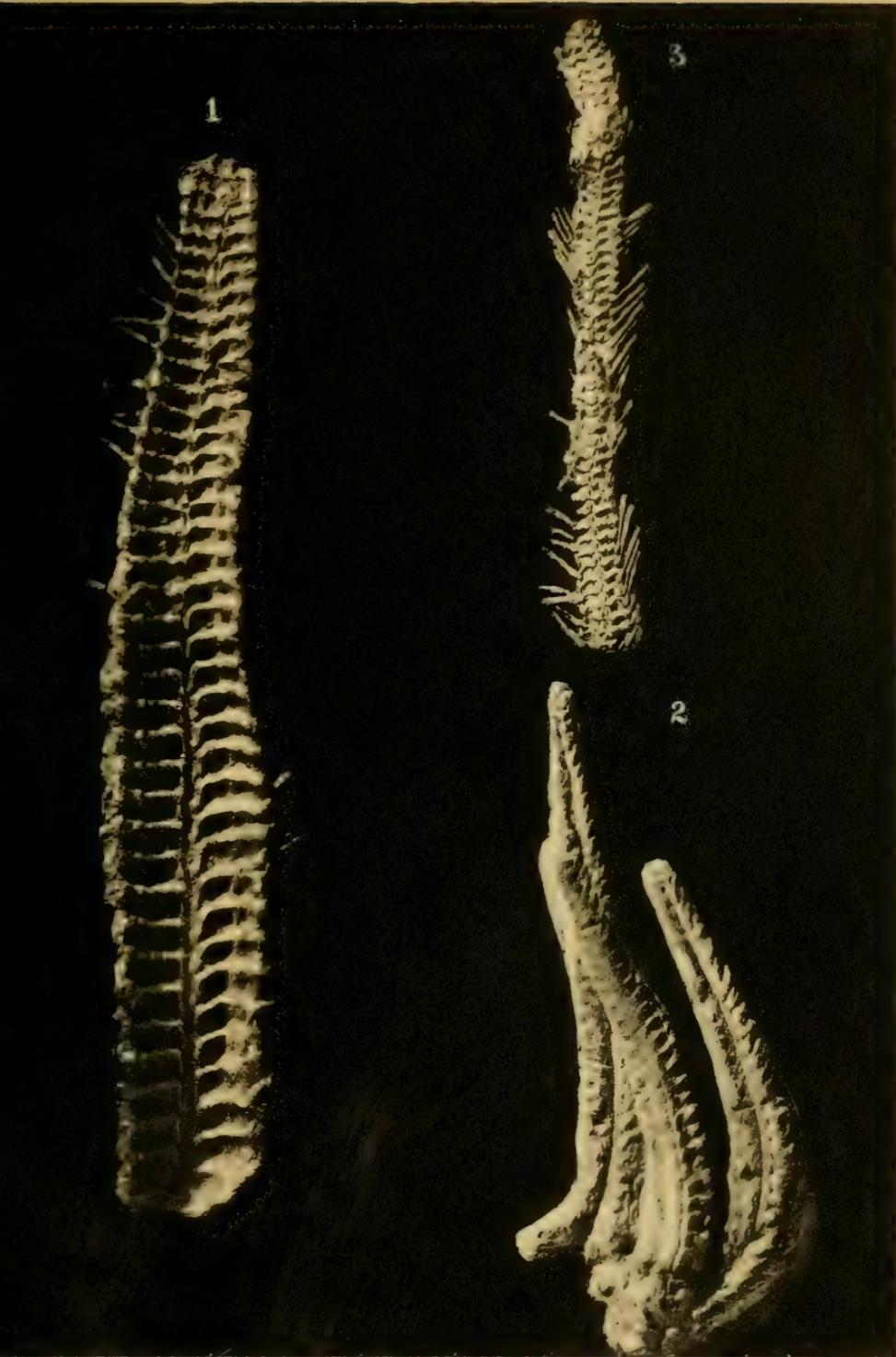


Plate 21

189

Klasmura mirabilis nov.

Page 64

(See plates 20, 22, 23)

- 1 Restoration of actinal view. The abactinal (dorsal) view of the rays is shown in the reflexed distal parts of the two rays. The outline of the interbrachial portions of the disk and the exterior aspect of the oral part of the disk are only conjectural.
x 2.

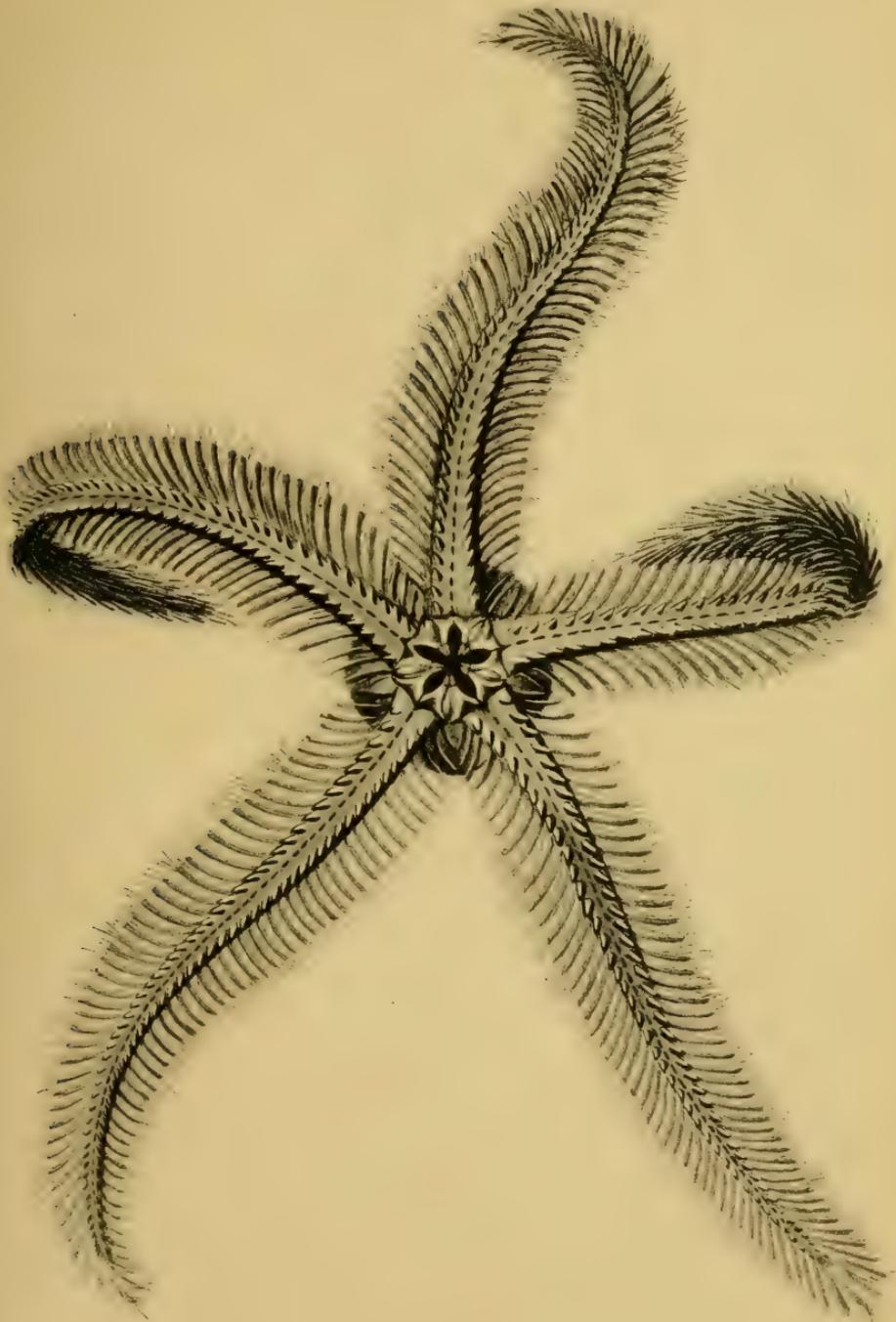


Plate 22

191

Klasmura mirabilis nov.

Page 64

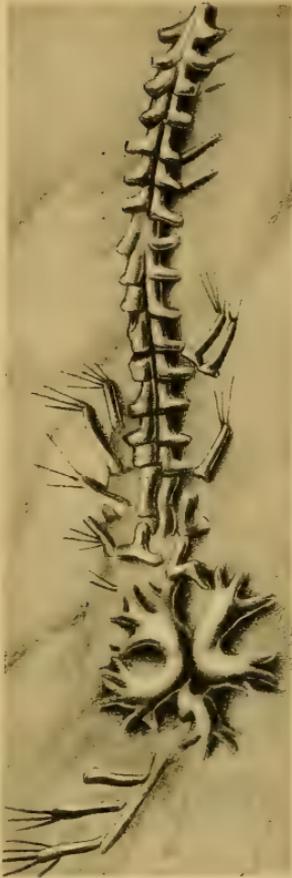
(See plates 20, 21, 23)

- 1 Specimen retaining ambulacral columns of one ray, some lateral spines and cast of oral aperture. x 5.
- 2 Oral frame of other specimen, with patches of integument. x 5.
- 3 Portion of abactinal side of ray, retaining the lateral wedge-shaped spines and the columns of dorsal plates, the side plates being covered by integument. x 5.
- 4 Another portion of abactinal side of ray, showing more in detail the shape of the dorsal plates. x 5.
- 5 Portion of actinal side of ray, showing the ambulacral ossicles and lateral spines. x 5.
- 6 Like view of another specimen, exhibiting a somewhat different shape of the ambulacrals, and their relation to the side plates, as well as the connection of the lateral spine bases. x 5.
- 7 Portion of actinal side of ray, retaining the integument and showing the median row of slits and the lateral rows of circular pits or perforations which may mark podial pores or spine bases. x 5.
- 8 Portion of another actinal view of ray which in upper part exhibits the test with the median slits and in the lower the underlying plates, namely, the ambulacral plates and in the median line incomplete ventral plates. x 5.

