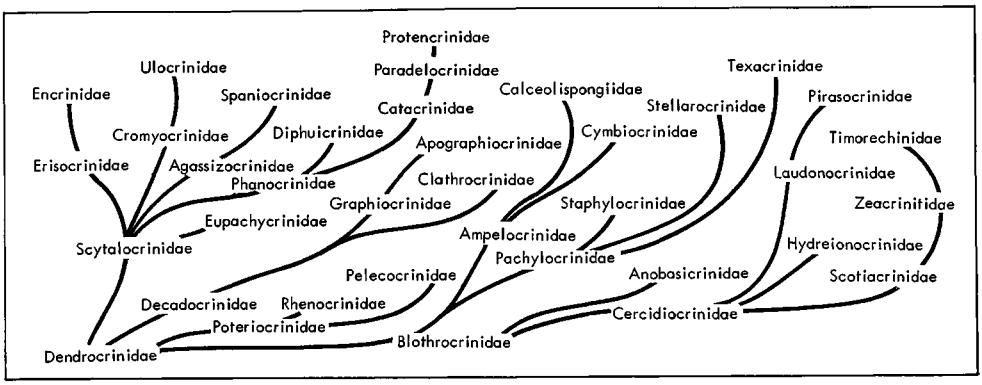


FIG. 412. Inferred phylogeny of suprageneric divisions of Poteriocrinina.

to or above tips of arms, composed of small polygonal plates. Relatively large stem round transversely. *L.Dev.-L.Penn., ?M. Penn.-?U.Perm.*

Family POTERIOCRINITIDAE Austin & Austin, 1842

[*nom. correct.* BASSLER, 1938, p. 20; *pro* fam. Poteriocrinoidea AUSTIN & AUSTIN, 1842, p. 108 *(nom. imperf.)* (=Poteriocrinidae AUSTIN & AUSTIN, 1843, p. 195)] [=Poteriocrininae, Poteriocrinidae JAEKEL, 1918, p. 61; Rhabdocrinidae WRIGHT, 1944, p. 266]

Crown large. Cup conical, with three or four anal plates in cup; radial articular facets narrow or peneplenary, all strongly rounded, mostly with well-developed transverse ridge; anal sac large, elongate, commonly with spinose summit plates, and may have pores or slits at plate boundaries. Arms uniserial, branching once or several times isotomously; pinnulate. *L.Dev.-L. Penn., ?M.Penn.-?U.Perm.*

[Although this family name was credited to ROEMER (1851) by BASSLER (1938), the first usage of the genus *Poteriocrinites* (=*Poteriocrinus*) as a type of a family-group name was by AUSTIN & AUSTIN (1842), who classified this group as the second family of their order Cionacineti. In 1843 they corrected the family name to Poteriocrinidae and the name was used in this form in their monograph (1846, p. 68). The family name was also used by BRONN, GÖPPERT, & VON MEYER (1848, p. 173) and credited to the AUSTINS, prior to citation of the family by ROEMER.]

This assemblage is now somewhat narrowly defined. According to common earlier classification, the family was so loosely and broadly expanded that virtually all dicyclic inadunates having a transverse ridge on the radial articular facets were included in it. The family seems to have no significant differences from the Botryocrinidae except in the beginning of signs of muscular articulation on the radial articular facets and in the higher development of pinnulation of the arms. The facets are narrow, rather strongly outward-downward sloping, and marked by a fairly distinct transverse ridge. Characters of the anal sac and the arrangement of anal plates of the cup suggest that the poteriocrinitids may have been derived from the Dendrocrinidae, rather than the Botryocrinidae. The oldest known representative of the Poteriocrinitidae occurs in Lower Devonian rocks of Europe; the type species of *Poteriocrinites* and several others occur in Lower Carboniferous deposits. Whether or not identifications of several Pennsylvanian and some Permian cups as belonging to *Poteriocrinites* are valid is not known, but the occurrence of undoubted representatives of the family in post-Mississippian rocks is not established.

Key to Genera of Poteriocrinitidae

A. Cup conical with truncate base; anal plates in cup 3-4, anal sac mostly large, elongate cylindrical .....
  I. Radial articular facets narrow; horseshoe shaped .....
    a. Arms 10, branching first on primibrachs *2*; stem pentagonal, cirriferous ..... *Denariocrinus*
    b. Arms 30 or more, branching first on primibrachs *1-14*; tall anal sac with laterally directed spines at summit ..... *Poteriocrinites*
    c. Arms 30-40, branching first on primibrachs *1-8*; anal sac with plicate plates .....
      1. Arms approximately 30, branching first on primibrachs *4*, anal sac

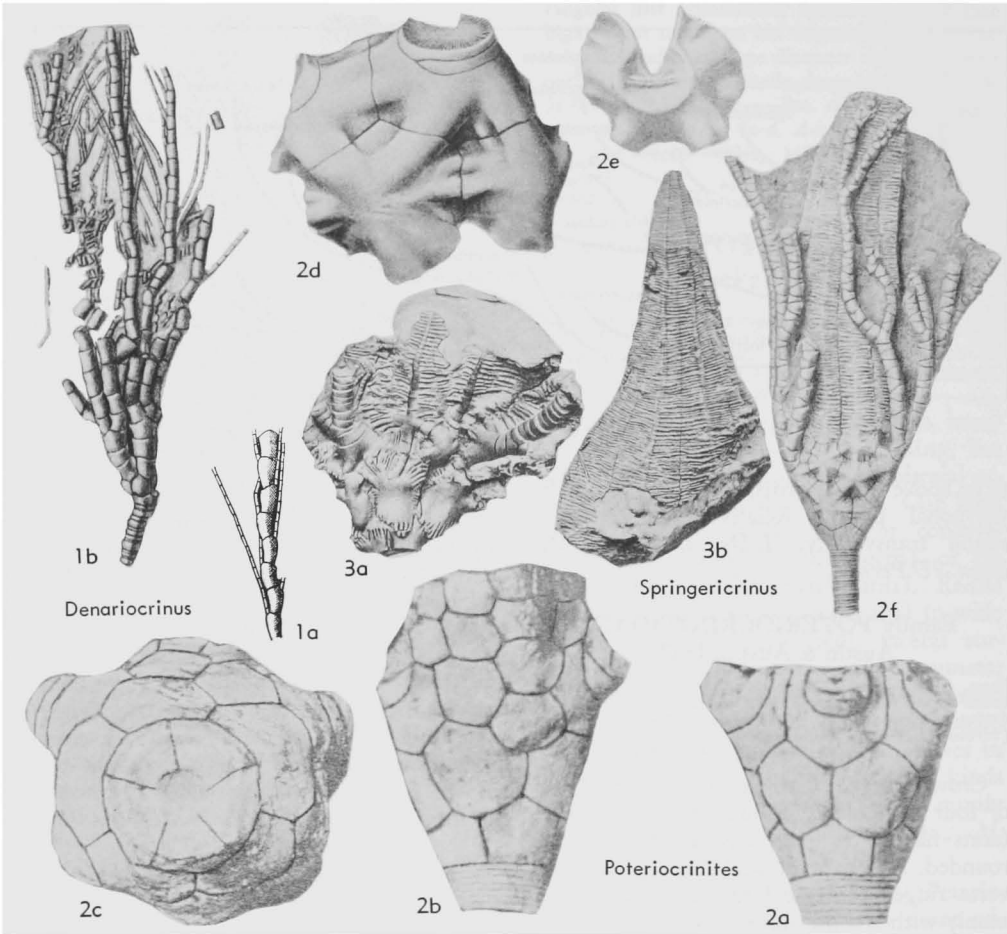


FIG. 413. Poteriocrinitidae (p. *T*632-*T*633).

with spines at summit .... *Propoteriocrinus*

2. Arms 40 or more, branching first on primibrachs *1-8*; anal sac very broad at base, terminating distally in point without summit spines; composed of plicate plates; cup plates fluted ..... *Springericrinus*

II. Radial articular facets concave, broadly rounded externally, lacking transverse ridge, crenulated along outer margin; many arms, branching first on primibrachs *13* or above ..... *Rhabdocrinus*

Poteriocrinites MILLER, 1821, p. 14 [**P. crassus*; M] [=*Poteriocrinus* AGASSIZ, 1836, p. 197]. Crown elongate, subcylindrical, or expanding uniformly upward. Cup conical, surface of plates smoothly rounded or with broad flutes normal to sutures; infrabasals 5, basals 5; radials wider than high, *C* radial slightly smaller than others, and elevated above their level, articular facets narrow, horseshoe shaped, with weak transverse ridge; radianal, anal *X* and 1 or 2 other anal plates in cup. Anal sac large, cylindrical or club shaped in some, commonly with long, spinose hexagonal plates at summit, pierced at sutures by pores or slits that penetrate margins of plates; anal opening rarely observed, but in all known, situated laterally and low on side of sac. Arms uniserial, long, branching isotomously several times; primibrachs *1* to *14* axillary; pinnulate. Stem transversely round or subpentagonal, composed of thin columnals with small, round lumen. *L.Dev.-U.Miss.(L.Carb.), ?U.Perm.*, USA-Eu.(Eng.-Ger.-Belg.-Ire.-France-Scot.)-Australia.——FIG. 413,*2a-c*. **P. crassus*, L.Carb., Eng.; ant., post., and dorsal views of cup, ×1.5 (Wright, 1950-54).——FIG. 413,*2d,e*. *P. macropleurus* (HALL), L.Miss., Iowa; basal view of incomplete cup and radial plate, ×1

(Springer, 1911c).——FIG. 413,*2f*. *P. doris* (HALL), L.Miss., Iowa; post. view of crown, ×0.7 (Springer, 1911c).

Denariocrinus SCHMIDT, 1942, p. 163 [**D. ferula*; M]. Crown narrow and elongate. Cup steeply conical; infrabasals very low; basals large and elongate; radials high and narrow; 4 anal plates in cup, posterior interray wide, radianal and anal *X* large, supporting 2 tube plates. Anal sac not known. Arms uniserial, branching isotomously on primibrachs *2*, with 10 main rami; brachials elongate, with inclined sutures that give slightly zigzag appearance to arms; pinnules long and very slender. Stem transversely subpentagonal, cirriferous. *M.Dev.*, Eu.(Ger.).——FIG. 413,*1*. **D. ferula; 1a,* distal brachials and pinnules, ×2; *1b,* ant. view of crown, ×1 (Schmidt, 1942).

Propoteriocrinus SCHMIDT, 1942, p. 110 [**P. follmanni*; OD] [=*Propoteriocrinus* SCHMIDT, 1934, p. 109 (*nom. nud.*, no description or figure of species)]. Crown tall, cylindrical. Cup small, bowl shaped, infrabasals low, basals relatively large; 3 anal plates in cup. Anal sac very large, elongate and cylindrical, composed of several rows of hexagonal, plicate plates, summit capped by plates with short, blunt spines. Arms uniserial, slender; primibrachs *4* axillary, with 2 higher isotomous branches in each half-ray; pinnules stout, directed obliquely upward, producing comblike appearance of arms. Stem transversely pentagonal. *L.Dev.*, Eu.(Ger.).——FIG. 414,*1a,b*. **P. follmanni; A*-ray and post. views of 2 partial crowns, one with anal sac preserved, ×1.5 (Schmidt, 1941).——FIG. 414,*1c*. *P. scopae* SCHMIDT; lat. view of crown, ×0.7 (Schmidt, 1934).

Rhabdocrinus WRIGHT, 1944, p. 266 [**Poteriocrinus scotocarbonarius* WRIGHT, 1937, p. 397; OD]. Cup cone shaped, with wide base and convex plates, depressions at plate angles; infrabasals large, upflaring, convex, widely truncate above large proximal columnal; basals large, convex; radials small, wider than high, with arcuate distal border, curved articular facets sloping strongly outward-downward; 3 large anal plates in cup. Anal sac not known. Primibrachs 13 or more, higher parts of arms not known; brachials very thin, rounded, proximal 3-5 brachials fixed into theca by small interradial plates in all interrays; articular surfaces of brachials with radiating fine crenellae next to outer edges. *L.Carb.(Tournais.)-U.Carb.(Namur.)*, Eu.(Scot.-Eng.-Ire.-Belg.-USSR).——FIG. 414,*2*. **R. scotocarbonarius* (WRIGHT), L.Carb., Scot.; *2a,b,* post. and ant. views of cup and proximal brachials, ×1; *2c-e,* ventral, lower, and int. views of radial plate, enl. (Wright, 1944).

Springericrinus JAEKEL, 1918, p. 62 [**Poteriocrinus magniventrus* SPRINGER, 1911c, p. 155; OD]. Crown large and explanate. Cup large, cone shaped, plates with distinctive radiating folds, subsidiary ridges and troughs disposed normal to sutures; rounded radial articular facets narrow, with weak transverse ridges, sloping outward-downward as in *Poteriocrinites*; 3 anal plates in cup. Anal sac very large, broad at base and tapering to point distally, anal opening apparently low on side of sac, plates wide, low, each with sharply elevated, rounded ridges and adjacent grooves; base of sac composed of thick, small ossicles. Arms uniserial, branching isotomously on primibrachs *1-3*, with 2 or 3 higher bifurcations; brachials short, wedge shaped, pinnules short and stout. Stem composed of alternating thick and thin round columnals; lumen very large. *L.Miss.*, USA(Ind.-Iowa).——FIG. 413,*3*. **S. magniventrus* (SPRINGER), Ind.; *3a,b,* post. view of theca and base of anal sac, and isolated anal sac, ×0.5 (Springer, 1911c).

Superfamily RHENOCRINACEA Jaekel, 1918

[*nom. transl.* MOORE in MOORE & STRIMPLE, 1973, p. 19 (*ex* Rhenocrinidae JAEKEL, 1918, p. 59)] [Materials for this superfamily prepared by R. C. MOORE, H. L. STRIMPLE, and N. GARY LANE]

Similar to Poteriocrinitacea, differing in having peneplenary radial articular facets, mostly with shallowly curved outer facet margins, interradial notches at rim of cup narrow to moderately wide and distinct. *L.Dev.-U.Miss.; M.Penn.*

Family RHENOCRINIDAE Jaekel, 1918

[Rhenocrinidae JAEKEL, 1918, p. 59] [=Glossocrinidae GOLDRING, 1923, p. 389]

Cup low cone shaped; differing from Poteriocrinitidae in shallowly curved outer margin of its radial articular facets; three anal plates in cup. Anal sac large, elongate, mostly with posterior longitudinal row of large sac plates bordered laterally by small, low plicate plates. Arms slender, uniserial, pinnulate, with one or several isotomous branches, or, rarely, atomous; two, three, or numerous primibrachs present in a ray. Stem transversely pentagonal or rarely round. *L.Dev.-U.Miss.; M.Penn.(Atokan)*.

Crinoids of this group are differentiated from the Poteriocrinitidae only by wider radial facets and some details of arm structure. Several rhenocrinid genera have a prominent row of plates extending upward on the posterior side of the anal sac. The family seems to be a branch of the poteriocrinitid stock.

Key to Genera of Rhenocrinidae

A. Cup plates smooth, not fluted; anal sac

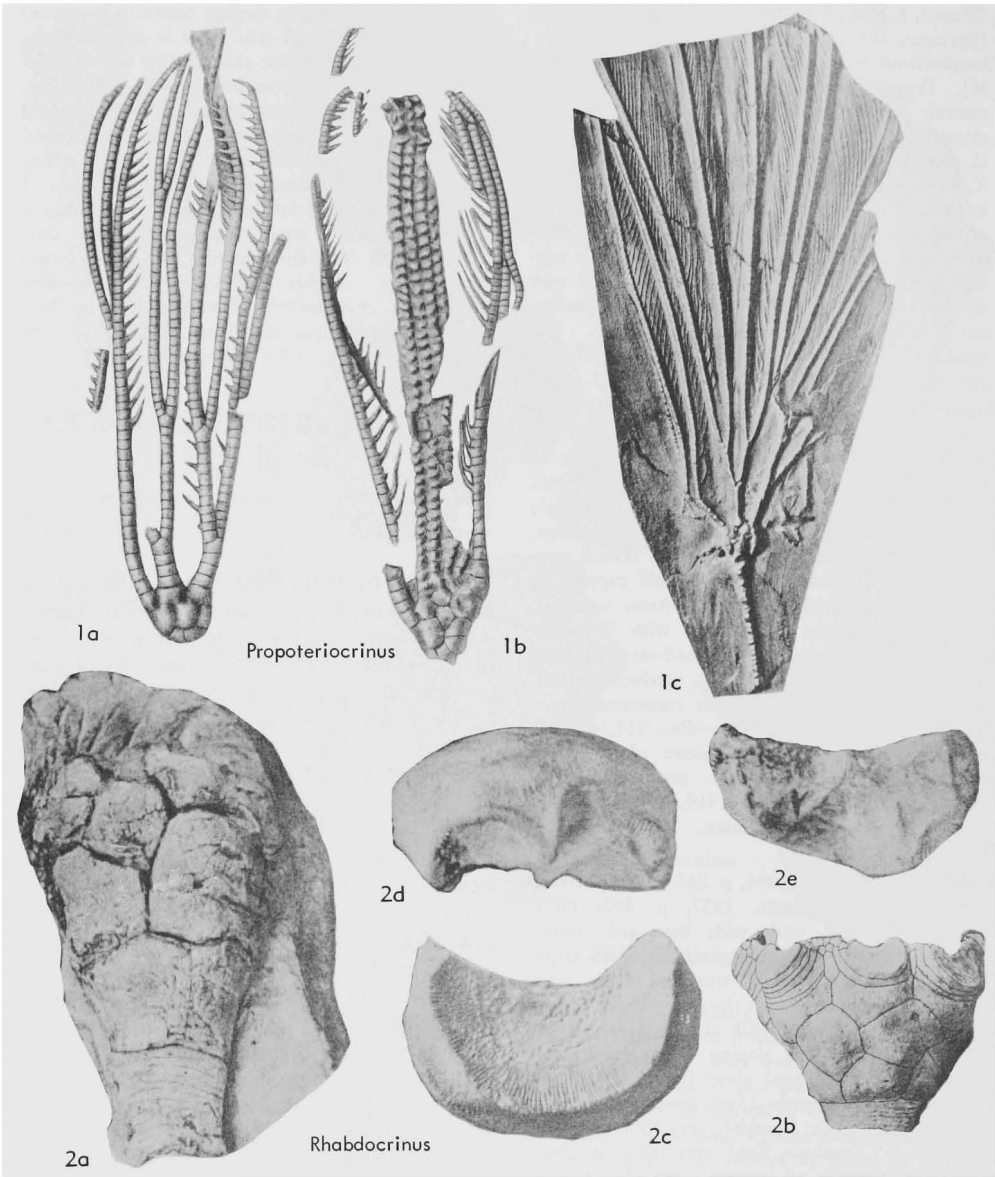


FIG. 414. Poteriocrinitidae (p. *T633*).

lacking prominent "backbone" of large polygonal plates on posterior side; stem transversely round .....

I. Arms few, uniserial, pinnulate; radial articular facets moderately wide, well curved outwardly .....

a. Arms 20 or more, branching isotomously first on primibrach *4* or *5*, very tall anal sac composed of vertical rows of plicate plates .... *Araeocrinus*

b. Arms 20 or more, each half ray endotomous, anal sac unusually broad, tall, composed of large nodose plates with radiating ridges ..... *Cydrocrinus*

c. Arms 7-10, branching on primibrachs *6-36*, some arms atomous .... *Rhenocrinus*

d. Arms 10, without endotomous smaller arms, anal sac composed of longitudinal small hexagonal plates

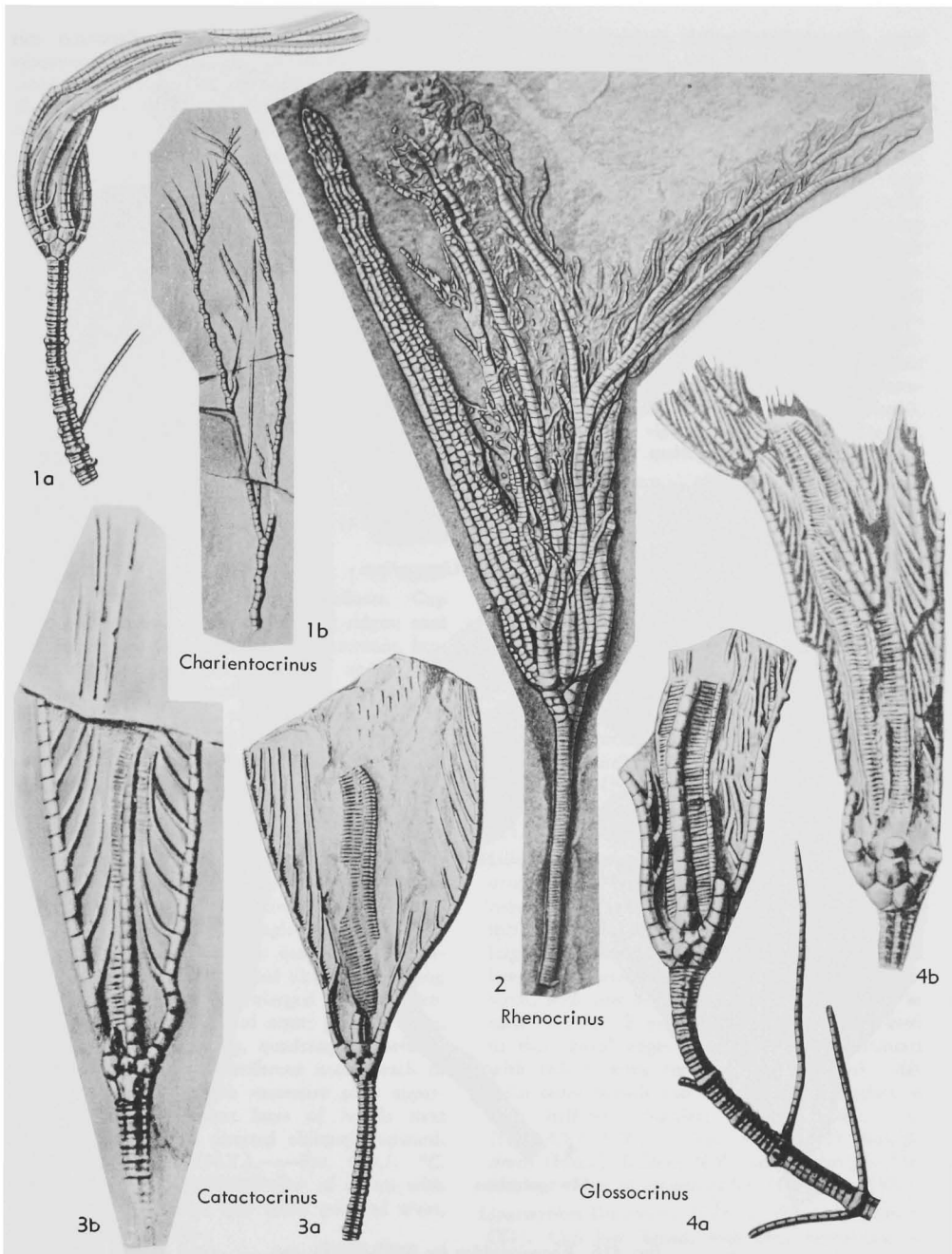


FIG. 415. Rhenocrinidae (p. *T636-T637*).

..... *Maragnicrinus*

II. Arms 80-90, branching first isotomously on primibrach *3*, and then heterotomously .....
In endotomous pattern; anal sac plates plicate ..... *Hallocrinus*

B. Cup plates fluted, with pits at plate angles; anal sac with prominent longitudinal row of polygonal plates on posterior side; stem transversely pentagonal or pentalobate ....
I. Arms 5; stem pentalobate ..... *Catactocrinus*
II. Arms 5-10; stem cirriferous .....

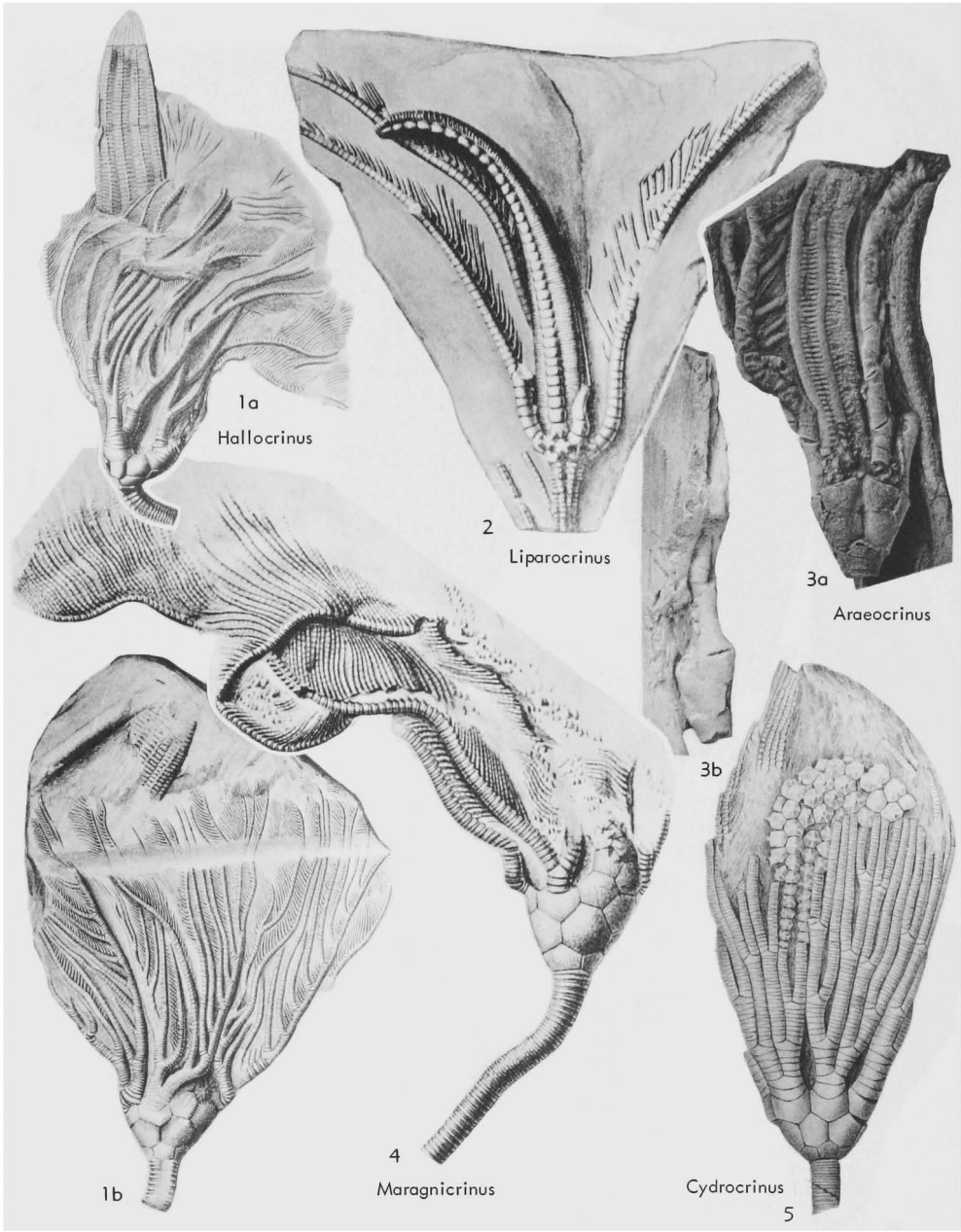


FIG. 416. Rhenocrinidae (p. *T637-T638*).

a. Arms branching on primibrachs *19-20*; anal sac with rows of small polygonal plates; stem pentagonal .... *Charientocrinus*

b. Arms branching on primibrachs *2-6*; anal sac with rows of plicate plates; stem pentagonal ..... *Glossocrinus*

c. Arms branching on primibrachs *7* or higher; anal sac with rows of plicate plates; stem pentalobate .... *Liparocrinus*

Rhenocrinus JAEKEL in SCHMIDT, 1906, p. 544 [**R. ramosissimus*; M]. Cup small, low, broadly trun-

cate proximally, plates smooth; cup anal plates supporting large, elongate, cylindrical sac composed of several vertical rows of small, hexagonal plates. Arms long and slender, unbranched or with single isotomous division high above cup; long stout ramules on alternate sides of every second brachial. Stem transversely round. *L.Dev.*, Eu.(Ger.).——FIG. 415,*2*. **R. ramosissimus; B*-ray view of crown and part of stem, ×1 (Schmidt, 1934).

Araeocrinus STRIMPLE & WATKINS, 1969, p. 196 [**A. bassus*; OD]. Cup high cone shaped; infrabasals rising evenly from columnar attachment area; radial articular facets not quite filling width of plates. Arms uniserial, 20 or more, branching first isotomously on primibrachs *4-5*, cuneate brachials, syzygial pairs common, large pinnules. Tall anal sac composed of thin plicate plates. Column transversely round. *M.Penn.(Atokan)*, USA (Texas).——FIG. 416,*3*. **A. bassus*, Marble Falls F., San Saba Co., Texas; *3a,b*, holotype crown from *D*-ray and post. sides, ×1.5 (Strimple & Watkins, 1969).

Catactocrinus GOLDRING, 1923, p. 405 [**C. leptodactylus*; OD]. Crown slender, delicate. Cup small, cone shaped; plates with radial ridges; anal sac like that of *Glossocrinus*. Arms atomous, brachials elongate, pinnules very long and robust. Stem pentagonal proximally, becoming round distally, without cirri in proximal parts. *U.Dev.*, USA(N.Y.).——FIG. 415,*3*. **C. leptodactylus; 3a,b*, ant. and post. views of incomplete crowns with attached stems, ×2 (Goldring, 1923).

Charientocrinus GOLDRING, 1923, p. 402 [**C. ithacensis*; OD]. Crown long and slender. Cup low, broad; vertical row of large anal sac plates as in *Glossocrinus*. Arms very long, with numerous primibrachs, first isotomous division occurring on primibrachs *17-20*, with single higher division rarely in some rays; brachials quadrangular proximally, becoming wedge shaped distally, with long pinnule on every second enlarged brachial, producing zigzag appearance of arms; pinnules long, slender, composed of long, quadrangular ossicles. Stem pentagonal, with cirriferous nodals each of which bears 2 cirri, with successive pairs apparently borne by different faces of nodals next above or below, cirri directed obliquely upward. *M.Dev.-U.Dev.*, USA(N.Y.).——FIG. 415,*1*. **C. ithacensis*, U.Dev.; *1a,b*, lat. view of crown with proximal part of stem, and distal parts of arms, ×1 (Goldring, 1923).

Cydrocrinus KIRK, 1940, p. 323 [**Poteriocrinus coxanus* WORTHEN, 1882, p. 4; OD]. Crown of medium height, compact, expanding gradually to about three-fourths height, then contracting. Cup broadly turbinate, plates relatively thin, unornamented; infrabasals large, making up appreciable amount of cup; basals large. Radianal large, pentagonal, not entering deeply between posterior and right posterior basals; anal *X* large, extending well above level of radials, right tube plate small. Anal sac unusually broad and stout, three-fourths to three-fifths height of crown, composed of large nodose plates with radiating ridges, but not spinose. Arms parendotomous (i.e., each half-ray endotomous); 2 primibrachs in all rays (variation possible in anterior ray, as apparently in type specimen of *C. concinnus*, the only example known; 2 or 3 divisions in each half ray, giving a great number of closely crowded rami. Brachials wedge shaped to cuneate, pinnules long, moderately stout; arm facets plenary, slightly crescentic, sutures not gaping. Stem transversely circular, lumen pentalobate. [Most nearly resembles *Blothrocrinus* but differs in relatively short, compact crown and numerous rami.] *L.Miss.*, USA(Iowa-Ind.-Ill.).——FIG. 416,*5*. **C. coxanus* (WORTHEN), Keokuk, Ill.; ant. view of crown, ×0.5 (Worthen, 1883).

Glossocrinus GOLDRING, 1923, p. 389 [**G. naplesensis*; OD]. Crown long and slender. Cup low cone shaped, plates convex and with radiating ridges; right tube anal plate supporting vertical row of large convex quadrangular anal sac plates; other plates of elongate sac with 4 or 5 high thin folds, giving sac a plicate appearance. Arms uniserial, stout and long, brachials quadrangular or slightly wedge shaped in side view; primibrachs *2* to *6* axillary, one higher isotomous division; except axillaries all brachials bearing long pinnules. Stem pentagonal in section, with long, widely spaced, upwardly directed cirri along its length. *U.Dev.*, USA(N.Y.).——FIG. 415,*4*. **G. naplesensis; 4a,b*, post. and ant. views of crown and stem, ×1.4 (Goldring, 1923).

Hallocrinus GOLDRING, 1923, p. 374 [**Cyathocrinus ornatissimus* HALL, 1843, p. 247; OD]. Cup low cone shaped, plates with depressions at angles; infrabasals low; radials low and broad. Anal sac large, composed of several longitudinal rows of low, broad, transversely plicate plates. Arms uniserial, with low broad brachials; 3 primibrachs in each ray, first 2 primibrachs may be constricted so that lateral edges of primaxil are in contact with radial; arms endotomously branched, with main outer branch and 7 or 8 inner branches of each half-ray pinnulate. *L.Dev.-L.Carb.*, Eu. (Ger.)-USA(N.Y.).——FIG. 416,*1*. **H. ornatissimus* (HALL), U.Dev., N.Y.; *1a,b*, *D*-ray and *CD*-interray views of crown, ×0.6 (Goldring, 1923).

Liparocrinus GOLDRING, 1923, p. 397 [**L. batheri*; OD]. Cup low, broad, with deep depressions at plate angles; radials small, fluted; 3 anal plates in cup, right tube plate large, radial-like in appearance and supporting longitudinal row of large quadrangular convex sac plates bordered laterally by thin, plicate plates; anal sac large, tapering to point distally. Arms long, stout, brachials quadrangular in side view and convex; one isotomous division in each ray high above cup; pinnules stout and long. Stem strongly pentalobate proximally,

with stout cirri directly obliquely upward. *U.Dev. (Chemung.)*, USA(N.Y.).——FIG. 416,*2*. **L. batheri; CD*-interray view of crown and proximal part of stem, ×0.93 (Goldring, 1923).

Maragnicrinus WHITFIELD, 1905, p. 17 [**M. portlandicus*; M]. Cup moderately high bowl shaped; plates with fine sculpture; infrabasals high; radials with widely rounded peneplenary articular facets; 3 anal plates in cup, anal *X* and right tube plate supporting 3 large sac plates followed by several longitudinal rows of hexagonal plates bearing radiating ridges. Arms uniserial, long, slender, branching on primibrachs *3*, secundibrachs low, outwardly wedge shaped, pinnulate. Stem transversely round. *U.Dev.(Portage Gr.)*, USA(N.Y.). ——FIG. 416,*4*. **M. portlandicus; D*-ray view of crown and partial stem, ×0.93 (Whitfield, 1905).

Family PROCTOTHYLACOCRINIDAE Kier, 1952

[Proctothylacocrinidae KIER, 1952, p. 71]

Cup small, highly ornamented; radials with wide, deep articular facets not extending full widths of the plates; three anal plates in cup; anal sac large, cylindrical, plates highly plicate. Arms branching isotomously several times; nonpinnulate. *M.Dev.*

Proctothylacocrinus KIER, 1952, p. 71 [**P. longus*; OD]. Cup steeply conical and broadly truncate at base; cup plates with strong radiating ridges; infrabasals low, spear shaped, projecting distally between basals, circlet only slightly wider than proximal columnal; basals pentagonal, separated by deep indentations, bridged across sutures by ridges; radials pentagonal, slightly wider than high, and smaller than basals; radiating ridges connecting to all adjacent plates except first primibrachs; radial articular facets wide, deep, subovate, not extending full width of plates; leaving small interradial notches; 3 anal plates in cup, radianal slightly smaller than radials, pentagonal; anal *X* and 2 to 4 succeeding sac plates larger, more inflated than remaining anals. Anal sac large, plates low, broad, bearing prominent transverse ridges. Arms branching isotomously several times, composed of quadrangular brachials, nonpinnulate; primibrachs *3* to *5* axillary. Stem composed of thin round columnals. *M.Dev.*, USA(Ohio).——FIG. 417,*1*. **P. longus; 1a,b, CD*-interray views of incomplete crown with very tall anal sac and attached stem, ×0.87, ×1.6; *1c*, ant. of crown with stem, ×0.87 (Kier, 1952).

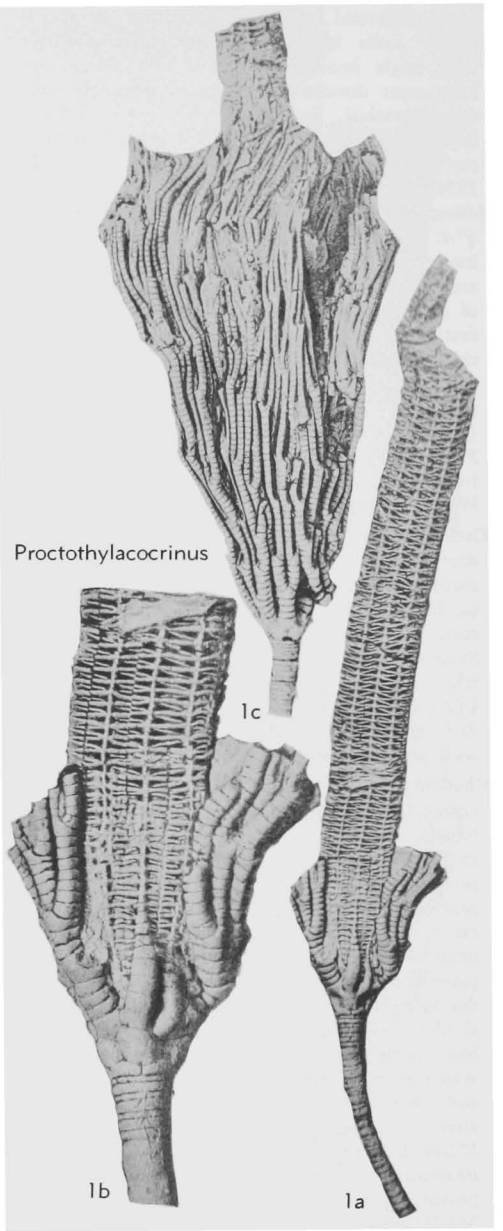


FIG. 417. Proctothylacocrinidae (p. *T638*).

Superfamily SCYTALOCRINACEA Moore & Laudon, 1943

[*nom. transl.* MOORE & STRIMPLE, 1973, p. 19 (*ex* Scytalocrinidae MOORE & LAUDON, 1943a, p. 59)] [incl. Hydriocrininae JAEKEL, 1918, p. 63] [Materials for this superfamily prepared by R. C. MOORE and H. L. STRIMPLE]

Crown mostly tall, with few to very many erect uniserial arms. Cup conical, with infrabasals visible in side view; radial articular facets plenary. Arms branching isotomously. Stem transversely round. *M. Dev.-U.Perm.*

Family SCYTALOCRINIDAE Moore & Laudon, 1943

[Scytalocrinidae Moore & Laudon, 1943a, p. 59] [=Scytalecrinidae Bather, 1899b, p. 922]

Crown slender, tall. Cup conical; infrabasals five, visible from side; radial articular facets wide, bearing transverse ridge and ligament pits; three anal plates in cup. Anal sac tall, slender. Arms uniserial (exceptionally biserial), branching on primibrachs *2* in early forms and usually on primibrachs *1* in later ones but may remain unbranched; pinnulate. *M.Dev.-U.Perm.*

Several families thought to have been derived from dendrocrinid stock show development along lines that differ from those of the blothrocrinids and their presumed allies. The oldest of this group is the Scytalocrinidae, which appear in the Middle Devonian and range to Upper Permian. The cup of the scytalocrinids is only a little changed from primitive form and structure. The longitudinally straight sides slope steeply, and the infrabasal plates are visible from the side, but not uncommonly the base is truncate. Three anal plates occur on the posterior side of the cup. The arms are distinctly advanced in evolution, although they may be interpreted as a development toward simplified structure. A single isotomous division occurs in each ray immediately above the lowermost brachial; the uniserially arranged arm segments bear pinnules. This arm plan does not differ from that of a moderately advanced mastigocrinid, such as *Lasiocrinus,* except that the isotomous division is closer to the cup, and the branchlets, or pinnules, are much more numerous, being borne by every brachial. The blothrocrinids and most allied genera retain the early dendrocrinid habit of several isotomous arm divisions; the scytalocrinids suppress this tendency. Evidence is not now at hand to prove that many-branched crinoids, such as the blothrocrinids, were not evolved from five- or ten-armed types, like the scytalocrinids, or vice versa, but the phylogeny of the families seems to be interpreted best as represented diagrammatically in Figure 412. The tall anal sac of the Scytalocrinidae is of dendrocrinid type; its many small plates seem to be less firmly united than in other families so far considered.

Key to Genera of Scytalocrinidae

A. Arms 20 or more .....
  I. Branching isotomously on primibrach *1,* secundibrachs *4* and higher .....
    a. Cup cone shaped, anal sac reflexed tube of stout rugose plates .. *Haeretocrinus*
    b. Cup bowl shaped with upflared infrabasals, anal sac unknown, 3 anal plates advanced, anal *X* and right tube plate with confluent distal surfaces ..... *Tundracrinus*
  II. Branching on primibrachs *1* or *2* and secundibrachs *7-11,* anal sac thin-plated recurved tube ..... *Sostronocrinus*

B. Nine or ten uniserial arms (except *Hydriocrinus*) .....
  I. High, steep-sided cup, prominent infrabasals .....
    a. Brachials somewhat elongated .....
      1. Arms divided on primibrachs *1* or *2*; anal *X* and right tube plate with common distal articulating facets ..... *Melbacrinus*
      2. Arms divided on primibrachs *2* or *3* ..... *Logocrinus*
      3. Arms divided on primibrachs *2* ..
        a). Impressed sutures, depressions at plate angles, transversely pentagonal stem .. *Corematocrinus*
        b). Smooth cup, sutures not impressed ..... *Bridgerocrinus*
        c). Advanced anal plates, radianal in CD position ..... *Prininocrinus*
    b. Brachials short .....
      1. *A* ray undivided commonly or invariably .....
        a). Cup low truncate conical, arms relatively stout .. *Histocrinus*
        b). Cup high conical, arms slender ..... *Hypselocrinus*
      2. All rays divided on primibrachs *1* (except *Phacelocrinus* which may have 1 or 2 primibrachs) .....
        a). Pentagonal stem .....
          1). Three anal plates in cup with normal arrangement, 10 arms ..... *Phacelocrinus*
          2). Anal *X* and right tube plate with confluent distal articulating facets, arms may branch twice .... *Hydriocrinus*
        b). Round stem .....
          1). Narrow arms .....
            aa. Three anal plates (normal) .... (part) *Scytalocrinus*
            bb. One anal plate .... *Atrapocrinus*
          2). Wide arms ..... *Morrowcrinus*

3. All rays divided on primibrachs *2*
a). Brachials of moderate width ..... *Pegocrinus*
b). Wide brachials ..... *Bollandocrinus*

II. Medium cone-shaped cup, infrabasals not prominent .....
All rays divided on primibrach *1*, brachials short ..... (typical) *Scytalocrinus*

C. Four to six arms .....
I. Uniserial arms .....
a. High cone-shaped cup, prominent infrabasals .....
1. Four arms (*B* radial armless) .....
..... *Linobrachiocrinus*
2. Five or six arms .....
..... (typical) *Ophiurocrinus*,
(part) *Anemetocrinus*, *Gilmocrinus*
b. Low cone-shaped cup, infrabasals not prominent ..... (part) *Ophiuriocrinus*

II. Five incipiently biserial or equibiserial arms ..... (part) *Anemetocrinus*

D. Arms unknown .....
I. High cone-shaped cup, prominent infrabasals, round stem, single anal plate .....
..... *Roemerocrinus*

Scytalocrinus WACHSMUTH & SPRINGER, 1880, p. 116 [**Scaphiocrinus robustus* HALL, 1861a, p. 315; SD S. A. MILLER, 1889, p. 281] [=*Dactylocrinus* SLADEN, 1878, p. 245 (*non* QUENSTEDT, 1876) (type, *D. loreus*); *Scytalecrinus* BATHER in LANKESTER, 1900a, p. 180 (obj.)]. General form of crown very slender, almost cylindrical. Calyx obconical or bell shaped; infrabasals well developed, bent upward; radials and primibrachs of nearly same form; articular facets between them, straight, occupying entire width of plates; radianal obliquely on *BC* and *CD* basals, anal *X* may not touch *CD* basal. Arms long, composed of externally rectangular or slightly cuneiform joints, unbranched above primibrachs, pinnules of moderate size; anterior ray may bear single unbranched arm. Stem transversely round or obtusely pentagonal. *U.Dev.-U.Penn.*, USA.——FIG. 418,*5a-c*. **S. robustus* (HALL), L. Miss.(Keokuk), Ind.; *A*-ray, *CD*-interray, and dorsal views, ×1.5 (Hall, 1872). ——FIG. 418,*5d,e*. *S. validus* WACHSMUTH & SPRINGER, L.Miss.(Keokuk), Ind.; *5d*, ant. view with exposed sac, anal opening at midheight; *5e*, another specimen showing single arm in ant. ray; both ×1 (Springer, 1926a). [=*Pininocrinus* GOLDRING, 1938.]

Anemetocrinus WRIGHT, 1938, p. 339 [**A. biserialis*; OD]. Cup conical, low or high; anal area normal with radianal, anal *X*, and right tube plate within limits of cup. Arms 5, simple unbranched, wholly or partly biserial, brachials wedge shaped to interlocking. *L.Carb.*, Eu.(Scot.). ——FIG. 419,*2a,b*. **A. biserialis*, Low. Ls. Gr.; Fife; *2a*, dorsal view with arms, ×0.7; *2b*, dorsal view, ×1.5 (Wright, 1950-54).——FIG. 419,*2c*. *A. ardrossensis* WRIGHT, Calciferous Ss. Ser., Fife; post. view, ×1.9 (Wright, 1950-54).

Atrapocrinus STRIMPLE, 1975, p. 5 [**A. mutatus*; OD]. Crown cylinder shaped; cup low cone shaped with flat or mildly convex base; large basals with proximal tips curved into basal plane, large radials, one narrow anal plate. Arms 10, uniserial, brachials long, narrow, primibrachs *1* axillary. *M.Penn.*, USA(Okla.).——FIG. 420,*1*. **A. mutatus*, Atokan; holotype, *1a-c*, crown from *E* ray, *CD* interray, and *B* ray, ×2.5 (Strimple, 1975b).

Bollandocrinus WRIGHT, 1951, p. 62 [**Poteriocrinus conicus* PHILLIPS, 1836, p. 205; OD]. Cup moderately large, turbinate, plates thick; height of cup approximately equal to width across radials; infrabasals high, steeply upturned distally; basals and radials large; articular facets horizontal, full width of radials, with strong transverse ridge and deep ligamental furrow; anal area normal, with radianal and anal *X* adjoining *CD* basal. Anal sac unknown. Arms 10, stout, recti-uniserial, pinnulate, branching on short primibrachs *1*. Stem transversely round, heteromorphic, lumen pentalobate. *L.Carb.(Tournais.-Visean)*, G.Brit. ——FIG. 418,*4a*. **B. conicus* (PHILLIPS), Mtn. Ls., Eng. (Lancash.); post. view, ×0.7 (Wright, 1950-54).——FIG. 418,*4b,c*. *B. erectus* WRIGHT, Eng.(Yorks.); ant., post. views of holotype, ×1 (Wright, 1950-54).

Bridgerocrinus LAUDON & SEVERSON, 1953 [**B. fairyensis*; OD]. Cup steeply conical; infrabasals upturned distally, confluent with higher circlets of cup; articular radial facets occupying entire upper surface of plates; radianal pentagonal, resting on *BC* and *CD* basals, anal *X* on truncated upper surface of *CD* basal. Anal sac long and slender, composed of small hexagonal plates in parallel rows. Arms uniserial, long, slender, bifurcating once on primibrachs *1*, or *2*, or *3*, one long slender pinnule on each brachial. *U.Dev.-L.Miss.(Osag.)*, USA.——FIG. 418,*1*. **B. fairyensis*, L.Miss.(Lodgepole Ls.), Mont.; *1a*, post. view of paratype; *1b,c*, lat. views of holotype and paratype, all ×1.5 (Laudon & Severson, 1953).

Corematocrinus GOLDRING, 1923, p. 434 [**C. plumosus*; OD]. Crown moderately tall, expanding upward. Cup rather low truncate conical, incipient ridges and furrows at plate borders; infrabasals small, pentagonal, with distal parts visible from side; basals large, hexagonal, except for heptagonal *BC* basal; radial articular facets occupying full width of these plates; anals in cup as in *Scytalocrinus*. Anal sac tall and slender, composed of hexagonal plates arranged in vertical rows. Arms 10, uniserial, not appressed, branching isotomously once on primibrachs *2*, pinnules long and moderately stout. Stem strongly pentagonal transversely. *U.Dev.*, USA.——FIG. 418,*6*. **C. plumosus*, low. Chemung F.(Portage Ss.), N.Y.; *C*-ray view, ×1.5 (Goldring, 1923).

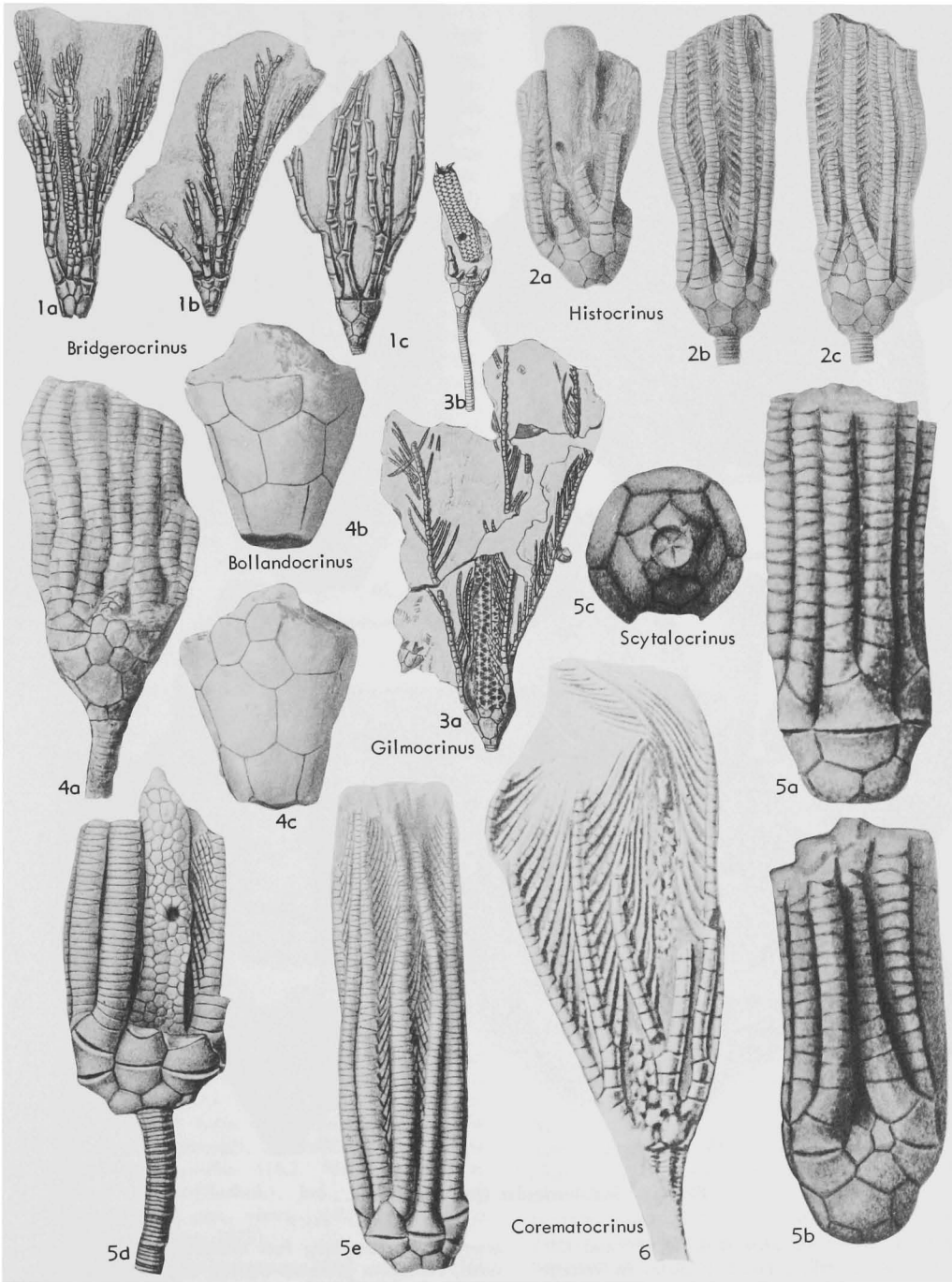


FIG. 418. Scytalocrinidae (p. *T640-T643*).

Gilmocrinus LAUDON, 1933, p. 70 [**G. iowensis*; OD]. Cup steeply conical, basals hexagonal except for *BC* and *CD* plates, which are heptagonal; radianal in contact laterally on one side with

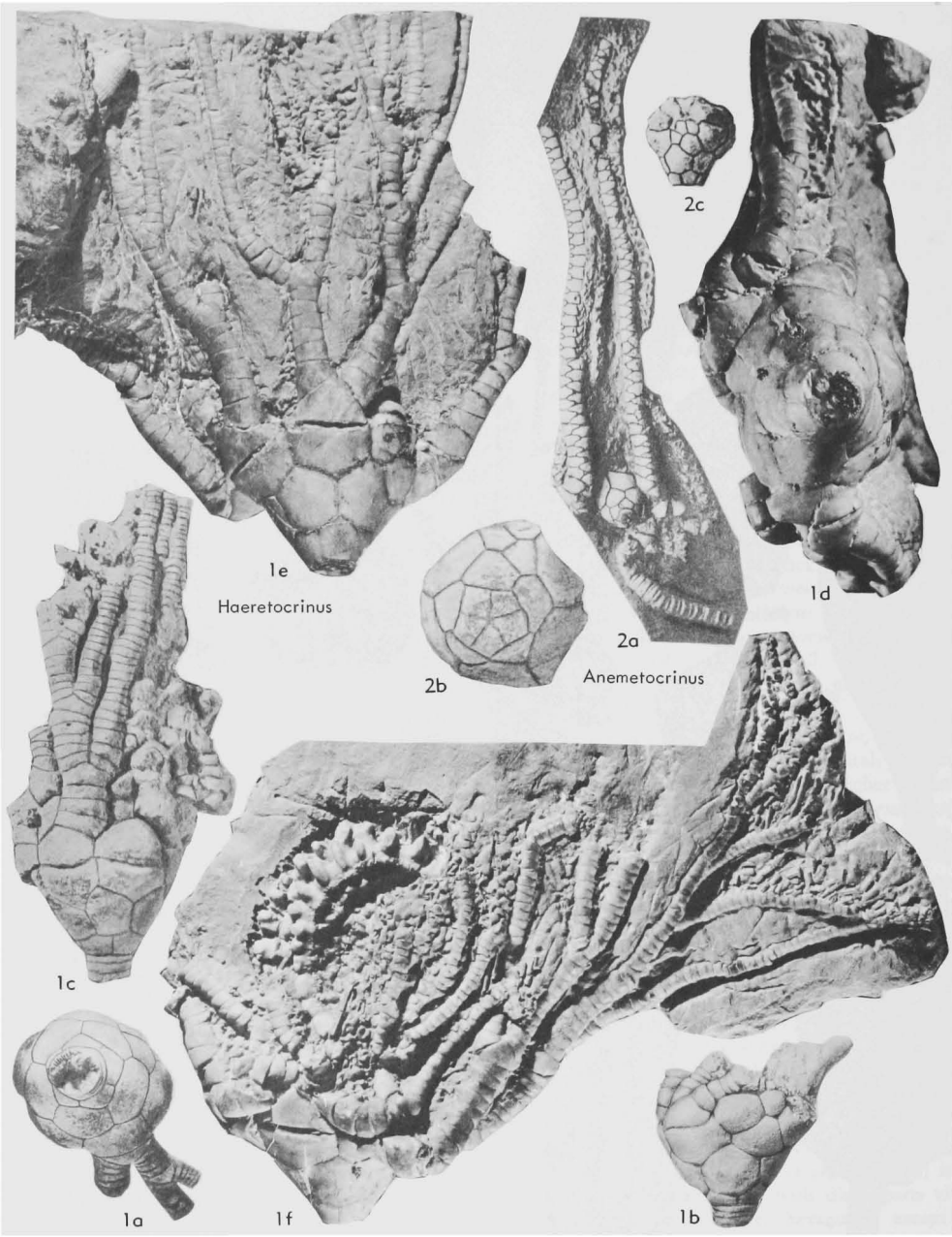


FIG. 419. Scytalocrinidae (p. *T640*, *T643*).

radial and basal, on other with anal *X* and *CD* basal; anal sac tall, cylindrical, plates in vertical rows, ornamented by raised radiating ridges, summit of sac carrying several spines, anus low on anterior side, much as in *Culmicrinus*. Arms slender, exceptionally long in adult specimens and comparatively short in immature ones, latter characterized by very long first brachials, arms uniserial, cuneiform brachials bearing stout pinnules; arms usually single but one of them may branch once, apparently with no regularity as to ray. *L.Miss.(Kinderhook.), Miss.,* USA(Mont.-Iowa); *L.Carb.,* G.Brit.(Scot., Isle of Man).——FIG. 418,*3*. **G. iowensis,* L.Miss.(Gilmore City Ls.),

Iowa; *3a,* holotype from post. side, ×0.7; *3b,* paratype, ant. view, ×1 (Laudon, 1933).

Haeretocrinus Moore & Plummer, 1940, p. 109 [**H. missouriensis*; OD]. Cup moderately high, cone shaped, infrabasals prominent, upflared confluently with higher circlets of cup; radials with wide articular facets; 3 anals in cup. Anal sac large recurved, tube composed of rugose plates with anal opening at midheight on anterior side. Arms robust, uniserial, first branching isotomously on primibrachs 1, then on secundibrachs *4* and at higher points, pattern exotomous. Stem large, transversely circular. *M.Penn.(Desmoines.)-U. Penn.(Virgil.),* USA(Ill.-Mo.-Okla.-Kans.-Texas). ——Fig. 419,*1a,b.* **H. missouriensis,* Missour. (Lane Sh.), Mo.; holotype from base and post. side, ×1 (Moore & Plummer, 1940).——Fig. 419,*1c. H. turbinatus* Strimple, Missour.(Wann F.), Okla.; paratype crown from left *(DE)* side, ×1 (Strimple, 1952e).——Fig. 419,*1d-f. H. wagneri* Strimple & Moore, Missour.(LaSalle Ls.), Ill.; hypotype viewed from dorsal side (*CD* interray directed downward to right), *D* ray, and *AB* interray showing large, recurved anal sac, ×0.93 (Strimple & Moore, 1971a). [=*Haerteocrinus* Strimple, 1952e *(nom. null.).*]

Histocrinus Kirk, 1940, p. 327 [**Poteriocrinus (Scytalocrinus) grandis* Wachsmuth & Springer, 1880, p. 118 (=*P. coreyi* Worthen in Worthen & Meek, 1875, p. 516); OD]. Crown compact, high, cylindrical but arms not appressed. Cup subturbinate, plates smooth, or faintly plicated; infrabasals well exposed in side view; basals medium sized; radials with notches between them, articular facets slightly crescentic, extending full width of radial summits, sutures not gaping; large radianal resting subequally on *BC* and *CD* basals, anal *X* large, extending well above radial summits, right tube plate smaller and almost entirely above level of radials. Anal sac subcylindrical, expanding slightly upward, reflexed so as to carry tip of sac and anal opening well down on anterior side, posterior side with 5 vertical series of plates; in distal recurved portion sac plates are tumid to subspinose. Arms moderately stout, composed of cuneate brachials, 2 primibrachs in all rays except anterior, which may be atomous; pinnules moderately stout, standing out stiffly from arms. Stem transversely circular, heteromorphic, made up of prominent series of nodals and internodals. *L.Miss.(Osag.),* USA(Miss. Valley-Ind.).——Fig. 418,2. **H. coreyi* (Worthen), L.Miss.(Keokuk), Ind.; *2a-c,* ant., left ant. (*E*-ray), post. views, ×0.7 (Worthen in Worthen & Meek, 1875).

Hydriocrinus Trautschold, 1867, p. 16 [**H. pusillus*; OD]. Crown moderately tall, inverted pear shaped. Cup high conical, with 5 prominent, upflared infrabasals; articular facets of radials wide, sutures gaping; 3 anal plates with anal *X* in broad contact with *CD* basal and having an outer ligament pit for articulation with first tube plate, right tube plate on radianal, also with upper articulating facet, distal edges of anal *X* and right tube plate not extending appreciably above radial summits and forming a confluent plane. Anal sac small, cylindrical, composed of rows of diminutive plates. Arms slender with well-rounded exteriors, elongate cuneate brachials with long side pinnule bearing; primibrachs *1* elongate, midsection slightly constricted, axillary; a second dichotomy may appear high in arms. Stem transversely pentagonal or subpentagonal at cup. [*Hydriocrinus* is thought to have evolved from *Phacelocrinus* and older forms assigned to the genus are probably not congeneric.] *M.Penn.(Desmoines.)-*

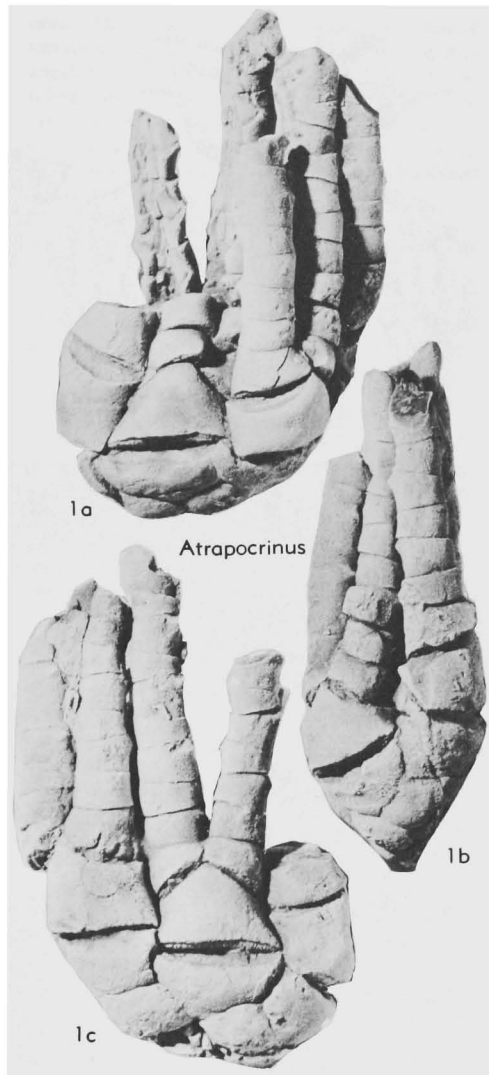


Fig. 420. Scytalocrinidae (p. *T*640).

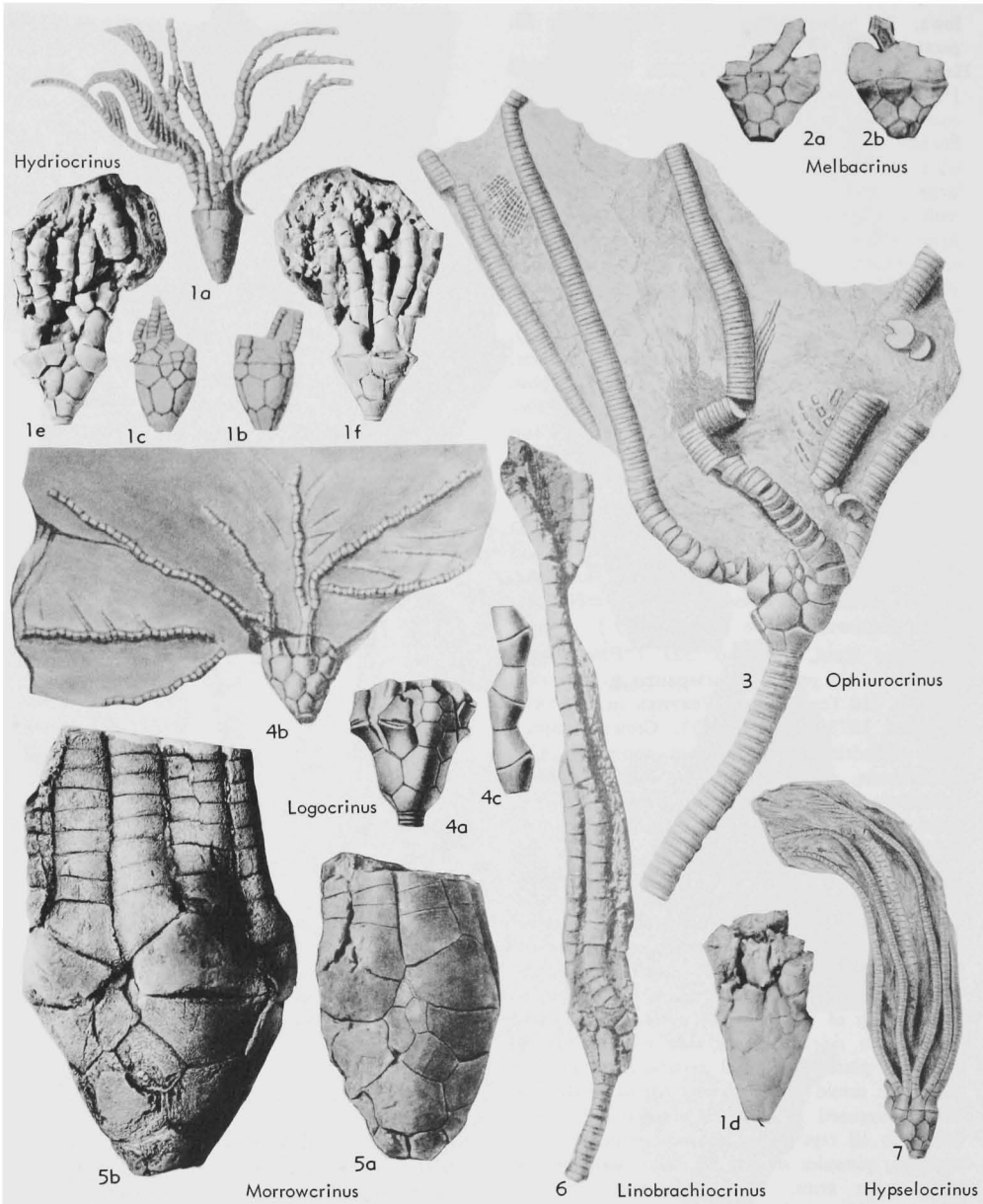


FIG. 421. Scytalocrinidae (p. *T643-T645*).

U.Penn.(Missour.), USA; *U.Carb.*, USSR.——FIG. 421,*1a-d*. **H. pusillus*, U.Carb.(Moscov.), Myachkovo, USSR; *1a-c*, ant. view of crown, ant. and post. views of cup, ×0.93 (Trautschold, 1867); *1d*, topotype showing anal tube, ×0.93 (Strimple, 1971d).——FIG. 421,*1e,f*. *H. turbinatus* STRIMPLE, U.Penn.(Missour., Wann F.), Okla.; holotype crown from post. and ant. sides, ×0.93 (Strimple, 1971d).

Hypselocrinus KIRK, 1940, p. 325 [**Poteriocrinus hoveyi* WORTHEN in WORTHEN & MEEK, 1875, p. 516; OD]. Crown very tall and slender. Cup high, narrowly turbinate; infrabasals long, forming lower 0.25 of cup; basals and radials large, articular radial facets not gaping; radianal high on upper shoulders of *BC* and *CD* basals, anal *X* large, right tube plate approximately half within

cup. Anal sac long, slender, 6 or 7 times height of cup, composed of 10 or more vertical series of hexagonal plates. Arms very long, slender, typically not dividing above primibrachs *1* and may be atomous in *A* ray, brachials cuneate, pinnules long, slender. Stem circular in section. [Differs from *Scytalocrinus* in taller, steeply conical cup with long upturned infrabasals, slender arms, and tall anal sac.] *L.Miss.(Osag.),* USA(Ind.-Iowa). ——FIG. 421,*7*. **H. hoveyi* (WORTHEN), Keokuk (Borden Gr.), Ind.; lat. view, ×0.47 (Worthen in Worthen & Meek, 1875).

Linobrachiocrinus GOLDRING, 1939, p. 354, *pro Linocrinus* GOLDRING, 1938b (Aug.), p. 19 (*non* KIRK, 1938[April]) [**Linocrinus kindlei* GOLDRING, 1938b, p. 21; OD]. Crown extremely tall and slender, arms almost appressed. Cup elongate obconical; infrabasals 5, comparatively small and inconspicuous, but visible from side; basals very large; radials considerably smaller than basals, with linear articular facets occupying full width of radial; *B* radial crowded by *C* radial, considerably reduced in size and apparently armless; radianal, anal *X,* and right tube plate within cup, *X* in line with radials. Arms unbranched throughout length, 4 in number, each brachial bearing 2 pinnules. Stem stout and transversely round. [Very similar to *Cradeocrinus* in character of cup, *Linobrachiocrinus* is distinguished by its 4 unbranched arms and irregularity shown by *B* and *C* radials.] *U.Dev.,* Can.(Mackenzie Basin, NW. Terr.).——FIG. 421,*6*. **L. kindlei* (GOLDRING); *C*-ray view, ×1 (Goldring, 1938b).

