

XVII.—*The Calceocrinidæ: A Revision of the Family, with Descriptions of some New Species.*

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The confusion existing in regard to the nomenclature of the species included in this family, as well as to the proper terminology of the component parts of the calyx and arms, makes a complete revision imperative.

The bibliography on the subject will not be reviewed here, since that has already been done by Messrs. Wachsmuth and Springer in their "Revision of the Palæocrinoidea"; to which those wishing to examine it can refer.

The first attempt to meet the evident necessity for a separation of the family into more than one genus was made by Mr. E. O. Ulrich, who, in 1886, revised the family, calling it *Cremacrinidæ*, in place of *Calceocrinidæ* already proposed by Meek and Worthen, and then proceeded to divide it into three new groups or genera;—*Cremacrinus*, *Halysiocrinus* and *Deltacrinus*,—totally rejecting the generally accepted genus *Calceocrinus* Hall, except as a sort of convenient receptacle into which could be thrown all such species as would not readily fall under one or the other of his new genera.

While acknowledging the fact that the differences exhibited by the various species called for further generic separation, it must be conceded, with Wachsmuth and Springer, that the setting aside of the family *Calceocrinidæ* and genus *Calceocrinus* was unwarranted.

A division of the family into several genera is essential for a proper classification of the species contained in it; and our first step must be, in deference to the general acceptance of the term *Calceocrinus*, to decide to what type of calceocrinoid structure Hall's *original* species belongs, before any further divisions are made or others recognized.

It has been thought preferable to do this under the head of *Calceocrinus*, in its proper position in the family, instead of

discussing that point here,—so as to prevent a repetition when that species comes to be described and considered.

CALCEOOCRINIDÆ Meek and Worthen.

(Revised by Ringueberg.)

Calyx and arms drooping, being bent into an inverted position, and hanging downward alongside or against the column; parallel with it or diverging at a slight angle from it. Posterior side proximal to the column. Column round, straight, or slightly curved towards the calyx at its upper end, which is attached to the posterior side of the calyx.

Arms three or more, always one anterior and two lateral, and in some they are present on the posterior side. Ventral tube large.

Calyx flattened anteriorly with a truncate base; lateral sides parallel or nearly so, anterior and posterior sides divergent from the truncate base. Posterior side more or less rounded.

Basal plates consolidated into a semicircular or subtriangular piece, which is placed entirely upon the posterior side of the calyx and has its straight side, which is nearly or quite as wide as the base of the calyx, articulating with the truncate base-line of the anterior side by means of a hinge-like joint, while its posterior rounded or truncate pyramidal side fits loosely into an arch, having a similar outline, on that side of the calyx.

The basal piece is somewhat scoop-shaped, having the column inserted at or near the posterior rounded margin, and directed more or less outward from it, forming the handle of the scoop;—the posterior margin, which is incurved, representing the back, and the straight anterior margin the edge.

The anterior margin of this piece, and the adjoining radial articulate margin, are both furnished with grooves extending along the entire margin, or have external semicircular depressions which extend half-way through the plates from the outer side of the margin. These depressions, when present, are most prominent on the anterior or radial side of the articulation, and may be absent on the posterior or basal side, their place being taken by slight sinuosities of the outer non-articular side of the margin.

The grooves and depressions are for the reception of elastic ligaments uniting the two sides.

Externally this articulation has the appearance of a gaping joint or fissure, closed by means of a flexible integument, but internally is actually closed by the exact approximation of the inner edges of the ligament-bearing grooves, and over which the ligaments pass.

The posterior or curved margin was not attached directly to the arch into which it fits, but was united by means of some elastic and flexible medium, which allowed a considerable degree of separation at this point.

This peculiar conformation, the hinge on one side of the piece, and the mobility of the opposite side, allowed the basal piece to swing upon its hinge like a door or lid,—or, more strictly speaking, allowed the radial portion of the calyx to erect itself upon the basal portion. This function was possessed in variable degrees by the different species.

The incurved portion normally lies within the surface of the crinoid when it is at rest, allowing the column, which is inserted into the convexity formed by the curvature, to rest against the arch receiving this portion; and in those species in which the column is straight, or nearly so, and which have the calyx resting against it, the calyx is at times somewhat grooved beyond this point for its reception. Margin of the calyx very irregular, rising into high acute points laterally, with a depression between them on the anterior side and a deeper one on the posterior side.

Calyx composed of two rings of plates, whose number and position vary somewhat in the different genera, due to ankylosis and the modification of some of their functions, but they have the same general disposition in all.

The first or basal ring forms the consolidated basal piece; this is composed of three or four plates, consisting of two anterior basals or their ankylosed equivalent, and two lateral basals. The two lateral basals are the largest, and, taken together, they form the entire posterior margin of the piece extending to the outer angles. The point of attachment for the column is always upon the line of their union, while the apices of the anterior basals may or may not enter into the formation of the columnar facet. These plates together form a somewhat lunate-shaped piece, and are usually not ankylosed.¹

The anterior basals or their ankylosed equivalent are triangular, and occupy the median portion, or the whole, of the anterior margin. When the two anterior basals are not ankylosed, the dividing suture-line is a continuation of the one separating the lateral basals, and divides the piece into equilateral halves. As they are of equal size and shape, they will—for the sake of brevity—be described only in the ankylosed form.

Anterior ankylosed basal triangular, with the inner angle at times prolonged into a slender process extending up to or towards the column. Suture-lines between it and the lateral basals generally sinuous.