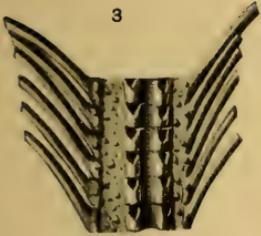
Devonian: West Hill flags of Naples beds, Deyo Basin, near Naples, N. Y.

The originals of all figures are in the New York State Museum. The figures, with the exception of figure 7, are taken from gutta-percha squeezes.

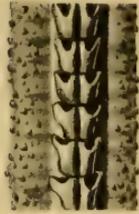
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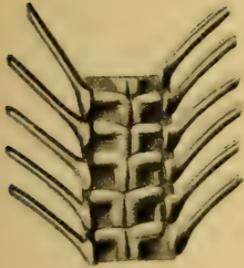
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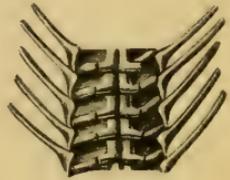
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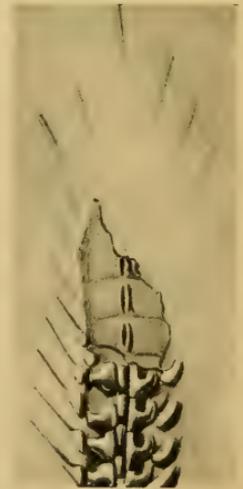
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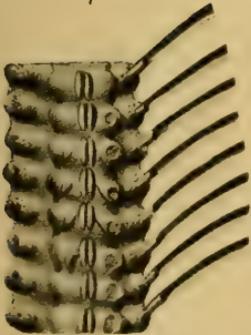
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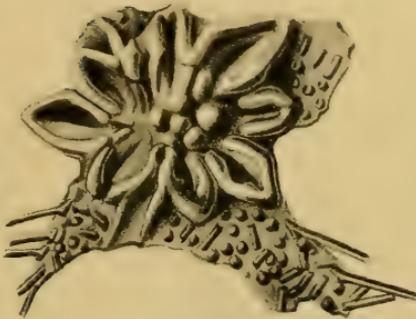


Plate 23

193

Klasmura mirabilis nov.

Page 64

(See plates 21 and 22)

- 1 Portion of abactinal (dorsal) view of ray, showing in upper part the integument, densely covered with spines and in the lower part the underlying dorsal plates. The lateral spines retain in part the paxillae. x 5.
- 2 Another portion of an abactinal side of ray, which also retains the integument but only the spine bases. x 5.
- 3, 4 Portions of actinal side of two rays exhibiting the median columns of ventral plates and their relation to the ambulacral plates. x 5.
- 5 Separate lateral spines showing the shape of their bases. x 5.
- 6 A lateral spine still further enlarged to show the paxillae upon its base.
- 7 Mold of lateral margin of ray, showing the bundles of paxillae upon the bases of the lateral spines and the wedge-shaped form of the paxillae upon the ends of the lateral spines. x 5.
- 7a A lateral spine still further enlarged.
Devonian: Portage group, West Hill flags of Naples beds, Deyo Basin, near Naples, N. Y.

Klasmura clavigera nov.

Page 66

- 8 Small portion of paratype, showing the character of the ambulacral ossicles, of the adambulacrals or side plates and the outlines of the podial depressions. x 5.
- 9 View of holotype, x 5. Actinal side of a part of a ray.
Devonian: Portage group, West Hill flags of Naples beds, Deyo Basin, near Naples, N. Y.
All figures are taken from gutta-percha squeezes. The originals are in the New York State Museum.

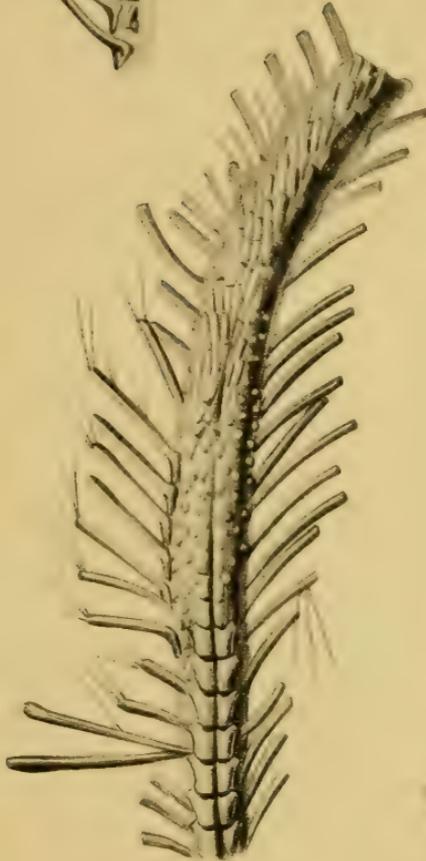
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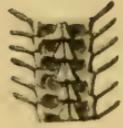
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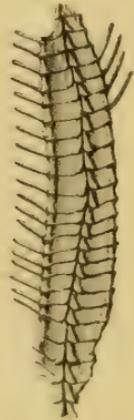
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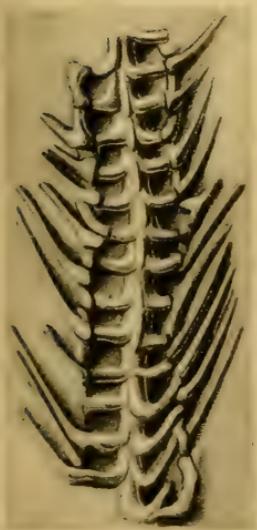
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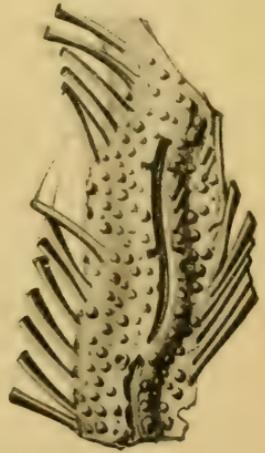
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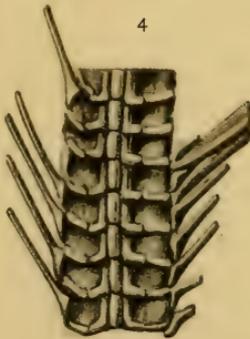
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2



4



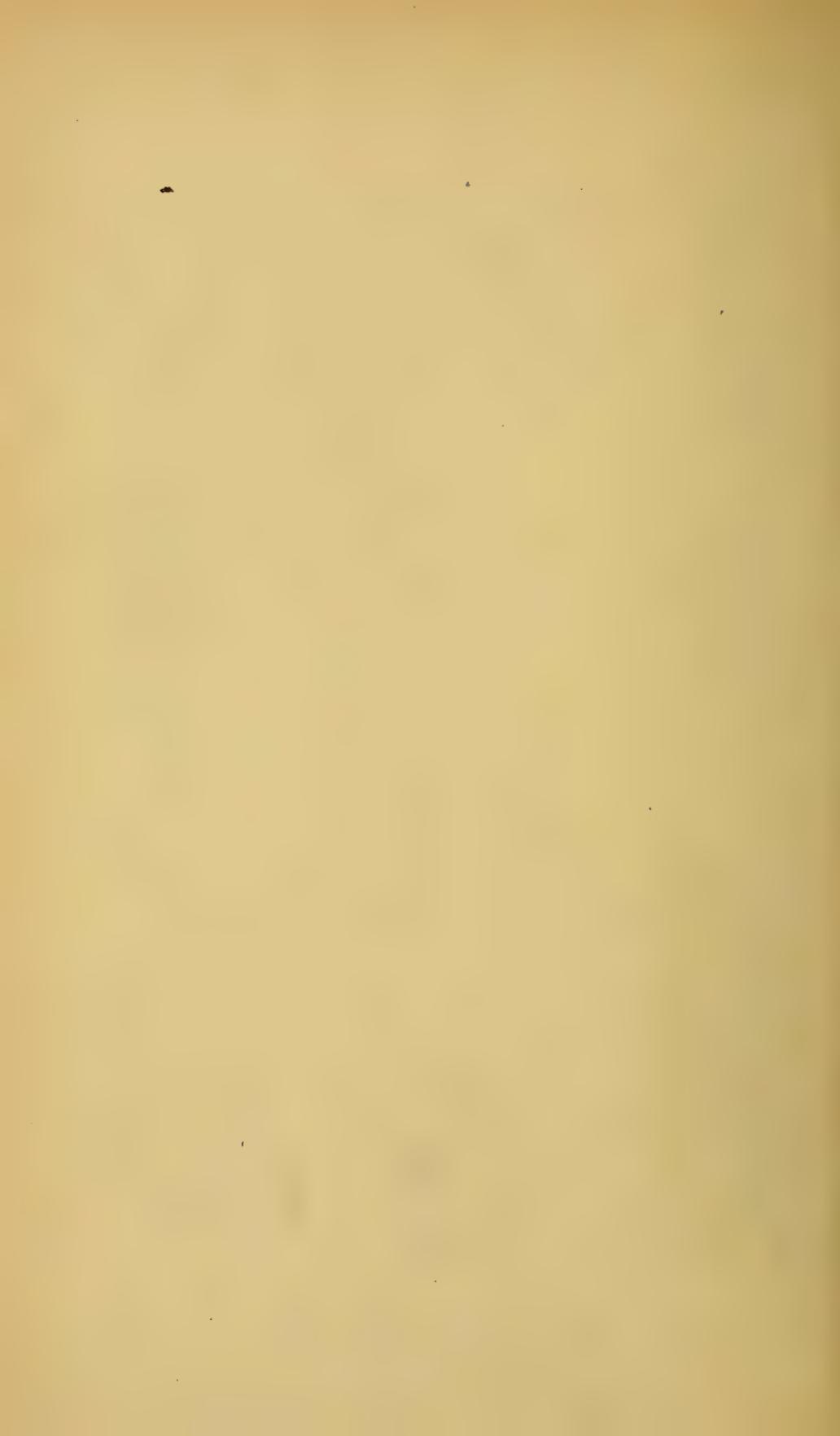


Plate 24

195

Orbiculoidea molina nov.