Logocrinus GOLDRING, 1923, p. 437 [**L. geniculatus*; OD]. Crown expanding upward, with widely separated arms. Cup steeply conical or bell shaped; infrabasals pentagonal, wider at top than at base, large, with length half that of basals; basals hexagonal except for heptagonal *BC* and *CD* basals; radials pentagonal, 2 posterior ones smaller than others, flaring out slightly near tops, articular facets straight, occupying entire upper face of radials; radianal pentagonal, fairly large, about same in size as infrabasals; anal *X* hexagonal, smaller than posterior radials, slightly larger than radianal, its upper edge even with or slightly above summits of radials. Arms very slender, well rounded, with zigzag succession of cuneate brachials; 2 primibrachs in *D* ray and 3 in others (or uncommonly with 2 primibrachs in *B* and *D* rays); stout pinnules borne by some brachials but pattern undetermined. Only lower plates of anal tube exposed; large, hexagonal. Stem heteromorphic, proximal columnals slightly subpentagonal but circular below. *M.Dev.,* USA (N.Y.).——FIG. 421,*4*. **L. geniculatus,* Hamilton Gr.; *4a, D*-ray view, ×2; *4b, A*-ray, ×1.4; *4c,* brachials, × 4.7 (Goldring, 1923).

Melbacrinus STRIMPLE, 1939, p. 17 [**M. americanus*; OD]. Cup evenly expanded, cone shaped; infrabasals flared evenly upward from columnal attachment; articular facets of radials straight, filling their full width; 3 anal plates in *CD* interray, anal *X* and *RX* with confluent distal faces even with cup summit. Primibrachs compound with division apparent in some rays. Column transversely round. *U.Penn.,* USA(Okla.).——FIG. 421,*2*. **M. americanus,* Missour.(Wann F.), near Bartlesville, Okla.; *2a,b,* holotype from post. and ant. side, ×2 (Strimple, 1939a).

Morrowcrinus MOORE & PLUMMER, 1938, p. 242 [**M. fosteri*; OD]. Cup conical, height approximately equal to width; infrabasals 5, upflared, clearly visible from side; basals moderately large (abnormal in *BC* interray of holotype of *M. fosteri* by occurrence of horizontal suture dividing plate into lower and upper parts but normal in *M. defendens*); radials 5, moderately large, with nearly straight articular facets occupying full width of these plates; 3 anal plates in cup comprising relatively large radianal obliquely at right above *CD* basal, followed above by anal *X* and right tube plate, which project slightly above radials. Well-developed anal sac indicated by cross section at height of secundibrachs *6* or *7*. Appressed arms at least 10 above first axillary primibrachs which are slightly larger than radials, arms uniserial, composed of large quadrangular segments; pinnules not observed. Stem transversely round, with strongly pentalobate axial canal. *L.Penn. (Morrow.),* USA(Okla.-Ark.-Utah).——FIG. 421, *5a*. **M. fosteri,* Ark.; post. view, ×1.5 (Moore & Plummer, 1938).——FIG. 421,*5b*. *M. defendens* (WASHBURN), Morrow.(Oquirrh F.), Provo Canyon, Utah; post. view of holotype, ×1.4 (Strimple, n; Brigham Young Univ. 1496).

Ophiurocrinus JAEKEL, 1918, p. 62 [**Poteriocrinus originarius* TRAUTSCHOLD, 1867, p. 2; M]. Cup conical with upflared large infrabasals visible from side; basals and radials large, latter with linear straight articular facets equal to full width of these plates; large radianal and anal *X* on *CD* basal, only lower tip of small right tube plate in cup. Anal sac unknown. Five very robust uniserial long arms almost circular in section, resembling stout homeomorphic stems, brachials very short. Stem circular in section, distinctly heteromorphic, with alternating thick and thin columnals. *U.Carb.,* USSR-G.Brit.-Eire; *U.Miss.,* USA. ——FIG. 421,*3*. **O. originarius* (TRAUTSCHOLD), Moscov., USSR; *CD*-interray view, ×0.7 (Trautschold, 1967).

Pegocrinus KIRK, 1940, p. 331 [**Poteriocrinus bijugus* TRAUTSCHOLD, 1867, p. 14; OD]. Crown high, with long cylindrical well-separated arms. Cup broadly turbinate, thick plated; infrabasals small, partially anchylosed into firm circlet, clearly visible in side view, sutures distinct; basals variable in size and shape, pointed at top and barely

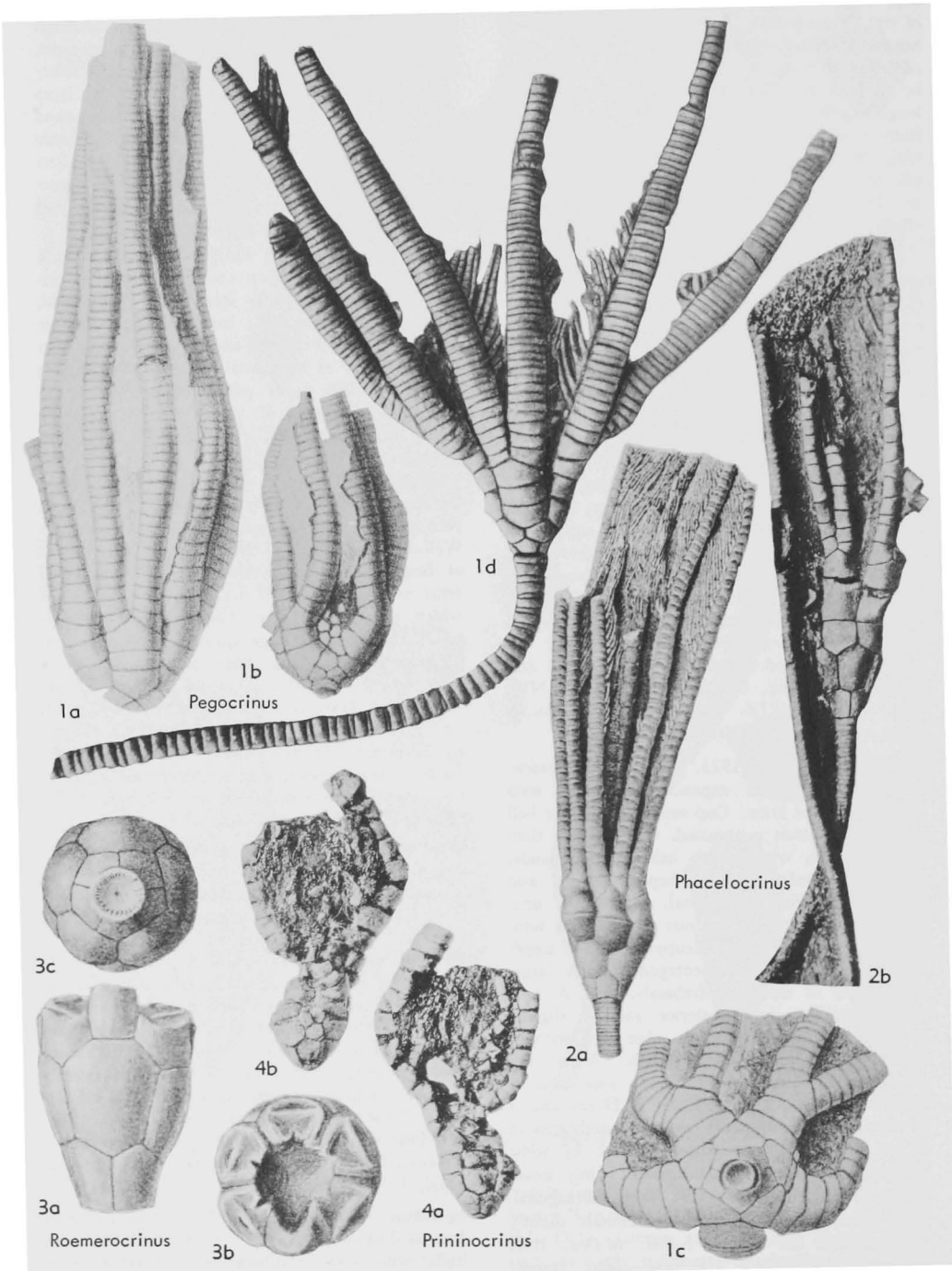


FIG. 422. Scytalocrinidae (p. *T*645-*T*647).

meeting laterally or on very short faces; *CD* basal high, narrow, supporting radianal on its long, upper right shoulder, barely meeting anal *X* above. Radials large, with articular facets full

width of radial, apposed edges of radials and primibrachs along strongly crenulate sutures, not gaping, facets with prominent fulcral ridge, deep ligament pit, and large, well-defined pair of muscular fossae. Radianal small, elongate, narrow; *X* small, high narrow; right tube plate small. Anal sac poorly known (one specimen shows partially dissociated plates in approximately their original position indicating sac to be short, erect, and fairly stout in relation to cup, with small thin plates forming fragile structure). Arms uniserial, robust, long, with 2 undivided branches to each ray; 2 or 3 primibrachs variable in number without respect to rays (usually 2); brachials low, nearly cylindrical, quadrangular as seen from side, each bearing long, stout pinnule. Stem transversely circular, with stellate lumen. *U.Carb. (Moscov.),* USSR.——Fig. 422,*1*. **P. bijugus* (Trautschold); *1a-c,* Moscow, *A*-ray, *CD*-interray, and dorsal views of 3 specimens, ×1 (Trautschold, 1867); *1d,* Myachkovo, ant. view of crown and stem, ×1 (Yakovlev & Ivanov, 1956).

Phacelocrinus Kirk, 1940, p. 329 [**Poteriocrinus wetherbyi* S. A. Miller, 1879a, p. 36; OD]. Crown high, subcylindrical or spreading somewhat upward. Cup steeply conical; infrabasals high; basals medium sized; radials large, articular facets straight, occupying full width of radials, sutures gaping; radianal reaching well down between *BC* and *CD* basals; anal *X* extending above level of radials, right tube plate mostly out of cup. Anal sac cylindrical, with maximum height about 4 times that of cup, composed of vertical rows of hexagonal plates. Arms uniserial, very long and slender, primibrachs 2 in each ray or fusing to single primaxil constricted medially, 2 undivided arms to each ray typically, but irregular branching may occur in some Chester forms; brachials quadrangular or slightly cuneate, with long slender pinnules. Stem pentagonal in section. *L.Carb.,* Eu.; *U.Miss.(Chester.),* USA(Miss.Valley-Ala.-Ky.-Ill.).——Fig. 422,*2a*. **P. wetherbyi* S. A. Miller, U.Miss.(Kaskaskia Gr.), Ky.; ant. view of crown, ×1 (S. A. Miller, 1879a).——Fig. 422,*2b*. *P. rostratus* (Austin & Austin), L.Carb., Eire; lat. view, ×1.5 (Wright, 1950-54).

Prininocrinus Goldring, 1938, p. 18 [**P. robustus*; OD]. Cup cone shaped with small upflared infrabasals; basals elongated; radials moderate sized, articular facet occupying full width of radial; 3 anal plates in advanced arrangement (radianal in *CD* position with equidimensional anal *X* and right tube plate above). Anal sac unknown. Arms relatively large, uniserial, pinnulate, branching once on primibrachs 2. Stem apparently round. [*Prininocrinus* was assigned by Goldring to the family Poteriocrinidae (*nom. null.* =Poteriocrinitidae); its wide radial articular facets are atypical of this family, however, and assignment is made here to the Scytalocrinidae.] *U.Dev.,* N.Am.(Can.).

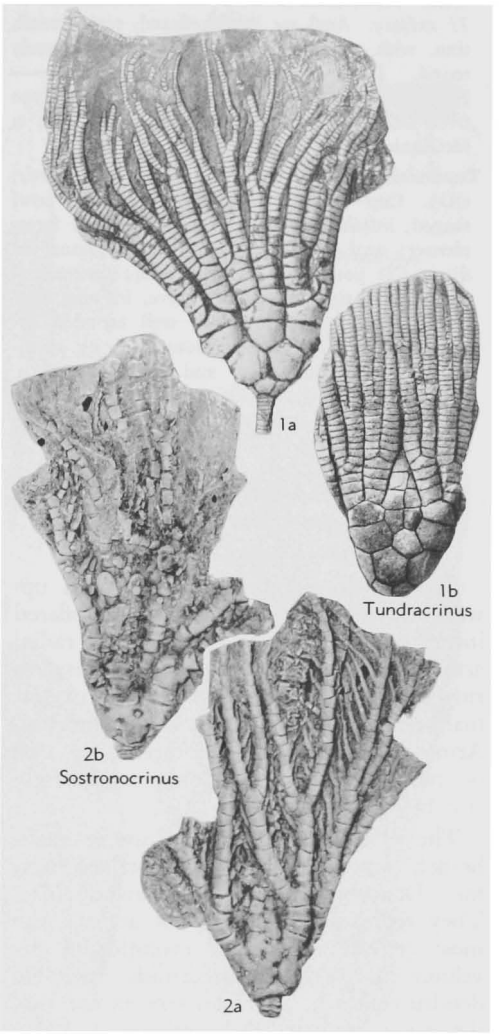


Fig. 423. Scytalocrinidae (p. *T*647-*T*648).

——Fig. 422,*4*. **P. robustus; 4a,b,* holotype from ant. and post. sides, ×1.5 (Goldring, 1938b).

Roemerocrinus Wanner, 1916, p. 205 [**R. gracilis*; OD]. Characters of family; with one anal plate in cup. *L.Perm.-U.Perm.,* Indon.(Timor, Basleo)-Eu.(USSR, Krasnoufimsk).——Fig. 422,*3*. **R. gracilis,* Indon.(Timor); *3a-c,* post., ventral (*CD* interray downward), and dorsal views of cup, ×3 (Wanner, 1916).

Sostronocrinus Strimple & McGinnis, 1969, p. 21 [**S. superbus*; OD]. Crown elongate, expanded, uniserial, pinnule-bearing arms not apposed. Cup truncate cone shaped, angles of plates impressed, distal ends of infrabasals visible in side view of cup; composed of 5 infrabasals, 5 basals, 5 radials and 3 anal plates in normal (primitive) arrange-

ment. Primibrachs *2* or *3* and secundibrachs *7-11* axillary. Anal sac long, reflexed, plates small, thin, with radiating ridges. Column transversely round. *L.Miss.(Kinderhook.)*, USA(Iowa).——FIG. 423,*2*. **S. superbus*, Iowa; *2a,b*, holotype from *CD* interray and *A* ray, ×1.6 (Strimple & McGinnis, 1969).

Tundracrinus YAKOVLEV, 1928, p. 1 [**T. polaris*; OD]. Cup slightly rotund but essentially bowl shaped; infrabasals upflared; radial articular facets plenary; anal plates advanced, with radianal in direct *CD* position, followed by equidimensional anal *X* and right tube plate above, forming confluent horizontal facet. Arms well rounded externally, uniserial, branching isotomously on primibrachs 1, secundibrachs *4* and at higher points. *L.Perm.*, USSR(NE.Eu.Russia).——FIG. 423,*1*. **T. polaris; 1a,b*, ant. and post. views of crown, ×0.75 (Yakovlev, 1928b).

Family BLOTHROCRINIDAE Moore & Laudon, 1943

[Blothrocrinidae MOORE & LAUDON, 1943a, p. 55]

Crown tall, cylindrical or expanded upward. Cup conical, five or three upflared infrabasals readily visible from side, radial articular facets plenary, bearing transverse ridge and ligament pits; three anals in normal arrangement. Anal sac tall, cylindrical. Arms uniserial, pinnulate, branching two or more times. Stem long, transversely circular. *L.Miss.-L.Perm.*

The Blothrocrinidae constitute a main branch identified tentatively as derived from the Dendrocrinidae or Ottawacrinidae. They represent the central or at least the most generalized line of evolutionary development. The blothrocrinids resemble dendrocrinids in all characters except that the arms are advanced toward numerous isotomous divisions and an abundance of well-developed pinnules.

Key to Genera of Blothrocrinidae

A. Cone-shaped cup, with 5 prominent upflared infrabasals; 3 anal plates in cup .....
  I. First arms branching on primibrachs *1* in all rays .....
    a. Arms slender, second branching on secundibrachs *1* or rarely on *2* unbranched above ..... *Ulrichicrinus*
    b. Arms slender, second branching on secundibrachs *1*, additional divisions above ..... *Nebraskacrinus*
    c. Arms very stout, second bifurcation on secundibrachs *7* or *8*, unbranched above ..... *Woodocrinus*
  II. First arm branching on primibrachs *2*, brachials equiuniserial .....
    a. Second arm branching on secundibrachs *6-13*, arms stout ..... *Stinocrinus*
    b. Second arm branching on secundibrachs *6* or *7*, arms slender .... *Blothrocrinus*
    c. Second arm branching on secundibrachs *6-10*, arms stout ..... *Fifeocrinus*
    d. Second arm branching normally on secundibrachs *2* ..... *Moscovicrinus*
  III. First branching of arms above primibrachs *2*, second above secundibrachs *2* .....
    a. Radial articular facets wide, no interradial notches ..... *Culmicrinus*
    b. Prominent notches between radial articular facets ..... *Carcinocrinus*

B. Same as A but with only 3 infrabasals, first branching on primibrachs *1* or *2* in all rays ..... *Elibatocrinus*

Blothrocrinus KIRK, 1940, p. 321 [**Poteriocrinus jesupi* WHITFIELD, 1881, p. 7; OD]. Crown elongated, expanded. Cup steeply conical; 5 upflared infrabasals prominent; 3 anal plates in normal (primitive) arrangement. Arms numerous (50-60), uniserial, well-rounded exteriors, first branching on primibrachs *2* with several irregular isotomous bifurcations above. Stem large, transversely round, homeomorphic, composed of thin columnals. *L.Miss.(Kinderhook.-Osag.)*, USA; *L.Carb.(Tournais.)*, Eng.-Afr.(Morocco)-USSR(Kazakh.).——FIG. 424,*2*. **B. jesupi* (WHITFIELD), Miss. (Osag., Burlington Ls.), Iowa; *2a*, post. view of crown, ×0.5 (Whitfield, 1881); *2b*, plate diagram of cup (radials black, radianal cross ruled, other anal plates stippled) (Moore, 1962b).

Carcinocrinus LAUDON, 1941, p. 390 [**C. stevensi*; OD] [=*Carinocrinus* STRIMPLE, 1953b, p. 201 *(nom. null.)*]. Crown large, relatively slender arms extending about a massive, cylindrical anal tube. Cup sharply conical, infrabasals upflared, prominent; distal portions of radials separated by large notches, but articular facets equal in width to radial summits; 3 anal plates in normal (primitive) arrangement. Anal sac cylindrical, as wide as cup, exceptionally tall, with rounded summit well above arm tips, composed of series of hexagonal plates, with large snoutlike projection at about midheight of crown on anterior side. Arms uniserial, brachials cuneate above first bifurcation on primibrachs *5* (only *B* and *C* rays known), second isotomous branching in 3 half-rays and a third in one outer ray. Stem transversely round, slightly tapered, columnals thin. *U.Miss.(Chester.)*, USA.——FIG. 424,*3*. **C. stevensi*, NE.Okla.; *BC* side of holotype crown, ×0.7 (Laudon, 1941).

Culmicrinus JAEKEL, 1918, p. 62 [**Poteriocrinus*

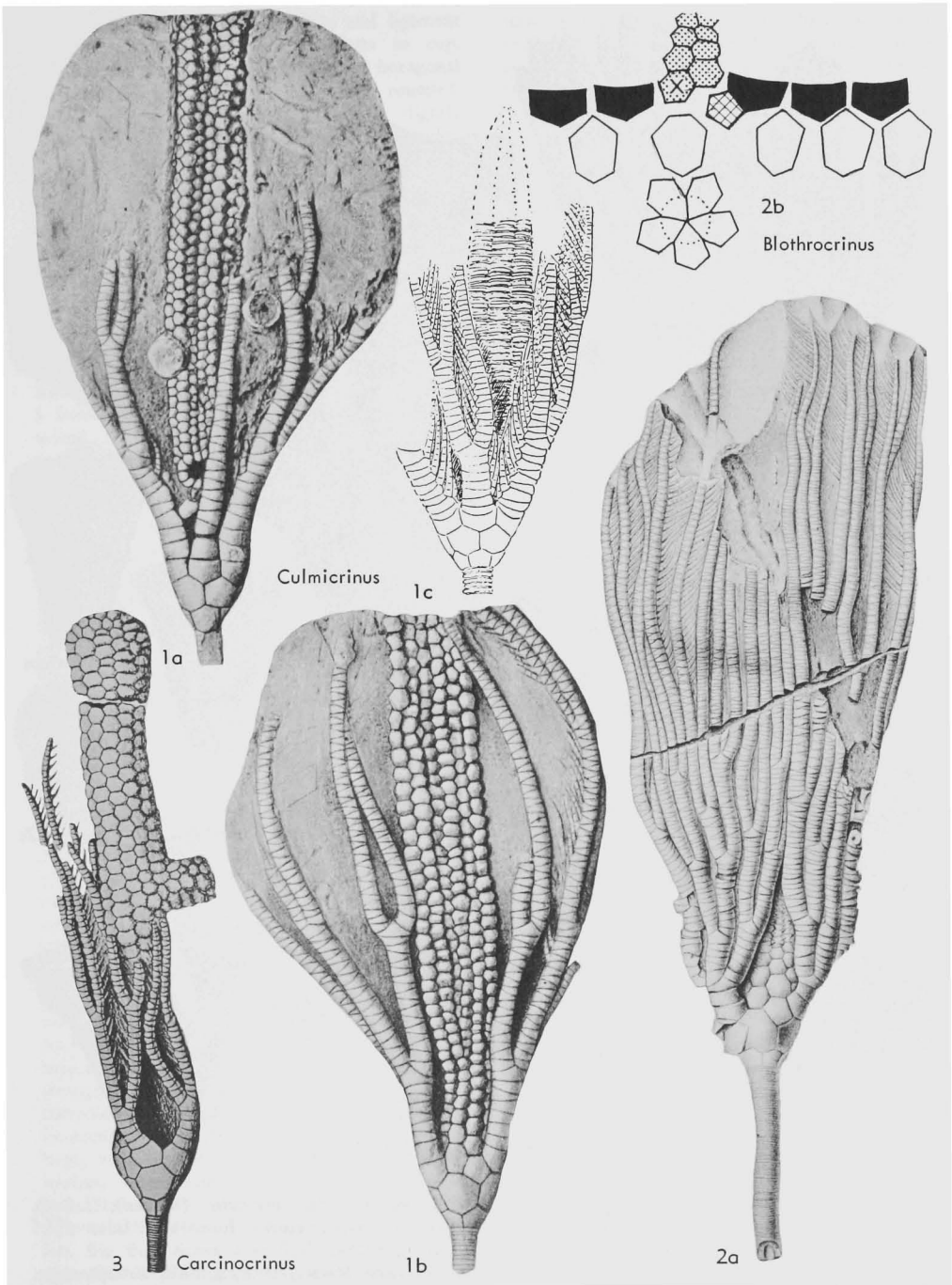


FIG. 424. Blothrocrinidae (p. T648-T650).

regularis MEYER, 1858, p. 119; OD]. Cup tall, cone shaped; infrabasals prominent; basals moderately long; 3 anal plates in normal (primitive) arrangement. Anal sac long, slender, recurved tube with anal opening on anterior side, sac plates small, in numerous vertical series. Arms uniserial,

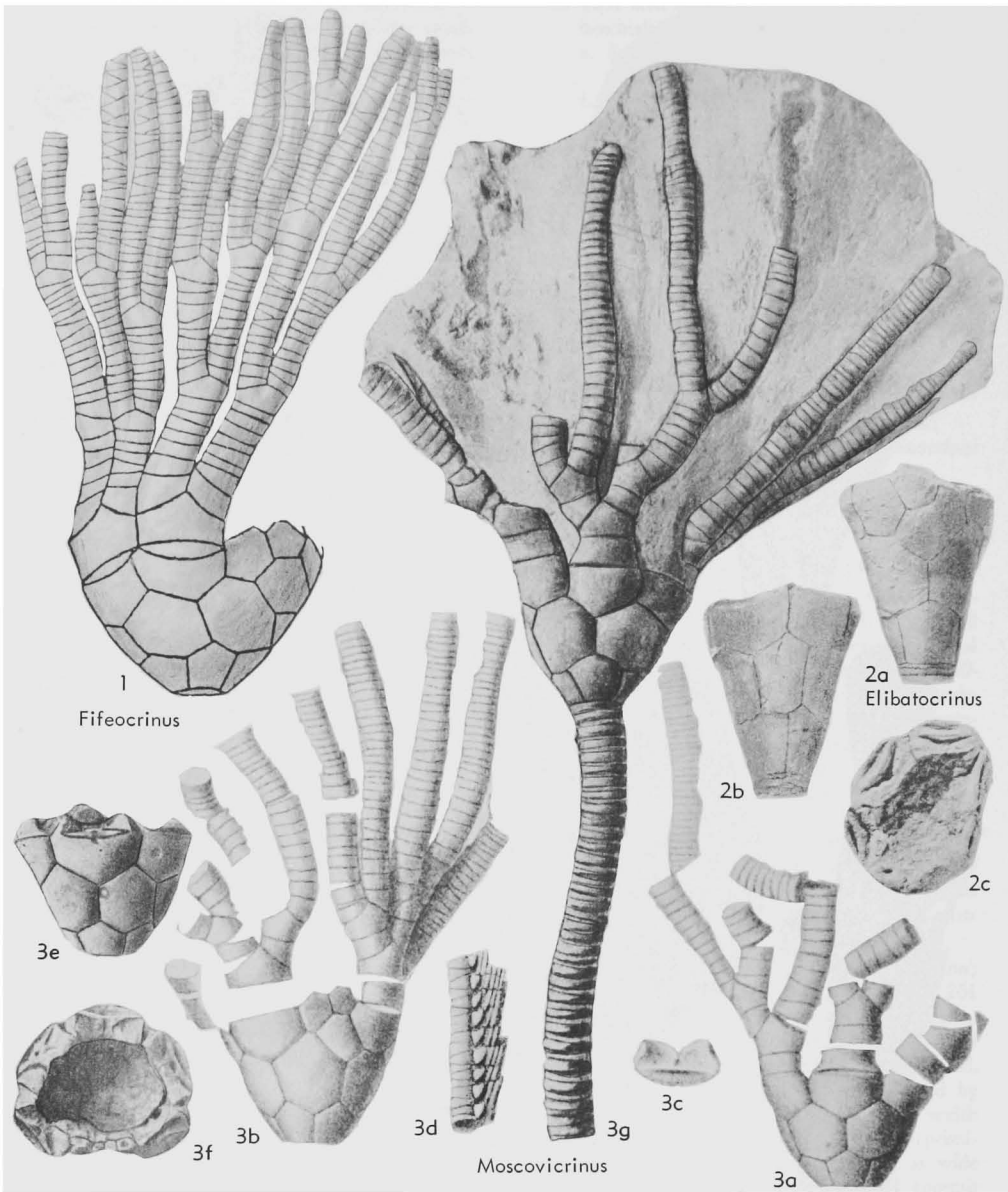


FIG. 425. Blothrocrinidae (p. T650-T651).

exteriors well rounded, first branching above primibrachs 2, usually *A*-ray branching much higher than in other 4 rays, second isotomous division at about midheight of crown. Stem transversely round (exception, *C. thomasi* LAUDON, which may have subpentagonal proximal columnals). *L.Miss.(Kinderhook.)-U.Miss.(Chester.)*, USA; *L.Carb.*, Eu.——FIG. 424,*1a,b*. *C. elegans* (SPRINGER), Chester.(Glen Dean), Ky.; ant. and post. views of crown, ×1 (Springer, 1926b).——FIG. 424,*1c*. **C. regularis* (MEYER), L.Carb. (Visean), Ger.; crown from ant. side, ×1.5 (Jaekel, 1918).

Elibatocrinus MOORE, 1940, p. 36 [**E. leptocalyx*; OD]. Crown moderately tall, slender. Cup steep sided conical; infrabasals 3, elongate, externally visible parts beyond stem forming one-third height of cup, much thickened proximally but thin at distal margins, small azygous plate in position of *C* ray; radial articular facets equal to radials in

width, with strong transverse ridge and ligament fossae slightly shorter; 3 anal plates in cup. Anal sac tall but shape unknown, small hexagonal sac plates with slitted margins. Arms rounded, slender and very long, 2 in each ray, slightly cuneate brachials uniserial, bearing long pinnules. Stem transversely circular, heteromorphic. *M.Penn.(Desmoines.)-U.Penn.(Virgil.)*, USA(Kans.-Okla.-Texas).——FIG. 425,*2*. **E. leptocalyx*, Missour. (Stoner Ls.), Wilson Co., Kans.; *2a-c*, holotype from post. and ant. sides and ventral view of cup (*A* radial upward), ×2 (Moore, 1940a).

Fifeocrinus WRIGHT, 1951, p. 41 [**Pachylocrinus tielensis* WRIGHT, 1936, p. 399; OD]. Cup medium tall conical; infrabasals upflared, prominent; 3 anal plates in normal (primitive) arrangement. Arms equiuniserial, moderately stout, usually with 3 isotomous branchings, first on primibrachs 2, second on or about secundibrachs *6-10*, with further erratic branching high in crown. *L.Carb.(Visean)*, Eu.(G.Brit.).——FIG. 425,*1*. **F. tielensis* (WRIGHT), Lower Ls. Gr., Scot.; *D*-ray view of holotype, ×1 (Wright, 1950-54).

Moscovicrinus JAEKEL, 1918, p. 62 [**Poteriocrinus multiplex* TRAUTSCHOLD, 1867, p. 6; OD]. Cup conical, upflared infrabasals prominent, radial articular facets plenary, but interradial notches present. Arms isotomous, branching 3 times in some rays, first bifurcation on primibrach *2* (or may be *3* in *A* ray), second usually on secundibrach *2* but may be on *4* to *7*, third usually on tertibrach *2* but may be higher. *U.Carb.(Moscov.)*, USSR; *L.Perm.(Wolfcamp.)*, USA-Indon.(Belitung).——FIG. 425,*3*. **M. multiplex* (TRAUTSCHOLD), Moscov., USSR(Moscow Bas.); *3a,b*, crown from ant. and post. sides; *3c*, summit view of radial; *3d*, part of arm and attached pinnules in side view; all ×1 (Trautschold, 1867); *3e,f*, cup from ant. side and ventral view; *3g*, ant. view of crown with part of attached column; all ×1 (Yakovlev & Ivanov, 1956).

Nebraskacrinus MOORE, 1939, p. 198 [**N. tourteloti*; OD]. Cup conical with sides somewhat steeper in upper part than in lower; infrabasals readily visible in side view; *CD* interray slightly bulged, 3 large anal plates in normal (primitive) arrangement. Anal sac strong, tapering upward, composed of several columns of plates without intervening slits. Arms uniserial, primibrachs *1* large, wide, axillary, branching thereafter heterotomous, with secundibrachs *2* axillary in some rays. Stem transversely round, lumen pentastellate. *L.Perm.*, USA(Neb.).——FIG. 426,*2*. **N. tourteloti*, Big Blue Series (Winfield Ls.); *2a,b*, holotype from *AB*-interray and post. sides, ×1.4 (Moore, 1939c).

Stinocrinus KIRK, 1941, p. 84 [**S. granulosus*; OD]. Crown medium in height. Cup low bowl shaped; infrabasals barely visible in side view, radials dominant cup elements, 3 anal plates in normal (primitive) arrangement. Arms equiuniserial, first branching on primibrachs *2* in all rays except *A* ray, which may have as many as 9 primibrachs, second isotomous branching high in crown on secundibrachs *6-13* (except *A* ray), with third branching in some outer half-rays. *L.Miss.(Osag.)*, USA(Ky.).——FIG. 426,*4*. **S. granulosus*, New Providence F.; *4a,b*, holotype from *D*-ray and *AB*-interray sides; ×1.4 (Kirk, 1941b).

Ulrichicrinus SPRINGER, 1926, p. 75 [**U. oklahoma*; OD]. Crown tall. Cup conical, infrabasals readily visible from side; first primibrachs low, axillary, second bifurcation on secundibrachs *1* or *2* in some half-rays. *L.Miss.(Osag.)-U.Miss.(Chester.)*, USA(Okla.-Ga.-Ind.); *L.Miss.(Osag.)-M.Penn.(Desmoines.)*, USA(Okla.-Texas).——FIG. 426,*1*. **U. oklahoma*, L.Penn.(Morrow.), Okla.; *1a,b*, holotype from post. *D*-ray and *AB*-interray sides, ×0.62 (Springer, 1926b).

Woodocrinus DE KONINCK, 1854, p. 210 [**W. macrodactylus*; OD]. Crown widely expanded. Cup low cone shaped; 5 infrabasals upflared but not prominent, tendency toward short sutures between basals, 3 anal plates in normal (primitive) arrangement. Arms typically 20, uniserial, composed of exceptionally wide, very short brachials, first branching on primibrachs *1* in all rays, second branching on about secundibrachs *6-8*, no higher bifurcations, branching variable among specimens and species, including lack of second bifurcation in some rays. *U.Carb.(Namur.)*, Eu.(Eng.).——FIG. 426,*3*. **W. macrodactylus*, Namur.(Red Beds above Main Ls.); *3a*, lectotype crown from post. (*C*-ray) side, ×0.62 (Springer, 1926b); *3b*, slab bearing several crowns of this species, approximately ×0.2 (Wright, 1950). [=*Philocrinus* DE KONINCK, 1863.]

Family CERCIDOCRINIDAE Moore & Laudon, 1943

[Cercidocrinidae MOORE & LAUDON, 1943a, p. 55]

Cup small, low; three anal plates in cup. Anal sac recurved, slender or with greatly expanded distal extremity. Arms stout, uniserial, branching isotomously on first primibrachs and then endotomously several times; primibrachs *1* axillary in all rays. Stem transversely round. *L.Miss.*

Suppression of certain isotomous bifurcations of the blothrocrinid arms produces the endotomous structure that characterizes the pinnule-bearing arms of the Cercidocrinidae. Except in arm structure, and possibly greater inflation of the anal sac, the cercidocrinids do not differ from the blothrocrinids, and doubtless they were developed from this stock.

Cercidocrinus KIRK, 1938, p. 163 [**Poteriocrinus bursaeformis* WHITE, 1862, p. 10; OD]. Cup cone

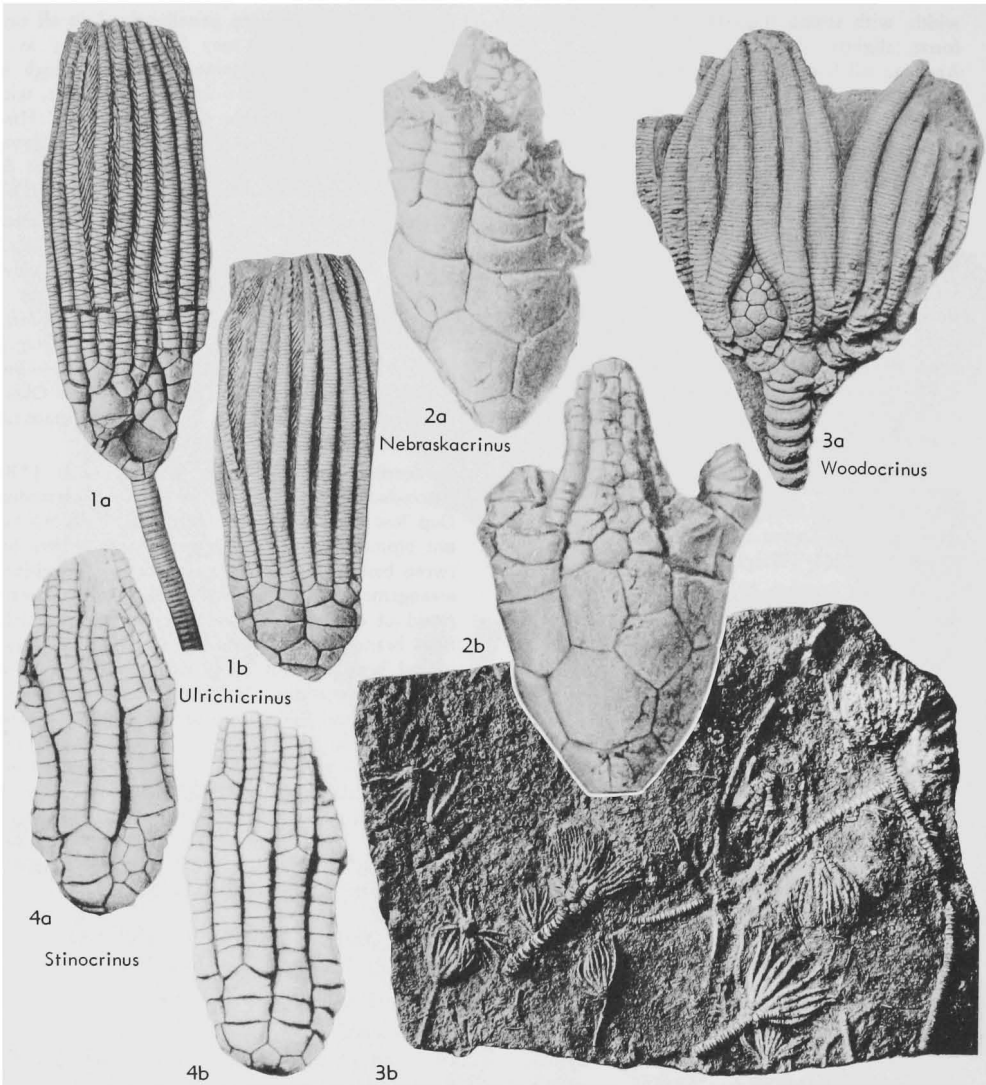


FIG. 426. Blothrocrinidae (p. T651).

shaped, plates smooth; infrabasals low, clearly visible in side view; radial articular facets fully as wide as radials. Arms stout, rounded, branching isotomously on first primibrachs and then endotomously several times; brachials low and broad, pinnulate. *L.Miss.*, USA(Iowa-Mo.).——FIG. 427,*3*. **C. bursaeformis* (WHITE), Burlington Ls.(Osag.), Iowa; post. view of crown, ×0.7 (Springer, 1926b).

Ascetocrinus KIRK, 1940, p. 324 [**Scaphiocrinus rusticellus* WHITE, 1863, p. 505; OD]. Crown elongate and slender. Cup small, cone shaped, with small pits at plate angles; infrabasals small, barely visible in side view; radials large, articular facets plenary; sutures with primibrachs gaping; right tube plate just below top of *C* radial. Anal sac slender, with 8 vertical rows of plates, recurved, anal opening about midway on anterior side, plates with pores at angles. Arms long, slender, branching endotomously 2 or 3 times above axillary first primibrachs; brachials high, wedge shaped, with marked lateral shoulders for support of long, slender pinnules. *L.Miss.*, USA (Iowa).——FIG. 427,*2*. **A. rusticellus* (WHITE), Burlington Ls. (Osag.); lat. view of crown and proximal stem, ×1 (Springer, 1926b).

Coeliocrinus WHITE, 1863, p. 498 [**Poteriocrinus dilatatus* HALL, 1861b, p. 6; SD S. A. MILLER, 1889, p. 233]. Cup low, broad bowl shaped; infrabasals barely visible in side view of cup;

radial articular facets as wide as radials. Anal sac large, strongly inflated distally, composed of numerous stout plates with strong radiating ridges or with spinose summit plates. Arms with up to 5 endotomous branches above large, axillary first primibrachs; brachials strongly wedge shaped, pinnulate. *L.Miss.*, USA(Iowa-Mo.-N.Mex.).——Fig. 427,*1a-d*. **C. dilatatus* (Hall), Burlington Ls. (Osag.), Iowa; *1a,b, D*-ray and *BC*-interray views of crown, ×1.5; *1c,d, D*-ray, and *BC*-interray views of another crown, ×1.5 (all Springer, 1926b).——Fig. 427,*1e,f*. *C. ventricosus* (Hall), Burlington Ls.(Osag.), Iowa; proximal and distal views of isolated inflated part of anal sac, ×1 (Springer, 1926b).

Family APHELECRINIDAE Strimple, 1967

[Aphelecrinidae Strimple, 1967, p. 82]

Crown slender cylindrical, flared upward, ovoid. Cup moderately low cone shaped, height and width subequal; five small infrabasals upflared, rising directly from round columnar cicatrix; five relatively short basals; five radials and three anal plates in normal (primitive) arrangement. Arms uniserial, branching on primibrachs *1* in all rays except that in earlier forms first branching in *A* ray is above primibrach *2*, all rays with one or subsequent isotomous bifurcations, pinnules long and stout. Anal sac slender, moderately to strongly reflexed, composed of series of small, polygonal plates. Column round (exception, *Aphelecrinus mundus* Kirk, and *A. oweni* Kirk, reportedly with subpentagonal proximal columnals [Kirk, 1944b]), cirriferous in few forms. *L.Miss. (Kinderhook.)-U.Miss.(Chester.)*.

Key to Genera of Aphelecrinidae

Crown slender cylindrical or upflared, arms in most or all rays branching on primibrachs 1 .....

I. Arms branching isotomously in all rays on primibrachs *1*, stem not cirriferous ..
   a. Crown slender cylindrical, brachials externally cuneate ..... *Cosmetocrinus*
   b. Crown flared upward, brachials externally rectangular ..... *Aphelecrinus*

II. Arms branching in *A* ray above primibrach *1*, stem proximally very cirriferous ..... *Paracosmetocrinus*

Aphelecrinus Kirk, 1944, p. 190 [**A. elegans*; OD] [=*Amphelecrinus* Laudon & Severson, 1953 *(nom. null.); Ampelecrinus* Laudon, Parks, & Spreng, 1952 *(nom. null.)*]. Crown moderately high. Cup cone shaped, infrabasals rising evenly from columnar cicatrix; 3 anal plates in normal placement; arms branching on primibrachs *1* in all rays and once again in higher positions (at

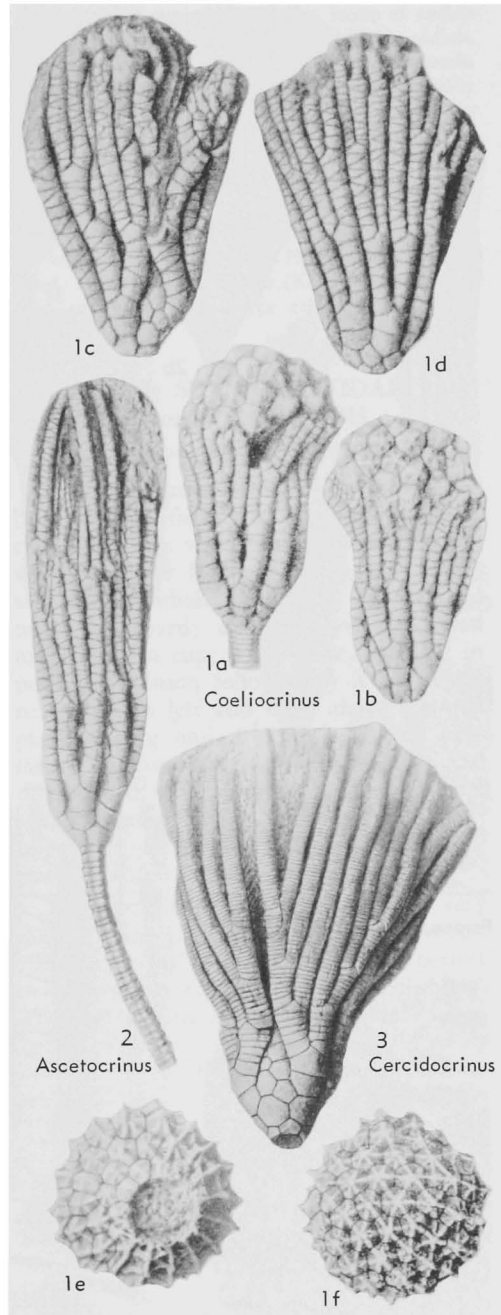


Fig. 427. Cercidocrinidae (p. *T*651-*T*653).

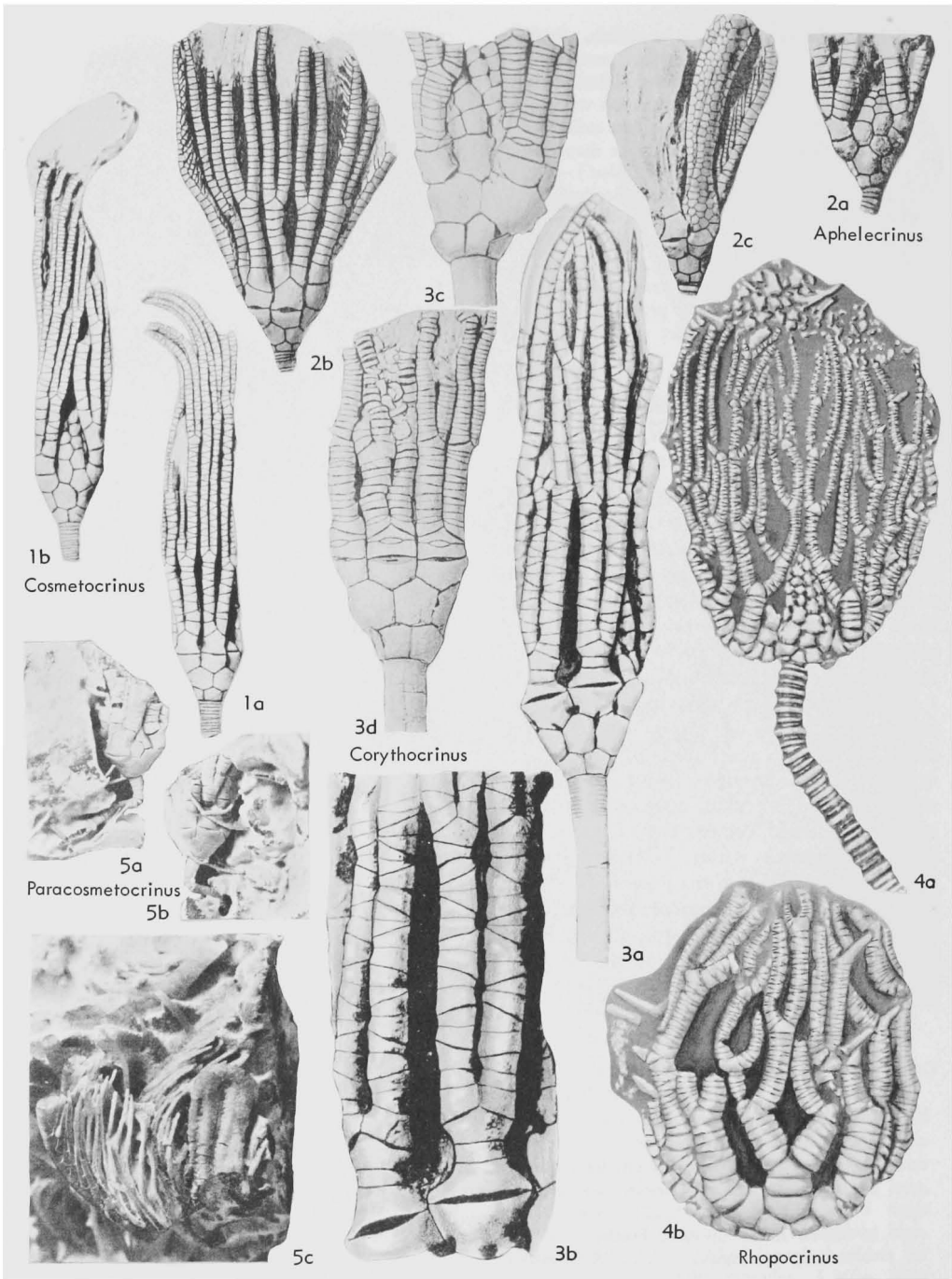


FIG. 428. Aphelecrinidae *(1,2,5)*; Corythocrinidae *(3)*; Stellarocrinidae *(4)* (p. T653-T655, T671).

about 0.3 to 0.5 height of arms), sporadic divisions above uncommon, brachials with slightly sloping articular facets in earlier species, becoming cuneate in later forms. Anal sac extending to about one-half or two-thirds height of arms, reflexed and composed of numerous vertical rows of small polygonal plates. Stem typically circular in section but in 2 species *(A. oweni, A. mundus)*

proximal columnals are subpentagonal. *L.Miss. (Kinderhook.)-U.Miss.(Chester.)*, USA; *L.Carb.*, Eu.(G.Brit.).——FIG. 428,*2*. **A. elegans*, Meramec.(Ste.Genevieve Ls.), USA(Ala.); *2a,b*, holotype crown from post. and ant. sides; *2c*, ant. view of paratype showing tall, cylindrical anal sac, ×1.5 (Kirk, 1944b).

Cosmetocrinus KIRK, 1941, p. 86 [**C. gracilis*; OD]. Crown tall, slender; 3 anals in cup; brachials rectangular to cuneate externally, arms branching isotomously on primibrachs *1* in all rays and once or twice at higher positions; sutures between radials and primibrachs *1* somewhat gaped. *L.Miss.(Osag.)-U.Miss.(Chester.)*, USA (Ind.-Okla.).——FIG. 428,*1*. **C. gracilis*, Osag. (Keokuk, Borden Gr.), Ind.; *1a,b*, holotype from ant. and post. sides, ×0.7 (Kirk, 1941b).

Paracosmetocrinus STRIMPLE, 1967, p. 82 [**P. straki*; OD]. Like *Cosmetocrinus* except that first branching in *A* ray is above primibrach *1*, branching in all other rays on primibrachs *1*. Proximal columnals very cirriferous, with cirri extending upward around crown. *L.Miss.(Kinderhook.-Osag.)*, USA(Mont.-Iowa-Ind.).——FIG. 428,*5*. **P. straki*, Kinderhook.(Wassonville Chert), Iowa; *5a,b*, holotype from post., ant. sides, ×1.3; *5c*, paratype showing termination of anal sac and arms, ×2.2 (Strimple, 1967).

Family CORYTHOCRINIDAE
Strimple & Watkins, 1969

[Corythocrinidae STRIMPLE & WATKINS, 1969, p. 195]

Cup high, even sided, conical; five infrabasals with surfaces beyond stem impression abruptly turned upward so as to be confluent with higher cup plates, readily visible from side; radial articulating facets wide, filling distal face of these plates; one large anal plate (radianal) in cup in line with radials, obliquely in contact with *CD* basal. Anal sac tall, slender. Arms uniserial, pinnulate; usually branching isotomously two or more times, syzygial pairs of brachials present. Stem large, heteromorphic, composed of alternating thin and thick circular columnals with pronounced crenulations visible in side view. *L.Miss.(Osag.)*.

Corythocrinus KIRK, 1946, p. 272 [**C. insculptus*; OD]. Crown subcylindrical, composed of conical cup surmounted by slender, well-rounded, closely spaced arms lacking observed pinnules. Cup with wide even base at stem impression and evenly steep-sloping sides formed by prominent circlets of 5 infrabasals, 5 moderately large basals, and 5 radials, interrupted on posterior side by large anal plate (radianal) resting mainly with oblique suture on *CD* basal and short oblique suture on *BC* basal, its upper part rising well above even line of radial summits; articular facets of radials with first primibrachs equal in width to radials, gaping, arms branched isotomously on primibrachs *3*, above which nearly all brachials are syzygially paired, with isotomous branching also once or twice in upper part of arms. Round homeomorphic stem composed of very thin columnals. *L.Miss. (Osag.)*, USA(Ind.-Iowa).——FIG. 428,*3a,b*. **C. insculptus*, Borden Gr.(Keokuk), Ind.; *3a*, holotype crown from *D* ray side, ×1; *3b*, portion of *D* and *E* rays, ×2 (Kirk, 1946b).——FIG. 428, *3c,d*. *C. fragilis*, Borden Gr.(Keokuk), Ind.; post. and ant. views of holotype crown, ×0.7 (Kirk, 1946b).

Family SPANIOCRINIDAE
Moore & Laudon, 1943

[Spaniocrinidae MOORE & LAUDON, 1943a, p. 60]

Cup low, cone or bowl shaped; infrabasals two to three, five, or ?lacking, may or may not be visible in side view of cup; radial articular facets occupying full distal surface of radials, horizontal or inclined outward-upward; one to three advanced anal plates in cup; when three, radianal in posterior position followed by *X* and right tube plate to left and right above, or anal plate lacking and cup with perfect pentameral symmetry. Arms five, single and unbranched, or branching on primibrachs *1* in all rays or in all but *A*-ray; brachials uniserial or biserial. Stem transversely round. *L.Miss.; L.Penn.-U.Perm.*

The Spaniocrinidae, a family of very doubtful lineage, consist chiefly of Permian crinoids having simple structure and perfect or nearly perfect pentamerous symmetry. The cup retains a primitive conical form, but anal plates commonly are reduced to one or none. The radial articular facets are very wide (plenary) and show highly developed muscular articulation of the arms, which in known genera are like those included in the Erisocrinacea. The Spaniocrinidae are not offshoots of the Erisocrinidae but may have come from slightly antecedent crinoids belonging to the same line.

Spaniocrinus WANNER, 1924, p. 292 [**S. validus*; OD]. Cup low conical, with perfect pentameral symmetry; infrabasals low, visible in side view; basals hexagonal; radials twice as wide as high and in contact all around cup; no anal plates or anal sac. Arms 5, simple and unbranched, uniserial, composed of massive, externally quadrangular brachials interlocked along their lateral

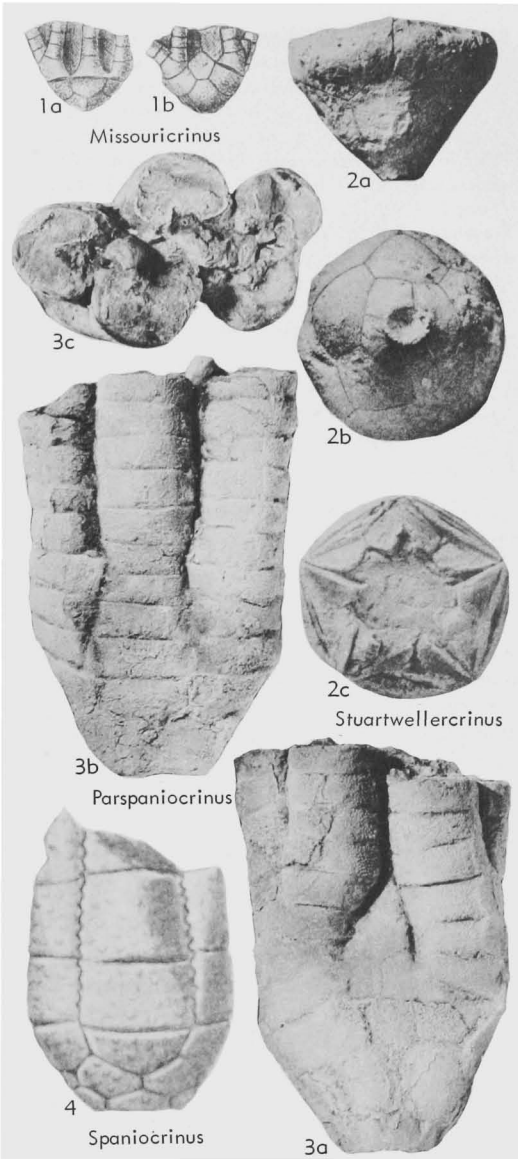


FIG. 429. Spaniocrinidae (p. T655-T656).

edges. *U.Perm.,* Indon.(Timor, Basleo).——FIG. 429,*4*. **S. validus*; lat. view of partial crown, ×2 (Wanner, 1924).

Missouricrinus S. A. MILLER in MILLER & GURLEY, 1891, p. 31 [**M. admonitus*; OD]. Cup bowl shaped; infrabasals ?lacking; basals large; radials pentagonal, with articular facets occupying full width of radials; single large anal plate directly above *CD* basal and between posterior radials. Arms rounded, primibrachs *1* axillary in all but *A* ray, which has at least 3 primibrachs; arms not known above secundibrach *3* in *A* ray. [May or may not have infrabasals and may be assigned incorrectly to Spaniocrinidae.] *L.Miss.,* USA(Mo.). ——FIG. 429,*1*. **M. admonitus; 1a,b,* ant. and post. views of partial crown, ×1 (Miller in Miller & Gurley, 1891).

Parspaniocrinus STRIMPLE, 1971, p. 1040 [**P. beinerti*; OD]. Closely similar to *Spaniocrinus* but having 3 anal plates in cup, radianal obliquely across *CD* basal with *2* equidimensional anal plates above; anal *X* above *CD* basal. *L.Perm.,* Mex. (Coahuila).——FIG. 429,*3*. **P. beinerti,* Wolfcamp., Las Delicias; *3a-c,* post., ant., and ventral views of incomplete crown (holotype), ×1.3 (Strimple, 1971c).

Stuartwellercrinus MOORE & PLUMMER, 1938, p. 305 [**Cibolocrinus turbinatus* WELLER, 1909, p. 632; OD]. Cup small, steeply conical, base narrow; infrabasals 3, upflaring and visible in side view, small infrabasal generally in *A, C,* or *D* ray. Basals 5, *CD* basal typically larger than others and truncated beneath single anal plate; radials with broad articular facets projecting inward so as to constrict opening to visceral cavity; single anal present between posterior radials, or above cup. Arms not known. *L.Penn.(Morrow.)-L. Perm.(Wolfcamp.),* USA(Texas-Mo.)-Indon.(Timor).——FIG. 429,*2*. *S. symmetricus* (WELLER), L.Perm., Texas; *2a-c,* post., dorsal, and ventral views of cup, ×1.5 (Moore & Plummer, 1940).

Superfamily CUPRESSOCRINITACEA Roemer, 1854

[*nom. transl.* MOORE & LANE in MOORE & STRIMPLE, 1973, p. 20 (*ex* Cupressocrinitidae ROEMER, 1854, *nom. correct.* BASSLER, 1938, p. 16)] [Materials for this superfamily prepared by R. C. MOORE and N. GARY LANE]

Characters of family; differentiated as superfamily correlative with others of this rank among cladid inadunates because assignable to none of them. *L.Dev.-U.Dev.*

Family CUPRESSOCRINITIDAE Roemer, 1854

[*nom. correct.* BASSLER, 1938, p. 16 (*pro* Cupressocrinidae ROEMER, 1854, p. 227)]

Crown compact, arms five, massive, unbranched; first primibrachs short, wide; higher brachials three to many, large externally quadrangular, short or elongate, hyperpinnulate; stem quadrangular to round, with three or four peripheral canals. *L.Dev.-U.Dev.*

The Cupressocrinitidae, from Middle Devonian rocks of Germany and Spain, are set apart by specialized morphological characters and because of our entire uncertainty

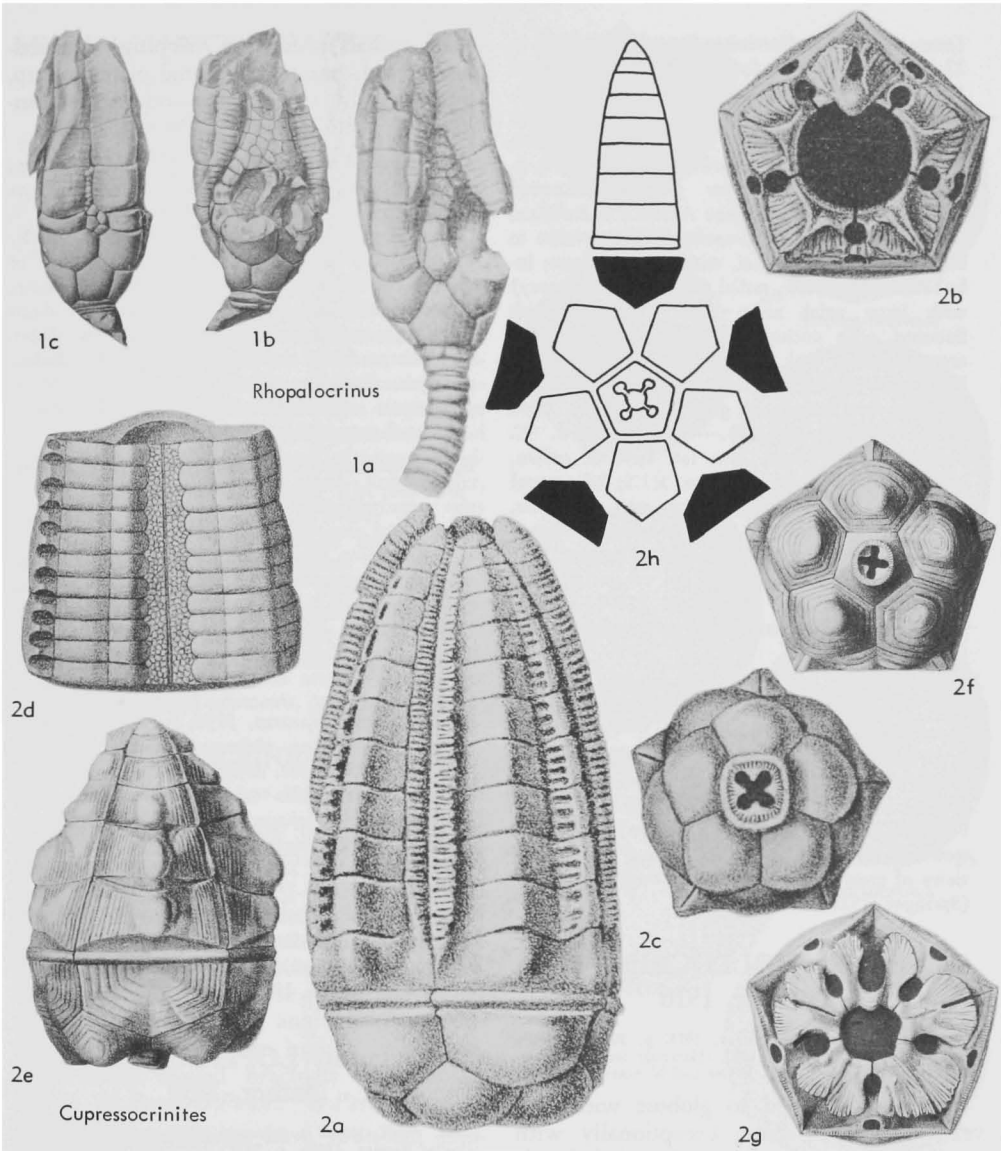


FIG. 430. Cupressocrinitidae (p. *T657-T658*).

as to their phylogenetic relations. Study of representative specimens and of discussions of these fossils by other workers has not resolved the questions. The cup is one of advanced evolutionary type in having perfect pentamerous symmetry and in characters of the base, which is flattened and mainly composed of solidly fused infrabasals. The radial articular facets are wide and straight and have decidedly special surface features. Five very peculiarly modified orals constitute a so-called "consolidating apparatus" at the summit of the cup, and surrounding them are the five unbranched arms, composed of broadly hollowed uniserially arranged brachials that bear multiple pinnules. The subquadrangular column has four peripheral canals and an axial canal.

Cupressocrinites GOLDFUSS, 1831, p. 212 [**C. crassus*; SD WACHSMUTH & SPRINGER, 1886, p. 105] [=*Cupressocrinus* AGASSIZ, 1836, p. 198

(nom. van.); Cypellocrinites STEININGER, 1849, p. 22 (type, *C. elegans*); *Cypressocrinites* STEININGER, 1849, p. 20; *Cypellocrinus* BATHER in LANKESTER, 1900a, p. 177; *Halocrinites* STEININGER, 1831, p. 23 (type, *H. schlotheimi*); *Halocrinus* D'ORBIGNY, 1852, p. 140; *Procupressocrinus* JAEKEL, 1918, p. 82 (type, *Cupressocrinites gracilis* GOLDFUSS, 1831, p. 213); *Aviadocrinus* ALMELA & REVILLA, 1950, p. 11 (type, *A. sampelayoi*)]. Cup cone to bowl shaped, symmetrical, without anal plates; infrabasals low, fused; radial facets wide (plenary) with large axial nerve canal. Tegmen with flattened orals enclosing ambulacral tracts from arms; posterior oral madreporitic; anal sac small. Five massive arms uniserial, with delicate pinnules covering deep ambulacral grooves. *L.Dev.-U.Dev.*, Eu.(Ger.-Spain-Belg.-Eng.).——FIG. 430,*2a-d*. **C. crassus*, M.Dev., Ger.; *2a-c*, lat. view of crown, ventral and dorsal views of cup, ×1.5; *2d*, ventral view of brachials and pinnules, ×3 (Schultze, 1867).——FIG. 430,*2e-g*. *C. abbreviatus* GOLDFUSS, M.Dev., Ger.; *2e*, lat. view of crown, ×1; *2f*, dorsal view of cup, ×1; *2g*, ventral view of cup and orals, ×1 (Schultze, 1867).——FIG. 430,*2h*. Plate diagram for genus (radials black) (Moore, n).

Rhopalocrinus WACHSMUTH & SPRINGER, 1880, p. 57 [**Taxocrinus gracilis* SCHULTZE, 1866, p. 39 (*non* MEEK & WORTHEN, 1865a); OD]. Like *Cupressocrinites* except for single anal plate between posterior radials; anal sac wide based and massive; orals unknown. *M.Dev.*, Eu.(Ger.).——FIG. 430,*1*. **R. gracilis* (SCHULTZE); *1a*, post. view of crown, ×1.5; *1b,c*, *C*-ray and *AE*-interray views of crown and proximal part of stem, ×1.5 (Springer, 1920).

Superfamily MOLLOCRINACEA Wanner, 1916

[*nom. transl.* MOORE & STRIMPLE, 1973, p. 20 (*ex* Mollocrinidae WANNER, 1916a, p. 67)] [Materials for this superfamily prepared by R. C. MOORE and N. GARY LANE]

Cup bowl shaped to globose with convex or flattened base, exceptionally with small shallow basal concavity; infrabasals five, four, three or fused into single solid plate, generally but not universally visible from side; radial articular facets narrow, separated by interradial notches; one to three anal plates in cup. Anal sac low rounded. Stem transversely circular, slender to robust. *L.Penn.-U.Perm.*

Family MOLLOCRINIDAE Wanner, 1916

[Mollocrinidae WANNER, 1916a, p. 67]

Cup small, conical to globose; radial articular facets angustary (much narrower than radials), concave, sloping outward-downward; one to three anal plates in cup, but generally two. Arms and tegmen unknown. Stem round. *L.Penn.-U.Perm.*

Mollocrinus WANNER, 1916, p. 67 [**M. poculum*; OD]. Cup globose, infrabasals 3, low, azygous small one in *A* ray, visible from side; basals 5, large, as wide as high; radials pentagonal, smaller than basals, their articular facets with trace of transverse ridge and slitlike ligament groove; quadrangular radianal and anal *X* in cup. Arms and tegmen unknown. Stem transversely round, with large round central canal. *U.Perm.*, Indon. (Timor, Basleo).——FIG. 431,*3*. **M. poculum; 3a,b*, post. and ventral (*CD* interray downward) views of cup, ×1.5 (Wanner, 1916a).

Hemimollocrinus YAKOVLEV, 1930, p. 97 [**H. uralensis*; M]. Cup small, low conical; infrabasals 5, low, visible in side view; basals and radials about equal in size; radial articular facets narrower than radials, rounded, with well-developed transverse ridge; 3 anal plates in cup. *L.Perm. (Artinsk.)*, USSR(Krasnoufimsk).——FIG. 431,*1*. **H. uralensis; 1a,b*, post. and ventral (*CD* interray downward) views of cup, ×1.5 (Yakovlev, 1930a).

Strongylocrinus WANNER, 1916, p. 72 [**S. molengraffi*; OD]. Cup globose; infrabasals 3, low, but visible from side, azygous small one in *C* ray; basals large; radials smaller than basals, with narrow horseshoe-shaped articular facets facing directly upward; single anal plate in cup directly above *CD* basal and between posterior radials. *L.Penn.(Morrow.)-U.Perm.(Basleo beds)*, USA (Okla.)-Indon.(Timor).——FIG. 431,*2*. **S. molengraffi*, Perm., Timor; *2a-d*, post., ventral (*CD* interray downward), dorsal, and ant. views of cup, ×2 (Wanner, 1916a).

Superfamily LOPHOCRINACEA Bather, 1899

[*nom. transl.* MOORE & STRIMPLE, 1973, p. 20 (*ex* Lophocrinidae BATHER, 1899b, p. 922)] [Materials for this superfamily prepared by R. C. MOORE, H. L. STRIMPLE, and N. GARY LANE]

Crown tall, expanding upward. Cup conical, with five upflared infrabasals readily visible from side; radial articular facets wide but less than full width of radials, leaving interradial notches at upper corners of these plates; three or single anal plates in cup. Anal sac tall, cylindrical or markedly narrowing upward, mainly composed of subhorizontally plicate plates. Arms five to highly branched, slender, uniserial. Stem transversely circular. *L. Miss.-U.Perm.*

Family LOPHOCRINIDAE Bather, 1899

[Lophocrinidae Bather, 1899b, p. 922]

Cup small, conical single large anal plate in cup between posterior radials. Anal sac large, cylindrical. Arms slender, unbranched, with small, unbranched ramules or pinnules on alternate sides of successive brachials. *Up.L.Carb.*

Lophocrinus von Meyer, 1858, p. 59 [**L. speciosus* (=*Poteriocrinus minutus* Roemer, 1850b, p. 47); M] [=*Carduocrinus* von Koenen, 1895b, p. 210 (type, *C. jaekeli* von Koenen, =*P. minutus*)]. Cup small, conical, plates smooth; infrabasals and basals higher than wide; single large anal plate in cup between posterior radials. Anal sac large, cylindrical, composed of several longitudinal rows of small, convex plates. Arms slender, atomous, bearing long pinnules on alternating sides of successive brachials, which are low, wedge shaped. Stem transversely round, columnals alternating in width proximally, becoming higher and equal in width distally. *Up.L.Carb.(Visean)*, Eu. (Ger.-Spain).——Fig. 432,*6*. **L. minutus* (Roemer), Ger.; *6a*, lat. view of crown and column, ×0.7; *6b-f*, side views and articular surfaces of proximal and distal columnals, ×6 (Jaekel, 1895).

Family PELECOCRINIDAE Kirk, 1941

[Pelecocrinidae Kirk, 1941b, p. 82]

Crown tall, ovoid. Cup low, bowl shaped, with shallow basal concavity; infrabasals five, rarely four, barely visible or not visible in side view; radial articular facets peneplenary, narrower than radials, inclined slightly to strongly outward-downward, with prominent transverse ridge, interradial notches distinct; three anal plates in cup. Arms isotomous where known, pinnulate, with wedge-shaped brachials. *L.Miss.-U. Miss.; M.Penn.-U.Penn.; U.Perm.*

The Pelecocrinidae have rounded, relatively narrow radial articular facets that slope strongly outward-downward, as in the Poteriocrinitidae, but they show advancement in evolution of the shape of the cup and in structure of the arms. The cup is low bowl shaped, gently convex or slightly concave at the base. The arms have cuneate uniserial or biserial brachials that bear pinnules, and they branch isotomously twice or more.

