

SOME NEW TAXA OF RECENT STALKED CRINOIDEA

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SYNOPSIS

Two small families of present-day stalked crinoids are reviewed. The Hyocrinidae is divided into two subfamilies, one including a new genus from the North Atlantic. Another new genus from the same area is added to the Phrynocrinidae, from which the genera *Porphyrocrinus*, with a new species from the southern Indian Ocean, and *Naumachocrinus* are split off as a new family. The range of the bathycriinid *Democrinus chuni* is extended. New diagnoses are given for the four families mentioned and illustrations of the holotypes of two previously known species.

THE small remnant of the class Crinoidea surviving to the present day consists primarily of the free-living Comatulida or feather stars, leaving only about seventy recognized species of stalked sea-lilies. Nearly half of this total is made up by the handsome Isocrinidae, well known for more than 200 years despite their absence from shallow water and distinguished by their relatively large size, with stalks often more than half a metre long bearing whorls of jointed cirri. The present paper is, however, concerned mainly with two of the lesser-known four remaining families – the Phrynocrinidae with four species and the Hyocrinidae with seven. Recent collecting by the National Institute of Oceanography in the North Atlantic has yielded two new genera, one belonging to each of these families and has prompted a review of the included taxa.

I am indebted to Mr B. Rowbury of N.I.O. and also to Professor J. H. Day of the University of Cape Town, from whom came a third new species, this time from an un-named sea mount in the southern Indian Ocean.

Family **HYOCRINIDAE** P. H. Carpenter

Hyocrinidae P. H. Carpenter, 1884 : 217–218 ; Koehler & Bather, 1902 : 78 ; Koehler, 1909 : 264 ; A. H. Clark, 1912 : 272 ; Gislén, 1939 : 7–17.

In his review of this family, Gislén (1939) listed a number of differences between *Calamocrinus* Agassiz, 1890 and the remaining genera included, namely the presence of five basal plates, a marked angle between the basal and radial rings, arms almost as stout as the radials and branching several times, the brachials short and broad, the distal syzygies separated by more or less numerous muscular joints, the proximal pinnules only about a fifth as long as the arms, the tegmen (or disc) relatively high, extending to about the tenth post-radial ossicle, and the orals relatively small.

The angle in the calyx between basal and radial rings appears slight in Agassiz's drawings of the syntypes of *Calamocrinus diomedae* (Agassiz, 1892, pls. 2 and 3) though well marked in the additional specimen drawn by Westergren (in Agassiz's pl. 28). A new member of the family described below, closely related to *Hyocrinus*,

does have a distinct angle between the two rings, at least in the anterior part of the calyx, and I do not think that this character is very significant. Some of the other differences, such as the relative stoutness of the arms of *Calamocrinus* in comparison with the radials and the shortness of the brachials, are likely to be correlated with the large size of the type material, calyx height *c.* 12 mm, whereas most of the other hyocrinids known do not exceed 8 mm calyx height. The relative shortness of the proximal pinnules, I think, is correlated with the fact that the arms branch. However, the presence of five basal plates (presumably primitive), the relatively small oral plates, the numerous muscular joints in the arms in comparison with the number of syzygies and possibly the fact of the arms branching and the very large size of the tegmen I consider are characters of supra-generic weight. Accordingly I am proposing a separate subfamily for *Calamocrinus*.

DIAGNOSIS OF FAMILY HYOCRINIDAE. A family of Articulata with a rounded stalk, sometimes slightly polygonal proximally with small tubercles in vertical series, without cirri, numerous proximal columnals discoidal and inflexibly jointed by synostoses in adults, increasing in number by intercalation between several segments, not just above the topmost one, attached to the substrate by an expanded terminal plate (when the attachment is known); the calyx with thin-walled plates, the sutures between the two rings and between the radials distinct, the three (rarely five) between the basals indistinct or lost by fusion; the arms (or division series) abruptly narrower than the radials in adults, well separated laterally exposing the prominent tegmen (or disc), usually five simple arms (irregular branching normally in only one genus), syzygies usually alternating with muscular joints (except in *Calamocrinus* where syzygies are fewer and *Hyocrinus* where they are more numerous); only P_1 and P_a undeveloped, the proximal pinnules very long, with gonads lined by large side plates and with distinct cover plates running the whole length of the ambulacra; oral plates usually enlarged.

Subfamily CALAMOCRININAE nov.

DIAGNOSIS. A subfamily of Hyocrinidae with the basal ring made up of five similar plates; arms branching several times irregularly, the first axillary not usually before the tenth post-radial ossicle; muscular articulations considerably outnumbering the syzygies; tegmen (or disc) very large, reaching up to about the tenth post-radial ossicle in adults; oral plates inconspicuous.

INCLUDED GENERA. *Calamocrinus* A. Agassiz, 1890, type-species *C. diomedae* A. Agassiz, 1890; monotypic.

Subfamily HYOCRININAE

DIAGNOSIS. A subfamily of Hyocrinidae with the basal ring made up of either a single fused ossicle or of three unequal plates (the sutures more or less indistinct); the arms normally unbranched; the syzygies alternating regularly with muscular joints, with a few exceptions proximally where two successive muscular

joints may occur; the oral plates much enlarged, forming a conspicuous cone in the centre of the disc, which is of moderate height, not usually extending beyond about the fifth brachial.

INCLUDED GENERA. *Hyocrinus* Wyville-Thomson, 1876, type-species *H. betheliani* Wyville Thomson, 1876; monotypic.

Gephyrocrinus Koehler & Bather, 1902, type-species *G. grimaldii* Koehler & Bather, 1902; monotypic.

Ptilocrinus A. H. Clark, 1907, type-species *P. pinnatus* A. H. Clark, 1907; also including *P. antarcticus* Bather, 1908 and *P. brucei* Vaney, 1939.

Thalassocrinus A. H. Clark, 1911, type-species *T. pontifer* A. H. Clark, 1911; monotypic.

The following new genus is now added :

*ANACHALYPSICRINUS** gen. nov.

DIAGNOSIS. A genus of Hyocrininae with the more proximal stalk segments at least all discoidal in adult specimens, those immediately below the calyx tending to alternate in thickness and projection, with thicker and slightly tubercular-edged plates alternating with thinner intercalary ones; [the distal part of the stalk and its attachment unknown]; the calyx distinctly asymmetrical in adults owing to a marked inclination backwards (i.e. towards the CD interradius containing the anal cone) of the anterior half of the radial ring, although the basal ring is more evenly inverted-conical; three faint inter-basal sutures just distinct; arms unbranched, arising almost vertically from the calyx, only Br_3 with a muscular joint at both ends, elsewhere such joints alternating with syzygies, the brachial formula, $1 + 2, 3, 4 + 5, 6 + 7, 8 + 9$, etc., the first pinnule, P_2 , being on the left side of Br_5 in each case.

TYPE-SPECIES. *Anachalypsocrinus nefertiti* sp. nov.

AFFINITIES. These are discussed after the description of the type-species.

Anachalypsocrinus nefertiti sp. nov.