Page 71

- 1 Pedicle valve, x 4. Holotype.
- 2 Profile of brachial valve, x 3.
- 3, 4 Brachial valves, x 3. Paratypes.
Silurian: Pittsford waterlime at Farmer's Mills near Utica
N. Y.

Lingula semina nov.

Page 67

- 5 Pedicle valve, partly exfoliated and showing muscle-scars (syntype). x 3.
- 6 Pedicle valve with test preserved (syntype). x 3.
Silurian: Pittsford shale, Pittsford, Monroe county, N. Y.

Lingula testatrix nov.

Page 67

- 7 Brachial valve. Syntype. x 2.
- 8 Pedicle valve. Syntype. x 2.
Silurian: Bertie waterlime, Litchfield, N. Y.

Lingula subtrigona nov.

Page 69

- 9 Pedicle valve. Syntype. x 3.
- 10 Brachial valve (syntype), with posterior margin of pedicle valve and trace of pedicle groove exposed. x 3.
Silurian: Manlius limestone, on Frontenac island near Union Springs, N. Y.

Lingula vicina nov.

Page 68

- 11 Pedicle valve. Holotype. x 3.
- 12 Profile of pedicle valve. x 3.
Silurian: Pittsford waterlime at Farmer's Mills near Utica
N. Y.

Dinobolus canadensis (Billings)

Page 72

- 13, 14 Figure of mold and gutta-percha squeeze. Natural size.
Ordovician: Black River group, Watertown limestone, Watertown, N. Y.
The originals of all figures are in the New York State Museum

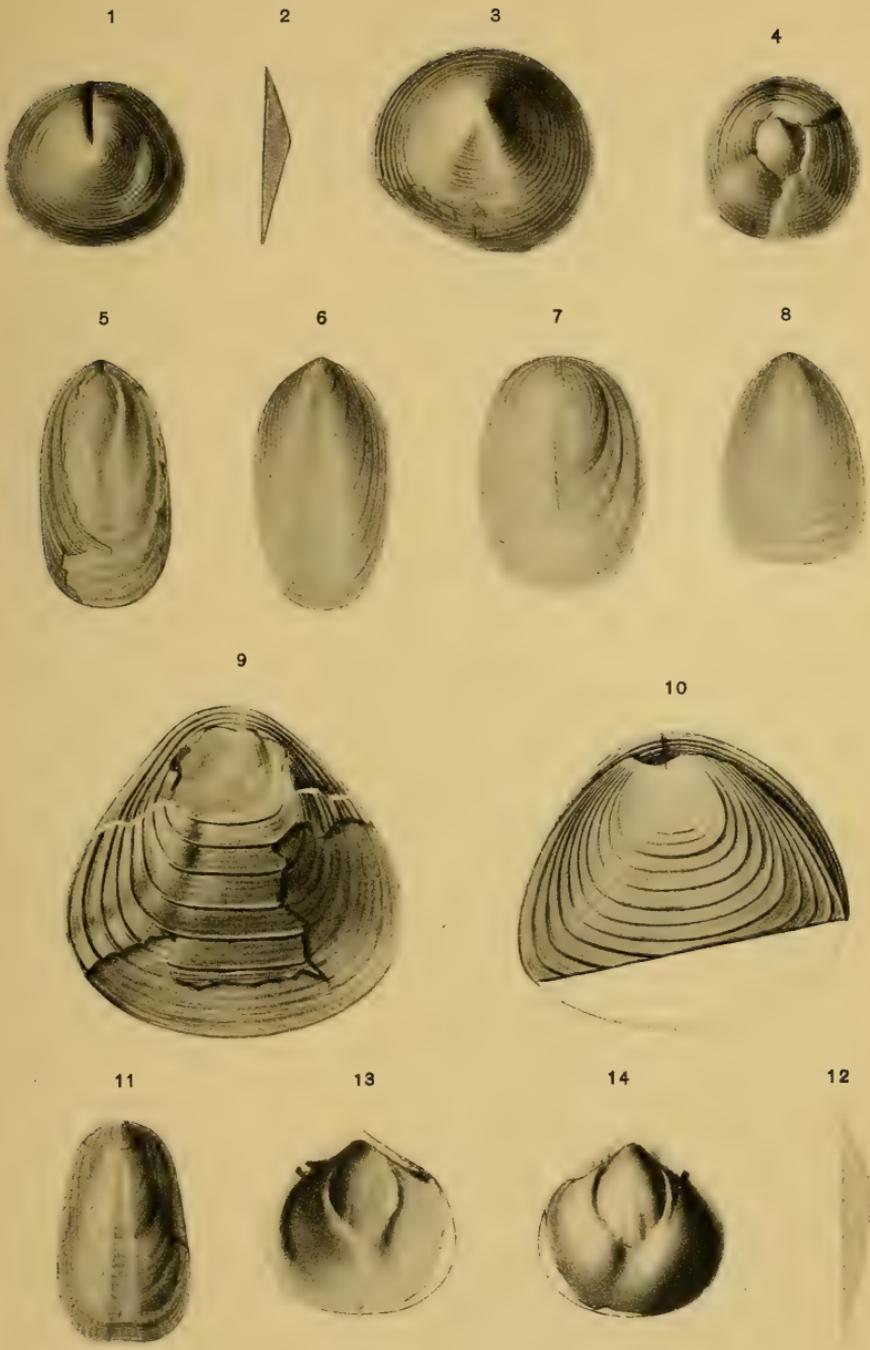


Plate 25

197

Protospira minuta nov.

Page 72

1, 2 Two views of holotype. x 3.

Upper Cambrian (Ozarkian): Hoyt limestone, Hoyt quarry, town of Greenfield, Saratoga county, N. Y.

Hormotoma gregaria nov.

Page 73

3 Type specimen. x 3.

4 Group of specimens. Natural size.

Silurian: Lower Bertie waterlime, Marcellus, N. Y.

Pterinea poststriata nov.

Page 74

5 Left valve preserving surface sculpture. Syntype. Natural size.

6, 7 Interior casts of two right valves (syntypes), showing hinge and muscle-scars. Drawn too convex. Natural size.

Silurian: Pittsford shale, Pittsford, Monroe county, N. Y.

Ctenodonta salinensis nov.

Page 75

8 Right valve. Syntype. x 2.

9 Left valve. Syntype. x 2.

Silurian: Salina beds, Bull's quarry, town of Lenox, Madison county, N. Y.

Orthoceras vicinus nov.

Page 76

10 Holotype. Natural size.

Silurian: Bertie waterlime, Marcellus, N. Y.

The originals of the figures are in the New York State Museum.