Key to Genera of Pelecocrinidae

A. Base of cup flat or shallowly concave .....
  I. Infrabasals, basals, and radials 5 .....
    a. Radial articular facets sloping gently outward-downward .....
      1. Stem impression narrow, round .. .. *Forthocrinus*
      2. Stem impression very wide, round ..... *Tetrabrachiocrinus*
    b. Radial articular facets sloping steeply outward-downward, round stem, impression very wide ..... *Malaiocrinus*
  II. Infrabasals, basals, and radials 4 .... *Depaocrinus*
B. Base of cup convex .....

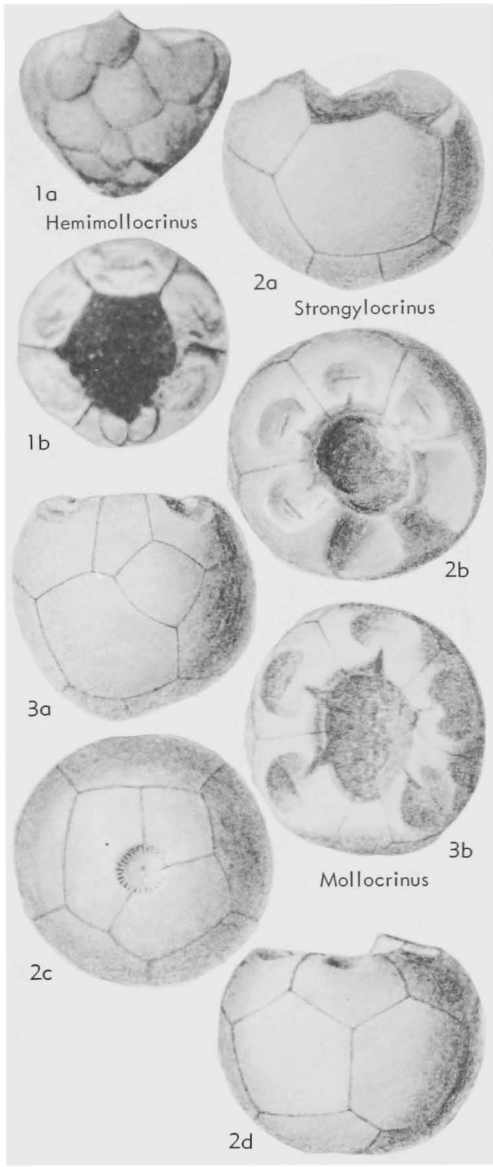


Fig. 431. Mollocrinidae (p. *T659*).

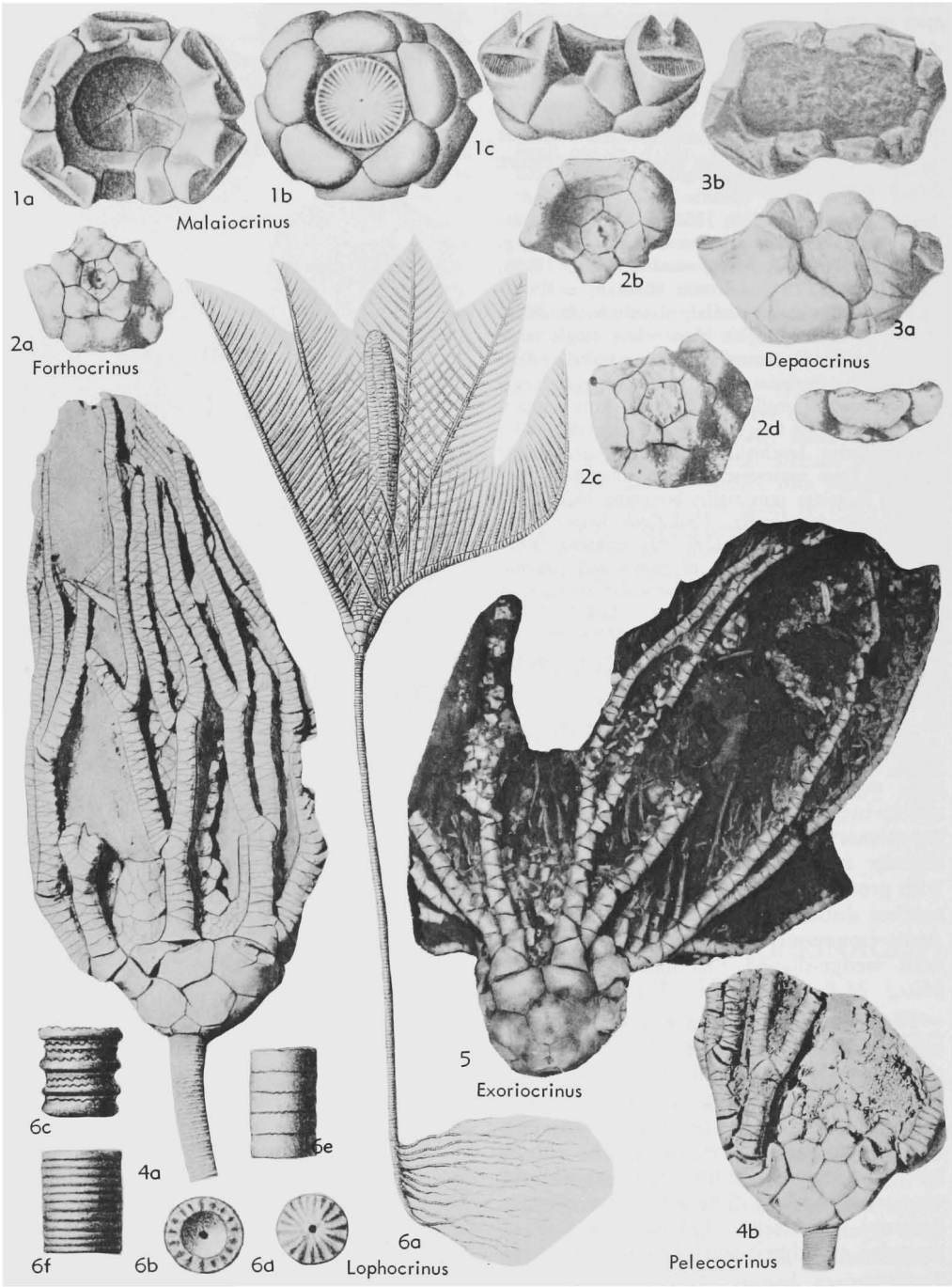


FIG. 432. Lophocrinidae *(6)*; Pelecocrinidae *(1-5)* (p. *T*659-*T*662).

I. Stem round ..... *Pelecocrinus*
II. Stem pentagonal ..... *Exoriocrinus*

Pelecocrinus KIRK, 1941, p. 82 [**P. insignis*; OD]. Crown large, expanding upward to about one-third

of its height and then contracting in width; bases of arms widely spaced with divergent rami. Cup bowl shaped; infrabasals 5, low, visible in side view; basals large; radials large, pentagonal, with rounded peneplenary articular facets, sloping outward-downward, interradial notches shallow and wide; 3 anal plates in cup. Anal sac short, slender, composed of 10 or more vertical rows of irregular polygonal plates; summit with heavy, spinose plates. Arms branching isotomously 2 or 3 times; first primibrachs axillary in all but *A* ray, which has 10 to 12 primibrachs; brachials strongly wedge shaped, rounded, axillaries large, widely pentagonal to triangular and convex; pinnules long and stout. Stem transversely round. *L.Miss.*, USA (Iowa)-Can.(Alta.).——Fig. 432,*4*. **P. insignis*, Iowa; *4a,b*, *A*-ray view of crown and post. view of partial crown, ×0.7 (Kirk, 1941b).

Depaocrinus Wanner, 1937, p. 152 [**D. ottowi*; OD]. Cup bowl shaped, base flat to slightly concave, greatest width at top of radials; infrabasals 4, circlet quadrangular in outline, mostly covered by stem impression, not visible in side view; basals and radials 4; radial articular facets peneplenary, sloping outward-downward in side view and occupying about four-fifths of radial plate width; 3 anal plates in cup. Stem impression round. *U.Perm.*, Indon.(Timor, Basleo).——Fig. 432,*3*. **D. ottowi; 3a,b*, post. and ventral views of cup, ×1 (Wanner, 1937).

Exoriocrinus Strimple & Moore, 1971, p. 15 [**Poteriocrinus lasallensis* Worthen in Worthen & Meek, 1875, p. 526; OD]. Cup moderately large, medium bowl shaped, infrabasals visible from side, 5 large basals; 5 large radials with notches between, subhorizontal plenary articular facets. Anal sac unknown. Arms 20, slender, rounded, not appressed, branching isotomously on primibrachs *1* and again higher in each ray, nonaxillary brachials strongly cuneate in external view; pinnules short and stout. Stem pentagonal in section proximally and circular distally, lumen pentalobate. *M.Penn.-U.Penn.*, USA(Okla.-Ill.).——Fig. 432,*5*. **E. lasallensis* (Worthen), U.Penn. (Missour., LaSalle Ls.), near Pontiac, Livingston Co., Ill.; *B*-ray view of hypotype crown, ×1.4 (Strimple & Moore, 1971a).

Forthocrinus Wright, 1942, p. 274 [**F. lepidus*; OD]. Cup low, wide saucer shaped, with small shallow basal concavity; plates thin, internal cavity of cup large; plates ornamented with large nodes; infrabasals small, not visible in side view; basals convex and nodose; radials wide, with proximal tips in depressed areas between nodes; interradial sutures notched distally, articular facets slightly narrower than radials and inclined outward-downward; 3 anal plates in cup. *L.Carb.*, Eu.(Eng.).——Fig. 432,*2*. **F. lepidus; 2a,c*, dorsal views; *2b,d*, ventral and ant. views of cups, ×1 (Wright, 1954).

Malaiocrinus Wanner, 1924, p. 183 [**Zeacrinus? sundaicus* Wanner, 1916a, p. 147; OD]. Cup low, broad, plates convex; infrabasal circlet wide, flat, not visible in side view, mostly covered by stem impression; basals large, low, strongly convex; radials large, higher than wide, with articular facets large, rounded, steeply inclined outward-downward, with prominent transverse ridge; interradial notches prominent; 3 anal plates in cup. Arms and tegmen unknown. Stem impression round, with numerous fine culminae. *U.Perm.*, Indon.(Timor).——Fig. 432,*1*. **M. sundaicus* (Wanner), Basleo; *1a-c*, ventral, dorsal, and post. views of cup, ×2 (Wanner, 1924).

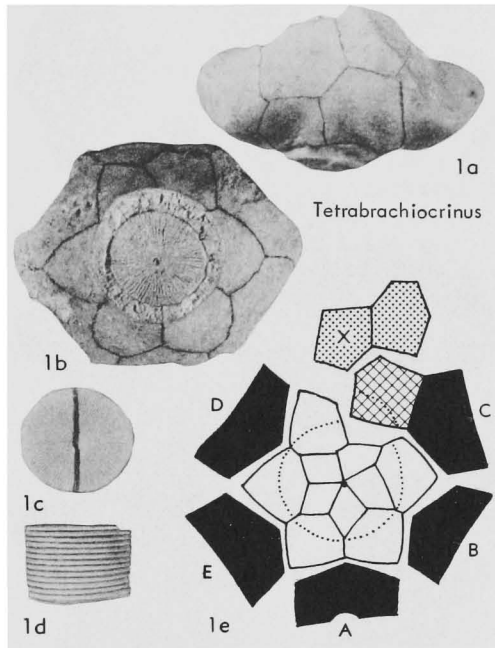


Fig. 433. Pelecocrinidae (p. *T*661).

Tetrabrachiocrinus Yakovlev, 1934, p. 276 [**T. fabianii*; OD] [=*Heterobrachiocrinus* Yakovlev, 1938, p. 249 (obj.)]. Cup large, hexagonal in outline in dorsal or ventral view, wider than high, base broad and flat; infrabasals small, covered by stem; proximal edges of basals covered by stem; radials large, unequal in size, *A* radial smaller than others and with a narrow facet, other facets large, rounded, steeply inclined; anal plates three, large, projecting above level of radials; arms unknown; stem large, round, with narrow lumen and wide, thin columnals. *U.Perm.*(Sicily).——Fig. 433,*1a-d*. **T. fabianii; 1a-d*, post. and dorsal views of cup, articular and lat. views of stem, ×2 (Yakovlev, 1934).——Fig. 433,*1e*. Plate diagram for genus, of cup, ant. ray up (radials black, anal plates stippled, radianal cross ruled) (Moore, n).

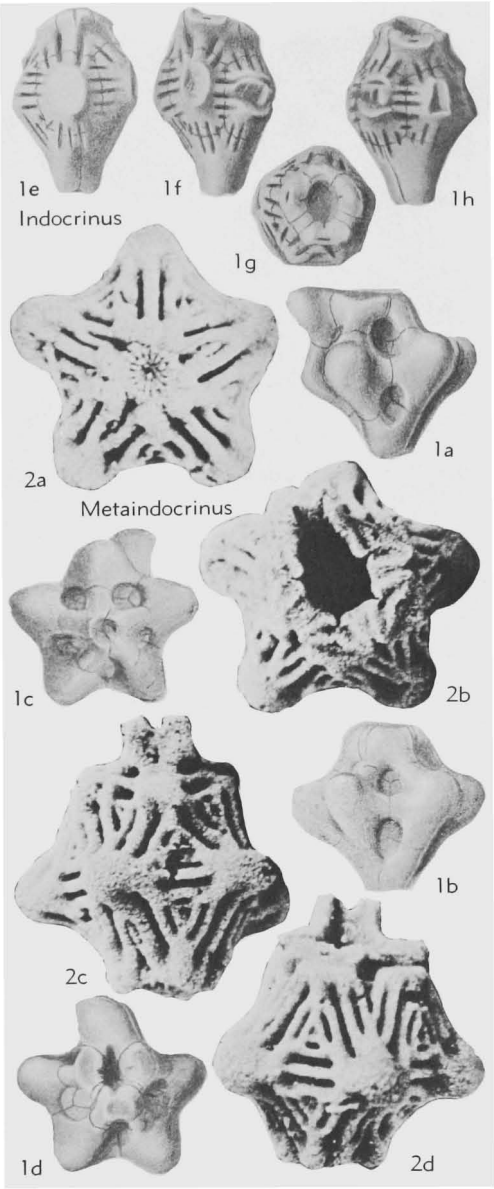


FIG. 434. Indocrinidae (p. *T662*).

[After YAKOVLEV published the name *Tetrabrachiocrinus* in 1934, he later (1938), in a short note, stated that this name was preoccupied by that of a Mesozoic crinoid, without giving author or reference for the earlier usage. Search of literature and correspondence with several authorities have failed to reveal the use of *Tetrabrachiocrinus* by any author prior to YAKOVLEV, 1934. YU. ARENDT believes that YAKOVLEV may have mistaken *Tetracrinus* for *Tetrabrachiocrinus*. For this reason YAKOVLEV's substitute name, *Heterobrachiocrinus*, is here rejected as a junior objective synonym of *Tetrabrachiocrinus*.—N. GARY LANE.]

Family INDOCRINIDAE Strimple, 1966

[Indocrinidae STRIMPLE, 1966b, p. 80]

Cup small, globose or biturbinate; infrabasals three, visible in side view; basals large, nodose or convex, cup plates mostly with epispires across plate sutures; radials small, restricted in width and outer surface incurved distally, *B* and *E* radials or only *B* radial armless; one or three anal plates in cup. *L.Perm.-U.Perm.*

Key to Genera of Indocrinidae

A. Cup biturbinate, pentalobate transversely, large protuberant basals; epispires crossing plate sutures .....
  I. *B* and *E* radials narrow, armless; single anal plate *(X)* in cup ..... *Indocrinus*
  II. Only *B* radial armless; 3 anal plates in cup ..... *Metaindocrinus*

B. Cup globose, constricted at top; no epispires; *B* and *E* radials armless; 3 anal plates in cup ..... *Proindocrinus*

Indocrinus WANNER, 1916, p. 74 [**I. elegans*; OD]. Cup biturbinate in side view and pentalobate in basal view; infrabasals 3, high, circlet cone shaped, small infrabasal in *A* ray or rarely in *D* ray; basals large, protruding, strongly nodose, with deep depressions at plate angles which contain epispires transverse to sutures; radials small, restricted in width, unequal in size; *B* and *E* radials narrow and armless; other 3 radials larger and with narrow, rounded articular facets; single anal plate in cup, large, strongly convex and protruding, quadrangular, directly above *CD* basal. *U.Perm.*, Indon.(Timor).——FIG. 434,*1a-d*. **I. elegans*, Basleo; *BC*-interray, *A*-ray, dorsal, and ventral views of cup, ×1.7 (Wanner, 1916a).——FIG. 434,*1e-h*. *I. rimosus* WANNER, Basleo; post., *C*-ray, ventral, and *A*-ray views of cup, ×1.7 (Wanner, 1916a).

Metaindocrinus STRIMPLE, 1966, p. 81 [**M. cooperi*; OD]. Cup small, biturbinate, pentalobate in basal view; infrabasals 3, low, visible in side view; basals 5, large, with strong projecting central node; radiating epispires present across all cup plate sutures, epispires deeply depressed between prominent ridges; radials small, restricted in width, *B* radial armless, others with wide horizontal articular facets; large radianal above *CD* basal, succeeded by 2 small anal plates. Stem impression round. *U.Perm.*, USA(Texas).——FIG. 434,*2*. **M. cooperi*, Word F., Glass Mts., Texas; *2a-d*, dorsal, ventral, post., ant. views of cup, ×3.4 (Strimple, 1966b).

Proindocrinus YAKOVLEV, 1939, p. 832 [**Indocrinus piszowi* YAKOVLEV, 1926a; M]. Cup globose, plates smooth and without epispires; infrabasals large, visible in side view; basals large; radials small, restricted in width, circlet constricted distally, articular facets confined to *A*, *C*, and *D*

radials; large radianal, small anal *X*, and right tube plate in cup. *L.Perm.(Artinsk.)*, USSR (Krasnoufimsk).

Family LAUDONOCRINIDAE Moore & Strimple, 1973

[Laudonocrinidae Moore & Strimple, 1973, p. 20]

Cup bowl shaped, with flat or faintly convex base and subvertical sides near rim, arm facets peneplenary, interradial notches seen in dorsal and ventral views; two or three anals in cup; anal sac mushroomlike with horizontal girdling spines at summit; arms endotomous. *U.Miss.-L.Perm.*

Laudonocrinus Moore & Plummer, 1940, p. 174 [**Hydreionocrinus subsinuatus* Miller & Gurley, 1894b, p. 40; OD] [=*Appalachiacrinus* Burke, 1974, p. 5 (type, *A. erwini*; OD)]. Cup moderately low bowl shaped, characterized essentially by smooth contour of surface; base flat; summit of interradial sutures with well-defined notch and *CD* interray wide, concave at cup summit; infrabasals forming small subhorizontal regular pentagon, mostly covered by round stem impression; basals essentially equal but *CD* basal slightly longer and *BC* basal wider than others; basals flared upward and clearly visible from side; radials pentagonal, with width generally about twice length; peneplenary articular facets sloping outward-downward at moderate angle, transverse ridge and ligament areas clearly defined; anal plates 3, radianal larger than others, resting on *BC* and *CD* basals. *L.Penn.-U.Penn.(Missour.)*, N.Am.(Midcontinent region). ——Fig. 435,*2a*; 436,*5*. **L. subsinuatus* (Miller & Gurley), Missour.(Kansas City F.), Kansas City, Mo.; 435,*2a*, dorsal view of cup, ×2 (Moore & Plummer, 1940); 436,*5a,b*, diagram. long. secs. through midlines of *A* and *D* radials, ×2.25 (explanation on p. T723) (Moore, n).——Fig. 435,*2b-d*. *L. catillus* Moore & Plummer, Millsap Lake Gr.(Desmoines.), Palo Pinto Co., Texas; dorsal, post., ventral views of cup, ×1.5 (Moore & Plummer, 1940).

Anchicrinus Strimple & Watkins, 1969, p. 206 [**A. toddi*; OD]. Cup low, bowl shaped, with broad basal plane and shallow concavity; infrabasals downflared except at distal tips, which are subhorizontal; sutures impressed, with dimplelike depressions at plate corners. Arms long slender uniserial, branching endotomously 5 times; axillaries spinose except primibrachs *1* which are tumid but seldom spinose. Tegmen terminates at summit of crown with small platform of few polygonal plates surrounded by 8 outwardly directed spinelike plates. *L.Penn.-M.Penn.*, USA (Okla.-Texas).——Fig. 437,*2*. **A. toddi*, M.Penn. (Millsap Lake F., Brannon Bridge Ls. Mbr.), near Brock, Parker Co., Texas; *2a,b*, holotype, lat. and post. views of crown, ×1.1; *2c,d*, paratype, dorsal, ventral views, ×1.7 (Strimple & Watkins, 1969).

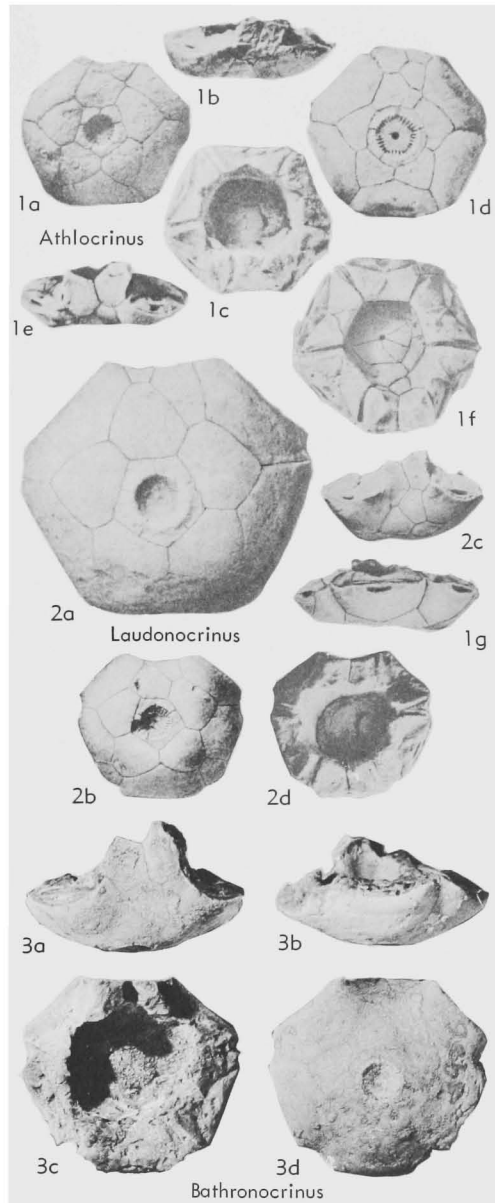
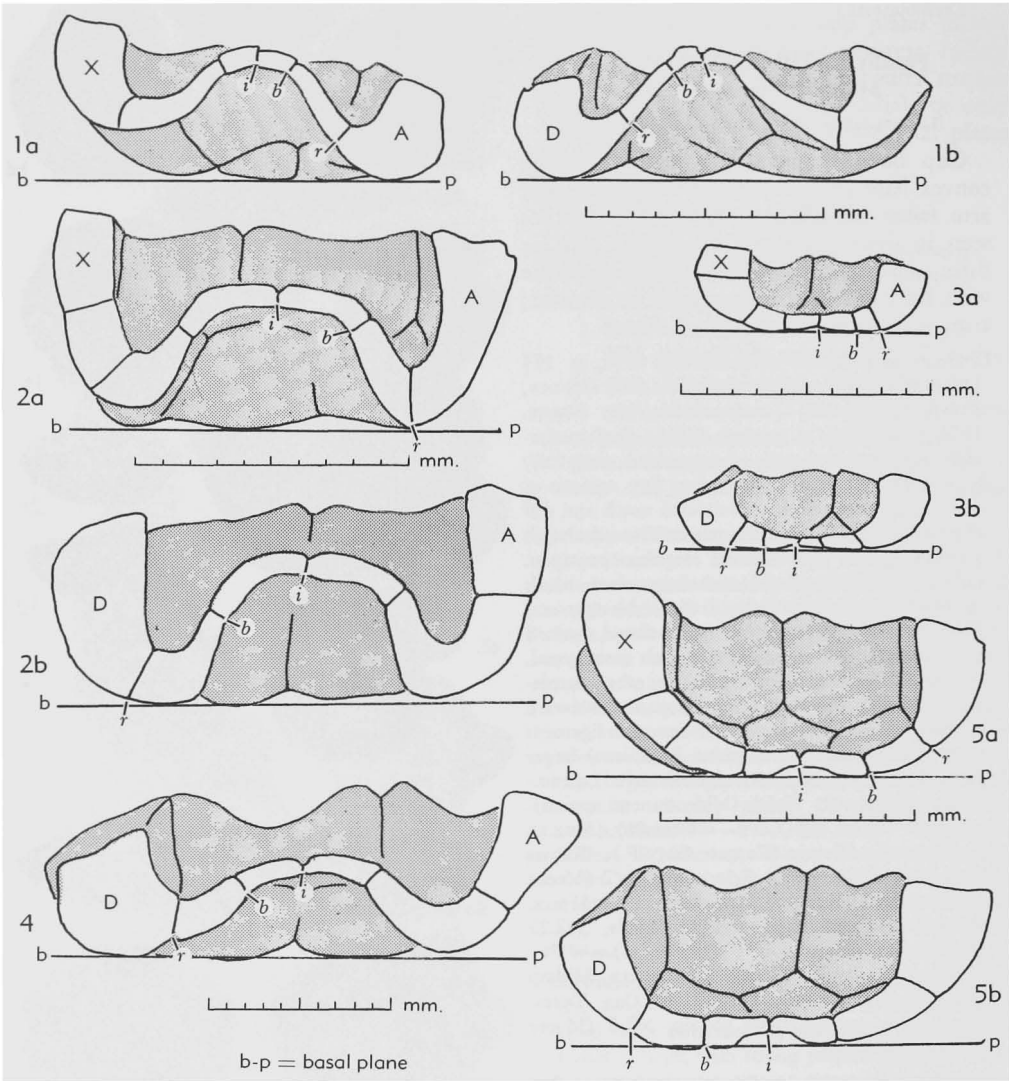


Fig. 435. Laudonocrinidae (p. T663, T665-T667).

Athlocrinus Moore & Plummer, 1940, p. 169 [**A. placidus*; OD]. Cup extremely shallow saucer shaped, with base almost perfectly flat, except for indentation of round stem impression; sides flaring gently upward to subvertical at summit plane; *CD* interray narrower than in *Laudonocrinus*, interradial notches small; sutures not at all impressed, and contour of surface of cup entirely smooth;



		A ray			D ray		
		i	*b*	*r*	*i*	*b*	*r*
1a,b.	Pirasocrinus	−	−	−	−	−	−
2a,b.	Perimestocrinus	−	−	0	−	−	0
3a,b.	Athlocrinus	−	0	0	−	0	0
4.	Aatocrinus				−	−	−
5a,b.	Laudonocrinus	−	0	+	−	0	+

FIG. 436. Cross sections of cups of Laudonocrinidae *(3,5)* and Pirasocrinidae *(1,2,4)*, portion of cup beyond the plane of the section shaded (Moore, n, after Moore & Plummer, 1940). [Explanation: *i*, proximal tip of infrabasal; *b*, proximal tip of basal; *r*, proximal tip of radial. Symbols: minus sign (−), infral (above basal plane within basal concavity of cup); zero (0), basiplanal (in or tangent to basal plane of cup); plus (+), supral (above basal plane on outer side of the cup).]

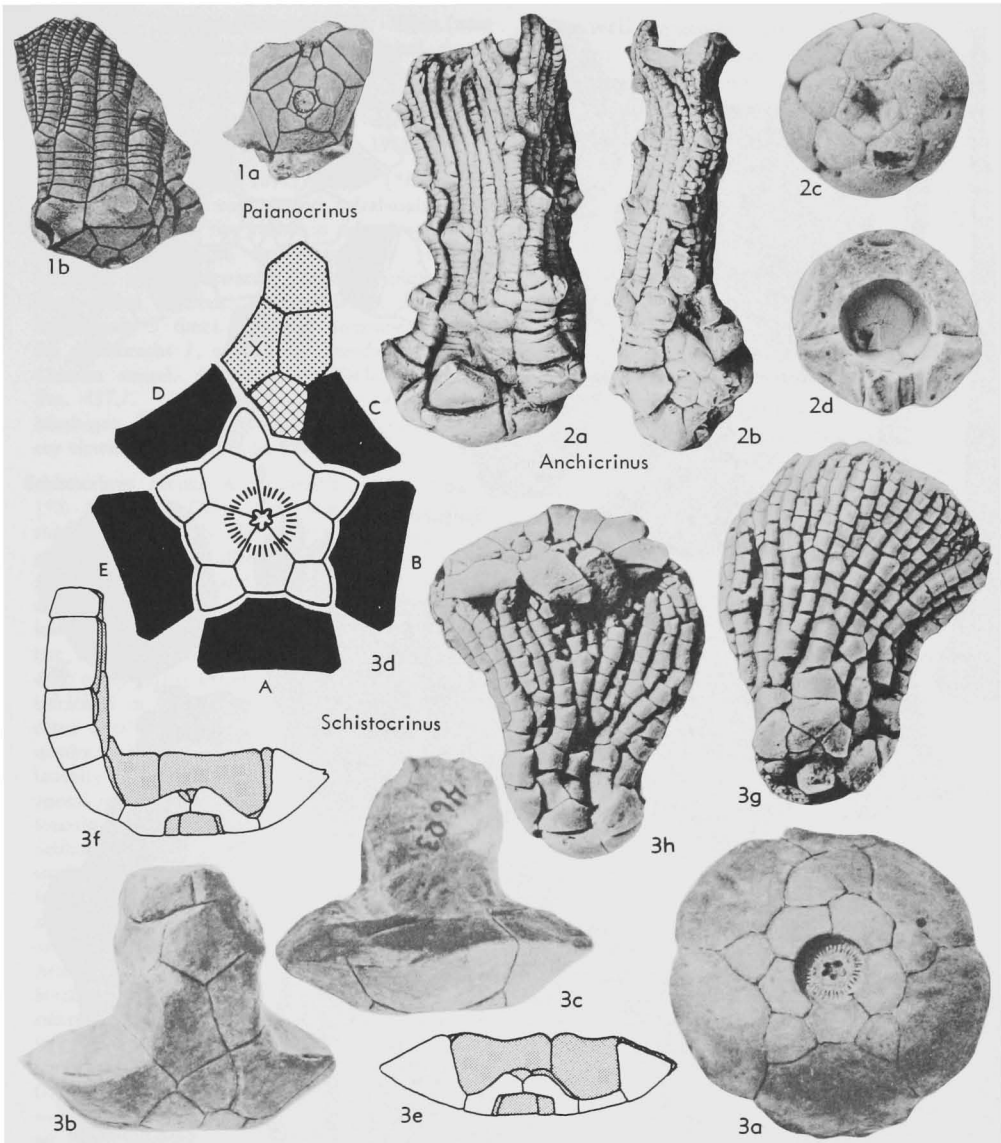


FIG. 437. Laudonocrinidae (p. *T663*, *T667*).

infrabasals forming regular pentagon covered largely by indented stem attachment, distal parts of infrabasals horizontal, not visible in side view; subequal basals, with horizontal proximal parts, distally upflared and visible in side view; radials with proximal tips in basal plane of cup (formula, 000), articular facets less than maximum width of radials, slope of facets gently outward-downward; anals 3, anal *X* resting on truncate distal tip of *CD* basal. *M.Penn.(Desmoines.)-U.Penn. (Missour.)*, USA(Texas-Okla.-Kans.).——FIG. 435, *1a-c*; 436,*3*. **A. placidus*, U.Penn.(Plattsburg Ls.), Altoona, Kans.; 435,*1a-c*, dorsal, post., ventral views of holotype, ×2 (Moore & Plummer, 1940); 436,*3a,b*, diagram. long. secs. of cup through midline of *A* and *D* radials, ×2.25 (Moore, n).——FIG. 435,*1d-g*. *A. clypeiformis* MOORE & PLUMMER, U.Penn.(Merriman Ls., Graford F.), Palo Pinto Co., Texas; *1d-g*, dorsal, post., ventral, ant. views of cup, ×2 (Moore & Plummer, 1940).

Bathronocrinus STRIMPLE, 1962, p. 37 [**B. turioformis*; OD] [=*Hypermorphocrinus* ARENDT, 1968a, p. 99 (type, *H. magnospinosus*; OD)].

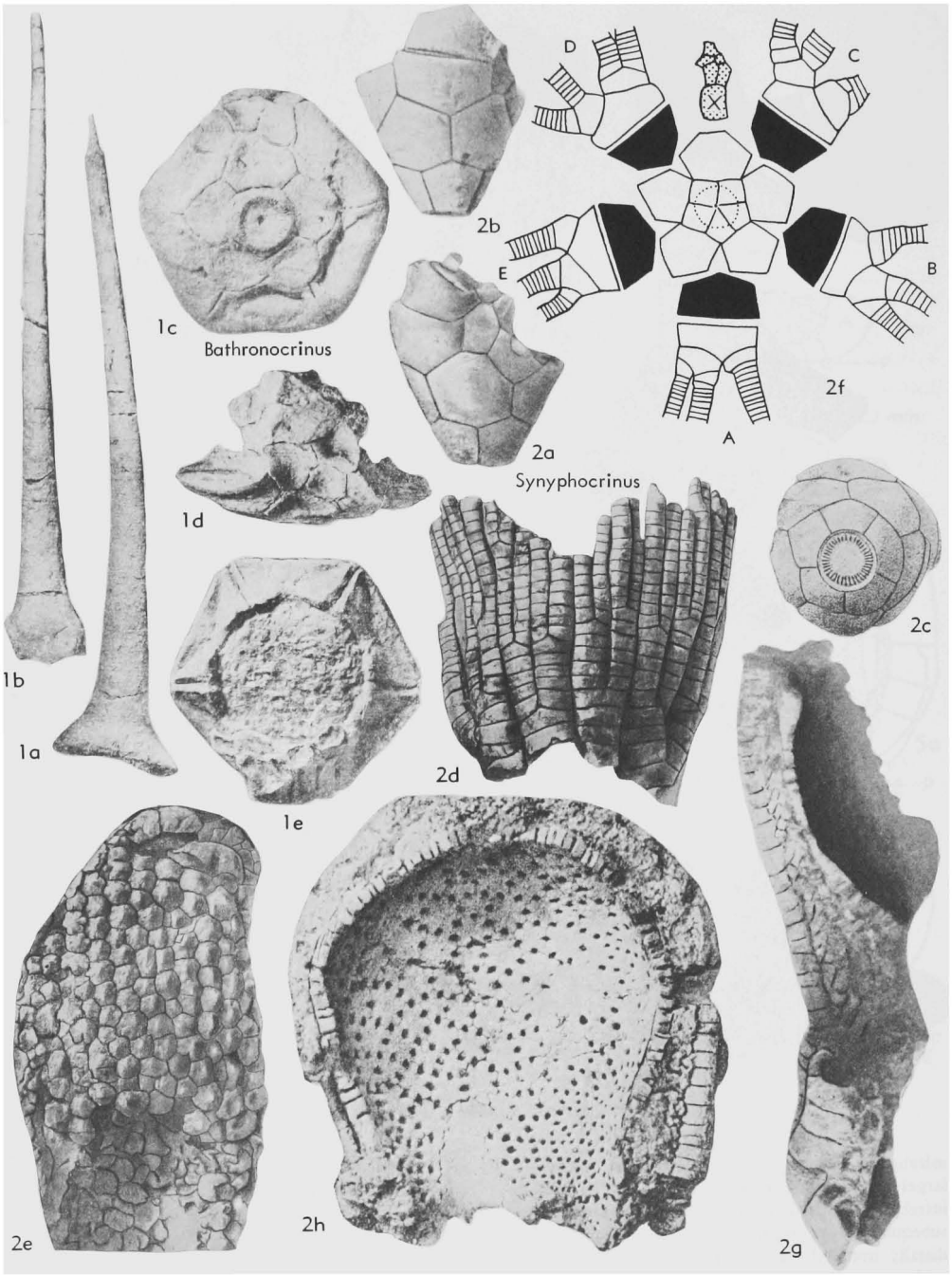


FIG. 438. Laudonocrinidae *(1)*; Anobasicrinidae *(2)* (p. *T665-T667*, *T680*).

Cup like *Paianocrinus* except for slight curvature of distal portions of radials and notched appearance between radials at summit. *Laudonocrinus* has a taller cup with proximal ends of basals flexed as though to form a basal concavity, distal ends of infrabasals upflared but barely visible in side view of cup. *M.Penn.*, USA(Okla.); *L.Perm.*, USSR(Krasnoufimsk, Urals.).——FIG. 435,*3*. ***B.**

turioformis, M.Penn.(Oologah F.), Okla.(near Tulsa, Tulsa Co.); *3a-d,* post., ant., ventral, dorsal views, ×2.5 (Strimple, 1962a).——Fig. 438,*1. B. magnospinosus* (Arendt), L.Perm., Sib.; *1a-e,* primibrach spine, anal sac spine, dorsal, post., ventral views of cup, ×1 (Arendt, 1968a).

Paianocrinus Strimple, 1951, p. 669 [**P. durus*; OD]. Cup truncate cone shaped, infrabasals gently upflared and distal tips visible in side view of cup. Anal sac cylindrical, terminating in platform bordered by 6 outwardly directed spines with bases joined together. Arms uniserial, branching isotomously 3 times, axillaries nonspinose except for primibrachs *1,* which are extended as spines. Column round. *U.Miss.,* USA(Okla.-Ark.).——Fig. 437,*1. *P. durus,* Pitkin F., near Braggs, Muskogee Co., Okla.; *1a,b,* holotype, dorsal, *D*-ray views, ×1.2 (Strimple, 1951d).

Schistocrinus Moore & Plummer, 1940, p. 217 [**S. torquatus*; OD]. Cup low, shallow saucer shaped, base nearly flat except for sharply depressed, vertically walled, round stem impression; sides of cup gently and evenly upflared, posterior side with strongly elevated, firmly joined, thick lower anal plates; surface smooth, sutures distinct but not impressed; infrabasals not visible from side, except distal extremity of right posterior *(C)* infrabasal in posterior view, each infrabasal truncated distally for contact with radials; small, subquadrangular basals, shaped like arrowheads, not laterally in contact with other basals; large hexagonal radials, slightly wider than long, proximally touching infrabasals; radials with peneplenary articular facets and interradial notches; radianal on small right posterior *(C)* infrabasal supporting large anal *X* and right tube plate, which are mostly above summit line of radials but considered to be cup plates. Anal sac large, balloonlike. Arms branching isotomously on broad first primibrachs in all rays; succeeding brachials wide, short, externally rectangular segments or pentagonal axillary plates; division of branches in lower part of rays regularly isotomous. *M.Penn.(Desmoines.)-U.Penn.(Missour.),* USA(Midcontinent region).——Fig. 437,*3a-f. *S. torquatus,* Missour.(Winterset Ls.), Kansas City, Mo.; *3a-c,* dorsal, post. and ant. views, ×2 (Moore & Plummer, 1940); *3d,* plate diagram of cup (radials black, radianal cross ruled, anals stippled), ×1.5 (Moore, n); *3e,f,* long. secs. of cup through midlines of *D* and *A* radials, ×1.5 (Moore & Plummer, 1940).——Fig. 437, *3g,h. S. parvus* Moore & Plummer, Desmoines. (Millsap Lake F.), Parker Co., Texas; ant. and post. views of holotype crown, ×2 (Moore & Plummer, 1940).

Family STELLAROCRINIDAE Strimple, 1961

[Stellarocrinidae Strimple, 1961d, p. 108]

Crown typically spreading sideward, low; arms well separated from neighbors. Cup medium to low bowl shaped, commonly with broad, shallow basal concavity; infrabasals subhorizontal; basals large, usually protruded about basal depression; radials wider than long, articular facets not as wide as radials, strongly declivate, typically leaving well-marked interradial notches; cup anal plates three in normal to advanced arrangement with single anal plate (radianal) on *CD* basal, followed above cup by two equidimensional plates. Anal sac cylindrical, tall, composed of moderately large protuberant hexagonal plates in alternating vertical series; terminating in *Stellarocrinus* and *Brabeocrinus* with a few thick, short spines, anus covered by small polygonal plates at summit of sac. Arms strongly cuneate-uniserial to mostly biserial, not apposed, branching on primibrachs *1* in geologically younger forms, primibrachs *2* in older ones, with one or more subsequent branchings in all rays; pinnules stout, attached to inner surfaces of brachials. Column usually round, but transversely pentastellate in some Chesterian and Morrowan species, round in Visean and later forms. *U.Miss.(Chester.)-L.Perm.*

Key to Genera of Stellarocrinidae

A. Arms narrow, formed of uniserially arranged cuneate brachials, 3 normal (primitive) anal plates in cup .....
  I. Strong plications on cup plates; primibrachs *2* axillary; stem pentastellate .... *Heliosocrinus*
  II. Moderate plications on cup plates, primibrachs 2 axillary, stem round .... *Rhopocrinus*
  III. Cup plates smooth, primibrachs *1,* axillary, stem round ..... *Pedinocrinus*

B. Single anal plate in cup or one followed by two others, located between posterior radials; primibrachs *1* axillary; stem round ....
  I. Cup narrow box shaped, arms cuneate-uniserial to incipiently biserial .... *Brabeocrinus*
  II. Cup basally concave shallow bowl shaped, arms biserial .....
    1. Arms narrow, no plications on cup plates ..... *Brychiocrinus*
    2. Arms relatively wide .....
      a. Basals and radials strongly plicate ..... *Stellarocrinus*
      b. Cup plates smooth, not plicate ..... *Celonocrinus*

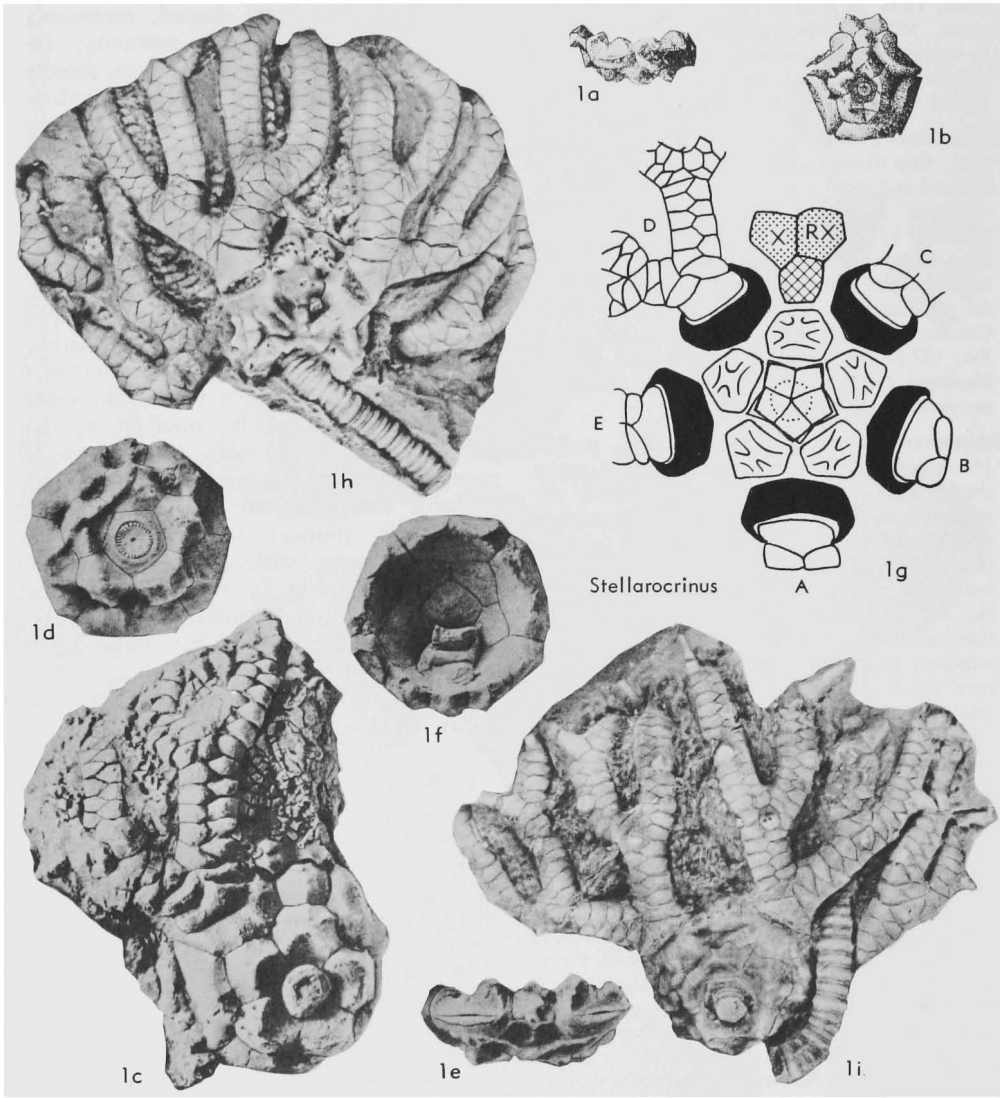


FIG. 439. Stellarocrinidae (p. *T668-T669*).

Stellarocrinus STRIMPLE, 1940(Mar.), p. 1 [*pro Whiteocrinus* STRIMPLE, 1939b, p. 4 (*non* JAEKEL, 1918, p. 58)] [**Cyathocrinus stillativus* WHITE, 1880b, p. 258; OD] [=*Apollocrinus* MOORE & PLUMMER, 1940 (May), p. 102 (type, *A. geometricus*)]. Arms equibiserial, wide; primibrachs *1* axillary, subsequent axillaries small, triangular in outline. Stem transversely round. *M.Penn.-L. Perm.*, USA(Texas-Ill.-Mo.-Kans.-Okla.).——FIG. 439,*1a,b*. **S. stillativus* (WHITE), U.Penn.(Virgil.), Kans.; *1a,b,* holotype viewed from *BC* interray, and dorsal view, ×1 (White, 1880b).——FIG. 439,*1c*. *S. florealis* (MOORE & PLUMMER), M.Penn.(Desmoines.), Texas; holotype, oblique view from below (*CD* interray upward), ×1.5 (Moore & Plummer, 1940).——FIG. 439,*1d-g*. *S. geometricus* (MOORE & PLUMMER), M.Penn.(Desmoines.), Texas; *1d-f,* holotype, dorsal, post., and ventral views, ×1.5 (Moore & Plummer, 1940); *1g,* plate diagram of cup and parts of arms (radials black, radianal cross ruled, anal *X* and right tube plate *RX* stippled), ×1.5 (Moore, n).——FIG. 439,*1h*. *S. bilineatus* STRIMPLE & MOORE, U.Penn.(Missour.), Ill.; post. view, ×1.2 (Strimple & Moore, 1971a).——FIG. 439,*1i*. *S. virgilensis* STRIMPLE, U.Penn.(Missour.), Okla.;

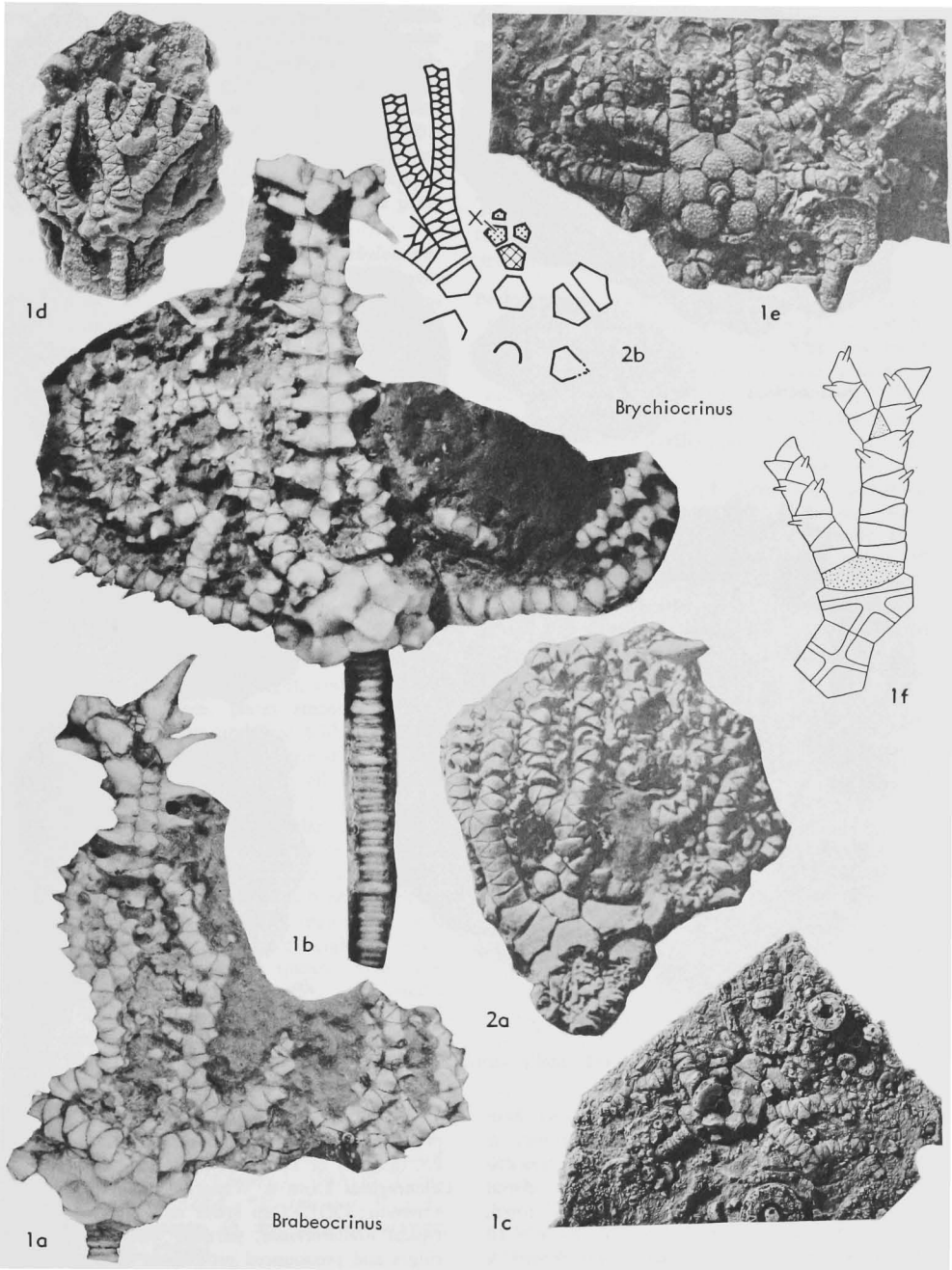


FIG. 440. Stellarocrinidae (p. T669-T670).

hypotype crown (*CD* interray upward), ×1.2 (Strimple & Moore, 1971a).

Brabeocrinus STRIMPLE & MOORE, 1971, p. 32 [**B. christinae*; OD]. Cup more boxlike than *Stellarocrinus* and arms uniserial (cuneate brachials) rather than biserial. *M.Penn.(Atokan)-L. Perm.(Wolfcamp.),* USA.——FIG. 440,*1a,b*. **B. christinae,* U.Penn.(Missour.), Ill.; holotype viewed

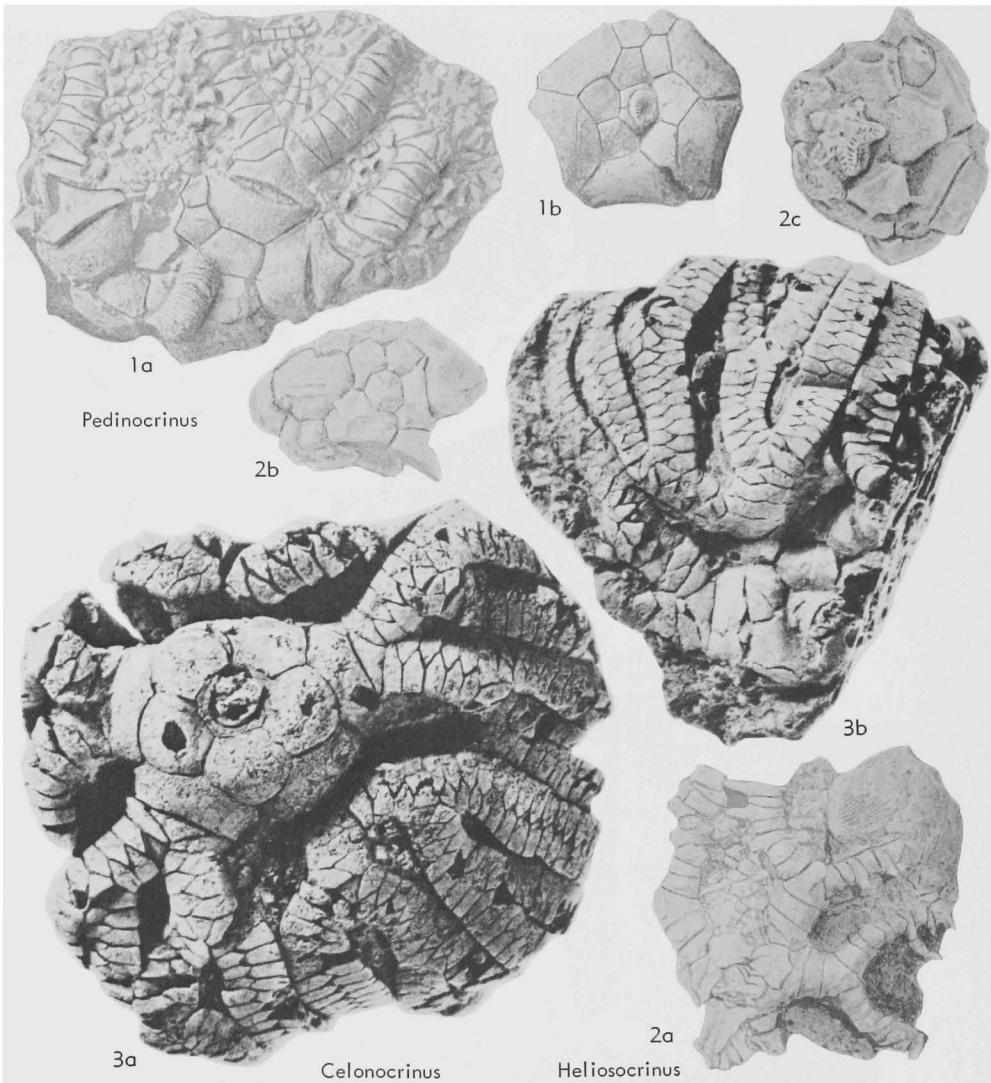


FIG. 441. Stellarocrinidae (p. T670-T671).

from *D* ray and opposite side (*AB* interray), both showing tall spinose anal sac, ×2 (Strimple & Moore, 1971a).——FIG. 440,*1c-f*. *B. cuneatus* (LANE & WEBSTER), L.Perm., Nev.; *1c,d,* dorsal (*CD* interray upward) and *C*-ray views of crown, ×0.7 (Lane & Webster, 1966); *1e,* dorsal (*AB* interray upward) view of crown, ×1 (Webster & Lane, 1967); *1f,* part of arm, ×2 (Webster & Lane, 1967).

Brychiocrinus MOORE & PLUMMER, 1940, p. 146 [**B. texanus*; OD]. Like *Stellarocrinus* except articular facets more nearly fill distal surface of radials and biserial arms are narrow. *M.Penn. (Desmoines.),* USA.——FIG. 440,*2*. **B. texanus,* Texas; *2a,* holotype viewed from base (*CD* interray upward), ×1.5 (Moore & Plummer, 1940); *2b,* diagram of *D*-ray arms, ×1.5 (Moore, n).

Celonocrinus LANE & WEBSTER, 1966, p. 47 [**C. expansus*; OD]. Cup lower and broader than in typical *Stellarocrinus,* partially owing to lack of ridges and pronounced protrusions on plates; arms wider and externally flatter than in *Stellarocrinus,* with angulated edges. Column transversely round. *U.Penn.-L.Perm.,* USA(Nev.-Kans.-Texas).——FIG. 441,*3*. **C. expansus,* L.Perm., Nev.; *3a,b,* holotype viewed from base and side, ×1 (Lane & Webster, 1966).

Heliosocrinus STRIMPLE, 1951, p. 675 [**H. af-*

tonensis; OD]. Anal plates 3, in normal (primitive) arrangement; basals flattened in basal plane, extended as long subhorizontal spines, articular facets not filling distal face of radials. Arms uniserial (cuneate brachials), first branching on primibrachs 2. Stem large, transversely pentastellate. *U.Miss.(Chester.)-L.Penn.(Morrow.)*, USA (Okla.).——FIG. 441,*2*. **H. aftonensis*, U.Miss. (Chester.), Okla.; *2a*, post. view of holotype crown, ×1; *2b,c*, post. and dorsal views of paratype, ×1.5 (Strimple, 1951a).

Pedinocrinus WRIGHT, 1951, p. 77 [**Pachylocrinus clavatus* WRIGHT, 1937, p. 405; OD]. Crown explanate, short, recumbent well-separated arms spread out laterally. Cup discoid, base concave; infrabasals mostly concealed by stem, not visible from side; proximal part of basals in basal concavity; radials wide, with peneplenary articular facets and strong interradial notches; 3 anals in cup; surface of all plates smooth. Arms uniserial, widely divergent, and branching at least once above axillary primibrachs *1*, brachials strongly cuneate, approaching biserial arrangement; pinnules very stout, clublike. Stem transversely round. *L.Carb.(Visean)*, Eu.(Scot.).——FIG. 441,*1*. **P. clavatus* (WRIGHT); *1a,b*, post. and dorsal (*CD* interray upward) views of holotype, ×1 (Wright, 1951-54).

Rhopocrinus KIRK, 1942, p. 152 [**R. spinosus*; OD]. Crown of medium height, compact. Cup low, broadly turbinate, plates smooth or with pits at angles of plates and low folds normal to edges, sharply defined ventral groovelike depression between adjacent radials in all known species; infrabasals small, but visible in lateral view; basals large; radials large, articular facets wide, extending full width of radial, linear to slightly crescentic, sutures not gaping; 3 large anals in cup. Anal sac formed by very many small nodose plates, with well-defined pits at their angles, sac wide and extending to 0.75 or more height of arms, distally bearing several stout spines. Arms uniserial, pinnulate, stout proximally, and slender distally, not appressed, primibrachs typically 2 in all rays, branching higher in crown parendotomous (i.e., above primaxils branches given off only to inside of each half-ray), axillaries tending to be spinose, brachials cuneate. Stem transversely circular, heteromorphic, with pentalobate lumen, nodals very prominent, bearing cirri to within 8 cm. of cup. *U.Miss.(Chester.)*, USA(Ill.-Tenn.-Ala.-Ky.).——FIG. 428,*4*. **R. spinosus*, Ky.; *4a*, post. view of holotype, *4b*, ant. view of paratype, both ×1 (Kirk, 1942b).

Family PACHYLOCRINIDAE Kirk, 1942

[Pachylocrinidae KIRK, 1942b, p. 151]

Cup low, truncate bowl shaped, base slightly concave; infrabasals not visible from side; radial facets wide, peneplenary, bearing transverse ridge and ligament pits; three anals in cup. Anal sac slender, composed of vertical rows of small plates. Arms uniserial, branching isotomously twice or more, pinnulate. *L.Miss.-L.Perm.*

Advancement in evolution of the cup shape is seen in the truncate, concave base of crinoids belonging to the Pachylocrinidae. The arm structure closely resembles that of the blothrocrinids, and these families probably came from the same stock.

Pachylocrinus WACHSMUTH & SPRINGER, 1880, p. 115(338) [**Scaphiocrinus aequalis* HALL, 1861b, p. 8; OD]. Crown tall, ovoid. Cup low bowl shaped, with shallowly concave base; infrabasals not visible from side; basals notably larger than other cup plates; radials with peneplenary articular facets, interradial notches small but well defined; 3 anal plates in cup. Anal sac tall, subcylindrical, composed of irregularly polygonal small plates. Arms uniserial, branching isotomously on primibrachs *2* and additionally at 2 or more higher levels, making approximately 40 arms in upper part of crown, brachials mostly somewhat cuneate; pinnules long and slender. Stem transversely round or obtusely pentagonal in section. *L.Carb.-U.Carb.*, USSR(Voskresensk, Kalinin); *L.Miss.-U.Miss.*, central N.Am.——FIG. 442,*2*. **P. aequalis* (HALL), L.Miss.(Keokuk), Ind.; post. view of crown, *D* and *B* rays at left and right margins, ×1.5 (Springer, 1926b).

Plummericrinus MOORE & LAUDON, 1943, p. 46 [**Pachylocrinus mcguirei* MOORE, 1939c, p. 205; OD]. Crown slender. Cup truncate bowl shaped, base narrowly concave; 5 infrabasals not visible from side, concealed by stem; 5 basals, distal portions reaching about midheight of cup; 5 radials projecting outward so as to make prominent interradial notches, transverse ridges of articular facets not meeting neighbors at interradial sutures; 3 anal plates in cup; anal sac tubular, curved forward, side plates plicated. Arms uniserial, pinnulate, branching on primibrachs *1* and higher heterotomously. Stem round. *L.Penn.-L.Perm.*, USA(Okla.-Texas-Kans.).——FIG. 442,*1a-d*. **P. mcguirei* (MOORE), U.Penn., Virgil.(Brownsville Ls.), near Strohm, Okla.; *1a-c*, holotype cup from post., ventral, and dorsal (*CD* interray upward) sides, ×1.5; *1d*, paratype crown from *EA*-interray side, ×1.5 (Moore, 1939c).——FIG. 442,*1e*. *P. striatus* STRIMPLE, Missour.(Francis Sh.), Ada, Pontotoc Co., Okla.; hypotype crown from ant. side, showing cuneate brachials and long pinnules, ×1 (Strimple & Moore, 1971b).——FIG. 442,*1f,g*. *P. uddeni* (MOORE & PLUMMER), M.Penn., Desmoines.(Mineral Wells F.), near Mineral Wells, Palo Pinto Co., Texas; holotype from dorsal (*A* ray downward) and post. sides, ×1 (Moore & Plummer, 1940).

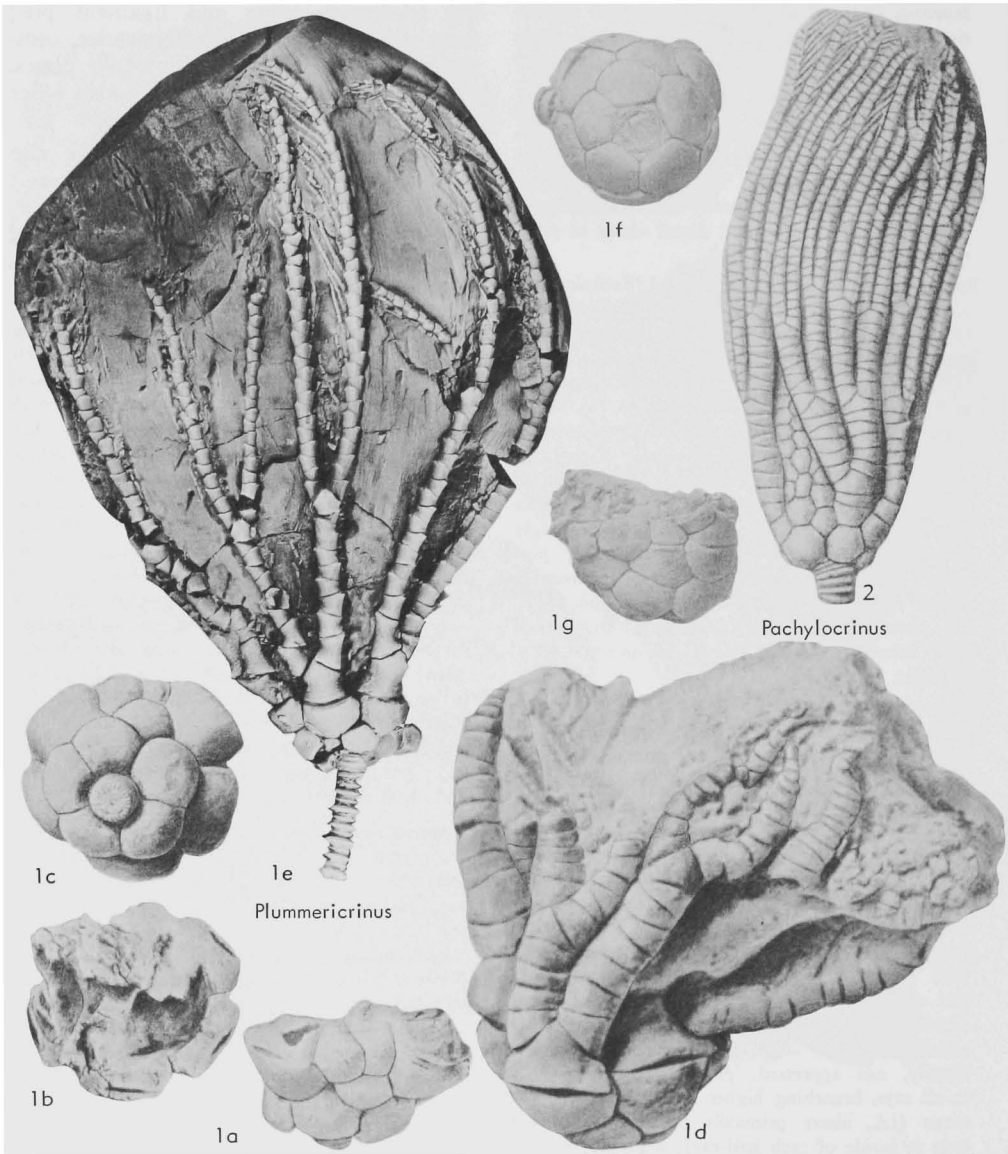


FIG. 442. Pachylocrinidae (p. T671).

Superfamily AGASSIZOCRINACEA S. A. Miller, 1889

[*nom. transl.* MOORE & STRIMPLE, 1973, p. 20 (*ex* Agassizocrinidae S. A. MILLER, 1889, p. 214)] [Materials for this superfamily prepared by R. C. MOORE, N. GARY LANE and H. L. STRIMPLE]

Crown cylindrical to pear shaped. Cup bowl shaped with convexly round base; infrabasals five or fused into single solid plate, readily visible from side; radial articular facets wide, occupying full width of radial summits; anal plates in cup none to four, joined very tightly in some to few lower posterior sac plates so as to form in effect upward projection of cup margin. Anal sac variably weak to strong, cylindrical or mushroom shaped. Arms mostly numerous, isotomously branched on primaxils and heterotomously above. Stem transversely

round or exceptionally pentagonal or pentalobate. *L.Miss.-U.Perm.*

Family BURSACRINIDAE Kirk, 1947

[Bursacrinidae Kirk, 1947, p. 287]

Crown compact; cup low, broadly conical; infrabasals small, upflared, visible from side; radial articular facets fully equal to radials in width; *X* only anal plate in cup. Anal sac short, rarely preserved. Arms stout, uniserial, closely appressed laterally, primibrachs *1* axillary; without higher branching or with several isotomous branches; pinnulate. *L.Miss.*

Bursacrinus Meek & Worthen, 1861, p. 136 [**B. wachsmuthi*; M]. Cup with high basals and low broad radials; single anal plate in cup between posterior radials. Anal sac unknown. Arms broad and externally flattened, closely abutting laterally; first primibrachs axillary in all rays, with at least one higher division in some or all rays; brachials low, broad, wedge shaped, pinnulate. *L.Miss.*, USA(Iowa).——Fig. 443,*2*. **B. wachsmuthi; C*-ray view of partial crown, ×0.75 (Meek & Worthen, 1868b).

Lebetocrinus Kirk, 1940, p. 74 [**L. grandis*; OD]. Cup low, broad, plates thin; infrabasals and basals large, radials with plenary articular facets; single anal plate in cup directly above *CD* basal; anal *X* large, supporting longitudinal row of large sac plates. Anal sac short. Arms uniserial, stout, rounded, and closely appressed laterally, branching isotomously several times, pinnulate; primibrachs *1* rarely *2* axillary, narrow, and completely or partially enclosed by radial and first secundibrachs in some rays. Stem large, transversely round, with large lumen. *L.Miss.*, USA(Ind.).——Fig. 443,*3*. **L. grandis; 3a,b, A*-ray and *CD*-interray views of crown and proximal part of stem, ×0.5 (Kirk, 1940d).

Nactocrinus Kirk, 1947, p. 288 [**N. nitidus*; OD]. Crown short and compact; cup cone-shaped, infrabasals barely visible in side view; radials and their articular facets as in *Bursacrinus*; anal *X* only in cup, supported by *CD* basal, or occupying a notch between the posterior radials; anal sac not known. Arms 10, uniserial, stout, closely appressed laterally; first primibrach axillary, large and broad; brachials large, externally rounded, pinnulate. *L. Miss.*, USA(Iowa).——Fig. 443,*1*. **N. nitidus; 1a,b*, side and *CD*-interray views of crown, ×1.12 (Kirk, 1947).