The second or radial ring contains from six to eight plates, of which the anterior radial and the lateral radials can always be made out, while the posterior radials are generally separate, though

¹In all species which I have had an opportunity to examine, the dividing suture-line could be made out, including several figured by their describers as being ankylosed.

occasionally merged by ankylosis with the lateral radials, in which case the lower portion of the ankylosed lateral radials extends around and upon the posterior side of the calyx.

The space between the posterior radials or the ankylosed lateral radials is occupied by an azygous plate; and when the brachials belonging to the posterior radials are present, they are crowded down between them and the azygous, and help to form the arch around the consolidated basal piece.

Anterior radial either quadrilateral, usually elongate, and supporting the inferior side of anterior first brachial, or triangular and supporting the lateral radials, which in the latter case meet above it.

The lateral radials are the largest plates of the calyx, and are of variable size and shape, separated by an elongate anterior radial, or else meeting over a triangular one, and always support the anterior brachial between them. Their outer angles, and in case of an ankylosis with the posterior radials, their outer sides, are bent around to the posterior side of the calyx. Their upper and outer sides are inclined posteriorly, and give rise to the lateral arms.

When the arm-bearing function of only one of the posterior radials is suppressed, the brachial lying above it gives support to the anal plates. In case both posterior arms are wanting, both radials support the large median anal plate, either directly or through the intervention of a T-shaped azygous plate lying between them.

Posterior radials, when present as such, lie in the angle formed by the hinge-line between the consolidated basal piece and the lateral radials.

Azygous plate elongate and narrow, T-shaped or broad and low, which latter form is probably due to ankylosis with another plate or plates adjoining.

The anal plate supports a large ventral tube, composed posteriorly of a single series of curved quadrangular plates, "the anterior side being composed of very small and delicate plates."¹

Anterior arm simple (?) or bifurcating once; if bifurcating, it may be pinnulate. Lateral arms bifurcating at the second brachial, beyond which point they may either increase by regular bifurcation or remain simple, and give off pinnules; or they consist of a series of axillary plates which are attached to the anals by their posterior faces, and more or less completely form an arch over the anal plates, the upper faces being arm-bearing.

Posterior arms when present resemble the lateral arms in structure.

In the following genera, the order of their probable evolution will be followed, and as that was in this case a kind of degener-

¹ Wachsmuth and Springer, "Revision of the Palæocrinoides," Pt. III., p. 281.

ation or suppression in part,—due to the extreme specialization of certain parts and functions at the expense of others,—the more complex forms will be considered first, because this method represents their natural sequence, and also furnishes an easy introduction to a proper understanding of the component parts of the more specialized forms, and to the nomenclature of the same.

This arrangement will place *Calceocrinus* last, as it is the most specialized form with which we are acquainted, and is consequently furthest removed from the as yet undiscovered or unrecognized five-armed ancestor.

I have revised the family, because the revision of Wachsmuth and Springer,—while a departure in the right direction,—is not quite satisfactory, for the reason that the consolidated base as defined by them agrees only with the base of *Calceocrinus*, and the true relations of the plates of the posterior side are not recognized. The arm-structure also varies more than that revision would indicate.

CASTOCRINUS n. gen.

Calyx hanging against the column, and generally having a slight groove for the reception of it. Column straight or nearly so. Arms four, one anterior, two lateral, and one posterior, the latter being to one side of the median line,—the anal plate and ventral tube occupying the opposite side. Anterior arm simple (?) or bifurcating; bifurcations bearing pinnules.

Lateral arms bifurcating once, with lateral armlets given off on alternate sides at every second joint beyond the place of bifurcation.

Consolidated base with the columnar facet on the posterior portion of the incurved margin. It is composed of two lateral basals, which meet posterior to the column, but are separated anterior to it by the attenuated apices of the anterior basals, or their anchylosed equivalent.

The anterior basals occupy the median portion of the anterior margin of the piece, the lateral basals occupying the outer portions.

Anterior radial higher than wide, usually narrow, and supporting the anterior brachial. Lateral radials irregularly hexagonal. Posterior radials irregularly triangular. Azygous elongate and placed between the two posterior brachials, which extend downwards between it and the posterior radials.

Anterior arm simple (?) or with four or more brachials, upon the last of which a bifurcation takes place. Bifurcations pinnulate; pinnules long; lateral arms having two brachials, the second of which is axil-

lary, and the posterior arm having three, the first of which enters into the formation of the posterior side of the calyx with the brachial of the opposite side. The latter brachial, with the elongate azygous, supports the anal plate, which in turn supports the other plates forming the ventral tube.

Type of genus, *Castocrinus furcillatus* W. R. Billings.

I wish here to express my indebtedness to Walter R. Billings, Esq., of Ottawa, Canada, who very generously placed his types and all the specimens of the genus in his possession at my disposal for the purpose of study.

Below will be found a few remarks on *C. furcillatus*, noting several points not given in the original description, they having been obscured by adherent shale till the specimen came into my hands.

***Castocrinus furcillatus* W. R. Billings.**

Pl. X., Fig. 1.

Calceocrinus furcillatus W. R. Billings.

The Ottawa Naturalist, Vol. I., No. IV., p. 51.

The anterior basals are prolonged to, and form a part of, the columnar facet, not stopping short of it, as represented in the diagram accompanying the original description.

The azygous is elongate and narrow, and extends from the basal plates to the anal plate, the inner corner of which it supports on its sloping upper side. It lies to the left of the median line; the larger of the two posterior brachials—the right—extending up to this line. The inner corner of this brachial is also prolonged upwards beyond the azygous and rests against the inner side of the anal plate.

The incurved margin of the consolidated basal piece is evenly rounded and meets in a narrow connecting band beneath the column.

