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ON THE FOSSIL CRINOID FAMILY CATILLOCRINIDAE

(With Five Plates)

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HISTORICAL INTRODUCTION

In connection with studies upon the Inadunate division of the fossil crinoids, I have from time to time made notes upon a number of rare or little known forms of which our knowledge has been increased by discoveries made since the time of the original descriptions. One of these is the singular type placed by Wachsmuth and Springer (Revision of the Palaeocrinoidae, pt. 3, 1886, p. 267) under the family name Catillocrinidae—highly specialized, and widely differentiated from other known forms, although evident lines of descent leading to it have been pointed out by Bather in 1893 and 1900, and by Jaekel in 1895.

As originally defined, the family consisted of only two genera, from the Devonian and the Lower Carboniferous, of Europe and America respectively. It is now increased by a third, described by Professor Wanner from the island of Timor, by which the geographic range of this peculiar crinoid type is enormously extended, and, if the present determination of its horizon as Permian should stand, its occurrence is brought down to a far later age than was before suspected.

The chief development of the type embraced in this family took place in the genus *Catillocrinus,* from the American Lower Carboniferous, through which it has an almost unbroken stratigraphic range in a succession of six species, admitting of interesting comparative studies. It was recognized by the pioneer geologist and paleontologist, Troost, in the course of researches covering a period of fifteen years ending in 1849, when he proposed the name of the genus with its type species, *C. tennesseeae,* in a " List of the Crinoids of Tennessee," read at the meeting of the American Association for Advancement of Science for that year, and published in the Proceedings under date of 1850. As the " List " was not accompanied by any descriptions, the names were without validity ; some were validated through subsequent publication by other authors, with credit to Troost, but many of them were superseded and lost. Troost prepared a monograph containing full descriptions and figures of his crinoid genera and species, for which he was never able to secure publication, and which remained in the MS stage until 1909, when it was issued by the National Museum as Bulletin 64, edited by Miss Elvira Wood.

The description on which the genus and its type species must rest for their names and validity is that of Shumard, published in his Catalogue of Paleozoic Fossils, St. Louis, 1866, p. 358. It was based upon specimens from Button Mould Knob in Kentucky ; but the author had seen the specimens used by Troost, obtained at White's Creek Springs, Tennessee, and he credited Troost with the names of the genus and species, but made the descriptions according to his own observations.

The horizon was stated by Shumard to be the Keokuk, in conformity with the opinion of the earlier geologists; but it is now known to be the New Providence shale (Knobstone), a much earlier formation at the base of the Lower Carboniferous, more or less equivalent to the Lower Burlington, Chateau of Missouri, Waverly of Ohio, and the Mountain limestone of Britain and Belgium (see Springer, Crin. Faun. Knobstone, Proc. U. S. Nat. Mus., vol. 41, 1911, pp. 175-208).

No figure of the type species was given by Shumard; but the form was so peculiar, and unlike any other then known, that there was never any difficulty in recognizing it from the description. The first published illustration of a specimen belonging to this genus was given by Meek and Worthen in 1868, under their species *C. wachsmuthi,* from the Upper Burlington limestone (Geol. Surv. Ill., III, pl. 18, fig. 5). This was followed in 1873 by their species *C. bradleyi,* from the Crawfordsville beds of the Keokuk (*Op. cit.,* V, pl. 14, figs. 10 *a, b*). *C. wachsmuthi* was further illustrated by Wachsmuth and Springer in 1886 (Rev. pt. III, pl. 5, figs. 15, 16). The range of the genus was extended into the Chester (Kaskaskia) through a species described by Wachsmuth in 1882 under the name *Allagecrinus carpenteri* (Bull. 1, Ill. St. Mus., p. 40; Geol. Surv. Ill., VII, pl. 29, fig. 14). The reference to *Allagecrinus* was made under a misunderstanding of the characters of a solitary specimen found by Professor Worthen in Monroe County, Illinois. In the course of collections made for me in recent years at the same locality, I obtained several specimens of this small crinoid in such preservation as to establish beyond question its identity with *Catillocrinus,* and also to show that it is the same form which had been previously found in equivalent strata at Huntsville, Alabama. In the meantime another small species appeared among my collections from Indian Creek, Montgomery county, Indiana, in a horizon of the Keokuk slightly lower than that of *C. bradleyi,* which has remained undescribed until now.

Thus we have in the American rocks a geological range for this greatly specialized genus extending from the earliest to the latest Lower Carboniferous, and occurring in most of its major subdivisions; while the genus itself is the most vigorous representative of a type which as now known ranges from the Devonian (or even Silurian in its direct ancestral form) through the Lower Carboniferous perhaps to the Permian. The relations and evolutionary stages of this type have been extensively discussed by Bather (1893, Crin. Gotl., p. 25; Lankester Zool., pt. III, 1900, p. 150), and by Jaekel (1895, Crin. Deutschl., p. 44).

According to these authors, the line starts with *Pisocrinus* in the Silurian, and, deriving through *Calycanthocrinus* in the Lower Devonian, evolves to *Mycocrinus* in the Middle Devonian of Germany, in which the structural plan afterwards so strongly developed in *Catillocrinus* of the American rocks was definitely established.

Catillocrinus had been referred by Zittel (1879, Handb. Pal., I, p. 348) and by De Loriol (1882, Pal. Franc., XI, p. 46) to the Pisocrinidae; and the relations of the genus with *Calceocrinus* (representing the present family Cremacrinidae) were pointed out by Wachsmuth and Springer in 1886 (Rev. III, p. 267). Discussion of these relations, or of the ancestral line, is not within the scope of this paper, which is intended merely to furnish new and authentic information upon the occurrence and structure of the type included in the family Catillocrinidae as originally defined by Wachsmuth and Springer.

A very notable addition to our knowledge of this type has been made by Professor Wanner in his epoch-making treatise on the Permian Echinoderms of Timor, Part I, published at Stuttgart under date of 1916, but not received in this country until 1921, so that many new genera proposed by him were unknown to American paleontologists until nearly five years after the date of their publication. In this work he has described under the name *Paracatillocrinus* a form which in some of the essentials combines the characters of the Devonian and Carboniferous forms. Thus this type, after a gap represented on this continent by the entire Pennsylvanian series (Coal Measures and Upper Carboniferous) reappears in that far-off region as part of a rich and varied fauna, in which post Devonian representatives from the Lower Carboniferous to the Permian are intermingled, and Mesozoic types anticipated, in a most amazing way.

Acquisition of new material during the years subsequent to the description by the earlier authors enables me more thoroughly to illustrate the species heretofore described, to supply some structural details previously unknown, and to add several new species. To this end it is advisable to assemble the pertinent facts relative to the known genera and species, in the order of their geological succession, beginning with the Devonian:

MYCOCRINUS Schultze

Mon. Echin. Eifl. Kalk., 1866, p. 222 (sep. p. 110)

In this genus, as represented by its type species, *M. boletus,* from the Middle Devonian of the Eifel, the essential structure was established which characterized the subsequent line, namely, a cup composed chiefly of unequal and unsymmetrical radials in contact, two of them much larger than the other three, separated at one end by two of the smaller ones abreast, and at the other end by the third smaller plate, which is somewhat larger than the other two. These radials are greatly thickened at the truncated upper face, which is traversed by curved and radiating food grooves leading to the inner cavity, and connecting at the outer edge with numerous small, thread-like arms, which are borne directly upon the radials, usually one from each of the smaller plates and several from each of the larger, up to a maximum of twenty-five or thirty. This is the generalized picture of the type; the further details apply to *Mycocrinus* especially.

Below the ring of massive radials is an equally massive basal ring, usually protruding as a subglobose knob about half the height and width of the cup, but in one case conical, expanding gradually to the radials. This encloses no cavity, but is solid for its entire height, except as pierced by the nerve canals. It is described as being composed of two unequal plates (Schultze, Echin. Eifl. Kalk. p. 222, (Sep. 110), and as undivided (Jaekel, Crin. Deutschl., p. 55). Of my specimens of the type species, one has the base undivided, and two have two distinct sutures; in one of the latter by a strong light a third line of division may be seen in the proper position. I have little doubt that the primary division was into three plates, of which the sutures were unequally obscured by compression or fusion in life, or by chemical changes during fossilization. A division into two unequal plates by sutures standing at an angle to each other, as in Schultze's figure 4*a,* is mechanically improbable, even in such an anomalous structure as this; there must have been originally a third.

Of the radial ring, the three smaller RR have partly straight sides, and a large curved indentation at the upper corners next to the large RR, which have corresponding projections to fit the space. By means of these lateral extensions the large radials, which at the basi-radial suture are but little wider than the smaller ones, are at the upper face at least twice as wide; but as between themselves there is little difference in size. The usual number of food grooves, one for each arm base, upon the large radials is about six, but may be four or seven, thus making the total number of arms from eleven to seventeen. The arms themselves have not been seen in this genus. The cup is usually more or less elliptic, and all known specimens are small, the maximum not exceeding 11 mm. long diameter.

Of the pair of small radials abreast, one has usually at its distal face to the left a small tooth like elevation, which from analogy of the structure in *Catillocrinus* we know to be connected with the anal plate and tube. This determines the orientation of the calyx, the radial last mentioned being the right posterior, its fellow small one the right anterior, and the third small one at the opposite side of the cup the left anterior; while the two large radials are the anterior and left posterior respectively. This orientation was not observed in some of the earlier descriptions and discussions (*e. g.*, Wachsmuth and Springer called the two large plates "antero-lateral"), which fact must be remembered when comparing them with later statements.

At the perimeter of the upper face of the radials, one opposite to each food groove, are certain slit-like openings, which perforate the plates and pass downward to the basal ring. Their continuation may be seen at the margin of the five-sided pyramidal upper face of the basal knob, of which I have a detached specimen (pl. 1, fig. 9). Considering the great asymmetry which prevails in the parts above, it is remarkable to find in this face a perfect pentagonal symmetry, the openings apparently entering it in regular clusters of three. Schultze describes them as twelve in number, three each in two of the sides and two each in three; but my specimen indicates that there is probably one for each arm.

These openings are for the lodgment of the dorsal nerve cords, which lie back of, or below, the other nerves connected with the food grooves, and proceed from the aboral motor nerve system. Usually they lie in the brachial groove itself, but sometimes, as in this case, they are lodged in a separate axial canal, which perforates the radial facet into the substance of the plates, where it divides and branches to the basals, passing ultimately into the chambered organ. Such perforation of the radials is common in the recent crinoids, and occurs in several Devonian genera, but is not often seen in other paleozoic crinoids. In *Mycocrinus* the canals apparently pass downward directly through the radials and concentrate in the basal knob. But in *Catillocrinus,* which has no such knob, they follow just underneath the food groove for some distance, separated from it by a thin partition (pl. 2, figs. 10, 11, 12), and then turn downward, passing into the usual branches and commissures too minute to be traced in the fossils.

In addition to Schultze's type, another species, *M. granulatus,* has been described by Jaekel, on account of its granular surface; and a third, *M. conicus,* is herein proposed because of its conical, instead of knob like, base. In both of these the base appears undivided, except for one faint suture in the latter.

CHANGES TOWARD CATILLOCRINUS

The change in calyx structure which took place from *Mycocrinus* to *Catillocrinus* consisted chiefly in the reduction of the high, massive, protruding basal knob to a relatively low, and in the typical species exceedingly thin, disk; and in the shape and proportions of the radial plates by which, except in one species, the two larger ones became relatively much wider above, at the expense of the three smaller ones, in two of which the upper face was reduced to a narrow apex. These plates also became bounded by curved lines, except some of those bounding the smaller pair which remained straight. In the last survivor of the degenerative series, *C. carpenteri* of the Chester, there is a tendency to return to the earlier plan; the three smaller radials fill nearly half the circumference of the cup, and their lines are mostly straight.