Family AMPELOCRINIDAE Kirk, 1942

[Ampelocrinidae Kirk, 1942c, p. 23] [incl. Ampelocrininae Kirk, 1942c (*nom. transl.* Strimple & Watkins, 1969, p. 185)]

Crown tall, subcylindrical or expanding. Cup low to medium bowl shaped or truncate conical, with upflared infrabasals, visible from side, or infrabasals in shallow basal concavity and not visible from side; radials large, articular facet wide, plenary, short, sloping outward-upward; one dominant anal plate in cup. Anal sac slender, may be recurved or straight. Arms usually ten but may branch twice or not at all; primibrachs *2-4* axillary except that in younger forms primibrachs *1* and *2* may fuse and become nonaxillary; long pinnules on opposite sides of alternate brachials unless syzygial pairs are present. Stem transversely round, subpentagonal, or decidedly pentagonal, with or without cirri. *L.Miss.-U.Perm.*

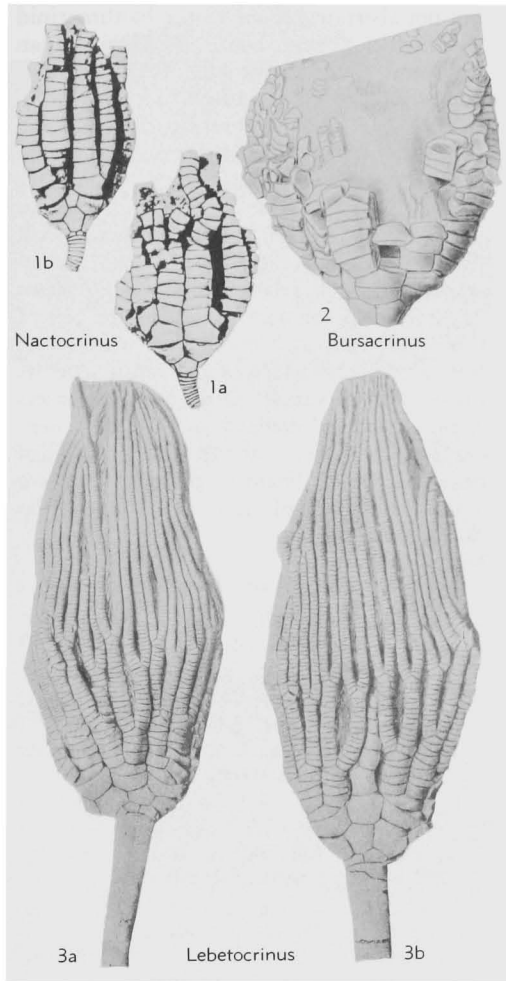


Fig. 443. Bursacrinidae (p. *T673*).

The ampelocrinids comprise a distinctive but not aberrant branch of the blothrocrinid stock which appeared in Early Mississippian time and persisted into the Permian. The cup is moderately advanced in evolution in that its base is very gently convex, flat, or slightly concave, and a single dominant anal plate occurs below the summit of the radials. Seemingly, this plate is the radianal, as indicated by obliquity of its contact with the *CD* basal in some specimens of *Ampelocrinus* and by its relation to overlying plates at the base of the anal sac. In other genera this anal rests squarely on the *CD* basal. Specialized characters of the family are its uncommon sursumate radial articular facets sloping outward-upward and the tall, slender but stout anal sac, formed of vertical rows of plates. Features of arm structure and development of cirri aid in differentiation of the family.

Key to Genera of Ampelocrinidae

A. Cup moderately tall, conical, infrabasals clearly visible from side, 1-2 anal plates in cup, 10 arms branching on primibrachs *2-4* .....
   I. Two anal plates, primibrachs *2* axillary ..... *Proampelocrinus*
   II. One anal plate, primibrachs *2-4* axillary ..... *Armenocrinus*

B. Cup bowl shaped with convex base, infrabasals visible from side, 3 anals in cup, arms branching isotomously on primibrachs *2* .....
   I. Brachials cuneate, pentagonal stem highly cirriferous ..... *Ampelocrinus*
   II. Brachials externally rectangular, cirri not observed ..... *Polusocrinus*

C. Arms in upper crown 10 to 30 or more, branching on primibrachs *2* .....
   I. Arms 10, branching above primaxils not observed, brachials cuneate, single anal plate in cup ..... *Moundocrinus*
   II. Arms 14-16, branching above primaxil on secundibrach *1*. Three anal plates in advanced position (radianal dominant) ..... *Arroyocrinus*
   III. Arms 20 or more; anal plate in cup 1
      a. Arms branching above primaxil on secundibrachs *9-10*; highly cirriferous pentalobate stem ..... *Chlidonocrinus*
      b. Arms branching above primaxil on secundibrachs *6-8* ..... *Spheniscocrinus*

D. Cup low, truncate cone shaped, arms branching on primibrachs *3* or *4* ..... *Halogetocrinus*

Ampelocrinus KIRK, 1942, p. 23 [**A. bernhardinae*; OD]. Cup low or high turbinate; some species reported with syzygial pairs of brachials. Anal tube recurved. Column transversely subpentagonal or pentagonal. *U.Miss.(Chester.)-L.Penn.*, USA. ——FIG. 444,*5*. **A. bernhardinae*, Chester.(Glen Dean F.), Ky.; side view of holotype crown, ×0.93 (Kirk, 1942c).

Armenocrinus STRIMPLE & HOROWITZ, 1971, p. 23 [**A. watersi*; OD]. Like *Ampelocrinus* except that older species have more nonaxillary primibrachs and cup is proportionately larger and higher. [*Armenocrinus* is thought to be derived from a form like *Culmicrinus thomasi* LAUDON (1933), from the Gilmore City Formation (Kinderhook.) and may represent the basic lineage of the Ampelocrinidae.] *L.Miss.(Osag.)-U.Miss.(Chester.)*, USA(Ind.-Pa.-Ala.).——FIG. 445,*1a*. **A. watersi*, Geneviev.(Monteagle F.), Ala.; holotype from *CD* interray, ×1.93 (Strimple & Horowitz, 1971).——FIG. 445,*1b,c*. *A. neglectus* (MILLER & GURLEY), Osag.(Borden Gr.), Crawfordsville, Ind.; holotype from *A* ray and *CD* interray, ×1.93 (Strimple & Horowitz, 1971).——FIG. 445,*1d*. *A. collinsi* STRIMPLE & HOROWITZ, Chester.(Greenbrier F.), Fayette Co., Pa.; holotype from *CD* interray, ×1.93 (Strimple & Horowitz, 1971).

Arroyocrinus LANE & WEBSTER, 1966, p. 40 [**A. popenoei*; OD]. Infrabasals not visible from side, 3 anal plates advanced (radianal oblique, in dominant posterior position followed above by anal *X* and right tube plate). Arms uniserial, closely apposed, 14 to 16 in number, branching on primibrachs *1* and secundibrachs *1*. *L.Perm.*, USA (Nev.).——FIG. 444,*1*. **A. popenoei*, Wolfcamp. (Bird Spring F.); *1a,b*, holotype from *A* ray, paratype from *CD* interray, ×0.46, ×0.35 (Lane & Webster, 1966).

Chlidonocrinus STRIMPLE & WATKINS, 1969, p. 189 [**C. echinatus*; OD]. Cup bowl shaped, large subhorizontal infrabasals, pronounced plications passing between plates, single large anal plate (radianal), faceted for 2 plates above. Arms branching more than twice, some with syzygially paired brachials. Cirri abundant. *U.Miss.(Chester.)-U.Penn.(Missour.)*, USA(Texas-Okla.).——FIG. 444,*3a*. **C. echinatus*, M.Penn.(Atokan), Texas; holotype viewed from ant. side, ×1.1 (Strimple & Watkins, 1969).——FIG. 444,*3b*. *C. ornatus* STRIMPLE & MOORE, Missour.(Francis Sh.), near Ada, Pontotoc Co., Okla.; holotype viewed obliquely from post. side, ×1.4 (Strimple & Moore, 1971b).

Halogetocrinus STRIMPLE & MOORE, 1971, p. 29 [**Aesiocrinus paucus* STRIMPLE, 1951a, p. 22; OD]. Cup low, saucer shaped; subhorizontal infrabasals, not visible from side; basals usually small; radials large, width and length about equal, with articular facets filling their upper face; one large anal (radianal) in line with radials, obliquely above posterior *(CD)* basal, fol-

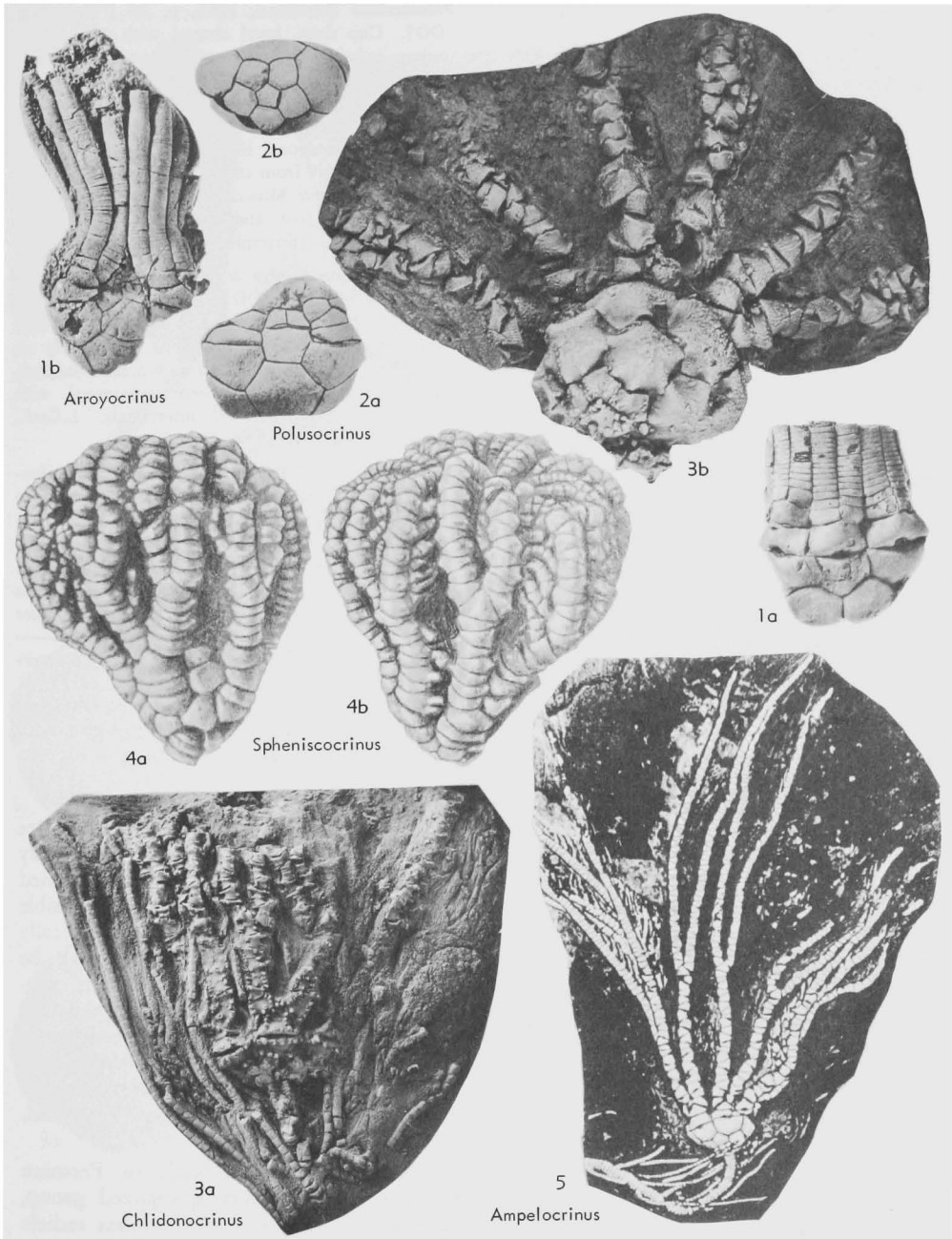


FIG. 444. Ampelocrinidae (p. *T674*, *T676*).

lowed evenly by 2 plates; brachials cuneiform above first branching, may be syzygial; armlets nonpinnulate, composed of rectilinear brachials, first branching on primibrachs *3* or *4*; stem very cirriferous. *U.Penn.(Missour.-Virgil.)*, USA(Ill.-Okla.-Kans.-Neb.).——FIG. 446,*2a-c*. **H. paucus* (STRIMPLE), Missour., Okla.; *2a-c*, from Wann F., Bartlesville, Okla.; holotype cup from dorsal, post., and ventral sides, ×2.5 (Strimple, 1951a); *2d*, hypotype, from LaSalle Ls., near Pontiac,

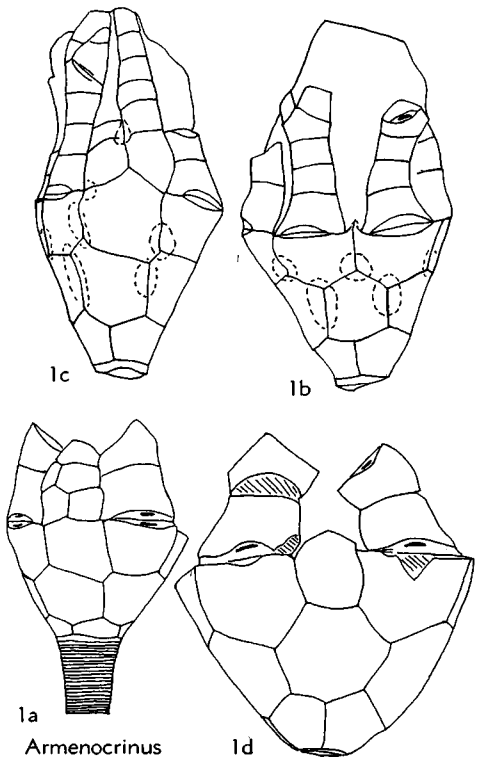


FIG. 445. Ampelocrinidae (p. T674).

Livingston Co., Ill.; crown from side, ×2.2 (Strimple & Moore, 1971a).——FIG. 446,*2e. H. tumidus* STRIMPLE & MOORE, Missour.(Francis Sh.), Ada, Pontotoc Co., Okla.; holotype crown from right post. side, ×2.7 (Strimple & Moore, 1971b).

Moundocrinus STRIMPLE, 1939, p. 9 [**M. osagensis*; OD]. Cup bowl shaped with subhorizontal base and nonimpressed sutures; infrabasals small, subhorizontal, or slightly downflared; basals wide, prominent; radials large, articular facets plenary but short; single anal plate extending only slightly about cup summit, faceted above for reception of one tube plate. Arms 10, very long, uniserial (mildly cuneate brachials), well-rounded exteriors, pinnules borne by alternate brachials on opposite sides, primibrachs *2* axillary unless fused with primibrachs *1*. Proximal columnals transversely pentagonal or subpentagonal. *U.Penn.(Missour.)*, USA(Okla.-Ill.).——FIG. 446,*3a-c. *M. osagensis*, Wann F., near Bartlesville, Okla.; holotype from ventral, dorsal, and post. sides, ×1.7 (Strimple, n; National Museum of Natural History S 4306). ——FIG. 446,*3d-f. M.* sp. cf. *M. osagensis* STRIMPLE & MOORE, Missour.(Bond F.), near Pontiac, Livingston Co., Ill.; holotype viewed from dorsal, ant., and ventral sides, ×2 (Strimple & Moore, 1971a).

Polusocrinus STRIMPLE, 1951, p. 24 [**P. avanti*; OD]. Cup deep, bowl shaped with erect lateral sides; infrabasals large, gently upflared; basals large; radials moderately large; single anal plate followed by two equidimensional tube plates. Arms uniserial; primibrachs *2* axillary. Proximal columnals pentagonal in outline becoming circular at short distance from cup. *U.Penn.*, USA.——FIG. 444,*2. *P. avanti*, Missour.(Avant F.), Okla.; *2a,b*, holotype from post. and dorsal (*CD* interray upward), ×0.93 (Strimple, 1951a).

Proampelocrinus GUPTA & WEBSTER, 1974, p. 337 [**P. himalayaensis*; OD]. Crown slender, elongate; cup high, conical, with 2 anal plates in cup. Arms long, slender, 10, branching isotomously on second primibrach in all rays, brachials cuneate. Anal sac long, slender. Stem pentagonal, with nodals and two series of internodals. *L.Carb.*, India(Ladakh, near Zanskar).

Spheniscocrinus WANNER, 1937, p. 175 [**S. spinosus*; OD]. Dish-shaped cup; infrabasals entirely covered by stem; 1 anal plate in cup, resting on posterior basal. Anal sac unknown. Straight articular facets occupying whole width of radials. Arms not adjoining, branching isotomously on primibrachs *2* and secundibrachs *6* to *8*; pinnules stout, resembling ramules. *U.Perm.*, Timor.—— FIG. 444,*4. *S. spinosus*, Basleo; *4a,b*, *CD*-interray and *A*-ray views, ×1.4 (Wanner, 1937).

Family SUNDACRINIDAE Moore & Laudon, 1943

[Sundacrinidae MOORE & LAUDON, 1943a, p. 62]

Cup small, bowl to globe shaped, plates massive; infrabasals five or three, mostly low, and visible in side view or confined to slight basal concavity and not visible from side; basals large; radials typically unequal in size and shape, or may be small and subequal; *B* and *E* radials commonly small, narrow, and without articular facets or with single, small, incurved primibrach fused to their summit; other radials larger and arm bearing; one or three anal plates in cup. Stem transversely round. *L.Perm.-U.Perm.*

The Sundacrinidae, chiefly of Permian age, are plainly a very specialized group, inasmuch as they have two armless radials of much reduced size. Variation of the anal plates ranging from three to one is seen within a single species. The ancestry of this family is very uncertain.

Key to Genera of Sundacrinidae

A. Base of cup convex .....

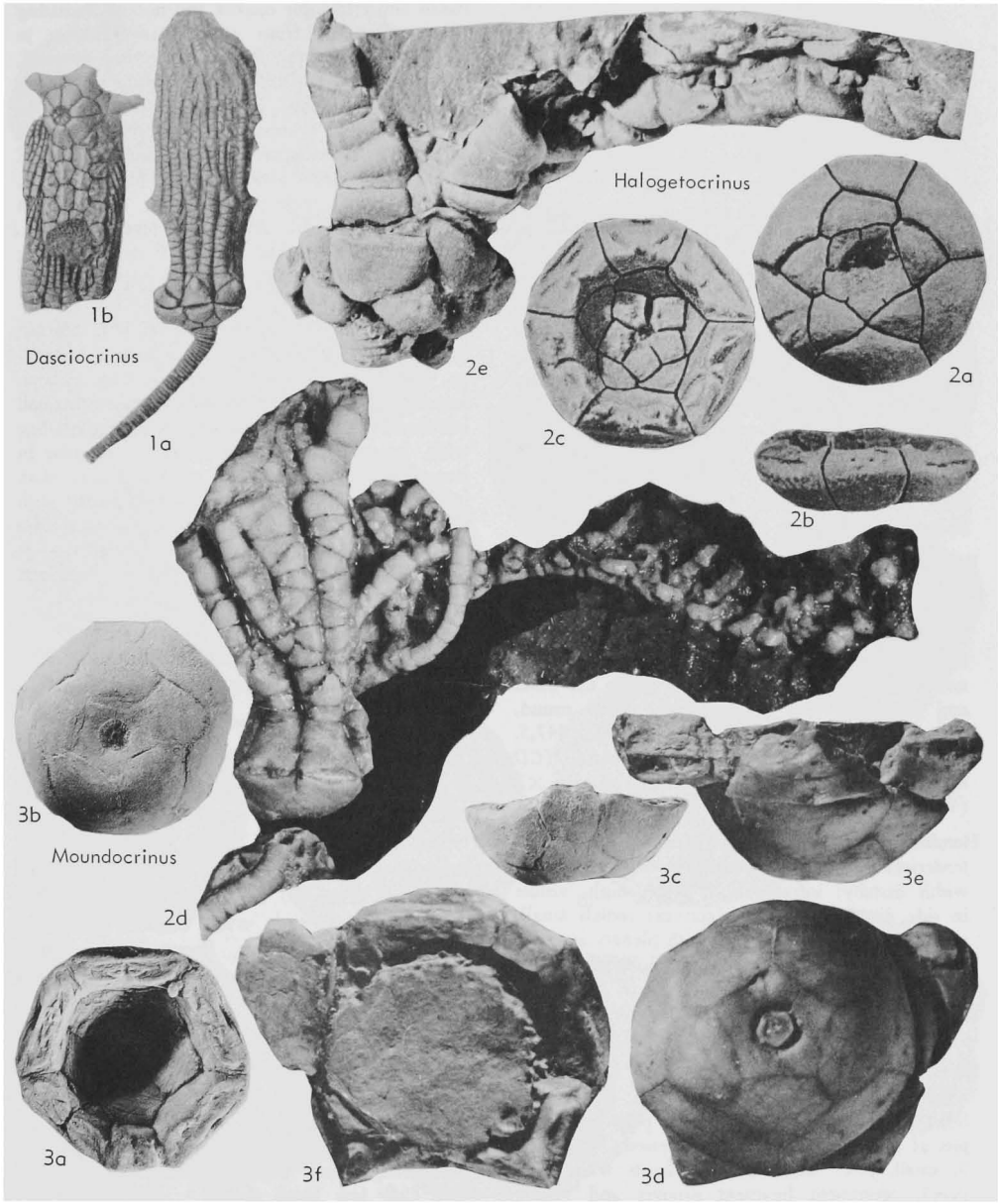


FIG. 446. Ampelocrinidae *(2,3)*; Pirasocrinidae *(1)* (p. T674-T676, T726).

I. Infrabasals 5 .....
  a. Small subequal articular facets on 5 radials; 3 anal plates in cup ..... *Hemiindocrinus*
  b. Large subequal articular facets on 5 radials; anal *X* alone in cup ..... *Laccocrinus*
  c. Large articular facets on *A*, *C*, and *D* radials, *B* and *E* radials armless; 1 or rarely 2 anal plates in cup ..... *Sundacrinus*

II. Infrabasals 3 .....
  a. Articular facets on *A*, *C*, *D*, and *E* radials large (that on *D* radial twice size of others), *B* radial armless; single anal plate in cup ..... *Parindocrinus*
  b. Articular facets on *A*, *C*, and *D* ra-

dials large, *B* and *E* radials armless; 3 anal plates in cup .... *Tribrachyocrinus*

III. Infrabasals 1, subequal radial articular facets, anal *X* alone in cup .... *Basleocrinus*

Sundacrinus WANNER, 1916, p. 219 [**S. granulatus*; OD]. Cup bowl shaped, base flat with central depressed stem impression, plates massive; infrabasals 5, low, distal parts visible from side; basals 4 or 5, unequal in shape, *BC* basal may be fused with *C* radial forming single plate; radials 5, those of *A, C,* and *D* rays large, low, twice as wide as high and bearing arm facets; *B* and *E* radials small, narrow, and without arm facets, all nearly as wide as radials, inclined outward-downward, with strong transverse ridge; single anal plate, or rarely 2 in cup, directly or obliquely above *CD* basal, or between upper edges of *CD* and *BC* basals; small, quadrangular radianal obliquely below *C* radial in some specimens. *U. Perm.,* Indon.(Timor).——FIG. 447,*3*. **S. granulatus,* Basleo; *3a-c,* post., dorsal, and ventral views of cup, ×2 (Wanner, 1916a).

Basleocrinus WANNER, 1916, p. 214 [**B. pocillum*; OD]. Cup bowl shaped; infrabasals low, fused into single plate visible from side; basals large; radials with wide articular facets bearing prominent ligament grooves and ridges; no interradial notches; single anal plate directly above *CD* basal and projecting well above radials. Stem round, narrow. *U.Perm.,* Indon.(Timor).——FIG. 447,*5*. **B. pocillum,* Basleo; *5a-c,* post., ventral (*CD* interray downward), and dorsal views of cup, ×3 (Wanner, 1916a).

Hemiindocrinus YAKOVLEV, 1926, p. 57 [**H. fredericksi*; M]. Cup small, globose, restricted in width distally; infrabasals 5, large, high, visible in side view; basals large, convex; radials small, narrow, equal in size and all with plenary articular facets; 3 anal plates in cup. *L.Perm.,* USSR (Urals-Krasnoufimsk).——FIG. 447,*1*. **H. fredericksi,* Krasnoufimsk; *1a,b,* lat. and ventral views of cup, ×1.5 (Yakovlev, 1926a).

Laccocrinus WANNER, 1949, p. 55 [**Basleocrinus scrobiculatus* WANNER, 1924, p. 267; OD]. Cup bowl shaped, with strongly convex plates and deep pits at plate angles, sutures impressed; infrabasals 5, small, low; radial articular facets wide (plenary), prominent ligament grooves and ridges, extended inward so as to restrict opening to visceral cavity; only anal *X* in cup, convex and projecting above radials. *U.Perm.,* Indon.(Timor).——FIG. 447,*4*. **L. scrobiculatus* (WANNER), Basleo; *4a-b,* post. and ventral (*CD* interray downward) views of cup, ×3 (Wanner, 1924).

Parindocrinus WANNER, 1937, p. 165 [**P. oyensi*; OD]. Cup pentalobate in basal view, asymmetrical, higher and protruding in *D* ray; infrabasals 3, low, broad, visible in side view, circlet truncate at base for wide, round stem impression; basals large, strongly convex and nodose, radiating ridges extending from nodes across sutures to adjoining cup plates; radials projecting outward, with wide large articular facet bearing prominent transverse ridge and ligament groove; *D* radial twice width of others; *C* and *A* radials normal in size, with wide arm facets; small narrow *E* radial with obscure articular facet; *B* radial small, without facet; single anal plate in cup between *C* and *D* radials. Arms unknown. *U.Perm.,* Indon.(Timor).——FIG. 447,*6*. **P. oyensi,* Basleo; *6a-c,* post., dorsal, and ventral views of cup, ×3 (Wanner, 1937).

Tribrachyocrinus M'COY, 1847, p. 228 [**T. Clarkii*; OD] [=*Tribrachiocrinus* WACHSMUTH & SPRINGER, 1886, p. 250 *(nom. van.)*]. Cup globose, large, plates massive; infrabasals 3, unequal, small infrabasal in *A* ray; basals very large, higher than wide, irregular in outline; radials 5, irregular in size and shape, *B* and *E* radials smaller than others and without arm facets, other radials with wide articular facets; 3 large anal plates in cup. *L.Perm.,* Australia(New S.Wales-Tasmania).——FIG. 447,*7*. **T. clarkii,* New S.Wales; *7a,b,* ant. and post. views of cup, ×1 (M'Coy, 1847).

Family ANOBASICRINIDAE Strimple, 1961

[Anobasicrinidae STRIMPLE, 1961d, p. 114]

Tall cone shaped to bowl shaped cup, flat or gently rounded at base; infrabasals subhorizontal to slightly upflared, mostly not visible in side view; three anal plates in cup. Large recurved anal sac may become bulbous. Arms 20 or more, long, slender, pinnulate, uniserial, with convex surfaces, primibrachs *1* axillary. Stem large, transversely round. *L.Penn.(Morrow.)-U.Perm.*

Key to Genera of Anobasicrinidae

A. Cup tall cone shaped to weakly convex bottomed bowl shaped with upward projection of anal plates in *CD* interray; peneplenary radial articular facets markedly declivate. Stem impression circular .....

I. Cup low bowl shaped .....

a. Base gently convex, infrabasals relatively large, very low, interradial notches small, anal sac balloon-like ..... *Anobasicrinus*

b. Basal concavity but with tips of infrabasals flexed upward, anal sac large, looped ..... *Terpnocrinus*

II. Tall cone-shaped cup, prominent upflared infrabasals, balloon-like anal sac ..... *Synyphocrinus*

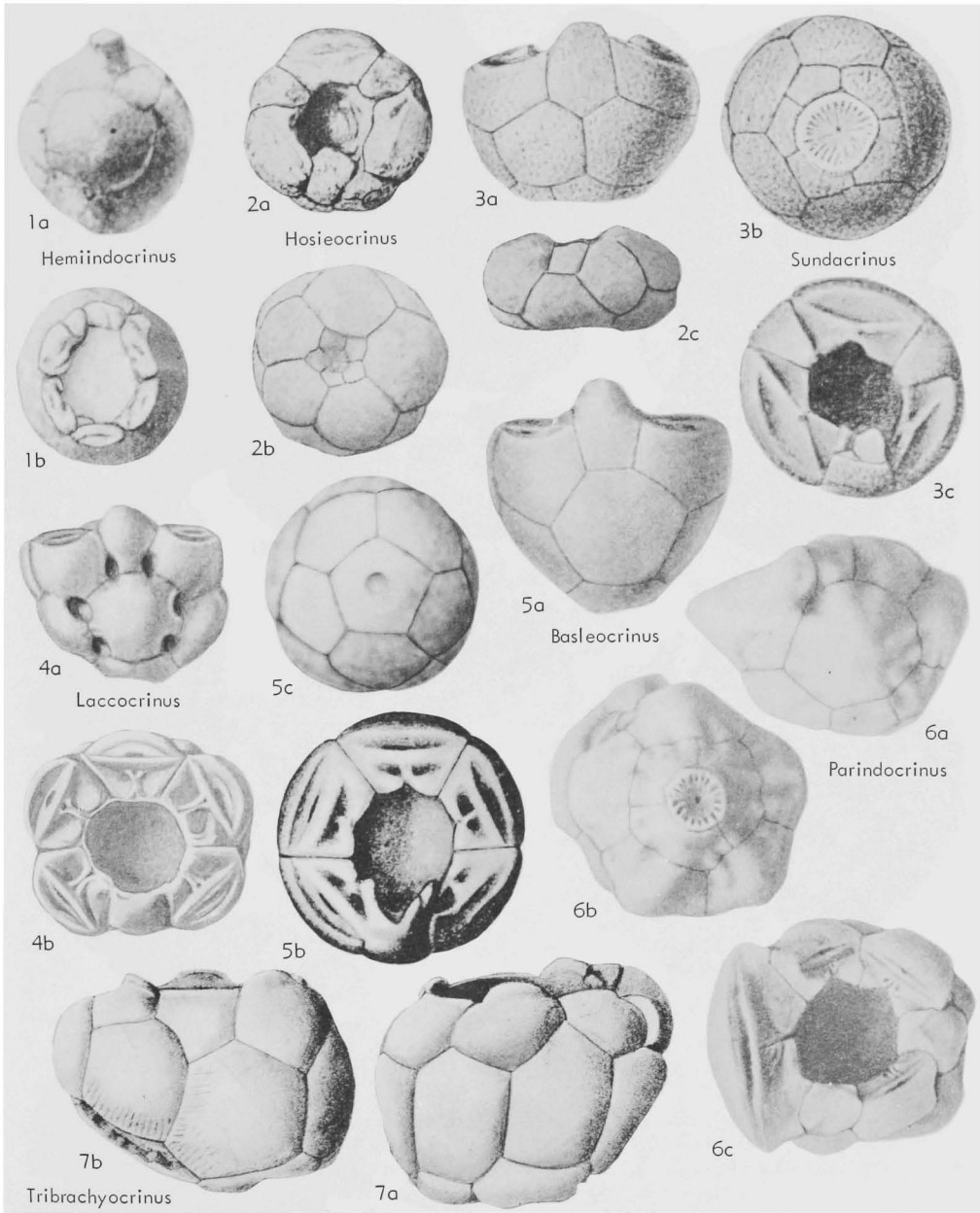


FIG. 447. Sundacrinidae *(1,3-7)*; Phanocrinidae *(2)* (p. *T678*, *T692*).

Anobasicrinus STRIMPLE, 1961, p. 115 [**A. bulbosus*; OD]. Crown expanding upward, with approximately 30 slender uniserial arms not apposed. Cup with evenly upflared longitudinally straight or curved sides and narrow flat to faintly convex or concave base; infrabasals generally not visible from side, radials large, with proximal tips well above basal plane of cup, their articular facets peneplenary, not quite equal in width to radial summits; 3 anal plates in cup. Anal sac low and broad balloon shaped distally, irregularly arranged rugose polygonal sac plates marginally slitted. Arms branching isotomously on primibrachs *1* and endotomously on secundibrachs *3* and higher, pinnulate. *L.Penn.(Morrow.)-U.Penn.(Missour.)*, USA (Okla.-Texas).——FIG. 448,*1a-c*. **A. bulbosus*,

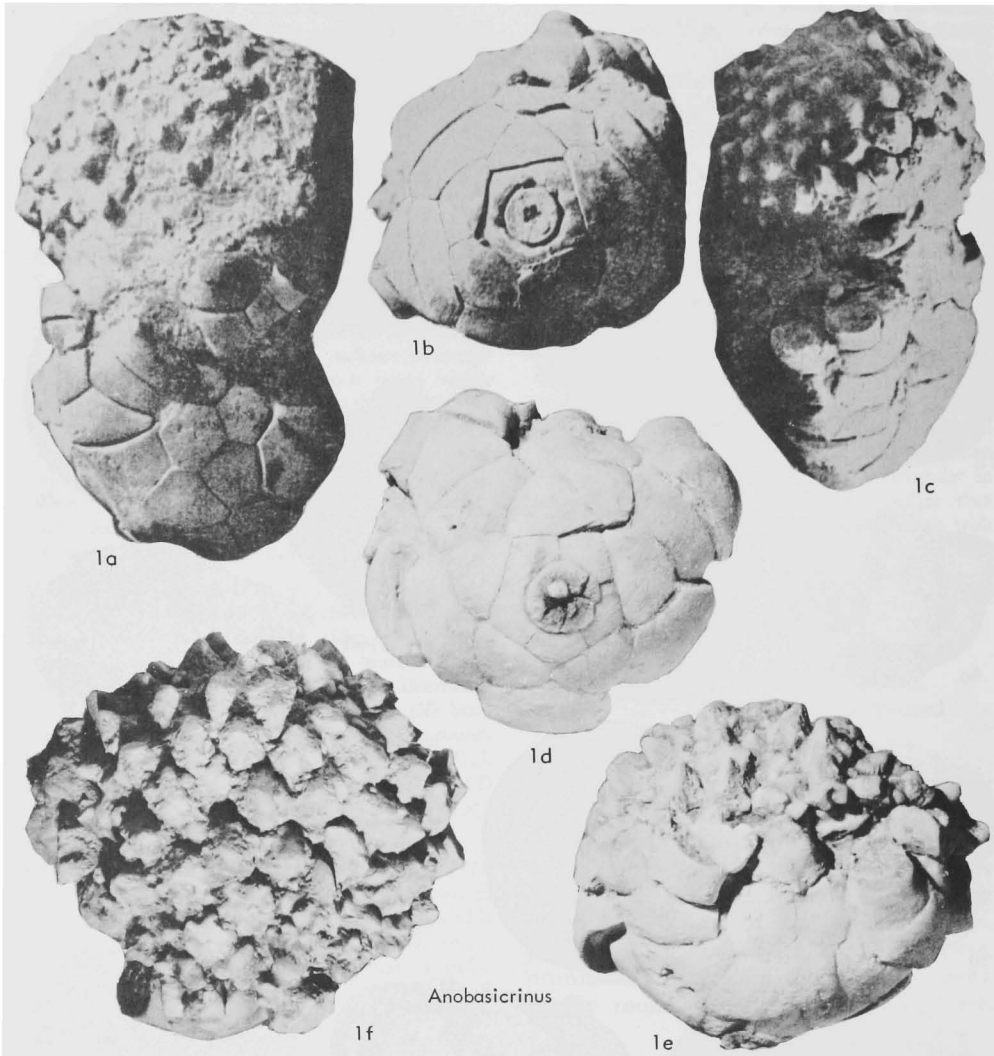


FIG. 448. Anobasicrinidae (p. T679-T680).

Desmoines.(Holdenville Sh.), near Beggs, Okmulgee Co., Okla.; *1a-c,* ant., dorsal (*CD* interray upward), and post. sides of crown, ×1 (Strimple, 1961d).——FIG. 448,*1d-f. A. brevis* STRIMPLE & MOORE, U.Penn.(Missour., LaSalle Ls.), Livingston Co., Ill.; *1d-f,* dorsal (*CD* interray upward), post., and ventral views of holotype, ×2 (Strimple & Moore, 1971a).

Synyphocrinus TRAUTSCHOLD, 1867, p. 1 [**S. cornutus*; OD]. Similar to *Haeretocrinus* except that anal sac composed of many vertical rows of rugose plates is broad balloon-like. *U.Carb.(Moscov.)-U.Perm.,* USSR(Moscow Basin)-Timor.——FIG. 438,*2a-e. *S. cornutus,* U.Carb., USSR; *2a-c,* post., ant., and dorsal sides of cup, ×1; *2d,e,* arms and ext. surface of anal sac, ×0.5 (Yakovlev & Ivanov, 1956).——FIG. 438,*2f. S. trautscholdi* (WANNER), Perm., Indon.(Timor); diagram of holotype (radials black, anal plates stippled) (after Wanner, 1924).——FIG. 438,*2g,h. S. magnus* YAKOVLEV & IVANOV, U.Carb.(Moscov.), Myachkovo, USSR; edge view of broken balloon-like anal sac, int. view of broken anal sac, showing pores penetrating sac wall from exterior, ×1 (Yakovlev & Ivanov, 1956).

Terpnocrinus STRIMPLE & MOORE, 1971, p. 23 [**T. ocoyaensis*; OD]. Cup more globose than bowl shaped, midportion of infrabasal circlet sharply impressed, but distal tips curved upward, visible from side. Anal sac large, recurved as in *Haereto-*

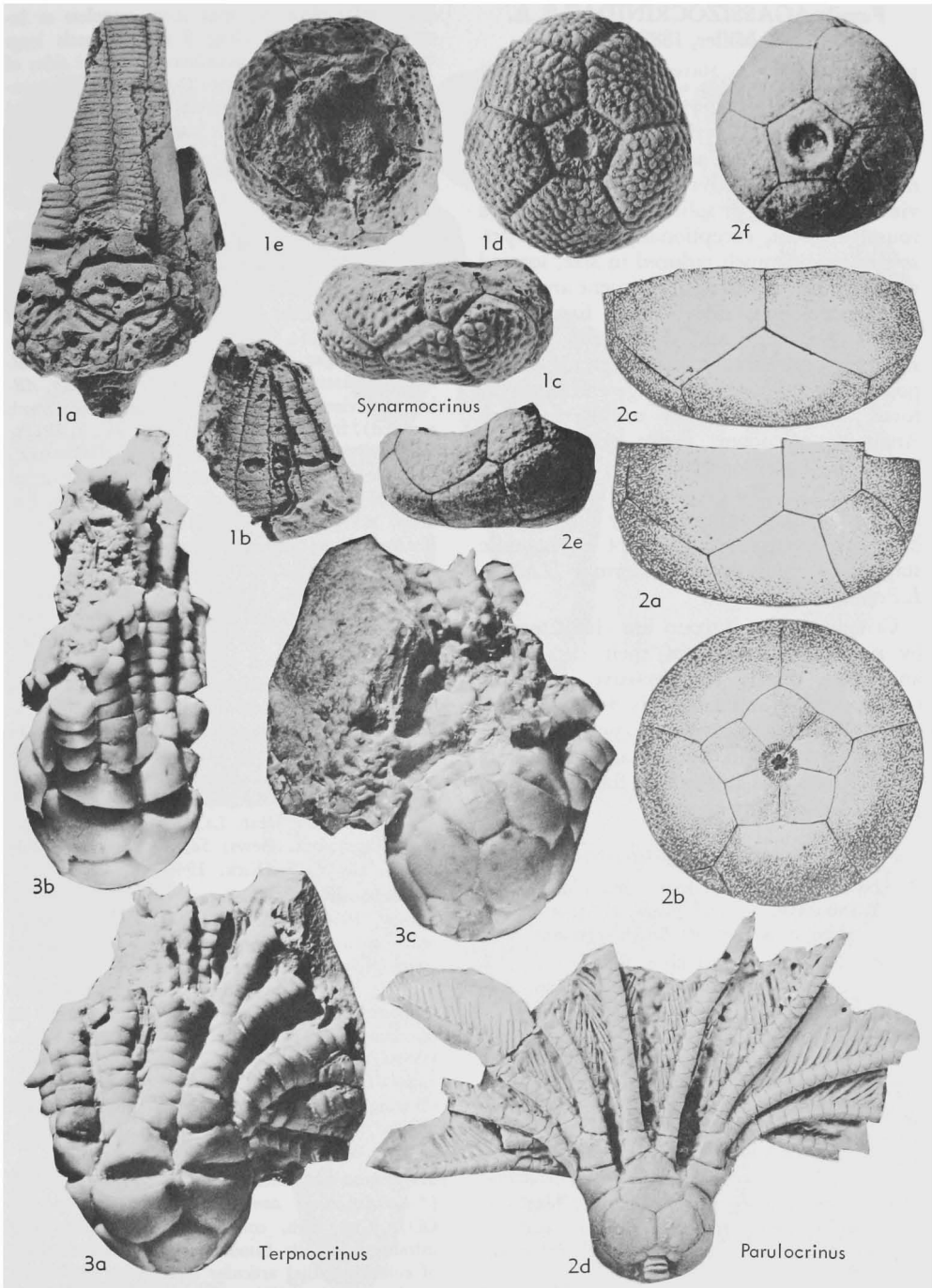


FIG. 449. Anobasicrinidae *(3)*; Cromyocrinidae *(1,2)* (p. T680-T681, T700-T701).

crinus. U.Penn.(Missour.), USA(Ill.-Neb.-Okla.). ——FIG. 449,*3*. **T. ocoyaensis*, Missour.(LaSalle Ls.), Ill.; *3a-c*, holotype viewed from *AE* interray, *B* ray showing recurved anal tube, and oblique dorsal sides, ×2 (Strimple & Moore, 1971a).

Family AGASSIZOCRINIDAE S. A. Miller, 1889

[Agassizocrinidae S. A. MILLER, 1889, p. 214] [incl. Paragassizocrininae STRIMPLE & WATKINS, 1969, p. 186 (assigned to Ampelocrinidae)]

Crown ovoid to pyriform, medium sized, Cup subconical to semiovoid; infrabasals normally five, relatively large and clearly visible from side, or solidly fused into single round element, exceptionally (e.g., *Epipetschoracrinus*) much reduced in size, located within depressed stem attachment area, and not visible from side; basals five, large; radials five, wide and short, with plenary subhorizontal articular facets bearing rather poorly defined transverse ridge and ligament fossae; anal plates four to one in cup. Anal sac unknown. Arms generally ten, branching isotomously on first primibrach, uniserial, pinnulate; in some forms each arm bifurcating approximately on secundibrach 6. Stem lacking except in juvenile stages and rarely in adult forms. *U.Miss.-L.Perm.*

Crinoids of this group are characterized by unusual thickness of their cup plates and large, mostly very massive infrabasal circlet, which commonly is fused into a single solid piece, with or without trace of stem impression. Radial articular facets are not extended inward by flangelike projection, as in many cladids.

Key to Genera of Agassizocrinidae

A. Lower part of cup convex, semiovoid .....
  I. Infrabasals 5, anal plates 3, hypertrophied arms in *B* and *E* rays .. *Anartiocrinus*
  II. Infrabasals 4, anal plates in cup 1 .... *Petschoracrinus*
  III. Infrabasals 1, comprising solidly fused circlet .....
    a. Anal plates in cup 4, arms branching isotomously on first primibrachs ..... *Agassizocrinus*
    b. Anal plate in cup 1, arms branching isotomously on primibrachs 2 .. .. *Paragassizocrinus*

B. Cup with extremely narrow and small basal concavity, basals very large, single anal plate in cup ..... *Epipetschoracrinus*

Agassizocrinus OWEN & SHUMARD, 1852, p. 93 [**A. conicus*; M] [=*Agassizocrinites* TROOST, 1850a, p. 420 *(nom. nud.); Astylocrinus* ROEMER, 1854, p. 229 (type, *A. laevis*; OD)]. Crown moderately tall, pyriform. Cup truncate ovoid, with well-rounded base; infrabasals mostly fused into thick, solid piece, but may show complete or incomplete sutures dividing 5 plates; basals large and thick, forming approximately vertical sides of cup; radials wide and low, *C* and *D* radials commonly narrower than others, with subhorizontal articular facet equal in length to thickness of plate; anal plates normally 4, including obliquely oriented quadrangular radianal. Arms 10, unequal, uniserial, composed of externally rectangular well-rounded brachials bearing closely spaced pinnules, arms branching on axillary first primibrach, which may have distinctly unequal distal facets. Stemless in adults. *U.Miss.(Chester.),* USA(Okla.-Ark.-Ill.-Ky.-Ala.).——FIG. 450,*2a.* **A. conicus,* Chester. (Okaw F.), Ill.; *?AB*-interray view of holotype, ×1 (Springer, 1926b).——FIG. 450,*2b-f. A. laevis* (ROEMER), Chester., USA(Ky.-Ill.); *2b, AB*-interray view of crown (ROEMER's type, much restored), from Okaw F., Ill., ×0.7 (Kirk, 1911); *2c,d, CD*-interray and *E*-ray views of ROEMER's holotype (unretouched photos) showing asymmetrical axillary primibrachs and stout unbranched arms, ×1 (Springer, 1926b); *2e,f, AB-* and *CD*-interray views of cups from Glen Dean Ls., Hardin Co., Ky., ×1 (Springer, 1926b).

Anartiocrinus KIRK, 1940, p. 47 [**A. lyoni*; OD]. Crown moderately tall, expanded. Cup tall, cone shaped, with upper portion subvertical; infrabasals 5, rising evenly from columnar attachment area; basals long; radials almost twice as wide as high, articular facets as wide as radials. Arms 10, rectiuniserial with well-rounded exteriors; primibrachs *1* axillary, short; some arms hypertrophied in right and left anterior rays. Column transversely round. *U.Miss.(Chester.),* USA(Ky.-Ohio).——FIG. 450,*5.* **A. lyoni,* Glen Dean Ls., Ky.; *5a-c,* holotype, post., *E*-ray, ant. views; *5d,* post. view juvenile crown, all ×1.5 (Kirk, 1940b).

Epipetschoracrinus YAKOVLEV in YAKOVLEV & IVANOV, 1956, p. 81 [**E. borealis*; OD]. Basals much enlarged, forming entire lower half of cup, seemingly not incorporating infrabasals fused with them (as inferred by author), but infrabasal circlet concealed in very diminutive basal concavity or resorbed; single anal plate *(X)* in cup. *L.Perm.,* USSR(Pechora Basin).——FIG. 450,*3.* **E. borealis*; *3a,b, CD*-interray and dorsal views of cup, latter showing only large basals *(?CD* basal directed upward), ×1.5 (Yakovlev in Yakovlev & Ivanov, 1956).

Paragassizocrinus MOORE & PLUMMER, 1940, p. 340 [**Agassizocrinus tarri* STRIMPLE, 1938, p. 10; OD]. Cup high, cone or bullet shaped, long infrabasals usually fused about proximal remnant of column; radial articular facets wide and short; single anal plate *(X)* resting evenly on *CD* basal and followed by 2 tube plates. Arms 10, uniserial, pinnulate, with rectangular well-rounded exteriors, branching on primibrachs *2. L.Penn.(Morrow.)-U.Penn.(Missour.),* N.Am.(USA).——FIG. 450, *4a,b.* **P. tarri* (STRIMPLE), U.Penn.(Missour.),

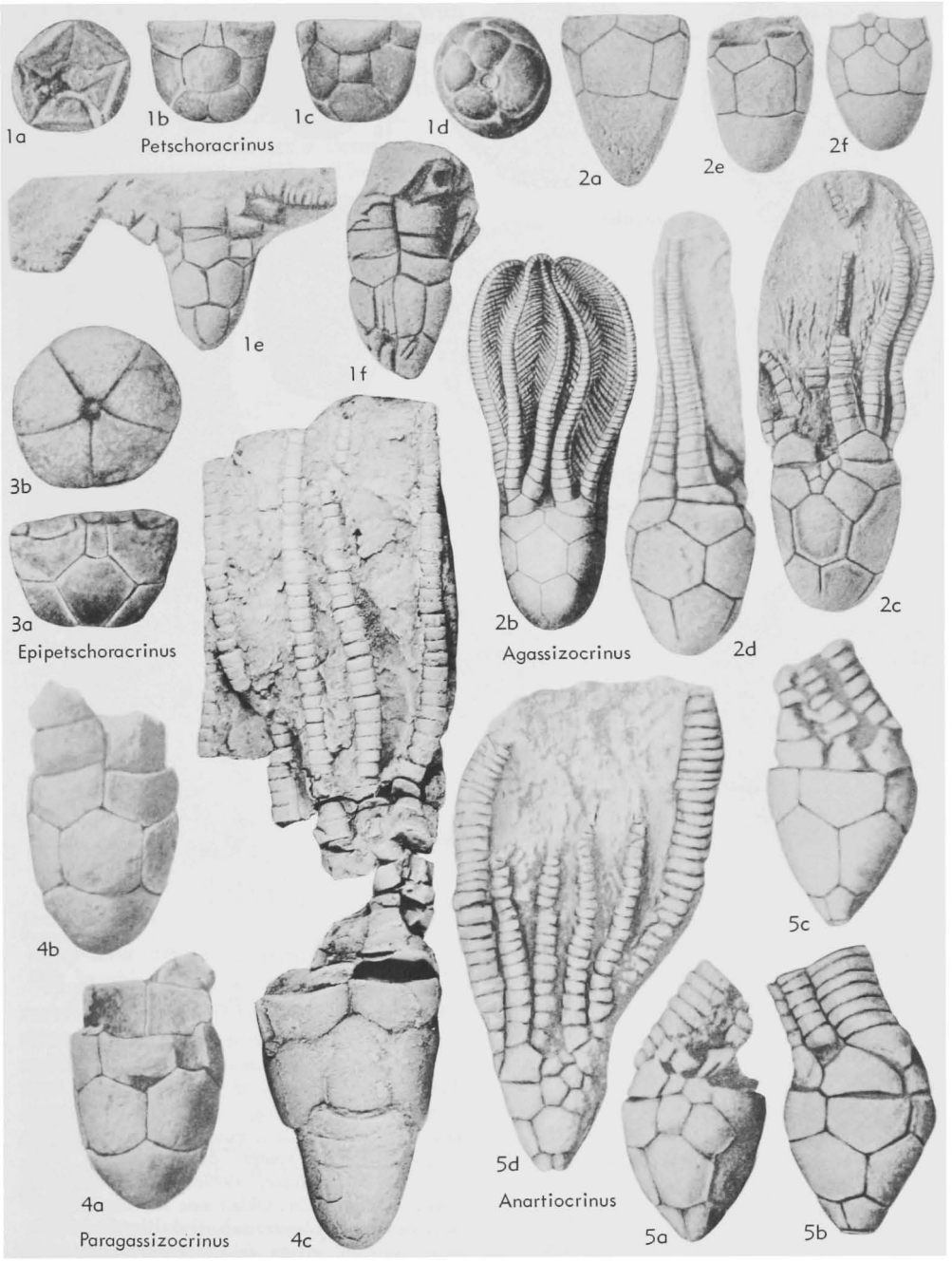


FIG. 450. Agassizocrinidae (p. *T*682-*T*684).

Kans.; cup from *D*-ray and *BC*-interray sides, ×1.5 (Moore & Plummer, 1940).——FIG. 450,*4c*. *P. kendrickensis* STRIMPLE & KNAPP, Morrow. (Kendrick Sh.), E.Ky.; hypotype crown from ant. *(AB)* side, ×1.4 (Strimple, n; Univ. Iowa SUI 42421).

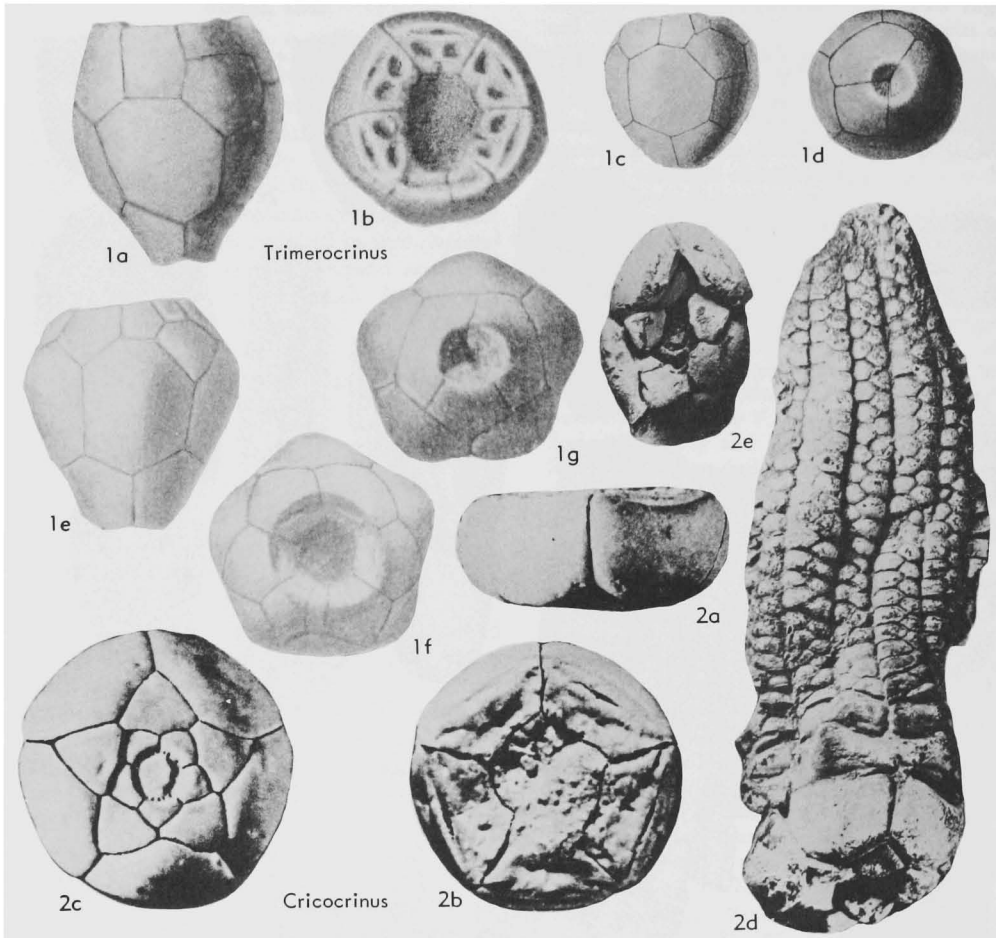


FIG. 451. Cricocrinidae *(2)*; Trimerocrinidae *(1)* (p. T684-T685).

Petschoracrinus YAKOVLEV, 1928, p. 5 [**P. variabilis*; OD]. Cup deep bowl shaped with 4 long infrabasals which tend to fuse but not solidly. Arms ?5. *L.Perm.*, USSR(Pechora Basin).——FIG. 450,*1*. **P. variabilis*, Pechora, Kojim R.; *1a-d*, cup from ventral, post., ant., and dorsal sides, ×1 (Yakovlev, 1928b); *1e,f*, side views of partial crown, ×1 (Yakovlev, 1934).

Family CRICOCRINIDAE
Moore & Strimple, 1973

[Cricocrinidae MOORE & STRIMPLE, 1973, p. 21]

Crown tall, slender, with ten erect closely parallel biserial pinnulate arms. Cup low bowl shaped, round in outline as seen from below or above, base flat, lacking even shallow concavity, plates smooth, with sutures between them not impressed; radials with plenary articular facets; anal plate *(X)* in notch at top on inner side of *CD* interradial suture. *M.Penn.(Desmoines.)*.

Cricocrinus STRIMPLE & WATKINS, 1969, p. 181 [**Paradelocrinus regulatus* STRIMPLE, 1949d, p. 325; OD]. Characters of family. *M.Penn.(Desmoines.)*, USA(Okla.).——FIG. 451,*2*. **C. regulatus* (STRIMPLE), *2a-c*, Pumpkin Creek F., Love Co., Okla.; post., ventral, dorsal views of holotype, ×1.5 (Strimple, 1949d); *2d,e*, Pumpkin Creek F., Carter Co., Okla.; side and dorsal views of somewhat crushed crown, with displaced lower plates of cup, giving false appearance of basal concavity, ×1.4 (Frederickson & Waddell, 1960).

Family TRIMEROCRINIDAE
Moore & Laudon, 1943

[Trimerocrinidae MOORE & LAUDON, 1943a, p. 62]

Cup globose, with narrow base and restricted in width at level of radials; infrabasals three, large; radials small, with plenary articular facets inclined obliquely outward-upward, restricting opening to body cavity, no interradial notches; three anal plates in cup. *L.Perm.-U.Perm.*

The Trimerocrinidae are a Permian family of very uncertain origin. The form of the cup is archaic, except for constriction toward the summit that produces an urn-shaped outline. The three anal plates of the cup are also a primitive character, whereas the steeply outward-upward sloping radial facets, which bear well-developed transverse ridges, are specialized features.

Trimerocrinus WANNER, 1916, p. 143 [**T. pumilus*; OD]. Cup bowl shaped to globose, expanding upward from narrow base and strongly restricted in width near top of cup; infrabasals 3, small one in *A* ray, upflaring and forming about one-third height of cup; basals 5, as high as wide; radials smaller than basals; 3 anal plates in cup, radianal 5-sided, quadrangular anal *X* on truncate upper edge of *CD* basal. Arms unknown. *L.Perm.-U.Perm.*, Indon.(Timor)-Eu.(USSR, Krasnoufimsk).——FIG. 451,*1a,b*. **T. pumilus*, Basleo, Timor; post. and ventral views of cup, ×4 (Wanner, 1916a).——FIG. 451,*1c,d*. *T. ventricosus* WANNER, Basleo, Timor; post. and dorsal views of cup, ×2 (Wanner, 1916a).——FIG. 451,*1e-g*. *T. pentagonus* WANNER, Basleo, Timor; post., ventral, and dorsal views of cup, ×2 (Wanner, 1916a).

Superfamily DECADOCRINACEA Bather, 1890

[*nom. transl.* STRIMPLE, 1975, p. 17 (*ex* Decadocrinidae BATHER, 1890b, p. 384)] [Materials for this superfamily prepared by R. C. MOORE and H. L. STRIMPLE]

Cup low conical to bowl shaped, sides curving inward near rim, radial arm facets commonly do not quite fill the width of radial, anal plates normally three in cup but may be reduced in number; arms ten, uniserial, pinnulate or bearing ramules, brachials usually zigzag in appearance; anal sac small, circular in outline. *M.Dev.-U.Penn.*

The Decadocrinidae was placed in the Erisocrinacea by MOORE, LANE, & STRIMPLE in MOORE & STRIMPLE (1973, p. 21), although the family is characterized by presence of three anal plates and the Erisocrinacea is characterized by one or no anal plate. Clathrocrinidae, whose members normally have three anal plates or rarely two, was placed in the Apographiocrinacea. Other apographiocrinaceans have one anal plate and relatively broad arms with delicate pinnules, quite unlike the arms of clathrocrinids or decadocrinids. The present grouping under a separate superfamily is deemed advisable.

Family DECADOCRINIDAE Bather, 1890

[Decadocrinidae BATHER, 1890b, p. 384] [incl. Decadocrininae JAEKEL, 1918, p. 63; Ramulocrinidae STRIMPLE & WATKINS, 1969, p. 199]

Crown slender. Cup widely expanded, truncate cone or bowl shaped with small basal concavity; five infrabasals with only distal tips at most visible in side view; five medium-sized basals; five radials with articular facets as wide as plates; one to three anals in cup; anal sac tall, slender. Arms ten, formed of cuneate uniserial brachials, branching isotomously on primibrachs *2* in geologically older forms and on primibrachs *1* in later ones, no further branching, arms sinuous or zigzag in appearance, pinnules stout, tending to resemble ramules. Stem preponderantly round transversely and noncirriferous (except *Aulocrinus*). [Similar forms from the Devonian lacking sinuous arms are included in the Scytalocrinidae.] *M.Dev.-U.Penn.*

Middle to Late Paleozoic genera assigned to the Decadocrinidae are characterized by having ten uniserial pinnulate arms which branch isotomously on the first or second primibrach in each ray. The arms have a noteworthy zigzag pattern resulting from the strongly cuneate form of the brachials. As a group these crinoids represent an intermediate evolutionary stage between uniserial arms composed of brachials having joint surfaces disposed at right angles to sides of the arms and a biserial arrangement of the brachials which is inferred to be an advanced structure.

Key to Genera of Decadocrinidae

A. Upflared or subhorizontal infrabasals, distal tips visible from side .....
  I. Primibrachs *2* axillary .....
    a. Small infrabasals ..... *Decadocrinus*
    b. Large infrabasals ..... *Zostocrinus*
  II. Primibrachs *1* axillary ..... *Ramulocrinus*

B. Infrabasals in basal concavity, not visible from side; primibrachs *1* axillary .....
  I. Brachials decidedly staggered or zigzag ..... *Glaukosocrinus*
  II. Brachials mildly staggered .....
    a. Elongate brachials .....
      1. Medium thick arms ..... *Trautscholdicrinus*
      2. Thin arms ..... *Eireocrinus*
    b. Short brachials .....
      1. Anal sac with specialized spout .. *Aulocrinus*
      2. Anal sac tall, cylindrical, lacking spout ..... *Acylocrinus*

Decadocrinus WACHSMUTH & SPRINGER, 1880, p. 119 [**Poteriocrinus (Scaphiocrinus) scalaris* MEEK & WORTHEN, 1861, p. 145; OD]. Calyx depressed, shallow truncate cone or bowl shaped; infrabasals small, usually visible in side view but may be hidden in concave base; radials and brachials with straight hinge line occupying entire width of plates. Arms invariably 10, branching isotomously on primibrach *2*, composed of angular wedge-shaped joints, zigzag, with their larger, longer sides alternating and projecting so as to support short, rounded pinnules, which may resemble ramules. Stem more or less pentangular in section. *M.Dev.-Miss.*, cosmop.——FIG. 452,*1a,b*. **D. scalaris* (MEEK & WORTHEN), L.Miss., Osag.(Burlington Ls.), Iowa; *1a, C*-ray view of holotype crown, ×1 (Meek & Worthen, 1873); *1b*, plate diagram of cup (radials black, radianal cross ruled, anal plates stippled) and pinnulate arms (Moore, 1962b).—— FIG. 452,*1c*. *D. tumidulus* MILLER & GURLEY, L.Miss.(Keokuk), Ind.; post. view of incomplete crown showing summit of anal sac, ×1 (Springer, 1926b).

Acylocrinus KIRK, 1947, p. 293 [**A. tumidus*; OD] [=*Tropiocrinus* KIRK, 1947, p. 299 (type, *Poteriocrinites (Scaphiocrinus) rudis* MEEK & WORTHEN, 1869, p. 139)]. Crown erect, of medium height, erect arms separated laterally. Cup bowl shaped, with sharply depressed pit for attachment of stem, surface of plates granulose, infrabasals small, not visible from side; basals relatively small, posterior one truncate for support of anal plate; radials large; single large anal plate in posterior interray rising well above level of radials, distally lunate in section; anal sac tall, slender. Arms 10, relatively long and slender, branching isotomously on medially constricted primibrachs *1*; brachials strongly cuneate, dorsally nodose or carinate, with elevations appearing on pinnuliferous side of each, pinnules long, stout. Stem transversely circular, columnals forming well-defined nodal and internodal series; lumen obscurely pentagonal. *L.Miss. (Osag., Burlington Ls.)*, USA(Iowa-Mo.).——FIG. 452,*2*. **A. tumidus*, Iowa; *2a-c, D-, A*-ray, and dorsal views of crown, ×1.5 (Kirk, 1947).

Aulocrinus WACHSMUTH & SPRINGER, 1897, p. 138 [**A. agassizi*; OD]. Monotypic genus founded on *A. agassizi*, figured without definition, or description, but based solely upon extraordinary form of the anal sac, which with its lateral spout exhibits a specialization almost without parallel among crinoids (exception, *Carcinocrinus* LAUDON, 1941). Form otherwise like *Decadocrinus* as to cup and arms, but differing in stem and cirri. Type species strongly characterized by sharp prominent wrinkles on calyx plates, angular and keeled brachials, well-defined pores at sides of hexagonal anal tube plates, and sharp, longitudinal rows in which these plates are arranged. Stem distinctly pentagonal in section, with strong cirri. *L.Miss.(Osag.)*, USA(Ind.).——FIG. 452,*3*. **A. agassizi*, Borden Gr., Ind.; *3a-c, A*-ray, *AB*-interray, and post. views of specimen showing anal sac; *3d, A*-ray view of another specimen; all ×1 (Springer, 1926b).

Eireocrinus WRIGHT, 1951, p. 102 [**E. ornatus*; OD]. Cup shallow truncate cone shaped, discoid, with basal concavity. Uniserial arms keeled, branching on elongated primibrachs *1* (in 3 exposed rays of type species holotype); secundibrachs slightly elongated. Column large, transversely subpentagonal. *L.Carb.(Tournais.)*, Eire.——FIG. 453,*3*. **E. ornatus*; side view of holotype crown, ×1.5 (Wright, 1951).

Glaukosocrinus STRIMPLE, 1951, p. 191 [**Malaiocrinus parviusculus* MOORE & PLUMMER, 1940, p. 100; OD] [=*Glaukosocrinus* STRIMPLE, 1961d, p. 114 *(nom. null.)*]. Cup low, truncate bowl shaped with evenly rounded sides and small basal concavity; 3 anal plates in normal (primitive) position in broad posterior interray; radial articular facets wide (plenary) but short. Ten arms, branching evenly on primibrachs *1*, secundibrachs zigzag in appearance, bearing free armlets (pinnules) on alternate sides. Column small, circular in outline. *M.Penn.(Desmoines.)-U.Penn.(Virgil.)*, USA (Okla.-Texas).——FIG. 452,*4a-c*. **G. parviusculus* (MOORE & PLUMMER), M.Penn.(Millsap Lake F.), Parker Co., Texas; holotype cup from dorsal, post., and ventral sides, ×3 (Moore & Plummer, 1940). ——FIG. 452,*4d*. *G. planus* STRIMPLE & MOORE, U.Penn.(Francis Sh.), near Ada, Okla.; post. view of holotype crown from obliquely below, ×1 (Strimple & Moore, 1971b).

Ramulocrinus LAUDON, PARKS, & SPRENG, 1952, p. 557 [**R. nigelensis*; OD]. Cup widely flaring, 3 anals in cup. Arms not branching beyond axillary primibrachs *1*, unbranched in *A* ray; arms with characteristic zigzag appearance of *Decadocrinus*. [*Ramulocrinus* is thought to have developed from Devonian *Decadocrinus* with sinuous arms in the same manner as *Scytalocrinus* is presumed to have descended from smooth-armed decadocrinids without elimination of branching in any ray.] *L.Miss.(Osag.)-M.Penn.(Desmoines.)*, Can.(Alta.), USA(Iowa-Texas).——FIG. 453,*4a*.

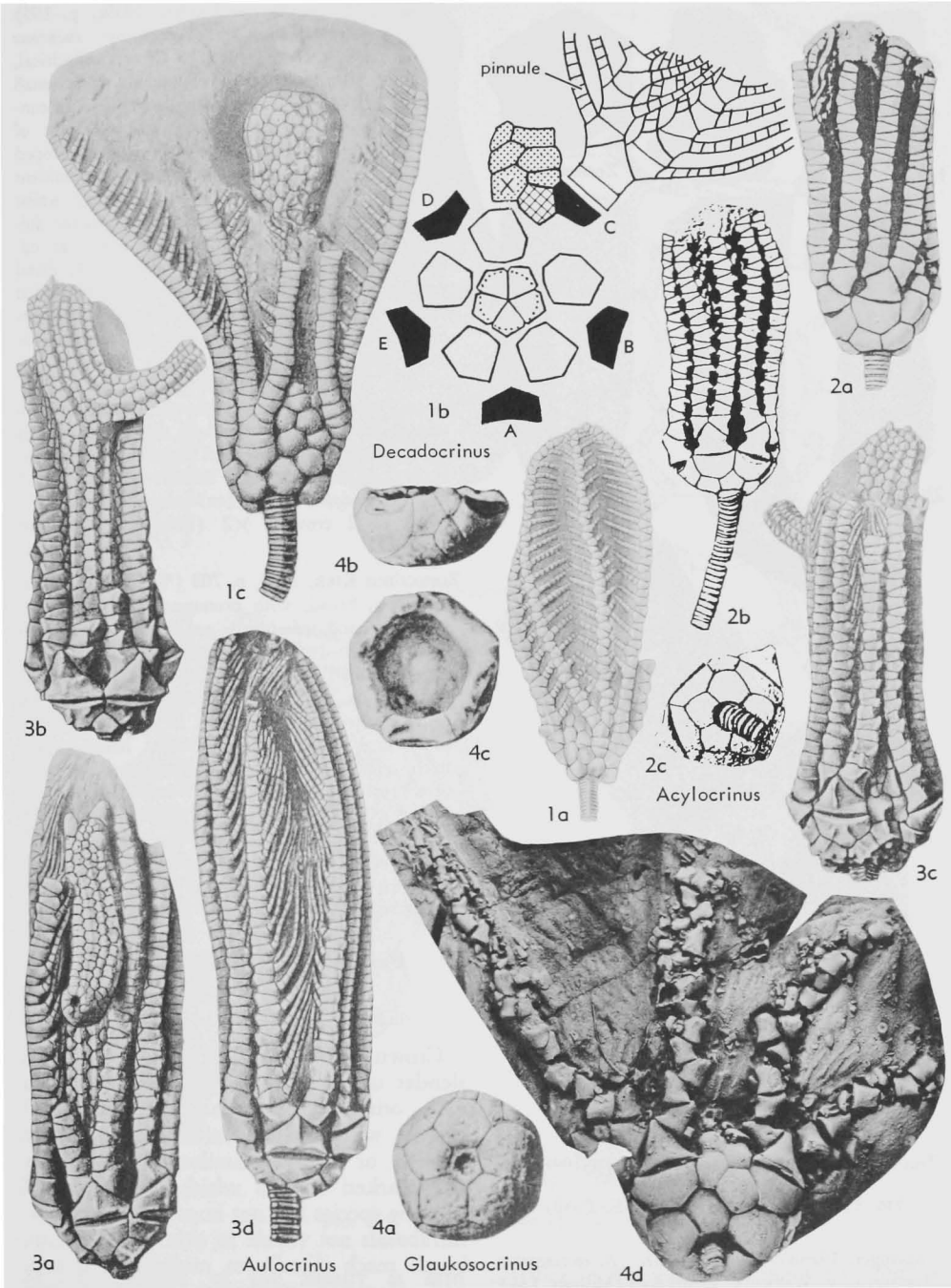


FIG. 452. Decadocrinidae (p. *T686*).