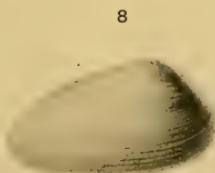
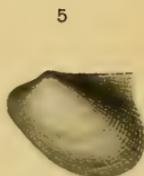
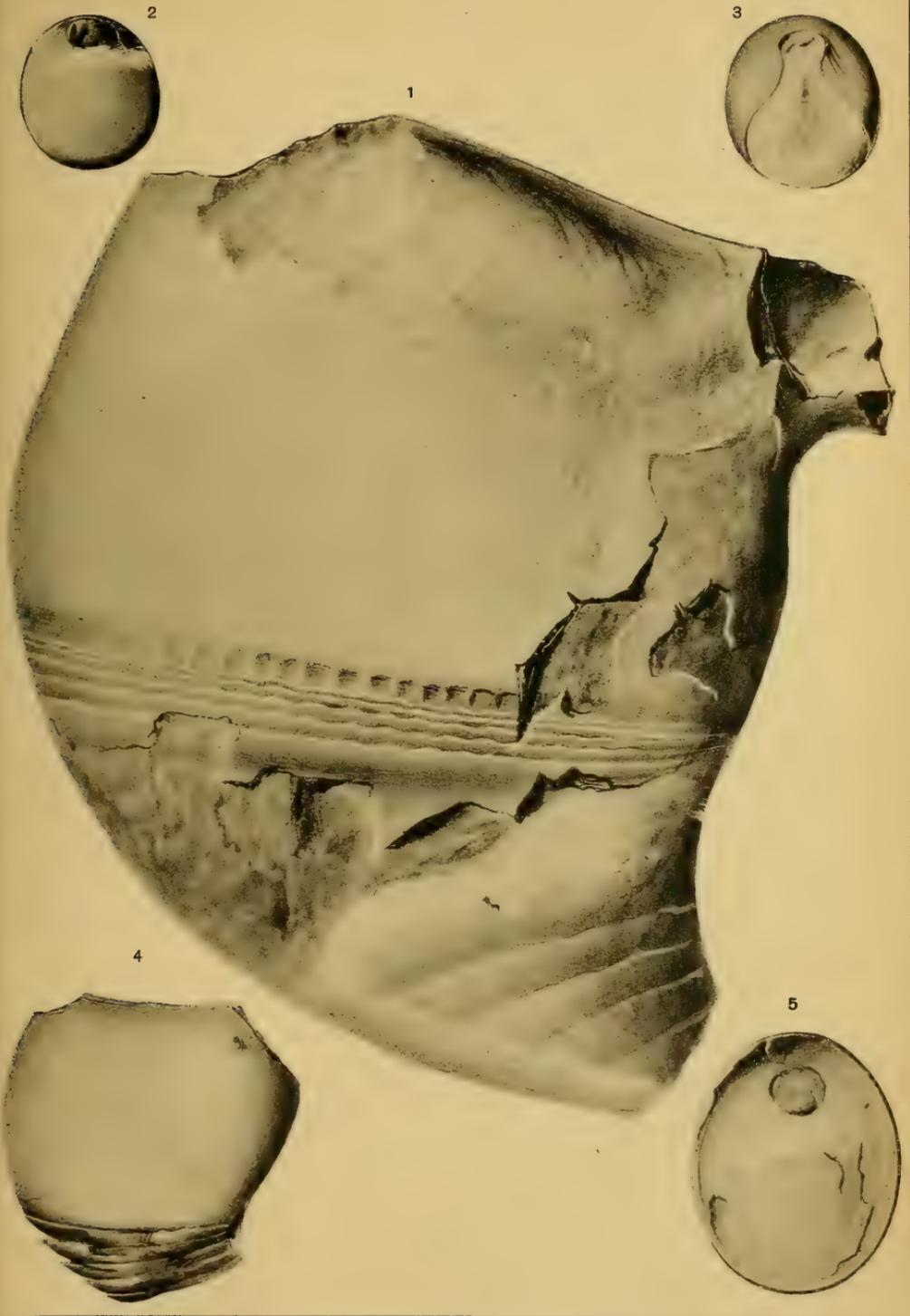


Plate 26

Phragmoceras accola nov.

Page 77

- 1 Large specimen. Type of species. Natural size.
 - 2 Septum with siphuncular segment. Natural size.
 - 3 Aperture of small specimen.
 - 4 Small specimen probably belonging to this species.
 - 5 Septum of largest specimen with siphuncular foramen.
- Silurian: Bertie waterlime, Litchfield, Herkimer county, N.
The originals are in the New York State Museum.



G. S. Barkentin del.

Plate 27

201

Septameroceras (?) sp.

Page 81

- 1 Single specimen observed.
Silurian: Pittsford shale, Pittsford, N. Y.

Hexameroceras microstoma nov.

Page 79

- 2 Dorsal view of largest specimen observed. Paratype. Natural size.
3 Septum with siphuncle. Paratype. Natural size.
4 Well-preserved specimen. Paratype. Natural size.
5, 6 Lateral and dorsal views of another specimen. Paratype. Natural size.
7, 8, 9 Ventral, lateral and apertural views of type specimen. Holotype. Natural size.
Silurian: Lockport (Guelph) limestone. Niagara Falls.

Gomphoceras osculum nov.

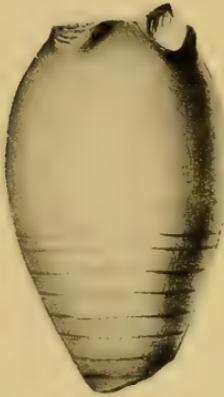
Page 76

- 10 Group of three type specimens. (Syntypes). Natural size.
11 Section of specimen. Natural size.
Silurian: Cobleskill limestone, Morganville, N. Y.
The originals are in the New York State Museum.

1



2



3



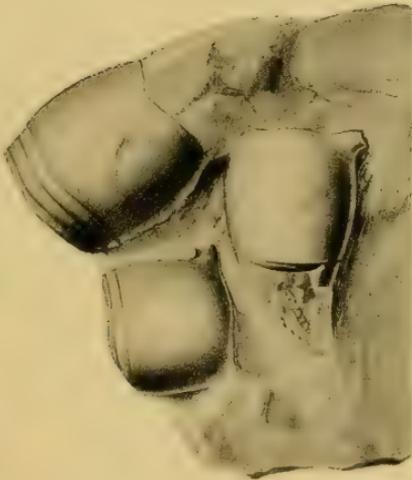
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5



6



7



8



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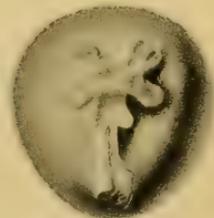


Plate 28

203

Serpulites magnus nov.

Page 88

- 1 Fragment of specimen. Natural size.
- 2 Surface, x 5, drawn too regular.
Ordovician: Canajoharie shale, Menands, Albany county,
N. Y.

Serpulites tener nov.

Page 88

- 3 Enlargement of portion of tube. x 5.
- 4 Type specimen. Natural size.
Devonian: Hamilton beds, Clarksville, N. Y.

Serpulites gracilis nov.

Page 87

- 5 Group of specimens attached to shell fragments. Natural size.
- 6 Group of several specimens drawn in natural size. Specimens retaining the chitinoid setae within the apertures of the tubes; enlarged (x 5) in figs. 6a and 6b.
- 7 Another specimen (figured natural size; portion enlarged) (fig. 7a, x 5), aperture with setae (fig. 7b, x 5). Holotype.
- 8 Longest specimen observed, with adhesion disk. The original of figure 5 is from the Upper Canajoharie (Dolgeville) shales at Dolgeville; those of figures 6-8 are from the Utica shale at Holland Patent.

All originals of this plate are in the New York State Museum.

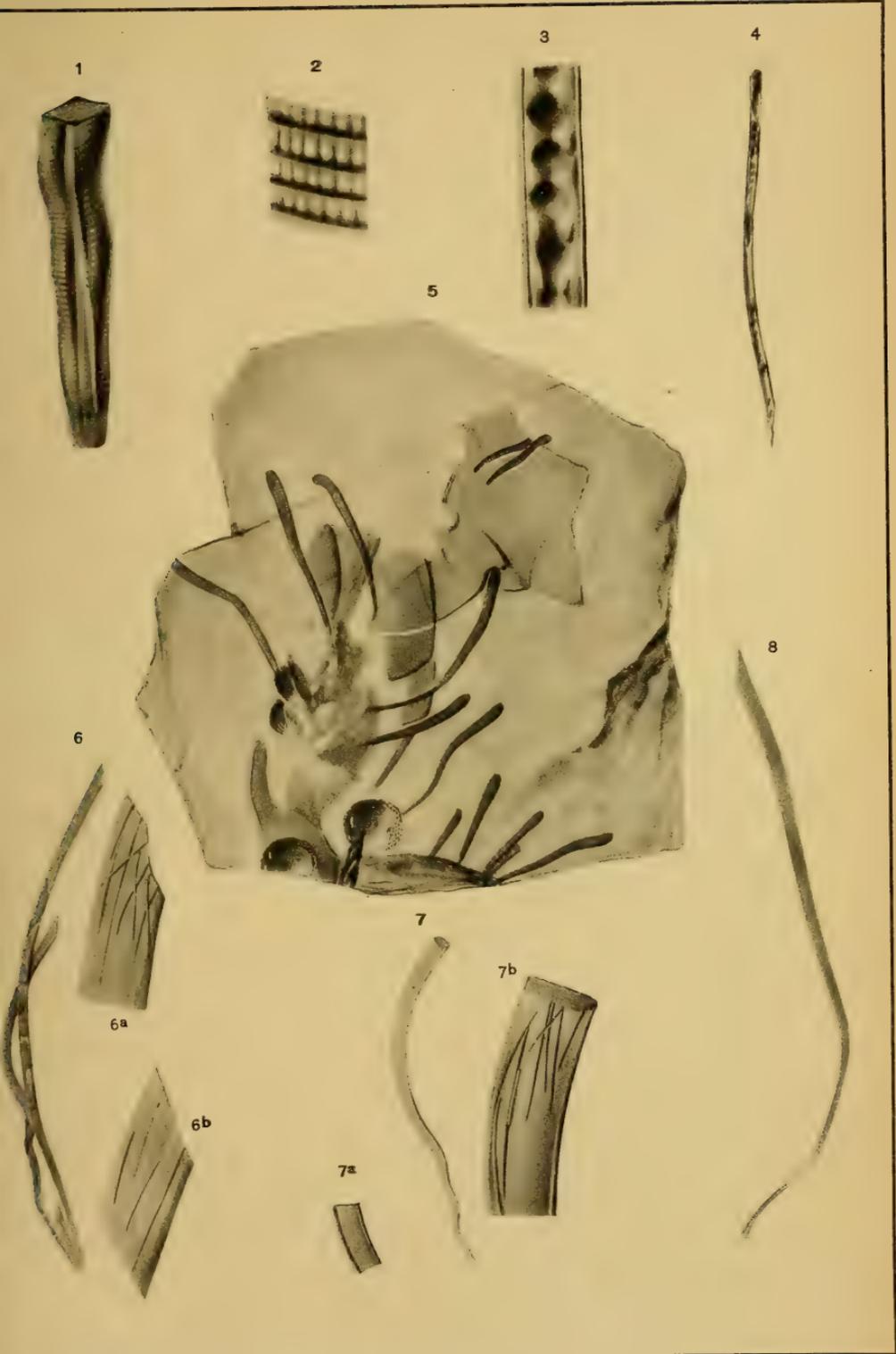


Plate 29

205

Serpulites interrogans nov.