The thinness of the base, in contrast with its massiveness in *Mycocrinus,* is most remarkable, and almost without a precedent among the crinoids. In the type species, *C. tennesseeae,* it is as thin as fine writing paper, and translucent, so that in some specimens the outline of the infrabasal ring, to be presently described, can be seen by transmitted light.

In this genus we first become acquainted with the actual structure of the slender arms, and of the relatively enormous anal tube, neither of which, however, were known to the earliest describers, nor in their full details until now.

CATILLOCRINUS (Troost) Shumard

Shumard, Catal. Pal. Foss, 1866, p. 357

Shumard's generic diagnosis is as follows:

Catillocrinus Troost, 1850

List, Crin. Tenn. Proc. Am. Assn. Camb. Meeting, p. 60

Generic character. Basal pieces 5, small, forming together a low cone. Primary radials 5? Secondary radials 5, very irregular in form, two of them large, transverse, somewhat lozenge-shaped; two subquadrangular, one lanceolate; their superior edges broad, and marked with strong, radiating, curved sulci. Arms slender, numerous (facets for 56 in the specimen before me), arising directly from the upper straight edges of the secondary radials. Column large, round, the superior joint concealing the basals and nearly the whole of the primary radials.

A fuller description is given under the type species, as follows, p. 358, foot-note:

Catillocrinus tennesseeae. Cup hemispherical, width one and a half times greater than the height. *Base* (concealed by the column) small, pentagonal, situated in a deep cavity, and projecting into the interior in the form of a low cone. *Primary radials* forming united an irregular pentagon, with curved margins which scarcely rise above the plane of the under surface of the cup, almost entirely concealed by the last joint of the column. *Secondary radials* very irregular in form, thick, convex; two very large, transverse, forming almost two-thirds of the cup; expanding rapidly from below upward so as to embrace nearly the whole of the superior circumference; between these on one side are wedged in two of the smaller pieces, one of them quadrangular with nearly parallel sides, the other linguaeform, and opposite these is a large quadrangular piece with sides converging from below upwards.

Adapted to present terminology, the foregoing descriptions undoubtedly call for a dicyclic base. Three ranges of calyx plates are described, one of them being the irregular radials which cannot be mistaken for anything else, and two others below these. It is clear that what the author called "primary radials" are our basals, and what he called "basal pieces" are our infrabasals; the latter form a "low cone, projecting into the interior," and the former an "irregular pentagon with margins which scarcely rise above the plane of the under surface of the cup"; and both of them are covered by the last joint of the column, which conceals "the basals and nearly the whole of the primary radials." In the generic diagnosis the number of small "basal pieces," forming the "low cone," is stated as "5," while in the specific description the number is not given. Shumard evidently had a very definite idea of the structure before him, and there is no ambiguity in his description. Wachsmuth and Springer, upon the evidence of other specimens accessible to them, but without having seen Shumard's, disputed his interpretation of the structure and maintained that there are "only two series of plates."

The descriptions in Troost's previously unpublished monograph were copied by Miss Wood in Bulletin 64, pp. 23, 24, where they may be consulted in full. They are not material to the present inquiry, except for the statement in the generic diagnosis: "Pelvis (base) subpentagonal, divided into 3 unequal plates"; and in the specific description: "Pelvis (base) irregular pentagon, more or less concave, bearing a circular impression for the column which occupies almost the whole of the pelvis." He recognized only two series of calyx plates, and not three as Shumard did; hence the "pelvis" of Troost is the same element that is called "primary radials" by Shumard.

Thus, while the generic diagnosis shows a divided base of three plates, the specific description, like Shumard's, says nothing about their number. Miss Wood (*Op. cit.*, p. 24), alluding to this, and to the statement by Wachsmuth and Springer (Revision III, p. 368), that the base is undivided, says: "Troost's observation appears to be correct, as the suture lines between the plates show distinctly on one of his specimens, and traces of them appear upon others."

I have the Troost types before me; the original of Miss Wood's figure 3 of plate 9 shows one very distinct suture under r. post. R, and two others, faint but distinguishable in a proper light, under l. post. and r. ant. RR. In the manuscript of Troost's monograph there is a diagram of the cup (not reproduced in the publication) showing two distinct interbasal sutures, and a third one indicated by a dotted line. The three sutures do not meet at the axial center, but connect with a small obtusely pentagonal area in which the thin plates are broken out.

Thus the actual construction of the basal ring has been a matter of doubt among different observers, Troost believing it to be composed of three plates, and Wachsmuth and Springer, and others following them, considering it as undivided; while Shumard puts the number as doubtfully five, with another series below or within them. It is important to ascertain, if possible, what the fact is.

COMPOSITION OF THE BASE

In addition to the Troost types in the original Troost collection in the National Museum, I have a number of good specimens of the type species from the two localities at which it has been chiefly found, Button Mould Knob, Kentucky, and White's Creek Springs, Tennessee; most of them consisting of the dorsal cup only. Careful examination under the best light conditions, including cutting and polishing of some specimens, fails to disclose distinct, unmodified interbasal sutures; but in all the lines of division between the plates are more or less obscured, either by compression, by secondary growth of stereom, or by molecular changes during the process of fossilization. The calcite of which the specimens are composed when not silicified is usually crystallized, developing its characteristic lines of cleavage which tend to obliterate fine sutures—even the basiradial sutures, which we know to be invariably present, being in some cases by no means distinct.

Furthermore, there is undoubtedly in this family a strong tendency to fusion of basals, which causes considerable uncertainty in the composition of the base as we find it in the fossil state. This is nothing unusual. In the extensive family Platycrinidae, which we know beyond question has primarily a tripartite base, there are many species in which the plates are completely fused into an undivided disk. Wanner finds both the divided and undivided base among the Timor species of *Platycrinus,* and of his new genera *Eutelecrinus* and *Neoplatycrinus.* In the Devonian *Triacrinus,* in which the three basals was the sole generic character specified to separate it from *Pisocrinus,* my specimens from the Eifel show 3, 4, and 5 BB. An excellent example showing how this character appears in practice is furnished by a species of *Synbathocrinus, S. robustus,* occurring in the same beds and localities, and under identical conditions of preservation, with *Catillocrinus tennesseeae;* out of 55 specimens, 16 show distinctly all three sutures of the divided base, six show one or two faintly, while in the remaining 33 the base appears undivided.

In the Burlington species of *Catillocrinus, C. wachsmuthi,* in which the basal ring externally appears much the same as in *C. tennesseeae,* though usually somewhat less concealed by the column, there is ample evidence of a divided base, although all the sutures are not usually seen. In three specimens there is a complete division into 3 BB, the sutures meeting at the axial lumen, and leaving no possible space (at the exterior) for infrabasals (pl. 3, figs. 7, 10). So also in the later species of the Keokuk and Chester groups, in which the basal ring is relatively higher and laterally more visible, three well-defined sutures are seen in several specimens, while in others of the same species none can be detected.

Therefore I think it may fairly be concluded from the evidence that the basal ring in some species of this genus is divided into at least three plates, but that owing to the tendency to fusion a partial or complete anchylosis may at any time occur, leaving the observer in doubt as to the actual number of plates. This fact must be strongly emphasized, because the negative evidence as to the presence of sutures in these forms is liable to be extremely misleading, as I have learned from some practical tests. In two fragmentary specimens of *C. tennesseeae,* I carefully prepared the inner surface of parts of the calyx opposite to some of the most prominent sutures, such as those between the radials, always very conspicuous at the exterior. They show that even these interradial sutures, of the presence and exact position of which we are always perfectly sure, are so compressed, or modified by the tendency to fusion, as to be very indistinct at the interior, and sometimes completely invisible. This happens in one case where the plates along the line of an adjacent suture have actually separated. The compression would be even greater in the base, where the surface is overgrown by the large column. Therefore the fact that sutures cannot be seen in a number of specimens in the position where they should be, must not be taken as conclusive of the absence of a primary division among the plates ; and a single specimen in which the sutures can be seen is of more weight as evidence than several in which they cannot.

There remain, however, still to be considered the statements in the original descriptions by Shumard, both generic and specific, indicating the presence of three rings of plates in the dorsal cup of *Catillocrinus tennesseeae,* which have hitherto been disregarded. At that time there were no controversies about the " Dicyclic " or " Monocyclic " base, which might influence opinion one way or the other. Shumard was a careful observer, and it has seemed to me improbable that he should have described a structure like this with such particularity without having some persuasive evidence in support of his interpretation. To say that the base was " small, concealed by the column, situated in a deep cavity and projecting into the interior in form of a low cone," was too definite a statement to be founded on mere supposition. Therefore when I acquired the Hambach collection at St. Louis, I looked with special interest among the Shumard types which it contained for the originals of his *Catillocrinus* description ; and to my great satisfaction found his two specimens from Button Mould Knob, Kentucky, one of which agrees with his statement above quoted in every particular. Other material contained in collections made for me at the type locality and at White's Creek, Tennessee, and those of S. S. and Victor W. Lyon, also acquired, have furnished considerable confirmatory evidence ; so that I am now enabled to present the facts with a wealth of detail unusual in so rare a form.

In the Shumard type specimen the low cone lies at the bottom of the visceral cavity on the inner floor of the calyx, invisible from the dorsal side—not because concealed by the column, as Shumard stated, for the proximal columnal is not attached, but because obscured by fusion, as elsewhere explained. It consists of three nearly equal plates, separated by perfectly distinct sutures which can readily be seen with the naked eye. These plates and their divisions are so distinct that I am forced to believe that where the published generic diagnosis says " basal pieces 5, forming together a low cone," it was due to a typographical error, and should have read " 3." At the interior surrounding the cone there is considerable indication of a division of the basal ring into five plates, which was the occasion of Shumard's doubtful statement of " primary radials (basals in our terminology as already explained), 5?"; but the suture lines are not sufficiently distinct to furnish a definite sketch of their position. The floor of the calyx at the median portion of the base is too thin to permit any manipulation of the plates at the exterior, where no trace of the boundary of the cone, nor of any interbasal sutures, can be seen.

The presence of the tripartite cone is fully confirmed by two other specimens, in one of which the cup has been fractured vertically in such a way that the median part of the base is left intact and free from matrix on both surfaces. This contains the cone in all respects similar to that of the Shumard type, with its three plates completely separated by sutures. Not only so, but the line of fracture of the thin base follows about half the perimeter of the infrabasal circlet, which is thus separated from the surrounding basals and left projecting so that its outline is perfectly defined, leaving no doubt that it passed through to the dorsal surface. I have been able to photograph this specimen from both aspects, and also the interior of the Shumard type, so that the structures are accurately shown without any retouching as to these details (pl. 2, figs. 2, 7, 8). In the third specimen (fig. 10*a*) the cone also appears very much as in the Shumard type, but owing to some distortion of the calyx does not yield so clear a photograph.

Two other specimens in which the interior is free from the matrix show the raised contour of the cone, but not the divided plates, the sutures being completely fused. Viewed by transmitted light through the thin base, the obtuse outline of the infrabasal circlet, similar to that which is exposed in the fractured specimen, can be fairly well seen. In all these interior views there are lines more or less obscured by fusion which in my opinion indicate a division of the plates surrounding the cone into five. Upon two other specimens filled with hard matrix, I ground and polished the base at the dorsal side, and found the sutures partially indicated in both, together with the rounded outline of the infrabasal circlet. In one of these I was able to locate four of the interbasal sutures, leaving the position of the fifth obvious. By means of these two specimens, supplementing those previously described, I have inferred the composition of the base, as seen from the dorsal side, consistent with the structure at the inner floor, substantially as I have drawn it in figure 9 of plate 2. The outline of the infrabasal ring is not sharply defined by lines and angles, but is obtusely angular or rounded, as the basal ring itself appears in the same specimens. Its appearance is not unlike that of the base in dicyclic genera like *Eupachycrinus,* where the small infrabasal cone is seen from the interior projecting at the end of a deep funnel.