**R. nigelensis,* L.Miss.(Banff F.), Alta.; *A*-ray view, ×1.5 (Laudon, Parks, & Spreng, 1952).——

FIG. 453,*4b*. *R. halli* (HALL), L.Miss.(up. Burlington Ls.), Iowa; post. view of crown, ×1

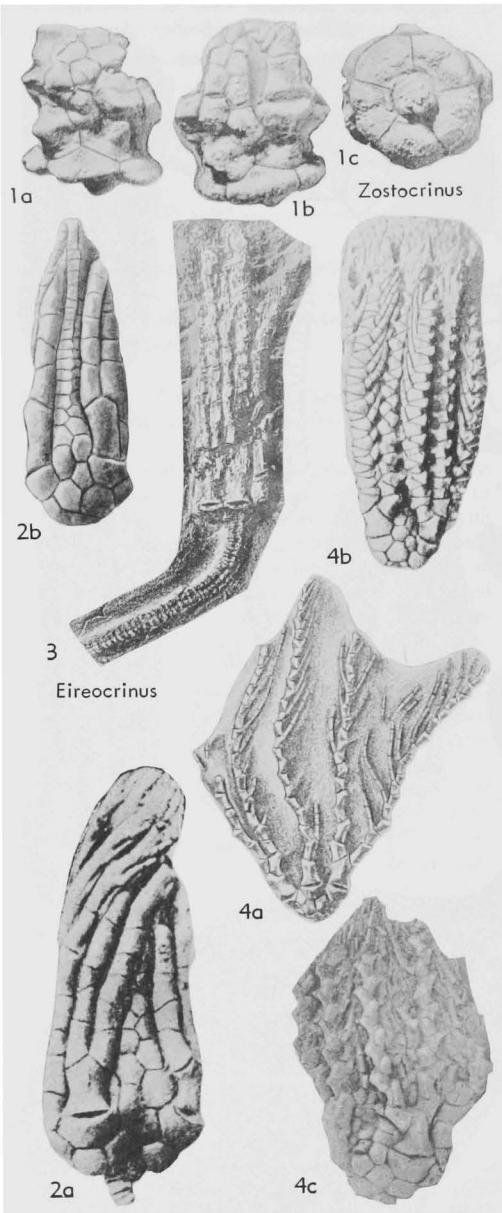


FIG. 453. Decadocrinidae (p. T686-T688).

(Springer, 1926b).——FIG. 453,*4c*. *R. consectatus* STRIMPLE & WATKINS, Desmoines.(Millsap Lake F.), Texas; post. view of holotype crown, ×1.5 (Strimple & Watkins, 1969).

Trautscholdicrinus YAKOVLEV & IVANOV in YAKOVLEV, 1939, p. 66 [**T. miloradowitschi*; OD] [=*Trautscholdicrinus* IVANOV, 1926 (no description or type species) (*non Trautscholdicrinus* MOORE & PLUMMER, in MOORE, 1939c, p. 195) (type, *T. jaekeli*, =*Synerocrinus incurvus* (TRAUTSCHOLD, 1867); OD)]. Crown cylindrical, arms not abutting. Cup expanded, with small basal concavity; infrabasals small, confined to concavity; basals large, extending to midheight of cup or above; radials large with well-developed subhorizontal articular facets having prominent adsutural slopes which extend to lateral cup walls; 3 large anal plates in normal arrangement followed above by large sac plates. Anal sac extending to top of crown (as preserved), distal portion composed in part of irregular plates but with at least one regular series bearing pore slits on lateral edges. Arms 10, elongate cuneate brachials with well-rounded exteriors, arranged uniserially, long side of each bearing stout pinnule; primibrachs *1* axillary, elongated, constricted in midsection. Column round in section, composed of alternatingly narrow and expanded columnals. *U.Carb.*, USSR(Moscow Basin).——FIG. 453,*2*. **T. miloradowitschi*, C_2(=Missour.); *2a,b*, post. views of 2 crowns, ×2 (Yakovlev & Ivanov, 1956).

Zostocrinus KIRK, 1948, p. 708 [**Z. ornatus*; OD]. Cup low, broad, with pronounced outward flare of radials and infrabasals, ornamented with high sharply defined ridges. Infrabasals hypertrophied, forming broad basal plane, flexing inward distally, basals short and small, radials large with wide articular facet; anal plates 3 in normal arrangement, anal *X* the largest element. Arms known from a few proximal brachials, branching with primibrach *2*, brachials long, deep and strongly keeled. Column pentagonal, lumen pentalobate. *M.Dev.(Hamilton)*, USA(N.Y.).——FIG. 453,*1*. **Z. ornatus; 1a-c*, hypotype, post., post. of another specimen showing proximal plates of anal tube, and base, ×3 (Goldring, 1954).

Family CLATHROCRINIDAE Strimple & Moore, 1971

[Clathrocrinidae STRIMPLE & MOORE, 1971a, p. 35]

Crown cylindrical to ovoid, with ten slender uniserial arms well separated from each other. Cup evenly rounded bowl shaped with small basal concavity, plates smooth or finely granulose, bounded by well-marked sutures which are impressed in some species but not impressed in others; infrabasals not visible in side views of cup, basals reach distally to midheight of cup, and proximal extremities of radials are above its basal plane; radial articular facets peneplenary, leaving distinct interradial notches; three anal plates occur in normal (primitive) arrangement. By far the most

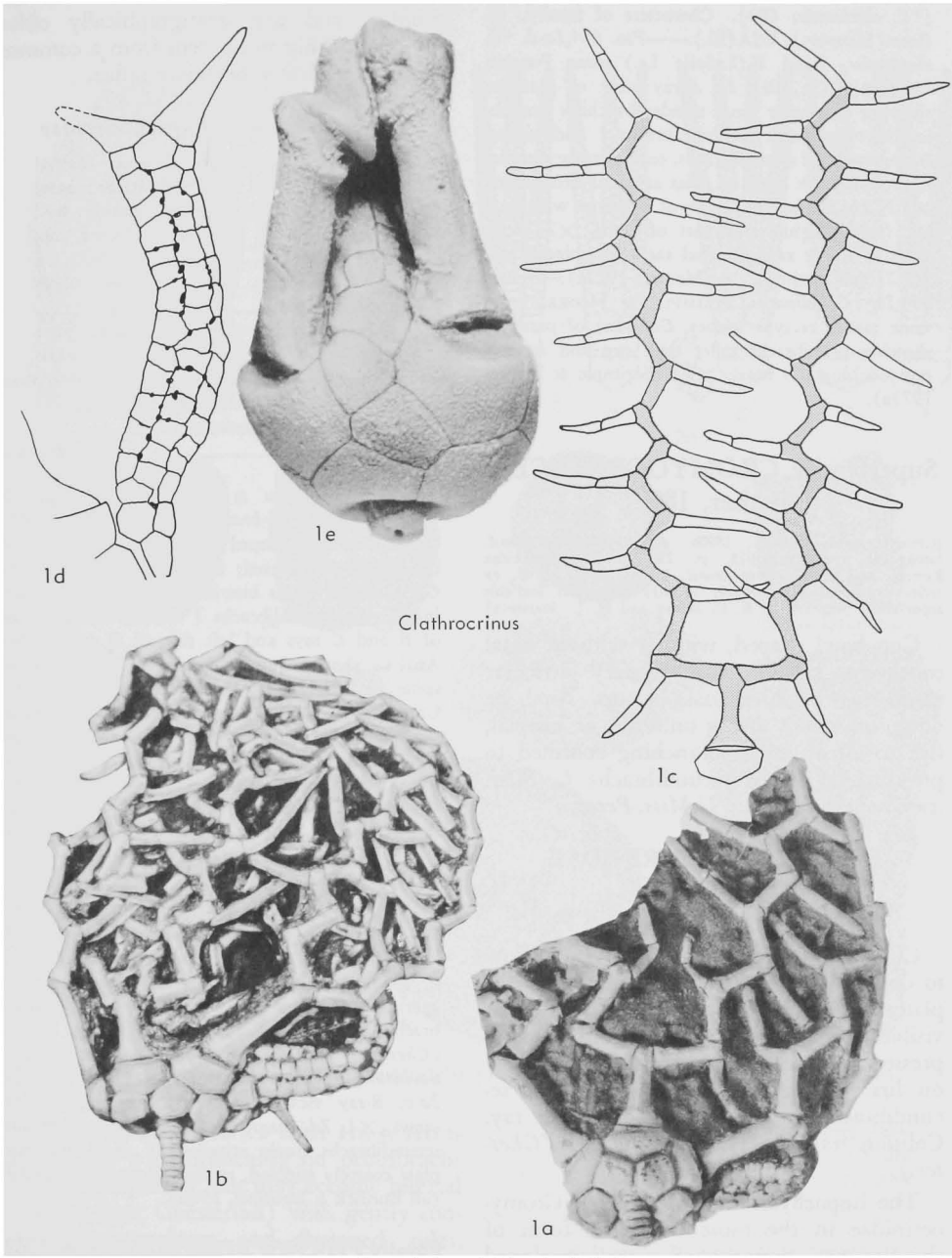


FIG. 454. Clathrocrinidae (p. T690).

striking feature of the family is arm structure, for all brachials are exceptionally long and slender, primibrachs and commonly secundibrachs being equal in length to height of the entire cup or greater than it; pinnules actually are ramules, little smaller in diameter than main arm components, which follow one another in a strongly zigzag manner, some with 90-degree deflections. Stem transversely circular. *U.Penn.-(Missour.)*.

Clathrocrinus STRIMPLE & MOORE, 1971, p. 35 [**C. clathratus*; OD]. Characters of family. *U. Penn.(Missour.)*, USA(Ill.).——FIG. 454,*1a-d*. **C. clathratus*, Bond F.(LaSalle Ls.) near Pontiac, Livingston Co., Ill.; *1a*, *E*-ray view of paratype showing extremely long, slender brachials branching at right angle on primibrachs *1* and zigzag arrangement of secundibrachs, each bearing ramule-like pinnule on opposite sides at distal extremities, ×2.7; *1b*, *EA*-interray view of holotype with anal sac (lower right) and part of stem, ×2; *1c,d*, arms of single ray and anal sac with spinose top, ×2.7 (all Strimple & Moore, 1971a).——FIG. 454,*1e*. *C. clinatus* STRIMPLE & MOORE, from same source as type species, *CD* view of paratype showing primibrachs taller than cup and anal *X* not touching *CD* basal, ×5.3 (Strimple & Moore, 1971a).

Superfamily CROMYOCRINACEA Bather, 1890

[Cromyocrinacea BATHER, 1890b, p. 385] [*nom. transl.* MOORE & STRIMPLE, 1973, p. 21 (*ex* Cromyocrinidae BATHER, May, 1890b, *nom. transl.* JAEKEL, 1918, p. 65, *ex* series Cromyocrinites BATHER, 1890b)] [Materials for this superfamily prepared by R. C. MOORE and H. L. STRIMPLE]

Cup bowl shaped, with or without basal concavity, radials with plenary articular facets, two or three anals in cup. Anal sac not prominent. Arms uniserial or biserial, five to 20 or more, branching confined to primibrachs *1* and secundibrachs *1*. Stem transversely circular. *U.Miss.-Perm.*

Family EUPACHYCRINIDAE S. A. Miller, 1890

[Eupachycrinidae S. A. MILLER, 1890, p. 350]

Cup bowl shaped with narrow shallow to deep basal concavity; two or three anal plates in *CD* interray; infrabasals not visible in side view. Arms biserial, appressed when closed, branching isotomously on first primibrachs and also on first secundibrachs, two to four branches per ray. Column transversely round. *U.Miss.(Chester.)*.

The Eupachycrinidae differ from Cromyocrinidae in the more depressed form of the cup and presence of a well-developed basal concavity. These features indicate evolutionary specialization. The arms branch isotomously once above the first brachial and may branch again in any half ray on axillary secundibrach *1*. Brachials are biserial and pinnular. In that Eupachycrinidae are more specialized in cup form and in arm structure than most Cromyocrinidae, and are stratigraphically older, any relationship must stem from a common ancestor, probably Scytalocrinidae.

Key to Genera of Eupachycrinidae

A. Crown tall cylindrical, with erect biserial arms. Cup mostly with well-defined basal concavity, proximal tips of radials well above basal plane on outer sides of cup, plates smooth .....
  I. Concavity deep, sutures between plates impressed .....
    a. Infrabasals downflared, proximal parts of basals transversely concave, 3 anals in cup, arms 14 ..... *Eupachycrinus*
    b. Basals not transversely concave, 2-3 anals in cup, arms 15-16 .... *Intermediacrinus*

Eupachycrinus MEEK & WORTHEN, 1865, p. 159 [**Graphiocrinus 14-brachialis* LYON, 1857, p. 477; OD]. Cup bowl shaped with deep basal concavity; infrabasals downflared; normally 3 anal plates in *CD* interray. Arms biserial, primibrachs *1* axillary in all rays, secundibrachs *1* axillary on right side of *B* and *C* rays and left side of *D* and *E* rays. Anal sac shorter than length of arms, with elongate spine at distal end. *U.Miss.(Meramec.-Chester.)*, USA(Ky.-Ind.).——FIG. 455,*3*. **E. quatuordecim-brachialis* (LYON); *3a-c*, specimen from Ste. Genevieve Ls.(Meramec.), dorsal, *DE*-interray, and *CD*-interray (post.) views of crown, ×0.93 (Kirk, 1937c); *3d*, specimen from Glen Dean Ls.(up. mid.Chester.), Ky.; radial articular facet, ×1.86 (Springer, 1911c).

Intermediacrinus SUTTON & WINKLER, 1940, p. 559 [**Eupachycrinus asperatus* WORTHEN, 1882, p. 34; OD]. Elongate, cylindrical crown. Cup medium sized, bowl shaped, with deep basal concavity; 2 or 3 anal plates in *CD* interray, *A* ray invariably bearing 2 biserial arms, in other rays secundibrachs *2* may be axillary, 4 arms in *C* ray. *U.Miss.(Chester.)*, USA(Ala.-Miss.-Ill.).——FIG. 455,*2*. *I. davidsoni* BURDICK & STRIMPLE, Jasper F., Ala.; *2a-c*, *B*-ray view (holotype), dorsal and *A*-ray views, ×1; *2d*, diagram of arm structure, axillary secundibrachs finely stippled, *X* and right tube plate coarsely stippled, radianal cross ruled, ×0.93 (all Burdick & Strimple, 1969).

Family PHANOCRINIDAE Knapp, 1969

[Phanocrinidae KNAPP, 1969 (March), p. 351] [=Phanocrinidae STRIMPLE & WATKINS, 1969 (July), p. 216]

Tall, comparatively narrow cylindrical crown with apposed arms. Cup bowl shaped, medium high or low, base concave or subhorizontal; radial articular facets plenary; three to one anal plates in cup.

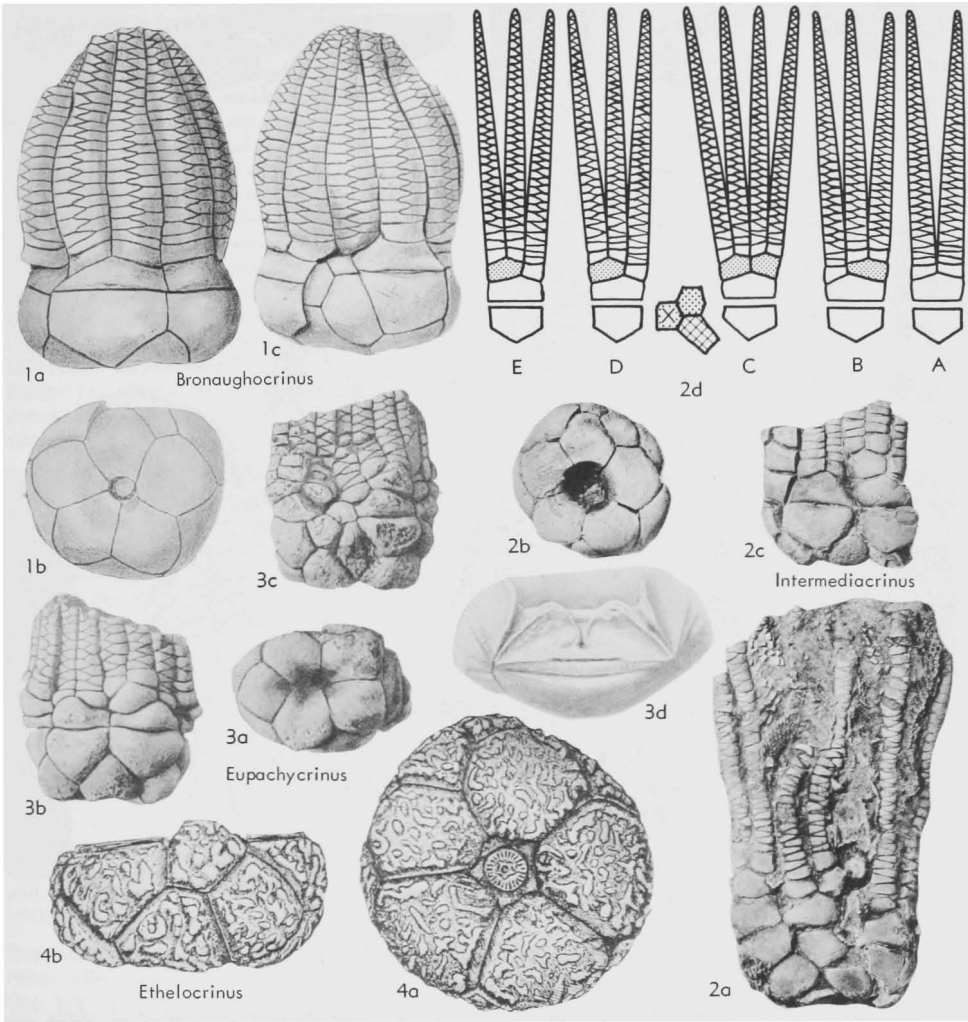


FIG. 455. Eupachycrinidae *(2,3)*; Phanocrinidae *(1)*; Cromyocrinidae *(4)* (p. T690, T692, T694).

Anal sac slender, shorter than arms. Arms five to ten with branching on primibrachs *1*, usually uniserial, but may become biserial (e.g., in later Chesterian) with gently convex outer surfaces and flattened sides, pinnulate. Stem transversely round. *U.-Miss.(Chester.), L.Carb.(Visean)-U.Carb. (Namur.)*.

Key to Genera of Phanocrinidae

A. Crown tall, cylindrical, with well-rounded erect arms. Cup bowl shaped, with or without basal concavity, plates smooth; anal plates in cup 1-3; arms 5-10 .....

I. Cup with very shallow to deep basal concavity; radials strongly rounded longitudinally to somewhat constricted summit of cup, 3 anals in cup; arms 10 .....

a. Sutures between plates moderately impressed; uniserial or incipiently biserial arms ..... *Phanocrinus*

b. Sutures between plates not impressed; equibiserial arms .... *Bronaughocrinus*

II. Cup with shallow basal concavity, not constricted at summit, sutures between plates not impressed; 3 anals in cup ..

a. Arms 8, *C* and *D* first primibrachs

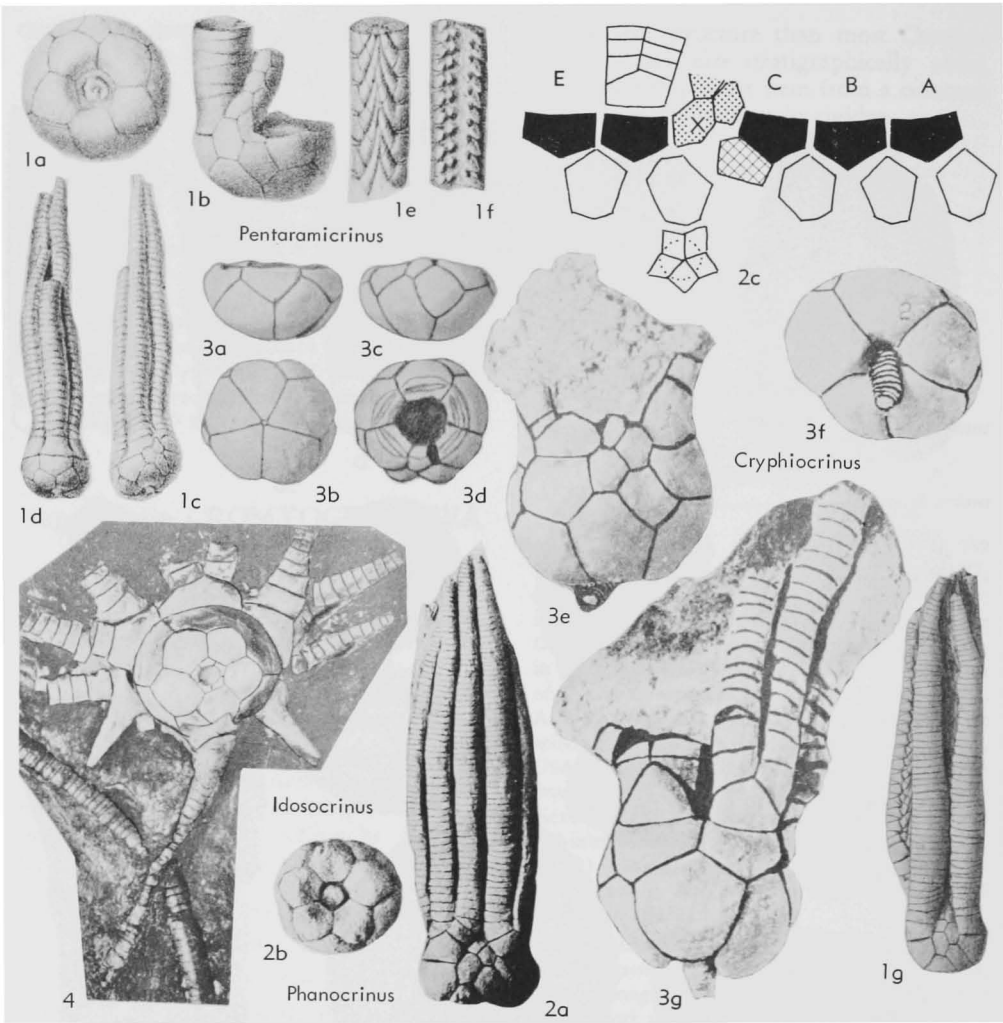


FIG. 456. Phanocrinidae (p. *T692-T693*).

spine bearing, arms of these rays unbranched ..... *Idosocrinus*

b. Arms 5-10, no spinose first primibrachs ..... *Pentaramicrinus*

III. Cup truncate ovoid, infrabasals small, basals very large; arms 10 .. *Cryphiocrinus*

B. Base of cup with small shallow concavity, infrabasals 5 or fused to 1, radial articular facets wide in *A, C,* and *D* rays, narrow in others ..... *Hosieocrinus*

Phanocrinus KIRK, 1937, p. 602 [**Zeacrinus formosus* WORTHEN in MEEK & WORTHEN, 1873, p. 549; OD]. Cup low bowl shaped, like *Pentaramicrinus* except that cup is proportionally lower and constricted near summit, and proximal tips of radials tend to enter basal plane. Considerable variability in arrangements of anal plates may be found in large populations; basal invagination may be narrow and deep, wide and deep, or shallow to essentially nonexistent, all of which affects attitude of infrabasals. Arms well rounded, consistently 10, uniserial, brachials short, externally cuneate, with tendency toward biserial arrangement in *Phanocrinus cooksoni* LAUDON (1941), from the upper Chesterian (Pitkin Ls.) of Oklahoma. Anal sac slender, with long spine at distal end. *L.Carb.(Visean),* Eu.(Brit.-Eire)-N.Afr.(Morocco); *U.Miss.(Chester.),* USA(Ala.-Ky.-Ark.-Okla.-Ill.-Ind.-?Nev.).——FIG. 456,*2*. **P. formosus* (WORTHEN), Chester., Ky.; *2a,b,* post. and dorsal views of crown, ×1 (Kirk, 1937c); *2c,* plate diagram (radials black, radianal cross ruled, *X* and other anals stippled) (Moore, 1962b).

Bronaughocrinus STRIMPLE, 1951, p. 671 [**B. figuratus*; OD]. Crown pear shaped with height less than twice width, narrowing markedly above midheight. Cup bowl shaped, rounding to vertical near summit, with deep basal concavity, proximal tips of radials slightly above basal plane of cup or barely reaching it, surface of plates smooth, sutures between them not impressed; infrabasal circlet very small, covered by stem at center of basal concavity; basals and radials large, latter with plenary articular facets; anals in cup 3, radianal largest and small right tube plate barely touching *C* radial; anal sac unknown. Arms 10, all branching isotomously on very low and wide primibrachs *1*, closely appressed, with slightly rounded exteriors very wide, equibiserial. Stem round, transversely and relatively slender. *U.Miss.(Chester.)*, USA(Okla.-Ga.).——FIG. 455,*1*. **B. figuratus*, Pitkin Ls., Muskogee Co., Okla.; *1a-c*, ant., dorsal, and post. views of holotype crown, ×0.93 (Strimple, 1951d).

Cryphiocrinus KIRK, 1929, p. 153 [**C. girtyi*; OD]. Crown moderately tall, cylindrical. Cup truncate ovoid with very narrow basal invagination for stem attachment; infrabasals small, not visible from side (solid plug may cover infrabasals if stem is reduced); basals very large and thick; radials wide and low with subhorizontal articular facets no longer than thickness of plates; 3 anal plates in normal arrangement. Arms 10, uniserial, pinnulate, branching on primibrachs *1*. Stem very small, when present, circular in outline. *U.Miss.(Chester.)*, USA(Ky.-W.Va.-Okla.). ——FIG. 456,*3a-d*. **C. girtyi*, Chester.(Greenbrier Ls.) near Crellin, W.Va.; holotype, *A*-ray, dorsal, *CD*-interray, and ventral views, ×2 (Kirk, 1929c). ——FIG. 456,*3e-g*. *C. bowsheri* (STRIMPLE), Chester.(?Hindsville F.), near Locust Grove, Okla.; post., dorsal, and ant. *(AB)* views, ×2 (Strimple, 1949a).

Hosieocrinus WRIGHT, 1952, p. 137 [**Tribrachiocrinus caledonicus* WRIGHT, 1936, p. 402; OD]. Cup low bowl shaped, with narrow basal concavity, plates with rugose surface; infrabasals 5 or fused together in small basal concavity, not visible in side view; basals 5, large, convex; 3 large pentagonal radials *(A, C, D)* with wide articular facets, 2 small narrow *(B, E)* radials with narrow articular facets and small triangular primibrachs curved forward and fused to upper surface of cup; 3 anal plates in cup, radianal large. *L.Carb.(Visean)*, Eu.(Eng.).——FIG. 447,*2*. **H. caledonicus* (WRIGHT); *2a-c*, ventral, dorsal, and post. views of cup, ×2 (Wright, 1952).

Idosocrinus WRIGHT, 1954, p. 167 [**I. bispinosus*; OD]. Characters of *Phanocrinus* except that cup is not constricted at summit and primibrachs *1* in *C* and *D* rays are extended as long spines and bear single arms, making total of 8 arms. [The development of spinose primibrachs represents the first appearance which later is a common character of all primibrachs of most representatives of *Delocrinus*.] *L.Carb.(Visean)*, Eu.(Scot.).——FIG. 456,*4*. **I. bispinosus*; dorsal view, ×1.5 (Wright, 1954).

Pentaramicrinus SUTTON & WINKLER, 1940, p. 248 (*emend.* BURDICK & STRIMPLE, 1969, p. 9) [**Cromyocrinus gracilis* WETHERBY, 1880a; OD]. Crown tall, cylindrical, with slender rounded arms. Cup medium high, with small shallow basal concavity, not constricted toward summit; 3 anal plates in cup. Anal sac tubular, formed of small polygonal plates. Arms 5-10. [As originally defined the genus was confined to *Phanocrinus*-like forms bearing 5 arms. BURDICK & STRIMPLE modified the concept to include species having erect lateral cup walls with no appreciable constriction in distal portion, regardless of the number of arms. In specimens where the distal end of the anal sac has been observed 2 rows of small spines occur. Variability in the arrangement of the 3 anal plates is common and forms with 5, 9, and 10 uniserial arms have been observed. Species with 5 arms appear to be confined to upper middle Chesterian strata and are therefore thought to represent advanced, divergent species rather than basic or primitive stock.] *U.Miss. (Chester.)*, USA; *U.Carb.(Namur.)*, Eu.(Brit.). ——FIG. 456,*1*. **P. gracilis* (WETHERBY), Chester. (Glen Dean Ls.), USA(Ky.); *1a,b*, dorsal and post. views of cup, latter showing lower part of anal sac, ×2; *1c,d*, *D*- and *A*-ray sides of crown, ×1; *1e,f*, inside view of arms with and without attached pinnules, ×2 (Wetherby, 1880a); *1g*, post. view of crown, ×1 (Kirk, 1937c).

Family CROMYOCRINIDAE Bather, 1890

[*nom. transl.* JAEKEL, 1918, p. 65, *ex* series Cromyocrinites BATHER, 1890b, p. 385] [=Ethelocrinidae STRIMPLE, 1961d, p. 77]

Cup more or less globe shaped, including forms with upflared or subhorizontal infrabasals; mostly three anal plates in cup but exceptionally only two. Anal sac very short and small. Arms uniserial, unbranched (e.g., *Cromyocrinus*), or branched isotomously on primibrachs *1* in all rays or biserial and often branching a second time on secundibrachs *1* in some half rays. Column transversely round. *L.Carb.(U.-Miss.)-Perm.*

The Cromyocrinidae are closely related to the Ulocrinidae. The cup is globose, radial articular facets have strongly marked evidence of muscular articulation and are characterized by their relatively large size and horizontal attitude. Juveniles have a mildly convex to subhorizontal base and

rather large infrabasals that changed with growth to shallowly concave to deeply concave basal invaginations and infrabasals of reduced size (Fig. 457). Anal plates were remarkably stable with a prominent radianal retained throughout the commonly included one or two additional plates. Arms were basically ten in number and progressed from uniserial to biserial. In many genera more arms were added with the second bifurcation on the first secundibrach. *Cromyocrinus* is the only genus in the family that bore five arms and the condition is considered to be divergent rather than primitive.

Key to Genera of Cromyocrinidae

A. Infrabasals slightly upflared .....
  I. Anal plates in cup 3 .....
    a. Arms 10, uniserial ..... *Mantikosocrinus*
    b. Arms 5, uniserial ..... *Cromyocrinus*
  II. Anal plates in cup 2 or 3, arms 10, biserial ..... *Metacromyocrinus*

B. Base of cup planate .....
  I. Anal plates in cup 3 .....
    a. Arms 10, cuneate brachials ..... *Dicromyocrinus*
    b. Arms 10, uniserial low, rectangular brachials ..... *Mooreocrinus*
  II. Anal plates in cup 2 but tip of right tube plate may enter cup, more than 10 biserial arms ..... *Parulocrinus*
  III. One anal plate in cup, 10 uniserial arms ..... *Moapocrinus*

C. Distal ends of infrabasals in basal plane but rest of infrabasal circlet forming an impressed base, anals 2 or 3 ..... *Goleocrinus*

D. Shallow basal concavity with subhorizontal infrabasal circlet composed of large plates ..
  I. Anal plates 2 or 3, surface of cup plates markedly rugose .....
    a. Arms 10, uniserial, 2 anal plates ..... *Synarmocrinus*
    b. Arms 10, biserial, 2 anal plates ..... *Paracromyocrinus*
  II. Same as I, except surface of cup plates finely rugose or smooth .....
    a. Surface of cup plates finely rugose, sutures strongly impressed, 2 or 3 anal plates, 16 biserial arms ..... *Aglaocrinus*
    b. Surface of cup plates smooth, sutures not impressed, 2 anal plates, 12 to 16 biserial arms ..... *Parethelocrinus*

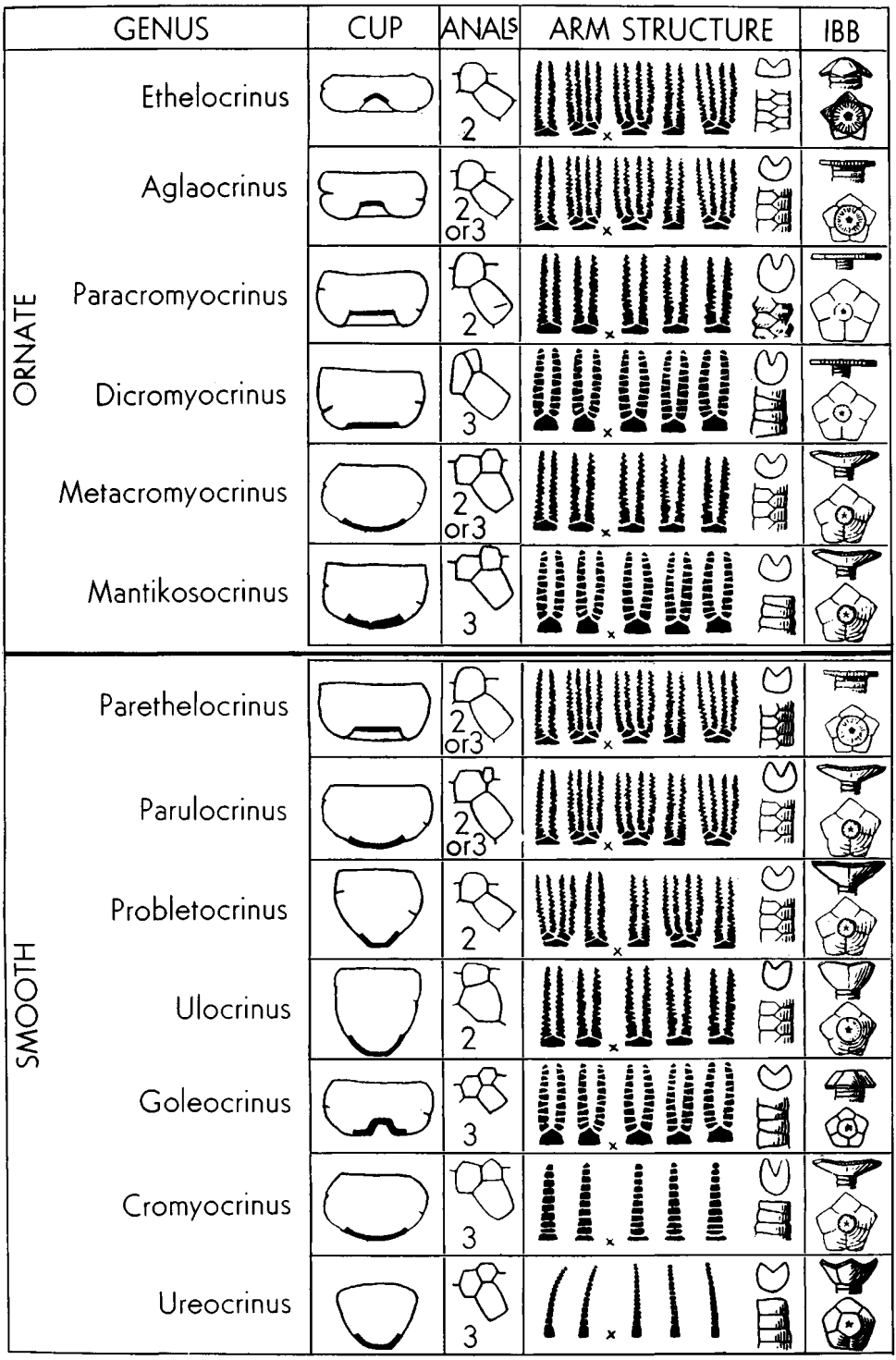
E. Deep basal concavity, downflared infrabasals, 2 anal plates, cup plates strongly ornamented, 16 to 18 biserial arms ..... *Ethelocrinus*

Cromyocrinus TRAUTSCHOLD, 1867, p. 12 [**C. simplex*; OD]. Cup subglobular with strong suture lines between plates and distinctly convex base although gerontic specimens may flatten; surface of cup plates and arms smooth or nearly so; 5 large infrabasals clearly visible from side, basals and radials fairly large but thin; 3 anal plates below summit of radials. Anal sac very short, tapering rapidly to small anus near summit. Arms 5, long, uniserial, composed of short, wide brachials. *Penn.-Perm.*, N.Am.(Okla.-Ark.); *L.Carb.-U.Carb.*, USSR(Moscow Basin); *L.Carb.*, Eu.(Spain).—— FIG. 458,*2*. **C. simplex*, U.Carb., Myachkova, USSR; *2a*, ant. view of crown, ×1 (Yakovlev & Ivanov, 1956); *2b-d*, topotype showing very short anal sac with attachment scars of gastropod *(Platyceras)*, and specimens with *Platyceras* attached, ×0.6 (Yakovlev, 1956); *2e*, plate diagram (radials black, radianal cross ruled, anal *X* and higher anal sac plates stippled), ×1 (Moore, 1962b).

Aglaocrinus STRIMPLE, 1961, p. 86 [**Ethelocrinus magnus* STRIMPLE, 1949d, p. 12; OD] [=*Tarachiocrinus* STRIMPLE, 1962e, p. 135 (*nom. subst. pro Ataxiacrinus* STRIMPLE, 1961d, p. 89, *non Ataxiacrinus* LYON, 1869, p. 463) (type, *Ataxiacrinus multiramus* STRIMPLE, 1961d, p. 90)]. Cup broad, low bowl shaped, surface finely rugose, sutures typically impressed deeply in V-shaped notches, shallow basal concavity; infrabasals subhorizontal or slightly downflared, forming moderately large disc; 5 basals, and 5 radials large; 2 or 3 large anal plates. Arms 16, equibiserial; primibrachs *1* low, axillary, secundibrachs 1 may be axillary in right and left posterior arms and anterior arm; pinnulate. Stem transversely round with crenulae visible from exterior columnals alternatingly expanded. *M.Penn.(Desmoines.)-L.Perm.*, USA(Iowa-Kans.-Okla.-Texas).——FIG. 458,*3*. **A. magnus* (STRIMPLE), *3a-d*, Pumpkin Cr. Ls., Dornick Hills F., Love Co., Okla.; post., ant., dorsal, ventral views of holotype, ×1 (Strimple, 1949d); *3e*, M.Penn.(up.Desmoines., Holdenville F.), Okmulgee Co., Okla.; holotype

(See facing page.)

FIG. 457. Diagram showing comparison of thirteen genera of poteriocrinines having subglobular cups with two or three anal plates in the cup; *1)* those with ornamented outer surfaces: *Ethelocrinus* KIRK, *Aglaocrinus* STRIMPLE, *Paracromyocrinus* STRIMPLE, *Dicromyocrinus* JAEKEL, *Metacromyocrinus* STRIMPLE, *Mantikosocrinus* STRIMPLE; and *2)* those with smooth surfaces: *Parethelocrinus* STRIMPLE, *Parulocrinus* MOORE & PLUMMER, *Probletocrinus* STRIMPLE & MOORE, *Ulocrinus* MILLER & GURLEY, *Goleocrinus* STRIMPLE & WATKINS, *Cromyocrinus* TRAUTSCHOLD, and *Ureocrinus* WRIGHT & STRIMPLE (Strimple, n).



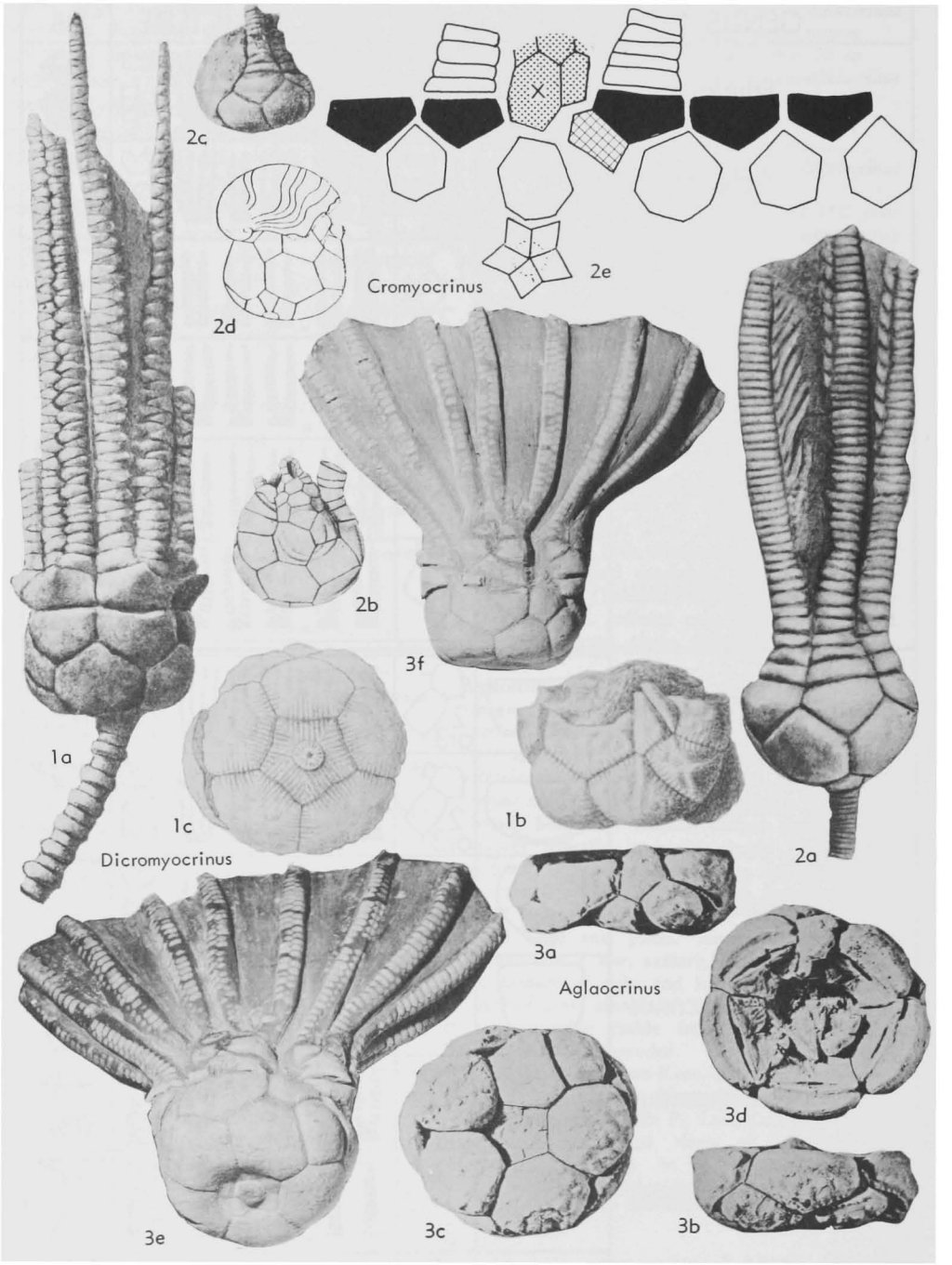


FIG. 458. Cromyocrinidae (p. *T694*, *T696-T698*).

crown, oblique dorsal view, ×0.8, and *3f*, left post. (*D*-ray) view, ×0.7 (Strimple, 1961d).—FIG. 459,*2*. *A. compactus* (MOORE & PLUMMER), Missour.(Brad F.), Palo Pinto Co., Texas; *2a-c*, dorsal, post., and ventral views, ×1 (Moore & Plummer, 1940).

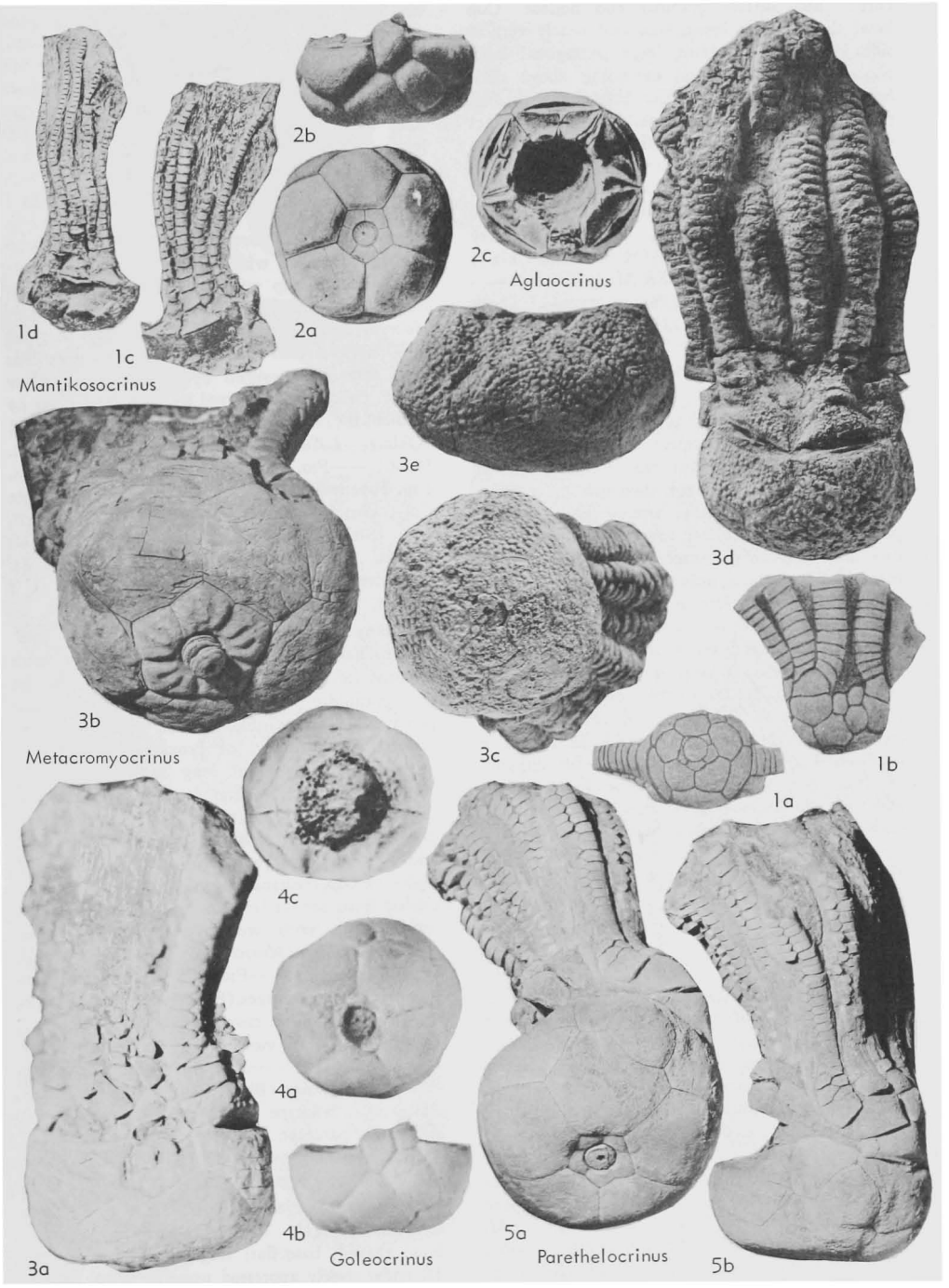


FIG. 459. Cromyocrinidae (p. *T*694, *T*696, *T*698, *T*700).

Dicromyocrinus JAEKEL, 1918, p. 66 [**Cromyocrinus ornatus* TRAUTSCHOLD, 1879, p. 121; SD MOORE & PLUMMER, 1940, p. 367]. Crown slender, tall and compact, arms abutting closely,

entire outer surface granular and nodose. Cup bowl shaped, with broad base and nearly vertical sides; infrabasals forming large pentagonal horizontal disc; basals large, extending above mid-height of cup; radials wider than long; 3 anal plates, radianal large, oblique, anal *X* in contact with posterior basal, extending well above cup summit, right tube plate narrowly in contact with radianal, extending above summit of anal *X*. Arms 10, long, slender, uniserial, typically with cuneate brachials, pinnulate. Stem transversely round. *L.Penn.-U.Penn.*, USA(Mont.-Texas-Okla.); *U.Carb.*, S.Am.(Brazil)-USSR-Afr.(Morocco).——FIG. 458,*1*. **D. ornatus* (TRAUTSCHOLD), U.Carb. (Moscov.), Myachkovo, USSR; *1a*, ant. view of large crown, ×1 (Yakovlev & Ivanov, 1956); *1b,c*, post. and dorsal views of cup, ×1 (Trautschold, 1867).

Ethelocrinus KIRK, 1937, p. 605 [**Eupachycrinus magister* MILLER & GURLEY, 1890, p. 4; OD]. Cup low basin shaped, with wide flattened base as viewed in profile and with tendency to constriction at summit of radial circlet; base concave, plates convex with surface covered by coarse granules and irregularly vermicular short ridges, sutures between plates impressed; basals large; radials broad and relatively low, articular facets occupying full width of radial with sharply defined transverse ridge and broad muscle fields, 2 anal plates in cup include large quadrangular radianal and hexagonal anal *X*. Arms biserial, commonly 16 (2 each in *B* and *E* rays, 4 each in others; an 18-armed specimen has 3 each in *B* and *E* rays and 4 in others). Stem transversely circular, proximal portion composed of alternate nodals and internodals; whorls of cirri in *Ethelocrinus magister* borne by column to within short distance of crown. *U.Penn.(Missour.)*, N.Am.——FIG. 455,*4*. **E. magister* (MILLER & GURLEY), Missour. (Lane Sh.), Kansas City, Mo.; *4a,b*, holotype cup from base and post. side, ×0.93 (Miller & Gurley, 1890).

?**Goleocrinus** STRIMPLE & WATKINS, 1969, p. 167 [**G. masonensis*; OD]. Cup medium bowl shaped, with broad base and central concavity, surfaces of plates smooth, sutures impressed; infrabasals down-flared from impressed stem attachment scar to distal tips flexed sharply into basal plane; anals 2-3, radianal dominant. Arms 10, recti-uniserial. [The form described as *Phanocrinus? vadosus* WASHBURN (1968) from the Bridal Veil Falls Member, Oquirrh F.(Morrow.), of Utah is referred to *Goleocrinus vadosus* (WASHBURN), Moore & Strimple, 1973, p. 56.] *U.Miss.(Chester.)-M. Penn.(Desmoines.)*, USA(Utah-Texas).——FIG. 459,*4*. **G. masonensis*, M.Penn., Big Saline F. (Atokan), Mason Co., Texas; *4a-c*, holotype from dorsal, post., and ventral sides, ×1.5 (Strimple & Watkins, 1969).

Mantikosocrinus STRIMPLE, 1951, p. 673 [**M. castus*; OD]. Cup bowl shaped with gently convex base; infrabasals extending slightly beyond column, visible from side; basals medium sized, evenly curved to midheight of cup; proximal tips of radials well above basal plane; 3 anal plates in normal arrangement, radianal slightly larger than anal *X*, latter in broad contact with *CD* basal and right tube plate which rests on distal face of radianal. Arms 10, recti-uniserial with gently convex outer face, pinnulate; primibrachs *1* axillary, wider than high. [*Mantikosocrinus* is closely similar to *Mooreocrinus* WRIGHT & STRIMPLE (1945), from which it differs in having more evenly curved cup walls and lacking pronounced forefacets in distal portion of radials, which typify *Mooreocrinus*. The form from Scotland ascribed to *Dicromyocrinus geminatus* TRAUTSCHOLD has been named *D. wrighti* by YAKOVLEV & IVANOV (1956, p. 20) and referred to *Mantikosocrinus* by STRIMPLE (1966a, p. 5).] *U.Miss.(Chester.)*, USA (Okla.); *L.Carb.(Calciferous Ss. Series)*, Eu. (Scot.).——FIG. 459,*1a,b*. **M. castus*, U.Miss. (up. Fayetteville F.), Okla.(Braggs Mt., Muskogee Co.); dorsal and post. views of holotype crown, ×1 (Strimple, 1951d).——FIG. 459,*1c,d*. *M. wrighti* (YAKOVLEV & IVANOV), Calciferous Ss. Ser., near St. Andrews, Scot.; side views of 2 crowns, ×1 (Wright, 1951).

Metacromyocrinus STRIMPLE, 1961, p. 68 [**M. holdenvillensis*; OD]. Cup globe shaped with upflared infrabasals, exterior ornate, with pustules and granules; 5 large infrabasals forming low pentagonal cone visible in side view, base impressed for reception of proximal columnal; 5 large basals, almost as long as wide, strongly curved longitudinally and laterally; radials with slight forefacet, plenary articular facets large, marked by outer ligament pit, transverse ridge and moderately large muscle areas; 2 or 3 anal plates in cup, radianal large, right tube plate excluded from cup in later forms. Arms 10, equibiserial, stout, with well-rounded exteriors, pinnulate. *L.Penn.(Morrow.)-M.Penn.(Desmoines.)*, USA(Okla.-Ark.).——FIG. 459,*3a,b*. **M. holdenvillensis*, up.Desmoines.(Holdenville F.), Beggs, Okla.; *3a*, holotype crown from post. side, ×1; *3b*, oblique dorsal view, ×1 (Strimple, n; Univ. Oklahoma 4125).——FIG. 459,*3c-e*. *M. gillumi* STRIMPLE, Morrow.(Bloyd F.), Sweetwater Creek, Ark.; *3c,d*, holotype crown from dorsal and ant. sides; *3e*, paratype cup from post. side, all ×2 (Strimple, 1966b; Univ. Iowa SUI 12279 and SUI 12280, paratype).

Moapocrinus LANE & WEBSTER, 1966, p. 30 [**M. rotundatus*; OD]. Crown tall, cylindrical; cup bowl shaped, base flat; single anal plate in cup; 10 wide, closely appressed uniserial arms, branching on primibrachs *1*. *L.Perm.(Wolfcamp.)*, USA (Nev.).——FIG. 460,*2*. **M. rotundatus*, Battleship Wash, Nev.; *2a-d*, paratype cup from ant., dorsal, post., and ventral sides, ×1 (Lane & Webster, 1966); *2e*, topotype, crown from right

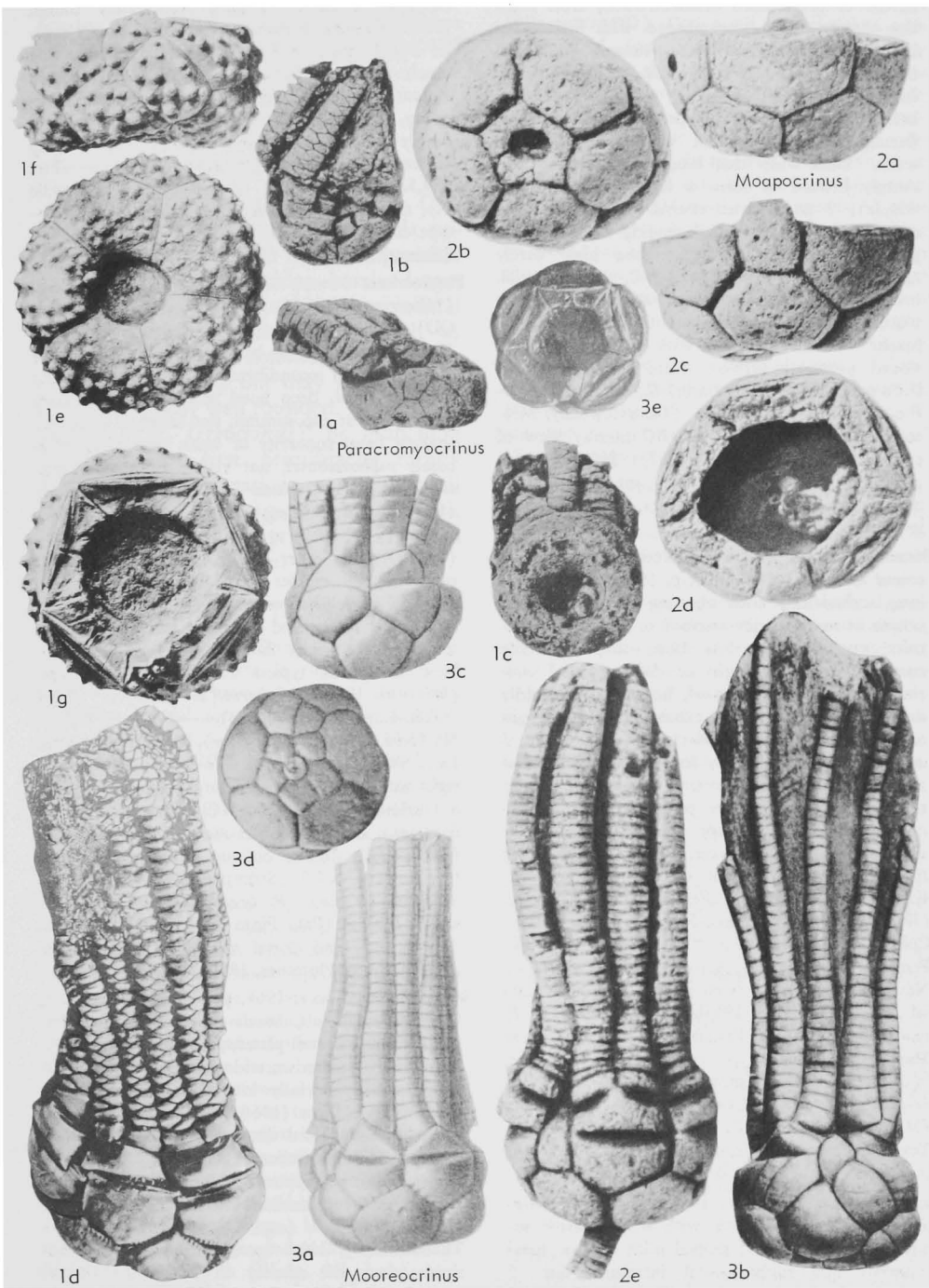


FIG. 460. Cromyocrinidae (p. *T*698-*T*700).

post. side, ×1 (Webster & Lane, 1967).

Mooreocrinus WRIGHT & STRIMPLE, 1945, p. 221 [**Cromyocrinus geminatus* TRAUTSCHOLD, 1867, p. 25; OD]. Crown tall, cylindrical, outer surface

devoid of pronounced ornamentation, arms abutting closely. Cup bowl shaped with broad, flat base and erect lateral walls, sutures impressed; infrabasals extending well beyond column, gently convex, distal tips visible in side view of cup; basals large with proximal portion in basal plane, flexing sharply to extend well up into lateral walls; radials wider than long, distal edges curved sharply inward to form a large forefacet (Fig. 460,*3e*); 3 anal plates normal or in advanced arrangement with radianal tending to migrate to posterior position and right tube plate barely notching cup summit. Arms 10, recti-uniserial, broad in proximal region but tapering to narrow width before attaining midheight, pinnulate; primibrachs *1* axillary, wide, with sharply inwardly sloped proximal surface. Stem relatively small. *U.Carb.*, USSR(Moscow Basin)-S.Am.(Brazil).——Fig. 460,*3*. **M. geminatus* (Trautschold), Moscov., Myachkovo, USSR; *3a, BC*-interray view of crown, ×1 (Trautschold, 1867); *3b-e*, topotype crowns from post. *(CD)* and ant. *(AB)* sides, cups from dorsal and ventral sides, all ×1 (Yakovlev & Ivanov, 1956).

Paracromyocrinus Strimple, 1966, p. 4 [**Parulocrinus vetulus* Lane, 1964b, p. 681; OD]. Crown long, cylindrical, arms abutting closely, surfaces ornate in most species ascribed to genus but typically smooth. Cup low bowl shaped, evenly curved sides, with slight or decided basal concavity; infrabasal disc broad, horizontal or mildly downflared; basals large, extending to midheight of cup; radials large, wider than high; 2 or 3 anal plates with tendency for very large radianal to dominate posterior interray. Arms 10, equibiserial, branching on low primibrachs *1*. [*Paracromyocrinus* has a more pronounced basal invagination than *Synarmocrinus* Lane, 1964, but main difference is in the arms, which are uniserial in the latter.] *L.Penn.(Morrow.)-L.Perm. (Wolfcamp.)*, USA(Okla.-Nev.-Texas-Kans.-Ark.-Colo.).——Fig. 460,*1a-c*. **P. vetulus* (Lane), L. Penn.(Bird Spring F.), Arrow Canyon, Clark Co., Nev.; holotype crown from post., ventral, and dorsal sides, ×1 (Lane, 1964b).——Fig. 460,*1d*. *P. marquisi* (Moore & Plummer); Missour.?, near Mason, Texas; holotype crown from ant. side, ×0.7 (Moore & Plummer, 1940).——Fig. 460, *1e-g*. *P. texasensis* (Moore & Plummer), L.Penn. (Morrow., Marble Falls F.), SW. of San Saba, Texas; holotype cup from dorsal, post., and ventral sides, ×1 (Moore & Plummer, 1940).

Parethelocrinus Strimple, 1961, p. 81 [**P. ellipticus*; OD]. Cup smooth, with nonimpressed sutures, broad, low bowl shaped with shallow basal concavity and subhorizontal infrabasal disc; 5 large basals, extending out of basal plane well into lateral cup walls; 5 large radials, wider than long, not extending to basal plane; 2 anal plates. Arms 12 to 16, equibiserial; primibrachs *1* low, axillary; secundibrachs *2* may be axillary in *C, D,* and *A* rays. Column transversely round. [*Parethelocrinus* is distinguished from closely similar *Parulocrinus* in having a basal concavity and much smaller infrabasal circlet. The associated *Aglaocrinus* has a more pronounced basal concavity, larger infrabasal disc, surface rugosity and deeply impressed sutures between cup plates.] *M.Penn.(Desmoines.)*, USA(Okla.-Texas).——Fig. 459,*5*. **P. ellipticus*, up.Desmoines.(Holdenville F.), near Beggs, Okmulgee Co., Okla.; *5a,b*, holotype crown in oblique post. and post. views, ×1 (Strimple, n; Univ. Oklahoma OU4135).

Parulocrinus Moore & Plummer, 1940, p. 360 [**Ulocrinus blairi* Miller & Gurley, 1893, p. 57; OD]. Crown moderately tall, having more than 10 long, biserial arms branching on primibrachs *1* in all rays and secundibrachs *1* in some rays. Cup medium sized, deep bowl shaped, without sharp constriction at cup summit, flat based or with very shallow basal concavity or weak convexity; infrabasals subhorizontal, not visible from side; typically with 2 anal plates in cup but proximal tip of right tube plate may enter cup. [*Parulocrinus* is closely similar to *Parethelocrinus* Strimple (1961d), the latter being distinguished by a proportionally smaller infrabasal circlet and a decided, though shallow, basal concavity, both of which are interpreted as more advanced characters than the wide, flat or faintly convex infrabasal circlet of typical *Parulocrinus*.] *U.Penn. (Missour.-Virgil.)-L.Perm.(Wolfcamp.)*, USA (Okla.-Kans.-Ill.-Mo.-Texas).——Fig. 449,*2a-c*. **P. blairi* (Miller & Gurley), Missour.(Argentine Ls.), SW. of Sedalia, Mo.; *2a-c*, post., dorsal, and right ant. *(AB)* views of holotype cup, ×1 (Miller & Gurley, 1893).——Fig. 449,*2d*. *P. pontiacensis* Strimple & Moore, Missour.(LaSalle Ls.), near Pontiac, Ill.; slightly oblique ant. view of hypotype crown, ×1.5 (Strimple & Moore, 1971a). ——Fig. 449,*2e,f*. *P. beedei* (Moore & Plummer), Missour.(Palo Pinto Ls.), west of Strawn, Texas; post. and dorsal views of holotype cup, ×2 (Moore & Plummer, 1940).

Synarmocrinus Lane, 1964, p. 678 [**S. brachiatus*; OD]. Five radials, basals and subplanate infrabasals in cup; 2 anal plates; primibrachs *1* axillary, supporting 10 massive, wide, uniserial arms; proximal brachials laterally interlocking when closed; stem round. [Lane (1964, p. 678) stated: "proximal brachials fixed into dorsal cup by lateral interlocking with adjacent brachials," a premise which cannot be supported. Many Upper Paleozoic inadunates have similar interlocking devices in proximal brachials (e.g., *Dicromyocrinus ornatus* Trautschold), which operate simply for thorough closure from the exterior to protect the visceral mass from small predators.] *L.Penn.(Morrow.)-L.Perm.*, USA(Nev.-Utah-Okla.).——Fig. 449, *1a,b*. **S. brachiatus*, L.Perm.(Bird Springs F.), Indian Springs, Nev.; *1a*, left post. (*D*-ray) view of holotype, ×0.7; *1b*, arm tips of paratype, ×1

(Lane, 1964b).——FIG. 449,*1c-e*. *S. fundunus* STRIMPLE, Atoka F., Clarita, Okla.; holotype cup from post. side, dorsal, and ventral, ×1.3 (Strimple, 1966a).

Family ULOCRINIDAE Moore & Strimple, 1973

[Ulocrinidae MOORE & STRIMPLE, 1973, p. 14]

Crown tall, arms not appressed. Cup globose, with convex base; infrabasals upflared, part outside of stem impression entirely visible from side; basals large; radials wider than high, with subhorizontal articular facets occupying full width of plates, no interradial notches; anals mostly two or three in cup but may be only one. Arms transversely well rounded, unbranched uniserial (e.g., *Ureocrinus*), or branching isotomously on first primibrachs mostly without higher bifurcations, ten arms in all (exceptionally 14-18, e.g., *Probletocrinus*), biserial, pinnulate (Fig. 457). *L.Carb. (Visean); M.Penn.-Perm.*

Key to Genera of Ulocrinidae

A. Infrabasals distinctly upflared, visible from side; 2 or 3 anal plates in cup .....
  I. Five uniserial arms ..... *Ureocrinus*
  II. Ten biserial arms, commonly 2 anal plates ..... *Ulocrinus*
  III. More than 10 biserial arms, 2 anal plates ..... *Probletocrinus*

B. Cup moderately low bowl shaped; infrabasals subhorizontal, not visible from side; one anal plate ..... *Tyrieocrinus*

Ulocrinus MILLER & GURLEY, 1890, p. 6 [**U. buttsi*; OD]. Crown tall, subcylindrical, with parallel erect arms not appressed. Globular to pyramidal calyx; infrabasals upflared weakly to strongly; basals as large or larger than infrabasal circlet; radials pentagonal, much wider than high, with subhorizontal broad articular facets filling full width of plates; single, large, quadrangular radianal resting obliquely between 2 basals, may reach *D* radial; anal *X* resting on truncate distal edge of *CD* basal or above radianal. Arms 10, long, well-rounded exteriors, secundibrachs cuneate in short proximal portions, equibiserial above. *M. Penn.(Atokan)-U.Penn.(Virgil.)*, USA(Ill.-Mo.-Okla.-Kans.-Texas); *L.Perm.*, USA(Texas)-USSR (Krasnoufimsk); *U.Perm.*, Indon.(Timor, Basleo)-Pak.(Salt Ra.).——FIG. 461,*4a*. **U. buttsi*, Missour., Kansas City, Mo.; post. view of holotype cup, ×0.7 (Miller & Gurley, 1890).——FIG. 461,*4b*. *U. convexus* (STRIMPLE), Missour.(LaSalle Ls.), Pontiac, Ill.; hypotype crown from *AB*-interray side, ×0.7 (Strimple & Moore, 1971a).

Probletocrinus STRIMPLE & MOORE, 1971, p. 26 [**P. curtus*; OD]. Crown tall, subcylindrical, with at least 14 (possibly 18) biserial arms. Cup somewhat pear shaped with posterior distal area protruded; infrabasals moderately large, gently upflared and readily visible in side view of cup; large basals decidedly curved longitudinally; radials large, 5-sided; 2 large anals, with radianal in oblique position and anal *X* plate in broad contact with posterior *(CD)* basal. Arms biserial, 2 arms preserved in *A* ray, 4 arms (with second branching on secundibrachs *1*) in *B* and *E* rays, other arms missing or unattached, but *C* and *D* rays almost certainly identical to *B* and *E* rays, total 18, arm exteriors mildly convex, pinnules imperfectly preserved. Anal sac not observed; columnar cicatrix round, crenulated, lumen subpentagonal. *U.Penn. (Missour.)*, USA(Ill.).——FIG. 461,*3*. **P. curtus*, Missour.(LaSalle Ls.), near Pontiac, Ill.; *3a,b*, *B*-ray and post. views of holotype crown, ×0.7 (Strimple & Moore, 1971a).

?Tyrieocrinus WRIGHT, 1945, p. 114 [**T. laxus*; OD]. Cup globose, much wider than high, plates rather thin, smooth, sutures flush; infrabasal circlet slightly convex to almost flat, just visible in side view and rather large in proportion to basals; radial circlet greatly constricted at summit, sloping upward-inward, plenary articular facets sloping slightly outward-upward, with strong articulating cross ridge; anal area occupied by single large plate resting on *CD* basal and extending slightly beyond line of radials. Arm structure unknown. *Up.L.Carb.*, Eu.(Scot.).——FIG. 461,*1*. **T. laxus*, Low.Ls.Gr.; *1a-c*, dorsal, post., ant. views of cup, ×1.5 (Wright, 1945).

Ureocrinus WRIGHT & STRIMPLE, 1945, p. 225 [**Poteriocrinus bockschii* GEINITZ, 1845; OD]. Cup globular, subglobular, or somewhat elongated, infrabasal circlet plainly visible from side; radial circlet commonly constricted; anal area of advanced type with large radianal surmounted by 1 or 2 small plates, with some variation. Arms 5, uniserial, brachials cuneiform. *L.Carb.*, Eu.(Brit.-Ger.).——FIG. 461,*2*. **U. bockschii* (GEINITZ); Eng.*(2a)*, Scot.; *2a*, lat. view of crown, *2b-d*, series of post. views, ×1; *2e*, post. view with primitive type of anal area and with part of left and right post. unbranched arms attached, all ×1 (Wright, 1950-54).