(Figs. 1a-e, 2. Pl. 1)

MATERIAL. 'Discovery' Investigations st. 7711/66; $53^{\circ}11'2''N : 20^{\circ}5'1''W - 53^{\circ}11'6''N : 20^{\circ}3'9''W$ (North Atlantic, c. 400 nautical miles west from Northern Ireland), 2432-2380 metres. Holotype [B.M. reg. no. 1972.12.5.1] and three paratypes.

DIAGNOSIS. As for the genus.

DESCRIPTION. The holotype (Pl. 1 fig. a) is the largest specimen and has the total height of calyx and disc 35 mm, much larger than any hyocrinid previously recorded. Numerical data from it are given in Table 1 with that from the two normal paratypes (the third being badly deformed).

* Discovery-lily, from the collecting vessel.

TABLE I

Some numerical data from the holotype (1) and two normal paratypes of *Anachalypsicrinus nefertiti* sp. nov. Measurements are in millimetres; larger parts of the first two specimens were measured with calipers and the naked eye; the rest with a micrometer eye-piece. The arm measurements are from the anterior arm in each case.

| | 1 | 2 | 3 |
|--|-----|------|-----|
| Stalk : | | | |
| Length remaining | 25 | 30 | 22 |
| Number of segments remaining | 50 | 68 | 76 |
| Number of segments in top 20 mm | 43 | 52 | 74 |
| Diameter (below flared top) | 3.8 | 3.6 | 1.1 |
| Calyx : | | | |
| Diameter of lower end of basals | 5.0 | 5.0 | 1.7 |
| Diameter of top of basals | 14 | 14 | 3.6 |
| Diameter (maximum) of radials | 22 | 19+ | 4.4 |
| Diameter (maximum) of one radial | 13 | 11.5 | 2.6 |
| Height of basals | 10 | 9 | 2.5 |
| Height of radials | 15 | 12 | 3.3 |
| Total height (including disc) | 35 | 27 | 7.5 |
| Post-radial series : | | | |
| Arm length | 170 | 126 | 22 |
| Breadth at 4 + 5 | 3.2 | 3.1 | 0.8 |
| Length Br ₁ to 4 + 5 | 4.0 | 4.2 | 3.5 |
| Length of longest pinnules | 52+ | 35 | 10 |
| Number of segments in longest pinnules | 50+ | 40 | 14 |

Only a short piece of the proximal part of the stalk remains attached to the calyx of the holotype. It emerges at a slight angle so that the two topmost columnals are incomplete on the posterior side. The sutures between the columnals are very irregular and undulating, often with isolated pockets in notches having some tendency to form vertical series and representing incipient intercalary segments. Just below the basal articulation is a ring of ten tubercles, which alternate with ten hollows in the basals. The very top of the stalk is slightly flared.

The basal ring is inverted conical, sloping fairly evenly anteriorly but slightly concave in posterior profile with a small bulge at the base. The three sutures lie approximately in radii B, C and E (see Fig. 1a), producing a small plate opposite interradius BC. The radial ring is much more asymmetrical, inclined posteriorly so that in side view it resembles the sloping headdress of the celebrated model of Queen Nefertiti, the posterior profile forming an almost straight line with the basal ring, whereas the anterior one makes an angle of about 140°. There is also some lateral compression so that the maximum diameter antero-posteriorly is distinctly greater than that at right angles to it. The radials curve inwards at the top all round so that the bases of the arms are vertical. There is a slight median convexity up each radial.

The individual arms are much narrower than the radials, being separated by more than their own width. The first brachial is partially occluded by the upper edge of the radial, so that it is shorter than the immediately following brachials, though these are short in comparison to the more wedge-shaped brachials that

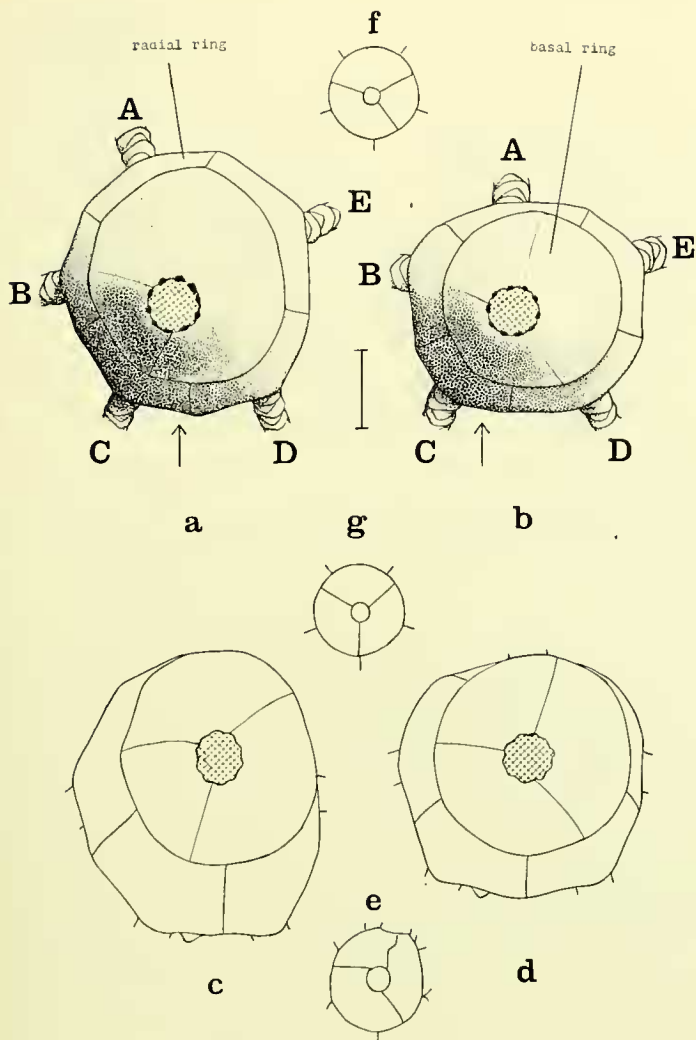


FIG. 1. a-e. *Anachalypsicrinus nefertiti* gen. & sp. nov. a and b. Holotype and large normal paratype viewed obliquely from below (the position of the stalk shown by cross-hatching) to show the sutures in the basal and radial rings [the scale equals 5 mm]. c and d. The same viewed vertically from below (parallel with the axis of the top of the stalk) showing the posterior offset of the radial ring. e. Basal ring of the abnormal paratype similarly. f and g. Diagrams of the basal rings from below of the holotypes of *Hyocrinus bethellianus* and *Thalassocrininus pontifer* drawn from descriptions.