In two other specimens an obtusely angular or rounded space at the middle of the base is pushed inward from the dorsal side; it is of the same size as the inner cone in other specimens, and looks as if it had been separated from the surrounding basals by external pressure, the central area in one remaining intact but depressed to a lower level than the adjacent surface (pl. 1, fig. 17). In four others a similar space at the center of the base is broken out, but not well defined (pl. 2, figs. 5, 6). It is evident that the infrabasal area was a weak spot in this thin base, since that portion alone is broken away in at least six specimens otherwise intact.

Putting these facts together, we have as evidence bearing upon the composition of the base in this species: Three specimens with the plainly divided cone in place at the inner floor of the calyx, in one of which the exterior boundary is clearly defined by fracture; two in which the space corresponding to it is displaced by external pressure; four in which it is broken out; two polished specimens in which the outline corresponding to the cone is seen from the dorsal side, and at least four sutures connecting with it; and the appearance at the interior of more than three basals surrounding the cone. I find myself unable to explain this assemblage of facts except as proof that in this species there is a dicyclic base, which, however much it may be modified by fusion, consisted primarily of three infrabasals and five basals, as originally described by Shumard.

Whether such a set of plates at the interior exists in any of the later species cannot be ascertained from the material available, but I am certain that infrabasals do not appear at the exterior in any of them; and in view of the definite proof of a division of the basal ring into three plates, as in *C. wachsmuthi* and *C. carpenteri,* in which the sutures are distinctly seen continuing to the axial center, I am of the opinion that in those species the base consists of only the one ring of plates.

If that be true, it means that in the course of successive modifications of this type as represented in the American Carboniferous, perhaps coincident with the decrease in size, the infrabasal ring was eliminated. Such a modification as this would be no more remarkable than the change from the massive, protruding base of *Mycocrinus* to the flat and thin basal disk of *Catillocrinus*. And we have striking examples, as shown in my work on the Crinoidea Flexibilia, pp. 119, 269, 277, etc., of the disappearance of infrabasals in individuals and in species, in *Ichthyocrinus* and other Flexibilia, due to atrophy in forms where, as in this case, almost the entire base is buried underneath the column.

In the Permian member of the family, *Paracatillocrinus,* as described by Professor Wanner, the basal ring appears usually to consist of two unequal plates (in one specimen only a single suture is seen), as is the case in some, but not all, specimens of the Devonian *Mycocrinus.* I very much doubt if that was the primary arrangement in any of them, but believe that the apparently unequal division into two plates is rather due to unequal fusion, as is shown by the fact that in some specimens of *Mycocrinus* the base is completely fused, in some divided unequally by two sutures, and in one by two distinct sutures with a third one present but obscure.

I have given the facts as I find them after a careful study of the excellent material now assembled, corroborated by the observation of a colleague of much experience in this kind of investigation. They present a condition different from what I formerly supposed, and which can only be interpreted as one in which, in a greatly specialized type, along with other departures from the usual habitus of the crinoids, there arose such a degree of instability of the base as to allow it to become dicyclic or monocyclic within the same genus; to be composed of 2, 3 or more plates; or to be entirely undivided. Wanner's studies on the Timor form (Perm. Echinod. Timor, p. 8) led him to the conclusion that the number of basals is not constant within his genus, or even within a species under it, and is therefore a character of only secondary importance.

The extreme flatness of the base, and thinness of its component plates, as exhibited in *Catillocrinus tennesseeae,* does not continue in the succeeding species, after *C. turbinatus*. In *C. wachsmuthi* the basal ring becomes somewhat, though still unsymmetrically, exposed in a side view all around, and correspondingly thickened, as is shown by a fractured specimen (pl. 3, figs. 9, 10) ; and in *C. bradleyi* and *C. carpenteri* it increases farther until it occupies one-fourth to one-third the total height of the cup. But in the Timor species, instead of a further development in this direction, we find a reversion, not toward the structure of the Devonian form, as in the rectangular shape of the smaller radials, but to the flat and extremely low base of *C. tennesseeae.*

ASYMMETRY OF RADIALS

The extreme disproportion in size of the radials in the type species of this genus is accompanied by a further asymmetry, unusual in the crinoids, due to the fact that the basal ring, most of which is covered by the column, projects more or less beyond the column at the anterior side, while at the opposite side it is either invisible or reduced to a narrow band. Also the radials toward the anterior side are somewhat higher than those opposite to them, so that the dorsal cup stands slightly oblique to the vertical axis of the column. This obliquity is more pronounced (but in the reverse direction) in the Timor form. In some of the later crinoids it becomes a very marked feature in their structure, *e. g., Cyrtocrinus mutans* and others figured by Jaekel in 1907 (Körperform der Holopocriniten, p. 279, *et. seq.*). When carried to an extreme, this would result in the complete bending of the calyx to a pendent position, as in the Cremacrinidae. Exceptionally the projection of the basal ring is at the posterior side (2 out of a dozen specimens in *C. tennesseeae,* but none in 8 specimens of *C. wachsmuthi*), which Wanner finds to be the rule in the Timor form, or as he states it the projection is least under l. ant. R. In the later American species, with the increase in height of the basal ring the difference in its projection becomes less.

In connection with the asymmetric proportions of the radials, it results that in the Catillocrinidae the cup is usually elliptic in outline, instead of circular as in most other crinoids. The long diameter bisects the two larger radials. This character is conspicuous in *C. tennesseeae,* the difference between the short and long diameter in an average of 14 specimens being about as 1 to 1.12; it prevails more or less throughout all the species, but least of all in *C. carpenteri* and in *Mycocrinus conicus.* In comparative measurements of the cup in different specimens, if only one figure is stated it means the long diameter.

The asymmetry of the cup in *Catillocrinus* goes so far that even the two larger radials are not equal. With but few exceptions, the anterior radial is wider at the upper margin than the opposite left posterior, and has a greater number of food grooves. The difference varies in the different species, the proportion in width of l. post R. to ant. R. being on an average from 1 to 1.24 minimum to 1 to 1.50 maximum in *C. tennesseeae, turbinatus, wachsmuthi,* and *shumardi;* while in

2

C. bradleyi it drops to 1 to 1.20, and in *C. carpenteri* still farther to 1 to 1.17—although in the latter case the reduction is due to an increase in r. ant. R. at the expense of ant. R.

The openings at the margin for the dorsal canals in *Catillocrinus* are round, instead of linear as in *Mycocrinus boletus;* in the latter they are very similar in form to those upon the radial facets in *Synbathocrinus.*

MODIFICATION IN LATER SPECIES

The three species next following *C. tennesseeae,* up to that of the earlier Keokuk, agree with it in the essential structure of the calyx other than that of the base—the arrangement and relative proportions of the radials being about the same within the limits above mentioned. In the progress of the type from there on some remarkable changes took place. The first of these relates to the mechanism of the anal side controlling the attachment of the tube to the cup, and it includes both *C. bradleyi* of the later Keokuk and *C. carpenteri* of the Chester. It is marked externally by the disappearance in the last two species of the raised process on the right posterior radial which is present in the first four, so that the distal face of that radial is at the same level as that of the others. This is accompanied by a singular modification of the anatomy at the base of the tube, which will be explained farther on.

But while *C. bradleyi* remained substantially in line with the four preceding species in the distribution and size of the radials, *C. carpenteri* proceeded to depart from all its predecessors by taking on a radial arrangement of its own differing from that of all others in the family. This is effected by an increase in the size of r. post. R. and r. ant. R. and reduction in that of the two larger radials until they occupy no greater part of the circumference of the cup than they do in *Mycocrinus.* But in addition to this the r. ant. R. is increased much more than its fellow of the pair, so that now, instead of narrowing to an apex as in other *Catillocrinus,* and bearing only a single arm as it does in all other species within the family, it becomes widest above, and supports almost as many arms as the adjoining ant. R.—having 3 to 5, or an average of 23 per cent of the total number of arms, as against 7 per cent in *Mycocrinus* and 2 per cent in *C. tennesseeae.* Such a departure from one of the prime characteristics of the family, correlated with the diminution in size, shows a loss of vigor in the type presaging its extinction.

THE ANAL TUBE

Considering the small size of the calyx otherwise, and the extreme delicacy of the arms, the anal tube of *Catillocrinus* is an extraordinary structure. It is of a type occurring also in *Pisocrinus, Deltacrinus* and probably other Cremacrinidae, and also, though rarely seen, in *Synbathocrinus,* but here carried to the extreme, viz., a long, heavy, semicylindrical appendage, reaching to (and probably beyond) the ends of the arms, and thicker at the base than half the diameter of the cup. It is composed of a single series of extremely heavy plates, longitudinally arranged, thickest at the back (posterior side) from which they are transversely curved like arm-plates, and taper in a crescent to thin edges, leaving a broad, semicircular furrow at the anterior. This furrow was enclosed by a flexible integument of small plates, so fragile that it is not preserved intact in the fossils, although I find some traces of it. Large ligament fossae on the apposed faces of the plates indicate some flexibility in the tube. The massive character of the tube and its component plates is seen in *C. tennesseeae* and *C. wachsmuthi* (pl. 2, figs. 14, 15; pl. 3, fig. 4), and its extreme elongation in *C. bradleyi,* where it reaches a length of fifteen times the height of the dorsal cup (pl. 3, figs. 14, 15), and in *C. carpenteri* twenty and twenty-eight times (pl. 4, figs. 1, 2). There is little diminution in thickness after the first plate.

In the lower part, the tube is marked externally by slight longitudinal grooves, which are the permanent imprint of the arms when closely folded against it. The lowest tube plate expands somewhat towards the cup, and serves in part the purpose of a tegmen; at the back it is almost as thick as the radials upon which it is superimposed, and its under surface is crossed by curving furrows partly, but not in full detail, corresponding to the food grooves upon the upper face of the radials, for which to that extent it forms a solid roof. As this lower tube plate only surmounts the upper face of so much of the radial circlet as lies at the posterior side, the food grooves toward the anterior must be covered by small covering pieces or perisome continuous with those upon the arms.

Now this lower tube plate, exactly at its thickest part, rests upon an elevated process upon the left shoulder of the right posterior radial which is usually rather narrow exteriorly, but widens considerably inward, forming a prominent trapezoidal platform separating the groups of food grooves upon the two large radials. At its outer edge the tube plate is indented with a curved socket for the reception of a triangular anal plate which appears between the arms at the exterior margin of the cup, and also extends deeply inward, where it interlocks with the tube plate by means of the socket. Among fragmentary specimens I have a number of separated tube plates, including several of the lower ones, all of which have the curved socket as above described (pl. 2, fig. 17) ; and in one of them (fig. 18) the anal plate remains firmly attached by the socket in its original position; in others (figs. 14, 16) the relation of the tube plate with its socket to the raised process at the margin of the cup is shown as it appears in the absence of the anal plate and arms.

This is the structure of the parts at the posterior side in *C. tennesseeae;* and in *C. wachsmuthi* I am able, after some careful preparation, to show the tube itself in position, with its interlocking key-plate wedged into the socket precisely as it was in life—an admirable device for anchoring such a ponderous appendage (pl. 3, figs. 4, 5). The two other closely associated species, *C. turbinatus* and *C. shumardi,* have the same elevated process for supporting the anal plate, and their structure in relation to the tube is undoubtedly the same—thus including in this class all species up to the earlier Keokuk.

But in the two succeeding species with which the series terminated, *C. bradleyi* of the later Keokuk and *C. carpenteri* of the Chester, a curious change occurs—a striking example of the infinite variety which characterizes the processes of nature. The raised platform disappears, and with it the anal plate; instead of them a rather wide plate rests directly upon the upper face of the radial, at the same level as that of the other radials, filling its entire width except space enough at the right side for one arm, and bending inward between the arms. This is entirely different from the separate anal plate above described, but is itself the first plate of the tube. The connection is beautifully shown in the two specimens of *C. bradleyi* (pl. 3, figs. 14, 15), in which the long tube is exposed from its origin on both right and left sides. It is also well shown in a specimen of *C. carpenteri,* on which I removed the arms sufficiently to expose the tube in a side view (pl. 4, fig. 18). Other specimens of both species, figured on the same plates show the form and proportions of the first tube plate seen directly from the posterior.