Family CADOCRINIDAE Moore & Laudon, 1943

[Cadocrinidae MOORE & LAUDON, 1943a, p. 62]

Cup strongly bowl shaped, with narrow, deep basal concavity; infrabasals not visible from side; radial articular facets occupying full summit of these plates; anal plates of posterior interray exceptionally variable in size and arrangement, occupying large part

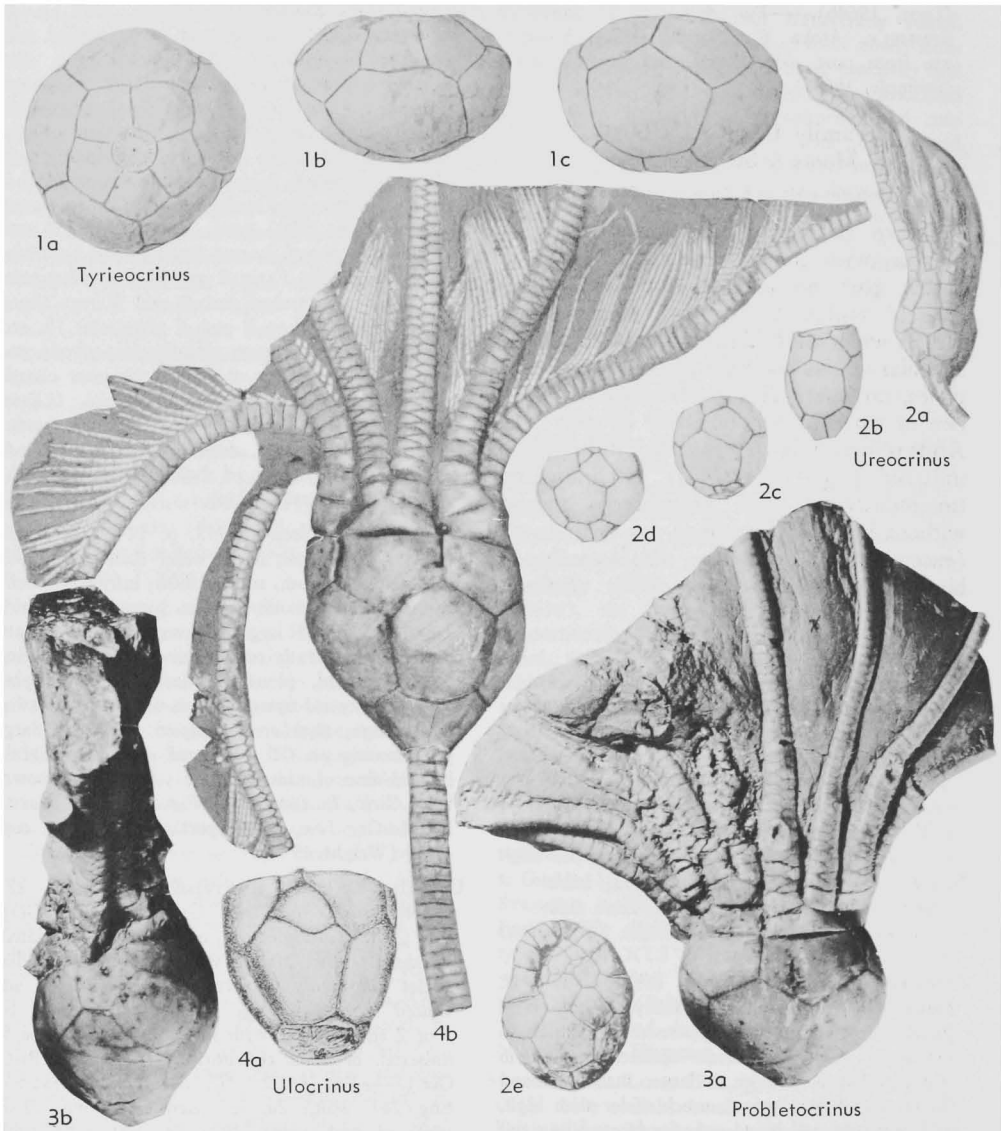


FIG. 461. Ulocrinidae (p. T701).

of cup or almost completely eliminated; and sac ?mushroom shaped. Arms unknown. Stem round, slender. *U.Perm.-(Basleo beds).*

The Upper Permian crinoids from Timor, described under the name *Cadocrinus,* are not satisfactorily referable to any other defined family and are placed in a separate group, the Cadocrinidae. Their globose cup suggests possible relationship with the cromyocrinids, but, if the anal sac that is supposed (WANNER, 1916a) to belong to this genus—not found attached to any cups—is correctly identified, the Cadocrinidae are far removed from the Cromyocrinidae. Variation of the anal plates in specimens belonging to the type species of *Cadocrinus* shows a recapitulation of the evolution of these plates, proceeding in some to the virtual exclusion of anals from the cup.

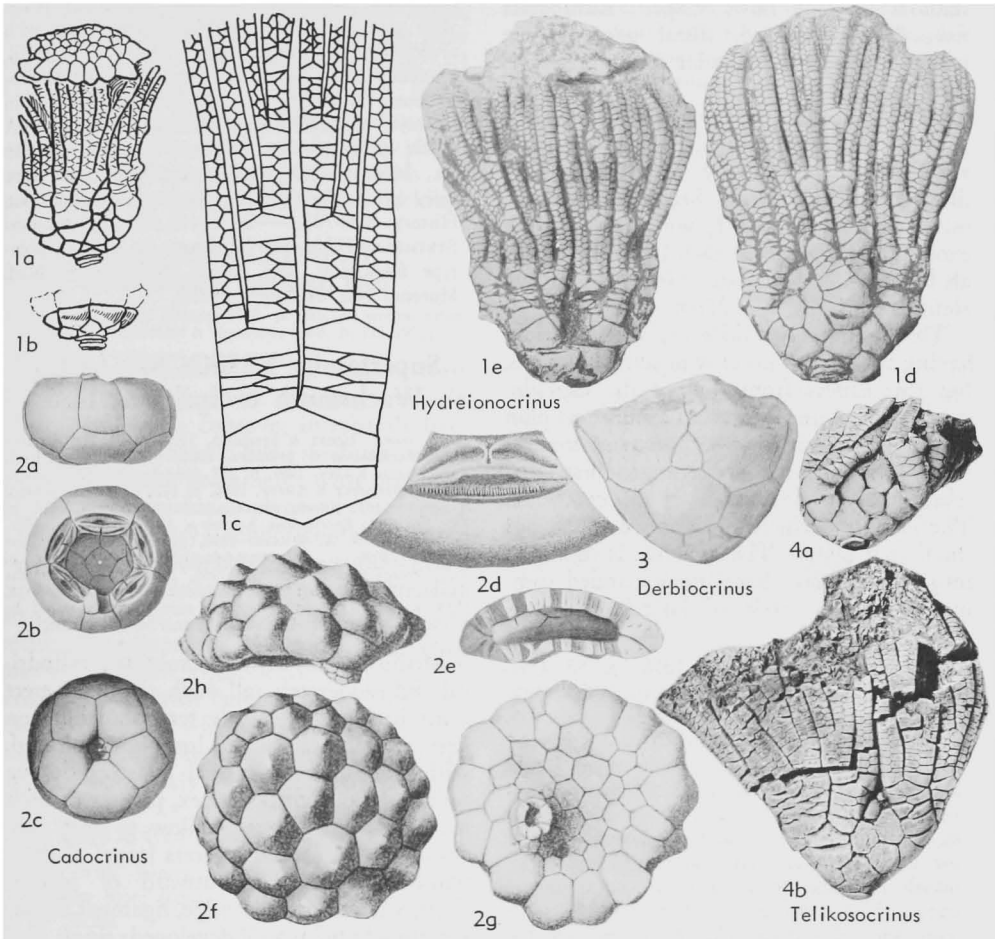


FIG. 462. Cadocrinidae *(2)*; Hydreionocrinidae *(1,3,4)* (p. T703-T704).

Cadocrinus WANNER, 1924, p. 250 [**Hydreionocrinus variabilis* WANNER, 1916a, p. 250; OD]. Cup bowl shaped, with very deep, narrow basal concavity; infrabasals small, confined to concavity; basals large and strongly arched; radials large, restricted in width and curved inward distally; anal plates 1 to 3 in cup, highly variable in size and position, radianal large and trapezoidal or moderate in size and quadrangular to small diamond shaped, anal *X* moderately large to quite small, either in or above cup; anal sac apparently mushroom shaped. Arms not known. Stem transversely round, slender. *U.Perm.(Basleo beds)*, Indon.(Timor).——FIG. 462,2. **C. variabilis* (WANNER); *2a-c*, post., ventral, and dorsal views of cup, ×1; *2d*, radial articular facet, ×10; *2e*, cross section of anal sac, ×1; *2f-h*, upper, lower, and side views of anal sac inferred to belong to *Cadocrinus*, ×1 (Wanner, 1916a).

Superfamily HYDREIONOCRINACEA Jaekel, 1918

[*nom. transl.* MOORE & STRIMPLE, 1973, p. 21 (*ex* Hydreionocrinidae JAEKEL, 1918, p. 63)] [Materials for this superfamily prepared by R. C. MOORE and H. L. STRIMPLE]

Cup low bowl shaped, sides flared outward at rim, plenary arm facets, arms biserial, exotomous; three anals in cup. *Up.L.Carb., U.Miss.*

Family HYDREIONOCRINIDAE Jaekel, 1918

[Hydreionocrinidae JAEKEL, 1918, p. 63]

Crown cylindrical or pear shaped with summit largely formed by bulged umbrella-

like platform which caps anal sac. Cup shallow to deep bowl shaped; infrabasals five, flaring upward, distal parts visible from side; radial articular facets plenary, three anal plates in cup. Anal sac slightly taller than arms, mushroom shaped, with summit platform of small polygonal plates surrounded peripherally by horizontally directed spines. Arms branching isotomously on primibrachs *1*, with two to four exotomous divisions in each half-ray, brachials biserial, nonpinnulate. Stem transversely round. *Up.L.Carb., U.Miss.*

The Hydreionocrinidae are specialized in having suppressed isotomy of some branches, but this differs from that of the Cercidocrinidae in giving rise to an exotomous plan of branching, instead of an endotomous one. The brachials are arranged biserially, which is an advanced type in evolution. The low cup, which has a convex base, has three anal plates. The anal sac is modified into a mushroom shape, the expanded summit bearing a circle of laterally directed spines.

Hydreionocrinus DEKONINCK, 1858, p. 93 [**H. woodianus*, p. 97; SD WACHSMUTH & SPRINGER, 1879, p. 131]. Cup low bowl shaped with rounded convex base; *BC* and *CD* basals beneath cup anal plates as well as radials; 4 or 5 tube plates above radianal and anal *X* forming posterior rigid upward projection of cup, above radials as in *Zeacrinites*. Arms 40 or more, biserial, branching isotomously on first primibrachs and exotomously at higher levels. Pore-slits occur around edges of platform plates of the umbrella-like termination of anal sac. *Up.L.Carb.*, Eu.(Scot.-Isle of Man-Eng.-Belg.).——FIG. 462,*1a-c*. **H. woodianus*, Carb., Eng.; *1a,b*, *D*-ray view of crown, lat. view of cup, diagram., ×0.7 (Moore, 1938); *1c*, plan of arms, ×2 (Moore, n).——FIG. 462, *1d,e*. *H. amplus* WRIGHT, Visean, Scot.; *C*-ray and *AB*-interray views of 2 crowns, ×0.7 (Wright, 1951).

Derbiocrinus WRIGHT, 1951 [**D. diversus*; OD]. Cup deep bowl shaped or conical; infrabasal circlet distinctly visible from side, expanding rapidly from column facet; radials somewhat spreading and indented at interradial sutures, articular facets horizontal with strong transverse ridge; anal plates of cup extremely variable; anal sac and arms unknown. *Up.L.Carb.(Visean)*, Eng.——FIG. 462,*3*. **D. diversus*, Derbyshire; post. view of type, ×1 (Wright, 1951).

Telikosocrinus STRIMPLE, 1951, p. 261 [**T. caespes*; OD]. Crown broadly expanded. Cup low cone shaped, with infrabasals readily visible in side view, radial articular facets plenary; anal sac cylindrical, extending to summit, or near summit of crown, composed of small polygonal plates with pore-slits along margins, terminating with several small subvertical spines. Arms equibiserial, branching twice isotomously and thereafter heterotomously at least twice, primibrachs *1* axillary in all rays. Column round. *U.Miss.(Chester.)*, USA (Okla.-Ark.).——FIG. 462,*4a*. **T. caespes*, Pitkin Ls., Muskogee Co., Okla.; holotype from post. side, ×1.2 (Strimple, n; National Museum Nat. History S-4970).——FIG. 462,*4b*. *T. residuus* STRIMPLE, Pitkin Ls., Muskogee Co., Okla.; holotype from post. side, ×1.2 (Strimple, n; Natl. Museum Nat. History S-4973).

Superfamily ERISOCRINACEA Wachsmuth & Springer, 1886

[*nom. transl.* MOORE & STRIMPLE, 1973, p. 21 (*ex* Erisocrinites WACHSMUTH & SPRINGER, 1886, p. 115(191))] [incl. Arkacrinidae KNAPP, 1969, p. 367 (=Arkacrininae); Diphuicrinidae STRIMPLE & KNAPP, 1966, p. 312; Encrinidae AUSTIN & AUSTIN, 1842 (*nom. correct.* AUSTIN & AUSTIN, 1843, p. 198, *pro* fam. Encrinoidea AUSTIN & AUSTIN, 1842, p. 108); Erisocrinidae S. A. MILLER, 1890, p. 351; Graphiocrinidae BATHER, 1899b, p. 922; Paradelocrinidae KNAPP, 1969, p. 352; Protencrinidae KNAPP, 1969, p. 353; Catacrinidae KNAPP, 1969, p. 365; Stachyocrinidae MOORE & STRIMPLE, 1973, p. 22] [Materials for this superfamily prepared by R. C. MOORE, H. L. STRIMPLE, and N. GARY LANE]

Medium-sized crown commonly cylindrical and moderately tall, with pinnulate erect arms juxtaposed, mostly ten, branching on first primibrach. Cup low bowl shaped, with sides mostly formed by steep-sloping radials, base slightly convex, planate or with narrow to broad and shallow to deep concavity, radial articular facets large, plenary, without appreciable outward or inward slope, with transverse ridge, ligament fossae, and muscle fields well developed; single anal plate next above *CD* basal, or located in notch between posterior radial articular facets and not visible externally. Anal sac cylindrical, composed of small plates in vertical series, commonly with terminal spine or spines directed upward. Stem transversely round. *L.Carb.(Miss.)-U.Perm.; M.Trias.*

The Erisocrinacea are cladids of comparatively simple but advanced evolutionary type. The low truncate bowl- or saucer-shaped cup, in which the infrabasals are not visible from the side, is more specialized than in the Scytalocrinacea. As here interpreted, the assemblage includes genera having advanced structure of the posterior side, characterized by occurrence of a single anal or absence of an externally visible anal in the cup. The arms are like those of many Scytalocrinacea, except that in numerous

genera evolution of brachials has advanced to a biserial arrangement; also, in some, suppression of isotomous arm division near the base of the rays produces unbranched (atomous) arms. The radial arm facets have marks of highly developed muscular articulation. The anal sac is thin plated and very weak, so that generally it is not preserved, or a sac may be entirely lacking.

Family ERISOCRINIDAE Wachsmuth & Springer, 1886

[*nom. transl.* S. A. Miller, 1890, p. 351, *ex* section Erisocrinites Wachsmuth & Springer, 1886, p. 115(191)]

Crown subcylindrical. Cup truncate cone or bowl shaped, base planate, weakly convex, or mildly concave; infrabasals five, subhorizontal; basals five, medium sized; radials five, very prominent, with proximal tips well above basal plane of cup, long and wide (plenary) subhorizontal articular facets; no anal plate other than rudimentary remnant in notch between *C* and *D* radial articular facets. Anal sac small, short, recurved, composed of small polygonal plates. Arms ten, equibiserial, primibrach *1* axillary, arms with flattened outer surfaces, closely appressed when closed, each brachial bearing a thin pinnule. Stem transversely round, moderately large. *U.Miss.-L.Perm.*

Key to Genera of Erisocrinidae

A. Cup with faintly convex, flat, or broad shallow base; plenary planate radial articular facets .....
  I. Cup with flat or shallowly concave base
    a. Small infrabasals, cup sides expanding ..... *Erisocrinus*
    b. Large infrabasals, cup sides erect .. .. *Sinocrinus*
  II. Cup with nearly flat, slightly convex base ..... *Exaetocrinus*

Erisocrinus Meek & Worthen, 1865, p. 174 [**E. typus*; OD] [=*Stemmatocrinus* Trautschold, 1867, p. 28 (type, *S. cernuus*; OD); *Libratocrinus* Knapp, 1969, p. 354 (type, *Erisocrinus mediator* Strimple, 1961d, p. 14; OD), M.Penn.(Desmoines.), Oologah Ls., NE.Okla.; *Pontotocrinus* Knapp, 1969, p. 352 (type, *Paradelocrinus wapanucka* Strimple, 1961e, p. 225; OD), L.Penn. (Morrow.), Wapanucka Ls., Pontotoc Co., Okla.; *Parerisocrinus* Knapp, 1969, p. 358 (type, *Paradelocrinus obovatus* Moore & Plummer, 1940, p. 326; OD), U.Penn.(Missour.), Texas-Okla.-Kans.]. Cup broadly truncate cone shaped, flattened base with little or no basal concavity, circular stem impression; cup outline typically pentagonal when viewed from above or below; 5 small infrabasals, or fused, confined to basal area together with proximal portions of 5 large basal plates; 5 radial plates forming most of lateral walls of cup; single anal plate confined to notch between radial articular facets. Arms 10, equibiserial, flattened exteriors, pinnulate, branching on short primibrach *1* on all rays. *L.Penn.(Morrow.)-L. Perm.(Wolfcamp.)*, USA(Ill.-Ind.-Iowa-Mo.-Kans.-Neb.-Nev.-Okla.-Texas); *U.Carb.(Moscov.)*, USSR. ——Fig. 463,*1a-d*. **E. typus; 1a,b*, M.Penn.(Desmoines.), Sangamon Co., Ill.; syntype cup from post. and dorsal sides, ×2 (Moore & Plummer, 1940); *1c*, U.Penn.(Missour.), Bond F., Livingston Co., Ill.; lat. view of hypotype crown, ×0.7 (Strimple & Moore, 1971a); *1d*, long. sec. of cup through midline of *A* radial and *CD* interray, ×2 (Moore, n).——Fig. 463,*1e,f*. *E. longwelli* Lane & Webster, L.Perm.(Bird Springs F.), Clark Co., Nev.; 2 views of holotype crown, ×0.7 (Lane & Webster, 1966).——Fig. 463,*1g-i*. *E. wapanucka* (Strimple), L.Penn.(Morrow., Wapanucka F.), Pontotoc Co., Okla., type of *Pontotocrinus* Knapp (1969, p. 352); ventral, dorsal, and post. views of holotype, ×2 (Strimple, 1961e).

Exaetocrinus Strimple & Watkins, 1969, p. 181 [**Stuartwellercrinus argentinei* Strimple, 1949c, p. 125; OD]. Cup truncate cone shaped, with subhorizontal to slightly upflared infrabasals, visible from side, contour of cup pentagonal when viewed from summit or base, large, subhorizontal radial articular facets; anal *X* plate in notch between posterior radials at inner margin of their articular facets. [Differs from *Erisocrinus* in visibility of infrabasals from side.] *L.Carb.(Visean)*, G.Brit.(Scot.)-*U-Carb.*, Afr.(Morocco); *U.Penn. (Missour.)*, USA(Kans.-Mo.-Okla.); *L.Perm.*, USSR(Kashira).——Fig. 463,*2*. **E. argentinei* (Strimple), Missour.(Argentine Ls.), Mo.; *2a-d*, dorsal, ventral, ant., and post. sides, ×2 (Strimple, 1949c).

Sinocrinus Tien, 1926, p. 17 [**S. microgranulosus* Tien, 1926, p. 17; OD]. Cup bowl shaped, with nearly flat base, impressed plate sutures, and pentameral symmetry; infrabasals 5, small, slightly upflared, forming pentagonal low cone basally hollowed for stem attachment; basals large, inflated; radials large, wider than high, with plenary horizontal articular facets; no anal plates in or above cup. Arms branching isotomously on large first primibrachs, which project outward as short or long spines; brachials biserial above primibrachs. *U.Carb.(Taiyuan)*, China.——Fig. 463,*3*. **S. microgranulosus; 3a,b*, lat. and dorsal views of cup with proximal part of arms, ×1; *3c-f*, outer, upper, inner, and lat. views of radial plate, ×1; *3g,h*, lat. and articular views of stem, ×1 (Tien, 1926); *3i*, plate diagram of cup (planes of perfect bilateral symmetry marked by heavy black lines, radials black) (Moore, 1962b).

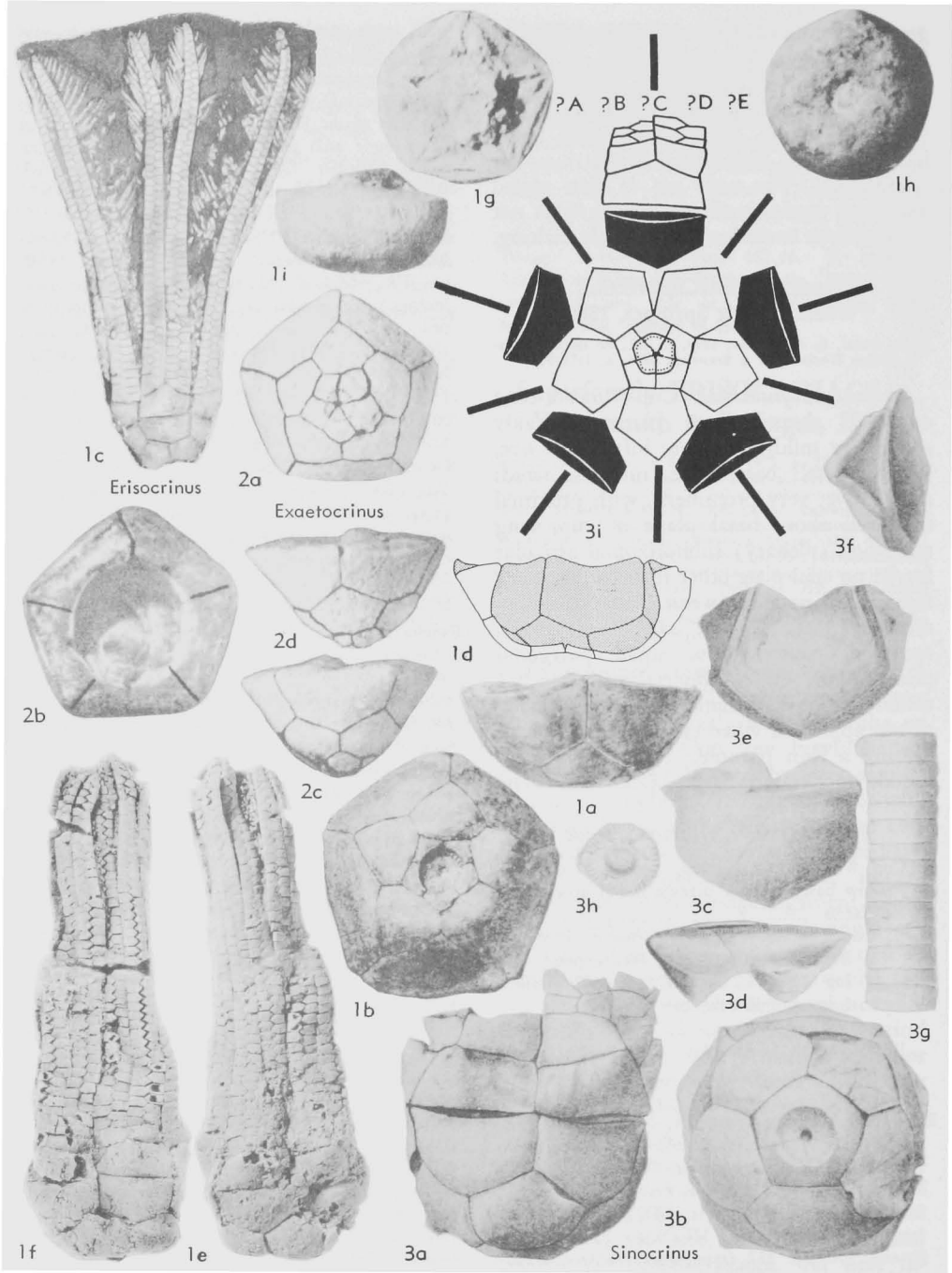


FIG. 463. Erisocrinidae (p. *T*705).

Family GRAPHIOCRINIDAE Wachsmuth & Springer, 1886

[*nom. transl.* BATHER, 1899b, p. 922 (*ex* series Graphiocrinites WACHSMUTH & SPRINGER, 1886, p. 115[191])] [=Scaphiocrinidae BATHER, 1899b, p. 922] [incl. Scaphiocrininae JAEKEL, 1918, p. 63]

Crown cylindrical, moderately slender or ovoid. Cup low, bowl or saucer shaped;

five small infrabasals, not visible in side view, may be in basal plane or in mild concavity; basals medium sized, with distal portions visible in side view; radials moderately large, wider than long, articular facets filling distal face of plates; single anal plate (*X*) in cup or absent in late genera. Arms ten, wide and usually recti-uniserial, branching on large primibrach *1* in all rays. Column transversely round. *Low.L.Carb.-(Miss.); M.Penn.-U.Penn.; U.Perm.*

The graphiocrinids were probably derived from Devonian decadocrinids. They retained the sinuous more or less zigzag arms with large pinnules and a pentagonal stem in geologically older forms, but eliminated all but one anal plate from the cup. Rather than progressing from cuneate uniserial brachials to biserial they reduced size of the pinnules and shifted attachment facets for pinnules toward the interior so that the arms were able to abut closely when closed. In several forms the brachials widened and became recti-uniserial or slightly cuneate.

Key to Genera of Graphiocrinidae

A. Crown slender cylindrical, small, with appressed erect arms. Cup bowl shaped; radial with wide (plenary) articular facets; 1 or 0 anal plate in cup. Arms 10, recti-uniserial, branching isotomously on primibrachs *1* in all rays .....
  I. Primaxils and anal *X* elongate, or absent, basals small .....
    a. Anal small, on truncate *CD* basal, basals lozenge shaped, arms medium in height ..... *Graphiocrinus*
    b. Anal pentagonal, not touching *CD* basal ..... *Euerisocrinus*
    c. Anal plate absent ..... *Permiocrinus*
  II. Primaxils short to medium in height, not projecting appreciably sideward, basals large .....
    a. Anal *X* short, narrow ..... *Contocrinus*
    b. Anal *X* large, wide ..... *Holcocrinus*

Graphiocrinus DE KONINCK & LE HON, 1854, p. 115 [**G. encrinoides*; M] [=*Scaphiocrinus* HALL, 1858b, p. 550 (type, *S. simplex*; OD)]. Greatest width of crown just above primibrachs. Anal plate long and slender, extending well above summit of radials, distal end terminating in an apex between sides of posterior primibrachs *1* which are closely abutting and closed over distal tip of anal. Ten arms composed of rather wide, gently convex segments with width only slightly greater than length, arms in close contact laterally. *L. Carb.(Tournais.),* Eu.(Belg.-G.Brit.-?Eire).——FIG. 464,*3*. **G. encrinoides,* Tournais., Belg.; *3a,b,* post. views of crown and cup with proximal portion of arms attached, ×2 (Springer, 1911c).

Contocrinus KNAPP, 1969, p. 355 [**Graphiocrinus stantonensis* STRIMPLE, 1939a, p. 12; OD]. Like *Graphiocrinus* except that basals are relatively large, anal *X* short and commonly truncated for contact with single tube plate, base of cup is typically planate and radial articular facets fill full width of plate. Arms uniserial, in close contact laterally. *M.Penn.(Desmoines.)-U.Penn.(Virgil.),* USA(Okla.-Kans.-Texas).——FIG. 464,*1a-c*. *C. lineatus* (STRIMPLE), Missour.(Wann F.), Okla.; *D*- and *B*-ray sides and base of crown, ×2 (Strimple, 1963c).——FIG. 464,*1d-f*. **C. stantonensis* (STRIMPLE), Missour.(Wann F.), near Ochelata, Okla.; hypotype crown from *C*-ray and opposite sides, cup from summit, *1d,e,* ×1.7; *1f,* ×2.8 (Strimple, 1962f).——FIG. 464,*1g,h*. *C. kingi* (MOORE & PLUMMER), M.Penn.(Mineral Wells F.), Palo Pinto Co., Texas; holotype crown from post. and ant. sides, ×1.5 (Moore & Plummer, 1940).——FIG. 464,*1i-k*. *C. delicatulus* (MOORE), U.Penn.(Virgil., Brownville Ls.), Osage Co., Okla.; dorsal, ventral, post. views, ×2.7 (Moore, 1939c).

Euerisocrinus STRIMPLE, 1939, p. 13 [**E. waysidensis*; OD]. Cup bowl shaped, with flat base or small basal concavity; infrabasals covered by stem; basals large, mostly visible from side; proximal ends of radials well above basal plane, articular facets filling distal face of radials, planate; anal *X* pentagonal, not touching posterior basal, extending well above cup summit, faceted for one tube plate. Anal sac and arms unknown. *U.Penn. (Missour.),* USA(Kans.).——FIG. 464,*4*. **E. waysidensis,* Stanton F., Montgomery Co., Kans.; *4a-c,* dorsal, post., and ant. views of holotype cup, ×2 (Strimple, n; Natl. Museum Nat. History S-4309).

Holcocrinus KIRK, 1945, p. 517 [**Graphiocrinus longicirrifer* WACHSMUTH & SPRINGER, 1890, p. 193; OD]. Crown very high, compact, arms 10 to 17 times height of cup. Cup broadly bowl shaped; 5 small infrabasals, barely visible in side view; 5 medium-sized basals; 5 large radials, with articular facets full width of plates; single large anal *X* plate resting on truncated distal end of *CD* basal, extending well above summit of radials and bearing single large tube plate on its distal face. Anal sac tall, extending nearly to tip of arms or beyond them. Arms 10, relatively slender with cuneate brachials which may bear spinose processes in later species; primibrachs *1* axillary, low. Column pentagonal in section in early species and pentagonal with concave faces in later forms. *L.Miss.(Kinderhook.-Osag.),* USA(Iowa-Mo.); *L.Carb.,* Eire.——FIG. 464,*2a,b*. **H. longicirrifer* (WACHSMUTH & SPRINGER), Kinderhook

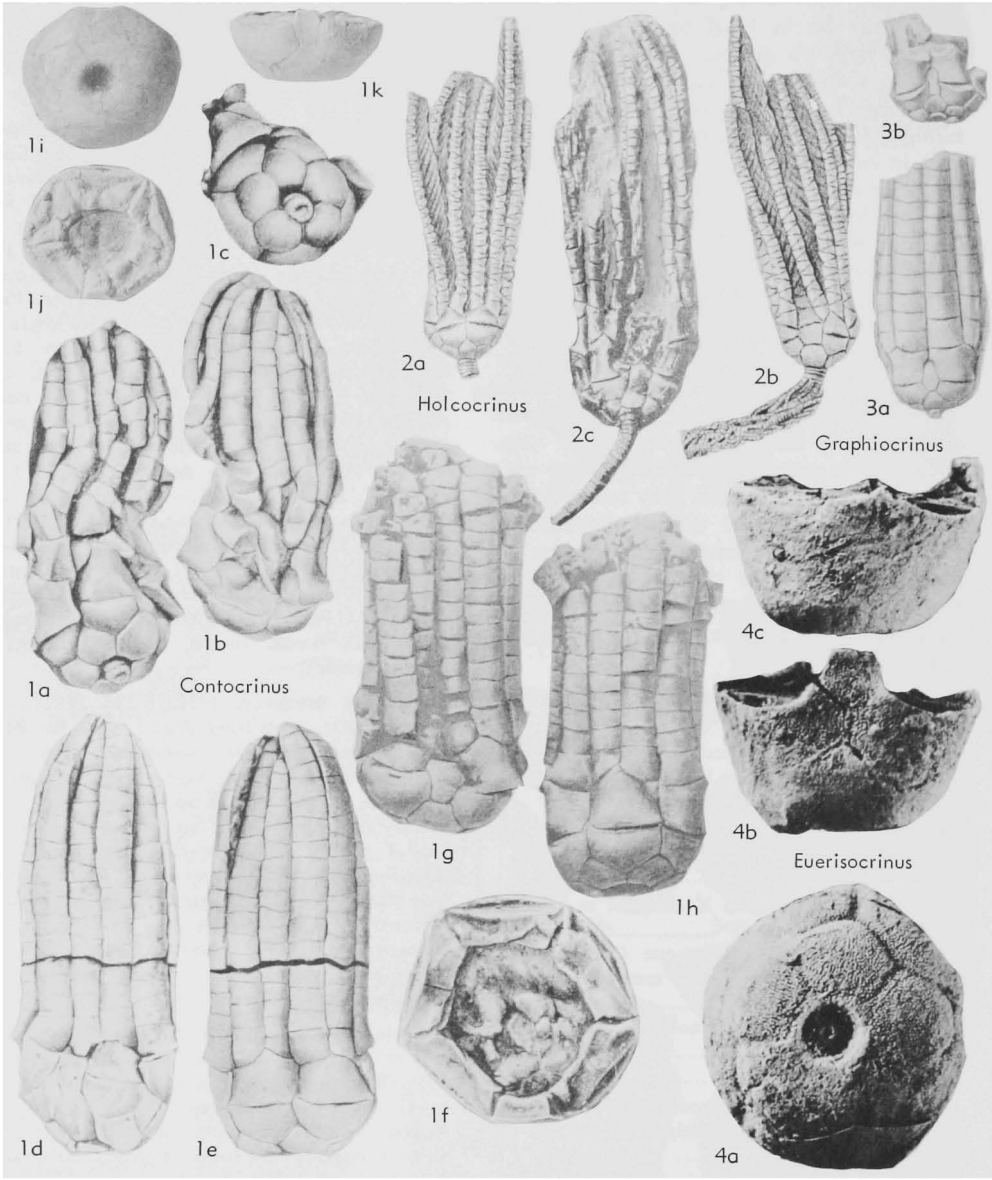


FIG. 464. Graphiocrinidae (p. *T*707-*T*708).

(Hampton F.), LeGrand, Iowa; holotype crown from ant. and post. sides, ×1 (Wachsmuth & Springer, 1890).——FIG. 464,*2c*. *H. smythi* (WRIGHT), Tournais.(Supra-dolomite beds), Eire (Hook Head, Wexford Co.); crown from post. side, ×1.5 (Wright, 1951-54).

Permiocrinus WANNER, 1949, p. 53 [**P. immaturus*; OD]. Crown small, cylindrical. Cup low, saucer shaped, with broad basal concavity; infrabasals small, not visible in side view, mostly covered by stem; basals small, convex, proximal parts forming edge of basal concavity; radials low, broad, convex; anal plates absent; anal sac not known. Arms uniserial, primibrach *1* axillary, very high in *A*-ray, shorter in other rays; secundibrachs high and narrow, distal parts of arms not known. Stem round. *U.Perm.,* Indon.(Timor). ——FIG. 465,*1*. **P. immaturus,* Basleo; *1a,b, A*-ray and *C*-ray views of partial crown, ×1.5 (Wanner, 1949b).

Family PARADELOCRINIDAE Knapp, 1969

[Paradelocrinidae KNAPP, 1969, p. 352] [incl. Atokacrininae KNAPP, 1969, p. 357]

Base of cup broadly to narrowly concave, moderate in depth or shallow; infrabasals five, downflared steeply or gently, mostly covered by stem; proximal part or all of basals included in concavity; radials wide, with planate facets occupying full width of radials; anal *X* in notch between posterior radials, generally not visible from side. Arms ten, biserial except in lower portions, branching on axillary first primibrachs. Stem transversely round. *U.Carb., Penn.(Morrow.); U.Perm.(Basleo beds).*

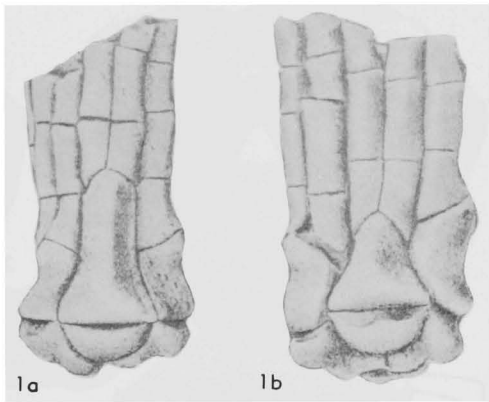
Paradelocrinids are somewhat smaller than associated catacrinids. They differ from Erisocrinidae, which also lack an externally visible anal plate, in smaller height of the cup, longitudinally rounded form of the radials, and narrower, deeper basal concavity.

Key to Genera of Paradelocrinidae

A. Cup low bowl shaped, with narrow moderately deep basal concavity, anal *X* mostly not visible from exterior of cup .....
  I. Cup plates smooth, sutures between plates impressed ..... *Neocatacrinus*
  II. Cup plates smooth, sutures between plates not impressed .....
    a. Basals transversely concave ..... *Sublobalocrinus*
    b. Basals not transversely concave ..... *Paradelocrinus*
  III. Cup plates with rugose surface .....
    a. Coarse nodes covering plates, 5 infrabasals ..... *Atokacrinus*
    b. Fine tubercles, aligned in longitudinal ridges, 3 infrabasals .. *Lopadiocrinus*

Paradelocrinus MOORE & PLUMMER, 1938, p. 294 [**P. aequabilis*; OD]. Characters of family, with smooth plates, arms unknown, and anal *X* in notch between posterior radial articular facets; cup very shallow, radials reaching basal plane but not in concavity. *L.Penn.(Morrow.)-U.Penn.(Missour.),* USA(Texas-Okla.-Ark.-Kans.).——FIG. 466,*4. *P. aequabilis,* Morrow.(Bloyd F.), Ark.; *4a-d,* holotype cup from ant., post., ventral (*A* ray upward), and dorsal (*A* ray downward) sides, ×1.5 (Moore & Plummer, 1938); *4e,* long. sec. of cup through midline of *A* radial and *CD* interray (portion of cup beyond section shaded), ×1.5 (Moore, n).

[BREIMER (1962, p. 172) reported two specimens from Spain as *Paradelocrinus* spec. 1 from the Upper Visean strata and as *Paradelocrinus* spec. 2 from Moscovian strata. *Paradelocrinus* spec. 1 is apparently an advanced *Cyathocrinites* that has eliminated the anal plate from the cup. *Paradelocrinus* spec. 2 is considered here as *Atokacrinus* sp.]



Permiocrinus

FIG. 465. Graphiocrinidae (p. *T*708).

Atokacrinus KNAPP, 1969, p. 358 [**A. obscurus*; OD]. Differs from *Lopadiocrinus* in having 5 infrabasals and proximal tips of radials above basal plane. Arms unknown. [This genus appears to be a direct derivative of *Palmerocrinus,* in which anal plate has migrated to position notching cup between radial articular facets.] *M.Penn. (Atokan-Desmoines.),* USA(Okla.-Mo.); *U.Carb.,* Eu.(Spain).——FIG. 466,*3a-c. *A. obscurus,* Atokan(Burgner F.), Mo.; holotype cup from dorsal, post., and ventral sides, ×1.5 (Knapp, 1969).——FIG. 466,*3d-f. A. decorus* STRIMPLE & MOORE, Desmoines.(Lester F.), Love Co., Okla.; dorsal, ventral, and post. views of holotype cup, ×1.7 (Strimple & Moore, 1971c).

Lopadiocrinus WANNER, 1916, p. 227 [**L. granulatus*; OD]. Cup shallow bowl shaped, with broad base and large basal concavity; infrabasals 3, small, almost covered by stem impression; basals narrow and moderately long but only distal tips visible in side view; radials large, with proximal portions entering basal plane, forefacet present near summit and pronounced outer ligament pit extending full width of plate, transverse ridge prominent and expanded in midportion of facet, muscle areas large; facet for rudimentary anal plate in built-up area between *C* and *D* radials toward inner edge of facets and sloping outward-upward (sursumate). Entire outer surfaces of cup covered by large granulations which may coalesce on radials and form longitudinal ridges. *U.Perm.(Basleo beds),* Indon.(Timor).——FIG. 466,*2. *L. granulatus,* Basleo; *2a-c,* holotype from ant., dorsal, and ventral sides, ×1.5 (Wanner, 1916a).

Neocatacrinus KNAPP, 1969, p. 366 [**Paradelocrinus protensus* MOORE & PLUMMER, 1940, p. 324;

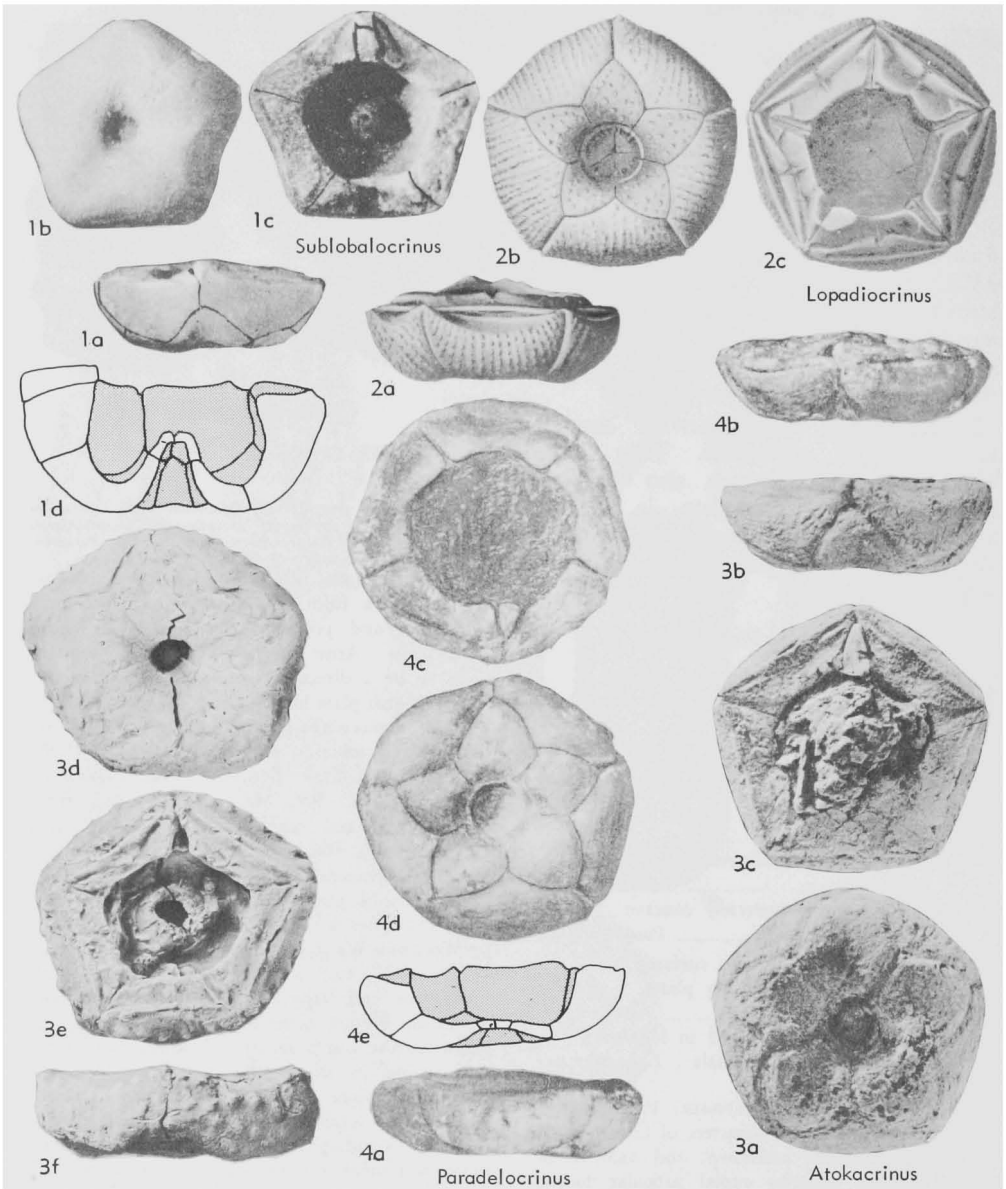


FIG. 466. Paradelocrinidae (p. T709-T710).

OD]. Cup low bowl shaped, with moderately deep basal concavity, plates smooth, sutures impressed; anal *X* confined to notch at inner side of *CD* interradial suture. Arms unknown. [Distinguished from *Paradelocrinus* by appreciably greater depth of the basal concavity and impressed nature of sutures between cup plates.] *U.Penn.(Missour.)*, USA(Texas).——FIG. 467,*1*. **N. protensus* (MOORE & PLUMMER), Graford F., Palo Pinto Co., Texas; *1a-c*, dorsal, post., ventral views of holotype, ×2 (Moore & Plummer, 1940); *1d*, long. sec. of cup through midline of *A* radial and *CD* interray (portions of cup beyond section shaded), ×3.5 (Moore, n).

Sublobalocrinus KNAPP, 1969, p. 365 [**Paradelocrinus iolaensis* STRIMPLE, 1949c, p. 124; OD]. Cup small, nearly straight-sided pentagonal with narrowly rounded corners as seen from above and

below, shallow bowl shaped in side profile, with very narrow deep basal concavity, plates smooth, without impressed sutures; basals transversely concave as in *Lobalocrinus* (Catacrinidae); radials extending to basal plane of cup but not into concavity; anal *X* in notch between *C* and *D* radials, its proximal part visible externally, well separated from *CD* basal, its medial and distal parts recumbent inward and nearly horizontal. Arms unknown. *U.Penn.(Missour.),* USA(Kans.).——Fig. 466,*1*. **S. iolaensis* (Strimple), Iola Ls., Allen Co., Kans.; *1a-c,* post., dorsal, ventral views of holotype, ×2 (Strimple, 1949c); *1d,* long. sec. of cup through midline of *A* radial and *CD* interray (portions of cup beyond section shaded), ×2.8 (height exaggerated) (Moore, n).

Family ARKACRINIDAE Knapp, 1969

[*nom. transl.* Moore & Strimple, 1973, p. 22 (*ex* Arkacrininae Knapp, 1969, p. 356)]

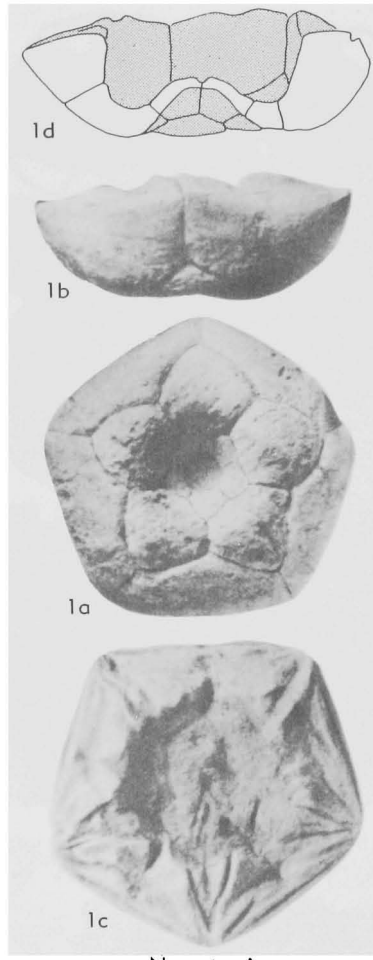
Cup bowl shaped, with deep basal concavity and constriction at upper margin, plates smooth and exceptionally thick; infrabasals five, distally downflared steeply; basals five, confined to concavity and also downflared steeply, concave transversely; radials five, subequal, broadly flattened medially and distally, with proximal tips reaching basal plane of cup, anal plate in notch between *C* and *D* radials, mostly at inner margins of their articular facets. Arms unknown. *L.Penn.(Morrow.).*

Arkacrinus Knapp, 1969, p. 357 [**Delocrinus dubius* Mather, 1915, p. 105; OD]. Characters of family. Arms unknown. *L.Penn.(Morrow.),* USA(Okla.-Ark.).——Fig. 468,*1*. **A. dubius* (Mather), Brentwood Ls., Ark.; hypotype, ant., ventral, and dorsal views, ×2 (Moore & Plummer, 1938); *1d,* long. sec. of cup through midline of *A* radial (portions of cup beyond section shaded), ×2 (Moore, n).

Family DIPHUICRINIDAE Strimple & Knapp, 1966

[Diphuicrinidae Strimple & Knapp, 1966, p. 312] [incl. Graffhamicrininae Knapp, 1969, p. 362]

Bowl-shaped cup with deep basal invagination, plates rugose and very thick; five infrabasals, steeply downflared; large basals and radials dominant in side view; one anal plate in contact with posterior basal or essentially eliminated from cup exterior, followed by either one or two tube plates. Arms ten, cuneate uniserial, branching on axillary primibrachs *1*. Stem small, transversely round. *L.Penn.(Morrow.)-L.Perm.*



Neocatacrinus

Fig. 467. Paradelocrinidae (p. *T*709-*T*710).

Diphuicrinus Moore & Plummer, 1938, p. 307 [**D. croneisi*; OD] [=*Parallelocrinus* Knapp, 1969, p. 362 (type, *P. typus*)]. Cup nearly circular in outline as viewed from above and below, low bowl shaped, with moderately deep basal concavity, composed of thick plates with rugose tuberculate exteriors and irregular finely crenulated interplate facets; subhorizontal radial articular facets with prominent crenulated transverse ridge and narrow deep ligament fossae; narrow but distinct forefacet at distal edge of radials; distal portion of single anal plate *(X)* elongated, recumbent inward, faceted distally for 2 sac plates. Arms uniserial, composed of cuneate brachials, pinnulate. Stem transversely round. *L.Penn.(Morrow.)-U.Penn. (Virgil.),* USA(Texas-Okla.-Mo.-Ark.-Ohio-Ky.-Kans.).——Fig. 469,*1a-j*. **D. croneisi,* Morrow. (Bloyd F.), Ark.; *1a-c,* holotype cup from ant.,

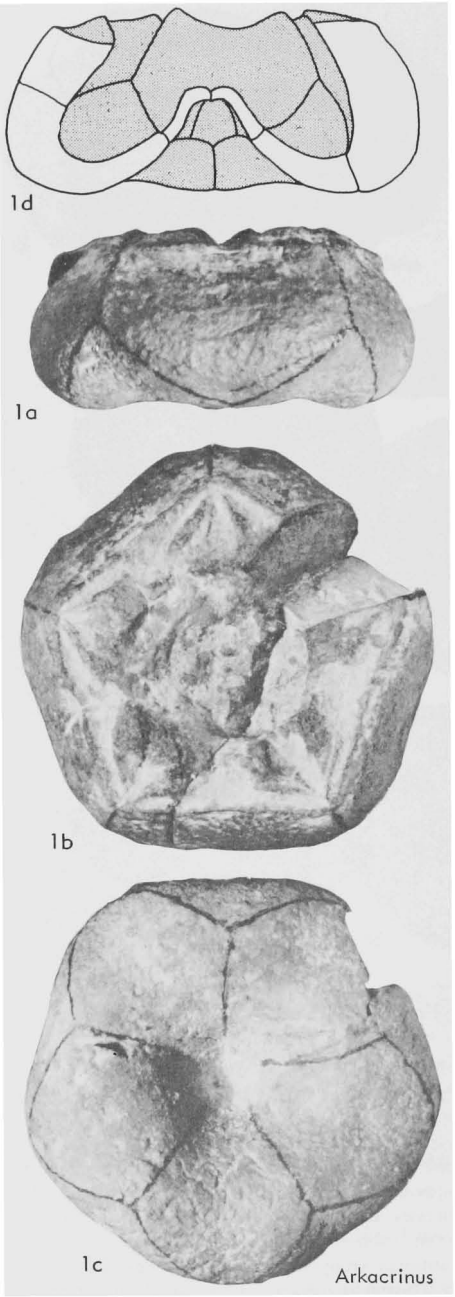


FIG. 468. Arkacrinidae (p. T711).

dorsal, and post. sides; *1d-g,* radial plate from summit, ext., int., and dorsal sides; *1h,* ventral view showing radial forefacets; *1a-g,* ×1.5, *1h,* ×2.4 (Moore & Plummer, 1938); *1i,j,* post., ant. views of hypotype crown, ×1.2 (Strimple & Knapp, 1966).——FIG. 469,*1k-m. D. pegmus* STRIMPLE & MOORE, Desmoines.(Frensley F.), Carter Co., Okla.; post., ventral, and dorsal views of holotype cup, ×3 (Strimple & Moore, 1971c).——FIG. 469,*1n-q. D. dovelyensis* STRIMPLE & MOORE, Desmoines. (Savanna F.), Roger Co., Okla.; dorsal, ant., post., and ventral sides of holotype cup, ×1.6 (Strimple & Moore, 1961c).——FIG. 470,*1. D. typus,* M.Penn.(Burgner F.), Jasper Co., Mo.; long. sec. of cup through midline of *A* radial and *CD* interray (portions of cup beyond section shaded), ×2 (Moore, n).

Graffhamicrinus STRIMPLE, 1961, p. 123 [**G. acutus*; OD] [=*Tholiacrinus* STRIMPLE, 1962e, p. 136 (type, *Corythocrinus undulatus* STRIMPLE, 1961d, p. 129; OD), M.Penn.(Desmoines.)-L. Perm.(Wolfcamp.), USA(Neb.-Kans.-Okla.-Texas)]. Cup similar to that of *Delocrinus* but surface of plates rugose. Anal plate typically erect, faceted for one tube plate, resting on truncated distal end of *CD* basal. Arms 10, equibiserial, ornate for at least half of their length. *M.Penn.(Atokan-Desmoines.)-L.Perm.(Wolfcamp.),* USA(Mo.-Okla.-Kans.-Neb.-Texas-Iowa).——FIG. 471,*1a-c.* **G. acutus,* Desmoines.(Holdenville F.), Okla.; *1a,b,* paratype from post. and dorsal sides; *1c,* holotype crown from ant. side, ×1.2 (Strimple, 1961d). ——FIG. 471,*1d-g. G. magnificus* (STRIMPLE), U.Penn.(Haskell Ls., Virgil.), Kans.; *1d,* post. view of holotype crown slightly oblique from below, ×1; *1e-g,* post., dorsal, and ventral views of paratype cup, ×1 (Strimple, 1947).——FIG. 471, *1h-o. G. granulosus* (MOORE & PLUMMER); *1h-k,* Desmoines.(Mineral Wells F.), Palo Pinto Co., Texas, dorsal, post., ventral, and ant. views of holotype cup, ×1.5 (Moore & Plummer, 1940); *1l-o,* Atokan, Okla., *1l,* int. mold showing form of anal tube, ×1; *1m,n,* restoration and cross section of anal sac, ×2; *1o,* rubber cast from ext. mold, ×1 (Moore & Strimple, 1941).

Family PROTENCRINIDAE Knapp, 1969

[Protencrinidae KNAPP, 1969, p. 353]

Crown tall, cylindrical. Cup saucerlike, smooth plated, with wide, shallow basal concavity; basals small, mostly confined to concavity; radials large, with proximal tips in basal plane of cup or extending into concavity; anal plate in notch at upper-inner edge of *CD* interradial suture, not visible externally. Arms ten, biserial, branching isotomously on primibrachs *1.* Stem round transversely. *U.Carb.(Moscov.), M.Penn.-(Atokan)-L.Perm.(Artinsk.).*

Protencrinus JAEKEL, 1918, p. 66 [**P. moscoviensis*; OD]. Cup very low; radials forming part of basal concavity; basals very small and tending to be separated laterally by infrabasals; proximal

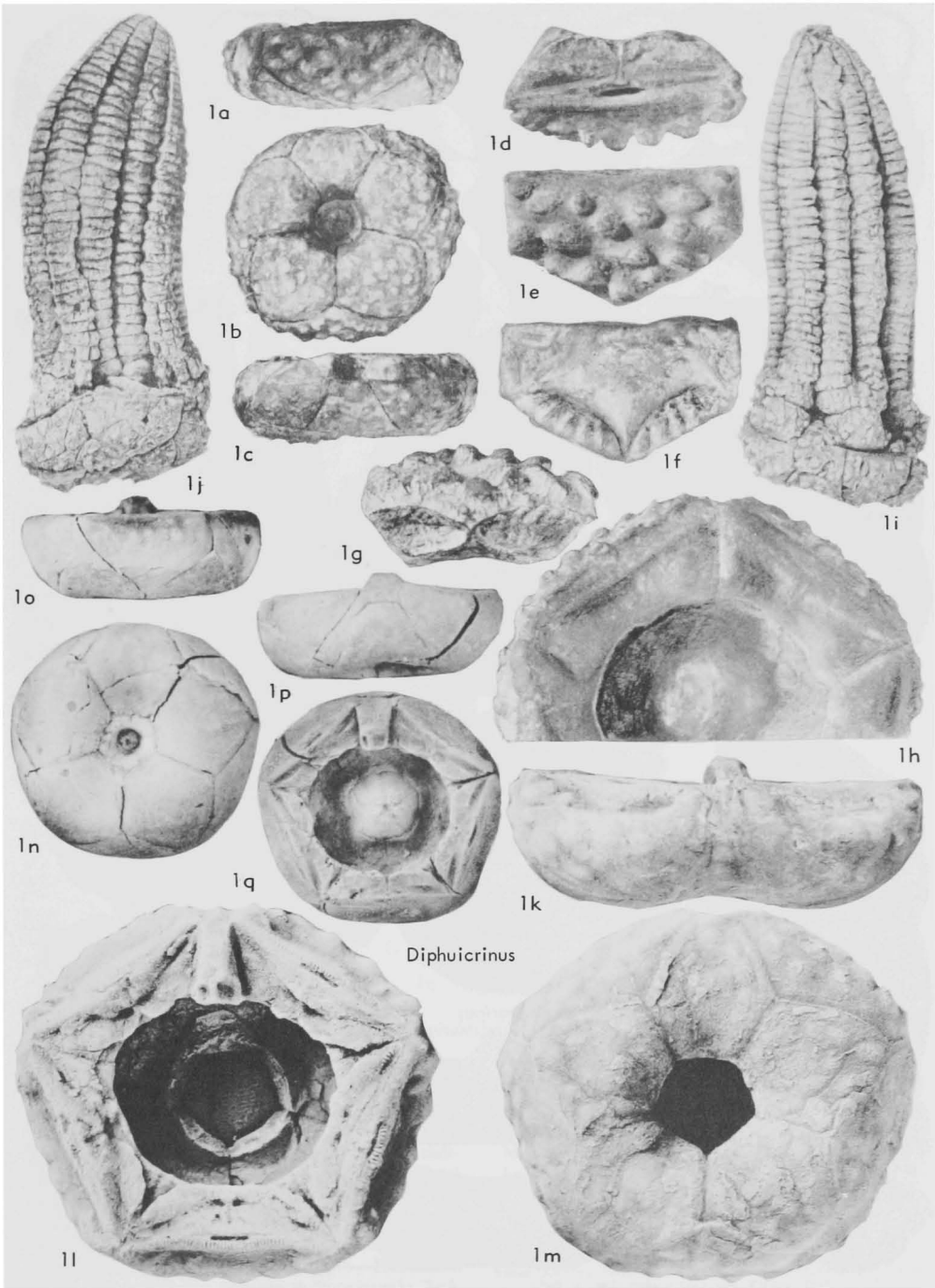


FIG. 469. Diphuicrinidae (p. T711-T712).

tips of radials touching infrabasals; no externally visible anal plate in cup. Arms 10, biserial except for proximal segments. *M.Penn.(Atokan-Desmoines.)*, USA(Okla.-Texas); *U.Carb.(Moscov.)*-

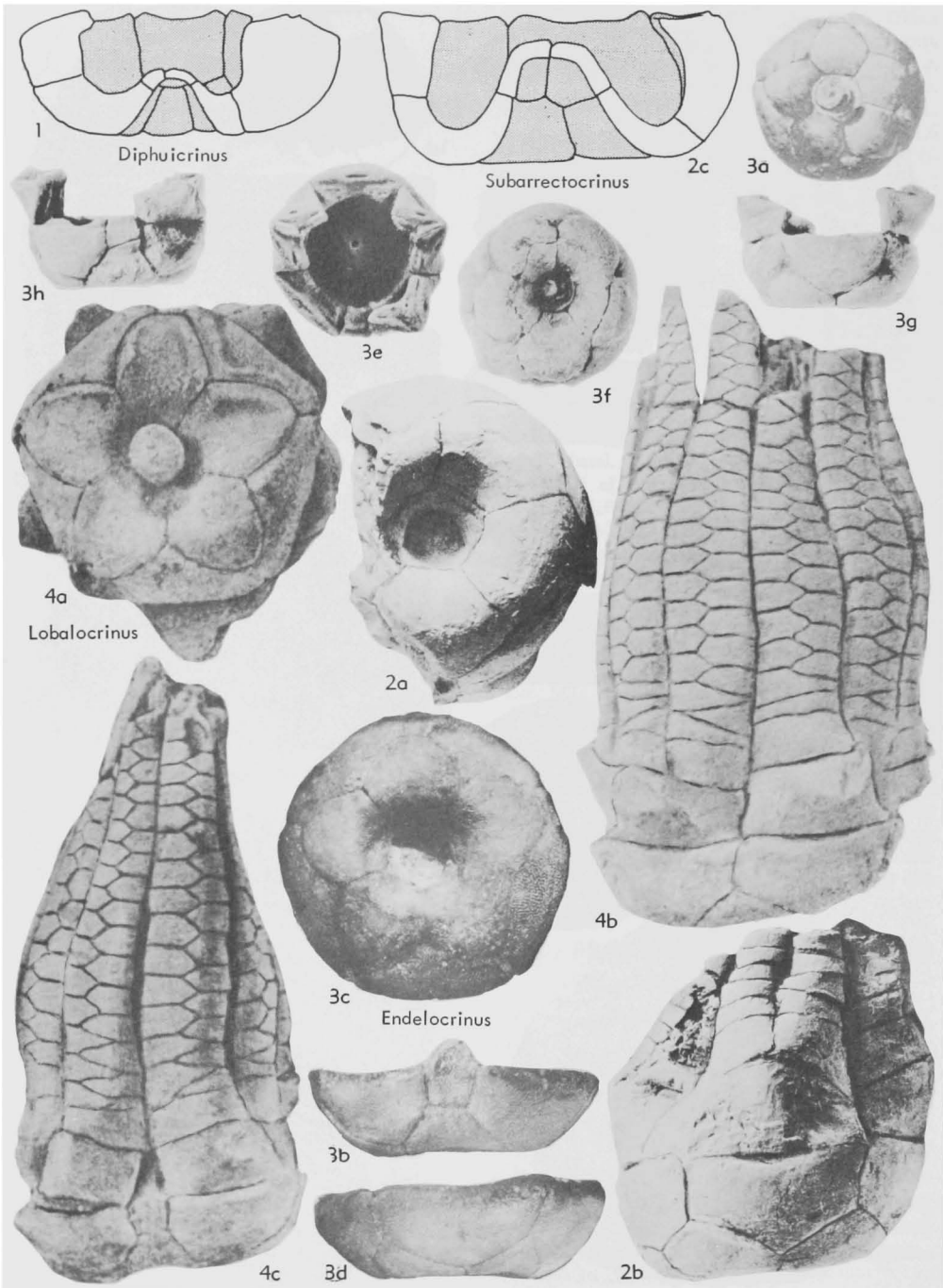


FIG. 470. Diphuicrinidae *(1)*; Catacrinidae *(2-4)* (p. *T711-T712*, *T717-T718*).

L.Perm.(Artinsk.), USSR(Moscow Basin, Timan). ——FIG. 472,*1*. **P. moscoviensis*, Moscov., USSR (Myachkovo); *1a,b*, crown from anal side and dorsal view, ×0.8 (Jaekel, 1918).

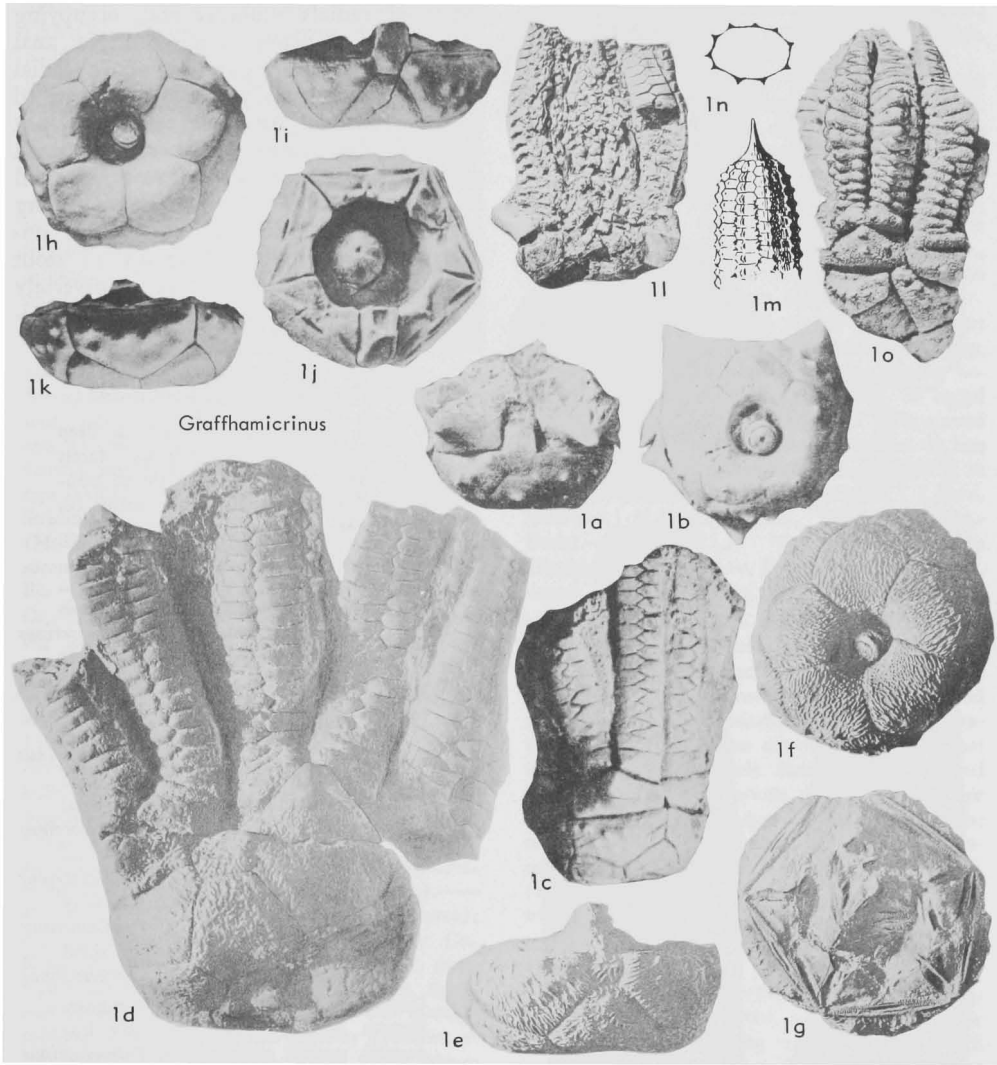


FIG. 471. Diphuicrinidae (p. T712).

Neoprotencrinus KNAPP, 1969, p. 354 [**Paradelocrinus subplanus* MOORE & PLUMMER, 1940, p. 321; OD]. Crown tall, cylindrical. Base of cup planate or mildly concave; proximal tips of radials in basal plane of cup but not entering basal concavity, well separated from infrabasals; anal plate in notch on inner side of *C* and *D* radial articular facets. Arms 10, equibiserial. *M.Penn. (Desmoines.)*, USA(Okla.-Texas).——FIG. 472, *2a-d*. **N. subplanus* (MOORE & PLUMMER); *2a,b*, Strawn Gr.(Millsap Lake F.), Hood Co., Texas, holotype cup from dorsal and ventral, ×2.4 (Moore & Plummer, 1940); *2c,d*, Oologah F., Okla.; *2c*, hypotype crown, ×1.8 (Strimple, 1962a); *2d*, long. sec. of holotype through midline of *A* radial and *CD* interray (portions of cup beyond section shaded), ×4 (Moore, n).——FIG. 472,*2e*. *N. brachiatus* (MOORE & PLUMMER), Millsap Lake F., Hood Co., Texas; side view of holotype crown, ×1.2 (Moore & Plummer, 1940).