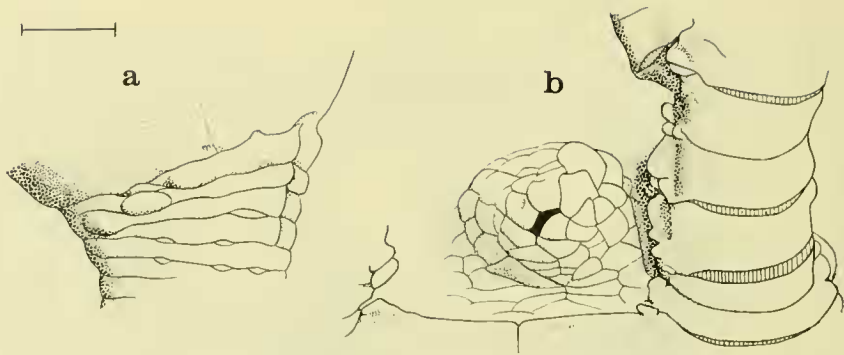


FIG. 2. *Anachalypsicrinus nefertiti*. Holotype. a. Junction of calyx and stalk from the side. b. Posterior edge of tegmen (interradius CD) showing anal cone and base of right posterior arm (C). [The scale equals 2 mm.]

follow. Br_3 is the only proximal brachial with a muscular articulation at each end, otherwise syzygies occur alternately, i.e. at 1 + 2, 4 + 5, 6 + 7, etc., though in the distal parts of the arms occasional instances occur of two consecutive muscular joints.

Although some of the arms are broken, there appears to be a size difference between the anterior and posterior ones, the latter being somewhat shorter and more slender. The breadth at brachials 4 + 5 is 3.2 mm on arm A but only 2.5 mm on arms C and D. [The paratype, specimen two, has a complete left anterior arm (E) 126 mm long, compared with c. 110 mm for one of its posterior arms.]

The first pinnule (which can be called P_2) is on the left side of Br_5 in each case. An intact one has 38 segments and measures 30 mm, though the immediately following pinnules are markedly longer. All the proximal pinnules have a smooth genital expansion from the third or fourth segment to the twelfth or thirteenth; this is enclosed partly by the pinnulars and partly by the series of rectangular side plates which stops abruptly at the end of the gonad. The ambulacra are supported by a series of smaller petal-like cover plates, three or four pairs of which correspond to each pinnular. The second to fourth pinnulars bear abruptly projecting lateral flanges. The joint between the first two pinnulars is capable of considerable vertical flexure, whereas those of the remaining segments are almost rigid. The genital area of each pinnule has a low rounded keel dorsally, lacking on the more distal segments.

The disc plating is most obvious on the anal cone (Fig. 2b) which is slightly offset in interradius CD towards the right posterior arm, C. The triangular interradial areas are sunken between the ambulacra and in each one there are up to 100 small, rounded papillae, projecting to various degrees, perforated individually by the water pores. In the concavity of the high, flange-like oral plate at the apex of each area there are one or two taller papillae and usually at least one capitate

papilla or spinelet. Radially the disc ambulacra merge into the arms at about the sixth brachial.

There are a number of free-living myzostomes among the pinnules.

PARATYPES. A large piece of stalk, broken at both ends, longer than those attached to the calyces, is included in the sample. It measures 155 mm in length, 3.75 mm in breadth and has 155 discoidal segments, the sutures between them rather irregular. At one end there is a fairly regular alternation of thick segments with intercalary thinner ones but the size evens up along the length of the piece. Very little flexure appears possible. The small specimen has the more distal (i.e. lowest) remaining columnals relatively long, 0.7 mm in height and 1.0 mm in diameter, but the upper segments are shorter, there being an abrupt change in length at about the fiftieth segment from the calyx. The upper extremity of the stalk is much less ornamented and fluted in the small specimen than in the larger ones.

The positions of the interbasal sutures (see Fig. 1a) agree in the small specimen with the holotype but the normal adult paratype (specimen two in Table 1) and the deformed specimen both have sutures in radii A and D instead of C and E, only the suture in radius B being common to all four specimens. Specimen two also differs from the holotype in the alignment of the maximum diameter of the radial ring. Although this in general slopes posteriorly, it is widest between radius E and interradius BC, almost at right angles to the antero-posterior plane. The small specimen (number three) does not show any distinct asymmetry.

As might be expected, the small specimen has the brachials relatively longer than in the others, the first three almost as long as broad (measuring median breadth rather than the expanded articular breadth) and the brachials after the sixth are longer than broad. It is preserved with its arms almost straight and vertical, only the very tips curling over. The total height of calyx and arms is 28 mm. It has six or seven pinnules on each side of each arm and the last three in each series are progressively shorter so that each ends about level with the arm tip. No gonads are evident.

The deformed specimen has the whole anterior half of the calyx bulging and covered with an irregular mosaic of plates. Only the two arms on the right side are normally developed; the two on the left are reduced and basally contiguous, one being twisted, while the anterior arm is completely absent.

A specimen of *Trichometra* was found attached by its cirri to the loose piece of stalk.

AFFINITIES. *Anachalypsicrinus nefertiti* is clearly closely related to the four genera currently included in the subfamily Hyocrininae. In comparison with these it agrees only with *Thalassocrinus* in having a combination of: separate basals, the second syzygy situated at brachials 4 + 5 and the first pinnule on Br₅. The positions of the interbasal sutures may approximate in *Thalassocrinus pontifer* to those in the holotype of this new species (A. H. Clark's description is not very precise but there is evidently a suture approximating to radii B and E, though the third is said to be in the posterior *interradius*, matching with the interradial suture

in CD). *Ptilocrinus* and *Gephyrocrinus* have fused basals, the second syzygy at 5 + 6 and the first pinnule on Br₄. *Hyocrinus* does agree in having distinct basals (though with sutures aligned like a mirror image of those of the holotype of *Anachalypsicrinus nefertiti*) but its second syzygy is at 3 + 4 and the first pinnule on Br₆; also the arms of *H. bethellianus* are much more slender relative to the width of the radials and the brachials are longer, even allowing for the smaller size of the described specimen – top stalk diameter 1.25 mm, while the anus is placed towards the left posterior arm, not the right. The holotype of *Thalassocrinus pontifer*, from the East Indies (Fig. 3) has the minimum stalk diameter just below the flared top 1.8 mm and the calyx c. 5.5 mm high, being considerably smaller than the two largest specimens of *Anachalypsicrinus*. This might account partially for the almost perfect radial symmetry of *Thalassocrinus* but the difference in this character coupled with the more laterally directed arms justifies a generic distinction in my opinion.

Geographically, the closest relative is *Gephyrocrinus grimaldii*, from the vicinity of the Canary Islands and Madeira, the holotype of which has the top stalk diameter only 1.0 mm, close to that of the smallest specimen of *A. nefertiti*. Unfortunately, Koehler's illustrations are poor but *G. grimaldii* evidently has the arms much less well marked off from the radials, while the ornamentation of the top of the stalk is considerably greater than in the small *A. nefertiti*, apart from the fused basals and different positions of the second syzygy and first pinnule.

Thalassocrinus pontifer A. H. Clark

(Fig. 3)

Thalassocrinus pontifer A. H. Clark, 1911 : 473-476 ; 1915, fig. 145.

The figure has been made from a rough sketch of the calyx of the holotype and only known specimen. It omits details of the tuberculation at the top of the stalk and on the tegminal plates. The interbasal sutures, described by A. H. Clark as 'almost obsolete' are not shown. The narrow bands at the edges of the radials (shown stippled) are slightly darker than the rest in the preserved specimen and give the impression of being bevelled, though I did not think them depressed as A. H. Clark described. Possibly they indicate recent growth.