Page 86

- 1 Larger specimen (natural size) with adhesion disk; 1a, x 5.
Syntype.
 - 2 Characteristic specimen (natural size) with adhesion disk;
2a, x 5. Syntype.
- Ordovician: Deep Kill graptolite shale, Grant's hollow, near
Melrose, N. Y.

Serpulites lumbricoides nov.

Page 87

- 3 Type specimen (x 2) and portion enlarged (x 5).
Ordovician: Trenton limestone, Trenton Falls, N. Y.

Serpulites crassimarginalis nov.

Page 87

- 4 Type specimen. Natural size.
 - 4a Enlargement (x 3) of portion of tube.
- Ordovician: Utica shale, Holland Patent, N. Y.

Serpulites longus nov.

Page 89

- 5 Type specimen. Natural size.
Carbonic: Keokuk beds, Crawfordsville, Ind.

Protonympha marcellensis nov.

Page 81

- 6 Type specimen.
 - 6a Enlargement (x 4) of anterior extremity.
 - 6b Enlargement (x 4) of middle portion.
- Devonian: Marcellus shale. Near Clarksville, N. Y.
The originals of this plate are in the New York State Museum

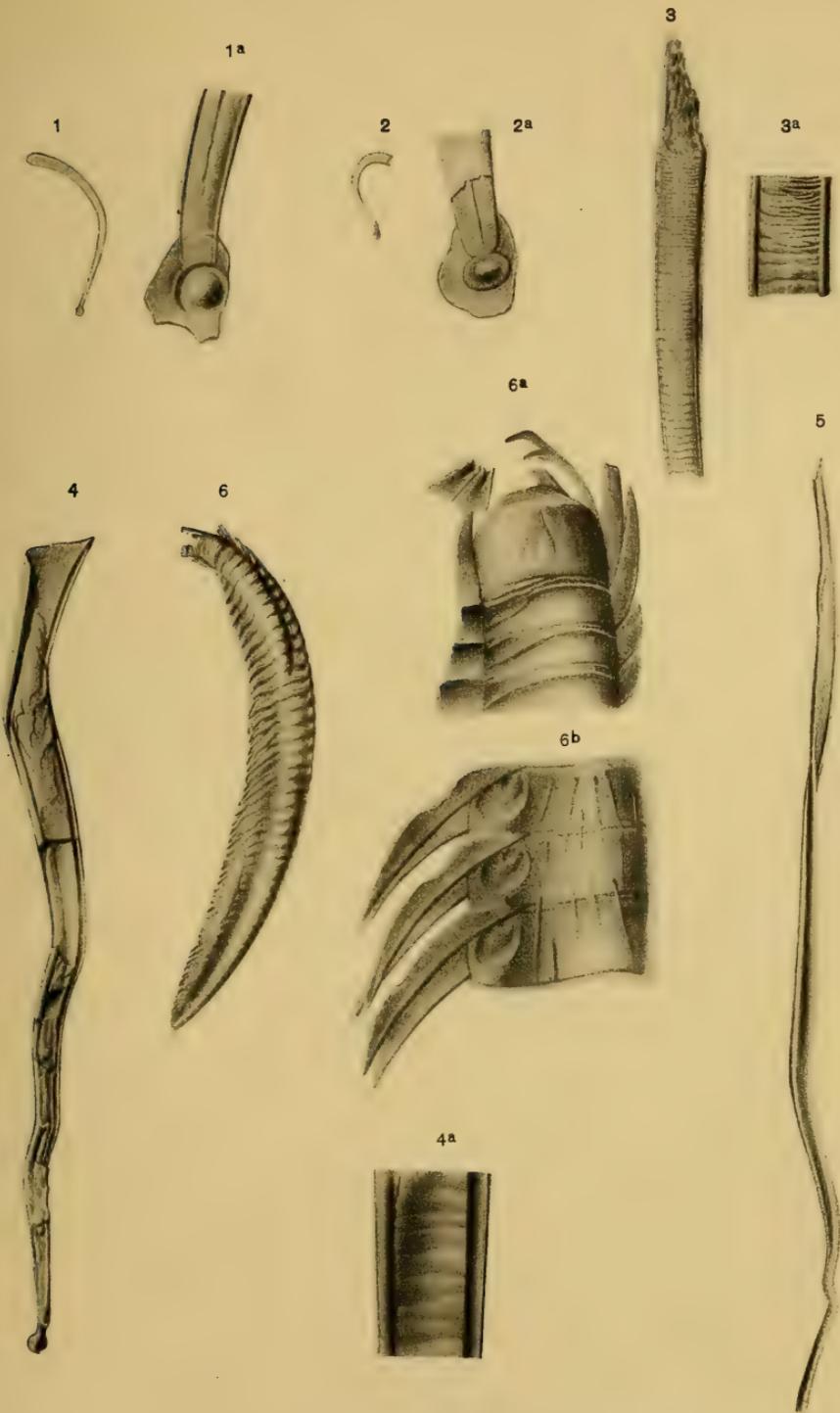


Plate 30

207

Agraulos cushingi nov.

Page 89

- 1-3 Three cranidia; figure 2, holotype, the others, paratypes.
Natural size.
4 Side view of cranidium. Natural size.
Ozarkian (Upper Cambrian): Theresa dolomite, Greenfield
near Saratoga, N. Y.

Amphilichas conifrons nov.

Page 90

- 5, 6 Top and posterior views of type specimen. Natural size.
7 Lateral view of cranidium with spines restored. Natural size.
8 Pygidium. Paratype. Natural size.
Ordovician: Trenton limestone, Trenton Falls, N. Y.

Ceraurus ruedemanni Raymond

Page 121

- 9 Type specimen. Natural size.
10 Glabella of smaller specimen. Paratype. Natural size.
11 Lateral view of cheek, imperfect in front, x 3.
12 Pygidium. Paratype. Natural size.
Ordovician: Upper Chazy (Valcour) limestone, Little Monty
bay, Chazy, N. Y.
The originals are in the New York State Museum.

1



2



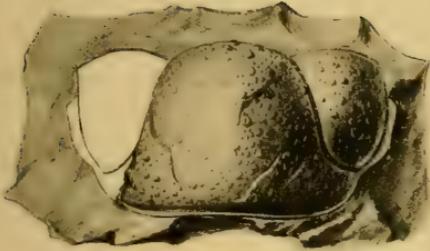
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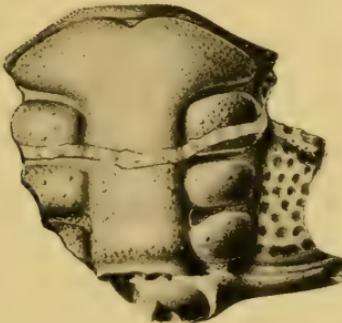
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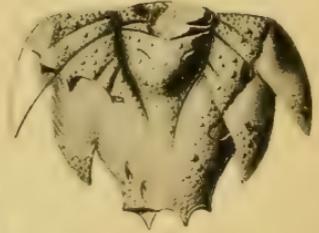
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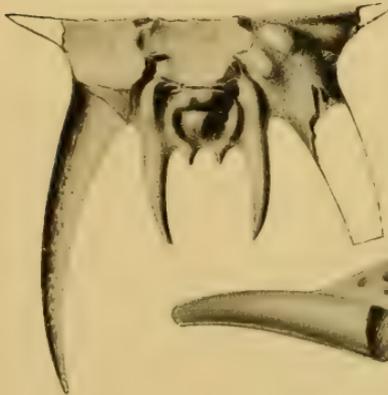
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12



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11

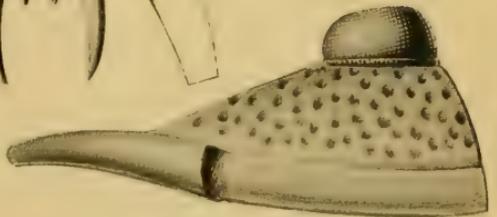


Plate 31

209

Spathiocaris williamsi nov.

Page 96

- 1 Type specimen. Natural size.
- 2 A smaller specimen, x 3, referred here with some doubt.
Carboniferous (Waverlyan): Cleveland shale, Mill creek, Newburg, near Cleveland, Ohio.

Spathiocaris cushingi nov.

Page 96

- 3 Large specimen. Paratype. Natural size.
- 4 Type specimen. x 3.
Carboniferous (Waverlyan): Cleveland (Olmstead) shale, Cahoon creek, North Dover, Cuyahoga county, Ohio.

Spathiocaris chagrinsensis nov.

Page 95

- 5 Holotype. Natural size.
Devonian: Chagrin shale (Chemung), Chippewa creek, Breckville, Ohio.

Spathiocaris lata nov.

Page 94

- 6 Holotype. Natural size.
Devonian: Chemung beds, Cotton farm near Avoca, Steuben county, N. Y.

Spathiocaris emersoni Clarke.