Family CATACRINIDAE Knapp, 1969

[*nom. transl.* MOORE & STRIMPLE, 1973, p. 22 (*ex* Catacrininae KNAPP, 1969, p. 365)] [incl. Arrectocrininae KNAPP, 1969, p. 363; Palmerocrininae KNAPP, 1969, p. 360]

Crown tall, cylindrical. Cup low bowl shaped, smooth plated or rugose, with moderately deep and narrow basal concavity, proximal tips of radials above basal plane

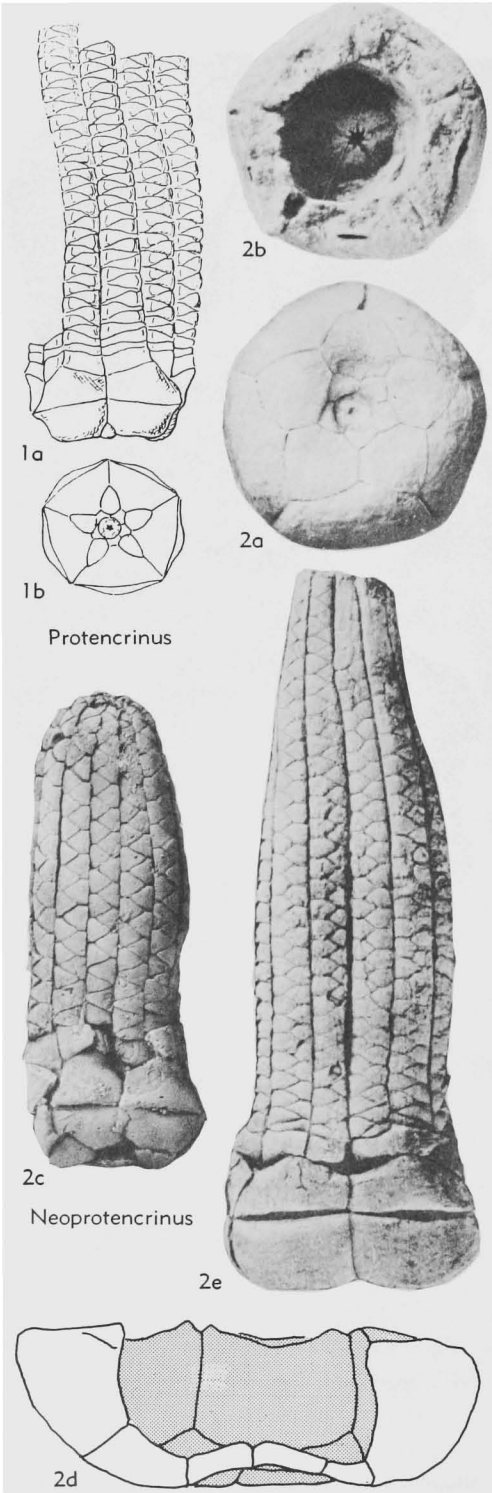


FIG. 472. Protencrinidae (p. T712-T715).

of cup or barely reaching it; articular facets of radials subhorizontal, occupying full width of plates; single upright anal plate (*X*) in cup extending above radial summits and distally recumbent inward in some genera. Anal sac cylindrical, not reaching above arms, composed of small polygonal plates in vertical rows, pointed at summit. Arms ten, biserial, branching isotomously on primibrachs *1*, which uncommonly is produced laterally as stout long spine, pinnulate. Stem transversely round, homeomorphic. *L.Penn.(Morrow.)-U.Perm.(Basleo beds).*

Key to Genera of Catacrinidae

A. Cup bowl shaped, with medium to deep basal concavity, radial articular facets planate and plenary; anal *X* plate on truncate distal edge of *CD* basal; arms 10, biserial; stem transversely round .....
  I. Cup plates smooth .....
    a. Sutures between plates impressed ..
      1. Cup low, infrabasals 5, basals transversely concave ..... *Lobalocrinus*
      2. Cup low, infrabasals 3, basals not concave ..... *Paraplasocrinus*
      3. Cup medium in height, basals not concave, pits at plate angles .... *Endelocrinus*
    b. Sutures between plates not impressed
      1. Cup low, exceptionally deep basal concavity ..... *Subarrectocrinus*
      2. Cup low, deep basal concavity .... *Delocrinus*
      3. Cup low, shallow basal concavity ..... *Pyndaxocrinus*
      4. Cup high, nearly straight sided longitudinally ..... *Arrectocrinus*
  II. Cup plates granulose to coarsely rugose. Sutures between plates distinctly impressed, surface granulose .... *Palmerocrinus*

Delocrinus MILLER & GURLEY, 1890, p. 9 [**Poteriocrinus hemisphericus* SHUMARD, in SHUMARD & SWALLOW, 1858, p. 26; OD) (neotype, ICZN Op. 1006, 1974, *D. hemisphericus* MILLER & GURLEY, 1890, p. 9, Univ. Chicago spec. 6234 in Field Museum Nat. History, Chicago, Lane Sh., Missour., Kansas City, Mo.)] [=*Catacrinus* KNAPP, 1969, p. 365 (type, *Delocrinus subhemisphericus* MOORE & PLUMMER, 1940, p. 258, obj. syn. of *D. hemisphericus* MILLER & GURLEY, 1890, with same type specimens; OD); *Asaccocrinus* WANNER, 1949b, p. 55 (type, *Delocrinus? malaianus* WANNER, 1916, p. 202; OD), U.Perm., Timor; *Wewokacrinus* KNAPP, 1969, p. 361 (type, *Delocrinus wewokaensis* STRIMPLE, 1940b, p. 7; OD), M. Penn.(Desmoines.), USA(Okla.); *Palmatocrinus*

KNAPP, 1969, p. 363 (type, *Delocrinus ponderosus* STRIMPLE, 1949, p. 341; OD), U.Penn., Virgil., USA(Okla.-Texas); *Cathetocrinus* KNAPP, 1969, p. 361 (type, *Delocrinus stullensis* STRIMPLE, 1947, p. 5; OD), U.Penn.(Virgil.), USA(Kans.)]. Cup low bowl shaped, with basal concavity moderately narrow and deep; infrabasals downflared, basals large, proximal ends of radials well above basal plane of cup or barely reaching it; erect or distally somewhat recumbent anal *X* resting on truncated tip of *CD* basal, typically faceted for 2 sac plates but commonly for single plate; anal sac slender, cylindrical, terminating in single spine. Arms 10, biserial, branching isotomously on first primibrach which may be projected as spine. Stem transversely round. *M.Penn.(Desmoines.)-U.Perm. (Basleo beds)*, cosmop.——FIG. 473,*2a-g*. **D. hemisphericus* (MILLER & GURLEY), U.Penn.(Missour., Lane Sh.), Mo.; *2a-d*, dorsal, ventral, post., and ant. views of neoparatype, ×2; *2e-g*, dorsal, ventral, and inner end articular views of neoparatype axillary primibrach *1*, all ×2 (Moore & Strimple, 1970).——FIG. 473,*2h*. *D.* sp., U.Penn. (Missour., Wann F.), Okla.; slender anal sac with summit spine, ×2 (Moore & Strimple, 1941).——FIG. 473,*2i,j*. *D.* sp., U.Perm.(Word F.), Brewster Co., Texas; interiors of radial and *CD* basal showing growth lines and ridges running to plate corners, ×2 (Moore, n).

Arrectocrinus KNAPP, 1969, p. 364 [**Delocrinus abruptus* MOORE & PLUMMER, 1940, p. 289; OD] [=*Metarrectocrinus* KNAPP, 1969, p. 364 (type, *Delocrinus major* WELLER, 1909b, p. 627; OD), *U.Penn.(Virgil.)-L.Perm.(Wolfcamp.)*]. Cup distinguished from that of *Delocrinus* by its exceptional height and longitudinally nearly straight sides; basal concavity deep. *U.Penn.(Virgil.)-L. Perm.(Wolfcamp.)*, USA(Kans.-Neb.-Texas).——FIG. 473,*1*. **A. abruptus* (MOORE & PLUMMER); *1a,b*, holotype from Florena Sh., Cowley Co., Kans., dorsal and post. views, ×1.5; *1c,d*, paratype from Moran F., Callahan Co., Texas, dorsal and ventral views, ×1.5; *1e*, long. sec. through midline of *A* radial and *CD* interray (portions of cup beyond section shaded), ×2.25 (*1a-d*, Moore & Plummer, 1940; *1e*, Moore, n).

Endelocrinus MOORE & PLUMMER, 1940, p. 296 [**Eupachycrinus fayettensis* WORTHEN, in MEEK & WORTHEN, 1873, p. 565; OD]. Characters of family with anal plate resting on truncated tip of *CD* basal, plates moderately tumid, with dimpled depressions at plate angles, arms 10, biserial, branching isotomously on first primibrachs. *L. Penn.(Morrow.)-L.Perm.(Wolfcamp.)*, USA(Okla.-Kans.-Texas-Neb.-Ill.-Mo.-Nev.-Pa.-Ariz.-Ohio).——FIG. 470,*3a*. **E. fayettensis* (WORTHEN), U. Penn.(Missour.), Ill.; holotype cup from base, ×2.5 (Moore & Plummer, 1940).——FIG. 470, *3b-d*. *E. matheri* (MOORE & PLUMMER), L.Penn. (Morrow., Brentwood Ls.), Okla.; holotype, post., dorsal, ant. views, ×2.5 (Moore & Plummer, 1938).——FIG. 470,*3e-h*. *E. solus* (WEBSTER & LANE), M.Penn.(Desmoines., Naco F.), Ariz.; ventral, dorsal, ant., and post. views of holotype, ×1.5 (Webster & Lane, 1970).

Lobalocrinus KNAPP, 1969, p. 366 [**Delocrinus wolforum* MOORE & PLUMMER, 1940, p. 278; OD]. Cup distinguished from that of *Delocrinus* by petaloid transversely concave basals; anal *X* erect and tall, resting on truncate distal edge of *CD* basal. Arms 10, biserial. *U.Penn.(Virgil.)*, USA (Texas).——FIG. 470,*4*. **L. wolforum* (MOORE & PLUMMER), Graham F., Cisco Gr., Brown Co., Texas; *4a-c*, dorsal, *AB*- and *CD*-interray views of holotype, ×1.3 (Moore & Plummer, 1940).

Palmerocrinus KNAPP, 1969, p. 360 [**P. comptus*; OD]. Basal concavity of cup narrow and deep, surface of plates covered by granules, sutures between them impressed; proximal tips of radial plates above basal plane, their distal parts curved sharply inward; anal *X* recumbent inward at low angle to horizontal. Arms 10, obliqui-uniserial in proximal portion, biserial distalward. *L.Penn. (Morrow.)-M.Penn.(Atokan)*, USA(Okla.-Mo.-Utah).——FIG. 473,*3*. **P. comptus*, Atokan (Burgner F.), Mo.; *3a-c*, holotype cup from post., dorsal, and ventral views, ×1.5 (Knapp, 1969).

Paraplasocrinus MOORE & PLUMMER, 1938, p. 306 [**Cibolocrinus transitorius* WANNER, 1916a, p. 208; OD]. Basal concavity deep, including 3 planate or slightly downflared infrabasals and proximal portions of basals, small azygous infrabasal in *C* ray; all plates smooth with sutures not impressed, or moderately tumid with impressed sutures; anal *X* on truncate tip of *CD* basal or only notching inner edges of posterior radials; radial articular facets plenary, planate, with muscular articulations for first primibrachs. *U.Perm. (Basleo beds)*, Indon.(Timor).——FIG. 474,*2*. **P. transitorius* (WANNER), Basleo; *2a-c*, post., ventral, and dorsal views of holotype cup, ×1 (Wanner, 1916a).

Pyndaxocrinus KNAPP, 1969, p. 365 [**Delocrinus separatus* STRIMPLE, 1949d, p. 26; OD]. Similar to *Delocrinus* in having a shallow cup with proximal tips of radials reaching basal plane, but differing in having very shallow basal concavity. Arms unknown. Stem small, transversely round. *U. Penn.(Virgil.)-L.Perm.(Wolfcamp.)*, USA(Kans.-Neb.-Nev.).——FIG. 474,*1*. **P. separatus* (STRIMPLE), Virgil.(Stull Sh.), Kans.; *1a-c*, holotype cup from post., ventral, and dorsal sides, ×1.3 (Strimple, 1949d).

Subarrectocrinus KNAPP, 1969, p. 365 [**Delocrinus? perexcavatus* MOORE & PLUMMER, 1940, p. 284; OD]. Cup high bowl shaped with very deep basal concavity, its bottom only little below summit of cup; plates smooth, sutures not impressed. Arms unknown above uniserial cuneate proximal secundibrachs, doubtless biserial distally. *U.Penn. (Virgil.)*, USA(W.Texas-Kans.).——FIG. 470,*2*. **S. perexcavatus* (MOORE & PLUMMER), Gaptank

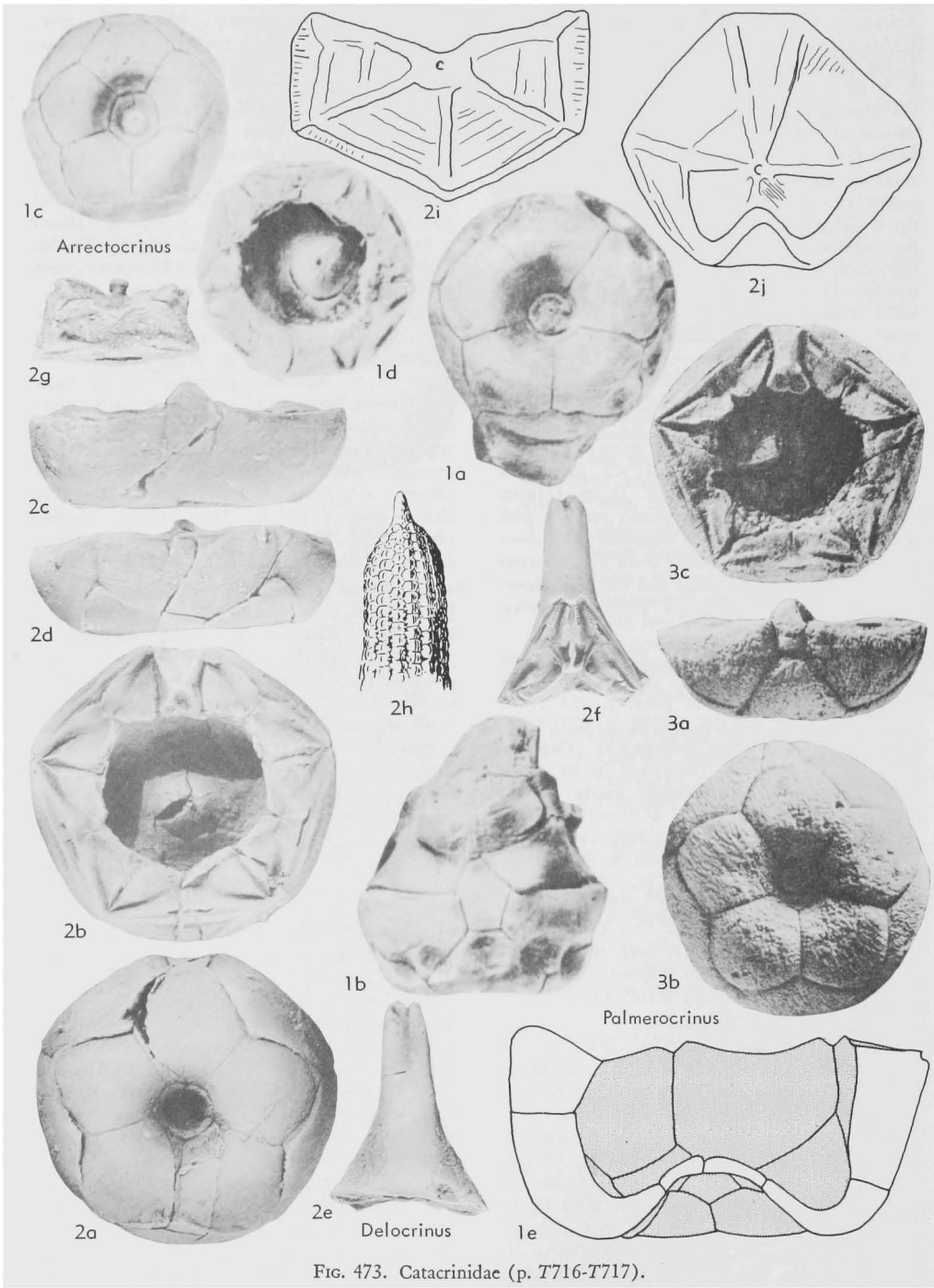


FIG. 473. Catacrinidae (p. *T716-T717*).

F., Brewster Co., Texas; *2a,b,* dorsal and ant. views of holotype, ×2 (Moore & Plummer, 1940); *2c,* long. sec. of cup through midline of *A* radial and *CD* interray (portion of cup beyond section shaded), ×2.25 (Moore, n).

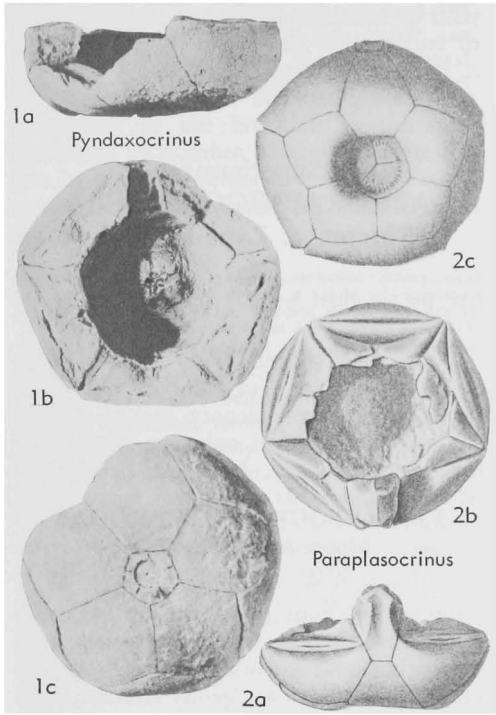


FIG. 474. Catacrinidae (p. T717).

Family STACHYOCRINIDAE
Moore & Strimple, 1973

[Stachyocrinidae MOORE & STRIMPLE, 1973, p. 22]

Crown cylindrical to ovoid. Cup low bowl or saucer shaped, with shallow basal concavity, proximal tips of radials reaching basal plane of cup or well above it; anal in notch between *C* and *D* radial articular facets, not visible from side. Arms ten, uniserial, brachials rectangular in side view. Stem impression circular. *U.Perm.(Basleo beds).*

Stachyocrinus WANNER, 1916, p. 233 [**S. zea*; OD]. Cup shallow bowl shaped with pronounced but narrow basal concavity; infrabasals covered by stem; basals small, narrow, confined to basal area; radials large, with proximal portions in basal plane of cup, small forefacet near summit; anal plate not visible when arms are in place. Arms 10, rectilinear, convex externally, abutting closely, primibrachs *1* axillary, very large and tumid, some assisting in support of secundibrachs belonging to arms of adjacent rays. *U.Perm.(Basleo beds),* Indon.(Timor).——FIG. 475,2. **S. zea,* Noil Fatoe; *2a-c,* dorsal and two lat. views of crown, ×2 (Wanner, 1916a).

Parastachyocrinus WANNER, 1949, p. 44 [**Eriso-crinus malaianus* WANNER, 1924, p. 42; OD]. Crown medium in height, cylindrical except for strongly protruded axillary primibrachs *1*. Cup

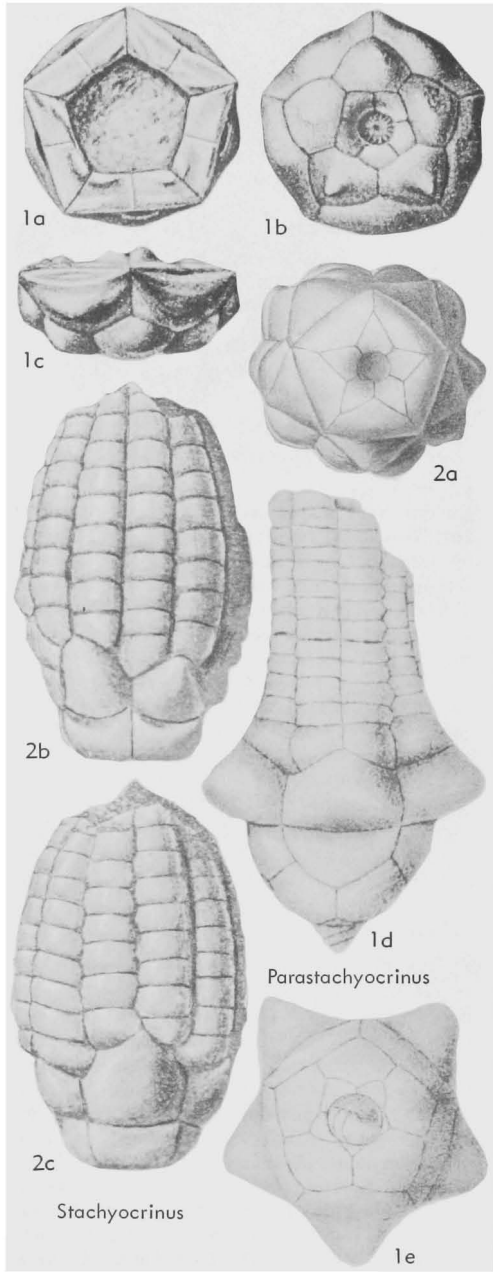


FIG. 475. Stachyocrinidae (p. T719-T720).

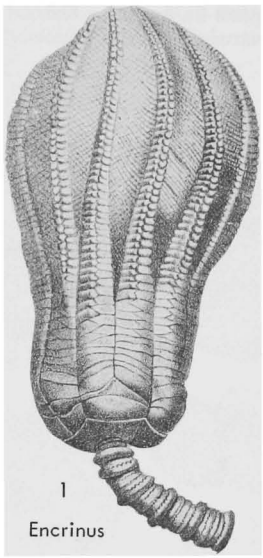


FIG. 476. Encrinidae (p. T720).

truncate bowl shaped with slight basal concavity; anal *X* excluded from exterior of cup but marked by notch on inner side between posterior radial articular facets, not visible externally from side. Ten arms, closely abutting, primibrachs *1* axillary, secundibrachs recti-uniserial. Column transversely round. *U.Perm.(Basleo beds)*, Indon.(Timor). ——FIG. 475,*1*. **P. malaianus* (WANNER), Basleo; *1a-c*, ventral, dorsal, and post. sides of holotype cup, ×1.5 (Wanner, 1924); *1d,e*, lat. and dorsal views of crown, ×1.5 (Wanner, 1949b).

Family ENCRINIDAE
Dujardin & Hupé, 1862

[*nom. correct.* ICZN, 1962 (Bull. Zool. Nomencl., v. 19, pt. 5, p. 263) (*pro* Encriniens DUJARDIN & HUPÉ, 1862, p. 161)]

Characters of *Encrinus*. *M.Trias.*

Encrinus LAMARCK, 1801, p. 379 [**E. liliiformis* LAMARCK, 1801, p. 379; SD ICZN, 1962 (plenary powers, Op. 636)]. Cup low basin shaped with moderate basal concavity, distinguished by perfect pentameral symmetry in arrangement of three plate circlets, absence of anal or anals, and 10 biserial, highly pinnulate arms. *M.Trias.*, Eu. (Ger.).——FIG. 476,*1*. **E. liliiformis*; lat. view of crown and proximal part of stem, ×0.7 (Bronn & Roemer, 1851-56). [=*Encrina* BRONN, 1848 *(nom. null.)*.] [=*Chelocrinus* VON MEYER, 1837, p. 316; *Flabellocrinites* KLIPSTEIN, 1845 (type, *F. cassianus*; M); *Chelocrinites* GEINITZ, 1846, p. 540 *(nom. van pro Chelocrinus)*; *Cassianocrinus* LAUBE, 1865, p. 274 (type, *?Encrinus cassianus* LAUBE); *Porocrinus* DITTMAR, 1866, p. 392 (*non* BILLINGS, 1857, p. 279); *Traumatocrinus* WÖHRMANN, 1889, p. 290; *Beyrichocrinus* JAEKEL, 1918, p. 67 (*non* WAAGEN & JAHN, 1899) (type, *Encrinus carnalli* BEYRICH, M; *Jenaicrinus* JAEKEL, 1918, p. 67.]

Superfamily
APOGRAPHIOCRINACEA
Moore & Laudon, 1943

[*nom. transl.* MOORE & STRIMPLE, 1973, p. 22 (*ex* Apographiocrinidae MOORE & LAUDON, 1943a, p. 55)] [Materials for this superfamily prepared by R. C. MOORE and H. L. STRIMPLE]

Cup bowl shaped with narrow basal concavity and steep to incurved sides near rim, arm facets peneplenary, anal on squarely truncate *CD* basal only cup anal, arms five or 10, uniserial. *L.Penn.-U.Perm.*

Family APOGRAPHIOCRINIDAE
Moore & Laudon, 1943

[Apographiocrinidae MOORE & LAUDON, 1943a, p. 55]

Crown medium sized, slender and subcylindrical. Cup low bowl shaped, composed of gently tumid smooth plates with slightly indented sutures; base gently concave, with horizontal infrabasals not visible from side; radials with facets less than greatest width of plates, leaving small interradial prongs, usually with finely tuberculose extrafacetal areas surrounded by fine thin line; single anal *X* plate resting on squarely truncate tip of posterior *(CD)* basal and followed by two equidimensional plates well above cup summit. Arms ten (five in one late genus), branching on slightly elongated primibrachs *1*, brachials rectiuniserial or slightly cuneate, pinnulate. Anal sac small, cylindrical, extending slightly above mid-height of arms. Stem transversely circular, noncirriferous, heteromorphic. *L.Penn.-(Morrow.)-U.Perm.*

The Apographiocrinidae are similar to poteriocrinitid stock in having peneplenary radial articular facets, but in other respects are more closely aligned with scytalocrinid-decadocrinid stock. The radial articular facets are advanced in evolutionary status, as indicated by their slope, so that the pronglike divisions bordering the facets are thought to be a specialized advanced feature rather than retention of the primitive structure found in Poteriocrinitidae. This is based on their being functional with

the proximal sides of the primibrachs resting on them and the anal sac attached to their inner facets. A single anal plate occurs in the cup. Presence of numerous pinnules is considered advanced, but the uniserial arrangement of the brachials is primitive. Reduction in number of arms from ten to five in one late genus is considered to be specialization but could be construed as atavistic.

Apographiocrinus Moore & Plummer, 1940, p. 115 [**A. typicalis*; OD]. Crown relatively tall and slender, subcylindrical, with arms generally held closely together. Cup small, slightly truncate bowl shaped, with small well-defined basal concavity; plates of cup slightly bulbous in typical examples; 5 small infrabasals, forming pentagon at bottom of basal concavity, nearly covered by stem; basals 5, subequal, except posterior basal, which is distinctly larger than others and truncated distally for contact with anal *X*, only very small proximal part of basals involved in basal concavity of cup; radials 5, pentagonal, length about two-thirds of width; transverse convexity giving scalloped appearance to summit of radials in ventral or dorsal view of cup; single anal plate in cup between posterior radials, resting on truncated tip of posterior basal, about 0.5 of its height generally raised above summit of radials followed by 2 equidimensional sac plates. Ten arms, composed of quadrangular or very slightly cuneate uniserial segments approximately uniform in size throughout length, branching isotomously on axillary primibrachs, those of left and right anterior rays slightly shorter than others, outer surface gently rounded but flat where sides of arms fit together, although some segments are marked by fine grooves and ridges for firmer union between arms, sharp angulation separating sides from outer surface of arms; pinnules not seen on lowermost parts of arms, but observed in some species throughout most of arm length, radial articular facets distinctly less than greatest width of radials in all North American forms, and extension of outer face of radials present along interradial sutures to inner border of facets where they are joined by small covering plates of tegmen, outer ligament area wide but short and rather strongly depressed, transverse ridge straight and well defined, inner ligament area sloping strongly outward-upward. Anal sac small, cylindrical, composed of irregular polygonal plates, extending slightly above midheight of arms. *L.Penn.-L.Perm.*, central USA; *U.Perm.*, USSR-Indon.(Timor).——Fig. 477,*1a-c*. **A. typicalis*, U.Penn.(Missour.); *1a*, from Plattsburg Ls., Wilson Co., Kans.; holotype crown from ant. (*AB* interray) side, ×1.8 (Moore & Plummer, 1940); *1b*, plate diagram (radials black, anal *X* stippled), enl.(Moore, n);

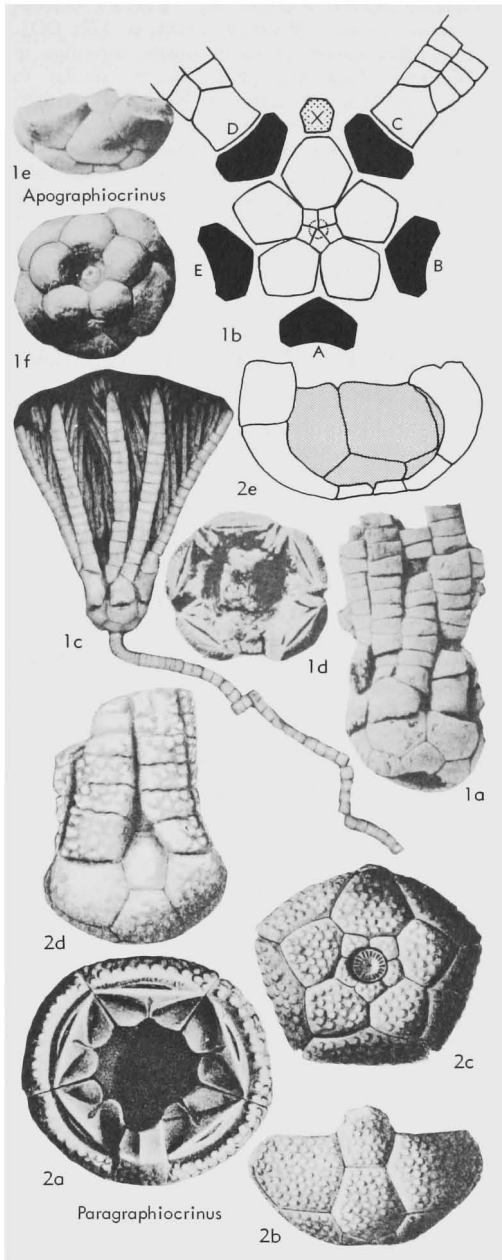


Fig. 477. Apiographiocrinidae (p. *T721-T722*).

1c, hypotype crown from LaSalle Ls., near Pontiac, Livingston Co., Ill., showing pinnulate arms and attached stem, ×1.2 (Strimple & Moore, 1971a).——Fig. 477,*1d-f*. *A. exculptus* Moore & Plummer, U.Penn.(Missour., Graford F.), NE.Texas; ventral, post., and dorsal views of holotype cup, ×1.8 (Moore & Plummer, 1940).

Paragraphiocrinus WANNER, 1937, p. 173 [**Graphiocrinus exornatus* WANNER, 1916a, p. 172; OD]. Cup either smooth of highly ornate, according to WANNER, shape and plate tumidity similar to *Apographiocrinus* except in lacking projections from the exterior between radial articulating facets. Five robust arms. *U.Perm.*, Indon.(Timor).—— FIG. 477,*2*. **P. exornatus* (WANNER), Basleo beds, Timor; *2a-c*, ventral, post., dorsal views of holotype, ×2 (Wanner, 1916a); *2d*, post. view of crown, ×1.3 (Wanner, 1937); *2e*, vert. sec. of cup through midline of *A* radial (portion of cup beyond section shaded), ×1.8 (Moore, n).

Superfamily PIRASOCRINACEA Moore & Laudon, 1943

[*nom. transl.* MOORE & STRIMPLE, 1973, p. 22 (*ex* Pirasocrinidae MOORE & LAUDON, 1943a, p. 58)] [Materials for this superfamily prepared by R. C. MOORE and H. L. STRIMPLE]

Crown pyriform; cup very low bowl shaped, with mostly deep basal concavity and rounded sides incurved at rim, arm facets peneplenary, interradial notches at rim, three anals in cup, anal sac tall, typically mushroomlike with girdle of horizontal spines around summit platform. *L.-Miss.-U.Perm.*

Family PIRASOCRINIDAE Moore & Laudon, 1943

[Pirasocrinidae MOORE & LAUDON, 1943a, p. 58] [incl. Aatocrininae KNAPP, 1969, p. 374; Affinocrininae KNAPP, 1969, p. 372; Exterocrininae KNAPP, 1969, p. 380; Lasanocrininae KNAPP, 1969, p. 369; Pirasocrininae MOORE & LAUDON, 1943a (KNAPP, 1969, p. 370); Psilocrininae KNAPP, 1969, p. 375; Sciadiocrininae KNAPP, 1969, p. 377; Triceracrininae KNAPP, 1969, p. 382]

Crown compact. Cup low; base slightly to deeply concave; infrabasals five, not visible from side, radial facets wide (peneplenary) and moderately long, sloping gently outward-downward (declivate), having distinct transverse ridge, muscle, and ligament areas; three anals in cup. Anal sac prominent, mushroom shaped. Arms uniserial, branching twice or more isotomously, beginning on first primibrachs. *U.Miss.-U.-Perm.*

The pirasocrinids are distinguished by their very low, almost dicoid cups with outward-downward sloping radial facets and multibranched uniserial arms, combined wherever known with a prominent flat-topped anal sac reaching to or above tips of the arms. The basal concavity of the cup may be broad and shallow or somewhat narrow and moderately to very deep. The nature of the low cup, arms, and mushroom-shaped anal sac are chiefly important characters. The horizontally outspread spines surrounding the summit of the anal sac range from short to exceptionally elongate (e.g., *Eirmocrinus* STRIMPLE & WATKINS, 1969, from the Middle Pennsylvanian of Texas).

KNAPP (1969, p. 369) stated: "Presumably, the ancestry of the pirasocrinids is in a phanocrinid-like dorsal cup, and by multiplication of the arms, lowering of the dorsal cup, and by decreasing the downflaring of the infrabasal plates, the Pirasocrinidae were established." The phanocrinid lineage is remarkably stable and, as demonstrated by KNAPP, continued with ten-armed derivatives into the Permian. It is not involved in the pirasocrinid lineage. We find no valid reason for questioning *Zeusocrinus* STRIMPLE as the probable progenitor of the pirasocrinids, as proposed by STRIMPLE (1961d, p. 21). *Zeusocrinus* has a low cup with multiple arms and a summit umbrellalike platform on the anal sac.

The family Pirasocrinidae appears to be polyphyletic, but the exact affinities of the included lineages are obscured. *Dasciocrinus*, of late Mississippian age, apparently gives rise to *Stenopecrinus rugosus* STRIMPLE of early Pennsylvanian age. *S. rugosus* has been assigned to the genus *Anchicrinus* by MOORE & STRIMPLE (1973), but has some atypical morphologic features (e.g., the cup of typical *Anchicrinus* has an almost imperceptible basal concavity and the tegmen spines have a broad, flattened base). The tegmen spines of *S. rugosus* have a narrow, rounded base and the basal concavity is pronounced. Narrow rounded tegmen spines are deemed to be primitive (i.e., like *Dasciocrinus*), and a pronounced basal concavity usually represents a more advanced state than a shallow basal concavity.

Zeusocrinus of late Mississippian age has a pronounced basal concavity (advanced?), flattened tegmen spines surrounding a small platform of polygonal plates, and agrees in all respects with Pennsylvanian genera assigned to the family.

The family Laudonocrinidae is closely related to the Pirasocrinidae. Basic stock of Laudonocrinidae is thought to have upflared infrabasals as represented by *Paianocrinus* STRIMPLE of late Mississippian age.

The cup is essentially flared cone shaped and is transformed to a planate base and then to a shallow basal concavity. Some species of *Laudonocrinus* of Missourian age can hardly be separated from young specimens of species of *Plaxocrinus,* which in turn casts some doubt on the viability of the family Laudonocrinidae.

Structural placement of plates belonging to successive circlets—infrabasals, basals, radials—of the cups of the Pirasocrinidae and similar crinoids having shallow to deep concave bases, as well as some broadly flat-bottomed forms (e.g., Anobasicrinidae), is important for purposes of taxonomic classification. This can be expressed most simply and explicitly in terms of the position of their proximal tips and somewhat less so of their distal extremities, both considered in relation to the basal plane of the cup and both determined by points on the exterior surface of the plates. Terms used are 1) **infral,** above basal plane within basal concavity of the cup, 2) **basiplanal,** in or tangent to basal plane of the cup, and 3) **supral,** above basal plane on outer side of the cup. In the *Treatise* these terms are given uniformly in the sequence: infrabasal plate, basal plate, and radial plate, which is outward from center of the stem impression. Symbols may be employed for most compact statement, minus sign (−) for infral, zero (0) for basiplanal, and plus sign (+) for supral.

Unless stated otherwise, terms and symbols for crinoid plate positions refer to proximal extremities because these seem to be more significant than distal ones. Finally, points for basal plates are located in an interradial plane at an approximate 36° angle from that of a neighboring radial plane containing extremities of infrabasal and radial plates. Points for plates of successive circlets are equally well given in longitudinal sections of cups through the midline of the *D* radial and *CD* interray or *C* radial and *AB* interray (Fig. 436). Irregularities introduced by the insertion of anal cup plates on the posterior side of the cup are ignored.

Examples of plate-position recording (all proximal tips) as explained here are for 1) *Pirasocrinus,* with very deep basal invagination (infral-infral-infral, − − −), 2) *Perimestocrinus,* with small, moderate basal concavity (infral-infrabasiplanal, − − 0), 3) *Athlocrinus,* with flat base, except for shallowly concave stem impression (infral-basiplanal-basiplanal, − 0 0), and 4) *Laudonocrinus,* with nearly flat base (infral-basiplanal-supral, − 0 +) (Fig. 436).

Key to Genera of Pirasocrinidae

A. Cup with proximal extremity of plates of all circlets confined to basal concavity (− − −) .....
  I. Concavity very deep, only radials and 3 anal plates in cup visible from side ..
    a. Axillary primibrach *1* bulbous ..... *Pirasocrinus*
    b. Axillary primibrach *1* spinose ..... *Eirmocrinus*
  II. Concavity moderately deep, only radials, *CD* basal and 3 cup anals visible from side ..... *Sciadiocrinus*
  III. Concavity moderately deep, all basals partly visible from side; plates of cup and arms smooth, interradial notches prominent ..... *Aatocrinus*

B. Cup with proximal extremities of infrabasals and basals confined to basal concavity, those of radials to basal plane (− − 0)
  I. Concavity moderately deep and wide, proximal part of basals transversely concave .....
    a. Plates tumid, sutures impressed .... *Affinocrinus*
    b. Plates not tumid, sutures not impressed ..... *Platyfundocrinus*
  II. Plates tumid, sutures impressed, interradial notches narrow .....
    a. Basals thick throughout their length, with proximal edges markedly overhanging infrabasals ..... *Stenopecrinus*
    b. Proximal margins of basals not overhanging infrabasals ..... *Vertigocrinus*
  III. Concavity shallow and wide, plates not tumid, sutures not impressed .....
    a. Interradial notches prominent, *CD* interray wide ..... *Metaffinocrinus*
    b. Interradial notches and *CD* interray narrow, rounded protuberances at middle of radials ..... *Lasanocrinus*
    c. No interradial notches, *CD* interray narrow, rounded median protuberances on both basals (as in *Utharocrinus*) and radials (as in *Lasanocrinus*) ..... *Metutharocrinus*
  IV. Concavity shallow and narrow, *CD* interray narrow .....
    a. Plates tumid, sutures impressed .... *Schedexocrinus*
    b. Plates not tumid, sutures not im-

pressed .....
1. Interradial notches wide and prominent ..... *Retusocrinus*
2. Interradial notches narrow but well defined, *CD* interray narrow ..... *Simocrinus*

C. Cup with proximal extremities of infrabasals and basals confined to basal concavity, those of radials above basal plane on outer side of cup (−−+) .....
I. Cup moderately high bowl shaped ....
a. Concavity deep and wide, plates tumid, *CD* interray wide .... *Exterocrinus*
b. Concavity shallow and narrow .....
1. Plates tumid, *CD* interray narrow
a.) Interradial notches well marked, plates lacking protuberances ..... *Separocrinus*
b.) Interradial notches small, tumid plates .... *Metaperimestocrinus*
c.) Interradial notches small and weak, prominent rounded protuberances on radials .... *Triceracrinus*
2. Plates not tumid, *CD* interray wide, interradial notches prominent ..... *Perimestocrinus*

II. Cup low, saucer shaped, plates not tumid, concavity wide .....
a. Concavity wide and very shallow, sutures impressed, base of cup nearly flat, interradial notches wide .... *Plaxocrinus*
b. Concavity wide and moderately deep, *CD* interray narrow ..... *Polygonocrinus*
c. Concavity moderate or narrow and shallow, small interradial notches ..
1. Distal spine plates of anal sac meet at base ..... *Dasciocrinus*
2. Distal spine plates of anal sac surround small platform of polygonal plates ..... *Zeusocrinus*
d. Concavity wide to somewhat narrow and shallow, small interradial notches, *CD* interray narrow, pointed protuberances directed obliquely downward developed on basals .... *Utharocrinus*

III. Cup low, plates not tumid, concavity narrow and shallow, well-defined interradial notches, wide *CD* interray .... *Psilocrinus*

Pirasocrinus Moore & Plummer, 1940, p. 235 [**P. scotti*; OD]. Crown tall, relatively slender, and widest at height of secundaxils, total height about 3 times greatest width; isotomous branching at uniform heights in each ray, combined with strongly bulbous nature of axillary brachials, provides a pagodalike, turreted appearance; horizontally placed sac spines spread outward above arm tips at crown summit. Cup very low bowl shaped with strongly concave base (formula for proximal tips of cup plates, −−−); except in posterior interray only radials visible in side view of cup; height of cup only about 0.1 that of crown and, because proximal brachials are considerably more bulky than any cup plates and project well beyond outer edges of radials, cup appears relatively small. Infrabasals almost or entirely covered by stem at base of deep central concavity, 5 subequal basals strongly downflared throughout their length and all pentagonal except posterior basal, which is hexagonal and truncated distally for contact with anal *X*, distal tip of *CD* basal visible in side view. Radials moderately convex transversely and extremely so longitudinally, with proximal parts sloping steeply into basal concavity and distal parts forming subvertical sides of cup; articular facets occupying slightly less than full width of radials, their plane sloping distinctly outward-downward; 3 anal cup plates in normal position, elongate radianal lying parallel to *CD* basal and narrowly touching *BC* basal, large anal *X* and right tube plate, former touching distal tip of *CD* basal. Anal sac formed of relatively strong plates rising to summit of crown and roofed by few broad plates that project laterally in form of spines. Arms long, rounded, branching isotomously at regular intervals, composed of uniserial externally rectangular segments that are much wider than long; axillary brachials bulbous and much thicker than succeeding segments; arms in each ray bifurcating typically 4 times, so that at top of crown maximum of 80 slender branches may occur; first 3 divisions of each ray very uniform, but fourth less regular; some branches apparently undivided above third dichotom, slender pinnules borne by at least upper arm branches; all specimens show arms parallel and closely adjoining. Stem transversely round. *M.Penn.(Desmoines.)*, USA(Texas).——Fig. 436, *1*; 478,*2*. **P. scotti*, Millsap Lake F., Hood County, Texas; 436,*1a,b*, diagram. secs. of cup through midlines of ant. and left post. *(D)* radials (portions of cup beyond section shaded), ×1 (Moore, n); 478,*2a*, plate diagram of cup (radials black, radianal cross ruled, anal *X* stippled) (Moore, n); 478,*2b,c*, *C*-ray and dorsal side of holotype crown and paratype cup, with *CD* interray directed upward, ×1 (Moore & Plummer, 1940).

Aatocrinus Moore & Plummer, 1940, p. 213 [**Zeacrinus? robustus* Beede, 1900b, p. 22; OD]. Cup very low, with inner margin of radial articular facets about as high above outer summit of radials as latter are above basal plane of cup; central part of base strongly depressed but distal portions of basals and radials flare upward and are not involved in basal concavity, plates somewhat tumid (formula for proximal tips of cup plates, −−−); infrabasals subhorizontal or slightly

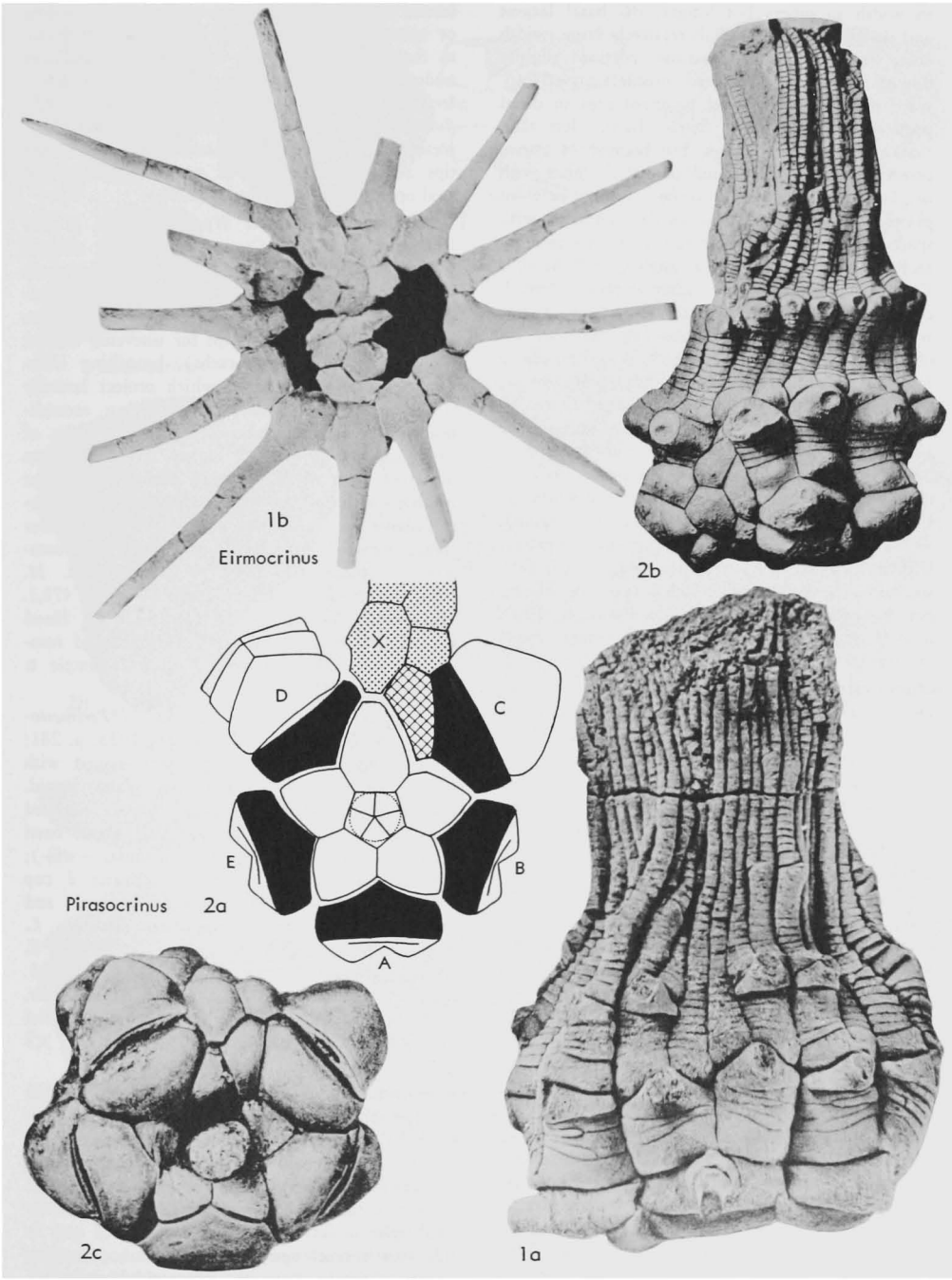


FIG. 478. Pirasocrinidae (p. *T724*, *T726*).

downflared forming small pentagon covered largely by stem; 5 basals subvertical near proximal margin, curving outward-downward to subhorizontal beyond midlength and then curving upward, strongly convex in longitudinal profile and moderately convex transversely; distal parts of

these plates visible in side view; *CD* basal equal in width to others but longer, *BC* basal largest and distinctly widest, radials relatively large, width about twice length, proximal portion slightly downflaring in longitudinal profile, curved upward to margin of facetal ligament area in distal portion; articular radial facets slightly less than maximum width of plates, but because of lateral projection of radials beyond points of union with neighbors well-defined notches occur between plates, and outer surface of cup is confluent with space along inner articular suture not covered by facets, which are declivate at angle of 30° to 40°; *CD* interray narrow and rather deeply indented, containing 3 anal plates, with radianal in contact with *BC* basal, anal *X* resting on truncated tip of *CD* basal, about 0.5 its length extending above facet of *D* radial, with right tube plate on *X*, radianal reaching only slightly below *C* radial. Anal sac unknown. Stem transversely round. [This genus differs from *Pirasocrinus* in its shallower basal concavity and from *Perimestocrinus* in its much deeper concavity.] *M.Penn.(Desmoines.)-U.Penn.(Missour.)*, N.Am.(Midcontinent region).——Fig. 436,*4*; 479,*3*. **A. robustus* (Beede), U.Penn.(Missour.), Kansas City, Mo.; 436,*4*, vert. sec. through midline of *A* radial (portions of cup beyond section shaded) (Moore & Plummer, 1940, mod.); 479,*3a-c*, dorsal, post., and ventral views of cup; ×1 (Moore & Plummer, 1940).

Affinocrinus Knapp, 1969, p. 372 [**A. concavus*; OD]. Cup low bowl shaped, with smooth tumid plates and impressed sutures; proximal extremities of infrabasals and basals confined to moderately deep and wide basal concavity, those of radials in basal plane of the cup (formula, − − 0); proximal parts of basals transversely concave, their distal tips visible in side view; summit outer parts of radials bearing arcuate impressed forefacet, planes of articular facets moderately declivate; interradial notches shallow; 3 anal plates in narrow *CD* interray. Arms unknown. Stem impression circular. *L.Penn.-M.Penn.(Atokan-Desmoines.)*, USA(Mo.).——Fig. 480,*2*. **A. concavus*, Atokan(Burgner F.), Jasper Co., Mo.; long. sec. of cup through midline of *D* ray (portion of cup beyond section shaded), ×2 (Knapp, 1969).

Dasciocrinus Kirk, 1939, p. 472 [**Cyathocrinus florialis* Yandell & Shumard, 1847, p. 24; OD]. Crown subcylindrical. Cup low, bowl or saucer shaped with invaginated base; infrabasals small, concealed by column within small basal pit; basals relatively small, proximal portions taking part in basal pit; radials large; articular facet extending full width of radial, linear, gaping; 3 anal plates in cup, radianal large, elongate, penetrating cup deeply and resting upon *BC* basal, anal *X* relatively small, meeting *CD* basal narrowly. Anal sac taller than arms with spinose processes (mostly 3 or 4) common on distal plates; anal opening lateral near distal end of sac. Arms uniserial, long, slender, endotomous, with few divisions; primibrachs *1* axillary in all rays, tending to be nodose or spinose; next branching high above primaxil, so that secundibrachs are numerous; all axillaries nodose and other brachials cuneate. *U.Miss.(Chester.)*, USA(Ill.-Ky.-Okla.).——Fig. 446,*1*. **D. florialis* (Yandell & Shumard), Ky.; *1a,b*, complete crown showing distal end of sac above arm tips and distal position of sac with spines and anal opening, ×1 (Springer, 1926b).

Eirmocrinus Strimple & Watkins, 1969, p. 204 [**E. grossus*; OD]. Crown robust, pear shaped, widest at about 0.25 of its height. Cup extremely low, saucerlike; deeply concave at base, only radials and 3 long, narrow anal plates visible from side. Arms uniserial (except for unevenly biserial arrangement of secundibrachs), branching isotomously on primibrachs *1*, which project laterally in stout spines, similar branching on secundibrachs *4-6* and endotomously on outer sides of each half-ray at 4 or 5 higher levels, all arms in upper part of crown very slender. Anal sac mushroom shaped, with expanded nearly flat summit above arm tips, approximately 13 long slender spines directed outward from central area composed of moderately large polygonal plates. *M. Penn.(Desmoines.)*, USA(Texas).——Fig. 478,*1*. **E. grossus*, Millsap Lake F.(Strawn Gr.), Hood Co., Texas; *1a,b*, *B*-ray view of crown and summit of anal sac from above, ×0.8 (Strimple & Watkins, 1969).

Exterocrinus Knapp, 1969, p. 380 [**Perimestocrinus pumilis* Moore & Plummer, 1938, p. 281; OD]. Cup moderately deep bowl shaped with wide and deep basal concavity, plates tumid, proximal tips of infrabasals and basals confined to concavity and of radials distinctly above basal plane on outer side of cup (formula, − − +); articular radial facets strongly declivate; 3 cup anal plates in wide *CD* interray. Anal sac and arms unknown. Stem impression circular. *L. Penn.(Morrow.)*, USA(Okla.).——Fig. 480,*3*. **E. pumilis* (Moore & Plummer), Bloyd F.; *3a,b*, dorsal and post. views, ×2 (Knapp, 1969); *3c*, long. sec. of cup through midline of *D* radial (portion of cup beyond section shaded), ×2 (Moore, n).

Lasanocrinus Moore & Plummer, 1940, p. 181 [**Hydreionocrinus daileyi* Strimple, 1940a, p. 5; OD]. Cup very low, almost discoidal, outline distinctly pentagonal in dorsal or ventral view but unlike most with angles of pentagon in midportion of the radials, greatest width of cup below midheight or at basal plane, outline of cup in side view subrectangular to trapezoidal, depending on orientation; sutures not impressed but distinct, surfaces of adjoining plates smoothly confluent; base of cup broadly and shallowly concave or marked by central moderate deep concavity that involves infrabasals and proximal parts of basals, proximal extremities of radials in basal plane of

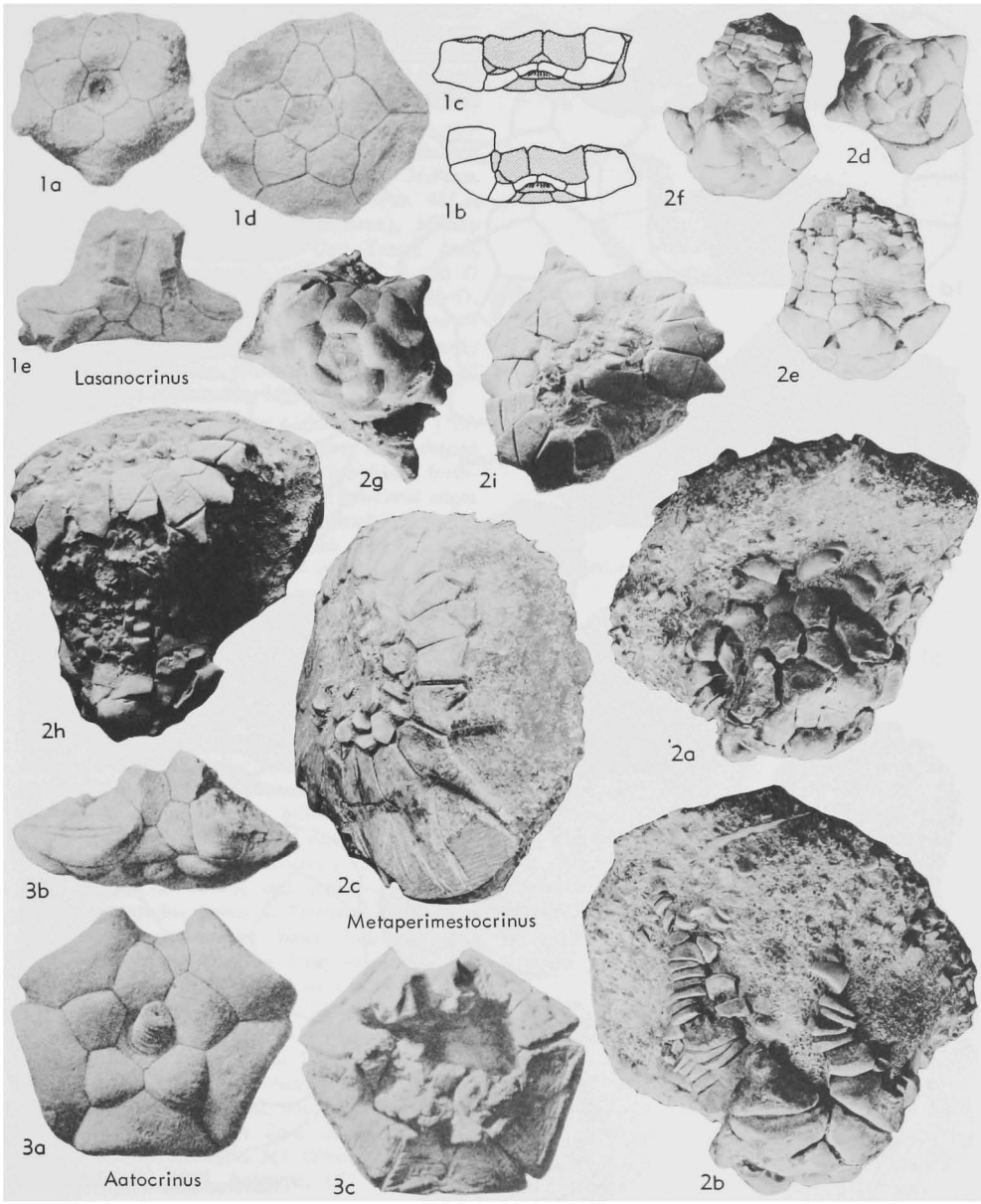


FIG. 479. Pirasocrinidae (p. T724-T729).

cup (formula, – – 0); infrabasals forming regular pentagon twice stem impression in diameter; subequal basals with subhorizontal midportions and distal parts gently upflared, *CD* basal slightly longer than others and truncated distally, for contact with anal *X*; radials strongly bulbous or spinose, articular facets sloping outward-downward, width of facets slightly less than maximum width of radials, transverse ridge and ligament areas well defined on facets; anal plates 3, elongate radianal with narrower end typically in contact with *BC* basal. Anal *X* on truncated distal extremity of *CD* basal obliquely above radianal; right tube plate relatively large and in normal contact with anal *X* and radianal. Arm structure unknown. Stem unknown but impression of it round. [Distinguished from other genera of low discoidal form by distinctive shape of cup and

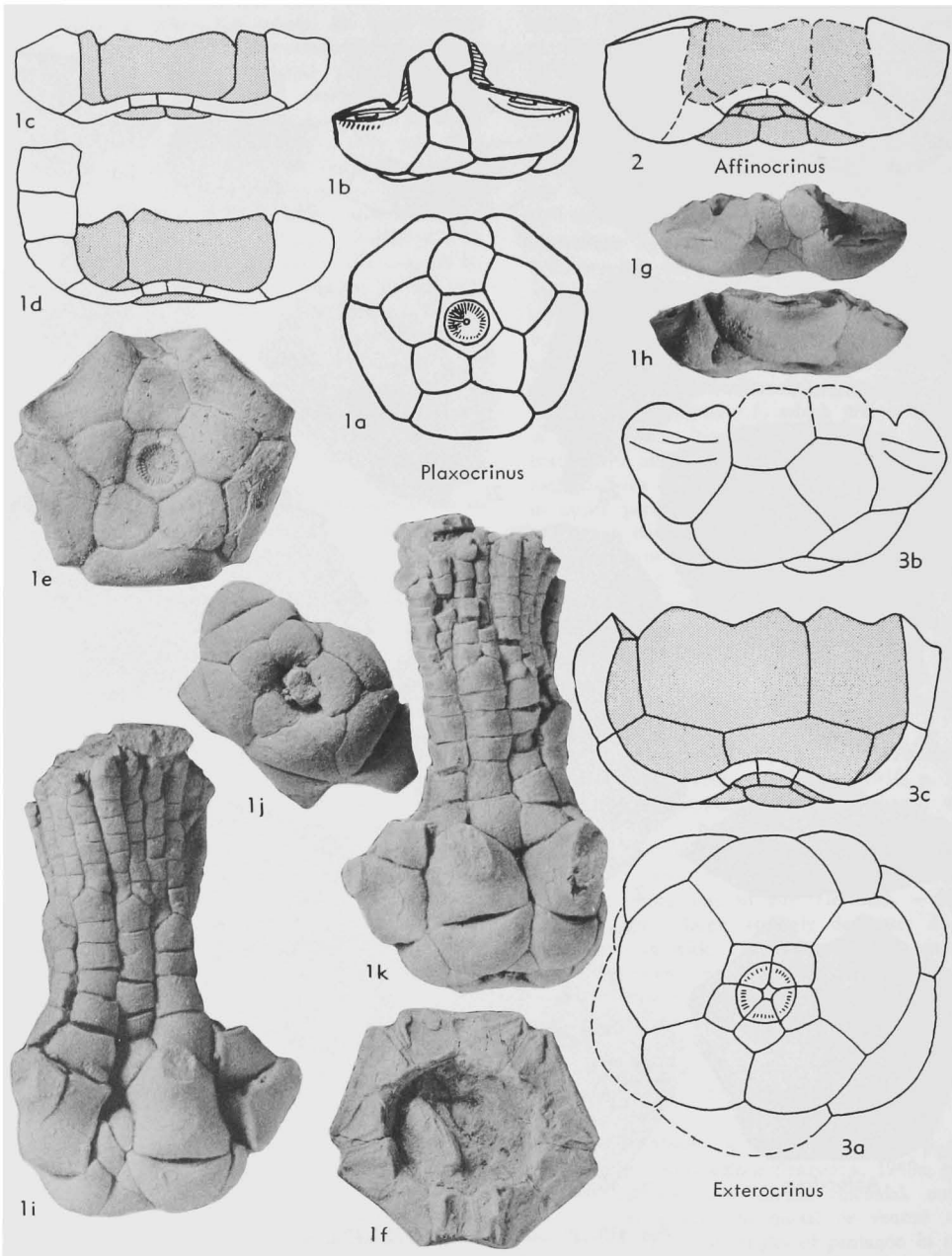


FIG. 480. Pirasocrinidae (p. T726, T731).

nearly horizontal attitude of radial facets.] *L. Penn.(Morrow.)*, USA(Okla.-Texas).——FIG. 479, *1a-c.* **L. daileyi* (STRIMPLE), Okla.; *1a,* dorsal view of cup, ×2; *1b,c,* long. secs. of cup through midlines of *A* and *D* radials; ×2 (Moore & Plummer, 1940).——FIG. 479,*1d,e. L. cornutus* MOORE & PLUMMER, Marble Falls Ls., San Saba Co., Texas; holotype, dorsal and post. views, ×2 (Moore & Plummer, 1940).

Metaffinocrinus KNAPP, 1969, p. 373 [**Plaxocrinus perundatus* MOORE & PLUMMER, 1940, p. 193; OD]. Cup low basin shaped, with shallow wide

basal concavity, proximal extremities of infrabasals and basals within concavity, those of radials in basal plane of cup (formula, − − 0), plates not tumid and sutures not impressed; interradial notches prominent; 3 anal plates in wide *CD* interray. Arms uniserial, branching isotomously on large, convexly rounded first primibrachs, secundibrachs *2*, and possibly at higher levels but unknown. Stem transversely round. *M.Penn. (Desmoines.)*, USA(Okla.-Texas).——Fig. 481,*1*. **M. perundatus* (Moore & Plummer), Millsap Lake F.(Strawn Gr.), Hood Co., Texas; *1a,b*, long. secs. of cup through midlines of *A* and *D* radials (portion of cup beyond section shaded), ×1.8; *1c-f*, dorsal, post., ant., ventral views of holotype; *1g*, post. side of paratype obliquely from below, showing proximal part of arms, all ×1.2 (Moore & Plummer, 1940).

Metaperimestocrinus Strimple, 1961, p. 37 [**M. spiniferus*; OD]. Cup low, truncate bowl shaped with mildly depressed basal area; infrabasals forming pentagonal, subhorizontal disc; proximal edges of basals within depression, only distal tips visible in side view; radials wider than long, entirely outside basal area (formula, − − +); anals usually 3 within cup, in normal arrangement (primitive type); anal sac umbrella shaped with wide summit composed of large flattened spines surrounding elliptical central area of many small plates. Arms uniserial, with axillary first primibrachs protruded as short, blunt spines, subsequent brachials externally rectangular, rounded in lower arms but rather flattened in higher ones; second bifurcation on secundibrachs *4* to *6*, which may be nodelike or bear short spine; other bifurcations on tertibrachs *7* to *10* in outer arms of each ray indicating minimum of 30 endotomous arms. Stem attachment circular in outline and crenulated. [Only closely comparable genus is *Stenopecrinus* which has a deeper and narrower basal concavity, proximal brachials extended as long slender spines, and terminating spines of anal sac less numerous.] *M.Penn.(Desmoines.)*, N.Am.(Midcontinent region).——Fig. 479,*2*. **M. spiniferus*, up.Desmoines.(Holdenville F.), near Beggs, Okla.; *2a-c*, oblique post., side, and ventral views of large paratype, ×1; *2d-f*, dorsal, ant., and post. views of small paratype, ×1; *2g-i*, dorsal, lat., and ventral views of holotype, ×1 (Strimple, n; Univ. Oklahoma OU 4015, holotype; OU 4013, paratype).

Metutharocrinus Moore & Strimple, 1973, p. 71 [**M. cockei*; OD]. Cup and median protuberances on basals as in *Utharocrinus* combined with similar protuberances on radials as in *Lasanocrinus*; 3 anal plates in narrow gently convex *CD* interray; no interradial notches. *L.Penn.(Morrow.)*, USA(Ark.-Okla.).——Fig. 482,*5*. **M. cockei*, Bloyd F., Crawford Co., Ark.; *5a-d*, holotype, dorsal, ant., post., ventral views, ×4.5 (Moore & Strimple, 1973).

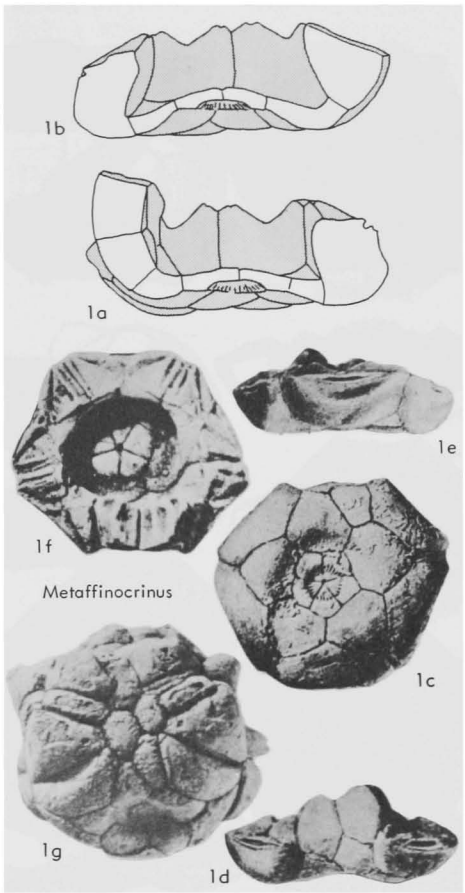


Fig. 481. Pirasocrinidae (p. *T728-T729*).

Perimestocrinus Moore & Plummer, 1938, p. 280 [**Hydreionocrinus nodulifer* Miller & Gurley, 1894b, p. 41; OD]. Crown moderately tall, cylindrical. Cup low, bowl shaped with flaring sides, base with sharply impressed concavity but shallow; infrabasals mostly small, curved by stem impression at bottom of basal concavity; basals subequal, proximally included in basal concavity but main part forming outer lower slope of cup; radials large, articular facets peneplenary, declivate, small interradial notches (formula for proximal plate extremities of cup circlets, − − +); anals 3. Anal *X* and right tube plate projecting well above summit of radials in wide *CD* interray. Arms poorly known; first primibrachs axillary, secundibrachs externally rectangular, uniserial, no branching observed above primibrachs. Stem transversely round. *M.Penn.(Desmoines.)-L.Perm.*, USA(Kans.-Mo.-Ill.-Okla.-Texas).——Fig. 436,*2*. *P. excavatus* (Weller), L.Perm.(Wolfcamp., Cibolo Ls.), Presidio Co., Texas; *2a,b*, vert. secs. of cup through midlines of *A* and *D* radials (portions of cup

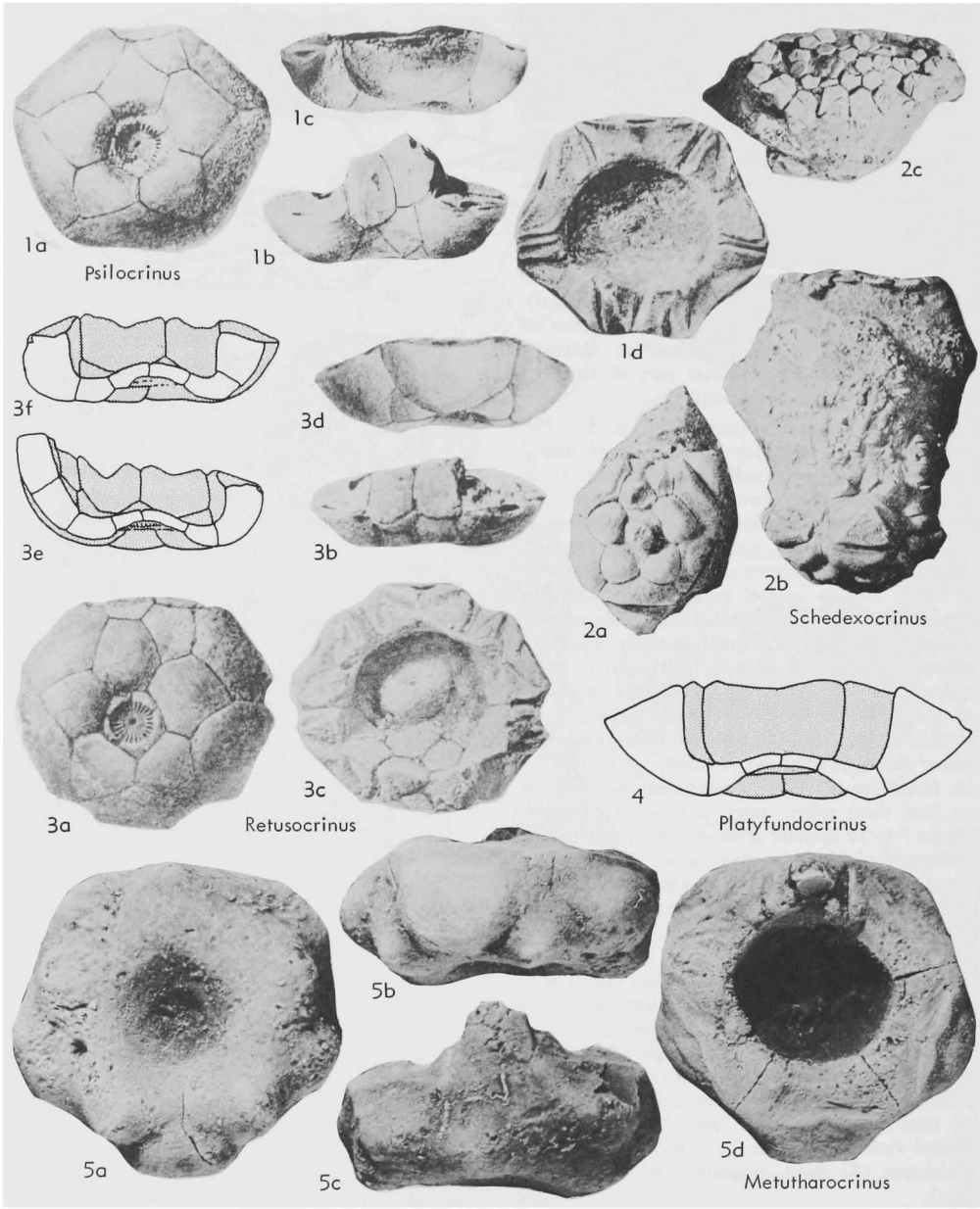


FIG. 482. Pirasocrinidae (p. T729-T732).

beyond section shaded) (Moore & Plummer, 1940, mod.).——FIG. 483,*1a-c*. **P. nodulifer* (MILLER & GURLEY), Missour.(Argentine Ls.), Kansas City, Mo.; post., ant., dorsal views, ×2 (Moore & Plummer, 1938).——FIG. 483,*1d-f*. *P. formosus* MOORE & PLUMMER, Missour.(Martins Lake Ls., Palo Pinto F.), Palo Pinto Co., Texas; dorsal, post., ventral views of cup, ×2 (Moore & Plummer, 1940).——FIG. 483,*1g-j*. *P. impressus* MOORE & PLUMMER, Desmoines.(Mineral Wells F.), Palo Pinto Co., Texas; dorsal, post., ventral, ant. views of cup, ×2 (Moore & Plummer, 1940). [=*Peremistocrinus* STRIMPLE, 1948a *(nom. null.)*.]