Family **PHRYNOCRINIDAE** A. H. Clark

Phrynocrinidae A. H. Clark, 1907 : 510 ; Gislén, 1925 (part) : 92.

The family was established by A. H. Clark, without diagnosis, to accommodate his new genus *Phrynocrinus*, type-species *P. nudus* from southern Japan. This was distinguished by having the stalk terminating below in a lobed attachment disc and above in only one or two discoidal columnals, all those in between being trapezoidal in shape (viewed from the side), broader than high, all joined by flexible synarthrial articulations of which the successive ones are flattened in alternate planes approximately at right angles so that they appear to be paired, the calyx

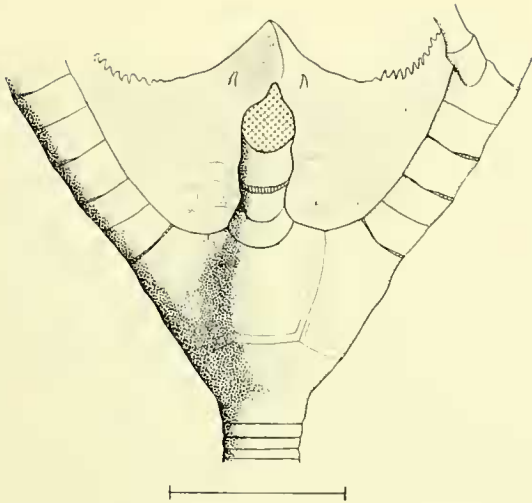


FIG. 3. *Thalassocrinus pontifer* A. H. Clark. Holotype. U.S. National Museum cat. no. 24783. Side view of calyx, adjacent ossicles and tegmen; the basal sutures not shown. The foremost arm is broken at Br₃. [The scale equals 5 mm.]

very squat and markedly flaring above, the arms diverging from the base leaving exposed extensive interradial areas of the tegmen or disc, relatively few syzygies present and no pinnules developed before the eighth or ninth post-radial ossicle, also branching occurs irregularly after the twelfth post-radial ossicle. The holotype of *P. nudus* is relatively large, the diameter of the topmost columnals 6 mm.

Two further genera, both monotypic, have since been referred to the family, namely *Naumachocrinus* A. H. Clark, 1912, type-species *N. hawaiiensis*, and *Porphyrocrinus* Gislén, 1925, type-species *P. verrucosus*, from the Kei Islands. Both of these genera have more or less numerous discoidal columnals proximally, the calyx elongated and approximately cylindrical, not appreciably wider than the top of the stalk, also the arm bases closely apposed laterally, continuing the vertical alignment of the radials. In fact, the general appearance is very like that of the Bathycrinidae, though some of the distal columnals with their compressed joints aligned in alternate planes are common also to *Phrynocrinus*. The arms of *Naumachocrinus hawaiiensis* are unknown beyond the first brachial and in *Porphyrocrinus verrucosus* the termination of the stalk is unknown. However, new material congeneric with *P. verrucosus* shows that the distal end of the stalk in this genus also terminates in a lobed disc. The bathycrinids are distinguished by the root-like ending of the stalk distally, with numerous irregular branching radicular 'cirri'. This precludes the inclusion of *Porphyrocrinus* and *Naumachocrinus* in the Bathycrinidae, if they are to be excluded from the Phrynocrinidae, which I am convinced must be done. It therefore becomes necessary to establish a new family to accommodate these two genera.

Since Gislén's diagnosis of the Phrynocrinidae allowed for the inclusion of *Porphyrocrinus*, a modified one follows.

DIAGNOSIS. A family of Articulata with the stalk round or elliptical in cross section, without cirri, even the topmost columnals linked by flexible synarthrial joints and only the most proximal one or two sufficiently short in adults as to be termed discoidal (though in immature specimens the uppermost segments are relatively shorter and several may be discoidal), only one new columnal developed at a time immediately below the calyx, the remaining segments giving a moniliform appearance owing to the compressed elliptical joints alternating in alignment, attached to the substrate by an expanded terminal plate; the calyx inverted conical in shape, relatively short and compact, the sutures between the five basals and five radial plates distinct, the two rings not widely dissimilar in height; the division series following the radials similar in width basally to the radials but diverging abruptly, exposing the large tegmen (or disc) to view, ten arms (possibly more) in the two known genera, most syzygies separated by two or three muscular joints; pinnules lacking basally from the first two or three possible positions on each side, the more proximal ones not markedly enlarged and with only small rods in the ambulacra, no conspicuous side or cover plates.

Phrynocrinus nudus A. H. Clark

(Fig. 4)

Phrynocrinus nudus A. H. Clark, 1907: 507-510, fig. 1.

Phrynocrinus obtortus Matsumoto, 1913: 221.

A sketch of the calyx of the holotype of *P. nudus* in the U.S. National Museum shows that in fact there are short vertical interbasal sutures and the individual basals are not really triangular as described by A. H. Clark, though he did note that the angles are blunted. The diameter of the top of the stalk is 6 mm, compared with 4 mm in the holotype of *P. obtortus* Matsumoto, also from southern Japan, and I think that this size difference is sufficient to account for the more obviously pentagonal shape of the basals in the latter. Judging from the material of a new member of the family described below, there may be some variation in the shapes of the columnals and the exact alignment of the successive stalk joints, which characters Matsumoto also used to try to distinguish his nominal species. Taking all this into account, including the geographical proximity of the type-localities, I consider that only a single species should be recognized and accordingly refer *P. obtortus* to the synonymy of *Phrynocrinus nudus*.

ZEUCTOCRINUS* gen. nov.

DIAGNOSIS. A genus of Phrynocrinidae with only the more proximal columnals markedly trapezoidal in side view with compressed alternating joints, the more distal ones becoming cylindrical (the distal termination of the stalk unknown);

* From Greek *zeuctos* - yoked or joined in pairs, referring to the appearance of the columnals.

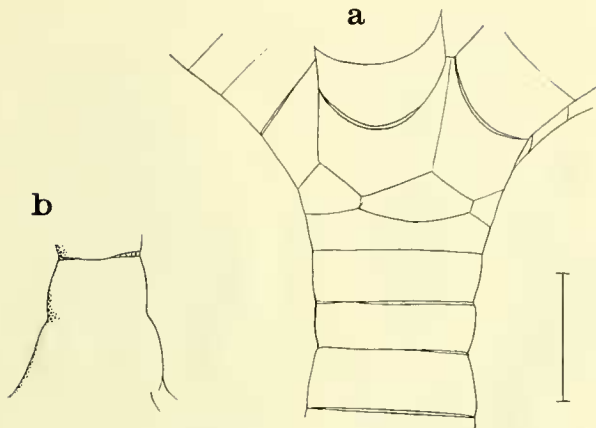


FIG. 4. *Phrynocrinus nudus* A. H. Clark. Holotype. U.S. National Museum cat. no. 22601. a. Side view of calyx and adjacent ossicles. b. Junction point of distalmost columnals and terminal stalk plate, showing the absence of a distinct suture at the last constriction, contrary to A. H. Clark's fig. 1D. [The scale equals 5 mm.]

the division series consisting normally of only two ossicles of which the IBr_1 in adults are proximally contiguous laterally but not in immature specimens, the two ossicles joined by syzygy; brachial syzygies normally at 1 + 2, 3 + 4, 7 + 8, 13 + 14 and then probably at intervals of three or four muscular joints; pinnules not developed in the first three possible positions, the first one being P_4 on Br_{10} or thereabouts.