Page 94

- 7 Large, laterally compressed specimen, natural size. Outline of flat projection of specimen.
- 8 Smaller, laterally compressed specimen. Natural size.
- 8a Lateral view of same.
- 8b Enlargement of median surface, x 4.
Devonian: Portage (Naples) beds, Naples, N. Y.
The originals of figures 1-5 are in the Museum of Adelbert College (Western Reserve University), Cleveland, Ohio; those of 6-8 in the New York State Museum.

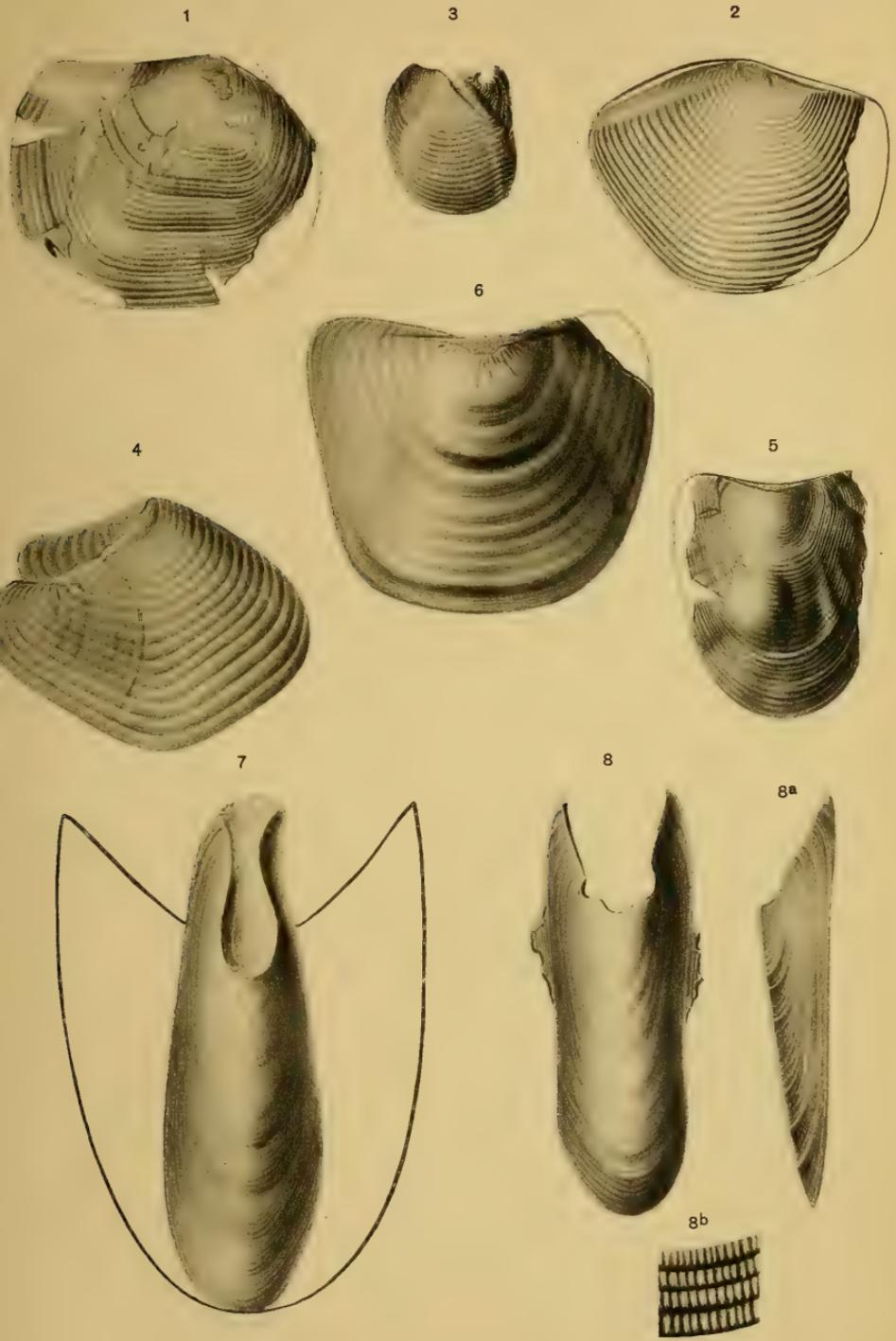


Plate 32

211

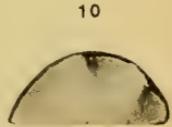
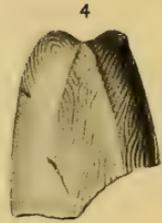
Anatifopsis wardelli nov.

Page 102

- 1, 2 Partially exfoliated valves showing the basal ridges. Figure 1, x 2; figure 2, x 3.
- 3 Valve retaining the surface sculpture, and the apex, probably plate of capitulum. x 2.
- 4 Valve with two apexes. x 3.
- 5 Fragment of valve showing cast of inner surface.
- 6 Large specimen, partly exfoliated and showing the basal ridges and apex. x 2.
- 7 Fragment of organism, consisting of series of four valves. x 4.
- 8 Fragment of valve with straight margin. x 2.
- 9 Rhomboidal plate, possibly belonging to pedicle. x 4.
- 10 Section of valve (capitulum plate). x 2.
- 11 Enlargement (x 15) of interior sculpture of plates, appearing when part of the valve substance has been weathered out.
- 12 Enlargement (x 10) of network of chitinous fibers on inside of valves.

Silurian: Longwood shales, Shawangunk mountains, Otisville, N. Y.

The originals (syntypes) are in the New York State Museum.



9

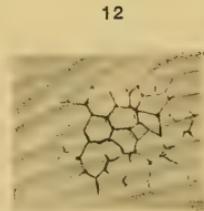


Plate 33

213

Ceratiocaris (Limnocaris) salina nov.

Page 92

- 1, 2, 3 Specimens (syntypes) showing the carapace and abdomen with telson. Figure 2 also shows the frontal rostrum; figure 3, the eye tubercle and rostrum. All x 5.
 - 4 Larger specimen in which the two valves are recognizable, as well as the anterior mucro of one of the valves, the rostrum (slightly displaced) and the posterior fringe. x 5.
 - 5 Well-preserved carapace with anterior mucro, eye tubercle and posterior fringe. Nearby is an abdomen, probably belonging to the carapace. x 5.
- Silurian: Pittsford shale, Pittsford, N. Y.

Pseudoniscus roosevelti Clarke

Page 105

- 6 Enrolled specimen, showing eyes. x 2.
 - 7 Specimen with eyes and suture lines. x 2.
- Silurian: Pittsford shale, Pittsford, N. Y.

Pseudoniscus clarkei nov.

Page 107

- 8 Specimen in which the carapace is slightly contracted longitudinally. Syntype. x 2.
 - 9 Type specimen. (Holotype). x 3.
- Silurian: Bertie waterlime, Litchfield, N. Y.

Eusarcus trigonus nov.

Page 111

- 10 Holotype. Natural size.
- Silurian: Bertie waterlime, Litchfield, N. Y.
The originals of this plate are in the New York State Museum.