The course of the four antecedent species, having the anal structure first above described, was marked by a steady decrease in size. *C. bradleyi,* in which the change was introduced, took on renewed vigor, with increase in size and relative number of arms. But the change was not permanently advantageous, and the next species, *C. carpenteri,* after undergoing still another modification in the arrangement of radials and arms, already mentioned, passed into an impoverished condition with which the line was extinguished.

Such a change in the anal structure as above described would in other groups be considered as ground for generic separation, but in a type so highly specialized as this, on the eve of its extinction, these characters are so completely overbalanced by those which have become dominant, that they may well be regarded as of secondary importance. The raised process is present in the Devonian genus, but apparently not in the Timor form; this would indicate that the tube structure in *Mycocrinus* was according to the plan of *C. tennesseeae* and its allies, while that of *Paracatillocrinus* was like that of *C. bradleyi* and *C. carpenteri*.

If it should be thought that my view of the significance of this character is too conservative, then the later section might be ranked as a new genus under the name *Eucatillocrinus,* with *E. bradleyi* as genotype. But in order to be consistent this should be followed up by setting off *C. carpenteri* as another genus on account of its difference in radials and arms.

With the enormous space enclosed by the tube in proportion to the small size of the cup, it must have had some other function than that of a mere excretory organ. It may have lodged the genital apparatus.

RELATIONS WITH OTHER GENERA

As already remarked, the tube is of the same type that occurs in *Pisocrinus, Deltacrinus* and *Synbathocrinus,* and doubtless throughout the families to which they belong. As it is rarely seen in these genera, I am giving figures of some specimens in which it is exposed (pl. 5, figs. 1, 3, 9, 20, 21). They show a certain relationship among these forms, notwithstanding their remarkable differences and specializations in other characters. Indeed the similarity is somewhat striking between *Synbathocrinus* and *Catillocrinus,* the one a model of symmetric adjustment of all its parts, and the other an example of the extreme to which a disturbance of the most stable element in crinoid morphology can go.

Aside from the asymmetry of the radials, the differences between the two genera are chiefly matters of degree. The general form of cup, plan of construction of tube and arms, and the mutual relation of these parts, are substantially the same in both, only the relative proportions are reversed. With the five strong arms in *Synbathocrinus* the tube which they enclose is dwarfed, while in *Catillocrinus* it is the ponderous tube that supports the thin and numerous arms. Both have the greatly thickened radial facets, which are accompanied in both by the rather rare feature of perforation by dorsal canals (see various figures on plates 2 and 5). Their respective families both started in the Devonian and culminated in the Lower Carboniferous of America or in the Permian of Timor. If we take *Pisocrinus* as the beginning of this line in the Silurian, then both ran a parallel course with the Cremacrinidae, except that the latter started first in the Ordovician, ended a little earlier in the Keokuk, and have not thus far been reported from Timor.

The description of the anal tube of *Synbathocrinus* given by Wachsmuth and Springer in Revision of the Palaecrinoidea, pt. 3, p. 167, pl. 4, fig. 11, as being composed of five longitudinal rows of plates, will have to be corrected. We have it now preserved in several specimens, and its structure is uniformly as shown in figs. 1 and 4 of plate 5, namely, a single longitudinal series of strong crescentic plates at the posterior, having the curve completed by an integument of small plates, substantially as in *Catillocrinus*.

THE ARMS

The arms are the most delicate in proportion to their length of any known in the fossil crinoids. They are unbranched, very long, extending nearly to the end of the tube, around which they are closely packed and supported when at rest in shallow grooves, abutting all around in a continuous circlet except for a short distance at the posterior side, where they are separated by the anal and tube plates above mentioned. They differ in size in the different species, those of *C. tennesseeae* being the thickest, about 1.33 mm. in width, while in *C. bradleyi* the arms are less than .50 mm. wide, being thus not only relatively, but actually, the thinnest of all. The fact that several arms, up to as many as 31 on a single plate, are borne directly upon some of the radials, differentiates this form and its congeners from the other crinoids generally, although this structure was foreshadowed in *Calycanthocrinus* of the Lower Devonian.

Considerable importance has been attached to the number of arms, especially by Jaekel, who has taken the increasing number as a controlling character in the progressive developmental series by which he traces the evolution of this type, conformably to the geological succession, from *Pisocrinus* of the Silurian with 5 arms, *Calycanthocrinus* and *Mycocrinus* of the Devonian with 9 to 17 arms, to the successive Lower Carboniferous species of *Catillocrinus* from *C.*

wachsmuthi with 34-38 arms to *C. tennesseeae* with 51-57 arms (Pal. Deutschl. 1895, p. 44). Wanner has pointed out (Perm. Echin. 1, 1916, p. 7) that the succession does not hold good for the Permian forms, in which the number of arms is reduced to 13-20. Jaekel's theory also falls when tested by the facts relating to the species of *Catillocrinus*. For *C. tennesseeae*, the species with the greatest number of arms, instead of being the last in the geological series, as then supposed and so listed in the works of that time, is the earliest; and the modification in number of arms in geological succession proceeds in exactly the reverse of what he assumed—diminishing from 35-58 in *C. tennesseeae* of the earliest Lower Carboniferous, to 13-20 in *C. carpenteri* of the latest member. Thus the end of the series in the American rocks is marked by a retrogression, finishing in the Chester (Kaskaskia) with a degenerate species, the smallest of all, ranging from 2.5 to 4.5 mm. diameter, and represented by a number of specimens from three distinct localities.

With our present knowledge of the different occurrences of this type, it seems evident that the number of arms is largely a matter of size, both as between the different species, and among individuals within the same species. And the two characters taken together form an excellent means of differentiating the species in the successive geological formations. In *C. bradleyi*, however, the arms are more slender than in any other species, and their number, in proportion to size of calyx, is greatly increased.

Catillocrinus tennesseeae, the earliest, is also the largest known species, ranging in our collections from 18 to 27 mm. (exceptionally 13) longer diameter of the elliptic dorsal cup, measured at the upper edge; and the number of arms increases correspondingly from 43 (exceptionally 36) to 58. The closely allied *C. turbinatus*, from the same formation, has a calyx of 11 to 21 mm., with 37 to 53 arms. In the next succeeding species, *C. wachsmuthi* of the Upper Burlington limestone, the size diminished to 6-12 mm., and the corresponding number of arms to 24-39. It was followed by the new species, *C. shumardi* in the Keokuk, a still smaller species with diameter of 4-6 mm., and arms 20-25. Next came *C. bradleyi* from a higher horizon of the Keokuk, a species of more vigorous growth but smaller arms, ranging from 6.5-8 mm. diameter with 40-46 arms. Finally, in the latest member of the Lower Carboniferous, the Chester (Kaskaskia), we have the end of a retrogressive series, in which the size is reduced to 2.5-4.5 mm. diameter, and the accompanying number of arms to 13-24. There is a sufficient number of specimens to prove

COMPARATIVE TABLE OF SPECIES

			Diameter	Height	L. ant.	L. post.	R. post.	R. ant.	Ant.	Arms.
Permian.		Paracatillocrinus.	12 ×13.5 9.8×12.7	4.9 4.5	1 1	9 5	1 1	1 1	11 6	23 14
Lower Carboniferous	Chester.	Catillocrinus carpenteri.	4 × 4.7 2 × 2.5	3 2	1 1	8 5	1 1	5 3	9 3	24 13
Lower Carboniferous	Keokuk, Upper.	Catillocrinus bradleyi.	5.2× 8 5 × 6.5	6 5	1 1	20 17	1 1	1 1	23 20	46 40
Lower Carboniferous	Keokuk, Lower.	Catillocrinus shumardi.	4.5× 6 2 × 4.5	2.2 2	1 1	10 8	1 1	1 1	12 9	25 20
Lower Carboniferous	Burlington.	Catillocrinus wachsmuthi.	11 ×12.5 5 × 6	5 3	1 1	16 9	1 1	1 1	20 12	39 24
Lower Carboniferous	New Providence Shale (Knobstone).	Catillocrinus turbinatus.	19 ×21 8 ×11	5 4.5	1 1	21 14	1 1	1 1	29 20	53 37
Lower Carboniferous	New Providence Shale (Knobstone).	Catillocrinus tennesseeae.	25 ×27 17 ×18	10 8	1 1	24 18	1 1	1 1	31 22	58 43
Middle Devonian..		Mycocrinus.	9 ×11 5 × 5.5	5 5	1 1	6 4	1 1	1 1	7 4	16 11

that the correlation of these two characters, size and number of arms, within the limits above stated, is constant for the several species, which are at the same time strictly limited in their stratigraphic position.

Stated in tabular form, the relation in this respect of the species, to which for further comparison I add the data for the Devonian and Permian forms, is shown on page 22, maximum and minimum figures of size being given with the corresponding number of arms.

The column has the tapering proximal enlargement of thin plates that is seen in many of the Flexibilia; and the top columnal is almost as large as the entire base, burying the greater part of its plates and thus producing a condition favorable to the atrophy of infrabasals. From the end of the tapering cone distalwards it is long and slender, terminating in a pointed root adapted to quiet conditions in the soft ooze.

Catillocrinus ranged through the long time interval of the Lower Carboniferous without any material change in the shape and relative proportions of its radial plates, except in the latest species on the eve of extinction. It is now a singular fact that when this specialized type, having run its course and become extinct in the seas which produced the sediments of the American continent, appears in another continent unconnected with this, it should be in a form which in regard to its radial structures reverts to the plan of the European Devonian, while in regard to the character of the base it takes on the plan of the American Lower Carboniferous—thus combining two of the leading characters of its widely separated predecessors.

RÉSUMÉ OF CHARACTERS

For convenience of reference, I will add a résumé of the characters showing the relation of the genera and species of this family, with citation of the principal pertinent literature.

Family CATILLOCRINIDAE

Wachsmuth and Springer, Rev. Pal. pt. 3, 1886, p. 267.—Bather, Crin. Gotl., 1893, p. 25; Lankester Zool., 1900, pt. 3, p. 150.—Jaekel, Crin. Deutschl., 1895, p. 44.

Inadunate crinoidea, highly specialized; with unequal radials all in contact, two much larger than the other three, greatly thickened at the distal face, traversed in a dorsoventral direction by food grooves, one for each arm, and perforated by dorsal canals. Numerous slender, unbranched, non-pinnulate arms are borne directly upon the radials, several to each of the larger plates. Cup generally transversely elliptic, low and broad, expanding upwards; dimensions ranging from 3 to 27 mm. long diameter, and from 2 to 10 mm. high; number of arms from 11 to 58.

Distribution. Devonian to latest Lower Carboniferous (? Permian); Europe, America and East Indies.

MYCOCRINUS Schultze

Echinod. Eifl. Kalk., 1865, p. 222.—Wachsmuth and Springer, Rev. Pal. pt. 3, 1866, p. 272.—Jaekel, Crin. Deutschl., 1895, p. 55.

Base high, protruding, at least half the total height of cup, forming a solid mass pierced by nerve canals, but enclosing no cavity; consisting of 2, probably 3, plates, which may be completely fused. The three smaller RR rectilinear, except where indented at the upper corners adjoining the large plates; the two large RR occupying not over 65 per cent of the perimeter at the upper edge of cup; r. post R has elevated process on left shoulder for support of anal plate.

Dimensions: Long diameter 5.4 to 11 mm.; height 3 to 5 mm.; number of arms 11 to 17.

Genotype. M. boletus Schultze. Three species; two heretofore described, and a new one proposed herein.

Distribution. Middle Devonian; Eifel, Germany.