-- Trenton formation, Ottawa, Canada. Type in the collection of W. R. Billings.

***Castocrinus rugosus* W. R. Billings.**

Pl. X., Fig 2.

Calceocrinus rugosus W. R. Billings.

The Ottawa Naturalist, Vol. I., No. IV., p. 53.

The position of the consolidated basal in the type specimen is evidently abnormal, as the plates of the posterior side seem to have been pulled downward after it, and out of their proper positions. This was probably caused by the ligaments, which united the two together in

such a manner as to allow of a partial but not complete erection of the calyx upon the base.

Trenton formation, Belleville, Ont. Type in the collection of W. R. Billings.

***Castocrinus billingsianus* n. sp.**

Pl. X., Fig. 8.

Calyx broad, wider than high, base broad, central portion of calyx depressed anteriorly and laterally, just above its middle. Posterior side evenly rounded, with a median furrow for the reception of the column, against which it rests. Anterior arm simple (?), lateral and posterior arms bifurcating. Ventral tube tapering. Column of medium size.

Base of anterior side of calyx with three semicircular depressions, of which the median is the largest, and has the sharpest curvature; lateral depressions well curved on their inner sides, but gradually rounding out towards the lateral angles. The consolidated basal has a shallow, well-defined, median depression, corresponding to the one on the opposite side of the hinge-line. Lateral depressions but faintly defined. Two ligamentous bands pass over the hinge-line from the dentate projections left on either side of the opposite median depressions.

Consolidated basal piece broad, evenly rounded from side to side, about twice as wide laterally as antero-posteriorly. It is composed of three plates, the anterior basals being anchylosed. Columnar facet situated on the posterior side of the curved portion, from the side of which the column projects in the same general plane as the piece.

Anterior anchylosed basal evenly tapering by slightly sinuous lines to the point of juncture with the column. Its base occupies something over half of the anterior margin of the plate, and has two dentate projections near the lateral angles, receiving the median depression between them.

Lateral basals about as wide at their distal as at their proximal ends.

Anterior radial high, moderately narrow, with a contraction at its upper third; basal end wider than the brachial end. Lateral radials pentagonal, with the lateral angles truncated.

Posterior radials small, triangular, the right (arm-bearing) radial being somewhat larger than the left.

Zygous unknown. The right posterior brachial is somewhat higher and larger than the left, and has its upper angles projecting upward, and clasping the base of the succeeding brachial between them, differing in this respect from the left pentagonal brachial, which supports the large anal plate. But three anal plates have been observed; they are large, quadrangular, and rapidly tapering towards the apex of the tube.

Anterior arm simple as far as observed, tapering for the first two

joints, from which point it is of nearly uniform size for the next ten. Joints higher than wide.

Lateral arms giving off long, slender, flattened pinnules from every second joint, and identical in structure with those in *C. furcillatus*.

Posterior arm similar in structure to the lateral, but having three brachials before bifurcation takes place.

Column composed of short joints, every alternate or second joint of which is shorter than the others.

From the Trenton formation, Ottawa, Canada. Named in honor of W. R. Billings, Esq., who collected the specimens. Types in Mr. Billings' collection.

This species is readily distinguished by its anchylosed basal; it also differs from *C. furcillatus* and *C. rugosus* in its anterior radial being broadest at its basal end instead of at the brachial end.

Castocrinus articulatus E. Billings.

Pl. X., Fig. 4.

Heterocrinus articulatus E. Billings, Geol. Rep. Canada, Dec. IV., p. 51.

Heterocrinus articulatus Wachsmuth and Springer, Rev. Palæocrinoidea, Pt. I., p. 70.

Calceocrinus (?) *articulatus* E. O. Ulrich, 14th Annual Rept. State Geol. Minn., p. 113.

Surface punctate, like that of *C. rugosus*, from which it differs in the very low and comparatively wide anterior radial, and from all the others here considered in the anterior and lateral radials being more nearly equal in size. The anterior basals have the same shape and size as in *C. rugosus*; lateral basals unknown.

Of the anterior arms only the first brachial is preserved. The lower bifurcation of the lateral arm gives off laterally compressed pinnules, which are strong at their base and wide from without inward; these are given off at the second, fifth, seventh, tenth, and fourteenth joints, beyond which point the division is imperfectly preserved.

The type specimen is rather imperfect, but is distinctive enough to prove it to be a good species.

Type in the collection of the Museum of the Geological and Natural History Survey of Canada.

Castocrinus inæqualis E. Billings.

Pl. X., Fig. 5.

Heterocrinus inæqualis E. Billings, Geol. Survey Canada, Decade IV., p. 51.

Heterocrinus inæqualis Wachsmuth and Springer, Rev. Palæocrinoidea, Pt. I., p. 70.

Cremacrinus inæqualis E. O. Ulrich, 14th Rept. State Geol. Minn., p. 113.

Calceocrinus inæqualis Wachsmuth and Springer, Rev. Palæocrinoidea, Pt. III., p. 282.

The type specimen lies on a slab and shows only the left side, consequently the fourth or posterior arm is obscured. The anterior arm is simple as far as observed, which is about fifteen joints.

Consolidated basal piece composed of two anterior and two lateral basals. The anterior basals extend to the column by quite strong processes.

The lateral arms differ from those of the other *Castocrini*, in giving off pinnules less frequently and at somewhat irregular intervals, and in not being much enlarged at the points giving rise to them.