TYPE-SPECIES. *Zeuctocrinus gisleni* sp. nov.

Zeuctocrinus gisleni sp. nov.

(Fig. 5. Pl. 2)

MATERIAL. 'Discovery' Investigations st. 7711/66; $53^{\circ}11.2' N$: $20^{\circ}5.1' W$ - $53^{\circ}11.6' N$: $20^{\circ}3.9' W$ (North Atlantic, c. 400 nautical miles west from Northern Ireland), 2432-2380 metres. Holotype [B.M. reg. no. 1972.12.5.4] and four paratypes.

DIAGNOSIS. As for the genus.

DESCRIPTION. All the specimens have the stalk broken, so that their distal ends and attachments are unknown.

The holotype (Fig. 5a, b, Pl. 2 figs. a, b) is the largest specimen, number 1 in Table 2. It has the topmost columnal only partially developed and almost discoidal but the second one is already more than half as high as its minimum diameter. Together they form a prominent synarthrial tubercle on one side, though the

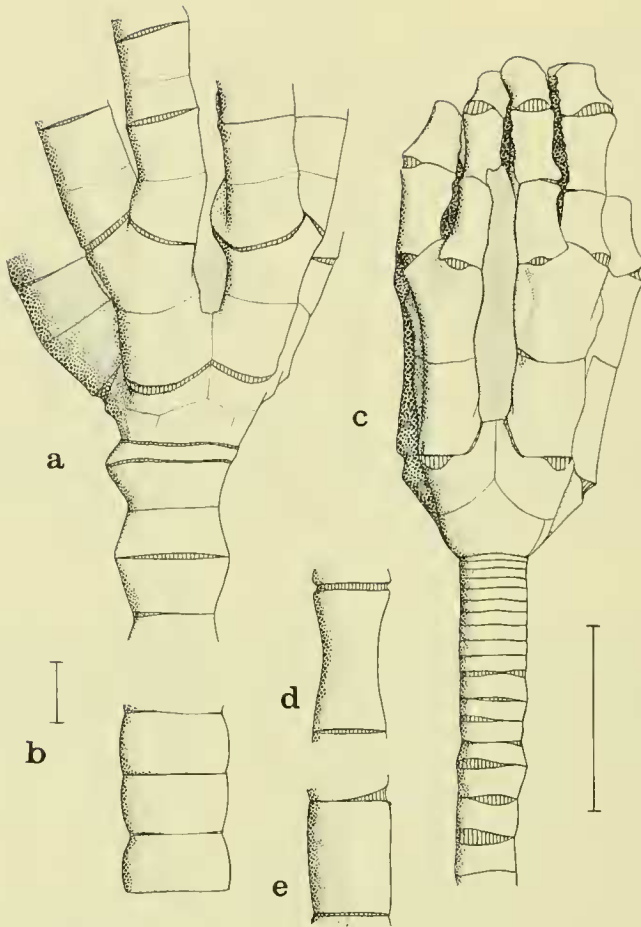


FIG. 5. *Zeuctocrinus gisleni* gen. & sp. nov. a and b. Holotype. a. Calyx and adjacent ossicles. b. Distal most remaining three columnals (numbers 31-34 from top) c-e. Smallest paratype. c. Crown and proximal part of stalk. d. Columnal 52. e. Columnal 59. [Both scales equal 2 mm; that on the right applies to c-e.]

opposite side is still flat. The next 25 or so segments have their joints symmetrically elongated in alternate planes almost at right angles (in fact the plane of elongation spirals through 90° during about six pairs of articulations). This produces a moniliform appearance to the stalk in side view, with the segments forming pairs. The modification in shape gradually lessens distally so that the last few columnals are almost cylindrical.

TABLE 2

Numerical data from the holotype (1) and four paratypes of *Zeuctocrinus gisleni* sp. nov.
Measurements are in millimetres.

| | 1 | 2 | 3 | 4 | 5 |
|------------------------------------|-----|-----|------|-----|-----|
| Stalk : | | | | | |
| Length remaining | 61 | 50 | 50 | 57 | 58 |
| Number of segments remaining | 34 | 26 | 40 | 50 | 62 |
| Number of segments in top 10 mm | 7 | 8 | 10.5 | 18 | 27 |
| Length of top 10 segments | 16 | 14 | 9 | 4 | 1.7 |
| Length of lowest remaining segment | 2.0 | 2.3 | 1.3 | 1.7 | 1.2 |
| Maximum diameter at lower end | 3.6 | 2.5 | 2.2 | 1.3 | 0.8 |
| Minimum diameter near top | 2.8 | 2.0 | 2.0 | 1.2 | 0.7 |
| Calyx : | | | | | |
| Diameter of lower end of basals | 3.6 | 2.6 | 2.4 | 1.2 | 0.7 |
| Diameter of top of radials | 5.2 | 4.2 | 3.7 | 2.4 | 1.8 |
| Maximum height radially | 1.9 | 1.7 | 1.7 | 1.1 | 0.6 |
| Post-radial series : | | | | | |
| Length IBr ₁ | 2.2 | 1.8 | 1.5 | 1.2 | 0.8 |
| Length IBr ₂ | 2.8 | 2.4 | 2.3 | 1.5 | 1.3 |
| Median breadth IBr series | 2.6 | 1.7 | 1.7 | 1.0 | 0.7 |
| Breadth at 3 + 4 | 2.2 | 1.5 | 1.7 | 0.8 | 0.4 |
| Length IBr ₁ to 3 + 4 | 9.4 | 7.9 | 7.0 | 5.0 | 3.9 |

The calyx is distinctly asymmetrical (Fig. 5a), lowest in radius E (the left anterior one viewing orally). The general skin-covering seems particularly opaque in this area and the sutures can only be seen by dissolving it in bleach – and then only very indistinctly. The suture between the basal and radial rings forms a zig-zag line. The interbasal and interrarial sutures are approximately equal in height since the latter are cut short by the meeting of the adjacent IBr₁ interradially; the interrarial calyx height is *c.* 2.7 mm. The division series and arms are almost cylindrical in cross section. The two ossicles of the division series (in one case four) are joined by syzygy.

All the arms are broken by or at the fourth syzygy, which is usually at 13 + 14 but in one case each at 12 + 13 and 14 + 15. The previous syzygies are at 1 + 2, 3 + 4 and 7 + 8 except on the pair of arms based on the IIBr series of four ossicles, which have syzygies at 2 + 3, 4 + 5 and 8 + with a pinnule on the *inside* of Br₆. All the other arms remaining beyond Br₈ have the first pinnule (P₄) on the *outside* of Br₁₀. It has 9 + (? *c.* 3) evenly tapering segments and measures 5.9 + mm in length (probably + *c.* 2.0 mm).