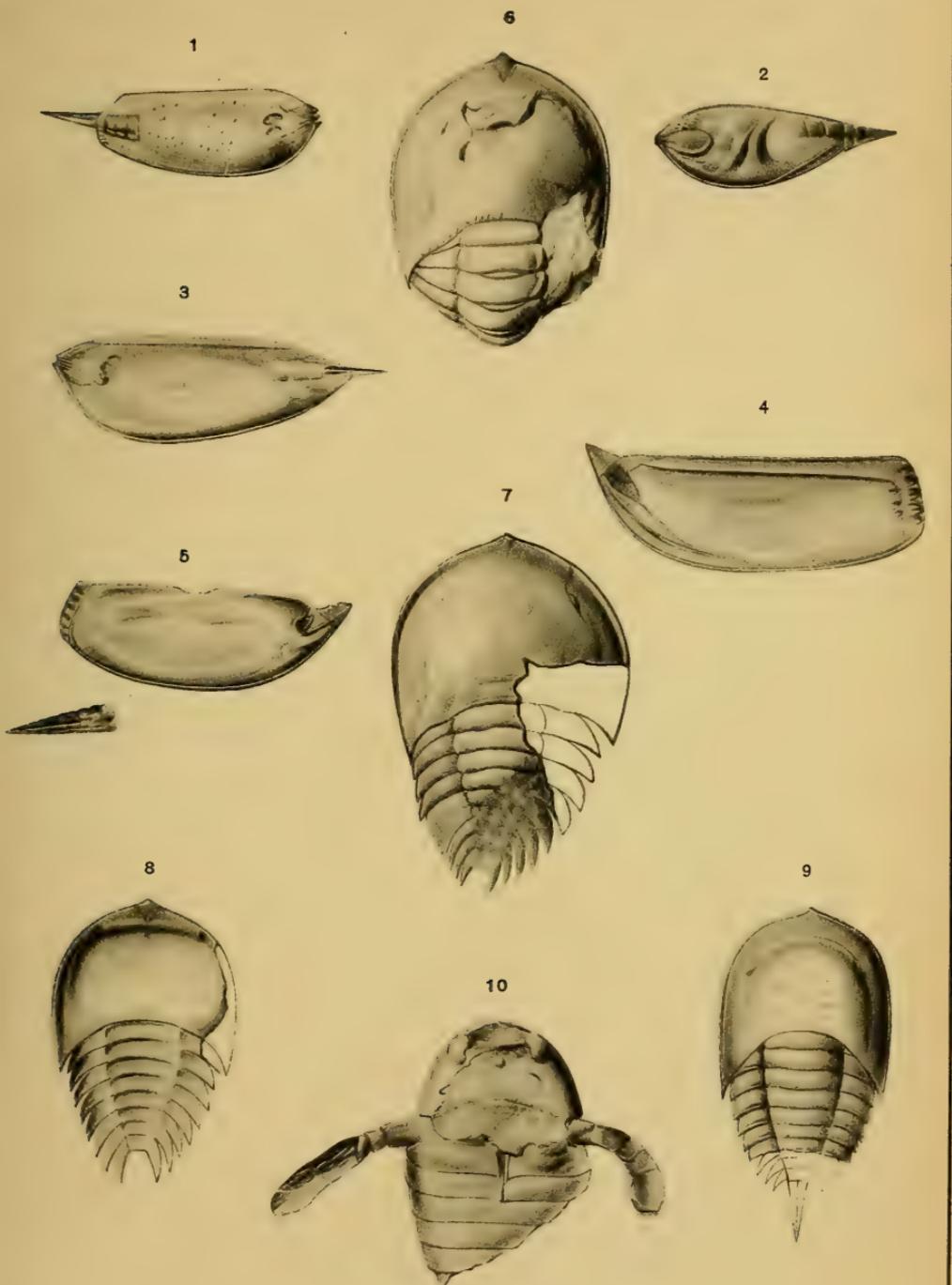


Plate 34

215

Cryptolithus tessellatus Green

(See pl. 35)

- 1 Lateral view of exfoliated glabella showing interior cast of median eye tubercle. x 5.
- 2 Lateral view of interior cast of eye tubercle, showing contrast between smooth upper and pitted lower surface of cast of tubercle, x 30.
- 3 Top view of same. Apex of cast of tubercle slightly rubbed or fractured (tubercle indicated by arrow). x 30.
Trenton limestone. Near Plattsburg, N. Y.

Trinucleus bucklandi Barrande

- 4 Specimen with exfoliated cephalon, exhibiting the lateral and median eye tubercles. (From Barrande).
- 5 Exfoliated cephalon, showing lateral eyes and median eye tubercle with pit (indicated by arrow). x 5.
Ordovician. Girvan, Scotland.

Isotelus gigas Dekay

- 6 Cephalon of adolescent specimen with distinct median eye tubercle (indicated by arrow). x 2.
Trenton limestone. Trenton Falls.

Asaphus expansus (Linn.)

- 7 Interior cast of median eye tubercle. x 5. On the left a portion of the very thick test is shown.
Ordovician: River Wolchow, Gouvern. Petersburg, Russia.

Illaeus ioxus Hall

- 8 Cranidium, showing small median eye tubercle. Natural size.
Silurian: Rochester shale. Lockport, N. Y.

Cheirurus niagarensis (Hall)

- 9 Partly exfoliated cranidium, showing pit in interior cast in place of median eye tubercle (marked by arrow). Natural size.
Silurian: Rochester shale. Rochester, N. Y.
All originals, with the exception of that of figure 4, are in the New York State Museum.

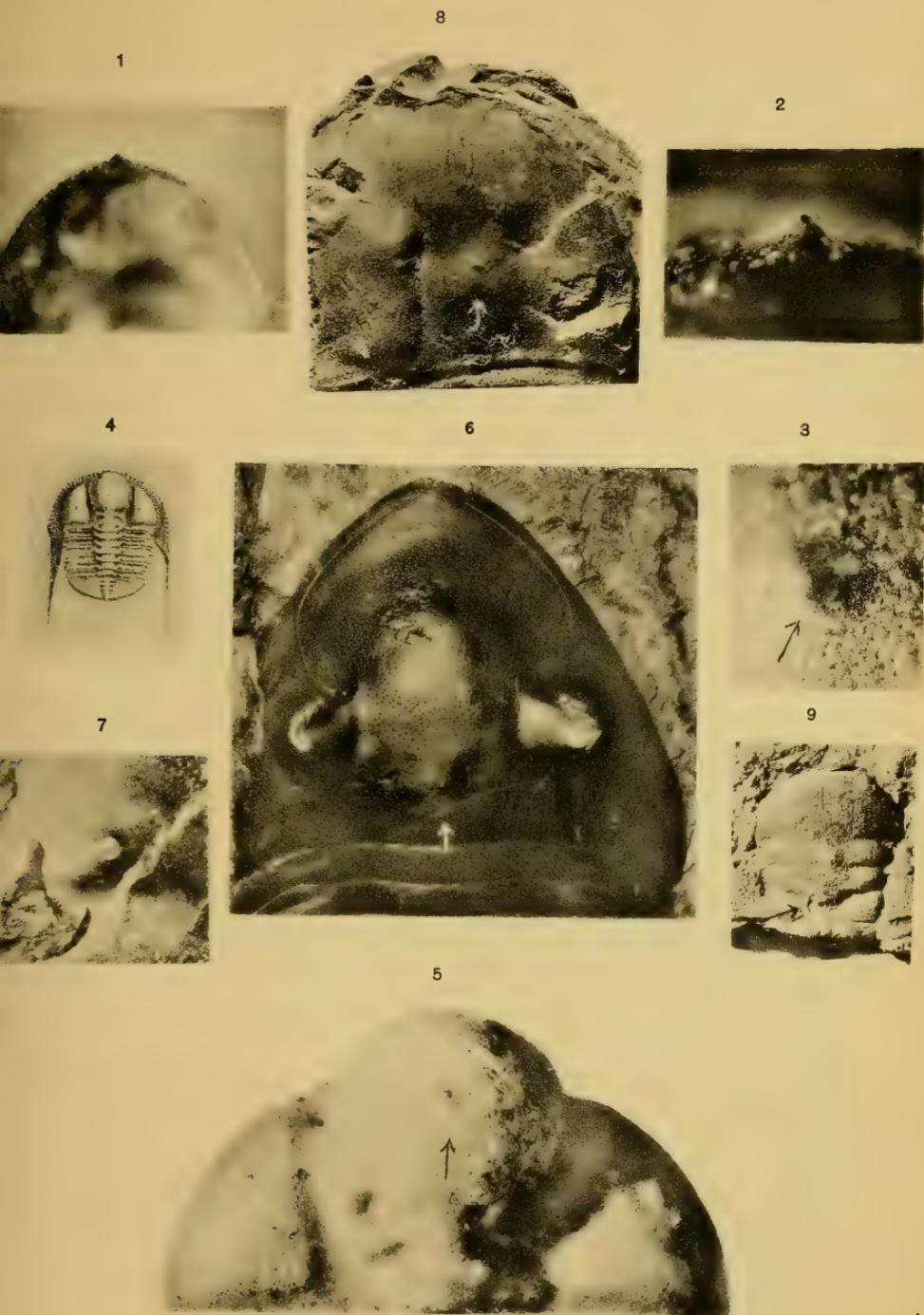


Plate 35

217

Cryptolithus tessellatus Green

(*Trinucleus concentricus* Hall)

(See pl. 34)

- 1, 2 Lateral views of two interior casts of median eye tubercles, showing the upper smooth, glossy, lenslike body, the pitted surrounding surface, and the minute tubercle in front (to the right in figure) of the eye tubercle. x about 100.
- 3 Thin longitudinal section through interior cast of glabella, showing interior cast of eye tubercle and anterior tubercle (at a). x 50.
- 4 Thin section of interior cast of eye tubercle, x 250, showing the inferior carbonaceous line of the lenticular body.

Figures 3 and 4 camera lucida outlines by author.

- 5 Section through crust, covering the median eye tubercle, showing its thinning in tubercle, enlarged x 75.
 - 6 Right half of cephalon, to show the posterior portion of facial suture. x 5.
 - 7 Exfoliated cranidium, showing interior cast of eye tubercle and frontal portion of facial suture. Space between eye tubercle and anterior tubercle drawn too small. x 5.
- Trenton limestone, Boonville, N. Y.

Cryptolithus (*Trinucleus*) ornatus (Sternberg)

- 8 Specimen showing posterior facial sutures. (From Barrande)

Asaphus expansus (Linn.)

- 9 Section through median eye tubercle, showing thinning of crust above tubercle. x 15.
- Ordovician (Glaukonitkalk B₂b). Wolchow river, Gouvern. Petersburg, Russia.

All the originals, except that of figure 8, are in the New York State Museum.