This species differs from *C. furcillatus*, in the calyx being more flattened anteriorly and depressed along its median portion, also in the larger anterior basals, the proportionately broader first anterior brachial in comparison with anterior radial, and the very fine, closely arranged punctæ, which of themselves afford an easy means of recognition. It also differs from the foregoing species in the simple anterior arm, in the method of giving off pinnules, and in the character of the lateral arms. From *C. billingsianus* it is distinguished by the surface and by the basals not being anchylosed.

Trenton formation, Ottawa, Canada. Type in the Museum of the Geological and Natural History Survey of Canada.

I am much indebted to Prof. J. T. Whiteaves, of Ottawa, Canada, of the Geological and Natural History Survey of Canada, who kindly loaned me the types of *C. inæqualis* and *C. articulatus*, for the purpose of study and comparison.

CHEMACRINUS? Ulrich.

This genus will belong here, between *Castocrinus* and *Proclivocrinus*, if Ulrich's diagnosis be correct; but as I have not had an opportunity to examine the type specimen, I will insert it provisionally.

PROCLIVOCRINUS n. gen.

Bilaterally symmetrical; calyx hanging alongside of the column, which is curved posteriorly at its upper end.

Arms three; anterior arm much the largest, simple (?) or not bifurcating till near the tip; lateral arms increasing by regular bifurcation, and not giving off pinnules.

Anal tube large, heavy, and occupying the centre of the posterior side; column round.

Consolidated basal piece triangular, with the posterior angle abruptly truncate at the columnar facet, where it is rounded up. It is composed of four plates, the two anterior of which extend to the column by attenuated processes; their outer portion occupies the middle of the anterior base-line, and does not extend to the lateral angles; suture-line between them and the lateral basals sinuous.

Second ring consisting of six plates; anterior radial high and very narrow, supporting the lower face of the anterior brachial. Lateral radials large, pentagonal, with the lateral angle prolonged to meet the lateral processes of the azygous plate.

Posterior radials rather large, triangular, and each inclosed between the proximate lateral radial, the basal, and the azygous.

Azygous plate broadly T-shaped, and consisting of a middle portion or body, an inferior arm which extends between the posterior radials to the arch around the basal plates, and two lateral arms which meet the processes of the lateral radials, inclosing the posterior radials beneath them; their anterior surface supports the large anal plate. These lateral arms and central body probably represent the first anal plate, while the inferior process is representative of the azygous plate which has been anchylosed to it.

Plates of the ventral tube large quadrangular. First anterior brachial broad. Lateral brachials two, the second of which is axillary; beyond this the lateral arms undergo regular bifurcations at every third or fourth joint. No pinnules observed.

Vault depressed below the margin of, and formed by processes from, the four plates forming the rim of the calyx, *i. e.*, the anterior and lateral radials and the azygous.

Column of medium size, with joints of the curved end arched from side to side so as to fit the antero-posterior depression of the columnar facet.

Type of genus, *Proclivocrinus radiculatus* Ringueberg.

Since the original description of the type was published, a number of other specimens have been found which more clearly elucidate points of structure not shown in the type specimen, or obscured by adherent shale, since removed, in that specimen; so that a partial redescription becomes necessary.

***Proclivocrinus radiculatus* Ringueberg.**

Pl. X., Fig. 6.

Calceocrinus radiculatus Ringueberg. Jour. Cin. Soc. Nat. Hist., Vol. V., p. 120, 1882.

Cremacrinus radiculatus E. O. Ulrich. 14th Annual Rept. State Geol. Minn., p. 111, 1886.

Calceocrinus radiculatus Wachsmuth and Springer. Rev. Palæocri-noidea, Pt. III., p. 282.

Consolidated basal piece strongly rounded at the point of juncture with the column, where it is of the same shape and size as the column, from which point it spreads out evenly to the flattened anterior margin. This plate is sometimes corrugated, the rugæ passing across it in an antero-posterior direction.

Articular margin furnished with a deep, sharp, ligament-bearing groove.

Lateral basals not forming an incurved margin underneath the column, but only united in the posterior part of the columnar facet, and divided anteriorly by the slender apices of the anterior basals. Anterior basals high, and occupying about one-half of the anterior articular margin of the piece. They taper very rapidly for about one-half of their height, from which point they are prolonged into attenuate processes, extending up to and forming a part of the columnar facet.

Anterior radial high, very narrow, rather abruptly constricted near the middle to one-half of the width of the basal end, which narrowing is continued throughout the brachial half.

Ends of the lateral processes of the lateral radials resting against and as wide as the turned-up portion of the lateral arms of the azygous plate. Posterior radials narrow, with all three sides convex, and the side next to the azygous much shorter than the others.

Azygous plate with the ends of the lateral arms of the plate turned up so as to clasp the base of the anal plate between them.

Posterior plates of anal tube large, quadrangular, and very gradually tapering with the tube; slightly arched posteriorly; but three plates have been seen above the azygous plate.

The five radials, the azygous, and the anterior brachial, seem to be generally consolidated into a single piece, some of the suture-lines being sometimes almost obliterated. These plates are at times also somewhat corrugated, the general direction being transverse.

Specimens vary from those with a strongly rugose surface to those in which it is smooth.

Anterior first brachial just as high as the notch between the upper angles of the lateral radials; second arm-joint tapers more rapidly than the rest. The anterior arm bifurcates at the ninth joint, above which four slender, tapering joints can be counted without further bifurcation.

The lateral arms have two brachials, the second of which is axillary; the anterior division bifurcates again at its third joint, and the lower or posterior undergoes two bifurcations, one at each succeeding fourth joint. Upper division unknown. The posterior primary branch has

two joints, at the second of which a bifurcation takes place, and again at the fourth joint above that.