The tegmen (disc) is joined to the arms to about Br₇ while the prominent anal cone reaches level with Br₁₂.

PARATYPES. Specimen 2 has the top columnal fully developed, forming a perfect inverted pair to the second one. The successive joints are again aligned at not quite 90° so that there is a slight spiralling effect of the joint faces. The calyx again is somewhat asymmetrical but in this case the anterior radius, A, is the lowest. The IBr series are not quite in contact laterally, allowing the radials to

be seen interradially to a height of 3.3 mm. There are slight lateral flanges on the proximal brachials. The longest remaining arm has 21 segments left, measuring 21 mm in length; when intact it was probably about as long again. The breadth at the distal end is 1.2 mm as opposed to 1.5 mm at 3 + 4. The positions of the syzygies are very irregular and in only one or two cases does the joint between brachials 1 and 2 appear to be a proper syzygy, though 3 + 4 is developed on each arm. In one case the next syzygy is not until 13 + 14, followed by 17 +, while another has 1 + 2, 3 + 4, 6 + 7, 9 +. One arm even has two successive syzygies, 3 + 4 + 5 (as described by A. H. Clark in the holotype of *Phrynocrinus nudus*), followed by 8 + 9 and 12 +. P₄ on Br₁₀ is normally the first pinnule again, though there is a pinnule on Br₇ in one case and on Br₉ or Br₁₁ in two others. P₄ has 14-18 segments, the basal ones stout, though longer than broad and flared at the joints, while the distal segments are attenuated. The length is 6.5-8 mm. P₅ may bear a small gonad near its base. There are some very slender and often branching rods in the ambulaera. One pinnule is bifurcated near its base.

Specimen 3 has several of the topmost columnals relatively short. The calyx is not appreciably asymmetrical. The sutures between basals and radials are distinct, even when wet, owing to a slight bevelling of the edges. The division series are again slightly spaced laterally. All the arms are broken by or at the fourth syzygy; the syzygies remaining are at 1 + 2, 3 + 4, 7 + 8 and 12 or 13 +, with the first pinnule on the outside of Br₁₀.

Specimen 4 has the four topmost columnals discoidal, while the lower ones conversely are much longer relatively than in the larger specimens and are medially constricted with length: median breadth 1.6:1. It too has the sutures in the calyx distinct by virtue of being bevelled at the edges. The maximum height of the basals is c. 0.8 mm. No appreciable asymmetry is present. The division series are separate laterally and have slight lateral flanges, continued on to the arm bases.

The smallest specimen (Fig. 5c-e) shows these same tendencies even better developed. Up to 11 of the uppermost columnals are discoidal and the distalmost are only just cylindrical, not stouter medially, while the longest segments have length: median breadth as much as 2.5:1. The upper segments are so short that the usual moniliform appearance is not obvious. The division series are widely spaced laterally and there are very marked lateral flanges on them and on the first few brachials.

The main ontogenetic changes can be outlined as follows: The younger specimens have a great disparity in the relative length of the upper (short) and lower (long) columnals. The basals and radials become relatively broader in larger specimens and the calyx takes on some degree of asymmetry, though it remains to be seen if this has an antero-posterior correlation. The division series are at first widely separated laterally at their bases but gradually approximate, to become contiguous when the basal diameter of the calyx exceeds about 3 mm; they have prominent lateral flanges, continued on to the arm bases, but these gradually become obsolete and the ossicles more nearly cylindrical.

AFFINITIES. In comparison with *Phrynocrinus*, the only other genus included in the family as here restricted, *Zeuctocrinus* differs in having the more distal columnals much less moniliform and the division series limited, normally to only two ossicles.

Family PORPHYROCRINIDAE nov.

The justification for establishing this new family is given in the discussion of the Phrynocrinidae above.

DIAGNOSIS. A family of Articulata with a rounded stalk, without cirri, with several of the proximal columnals discoidal and inflexibly jointed by synostosis but with new segments formed only between the topmost one and the calyx, the middle columnals elongated and more or less cylindrical (sometimes barrel-shaped or else waisted), with synarthrial joints which distally become elliptical, alternating in alignment, giving a moniliform appearance, attached to the substrate by an expanded terminal plate; the calyx probably thick-walled, relatively small and more or less cylindrical, not markedly flared at the top, the basals slightly or very much shorter than the radials; the arms continuing the alignment and width of the radials, closely approximating laterally and obscuring the tegmen (or disc) from lateral view, syzygies alternating usually with muscular joints and pinnules lacking basally from the first two or three possible positions on each side of the undivided arms, none markedly enlarged and all lacking conspicuous side or cover plates. [The syzygies and pinnules unknown in *Naumachocrinus*, the arms of the only known specimen being broken after the first brachial.]

INCLUDED GENERA. *Porphyrocrinus* Gislén, 1925, type-species *P. verrucosus* Gislén, 1925; hitherto monotypic.

Naumachocrinus A. H. Clark, 1912a, type-species *N. hawaiiensis* A. H. Clark, 1912a; monotypic.

PORPHYROCRINUS Gislén

Porphyrocrinus Gislén, 1925: 91-92.

? *Monachocrinus* (part; *M. incrassatus*) Gislén, 1933: 483-485.

The type-species, *Porphyrocrinus verrucosus* Gislén is only known from a single specimen taken near the Kei Islands (c. 5.5° S; 133° E) in 345 metres (a relatively small depth for a stalked crinoid). It lacks the distal end of the stalk so the form of attachment is unknown. As discussed under the heading of the Phrynocrinidae, I consider that Gislén was mistaken in referring it to that family. The general facies with closely apposed arms arising from the nearly cylindrical calyx without abrupt distinction and the discoidal, rigidly articulated, proximal columnals giving way distally to more or less cylindrical segments (though these are somewhat compressed at the joints in alternating planes), is far more like that of the Bathy-crinidae than of the Phrynocrinidae.