Mycocrinus boletus Schultze

Plate 1, figs. 1-10

Echinod. Eifl. Kalk, 1866, p. 222 (sep. p. 110), pl. 7, fig. 4.—Wachsmuth and Springer, Rev. pt. 3, p. 272.

BB forming a prominent knob, about one-half the height and width of cup; usually divided into two plates, in one specimen into three, and in one undivided. Transverse outline of cup strongly elliptic. Surface smooth. Diam. 7-11 mm.; height 3-5 mm.; arms 15-16.

Material studied, three specimens, besides the Schultze type at the M. C. Z., Harvard. Nollenbach, Prüm, Kerpen, Eifel.

Mycocrinus granulatus Jaekel

Crinoidea Deutschland, 1895, p. 55, pl. IV, figs. 4*a-c*

Like *M. boletus,* but surface granular, and arms 17; base undivided. Diam. 5.4 mm.; height 3 mm. Founded upon a single specimen from Prüm, Eifel.

Mycocrinus conicus n. sp.

Plate I, figs. 11-13

BB more than half the height of cup, and about as wide at the basiradial suture; not forming a prominent knob, but a cone sloping about evenly with the ring of radials; one interbasal suture visible, opposite r. post. R. Transverse outline of cup about circular. Diam. 5.5 mm.; height 5 mm.; arms 11.

Founded on a specimen in the author's collection from Nollenbach in the Eifel.

CATILLOCRINUS (Troost) Shumard

Catal. Pal. Foss. Trans. Acad. Sci., St. Louis, II, 1866, p. 357.—Meek and Worthen (*Nematocrinus*), Proc. Acad. Nat. Sci. Phil., 1866, p. 251; Geol. Surv. Ill., III, 1868, p. 465; V, 1873, p. 504.—Wachsmuth and Springer, Rev. Pal. pt. 3, 1866, p. 268.—Bather, Crin. Gotl.. 1893, p. 25; Lankester Zool., pt. 3, 1900, p. 150.—Zittel-Eastman, Text-book Pal., 1896, p. 153.—Jaekel, Crin. Deutschl., 1895, p. 44.—Wood, Bull. 64, U. S. Nat. Mus., 1909, p. 23.—Wanner, Perm. Echin. Timor, 1916, p. 6.

Cup broadly truncate above and below, with column facet covering almost the entire base. Base not protruding conspicuously but forming a low disk, usually flat, or projecting more or less unequally above the column; composed primarily either of five basal plates, usually anchylosed or compressed, with sutures invisible or obscure, and enclosing a circlet of three small infrabasals; or of a single circlet of three unequal plates, the smaller one in left posterior position. One of the small RR (r. post.) rectilinear; r. ant. R triangular with one side curved; l. ant. R heart-shaped or narrow triangular; each bearing a single arm. The two large RR usually occupying 80 to 90 per cent of perimeter at upper edge of cup, and bearing a like proportion of the arms; l. post. R. to ant. R as 1 to 1.4. Exception as to form and proportions of RR in *C. carpenteri*. Transverse outline of cup usually elliptic. Arms in contact all around, except where separated for a short distance at posterior side by anal or tube plate; their number varying with species and with individual growth. Anal tube large, massive, extending to or beyond the ends of arms. Column round, with proximal enlargement of short columnals, tapering and becoming longer distalwards.

Dimensions: Long diameter of cup 2.5 to 27 mm.; height 2 to 10 mm. Number of arms 13 to 58.

Genotype.—*C. tennesseeae* (Troost) Shumard. Six species; four described heretofore, and two here proposed as new.

Distribution.—Lower Carboniferous, Mississippian, from the earliest to the latest member. Interior continental area of North America.

Catillocrinus tennesseeae (Troost) Shumard

Plate 2, figs. 1-22

Catal. Pal. Foss. Trans. Acad. Sci., St. Louis, II, 1866, p. 358. Wood. Bull. 64, U. S. Nat. Mus., 1909, p. 24, pl. 9, figs. 1, 2, 3.

The largest species. Cup truncated above and below, broadly spreading, low hemispheric with convex sides, about three times as wide as high. Base flat, forming an irregularly pentagonal disk mostly covered by the column, projecting unsymmetrically chiefly at left anterior side; composed of two rings of plates, viz., 3 IBB forming a low cone, distinct at the inner floor, but fused externally beneath the column; and probably 5 BB, of which the sutures are usually obscure or invisible owing to fusion, and only irregularly identifiable. Arms stouter than in other species, being about 1.33 mm. in thickness. RR typical for the genus; r. post. R has elevated process on left shoulder, supporting triangular anal plate at outer margin, which interlocks inward with first tube plate. Surface strongly pustulose. Material studied, 30 specimens.

Diam. in 14 specimens, 18-27 mm.; height 7-10 mm.; arms 43-58. Exceptional specimen smaller.

Mississippian, New Providence shale; Button Mould Knob, Kentucky, and White's Creek Springs, Tennessee.

Catillocrinus turbinatus n. sp.

Plate 1, figs. 14-17

Similar to *C. tennesseeae,* and occurring in the same formation, but probably at a slightly different horizon. It is typically smaller and lacks the rounded contour of that species, the cup being turbinate, with nearly straight sides; and the base more erect at the sides and projecting above the column all around. Surface smooth or finely granular. It is founded on three good specimens, one a nearly complete crown. Two of them are of the minimum size, while the third is much larger, probably a variant from *C. tennesseeae.*

Diam. 11-21 mm.; height 5-7 mm.; arms 37-53.

Horizon and localities the same as those for the last species.

Catillocrinus wachsmuthi (Meek and Worthen)

Plate 3, figs. 1-11

Synbathocrinus (*Nematocrinus*) *wachsmuthi,* Proc. Acad. Nat. Sci., Phil., 1866, p. 251; *Catillocrinus wachsmuthi,* Geol. Surv. Ill, III, 1868, p. 465, pl. 18, fig. 5.—Wachsmuth and Springer, Rev. Pal. pt. 3, pl. 5, figs. 15, 16.

Of medium size, maximum individuals being much smaller than the typical minimum of *C. tennesseeae,* and the average smaller than the smallest of *C. turbinatus.* Cup broadly spreading as in the former, with rather straight sides as in the latter. Base low, projecting slightly and unequally above the column, chiefly at left anterior side; composed of three unequal BB, distinctly divided in three specimens without any indication of IBB, the interbasal sutures extending without interruption to the axial center; r. post. R has raised process supporting narrow elongated anal plate, which interlocks with first tube plate. Surface smooth or finely granular. Eight specimens.

Diam. 5-12 mm.; height 3-5 mm.; arms 24-39.

Mississippian, Upper Burlington limestone; Burlington, Iowa.

Catillocrinus shumardi n. sp.

Plate 3, figs. 12, 13

Similar to last, but uniformly smaller; 3 BB plates distinctly shown, with no evidence of IBB. Has raised process on r. post. R. Based on four good specimens.

Diam. 4-6 mm.; height 2-22 mm.; arms 20-25.

Mississippian, Keokuk limestone, lower horizon than next species; Indian Creek, Montgomery County, Indiana.

Catillocrinus bradleyi, Meek and Worthen

Plate 3, figs. 14-17

Geol. Surv. Ill., V, 1873, p. 504, pl. 14, figs. 10*a, b*

Of medium size. Cup higher and more rounded than in *C. wachsmuthi,* highest at anterior side. BB 3, unequal, about one-third the height of cup, sutures usually obscure. No IBB. Arms about .45 mm. in width, being the most slender of all species. Large RR proportionally not so large as in preceding species; r. post. R. has no raised process at outer edge, and no interlocking anal plate, but first tube plate rests directly on radial at same level as arm bases. Anal tube strong and of great length. Surface smooth or finely granular. Column attaining a length of 31-37 cm., with columnals alternating below the proximal enlargement for about one-third its length, and uniform beyond that to near the end, where it tapers to a fine point and bears a few scattering cirri. I have two specimens in which the column is preserved to its full length. Six specimens.

Diam. 6.5-8 mm.; height 5-6 mm.; arms 40-46.

Mississippian, Keokuk limestone, upper horizon; Crawfordsville, Indiana.

Catillocrinus carpenteri (Wachsmuth)

Plate 4, figs. 1-18

Allagecrinus carpenteri, Geol. Surv., Ill, VII, 1882, p. 341, pl. 29, fig. 14.

The smallest species, being the end of a degenerative series; represented by twenty specimens from three different localities, uniformly within the size limits given below. Cup relatively higher and less spreading than in the other species. No IBB. BB about one-third the height of dorsal cup, rising about equally all around; divided into three unequal plates by sutures under r. post., ant., and l. post. RR in several specimens, a single suture distinctly seen in several and none at all in some. Form and proportions of RR different from those of all preceding species; r. ant. R rectilinear and much larger, bearing 3 to 5 arms; l. ant. R narrower, and the two larger RR occupying but little over half the circumference of the cup at upper edge; r. post. R has no raised process, but first tube plate rests directly upon it at the level of the arm bases, without any separate anal plate. Arms very slender, mostly about .55 mm. in width, but in smaller specimens some arms may be stouter than others, especially the single arms on r. post. and l. ant. RR. Anal tube 25 to 30 times the height of dorsal cup.

Diam. 2.5-4.7 mm.; height 2-3 mm.; arms 13-24.

Mississippian. Lower part of Chester (Kaskaskia); Monroe County, Illinois, Owen County, Indiana, and Huntsville, Alabama.

This species, on the eve of extinction of the genus, shows a marked departure from its characters in the relative proportions of the radial plates. The two larger RR are relatively smaller, r. ant. R has lost the curve at the right side, and has become almost as large as ant. R, bearing 3 to 5 arms instead of only one as in other species. Ant. and l. post. RR lack the great increase in width at the upper side, and in consequence the upward expansion of the cup is less. These characters are constant in eight specimens, from the two principal areas, in which I was able to free the cup from the matrix sufficiently for accurate measurements. The species also, in common with *C. bradleyi,* departs from the others in the structure of the anal side.

PARACATILLOCRINUS Wanner

Plate 5, figs. 22, 23, 24

Permischen Echinodermen von Timor, I. 1916, p. 6

General form of calyx similar to that of *Catillocrinus.* Base forming a low disk, composed, so far as known, of two basal plates, or undivided; projecting unequally beyond the column, chiefly at the right posterior side. The three smaller RR rectilinear, and not narrowing upward; the two large RR proportionally wider below and narrower above than in typical *Catillocrinus.* Transverse outline of cup elliptic.

Dimensions: Long diameter 12 to 18 mm.; height 4.9 to 6; number of arms 13 to 23.

Three species. All from a formation considered Permian by the Dutch and German geologists. Island of Timor, Dutch East Indies.

Paracatillocrinus granulatus Wanner

Diam. 13.5 mm.; height 4.9-5.5; arms 22-23.

Paracatillocrinus spinosus Wanner

Diam. 18.8 mm.; height 5.2 mm.; arms 13.

Paracatillocrinus ellipticus, Wanner

Diam. 12.7 mm.; height 6 mm.; arms 14.

All described in Professor Wanner's work above cited, pp. 10-15; pl. XCVI, figs. 1-4.

NEW SPECIES OF COLLATERAL GENERA

As bearing on the geological range of *Synbathocrinus* in comparison with that of the Catillocrinidae, I have figured two new species of that genus, and another of one closely related:

Synbathocrinus hamiltonensis n. sp. Pl. 5, figs. 13, 14

Differs from other species in the great depth to which the notch for the reception of the anal plate is incised, and in the relatively large size of the anal and succeeding plates. It is represented by a single specimen from the Moscow shale of the Hamilton group, Middle Devonian; on Kashong Creek, near Bellona, New York. A small species from the western Hamilton, *S. matutinus,* was described by Hall,[1] which has been recognized in Iowa and Michigan. It has a much lower calyx than this.