What were described as lateral armlets in the anterior arm of the type specimen were found, upon further cleaning, to be portions of the lateral arms lying beneath and projecting out from under it, and not from its sides as first supposed.

Column round, smooth, consisting of joints as high as wide, except the last five or six proximal to the calyx, which rapidly get shorter and are higher on the outer side of the column, giving a strong curvature at this point, which still further facilitates the maintenance of the drooping position of the calyx.

§ The median antero-posterior elevation of the last joints, constitutes a marked somewhat saddle-shaped flexure in the last four; which flexure is received in a corresponding notch in the anterior margin of the articular facet.

Proclivocrinus chrysalis Hall.

Pl. X., Figs. 2 and 18.

Chierocrinus chrysalis Hall. 13th Rept. N. Y. State Cab. Nat. Hist., p. 128.

Calceocrinus chrysalis Shumard. Trans. Acad. Nat. Sci. St. Louis, Vol. II., p. 538, 1880.

Cremacrinus chrysalis E. O. Ulrich. 14th Annual Rept. State Geol. Minn., p. 111, 1886.

Calceocrinus chrysalis Wachsmuth and Springer. Rev. Palæocrinoidea, Pt. III., p. 281, 1886.

This species agrees with *P. radiculatus* in the general outline and relations of the plates to each other, but is distinguished by the much broader calyx; calyces corresponding in height being at least a third broader, and also usually less contracted in the middle, than is the case with *P. radiculatus*. Hall figures his types as having an anchylosed anterior basal in which the points do not extend to the column. This point, however, is usually so obscure that in all probability it was overlooked in this case, as it has been in others; the same remark will apply to the construction of the posterior side,—as two individuals from the same locality as Prof. Hall's specimens agree very well in other respects with his descriptions. Should the diagram, however, prove to be correct, the specimens here referred to will have to fall under another designation.

This species is readily distinguishable,—as before stated,—from *P. radiculatus*, by the much wider calyx and consequently broader plates; this is especially noticeable in the case of the posterior radials.

A unique specimen showing both the articular joint with its connecting ligaments, and the vault,—perfectly,—will furnish all that can be added to the descriptions already published.

The articular joint consists of two deep grooves in the opposite margins, the outer edges of which are widely separated when the crinoid is in its normal position of rest, while the inner two are in close apposition. Over these inner margins pass two bundles of elastic ligaments from one groove to the other.

They each arise in two parts from both sides of the termination of the two suture-lines of the anterior radial; one part coming from the anterior radial and the other from the adjoining lateral radial. These two parts or heads unite and pass over the inner margins of the two adjoining grooves, and are inserted into the groove of the consolidated basal piece, directly opposite their points of origin.

Faint traces of the integument uniting the two outer margins of the grooves and covering the elastic ligaments, can be seen. This integument is better shown in some other specimens of *P. radiculatus*, in one of which it is broken up into small pieces which at first glance have the appearance of "numerous little plates," such as are figured by Ulrich in "*Cremaerinus punctatus*."

The vault is covered by four projections from the inner sides of the four plates entering into the formation of the rim of the calyx proper. The top of the vault is smooth and evenly convex, its central portion being depressed to a point opposite one-half the height of the lateral radials, when measured from their lower to their upper angles. The only suture-lines observable are those commencing from the four suture-lines dividing the four plates, which proceed directly from their point of origin to the centre of the vault, where they all meet.

This arrangement gives three large triangular projections and one narrow wedge-shaped one. The outline of the concave space is rounding on the anterior side, with two lateral projections or grooves along the suture-lines, and one such groove in the centre posteriorly.

In the margins of the two lateral radials, can be observed two narrow slits which represent the continuation of the arm-grooves.

I was at first inclined to consider this vault as a kind of partition serving to strengthen the calyx and taking the function of the basal plates, which no longer served to maintain its rigidity.

From the lower third of the shale at Lockport, N. Y.

The revision of the genus *Calceocrinus* we will preface with a few introductory remarks concerning the original species upon which the genus was founded.

The original description speaks of the semicircular base as consisting of two pieces "anchylosed" (consolidated) together, a triangular one fitting into a somewhat lunate-shaped piece. A more careful examination of two specimens of the same portion of this species, shows a secondary suture-line starting from the

inner angle of the triangular piece, and passing through the excavation for the reception of the column, to the outer margin of the "lunate-shaped" piece, dividing it into equal halves. This suture-line is much less distinct than the other, and is consequently less noticeable. The anterior triangular piece is undoubtedly formed by the union of two anterior radials.

Having determined the composition of the consolidated basal piece of the typical form of *Calceocrinus*, we can place here all such as have the same structure.

This will be done with all that have been found upon examination to correspond to the typical form as shown in a quite perfect individual, so nearly like the type in basal structure and surface markings, that it was at first regarded as a young specimen of that species, but further study shows it to be a closely allied species differing distinctly in some minor details.

A specific description of the original species will be found under *Calceocrinus halli*.

CALCEOCRINUS Hall.

(Revised by Ringueberg.)

Calyx and arms hanging downward and directed outward at an angle from the column.

Column round, bent somewhat posteriorly at its upper portion so as to admit of a greater inclination of the calyx.

Arms three. Anterior arm simple (?) or bifurcating near its terminal portion. Lateral arms consisting of a series of axillary plates attached to, and forming a more or less complete arch over the anals on the posterior side, each of which gives rise to an armlet from its free or distal end.

Consolidated basal piece convex, semicircular, or partially triangular in outline, and formed of three consolidated plates,—two lateral basals and one broadly triangular anterior anchylosed basal, which extends to, or nearly to, the outer angles of the piece.