Another specimen which I think will prove to be referable to *Porphyrocrinus* is the holotype (and only known specimen) of the supposed bathyrcrinid *Monachocrinus incrassatus* Gislén, 1933, from St Helena, in which only one ossicle remains above each radial. Gislén discarded the idea of its affinity with *Porphyrocrinus* because in that genus 'the upper part of the stem is not thickened and the distal stem-joints only very gradually reach the type of long slender knobby stem-joints which is so well developed in most Bathyrcrinidae and all Monachocrini. Besides this, all the Phryncrinidae [with which he allied *Porphyrocrinus*] are large and stout forms, while the new species just as the Bathyrcrinidae is a small and slender form.' Although the holotype of *Phryncrinus nudus* was certainly much larger, the diameter at the very top of the stalk 6 mm, the same measurement in the holotype of *Porphyrocrinus verrucosus* is only 1.5 mm, compared with 0.8 mm in the holotype of *Monachocrinus incrassatus*. It seems to me premature to assume that the last nominal species is a small one on the basis of a single specimen and I believe that the differences in the stalk could well be correlated with the smaller size. Since the species of *Monachocrinus* are characterized by having division series and ten arms, it remains for more nearly complete specimens to be collected in the vicinity of St Helena with either arms or division series present beyond the first post-radial ossicle and preferably also the entire stalk to show where its true affinity lies. The possibility that *M. incrassatus* can be referred to *Porphyrocrinus* is enhanced by two stalked crinoids collected in the southern Indian Ocean, about mid-way between South Africa and Amsterdam Island, in 400 metres. These have the diameter at the top of the stalk 1.2 and 1.3 mm. Although both have the post-radial series broken after the first ossicle, fortunately two loose arms are present with them, indicating that the first ossicle is Br_1 not IBr_1 , though it is just possible that an intervening axillary and first brachial have been lost. These two specimens resemble *P. verrucosus* except that they have more numerous discoidal proximal columnals, the radials are relatively longer, though possibly within the range of specific variation, the first pinnule is on Br_{10} on both the loose arms, as in only one out of five arms of Gislén's specimens – the other four having a pinnule on Br_8 , and the texture of the stalk is smooth throughout, though the verrucose distal part of the stalk of the Kei Islands species may be unnatural. The likelihood of these two specimens being conspecific with the holotype of *Monachocrinus incrassatus* is discouraged by the occurrence in the same haul of the bathyrcrinid *Democrinus chuni* – well known from South Africa, which is half-way to St Helena but where *Porphyrocrinus* has not been taken. It seems necessary therefore to distinguish a new species.

*Porphyrocrinus polyarthra** sp. nov.

(Fig. 6a–g)

MATERIAL. Cape Town University no. AFR.A 12481, 36°48' S : 52°08' E (southern Indian Ocean, about half-way between South Africa and Amsterdam

* Many-joints, referring to the multiple consecutive rigid joints in the distal part of the stalk.

Island to the east), 400 metres.† Holotype with a complete stalk [to be deposited in the South African Museum], paratype [B.M.reg. no. 1972.12.5.7] incomplete distally, both lacking the arms after the first post-radial ossicle; also present several detached pieces of stalk and two arms.

DIAGNOSIS. A species of *Porphyrocrinus* with the columnals smooth throughout, up to seven consecutive distal ones rigidly jointed by synostosis, usually immediately above the multilobate terminal plate; numerous proximal columnals discoidal (c.17 when the topmost stalk diameter is 1.3 mm); calyx approximately cylindrical, but slightly constricted medially, flaring gently above and below (at least in the holotype and paratype but this may be subject to variation), the interbasal and interradian sutures distinct, the radials appreciably longer than the basals; the first pinnule probably P_3 on Br_{10} .

DESCRIPTION. The holotype is the first specimen in Table 3. The distal end of its stalk terminates in a much expanded plate with finger-like lobes closely applied around a piece of scleractinian coral. The six distalmost columnals are rigidly united by successive synostoses, superficially appearing as an interrupted line like a syzygy. The disarticulated joint faces (Fig. 6g) show about 15 radiating shallow grooves around a large figure-of-eight-shaped concavity. The alignment of the stalk bends round through about 90° just above the terminal plate. Two segments with flattened, alternating, flexible synarthrial joints follow, their maximum breadth 2.1 mm. Then come five more consecutive synostosomal joints succeeded by bollard-shaped segments about twice as long as their maximum (articular) breadths, the joints slightly elliptical in alternating planes, making up most of the length of the stalk. Towards the top (proximally) the columnals shorten so that the twenty-fifth one from the calyx is about as high as broad and the seventeenth and those above it can be called discoidal. At the very top the stalk broadens again after narrowing. There are about 90 columnals altogether and the length is c. 150 mm.

TABLE 3

Numerical data from the holotype (1) and paratype of *Porphyrocrinus polyarthra* sp. nov.

| | 1 | 2 |
|---------------------------------------|-----|-----|
| Stalk : | | |
| Number of discoidal proximal segments | 17 | 11 |
| Number of segments in top 5 mm | 22 | 18 |
| Diameter at extreme top | | |
| (= bottom diameter of basals) | 1.3 | 1.2 |
| Minimum diameter just below top | 0.9 | 0.9 |
| Calyx : | | |
| Diameter at top of basals | 1.1 | 1.1 |
| Diameter at top of radials | 1.4 | 1.4 |
| Height of basals (maximum) | 0.8 | 0.6 |
| Height of radials (maximum) | 1.1 | 1.1 |

† This locality is the highest point yet known on the South-west Indian Ocean submarine ridge.

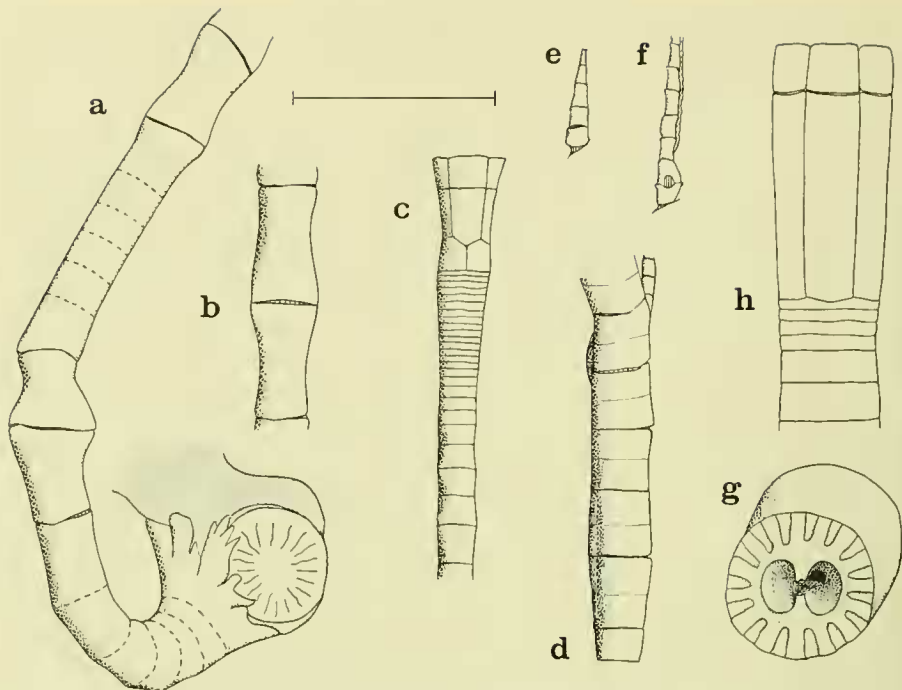


FIG. 6. a-g. *Porphyocrinus polyarthra* sp. nov. a-c. Holotype. a. Distalmost part of the stalk attached to coral (stippled). b. Columnals 59 and 60 from top. c. Calyx with adjacent ossicles. d. Proximal part of loose arm from Br_2 , showing bases of P_3 and P_4 . e. P_3 (tip missing). f. P_4 (tip missing). g. Face of distal synostosomal joint from large broken stalk fragment. h. *Naumachocrinus hawaiiensis* A. H. Clark. Holotype. U.S. National Museum cat. no. 29573. Outline of calyx with adjacent ossicles. [The scale equals 5 mm for a-f and h and 2 mm for g.]