Synbathocrinus onondaga n. sp. Pl. 5, figs. 15, 16

This is a small species of which the material is not sufficient for close comparison, but its special interest lies in the fact that it is the earliest known occurrence of the genus, being from the lower member of the Middle Devonian, the Onondaga; below the hydraulic

[1] Geology of Iowa, Vol. 2, p. 483, pl. 1, fig. 2.

beds, at Louisville, Kentucky. Two specimens are figured, and there is a third fragment in the collection; these were found by different collectors who all agreed in referring it to the horizon above stated.

Phimocrinus americanus n. sp. Pl. 5, figs. 17-19

This species is described here because it is the first occurrence in America of the closely related Synbathocrinid genus characterized primarily by having five basals, instead of three. Correlated with this character it presents a difference in the relative thinness of the radial plates, which also seem to lack the conspicuous processes which are prominent in both the Eifel species described by Schultze[1] when proposing the genus. In this respect, as well as in the elongate form of the calyx, and the sharply notched incision for the anal plate, our American species is to be compared with *P. jouberti* Ochlert, of a corresponding geological position, being from the Lower Devonian, at Sablé, France. The transverse lines indicating a primitive division of three of the radials mentioned by M. Oehlert in his description,[2] and by Bather,[3] are not seen in the unique type specimen of the present species, in which, also, the edge of the radials bordering the inner cavity at the ventral side is not very well defined.

The species is founded upon a single specimen from the Linden formation of the Helderbergian, Lower Devonian, in Benton County, Tennessee, where it was associated with *Edriocrinus dispansus*, *Stereocrinus helderbergensis*, and some other peculiar forms.

STRATIGRAPHIC POSITION OF THE TIMOR CRINOIDS

I have throughout this paper followed Professor Wanner in referring the Timor member of this family to the Permian age. The fossil faunas which have been uncovered in that Island by the Dutch and German geologists are amazingly prolific, and only a portion of them have as yet been described. Immense collections have been made subsequent to those upon which Wanner's first volume on the echinoderms, covering the crinoids only, is based. His treatise on the blastoids, which are said to be even more numerous than the crinoids, is yet to appear; and after that a supplementary part on the crinoids of the later collections. I have no doubt that the greater part of these faunas are properly referred to the Permian. But, speaking only of the echinoderms thus far described, I cannot avoid the impression that there is also a strong intermingling of Lower Car-

[1] Mon. Echin. Eifl. Kalk., p. 29, pl. 3, figs. 6, 7.

[2] Bull. Geol. Soc. de la France, t. X, 1882, p. 353.

[3] Lankester's Treatise on Zoology, pt. 3, 1900, p. 152.

boniferous types. Out of 24 genera of crinoids described by Wanner from Timor which either occur also in Europe or America, or both, or are of types comparable to others which so occur, 11 are restricted to the Lower Carboniferous or earlier, 8 range from the Lower to the Upper Carboniferous, 3 are known from the Upper Carboniferous only, and 2 from the Permian. From what I have been informed in regard to the blastoids, I should expect even a stronger representation of Lower Carboniferous types.[1]

There are, of course, other crinoid types which have no known representatives elsewhere.

The stratigraphy of Timor is extremely complicated. Great dislocations of the sedimentary deposits have taken place, caused by volcanic action and other earth movements, so that many of the richest fossiliferous strata have become isolated, and their continuity often abruptly disturbed. Professor H. A. Brouwer, of Delft, Holland, whose knowledge of the geology of Timor and adjacent islands is most intimate, based upon extensive personal investigations, informs me that during the Tertiary mountain-building process the Paleozoic, Mesozoic and older Tertiary rocks were intensely folded and overthrusted, the less resistant layers between the more resistant ones being sometimes entirely squeezed out, while blocks of hard limestone of very different age are frequently found close to each other. This phenomenon is often repeated in the details of a relatively thin complex of strata, and the result at many places is a mosaic of rocks of different character and age. Thus it is possible that sediments of different horizons have been thrown together, or so distributed that their relation to one another has been obscured.

Ninety-five per cent of the genera and at least 80 per cent of the species of crinoids described by Wanner are recorded from a limited area at and near Basleo and Niki-Niki, which is in the middle part of the Dutch possessions on the island; and in this relatively small region are found all those types characteristic of widely separated horizons elsewhere. No sufficient data are available to determine whether the intermingling of types as found in the fossils is due to the complicated structure resulting from the dynamic movements above mentioned, or whether it actually occurred in life as the result of faunal developments wholly independent of those occurring in other parts of the earth.

[1] Bather when describing two species of *Schizoblastus* from Timor in 1908 (Neues Jahrb. f. Min., Bd. XXV, p. 319) stated that until further facts were forthcoming he must "consider these species as of Lower Carboniferous age."

EXPLANATION OF PLATES

Unless otherwise stated, all figures are natural size, and all the specimens are in the author's collection in the United States National Museum.

Plate 1

PAGE

Mycocrinus boletus Schultze 24

Figs. 1, 2, 3. Right posterior, basal, and ventral views of specimen from Prüm; showing the knob-like basal ring (here completely anchylosed); the relatively large size of the three smaller radials, their indentation at the upper corners adjoining the larger plates; food grooves for 16 arms, and the slightly elongate openings for the corresponding dorsal canals at the arm facets; the raised process on r. post. R. is well shown. × 3.

4, 5, 6. Similar views of a smaller specimen from Kerpen; showing the same features as the last, but with 15 grooves, and basal ring unequally divided by two well-marked sutures. × 3.

7, 8, 9. Similar views of a detached basal ring from Nollenbach, divided by two distinct sutures and a third faint one; it shows the completely solid nature of these plates, enclosing no cavity, but rising on the upper side into a low pyramid, symmetrically pentagonal, pierced by the central axial canal, and three dorsal canals at each of the peripheral sides.

10. Generic diagram based upon the foregoing specimens.
All Middle Devonian, Eifel limestone; Eifel, Germany.

Mycocrinus conicus n. sp 25

11, 12, 13. Right posterior, left anterior, and ventral views of type, from Nollenbach; showing the relatively higher and more conical basal ring, obscurely divided, and food grooves and dorsal canals for 11 arms. × 3.
Same horizon and area as last.

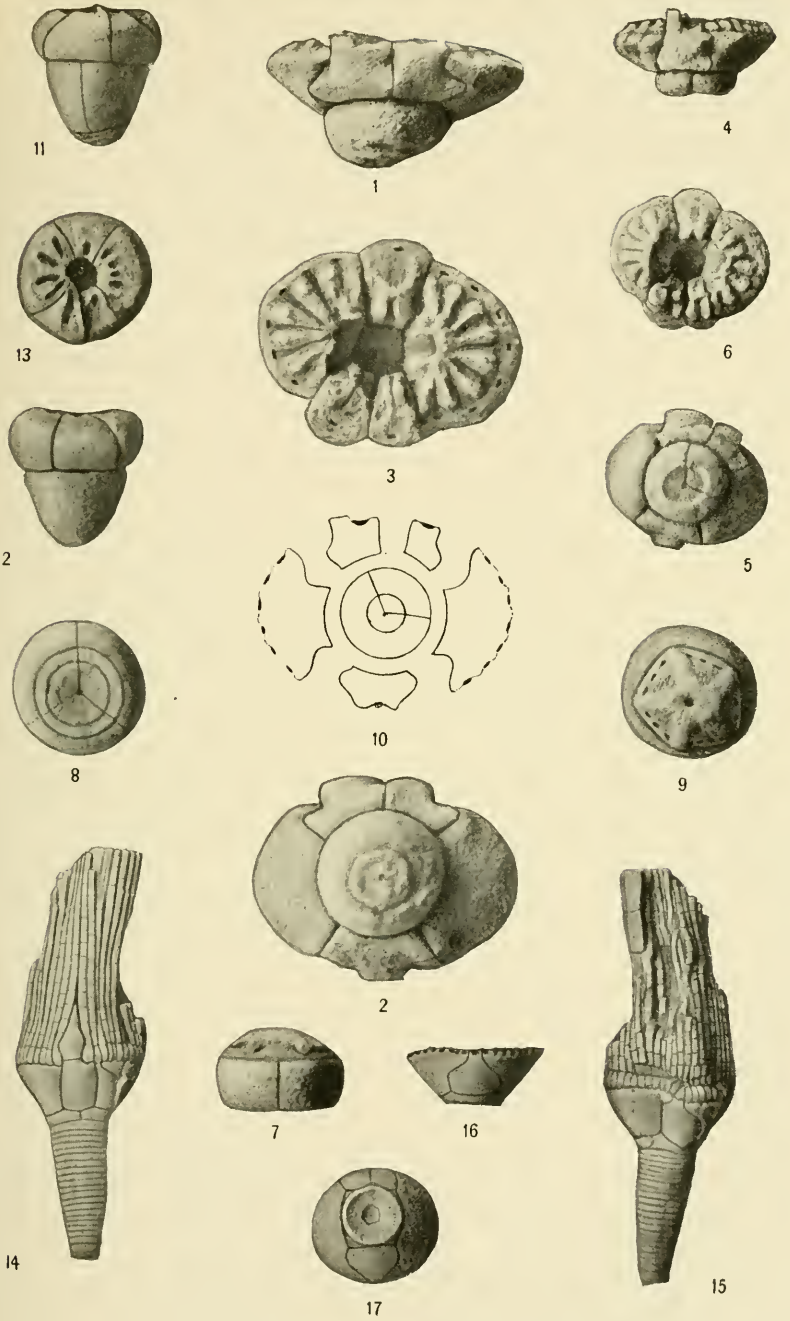
Catillocrinus turbinatus n. sp 26

14. A nearly complete crown free from matrix, with 34 arms and proximal enlargement of stem; posterior view, showing anal plate, basal ring about one-fourth the height of cup, and a very distinct suture under r. post R. × $\frac{3}{2}$.

15. Left anterior view of same. × $\frac{3}{2}$.

16. A dorsal cup, showing the turbinate form, as contrasted with the hemispheric contour of *C. tennesseensis;* left anterior view. × 2.

17. Dorsal view of same; the obtusely angular area appearing at the middle of base corresponding to the infrabasal cone in specimens of *C. tennesseeae* is pushed inward to a different level, at which the lumen for the axial canal shows; no sutures can be seen in this, nor in the basal ring surrounding it. × 2.
Mississippian, New Providence shale; Button Mould Knob, Kentucky.



SPRINGER on the family CATILLOCRINIDÆ.

PLATE 2

Figs. 1, 2. Shumard's type, from Button Mould Knob, Kentucky; dorsal and ventral views; fig. 2 shows the cone of three divided infrabasals at the inner floor of the cup.

3, 4. Similar views of a maximum specimen from same locality also used by Shumard, having 58 arm openings; the IBB cone is plainly shown at the inner floor of the cup, but its dividing sutures are not visible; the position of the interbasal sutures connecting with the fused infrabasals, as deduced from other specimens, is indicated as they appeared at various angles and by transmitted light.

5. Troost's type from White's Creek Springs, Tennessee; dorsal view, showing division of basal ring into three unequal plates by sutures running from the space occupied by the infrabasals, here broken out; the position of two of the sutures is distinct, that of the third obscure, but visible in certain lights. In this specimen the surface is worn smooth by erosion.

6. A similar, but less eroded specimen with pentagonal IBB area vacant and succeeding BB divided by three sutures.

7. Interior view of part of fractured calyx having most of the basals broken away, leaving the infrabasal ring intact, perfectly outlined by the fracture, and plainly divided into three plates. $\times \frac{3}{2}$.

8. Outer (dorsal) view of same; the pustulose surface well preserved, but indistinct in the figure. $\times \frac{3}{2}$.