Column attached to the suture-line dividing the lateral basals, and never coming in contact with the anchylosed anterior basal.

Calyx flattened anteriorly, rounded posteriorly.

Anterior radial triangular, supporting on its two upper sides the adjoining lateral radials. Lateral radials meeting in the median line above the apex of the anterior radial, and supporting in a broadly V-shaped notch between and above them the anterior brachial. Laterally, through anchylosis with the posterior radials, they extend around to and upon the posterior side and assist, with the low and broad

azygous, to form the arch around the curved side of the consolidated basal. They also receive between them the first anal lying immediately upon the azygous.

Their upper and outer sides support the first axillary pieces of the lateral arms.

Lateral arms, formed of from three to five axillary pieces arranged in succeeding order, with their inferior borders resting upon the anal plates and uniting (?), or nearly so, above them in the middle of the ventral side. Their upper ends each give rise to an arm or branch.

Type of genus : *Calceocrinus typus* Ringueberg.

It will be observed from the above description, and the diagram given of *Calceocrinus typus*, that Ulrich's genus *Halsiocrinus* agrees in all of the major points with the typical *Calceocrinus*, of which it must in all probability rank as a synonym. This will also probably be the case with his *Deltacrinus*, unless other and more important structural differences should be noted besides the number of axillaries upon which he bases his genus.

Calceocrinus typus n. sp.

Pl. X., Fig. 8.

Surface finely granulose, calyx flattened anteriorly; somewhat depressed and constricted in the centre of that side; rather square in outline; upper portion but little narrower than the lower; ventral side very gibbous, with a notch or depression to receive the upper end of the column.

Column round, composed of nodose joints which are as high as wide.

Consolidated basal piece evenly semicircular in outline, with the column attached just inside the posterior margin; anterior anchylosed basal half as wide as the base line. Anterior radial almost equilaterally triangular; somewhat wider than the anchylosed basal, but not quite so wide as the base of the calyx. Lateral radials large and anchylosed to the posterior radials; they form the lateral thirds of the arch around the consolidated basal piece on the posterior side, the low and broad azygous occupying the median third.

Azygous wide, slightly lower in the middle on account of the upward curvature of the lower margin receiving the basals, and a downward curvature of the upper margin for the reception of the anal.

First anal broad, low, with outer ends turned up abruptly, and receiving between them the broad base of the truncate pyramidal second anal; other anals, if any, unknown.

Anterior brachial extending somewhat beyond the upper angles of the lateral radials, pentagonal, and having its upper margin hollowed out to receive the first arm-joint.

This first arm-joint differs from the rest, in having a wide base and tapering rapidly towards its upper side, which is of the same width as the succeeding two or three joints. Seven joints are preserved, and no bifurcation takes place.

They are strongly arched, so as to be somewhat wider in their antero-posterior diameter than laterally, and are higher than wide.

Lateral arms composed of series of narrow axillary plates, five in number on each side, of which the first are the highest; being as long as the upper and outer sides of the lateral radials, against which they rest their full length; from these they decrease in height in regular order towards the centre of the arch which they form around the first two anals. Each axillary gives rise to an armlet, in which three joints can be observed, when a bifurcation takes place, or a pinnule is given off (exactly which, cannot well be determined on account of the imperfection of this portion of the specimen). Joints about as wide as long.

From the lower third of the shale of the Niagara Group at Lockport, N. Y.

Calceocrinus Halli n. sp.

Pl. X., Fig. 9.

Calceocrinus — n. gen. Hall. — Pal. N. Y., Vol. II., p. 352.

Anchylosed base triangular, broadly truncate in outline at the posterior angle, due to the abrupt turning-in of that portion at right angles with the upper surface of the piece. This bending inward extends from this portion along the posterior margins laterally, decreasing gradually towards the outer angles.

Just upon the abrupt posterior curvature of the plate, is situated the excavation for the reception of the articular facet for the column, which is situated at the bottom of it.

Anterior anchylosed basal very low and wide, extending laterally to the outer angles of the basal piece, and having its anterior border sharply grooved along its entire extent, for the reception of the elastic articular ligaments.

Lateral basals broad, due to the lowness of the anchylosed basal; columnar facet situated in about the middle of the suture-line formed by their union.

Surface thickly beset with strong granules, which coalesce to form larger ones on each side of the suture-lines, and upon the posterior curved portion of the plate.

Interior of plate concave, crossed by three grooves, two starting conjointly from the lateral angles and gradually becoming separated. The posterior of these is the deepest and is formed by the projection of a fold or sharp ridge along the line of curvature of the plate, and meets its fellow from the opposite side in the columnar foramen; the other

follows the suture-line of the anterior anchylosed basal, and incloses a lunate space between it and the other groove. The third groove starts at the columnar foramen and crosses the second groove, passing across the middle of the anterior anchylosed basal to the anterior margin, where it is all that remains of what was probably once a suture-line.

From the lower third of the Niagara Shale at Middleport, N. Y.

This basal piece is readily distinguished from the one belonging to *C. typus* by not presenting an evenly circular posterior outline, and by the anterior consolidated basal extending to the extreme outer angles. The rest of the calyx has not to my knowledge been found. This species has been named in honor of Professor James Hall, who was its original discoverer and who based the genus upon it.

***Calceocrinus bidentatus* n. sp.**

Pl. X., Fig. 10.