The calyx is very slender and slightly constricted at the upper end of the basals, though the radials flare out at the top, this even flaring being continued by the first brachials, which are broader than long. The sutures in the calyx are distinct, those between the basal and radial rings making a zig-zag line.

Two detached arms were found in the crinoid debris taken at this station which are very likely to have come from this specimen or the paratype. [Although *Democrinus chuni* was also collected, its arms differ in tapering from Br_3 and have the first pinnule on Br_6 .] The first ossicles on both these two arms have a syzygy on the proximal face and their breadth corresponds with that of the distal end of the first post-radial ossicle still attached to the calyx, so I am fairly confident that they can be regarded as Br_2 s. They expand to a maximum breadth of 1.5 mm at Br_5 , having well-marked lateral flanges, and only very slowly taper distally. Both measure c. 40 mm in length. Syzygies and muscular joints normally alternate from 1 + 2, 3 + 4 onwards but one of the two arms has extra muscular

joints at 13 - 14, 46 - 47, 53 - 54 and 58 - 59, though the other only has one such joint at 59 - 60. The last brachial remaining in both is Br_{66} , ending in a syzygy and showing no terminal modifications. The first pinnule is on the left side of Br_{10} and can be regarded as P_3 . It probably had six or seven segments and a fairly attenuated tip tapering from a stout base; the joint between the first two segments is particularly flexible and this is even more true on the subsequent pinnules (see Fig. 6e and f).

PARATYPES. The distal ends of two other stalks are present. One has the lobes of the terminal plate almost meeting around a cylindrical piece of coral and only two of the consecutive distalmost segments jointed by synostosis, though three further ones are similarly jointed after an interval of several synarthrial joints. The other is stouter and has the six distalmost joints rigid, curving through 90° as in the holotype. The surface of all these pieces of stalk is quite smooth. The calyx with incomplete stalk is very similar to that of the holotype except for having fewer discoidal proximal columnals.

AFFINITIES. The affinities of these specimens and justification for describing them as a new nominal species are recounted in the discussion of the genus *Porphyrocrinus*. However, the use of the number of discoidal proximal columnals as a character of specific weight needs some qualification. Gislén (1925) counted nine of the topmost columnals of the holotype of *Porphyrocrinus verrucosus* as discoidal but I would say that the ninth one was already too thick to be so described, at least judging from his figure 2, leaving only 8 compared with 11 and 17 in the two slightly smaller specimens of *P. polyarthra*. Even so, the wide variation in these two and the likelihood that the number of discoidal proximal segments decreases with growth (as it does in bathyocrinids and phrynocrinids) combine to suggest that this difference may not be significant. The holotype of *P. verrucosus* lacked the distal extremity of the stalk beyond the eighty-sixth columnal and Gislén only observed one distal synostosis, between segments 33 and 34. However, it is just possible that more distal ones were overlooked since the last 30 segments had their articulations obscured by the 'verruose' surface texture (though the shape should have indicated any absence from the usual alternating synarthrial jointing). If more nearly complete specimens from the vicinity of the Kei Islands also prove to show multiple distal synostoses and if the peculiar texture of the distal part of the stalk of the holotype of *P. verrucosus* turns out to be abnormal, then the distinction of two species will be difficult.

Naumachocrinus hawaiiensis A. H. Clark

(Fig. 6h)

Naumachocrinus hawaiiensis A. H. Clark, 1912a: 195-197; 1915, fig. 129.

A figure of the calyx of the holotype in the U.S. National Museum is given here, since it is very small in Austin Clark's figure. I could not detect the very short interbasal sutures. The basal ring is 0.3-0.4 mm high; the decimal point was omitted in A. H. Clark's description.

Family **BATHYCRINIDAE** Bather

Bathycrinidae Bather, 1899: 922; Gislén, 1924: 206-212; 1927: 53-54; 1938: 3-14; A. M. Clark, 1970: 13.

Although a number of diagnoses for this family have already been given (including one of my own which was largely comparative with the fossil Bourgueticrinidae), a modified version for comparison with those for the three preceding families may be useful.

DIAGNOSIS. A family of Articulata with a rounded stalk, without true cirri, with some of the proximal columnals discoidal and inflexibly jointed by synostosis but with new segments formed only between the topmost one and the calyx, the middle columnals elongated and more or less cylindrical (sometimes barrel-shaped or else waisted), with synarthrial joints which distally become elliptical, alternating in alignment, giving a moniliform appearance, attached to the substrate by irregular, branching, jointed, radicular 'cirri' arising from several of the distal-most columnals; the calyx thick-walled, relatively small and rather variable, ranging from almost cylindrical to inverted conical, the basals either separate or fused together, longer or shorter than the radials, which may also be distinct or occasionally fused with the basals; the division series or arms following the radials continuing the same alignment, closely approximating laterally and obscuring the tegmen (or disc) from lateral view, syzygies numerous, mostly alternating with muscular joints though proximally there may be several pairs of successive muscular joints, pinnules lacking basally from the first two or three possible positions on each side of the arms, none markedly enlarged and all lacking conspicuous side or cover plates.

REMARKS. This family is normally linked with the fossil Bourgueticrinidae in the suborder Bourgueticrinina on account of the root-like stalk attachment common to both (where known). However, the diagnosis just given is remarkably similar to that provided for the new family Porphyrocrinidae, except for the lobed attachment plate terminating the stalk in the latter (besides minor differences in the calyx). A thorough review of the relationships between the recent and fossil stalked Articulata is needed. Several of the families known only from recent material were omitted from the classification given by Ubahgs (1953). It is to be hoped that their affinities will be resolved by the long-awaited crinoid part of the *Treatise on Invertebrate Paleontology*.

Democrinus chuni (Döderlein)

Rhizocrinus chuni Döderlein, 1907: 14-15, pl. 1 fig. 5, pl. 6 fig. 6.

Democrinus chuni: Gislén, 1938: 26-27; A. M. Clark, 1972: 146-150, fig. 17.

MATERIAL. Cape Town University no. AFR.A 1248I, 36°48' S: 52°08' E (southern Indian Ocean, about half-way between South Africa and Amsterdam Island to the east), 400 metres. One specimen.

Cape Town University no. ABD 11F ['Anton Bruun' cruise 7, st. 389C], 30°12' S : 32°01' E (off Durban), 1360 metres. One small specimen.

The specimen from the southern Indian Ocean has about 100 mm length of stalk still attached to the calyx; probably this represents only about half the total length. The calyx has an extra transverse suture across the basal ring at about three-quarters of its height.

The small specimen shows the usual immature inverted conical shape of the calyx. The stalk trifurcates at the twenty-fifth segment, about 10 mm below the calyx.

RANGE. The first record provides an extension of range for this species, otherwise known from east and south Africa.

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