9. Specimen with base ground and polished, showing obscure outline of IBB, and five interbasal sutures; dorsal view.

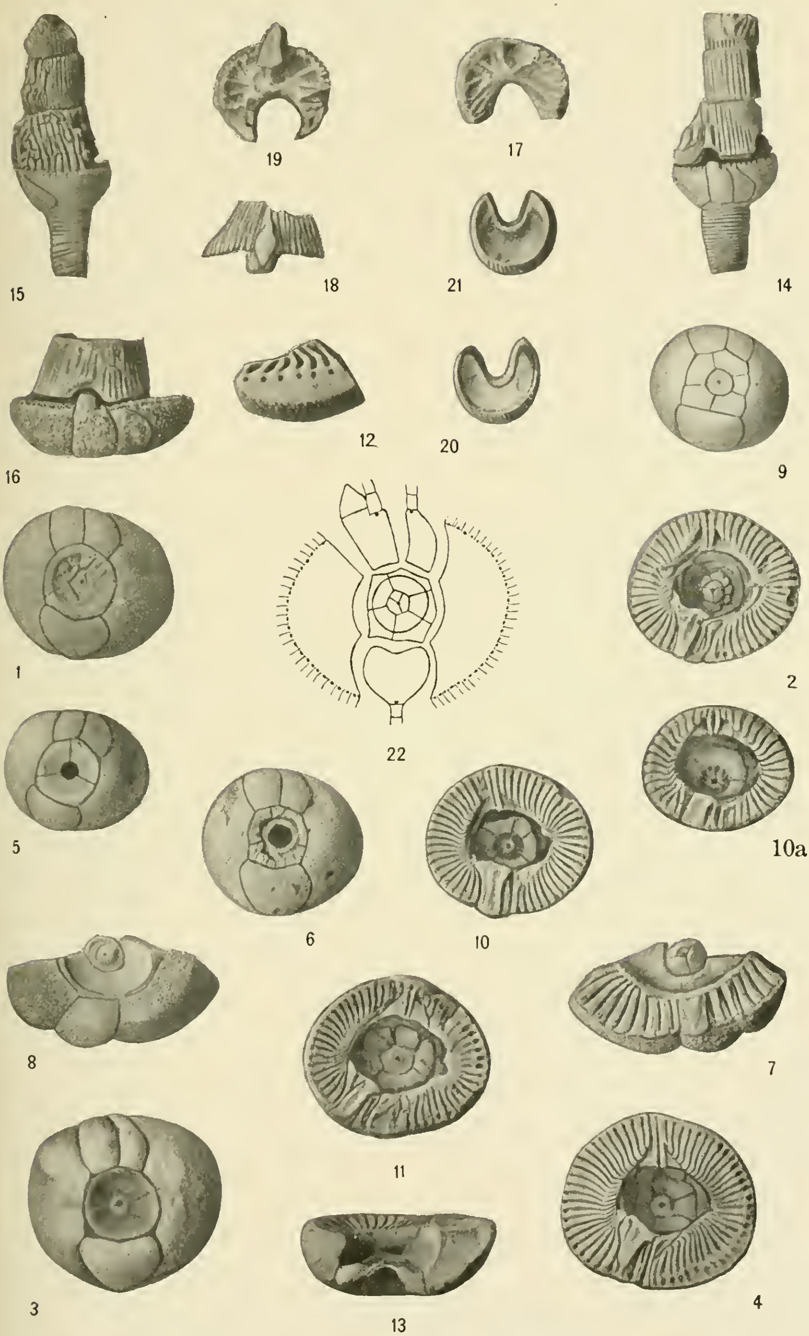
10. Ventral view of weathered specimen, showing the openings of dorsal canals at the arm facets, and their relation to the food grooves; also the extent, form and proportions of the raised process.

10a. Ventral view of smaller specimen with the infrabasal cone well defined.

11. Similar view of another large specimen, showing further details; the dorsal canals are seen passing inward under the floor of the food grooves. Division of basals into more than three plates is indicated in this and figure 10, not with complete regularity, but exactly as the inner floor of the calyx appeared to the artist without suggestion.

12. Section of radial transverse to the dorsal canals, showing their entrance below the level of the food grooves. $\times 2$.

13. Vertical section of dorsal cup, to show the great thickening at upper margin of radials contrasted with the extreme thinness of the base. $\times \frac{3}{2}$.



SPRINGER on the family CATILLOCRINIDÆ.

Catillocrinus tennesseeae (Troost) Shumard—*Continued*

14. Posterior view of specimen with part of stem, and anal tube (slightly displaced) having the longitudinal imprint of the slender arms; shows the raised process on r. post. R, and curved notch in first tube plate for reception of anal plate.
15. Left posterior view of same, with remnants of arms.
16. Posterior view of dorsal cup, with process on r. post. R, and a first tube plate in position notched for the anal plate, which is here wanting; to show the relation of these plates; strong pustulose surface shown, visible under a magnifier.
17. Proximal face of same tube plate, showing the radiating furrows facing the food grooves on dorsal cup.
18. A similar tube plate with the elongate anal plate attached in position interlocking with the notch.
19. Proximal, or under, side of same plate, showing the radiating furrows corresponding to food grooves on upper face of radial.

20, 21. Proximal and distal views of a higher tube plate, showing the crescentic cross section, and the large ligament fossae on both faces.

22. Diagram of calyx plates constructed from the specimens figured.

All Mississippian New Providence shale; Button Mould Knob, Kentucky, and White's Creek, Tennessee.

PLATE 3

PAGE

Catillocrinus wachsmuthi Meek and Worthen 26

FIG. 1. A nearly complete crown, with proximal enlargement of stem; from right anterior radius; the great length of the slender arms is shown, and the anal tube is exposed near the distal end.

2. A crown with 39 arms very perfectly preserved to nearly half their probable height, and exposing the massive tube; right posterior view, showing the elongated, pointed anal plate surmounting the raised process on r. post. R. $\times 2$.

3. Cross section at fractured distal end of same specimen, showing the massive crescentic tube surrounded by the delicate arms. $\times 2$.

4. A specimen in which the tube has been exposed from its origin, somewhat displaced at the base; left posterior view, showing in side view the anal plate interlocked with the lower tube plate, followed by a narrow, keel like projection. $\times 2$.

5. Posterior view of part of same, showing relation of the narrow anal plate to adjoining structures. $\times 2$.

6. A smaller specimen with 24 arms; posterior view showing elongate anal plate in position. $\times 2$.

7. Basal view of same specimen, showing three well-defined interbasal sutures meeting at the axial canal. $\times 2$.

8. Posterior view of another specimen with about 25 arms; stem omitted. $\times 2$.

9, 10. Left anterior and basal views of calyx of a fractured specimen in which one basal plate is detached at its bounding sutures, and the suture between the other two is distinct, showing beyond question the division of the base in this species into three plates. $\times 2$.

11. Diagram of calyx constructed from the foregoing specimen.

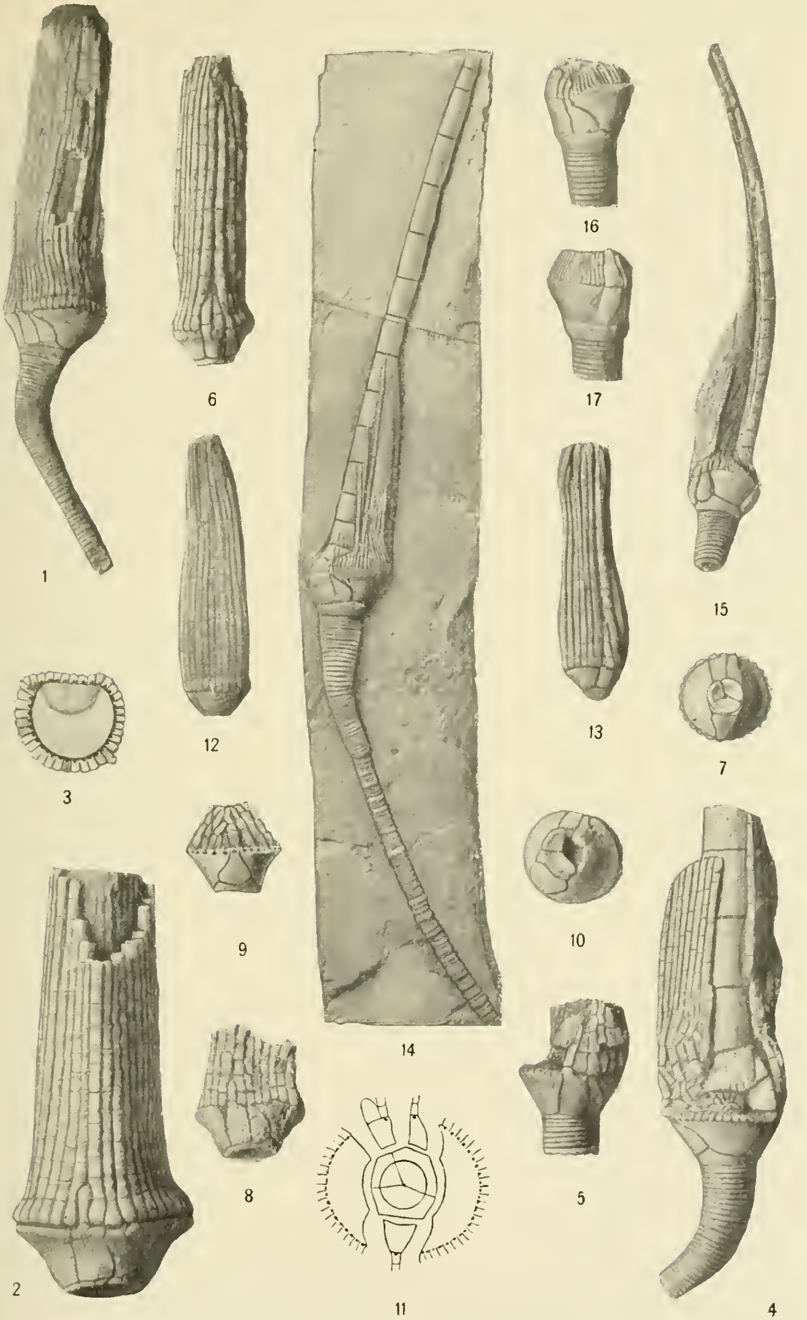
All Mississippian, Upper Burlington limestone; Burlington, Iowa.

Catillocrinus shumardi n. sp 27

12. A crown with nearly complete arms, anterior view. $\times 2$.

13. Right posterior view of another specimen; has raised process on r. post. R, and three interbasal sutures—not well shown in the figure. $\times 2$.

Mississippian, Keokuk limestone, lower horizon; Indian Creek, Indiana.



SPRINGER on the family CATILLOCRINIDÆ.

Catillocrinus bradleyi Meek and Worthen...................... 27

14. A specimen with anal tube almost complete, right posterior view, showing the tube rising directly from r. post. R, slightly displaced so that the anal plate is not shown; some of the extremely delicate arms (of which there are about 40 in all) are preserved, and the stem characters are well shown. On another specimen with calyx of the same size the complete stem is attached, about 37 cm. long, ending in a narrow point, with a few scattering cirri.
15. Left posterior view of another specimen with long tube, and short remnants of thread-like arms, the hollow side of the tube being seen; the basal ring is nearly one-third the height of the cup.

16, 17. Two calices with parts of arms and stem attached; l. ant. and post. views, showing the anal plate at same level as arms, directly following r. post. R, without any raised process. $\times \frac{3}{2}$.

Mississippian, Keokuk limestone, upper horizon; Crawfordsville, Indiana.

PLATE 4

PAGE

Catillocrinus carpenteri (Wachsmuth) 28

FIG. 1. A nearly complete crown with proximal part of stem, posterior view; showing the great length and delicacy of arms, with tube extending to their distal ends. $\times \frac{3}{2}$.

2. The tube in another specimen seen for almost its entire length, with remnants of arms at lower part—the calyx being lost. $\times \frac{3}{2}$.

3. Anterior view of a very small specimen with 13 arms, and delicate stem. Calyx was detached from matrix and arms counted. $\times \frac{3}{2}$.