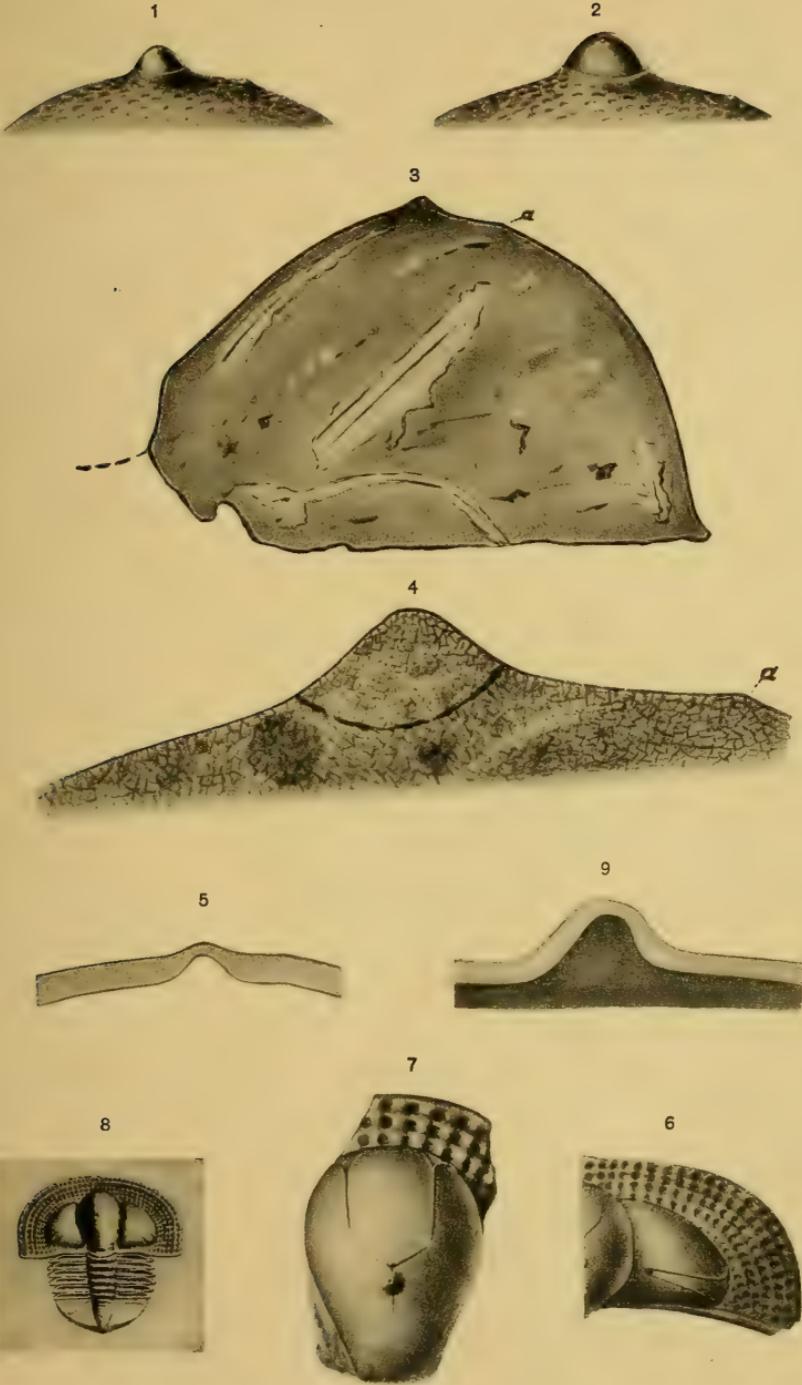


Plate 36

This plate contains a few figures of various genera of trilobites with median eye tubercles.

Isoteloides homalonotoides (Walcott)

- 1 Cephalon showing median eye tubercle. (From Raymond)
Ordovician: Black River beds, Pattersonville, N. Y.

Symphysurus convexus (Cleland)

- 2 Cranidium showing median eye tubercle. (From Raymond)
Ordovician: Beekmantown limestone. Columbia, N. J.

Basilicus kegelensis Schmidt

- 3 Partly exfoliated cephalon with median eye tubercle showing pit. (From Schmidt)
Ordovician: Kegel beds D₂, Kegel, Russia.

Symphysurus angustatus Sars & Boeck

- 4 Exfoliated cephalon with median eye tubercle. (From Moberg & Segerberg)
Ordovician: Orthoceras limestone. Fogelsang, Sweden.

Asaphellus monticola Raymond

- 5 Cranidium with distinct median eye tubercle. (From Raymond)
Tremadoc: Montagne Noire, Hérault, France.

Asaphus ludibundus mut. **jewensis** Schmidt

- 6 Exfoliated glabella with median eye tubercle and pit. (From Schmidt)
Ordovician: Jewe beds D₁, St Mathias, Esthonia, Russia.

Hemigyraspis collieana Raymond

- 7 Imperfect cranidium with distinct median eye tubercle. (From Raymond)
Ordovician: Beekmantown beds. Bellefonte, Pa.

***Nileus armadillo* Dalman**

- 8 Exfoliated cephalon (a portion of the very thick crust is still preserved at the right, above and below the eye) with distinctly pitted interior cast of eye tubercle. (From Schmidt)
Ordovician: Expansusstufe B₂b, Paulowsk, Gouvern. Petersburg, Russia.

***Ceratopyge forficula* Sars**

- 9 Partly exfoliated cranidium with interior cast of eye tubercle. (From Moberg & Segerberg)
Ordovician: Ceratopyge beds, Ottenby, Sweden.

***Hysterolenus törnquisti* Moberg**

- 10 Cranidium with well-developed median eye tubercle. (From Moberg & Segerberg)
Ordovician: Ceratopyge beds, Fogelsang, Sweden.

***Niobe insignis* Linnarsson**

- 11 Partly exfoliated cranidium with distinct interior cast of median eye tubercle. (From Moberg & Segerberg)
Ordovician: Ceratopyge beds. Ottenby, Sweden.

***Barrandia crassa* Barrande**

- 12 Partly exfoliated cephalon, showing distinct interior cast of median eye tubercle. (From Barrande)
Ordovician: d₁. St Benigna, Bohemia.

Aeglina umbonata

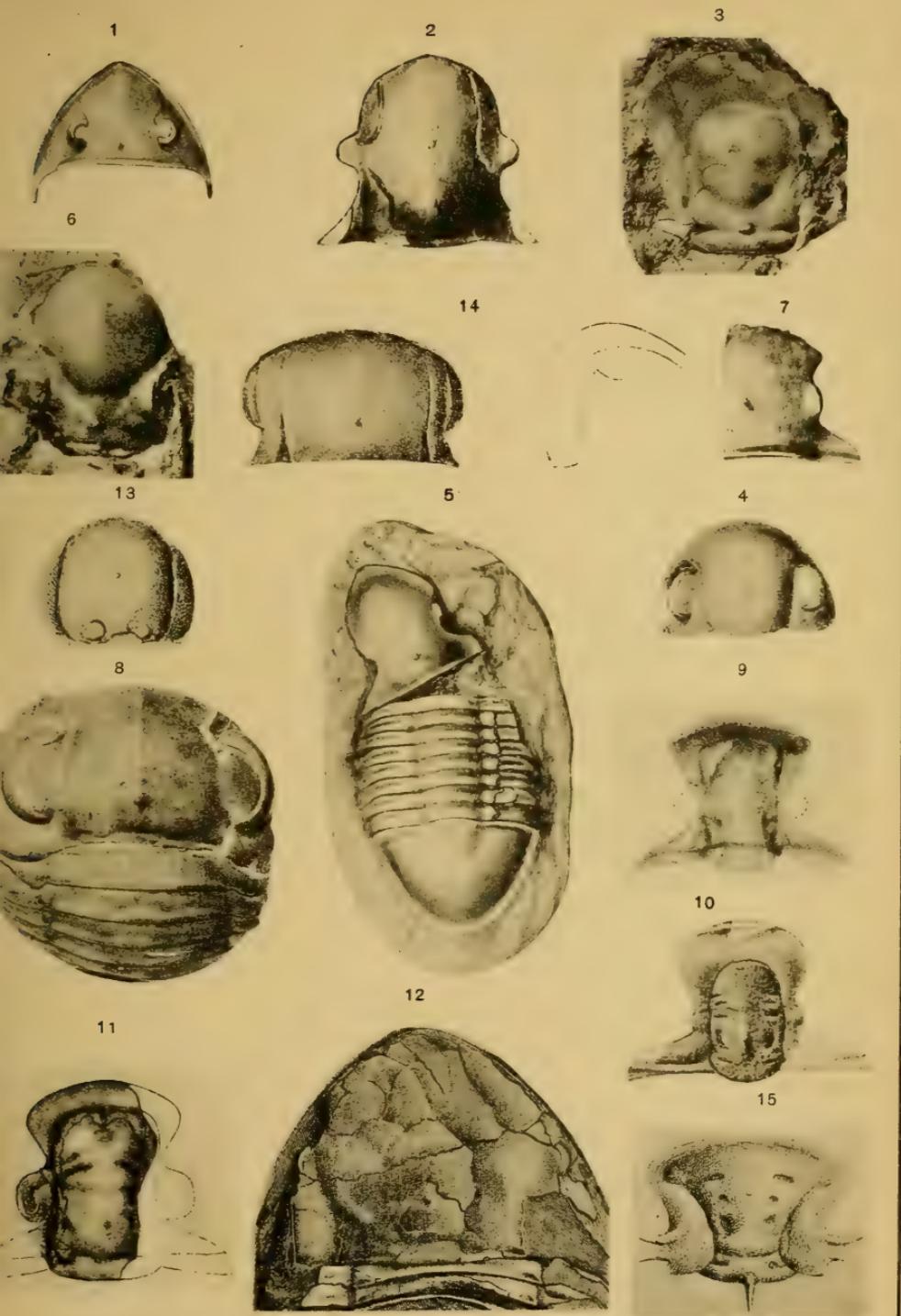
- 13 Exfoliated glabella with interior cast of median eye tubercle. (From Moberg)
Ordovician: Orthoceras limestone. Fogelsang, Sweden.

***Illaeus oriens* Moberg & Segerberg**

- 14 Dorsal view of cranidium with median eye tubercle and outline of profile view, to show apical position of tubercle. (From Moberg & Segerberg)
Ordovician: Ceratopyge beds. Ottenby, Sweden.

***Bronteus haidingeri* Barrande**

- 15 Cranidium with median eye tubercle. (From Barrande)
Silurian: E. Dlauha Hora, Bohemia.



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