Anterior portion of the calyx flattened, quadrangular in outline, with a slight depression along the median suture-line. The lower margin of the calyx bears upon its upper surface three semicircular depressions with sharply defined margins. The median one of these is the widest and has a smaller one with a sharper curvature on either side, leaving two sharp dentate projections between. Anterior basal high and but little more than half as wide as the base; its two suture-lines commence in the lateral depressions or cicatrices. Anterior brachial projecting somewhat beyond the upper angles of the lateral basals, and having its upper margin slightly curved downward for the reception of the anterior arm.

The outer sides of the lateral radials project but little on the posterior side of the calyx.

This species is of the type of calceocrinoid structure to which *C. stigmatus* Hall belongs, but is at once distinguished from it by the narrower anterior radial, and the fact that the suture-lines of it commence in the lateral cicatrices, instead of passing to the outside of them; various other minor differences can be noted, but the above will prove sufficient for diagnostic purposes.

From the lower third of the Niagara Shale at Lockport, N. Y.

***Calceocrinus contractus* n. sp.**

Pl. X., Fig. 12.

Consolidated basal piece quite convex posteriorly.

Posterior margin truncate. Anterior anchylosed basal extending

laterally to the outer angles. Articular facet for column situated a little inside of the margin, and with its face directed posteriorly.

Associated with the base just described, we find the anterior portion of a calyx that undoubtedly belongs to the same species. Anterior portion of calyx slightly but evenly arched from side to side, lower side wide, rapidly and evenly tapering to the insertion of the anterior brachial, which extends some distance beyond the upper angles of the lateral basals, and tapers more sharply than they do, thus giving the upper portion of the calyx a contracted appearance. Anterior radial broad and low, and extending to the outer angles; thus corresponding in size and proportions to the anterior consolidated basal. Anterior brachial extending for more than half of its height beyond the lateral radials; pentagonal in outline, and wider than high.

From the lower portion of the Niagara Limestone at Lockport, N. Y.

The consolidated basal piece of this species is distinguished from that of *C. halli* of the underlying shales by the much greater proportionate antero-posterior diameter, and by the position of the point of attachment, which is situated nearer to the posterior margin, and has its articular facet directed more nearly posteriorly.

REMARKS: The genus *Cremacrinus* of Mr. E. O. Ulrich is probably the only one of his genera which will hold good. Its pinnulate lateral arms, the punctate surface of the plates, and the sinuous border along the outer margin of the articulation, ally it to *Castocrinus*; while in its having only three arms, and in the arrangement of the plates on the ventral side, it would closely approach *Proclivocrinus*; so that its natural position would be between those two genera. The features distinguishing it from its closest ally *Proclivocrinus* would be those already pointed out as allying it to *Castocrinus*, together with a shorter and broader anterior radial than in *Proclivocrinus*, and in the anterior basals not extending to the columnar facet.

I speak of the anterior arm as "simple (?)" because I believe that all, or nearly all, the species which have been described as having a simple anterior arm, will be found to show a bifurcation, in case specimens are found preserving the arm to its tip.

The plate which is termed the "azygous," in the foregoing descriptions, may prove to be the first anal, and probably in

Proclivocrinus and *Calceocrinus* might more properly be so termed, except for the reason that in them it is the result of an anchylosis and modification of the azygous of the primitive forms with the first anal.

In *Proclivocrinus* the cross-bar of the T represents the first anal, and the stem the remains of the azygous; while in *Calceocrinus* the modification has gone still further, and the stem has become absorbed entirely—only the cross-bar remaining.

The modifications undergone by the members of this family will afford an interesting chapter in evolution, if the material ever presents itself which will allow of its complete working-out.

That the ancestral form was five-armed, there can seem to be no doubt, as the existence of the right brachial in the four-armed *Castocrinus* points conclusively to such a one. But whether this, as yet unknown or unrecognized, ancestor underwent the loss of its fifth arm after the crinoid had assumed the pendulous position of its calyx, and consequently formed a member of the Calceocrinidæ, or sustained this loss first and consequently belonged to another or a new family,—only the finding of it can set at rest.

That *Catillocrinus*,—the affinity of which to the Calceocrinidæ Wachsmuth and Springer have pointed out,—does not belong in the line of their evolution, is shown both by its structure and its geological position; although it may and probably did originate from the same stock.

The course of their specialization and modification of function among the known genera is shown in the successive steps from *Castocrinus* through *Proclivocrinus*, or some allied undiscovered form, to *Calceocrinus*.

But a more complete discussion of the reasons for the suppression of the posterior arms, on account of their being in the way in its new position, and the consequent lateral contraction of the calyx with its concomitant shortening, and the progressive development of the anterior arm and side to make up for the aborted posterior side,—I will leave for another paper at such time as the opportunity for the examination of a more complete series of forms shall present itself.

The types of *Proclivocrinus radiculatus*, *Calceocrinus halli*, *C. typus*, and *C. contractus*, are in my collection.

EXPLANATION OF PLATES X. AND XI.

PL. X.