4. Specimen with calyx plates displaced, showing small size of arms.

5. Specimen with calyx and part of arms detached from matrix, posterior view; showing full contour of calyx, strong suture under r. post. R, and anal plate at same level as arms, with no raised process at outer margin. $\times 3$.

6. The same in original condition, from anterior radial. $\times 3$.

7. The same, basal view of calyx, showing division into 3 plates. $\times 3$.

8. Diagrammatic view of same, showing form and proportions of plates.

9, 10, 11. Posterior, anterior and basal view of similar detached specimens in which the calyx structures are well shown. $\times 3$.

12. The type, from specimen in Illinois State Museum.

Nos. 1 to 12 from Monroe County, Illinois.

13, 14. Anterior and right anterior radial views of specimens showing details of arms. $\times \frac{3}{2}$.

15. Similar specimen showing the extremely narrow left anterior radial. $\times \frac{3}{2}$.

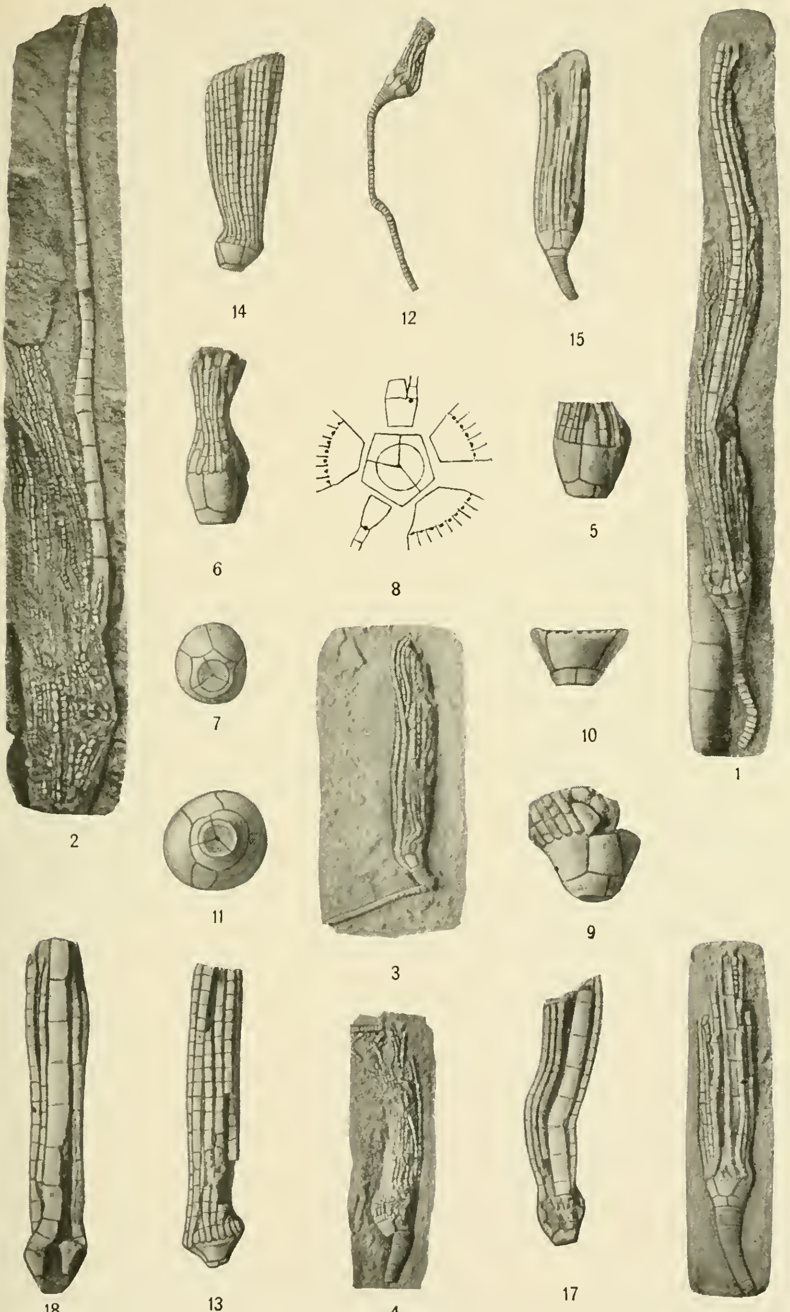
16. Anterior view of specimen with stem enlargement and calyx plates well shown; also the hollow side of tube. $\times \frac{3}{2}$.

17. Posterior view showing the rounded side of tube; the two basal plates have been detached at their sutures, leaving one of the three remaining in place. $\times \frac{3}{2}$.

18. Lateral view showing tube from its origin on r. post. R. $\times \frac{3}{2}$.

Nos. 13 to 18 from Huntsville, Alabama.

Mississippian, all from lower part of Chester, Illinois and Alabama.



SPRINGER on the family CATILLOCRINIDÆ.

PLATE 5

PAGE

Synbathocrinus wachsmuthi Meek and Worthen 19

FIG. 1. A specimen showing the heavy arms, with the anal tube passing up between them, distinguished by its smaller size and longer ossicles.

2. Posterior view of specimen with arms partly removed, showing the anal plate in position. $\times \frac{3}{2}$.

3. Lateral view of same, showing course of the tube plates following the anal; for comparison with figures 4 and 5 of plate 3; it shows also the ventral processes of the radials surmounted by the pyramid of oral plates. $\times \frac{3}{2}$.

4. Fragment showing grooved anterior side of anal tube plates contrasting in size and proportions with arm plates at same level. $\times \frac{3}{2}$.

5. Ventral view of calyx; showing the great thickening of the radials, their large muscle fossae, the groove leading to the anal tube, and the linear openings of the dorsal canals. $\times \frac{3}{2}$.

6. Basal view of same, showing division of basals. $\times \frac{3}{2}$.

7. General aspect of a small specimen with complete arms.

Mississippian Lower Burlington limestone; Burlington, Iowa.

Synbathocrinus wortheni Hall 19

8. A characteristic specimen from the Upper Burlington limestone; Burlington, Iowa.

Synbathocrinus dentatus Owen and Shumard 19

9. A maximum specimen of this large species, with arms complete; the anal tube, extending to nearly the full height of the arms, is readily seen in the specimen lying close under the left posterior arm, but is obscured by shadow in the figure.

10. A very young specimen from the same layer, with arms consisting of only about 10 brachials.

Mississippian, Upper Burlington limestone; Burlington, Iowa.

Synbathocrinus robustus Shumard 19

11. Ventral view of calyx showing thickened radials, wide arm facets, strong ventral processes, muscle fossae, groove at anal side, and linear openings of dorsal canals.

12. Basal view of another specimen.

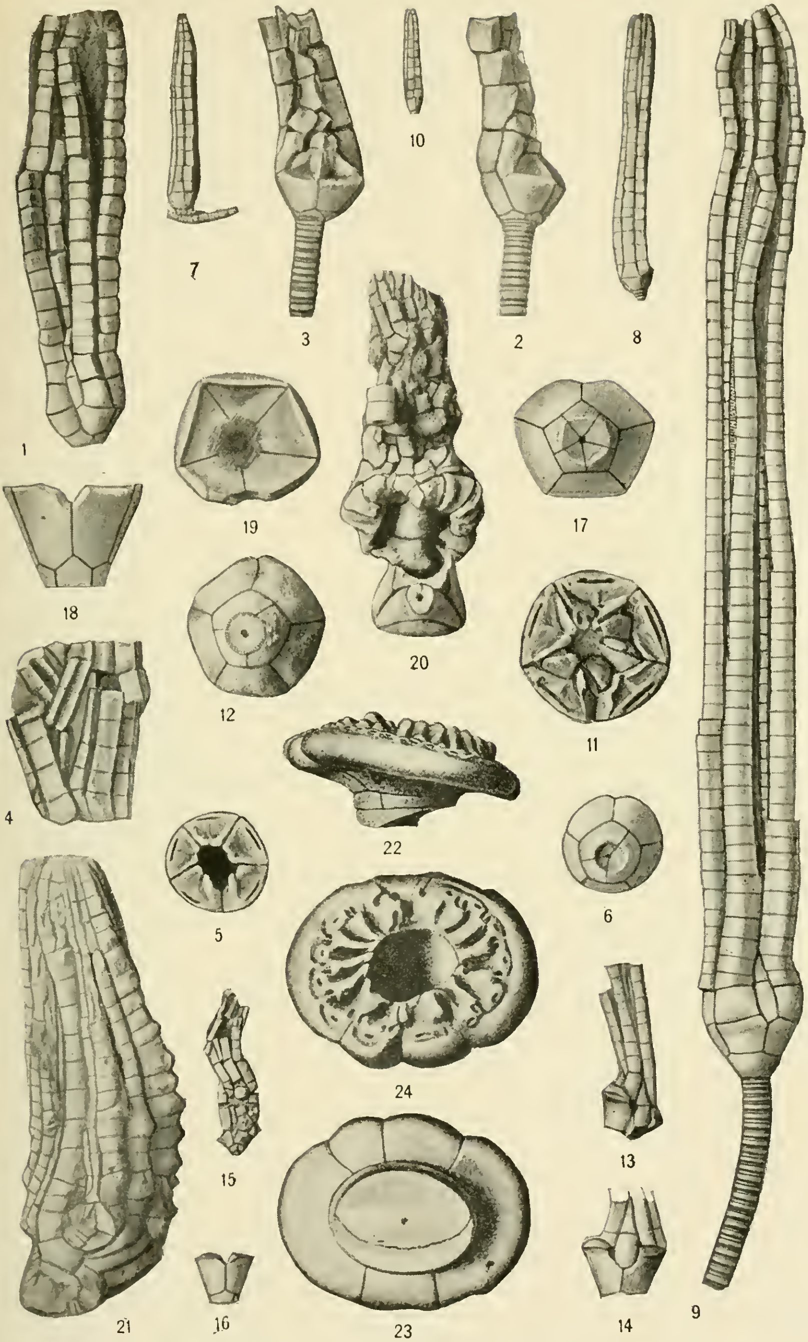
Mississippian, New Providence shale; White's Creek, Tennessee.

Synbathocrinus hamiltonensis n. sp 29

13. The holotype, showing radials deeply notched for the anal plate.

14. Posterior view of calyx of same, showing the anal structures in better detail. $\times \frac{3}{2}$.

Middle Devonian, Hamilton; Bellona, New York.



SPRINGER on the family CATILLOCRINIDÆ.

PAGE

Synbathocrinus onondaga n. sp. 29

15\. A small specimen from the Onondaga formation at Louisville, Kentucky, being the earliest known occurrence of the genus.

16\. Posterior view of calyx of another specimen, showing form and proportion of plates. $\times \frac{3}{2}$.

Middle Devonian.

Phimocrinus americanus n. sp. 30

17\. Basal view of holotype, showing division of base into five plates. $\times \frac{3}{2}$.

18, 19. Posterior and ventral views of same, the latter showing the absence of the great thickening of the distal face of radials. $\times \frac{3}{2}$.

Lower Devonian, Linden formation; Benton County, Tenn.

Deltacrinus dactylus (Hall) 19

20\. Posterior view of a specimen showing the beginning of the massive anal tube.

Mississippian, Upper Burlington limestone; Burlington, Iowa.

Deltacrinus nodosus (Hall) 19

21\. Specimen with calyx partly broken away, showing the heavy anal tube extending to full length of arms.

Mississippian, Keokuk limestone; Indian Creek, Indiana.

Paracatillocrinus granulatus Wanner 29

22\. Lateral view, showing strong slant of calyx from vertical axis of stem. $\times \frac{5}{2}$.

Paracatillocrinus ellipticus Wanner 29

23, 24. Basal and ventral views, for comparison with *Catillocrinus*. $\times \frac{5}{2}$.

The last two Permian (?); Island of Timor, Dutch East Indies. The figures are copied from Wanner, Taf. XCVI, figs. 1*b*, and 4*b*, *c*.