- FIG. 1. *Castocrinus furcillatus* W. R. Billings.
 a. Right side of type specimen.
 b. Left side of same.
- FIG. 2. *Castocrinus rugosus* W. R. Billings.
 Type specimen.
- FIG. 3. *Castocrinus billingsianus* n. sp.
 a. Anterior side of calyx.
 b. Posterior side of same.
 c. Right side of a smaller and nearly complete specimen.
- FIG. 4. *Castocrinus articulatus* E. Billings.
 Type specimen.
- FIG. 5. *Castocrinus inequalis* E. Billings.
 Type specimen.
- FIG. 6. *Proclivocrinus radicleus* Ringueberg.
 a. Type specimen.
 b. Specimen showing bifurcation of anterior arm.
 c. Anterior side of a calyx with portions of arms.
 d. Posterior side of same.
- FIG. 7. *Proclivocrinus chrysalis* Hall.
 a. Anterior side of a calyx.
 b. Posterior side of same.
- FIG. 8. *Calceocrinus typus* n. sp.
 a. Lateral view of type.
 b. Anterior view of same.
- FIG. 9. *Calceocrinus halli* n. sp.
 a. Outer side of consolidated basal piece of type specimen.
 b. Inner side of same.
- FIG. 10. *Calceocrinus bidentatus* n. sp.
 a. Anterior portion of calyx.
 b. Basal portion of same, $\times 2$.
- FIG. 11. *Calceocrinus stigmatus* Hall.
 Base of anterior portion of calyx (after Hall) for comparison with the last, $\times 2$.
- FIG. 12. *Calceocrinus contractus* n. sp.
 a. Base of an individual.
 b. Anterior part of calyx of another.
- FIG. 13. *Proclivocrinus chrysalis* Hall.
 a. View of the vault of Fig. 7, $\times 5$, to show structure.
 b. View of hinge-line of same, $\times 5$, showing elastic ligaments.

PL. XI.

DIAGRAMS ILLUSTRATING STRUCTURE OF THE CALCEOCCRINIDÆ.

FIG. 1. *Castocrinus* Ringueberg.

FIG. 2. *Proclivocrinus* Ringueberg.

FIG. 3. *Calceocrinus* Hall (revised by Ringueberg).

a. Right side. b. Anterior side. c. Posterior side. d. Analysis of calyx.

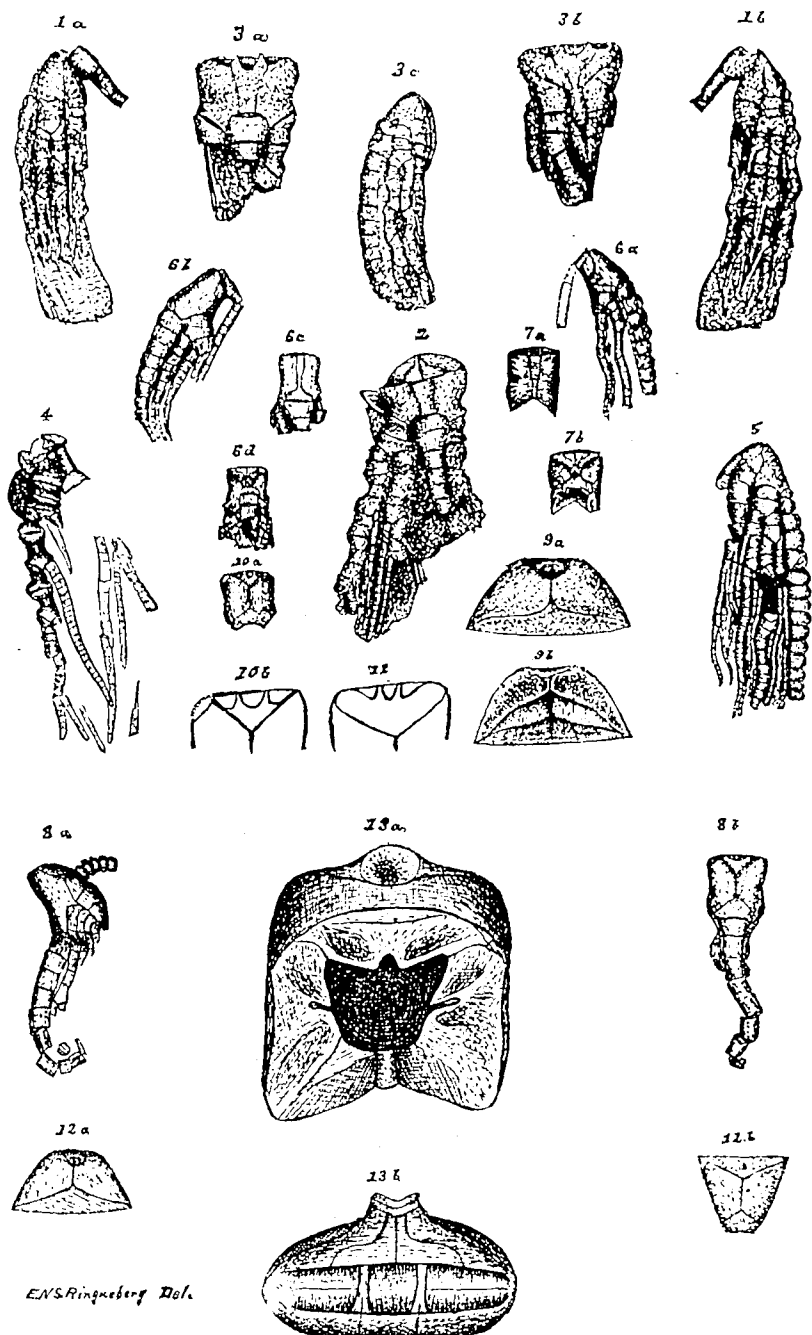
Letters referring to analysis (d):—*b*, basals; *r*, radials; *br*, brachials; *ax*, axillary; *an*, anals; *az*, azygous.

The posterior side of the calyx down and the anterior side up.

FIG. 4. Section of *Proclivocrinus*, illustrating the articulation of the base with the calyx and the manner of erection.

c, column; *cb*, consolidated basal piece; *ca*, calyx; *l*, elastic ligament; *int*, integument covering ligament; *m*, probable situation of muscles which held the calyx down.

PI. X.



Pl. XII