Platyfundocrinus KNAPP, 1969, p. 370 [**P. typus*; OD]. Similar to *Affinocrinus* except that cup plates are not tumid or sutures impressed, basal

concavity wide and shallow (proximal extremities of circlet plates −−0). *M.Penn.(Atokan)*, USA (Mo.).——Fig. 482,*4*. **P. typus*, Burgner F., Jasper Co., Mo.; long. sec. of cup through midline of *D* radial (portion of cup beyond section shaded), ×2 (Moore, n).

Plaxocrinus Moore & Plummer, 1938, p. 277 [**Hydreionocrinus crassidiscus* Miller & Gurley, 1894, p. 43; OD]. Crown moderately tall, cylindrical. Cup very low, saucerlike; with wide, shallow basal concavity; proximal extremities of infrabasals and basals within concavity, those of radials on outer side of cup above basal plane (formula, −−+); infrabasals largely covered by stem impression but not strongly depressed; basals subequal, interbasal sutures subhorizontal, distal parts of basals nearly horizontal; radials moderately convex, articular facets less than width of plates, declivate; interradial notches distinct; anal plates 3 in cup, thick, forming rather prominent protuberance at posterior side of cup. Arms branching isotomously on primibrachs *1* and secundibrachs *4-6*, axillary primibrachs spine-bearing. Stem transversely round. *M.Penn.(Atokan)-U.Penn.(Virgil.)*, N.Am.——Fig. 480,*1a-d*. **P. crassidiscus* (Miller & Gurley), U.Penn.(Missour., Argentine Ls.), Kansas City, Mo.; *1a,b*, dorsal, post. views of cup, ×1.3 (Moore, 1939c); *1c,d*, long. secs. of cup through midlines of *D* and *A* radials (portion of cup beyond section shaded), ×2 (Moore, n).——Fig. 480,*1e-h*. *P. modestus* Moore, Virgil.(Brownville Ls.), Osage Co., Okla.; dorsal, ventral, post., ant. views of cup, ×1.35 (Moore, 1939c).——Fig. 480,*1i-k*. *P. politus* Moore, U.Penn.(Barnsdall F.), Mo.; post., dorsal, ant. views of crown, ×2.7 (Moore, 1939c).

Polygonocrinus Strimple, 1961, p. 59 [**P. multiextensus*; OD]. Crown widely expanded and relatively short. Cup low, broad, truncate bowl shaped, with deep basal concavity; infrabasals forming subhorizontal disc at base of concavity; basals confined to concavity although their distal tips may be visible in side view, owing to deep, V-shaped depressions between radials; anal plates 3 (anal *X*, radianal, right tube plate) in normal primitive arrangement. Anal sac with wide summit platform higher than arms (in type species composed of 32 small, polygonal plates surrounded by 14 large, flattened, laterally directed spines). Arms as many as 70, uniserial or partly biserial, with isotomous branching, large axillary first primibrachs; secundibrachs *2* and *3* normally low and interlocking (biserial); second bifurcation usually on fourth secundibrachs, and another regular branching on about tertibrachs *10* in most rays and further branching in some rays in irregular pattern; axillary brachials above first division mildly tumid. Stem transversely round. *M. Penn.(Desmoines.)*, USA(Okla.).——Fig. 483,*2*. **P. multiextensus*, Holdenville F., Okmulgee Co., Okla.; *2a,b*, dorsal view of cup, summit of anal sac, ×0.4 (Strimple, 1961d).

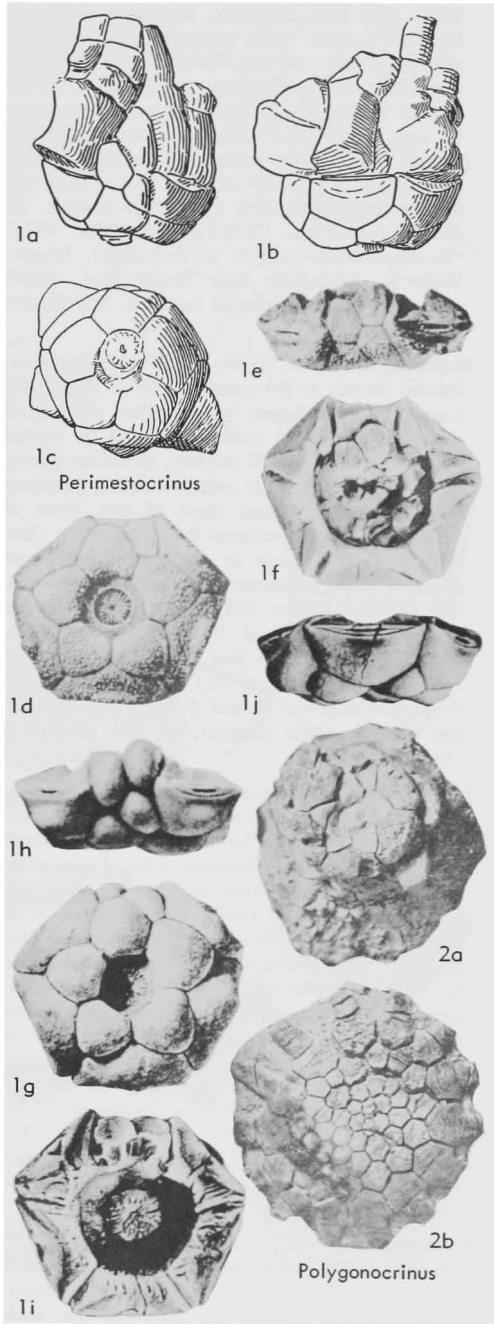


Fig. 483. Pirasocrinidae (p. *T729-T731*).

Psilocrinus KNAPP, 1969, p. 375 [**Plaxocrinus omphaloides* MOORE & PLUMMER, 1940, p. 194; OD]. Cup low, saucerlike, hexagonal outline in basal and summit views, plates smooth and sutures not impressed; narrow, shallow basal concavity containing small infrabasal circlet and proximal tips of basals, radials entirely above basal plane of cup; peneplenary articular facets on radials, narrow but distinct interradial notches; 3 large anal plates in cup, *CD* interray wide. Arms and anal sac unknown. Stem transversely circular. *M. Penn.(Desmoines.)*, USA(Texas).——FIG. 482,*1*. **P. omphaloides* (MOORE & PLUMMER), Mineral Wells F., McCulloch Co., Texas; *1a-d*, dorsal, post., ant., ventral views of holotype, ×2 (Moore & Plummer, 1940).

Retusocrinus KNAPP, 1969, p. 375 [**Plaxocrinus lobatus* MOORE & PLUMMER, 1940, p. 196; OD]. Cup low bowl shaped, with shallow wide basal concavity, hexagonal outline in dorsal or ventral view owing to wide *CD* interray, plates not tumid, interradial notches wide and prominent; proximal tips of radials in basal plane of cup, those of other plate circlets without basal concavity (formula, −−0); 3 anals in cup. Stem impression circular, arms unknown. *M.Penn.(Desmoines.)*, USA(Texas).——FIG. 482,*3*. **R. lobatus* (MOORE & PLUMMER), Mineral Wells F.(Strawn Gr.), McCulloch Co., Texas; *3a-d*, dorsal, post., ventral, ant. views of holotype; *3e,f*, long. secs. of cup through midlines of *A* and *D* radials (portion of cup beyond section shaded), all ×2 (Moore & Plummer, 1940).

Schedexocrinus STRIMPLE, 1961, p. 27 [**S. gibberellus*; OD]. Cup low, truncate, bowl shaped, with narrow, shallow basal concavity; infrabasals in bottom and basals forming sides of concavity, with distal parts of latter commonly curved upward enough to be visible in side view; wide radials with erect distal portions (formula for proximal tips of circlet plates, −−0); anal plates 3. Anal sac mushroomlike, extending above arms, summit typically composed of 15 long, flat spines directed outward and surrounding platform of about 32 small polygonal plates. Arms normally 40 or more, endotomous, uniserial or partially biserial. Stem circular. *M.Penn.(Desmoines.)*, N. Am.(Midcontinent region).——FIG. 482,*2*. **S. gibberellus*, Holdenville F., near Beggs, Okla.; *2a-c*, dorsal, ant. views of crown, and summit of anal sac (holotype), ×0.45 (Strimple, 1961d).

Sciadiocrinus MOORE & PLUMMER, 1938, p. 275 [**Zeacrinus (Hydreionocrinus) acanthophorus* MEEK & WORTHEN, 1870, p. 28; OD]. Crown short, somewhat expanded. Cup very low, with moderately deep basal concavity; similar to *Retusocrinus* except in confinement of radial proximal extremities to concavity and in having only distal tip of *CD* basal visible from side of cup, (formula, −−−); interradial notches distinct; anal sac mushroom shaped, cylindrical below, with large anal vent, summit wide and flat topped, composed of numerous small polygonal plates peripherally bordered by laterally directed marginal spines. Arms uniserial, rounded, branching isotomously, twice or more in each ray. Stem transversely round. *L.Penn.-U.Penn.(Missour.)*, N.Am.——FIG. 484,*1a-f*. **S. acanthophorus* (MEEK & WORTHEN), U.Penn.(Nodaway Ls.), Ill.; *1a,b*, dorsal, post. sides of crown (radials black), ×1.5; *1c,d*, ant. view of same showing mushroom-shaped anal sac with large opening (radials black) and widely expanded summit, ×1.5; *1e,f*, long. secs. through midlines of *A* and *D* radials (radials black) (Moore & Plummer, 1940).——FIG. 484,*1g-i*. *S. disculus* MOORE & PLUMMER, Missour.(Merriman Ls., Graford F.), Palo Pinto Co., Texas; dorsal, post., ventral views of cup, ×1.5 (Moore & Plummer, 1940).——FIG. 484,*1j,k*. *S. harrisae* MOORE & PLUMMER, Desmoines.(Millsap Lake F.), Hood Co., Texas; post., dorsal views of cup, ×1.5 (Moore & Plummer, 1940).——FIG. 484, *1l,m*. *S. confertus*, Desmoines.(Millsap Lake F.), Parker Co., Texas; summit of anal sac, arms in typical ray, ×0.75 (Moore & Plummer, 1940).

Separocrinus KNAPP, 1969, p. 382 [**Plaxocrinus praevalens* MOORE, 1939c, p. 229; OD]. Cup low bowl shaped, with narrow and shallow basal concavity, tumid plates and well-marked interradial notches, *CD* interray narrow; proximal tips of radials above basal plane, on outer side of cup, those of other plate circlets within basal concavity (formula, −−+); anal plates in cup 3; anal sac and arms unknown. Proximal columnals of stem circular. *U.Penn.(Virgil.)*, USA(Okla.).——FIG. 484,*2a-e*. **S. praevalens* (MOORE), Brownville Ls., Osage Co., Okla.; *2a-c*, dorsal view of holotype, dorsal and ventral views of primibrach spine; all ×1.5 (Moore, 1939c); *2d,e*, long. secs. through midlines of *A* and *C* radial and primibrach (portions of cup beyond section shaded), ×1.5 (Moore, 1939c).

Simocrinus KNAPP, 1969, p. 375 [**Plaxocrinus modestus* MOORE, 1939c, p. 227; OD]. Cup saucer shaped, plates not tumid; radials large, with peneplenary declivate articular facets, proximal tips on outer side of cup above basal plane, those of other plate circlets within concavity (formula, −−+); interradial notches distinct; *CD* interray narrow and depressed, containing 3 anal plates, anal *X* largest. Anal sac and arms unknown. Columnals of stem circular. *U.Penn.(Virgil.)*, USA(Okla.-Kans.).——FIG. 485,*3*. **S. modestus* (MOORE), Brownville Ls., Osage Co., Okla.; *3a-d*, dorsal, post., ventral, ant. views of holotype; *3e,f*, long. secs. of cup through midlines of *A* and *D* radials (portions of cup beyond section shaded), all ×1.5 (Moore, 1939c).

Stenopecrinus STRIMPLE, 1961, p. 40 [**Perimestocrinus planus* STRIMPLE, 1952, p. 787; OD].

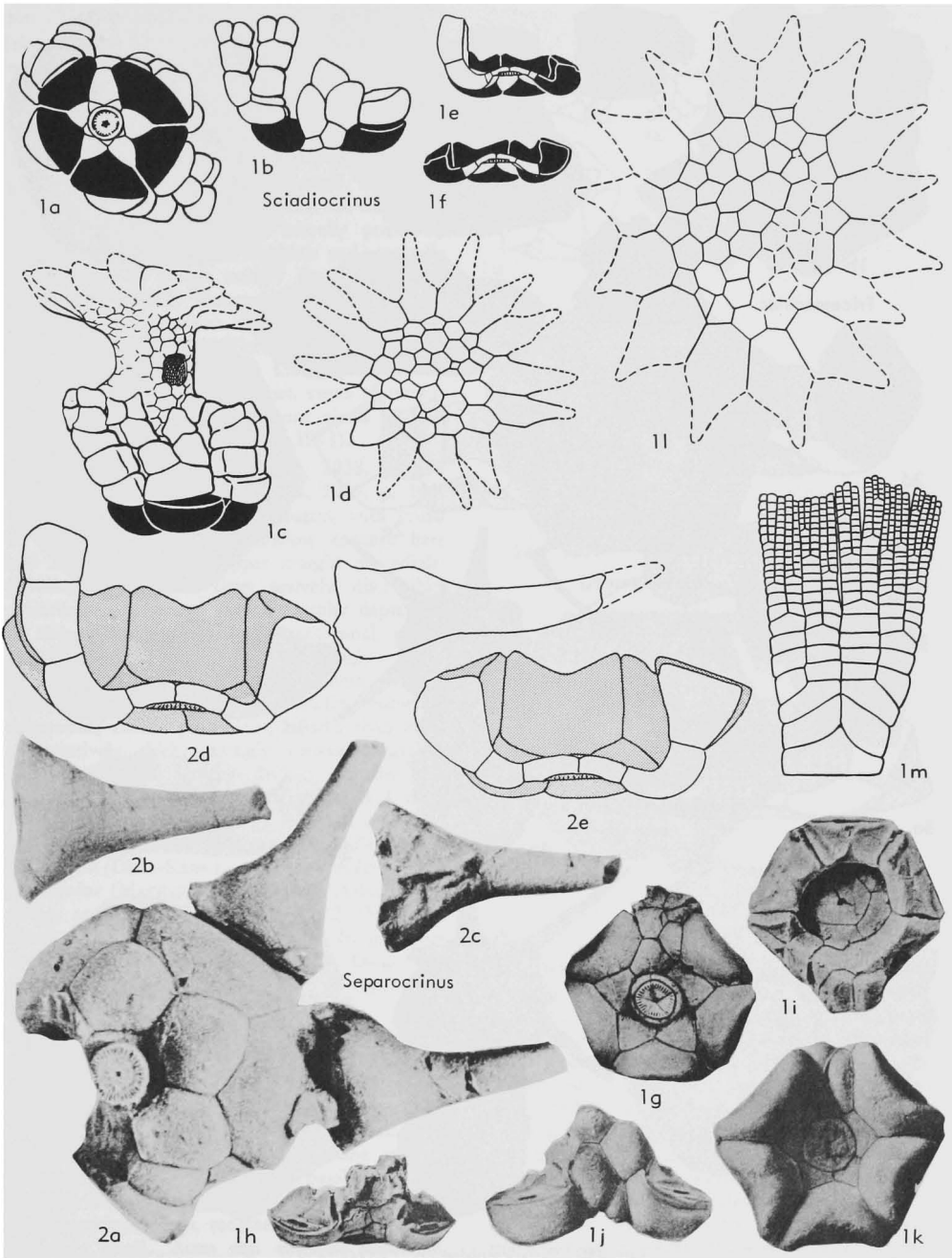


FIG. 484. Pirasocrinidae (p. T732).

Crown cylindrical, height medium. Cup low, bowl shaped, with rather deep, narrow basal concavity, plates tumid; infrabasals and proximal portions of basals restricted to concavity; large pentagonal radials with distal portions upright, and proximal extremities barely reaching basal plane of cup, notches at summit of interradial sutures not pronounced; cup anal plates 3. Anal sac with

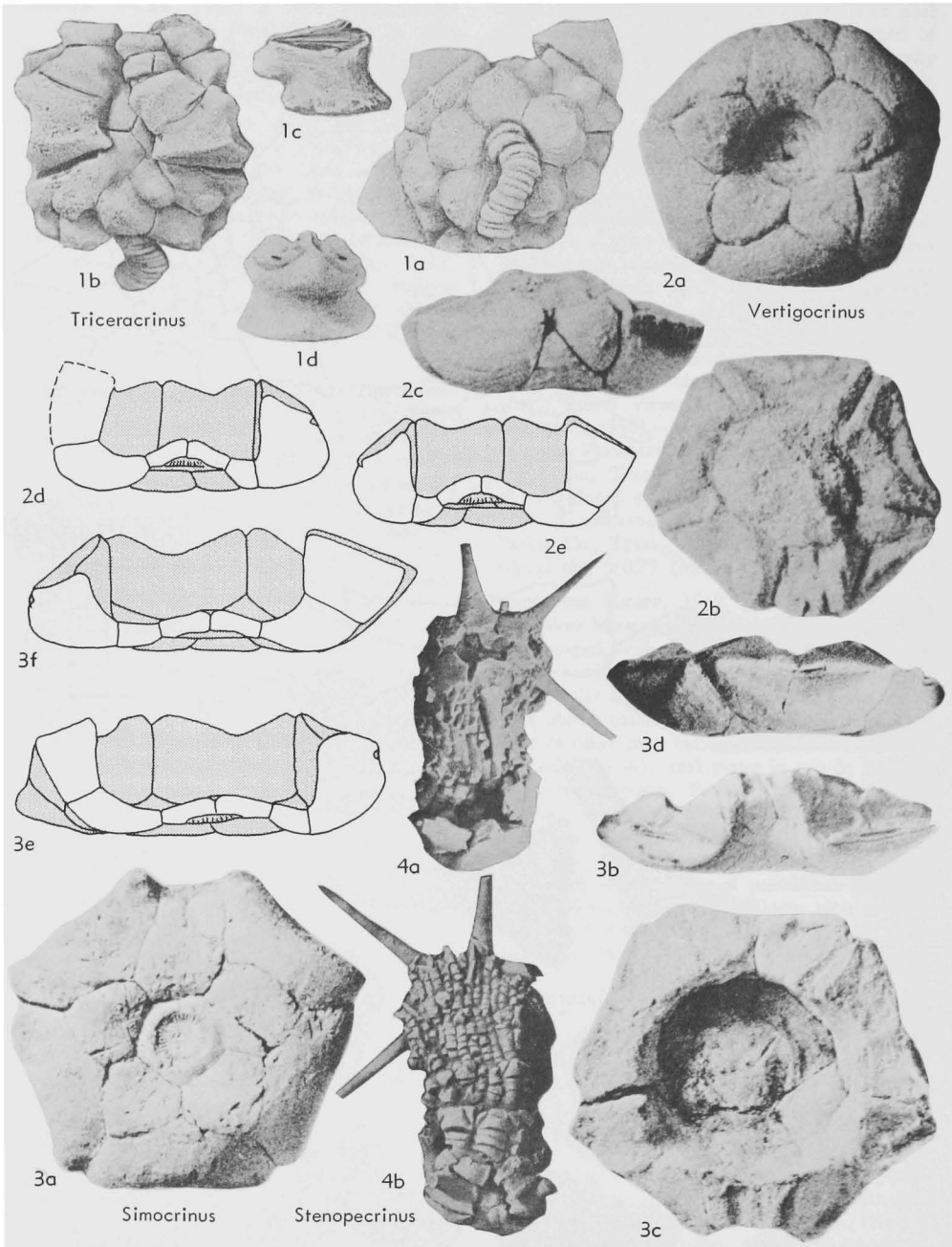


FIG. 485. Pirasocrinidae (p. *T732-T735*).

small platform at summit, bordered by very long flattened spines directed outward. Arms uniserial, endotomous, with curved exterior surfaces in distal portions, first primibrachs axillary, higher axillaries spinose. Stem transversely rounded and crenulate. *L.Penn.(Morrow.)-U.Penn.(Missour.)*, N.Am.(Midcontinent region).——FIG. 485,*4*. **S. planus* (STRIMPLE), Missour.(Barnsdall F.), Washington Co., Okla.; *4a,b*, post., ant. sides of crown

showing long terminal anal sac spines, ×1 (Strimple, 1961d).

Triceracrinus BRAMLETTE, 1943, p. 550 [**T. moorei*; OD]. Crown and cup resembling *Perimestocrinus,* but with cup plates much more protuberant; basal concavity narrow, proximal extremities of circlet plates disposed as in *Plaxocrinus* and *Perimestocrinus* (formula, − − +); with peneplenary articular facets leaving small interradial notches; anal plates in cup 3. Anal sac unknown. Arms uniserial, composed of laterally projecting longitudinally keeled thick brachials and especially characterized by robust axillary first primibrachs, which have broadly flattened lower surface next to gaping suture above radials. *L.Perm.(Wolfcamp.)-U.Perm.,* USA(Texas-Okla.-Kans.-Iowa).——FIG. 485,*1*. **T. moorei,* L.Perm., McCulloch Co., Texas; *1a,b,* dorsal and post. views of incomplete crown; *1c,d,* lat. and front views of first primibrach; all ×2 (Bramlette, 1943).

Utharocrinus MOORE & PLUMMER, 1938, p. 285 [**Delocrinus pentanodus* MATHER, 1915, p. 106; OD]. Cup small, low, basin shaped, with broad to somewhat narrow and shallow concave base and no constriction at upper margin of radials; infrabasals 5, suture lines scarcely discernible, projecting well beyond shallow circular depression of stem attachment; basals 5, pentagonal, except hexagonal *CD* basal, gently to strongly convex transversely, each plate bearing single massive subcentral horn-shaped node protruding outward-downward; radials pentagonal, broader than high, comparatively thick, strongly convex longitudinally; interradial notches distinct; narrow *CD* interray containing elongate radianal and 1 or 2 small additional plates. Arm structure and anal sac unknown. *L.Penn.(Morrow.)-U.Penn.(Virgil.),* USA(Okla.-Kans.).——FIG. 486,*1a-d*. **U. pentanodus* (MATHER), Morrow., NW.Ark.; dorsal, *D*-ray, ant., post. views of cup, ×2 (Moore & Plummer, 1938).——FIG. 486,*1e-g*. *U. quinquacutus* MOORE, Virgil.(Brownville Ls.), Osage Co., Okla.; dorsal, ventral, post. views of cup, ×2.7 (Moore, 1939c).

Vertigocrinus KNAPP, 1969, p. 377 [**Perimestocrinus subtilis* MOORE, 1939c, p. 235; OD]. Cup low, basally inverted bowl shaped with tumid plates and impressed sutures; proximal extremities of infrabasals and basals confined to basal concavity, those of radials in basal plane of cup (formula, − − 0), distal edges of basals not overhanging infrabasals; interradial notches small but clearly evident; large radianal, other 2 anals in cup very small. Arms and anal sac unknown. Stem transversely round. *U.Penn.(Virgil.),* USA (Okla.).——FIG. 485,*2*. **V. subtilis* (MOORE), Brownville Ls., Osage Co., Okla.; *2a-c,* dorsal, ventral, post. views of holotype; *2d,e,* long. secs. of cup through midlines of *A* and *D* radials (portions of cup beyond sections shaded), all ×1.5 (Moore, 1939c).

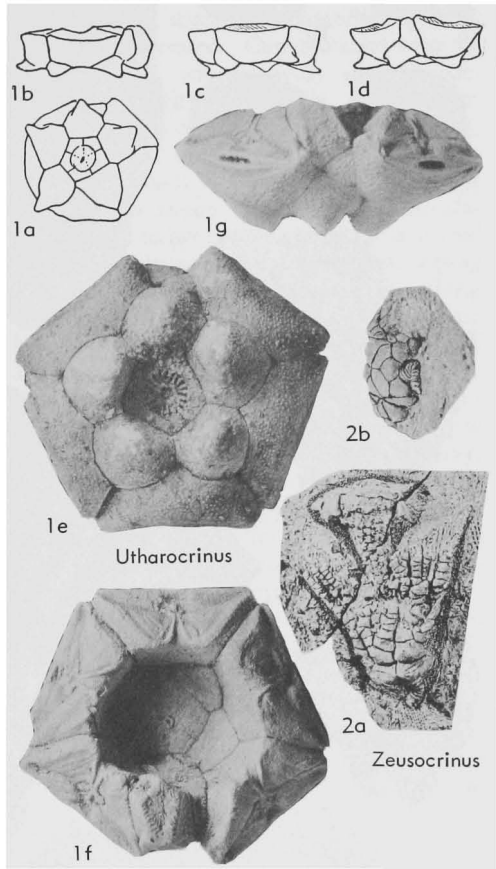


FIG. 486. Pirasocrinidae (p. T735).

Zeusocrinus STRIMPLE, 1961, p. 21 [**Tholocrinus foveatus* STRIMPLE, 1951d, p. 674; OD]. Diminutive with upflared compact crown. Cup low, bowl shaped with narrow basal concavity; infrabasals entirely obscured, within concavity; basals curving sharply out of concavity, readily visible in side view; radials wide, pentagonal, with proximal edges above basal plane of cup (formula, − − +); anal plates 3, in normal (primitive) arrangement; anal sac tall, mushroomlike, summit platform above arm tips, with circlet of horizontally directed, flat, spinose plates surrounding small polygonal plates. Arms uniserial, axillary brachials spinose, first bifurcation on primibrachs *1* and one other isotomous division known in some rays. Stem transversely round with alternating expanded columnals. *U.Miss.(Chester.),* USA (Okla.).——FIG. 486,*2*. **Z. foveatus* (STRIMPLE), near Ft. Gibson, Okla.; *2a,b, AB*-interray view of crown and cup, ×1 (Strimple, 1951d).

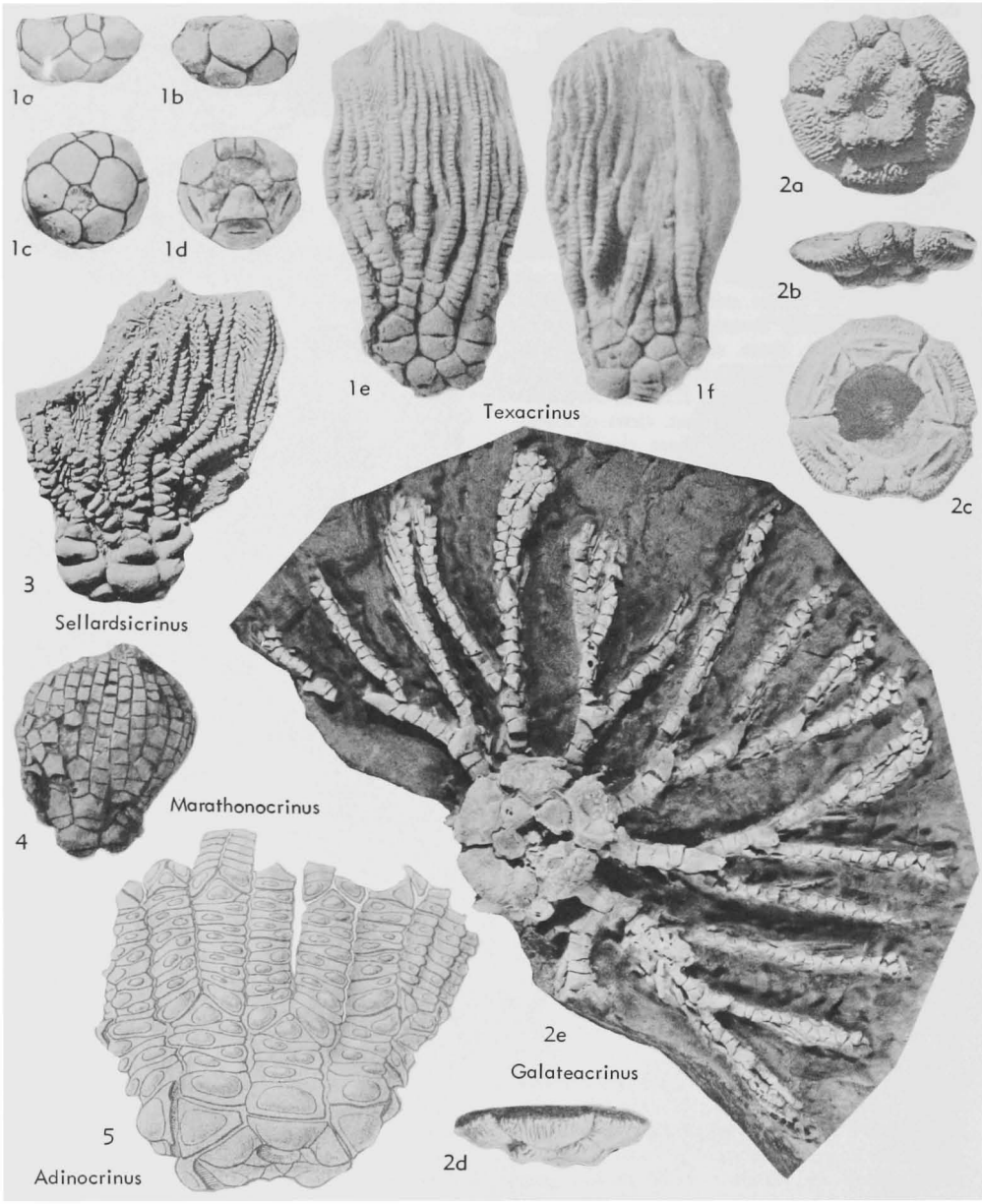


FIG. 487. Adinocrinidae *(2)*; Texacrinidae *(3,4)*; Galateacrinidae *(5)*; Sellardsicrinidae *(1)* (p. T737-T738).

Family ADINOCRINIDAE Strimple, 1961

[Adinocrinidae STRIMPLE, 1961d, p. 63]

Crown tall, expanded upward. Cup low, bowl shaped, pentagonal outline; infrabasals in wide shallow basal concavity; basals small, confined to basal concavity and separated by proximal ends of large radials; *CD* interray narrow; 3 anal plates; anal sac unknown. Primibrachs *1* axillary in all rays except *A* ray which has 5 primibrachs, arms branch twice in most rays. Column round. *L.Miss.*

The Adinocrinidae are as advanced in cup shape and structure as the Pennsylvanian (Missourian) species *Hydreionocrinus pentagonus* MILLER & GURLEY (1890), ascribed to the genus by MOORE & LAUDON, 1941. The Pennsylvanian species is considered here to belong to the pirasocrinids *(Sciadiocrinus)*; none of which are as advanced in cup structure as the adinocrinids.

Adinocrinus KIRK, 1938, p. 161 [**Zeacrinus nodosus* WACHSMUTH & SPRINGER, 1885, p. 243; OD]. Crown expanding upward, compact. Cup depressed basin shaped, small in comparison to size of crown, sharply pentagonal in outline; proximal extremities of plates in all circlets within basal concavity (formula, ---); infrabasals in bottom of concavity covered by column or slightly projecting beyond it; basals relatively very small, typically appearing as triangles separated by radials, which may touch infrabasals, *CD* basal larger than others; radials proportionally very large, with articular facets extending nearly full width of radials, suture gaping; plane of facets sloping strongly outward-downward; radianal low and narrow, meeting *CD* basal on long lateral face; anal *X* usually high in cup, separated from *CD* basal and lying on radianal, right tube plate on sloping upper right shoulder of *X*. Anal sac unknown. Arms uniserial, primibrachs 5 in anterior ray in 3 observed specimens, primibrachs *1* axillary in all other rays; branching isotomously, with 2 divisions above main dichotom; rami very stout, with rounded backs and composed mostly of externally rectangular brachials. All axillaries nodose, and proximal brachial of each series larger than succeeding ones and strongly convex to nodose; below tertaxils processes on lateral margins of brachials interlock with similar processes of juxtaposed arms. *L.Miss.(Osag.)*, USA(Ky.-Tenn.).——FIG. 487,*5*. **A. nodosus* (WACHSMUTH & SPRINGER), Keokuk, Tenn.; *A*-ray view of holotype crown, ×1 (Wachsmuth & Springer, 1886).

Superfamily TEXACRINACEA Strimple, 1961

[*nom. transl.* MOORE & STRIMPLE, 1973, p. 22 (*ex* Texacrinidae STRIMPLE, 1961d, p. 92)] [Materials for this superfamily prepared by R. C. MOORE and H. L. STRIMPLE]

Crown tall and slender, cup bowl shaped with basal concavity and steep sides near rim, arm facets plenary, one to three anals in cup, anal sac tall, composed of longitudinal rows of plates, arms long, commonly many (to 40) but five or 10 in some. *L.Miss.-U.Perm.*

Family TEXACRINIDAE Strimple, 1961

[Texacrinidae STRIMPLE, 1961d, p. 92] [incl. Texacrininae KNAPP, 1969, p. 381]

Crown tall, somewhat expanded upward, arms not appressed. Cup truncate cone or bowl shaped, usually with slightly constricted summit; infrabasals obscured in basal concavity and mostly covered by stem; five subequal, pentagonal basals except for *BC* basal which is hexagonal; five radials with length about 0.7 of width, articular facets equal to greatest width of radials; anal plates three, large radianal resting on sloping edges of *BC* and *CD* basals, also touching *CD* radial, other two plates barely reaching below summit of radials; double series of anal sac plates visible above these. Arms uniserial, branching isotomously in each ray on first primibrach, and with two or three exotomous higher divisions in each half-ray; long, slender pinnules borne by alternating brachials. [General appearance resembles *Pachylocrinus* but differs in arm structure with exotomous pattern of branching accentuated by each higher bifurcation of arms in half-rays and absence of pronounced indentations between radials.] *L.Penn.-L. Perm.*

Texacrinus MOORE & PLUMMER, 1940, p. 143 [**T. gracilis*; OD]. Characters of family. Holotype has 30 slender delicate arms with moderately long brachials. Some species have broad arms with very short brachials. *M.Penn.(Desmoines.-Missour.)-L.Perm.(Wolfcamp.)*, USA(Texas-Okla.-Nev.).——FIG. 487,*1e,f*. **T. gracilis*, M.Penn. (Millsap Lake F.), Parker Co., Texas; *3e,f*, ant., post. sides of holotype crown, ×1.5 (Moore & Plummer, 1940).——FIG. 487,*1a-d*. *T. associatus* STRIMPLE, Desmoines.(Oologah Ls.), Okla.; *1a-d*, post., ant., dorsal, ventral sides of holotype cup, ×1.5 (Strimple, 1952d).

Marathonocrinus MOORE & PLUMMER, 1940, p. 240 [**M. bakeri*; OD]. Crown pyriform. Cup apparently very low, with radials about twice as wide as long and strongly convex longitudinally; cup anal plates and anal sac unknown. Arms uniserial, pinnulate, isotomously branched on first primibrach and exotomously at higher levels. *L.Penn. (?Morrow.-Bend.)*, USA(Texas).——FIG. 487,*4*. **M. bakeri*; side view of crown, ×1 (Moore & Plummer, 1940).

Family GALATEACRINIDAE Knapp, 1969

[*nom. transl.* MOORE & STRIMPLE, 1973, p. 22 (*ex* Galateacrininae KNAPP, 1969, p. 382)]

Crown low, outspread laterally, with numerous, well-separated, cuneate uniserial arms, which are pinnulate. Cup discoid, mainly characterized by broadly flangelike nature of radials, infrabasals in concavity surrounded by bulbous basals, not visible from side. Stem transversely circular. *M. Penn.(Desmoines.)-U.Penn.(Virgil.).*

Galateacrinus MOORE, 1940, p. 45 [**G. stevensi*; OD]. Radials projecting laterally very prominently with interradial notches, rather sharply separated from basals, which are tangent to basal plane of cup at about their midlength. Radials extremely convex in longitudinal profile, their proximal and distal areas nearly horizontal, articular facets subhorizontal, short, distinctly narrower than greatest width of radials, but with ends of neighboring transverse ridges almost touching. Three anal plates in cup, radianal obliquely above *CD* basal and supporting large *X* plate, which also rests on *CD* basal; anal sac unknown. Arms with axillary first primibrachs in all rays, 30 or 40 endotomous arms present, brachials cuneate uniserial. Stem round transversely. *M.Penn.(Desmoines.)-U.Penn.(Virgil.)*, USA(Kans.-Okla.-Texas-Iowa-Neb.).——FIG. 487,*2a-d*. **G. stevensi*, Desmoines.(Oologah Ls.), NE.Okla.; *2a-d*, dorsal (*CD* interray up), post., ventral (*CD* interray down), and ant. views of holotype, ×2 (Moore, 1940a).——FIG. 487,*2e*. *G. ornatus* STRIMPLE & MOORE, Missour. (Francis Sh.), near Ada, Okla.; hypotype crown (*A* ray directed upward), ×2 (Strimple & Moore, 1971b).

Family SELLARDSICRINIDAE Strimple & Watkins, 1969

[Sellardsicrinidae STRIMPLE & WATKINS, 1969, p. 169]

Crown elongate. Cup low, truncate bowl shaped with slight basal concavity; plates tumid, sutures impressed; five infrabasals confined to concavity; large basals; prominent radials, with subhorizontal articular facets less than full summit width of radials, moderately short and lacking distinct flangelike inward extension; three large anal plates in normal (primitive) position followed by two series of prominent anal sac plates. Arms 40, biserial, pinnulate, with rounded exteriors, not appressed, unusually slender except for proximal brachials; three isotomous branchings, first on large, low primibrachs *1*, second on secundibrachs *3-10*, and third high in crown. *M.Penn.(Desmoines.)*.

Sellardsicrinus MOORE & PLUMMER, 1940, p. 357 [**S. marrsae*; OD]. Characters of family. *M. Penn.(Desmoines.)*, USA(Texas).——FIG. 487,*3*. **S. marrsae*, Millsap Lake F., Parker Co., Texas; side view of holotype crown, ×1 (Moore & Plummer, 1940).

Family CYMBIOCRINIDAE Strimple & Watkins, 1969

[Cymbiocrinidae STRIMPLE & WATKINS, 1969, p. 188]

Cup ranging from basally impressed bowl of medium height to very low with deep basal invagination; five infrabasals usually confined to basal concavity; five large to small basals; five medium to large radials, with articular facets filling width of these plates, sloping inward and short (except *Aesiocrinus* which has relatively long facets); one anal plate in line with radials normally extended above cup summit (except *Aenigmocrinus* which has two subequal anal plates on *CD* basal), followed by two tube plates or by single tube plate in some later forms. Anal tube slender and recurved in older forms but usually long and straight in later ones. Arms mostly ten, but may be five *(Allosocrinus)*, uniserial, primibrachs 2 normally axillary (primibrachs *1* and *2* may fuse in later forms), brachials may be cuneate, and syzygial pairs are not uncommon. Column transversely subpentagonal to pentagonal, or may become round. *U.Miss.-U.Penn.*

Key to Genera of Cymbiocrinidae

A. Cup large, bowl shaped, broad basal concavity .....
  I. Ten large arms, primibrachs 2 axillary, radianal followed by one tube plate .... *Proallosocrinus*
  II. Five large arms, brachials include many syzygial pairs ..... *Allosocrinus*

B. Cup medium, bowl shaped, anal plate followed by two tube plates .....
  I. Ten narrow, elongated, pinnulated arms, no syzygial paired brachials except for the two primibrachs ..... *Aesiocrinus*
  II. Same as BI except hyperpinnulated (one pinnule on each side of a brachial).... ..... *Paracymbiocrinus*

C. Cup shallow, saucer shaped .....
  I. *CD* basal followed by two equidimensional anal plates ..... *Aenigmocrinus*
  II. Large radianal in *CD* position followed by two tube plates which extend slightly below cup summit ..... *Cymbiocrinus*

D. Cup shallow, essentially discoid; primibrachs 2 axillary .....

I. Anal plate (radianal) followed by three tube plates, some arms hypertrophied .. .. *Lecobasicrinus*

II. Radianal narrow, followed by one tube plate ..... *Oklahomacrinus*

Cymbiocrinus KIRK, 1944, p. 233 [**C. romingeri*; OD]. Crown compact, subcylindrical. Cup shallow, patelliform or basin shaped, with flattened base; plates typically thick and convex; infrabasals small, lying within basal pit but usually extending well beyond column; basals relatively small, mostly lying within flattened base, but distal portions curving upward and clearly visible in lateral view, posterior basal truncate, usually supporting single anal (radianal) on its distal face, but in type species followed by 2 or 3 sac plates; radials very large, forming major part of cup, with strong sharply defined fulcral ridge extending full width of plates and dorsal ligament fossae narrow but distinct, large ligament pits cutting into and under fulcral ridge, pair of small, interarticular ligament fossae and pair of large muscle fields separated by intermuscular furrow. Anal sac formed by many small thin plates. Arms relatively short, composed of 2 stout primibrachs constricted medially, union of brachials strong, approaching anchylosis, except in earlier species (St. Louis and Ste. Genevieve), which have much looser union, junction of radials and primibrachs linear and gaping, first 2 secundibrachs closely united, appearing in some specimens as high, completely fused unit although sutures are clearly visible, especially in weathered juvenile specimens; distalward brachials have sloping articular faces, long pinnules of successive brachials or syzygial brachial pairs alternately on opposite sides. Stem transversely circular or subpentagonal with pentagonal lumen, unusually slender and weak, bearing whorls of short, slender cirri. *U.Miss.(Chester.)*, USA(Mo.-Ill.-Ala.-Ky.-Okla.); *L.Penn.(Morrow.)*, USA(Texas).——FIG. 488,*1a-c*. **C. romingeri*, U.Miss.(Ste. Genevieve Ls.), near Huntsville, Ala.; *BC* interray view of crown, dorsal and post. views of cup, ×1.5 (Kirk, 1944e).——FIG. 488,*1d,e*. *C. contentus* STRIMPLE & WATKINS, L.Penn.(Marble Falls F.), Espey Creek, San Saba Co., Texas; *C*-ray, *DE*-interray views of holotype crown, ×1.3 (Strimple & Watkins, 1969).

Aenigmocrinus STRIMPLE, 1973, p. 16 [**Poteriocrinus anomalus* WETHERBY, 1880b, p. 158 (*nom. correct.* STRIMPLE, 1973c, *pro P. anomalos* WETHERBY, 1880b); OD]. Crown rather compact but arms not abutting each other. Cup very shallow, basin shaped, with broad base containing small invagination; infrabasals small and mostly covered by stem; basals small and confined to basal concavity except *CD* basal which is exceptionally large, its distal apex almost reaching cup summit; radials large, with proximal ends entering basal plane of cup; 2 subequal plates on *CD* basal extending well above cup (plate at left may be termed anal *X* and that at right radianal, although the arrangement is rather unique); cup anal plates followed above by 2 series of tube plates; anal sac 0.8 or more height of arms, recurved, with large flattened, stout spines at summit. Arms 9 or 10, depending on whether anterior ray branches, stout, with well-rounded exteriors; primibrach 2 axillary in all except *A* ray which may branch on primibrach 6-7 or remain unbranched, brachials other than axillaries outwardly cuneate with constricted midsections, long sides bearing stout pinnules. Column round or subpentagonal. *U. Miss.(mid.Chester.)*, USA(Ill. basin).——FIG. 489, *1. *A. anomalus* (WETHERBY), Fraileys F., Ill.; *1a,b*, ant. view showing large, recurved anal sac, and ant. view with large plates of distal termination of anal sac, ×4 (Strimple, 1973c).

Aesiocrinus MILLER & GURLEY, 1890, p. 14 [**A. magnificus*; SD BASSLER, 1938, p. 34] [=*Pentadelocrinus* STRIMPLE, 1939a, p. 11 (type, *P. twinensis*; OD); *Phyalocrinus* TRAUTSCHOLD, 1870, p. 7 (*nom. nud.*); *Phialocrinus* TRAUTSCHOLD, 1879, p. 14 (type, *P. patens*; M) (*non* EICHWALD, 1856)]. Low bowl shaped cup with shallowly concave or planate base; radial facets wide, relatively long, with articular facets sloping downward-inward; radianal typically large, extending above cup summit and followed by 2 sac plates. Anal sac tall, tapering upward near summit, composed of vertical rows of rugose hexagonal plates with prominent pore slits, anus at distal end. Arms 10, long slender, with well-rounded exteriors, short nearly rectilinear pinnules. Stem transversely pentagonal. *L.Penn.(Morrow.)-U.Penn.(Missour.-Virgil.)*, USA(Mo.-Kans.-Okla.-Utah); *M.Carb.*, USSR.——FIG. 488,*2a,b*. **A. magnificus*, U.Penn.(Missour., Lane Sh.), Kansas City, Mo.; *2a*, side view of cup and anal sac, ×1 (Strimple, n); *2b*, crown showing oblique side view of crown from left (*D* ray), pinnulate outspread arms, rugose anal sac, and part of attached cirriferous stem (radials black, anal plates stippled), ×1 (Moore, 1952).——FIG. 488,*2c-h*. *A. dilatatus* MOORE, U.Penn.(Virgil., Brownville Ls.), Osage Co., Okla.; *2c*, drawing showing cross section of cup (portions beyond section shaded), *2d-h*, drawing of *A* radial plate (holotype), ext., int., summit, side and median section, all ×2.5 (Moore, 1939c).——FIG. 488,*2i*. *A. secundus* WASHBURN, L.Penn.(Morrow., Oquirrh F.), Utah; post. view of crown, ×1.4 (Washburn, 1968).

[WASHBURN (1968) described *Aesiocrinus secundus* based on a large specimen with an abraded base. In the same paper he proposed *Cymbiocrinus anatonus* and *C. cuneatus* for somewhat smaller specimens with better-preserved cups having a definite basal concavity. *C. anatonus* and *C. cuneatus* are considered here to be conspecific with *A. secundus*, and are thought to be progenitors of *Allosocrinus*.]

Allosocrinus STRIMPLE, 1949, p. 18 [**A. bronaughi*; OD]. Cup medium sized bowl shaped, with small deep basal concavity, basals large; anal plate

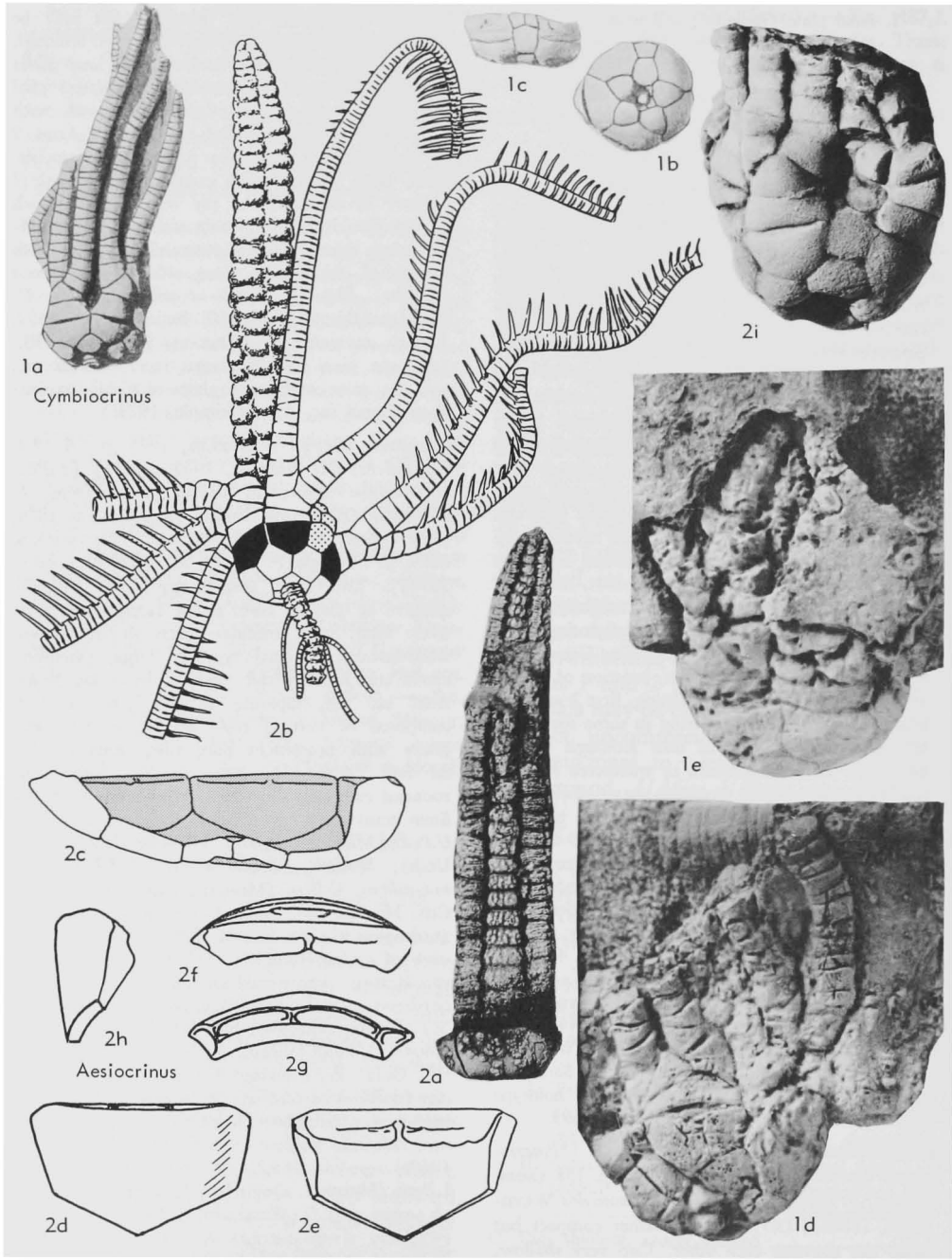


FIG. 488. Cymbiocrinidae (p. T739).

medium, followed by 2 sac plates. Arms 5, brachials cuneate, syzygially paired brachials common. Column may be transversely subpentagonal at cup but otherwise essentially round. *M.Penn.(Desmoines.)-U.Penn.(Missour.)*, USA(Okla.-Ill.).——

FIG. 490,2. **A. bronaughi; 2a-d*, U.Penn., Missour., Wann F., near Bartlesville, Okla.; holotype from dorsal, ventral, *B*-ray, and post. sides, ×1.5 (Strimple, 1949e); *2e*, LaSalle Ls., near Pontiac, Livingston Co., Ill.; hypotype crown, ×1.4 (Strim-

ple & Moore, 1971a).

Lecobasicrinus Strimple & Watkins, 1969, p. 191 [**L. kickapooensis*; OD]. Crown very tall, cylindrical. Cup shallow bowl shaped with flat to faintly concave base, small infrabasals mostly covered by stem; small basals subtriangular (except distally truncate *CD* basal) barely meeting neighbors so as to separate radials from infrabasals; large radianal only plate in interray. Anal sac unknown. Ten recti-uniserial pinnulate arms; isotomously branched in each ray on primibrachs 2. *M.Penn.(Atokan)-U.Penn.(Virgil.)*, USA(Texas-Kans.-Nebr.).——Fig. 490,*1*. **L. kickapooensis*, Desmoines.(Millsap Lake F.), Hood Co., Texas; *1a,b*, ant. and post. views of holotype crown, ×1.2 (Strimple & Watkins, 1969).

Oklahomacrinus Moore, 1939, p. 255 [**O. supinus*; OD]. Cup extremely depressed, consisting of nearly flat, straight-sided pentagonal disc with hollowed base; infrabasals forming slightly stellate pentagon in deepest part of basal concavity, distal portions flaring outward-downward, circlet appearing as cone on interior of cup that in some specimens is distinctly higher than radial facets; basals subequal and hexagonal in outline, except *CD* basal which is heptagonal, proximal portion of these plates flaring strongly outward-downward, distal tips visible in side view. Radials essentially horizontal, subequal pentagonal plates with midportions tangent to basal plane of cup; single quadrangular anal plate much longer than wide between posterior radials resting on truncated extremity of *CD* basal. Anal sac tubular, composed of plate rows with respiratory pores along sutures. Arms 10, curving outward and downward from nearly flat cup, composed of uniserial brachials with wide, short, quadrangular primibrachs *1* in each ray followed by triangular axillary primibrachs *2*, these plates joined by nearly immovable sutures and evidently forming a single functional unit commonly found attached to one another and cup; secundibrachs somewhat trapezoidal or rectangular in external view and arranged in structural pairs with smooth articular surfaces between members of pairs, whereas joints between successive pairs are marked by transverse ridges, ligament pits, and muscle areas. Radial articular facets plenary, with transverse strong ridge on outer margin of facets, outer ligament area deeply excavated and in subvertical position, inner ligament area short and gently declivate. Stem composed of thin subpentagonal columnals, heteromorphic, cirriferous. *M.Penn.(Desmoines.)-U.Penn.(Virgil.)*, USA(Okla.-Kans.-Texas).——Fig. 491, *1a-c*. **O. supinus*, Virgil.(Brownville Ls.), west of Strohm, Osage Co., Okla.; *1a,b*, dorsal and ventral views of holotype (*A* ray downward in *1a*, upward in *1b*), ×2; *1c*, oblique view of exterior from *B*-ray side, ×1.5 (Moore, 1939c).——Fig. 491,*1d-f*. *O. loeblichi* Moore, Missour. (Francis Sh.), Ada, Pontotoc Co., Okla.; *1d,e*,

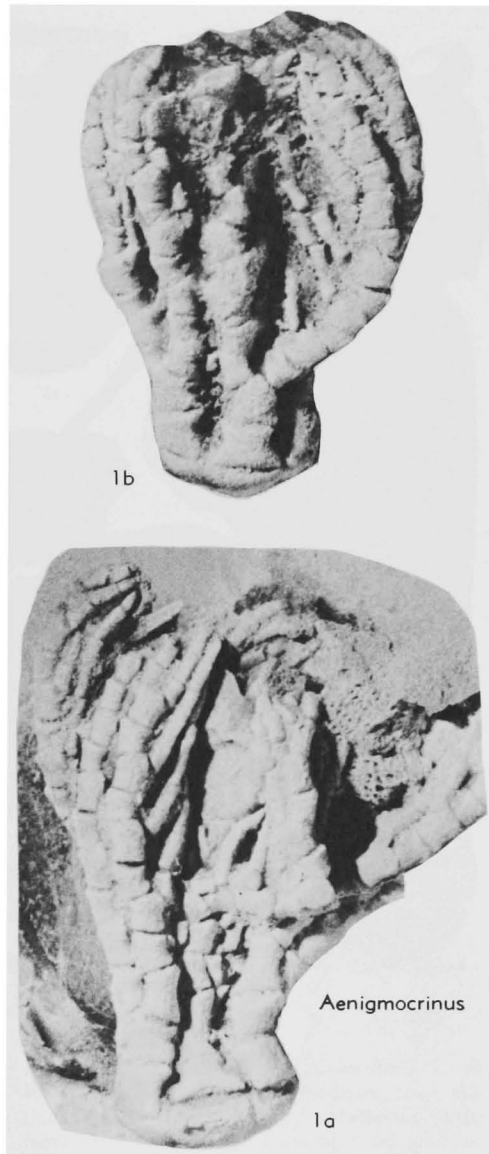


Fig. 489. Cymbiocrinidae (p. T739).

holotype from dorsal side (*A* ray downward), ×2, and oblique side view from below (*E* ray at right), ×1.5 (Moore, 1939c); *1f*, long. sec. of holotype cup (*A* ray at right), ×2 (Moore, 1939c).——Fig. 491,*1g-k*. *O. loeblichi* Moore(?); dissociated radial plate from outer, inner, upper, lower, and left sides, ×1.9 (Moore, 1939c).

Paracymbiocrinus Burdick & Strimple, 1973, p. 239 [**P. ormondi*, p. 240; OD]. Cup low bowl shaped with shallow basal invagination, plate sutures slightly impressed. Infrabasals small, down-

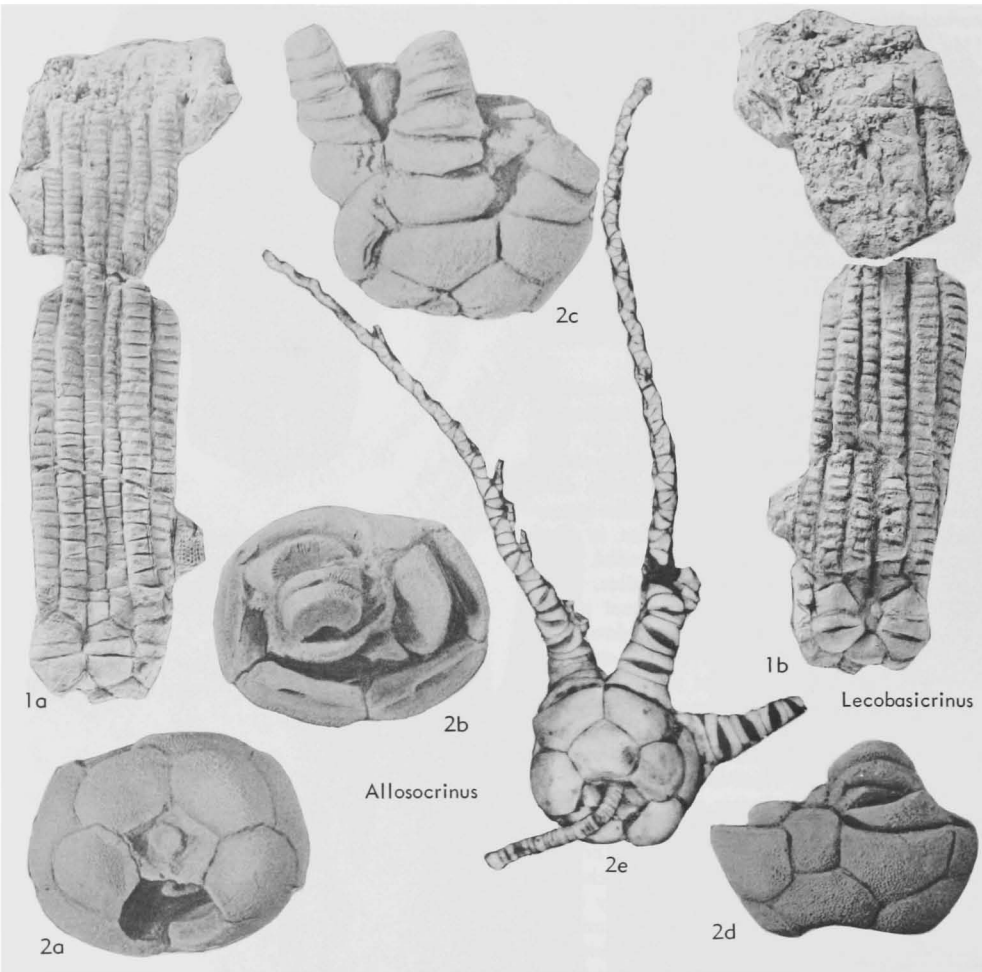


FIG. 490. Cymbiocrinidae (p. T739-T741).

flared, confined to basal concavity; basals large, *CD* basal truncated for reception of single anal plate; radials large with proximal ends almost reaching basal plane, articular facets wide; anal plate extends slightly above cup summit and is faceted for 2 tube plates, the larger one being to the right. Arms moderately long (10 times height of cup), dividing on primibrach 2; secundibrachs quadrangular when viewed from exterior and bearing a pinnule on each side of ambulacral groove. Column pentagonal. *U.Miss.(up.Chester.)*, USA(Okla.-Ark.).——FIG. 492,*1*. **P. ormondi*, Ark.; *1a-c*, basal, post., ant. views of crown, ×2.7 (Burdick & Strimple, 1973b).

Proallosocrinus MOORE & STRIMPLE, 1973, p. 77 [**P. glenisteri*; OD]. Like *Allosocrinus* but transversely nearly circular arms more robust and shorter, composed of thin wide brachials. Arms 10, branching isotomously on primibrachs 2, pinnulate. *L.Penn.(Morrow.)*, USA(Okla.).—— FIG. 491,*2*. **P. glenisteri*, Gene Autry F., Carter Co., Okla.; *2a,b*, post. and dorsal views of holotype crown, ×1.5; *2c-e*, articular surface of secundibrach, lat. and ventral views of radial, ×3 (Moore & Strimple, 1973a).

Family STAPHYLOCRINIDAE Moore & Strimple, 1973

[Staphylocrinidae MOORE & STRIMPLE, 1973, p. 31]

Crown tall, slender; cup bowl shaped, with basal concavity or exceptionally with fused infrabasal circlet gently convex and visible from side, arm facets plenary, uni-

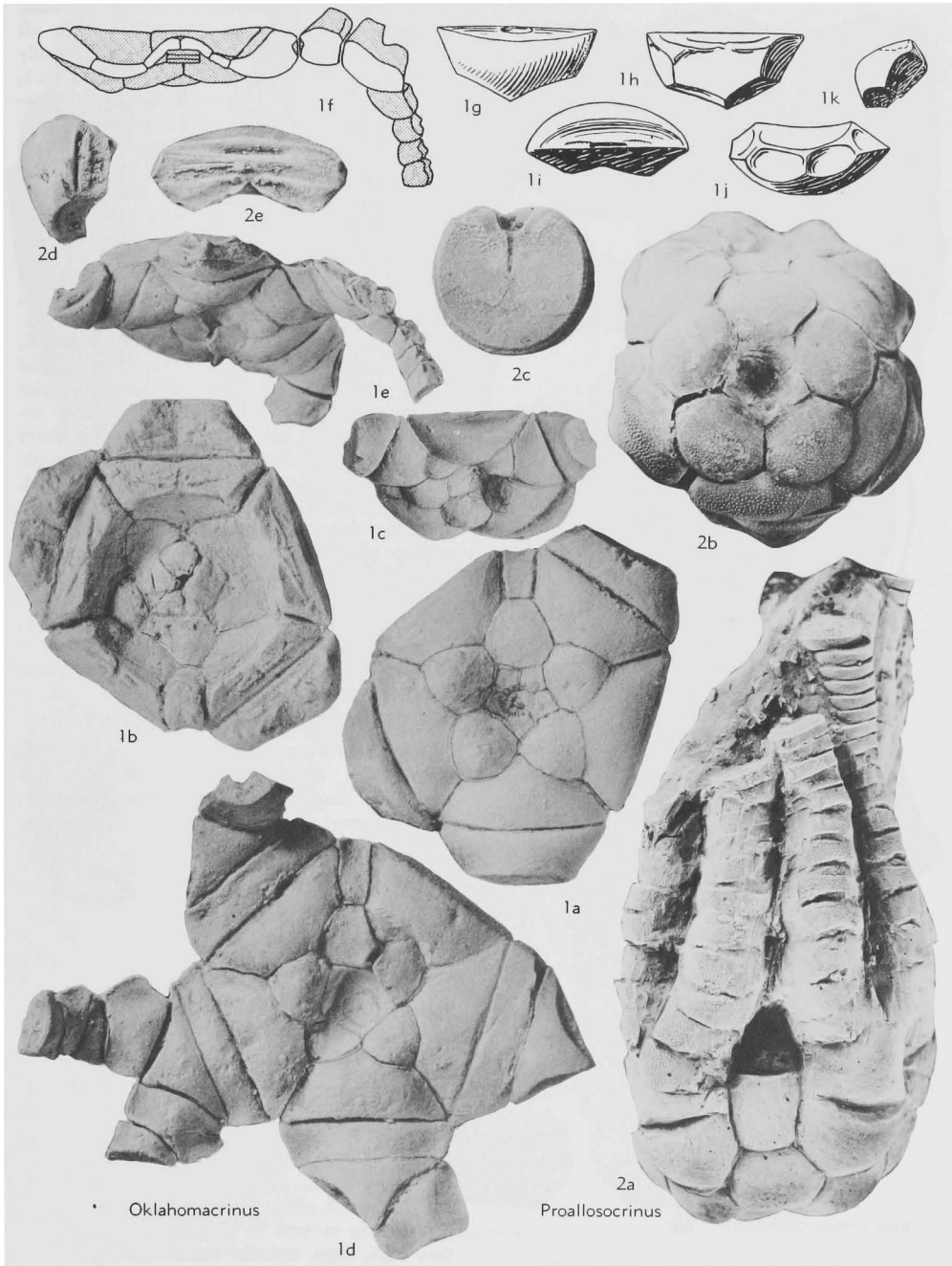


FIG. 491. Cymbiocrinidae (p. T741-T742).

serial arms 20 to 80 or more, two to three anals in cup. *L.Miss.-U.Miss.; M.Penn.-U. Perm.*

Staphylocrinus BURDICK & STRIMPLE, 1969, p. 9 [**S. bulgeri*; OD]. Cup bowl shaped, medium in height, composed of very thick tumid plates with tumidity extending to their margins, sutures

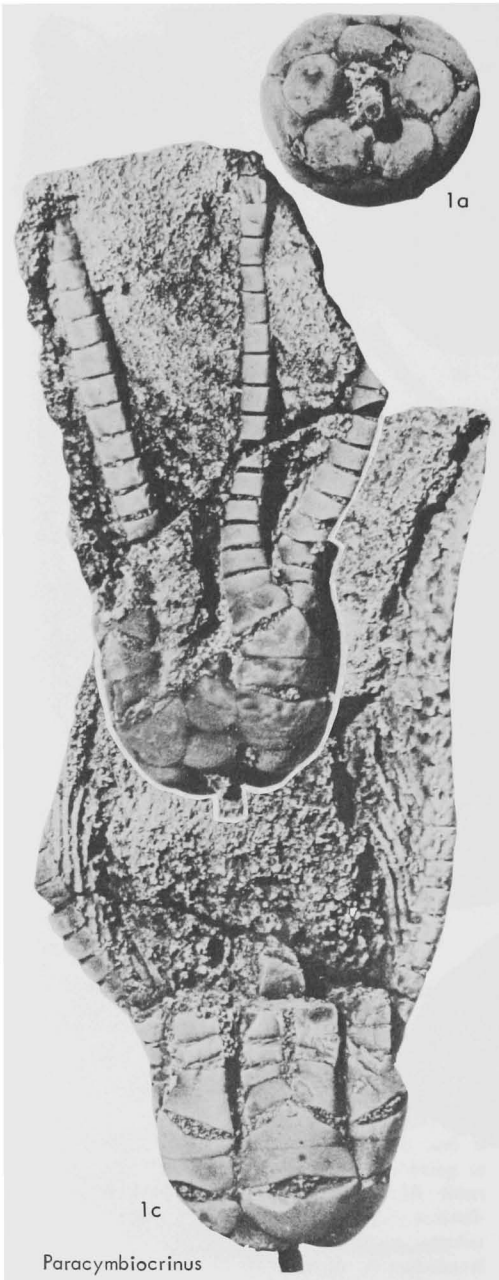


FIG. 492. Cymbiocrinidae (p. T741-T742).

impressed; infrabasal circlet fused in adults, visible from side as low element smoothly rounded below except for small central concavity marking attachment of vanished stem; 5 infrabasals separate in juvenile individuals; 3 thick, tumid anals in cup. Arms uniserial, composed of stout low brachials, branching isotomously on primibrachs *1* in all rays and again on axillary secundibrachs, generally secundibrach *6*. *U.Miss.(Chester.)*, USA(Ala.). ——FIG. 493,*4*. **S. bulgeri*, Monteagle Ls.(Gasper); *4a,b*, *CD*-interray view of paratype and *AB*-interray view of holotype obliquely from below, ×0.8; *4c*, diagram vertical sec. of cup (portions of cup beyond section shaded), *A* radial at upper left, ×0.8 (all Burdick & Strimple, 1969).

Abrotocrinus MILLER & GURLEY, 1890, p. 30 [**A. cymosus* (=*Scaphiocrinus unicus* HALL, 1861a, p. 313); OD]. Crown tall, subcylindrical. Cup low, bowl shaped; infrabasals 5, within shallow concavity; basals prominent in side view; radials 5, larger than basals, proximal ends well above basal plane, distal portion flared outward; posterior interray wide, anals 3 in normal (primitive) arrangement. Anal sac cylindrical, reaching above arm tips, composed of small plates and culminating at top in one or more spines. Arms uniserial, bifurcating twice or more, pinnulate, primibrachs *1* axillary in all except anterior ray which has axillary primibrach *2*, brachials cuneate, rounded exteriors. Column obscurely pentagonal in section next to cup, becoming round below. *L.Miss. (Keokuk)*, USA(Ind.-Ill.-Iowa-Ala.).——FIG. 493, *1*. **A. unicus* (HALL), Keokuk, Ind.; *1a*, *E*-ray view of crown and attached part of pentagonal stem, ×1 (Springer, 1926b); *1b*, *?E*-ray view of crown and stem, ×0.7 (Miller & Gurley, 1890).

Agnostocrinus WEBSTER & LANE, 1967, p. 15 [**A. typus*; OD]. Crown moderately tall cylindrical. Cup bowl shaped with shallow basal concavity, plates bulging; radial articular facets peneplenary, sutures beneath primibrachs gaping; one large tumid anal plate. Anal tube long, extending above summit of arms, cylindrical and narrow. Arms 16, uniserial, branching isotomously on first primibrachs in all rays and on first secundibrachs in *A*, *C* and *D* rays only. *L.Perm.-U.Perm.*, USA (Nev.-Texas).——FIG. 494,*2*. **A. typus*, Bird Springs F., Nev.; *2a,b*, holotype crown from ant. *(EA)* and post. sides (*D* ray at left), ×1 (Webster & Lane, 1967).

Dinotocrinus KIRK, 1941, p. 513 [**D. compactus*; OD]. Crown subcylindrical, expanding slightly to about 0.5 of its height, then contracting. Cup broadly truncate low conical with basal depression; infrabasals small, fused into entirely concealed flat pentagonal plate; basals large, forming lower part of cup as seen in side view; radials wider than high, large, articular facets linear, occupying full width of radials; anal plates in cup 3, radianal large, entering deeply between *CD* and *BC* basals, anal *X* and right tube plate small, but extending above radials. Anal sac slender, reflexed. Arms uniserial, relatively short and stout, branching isotomously on primibrach *1* in each ray, typically one isotomous division well above main dichotom;

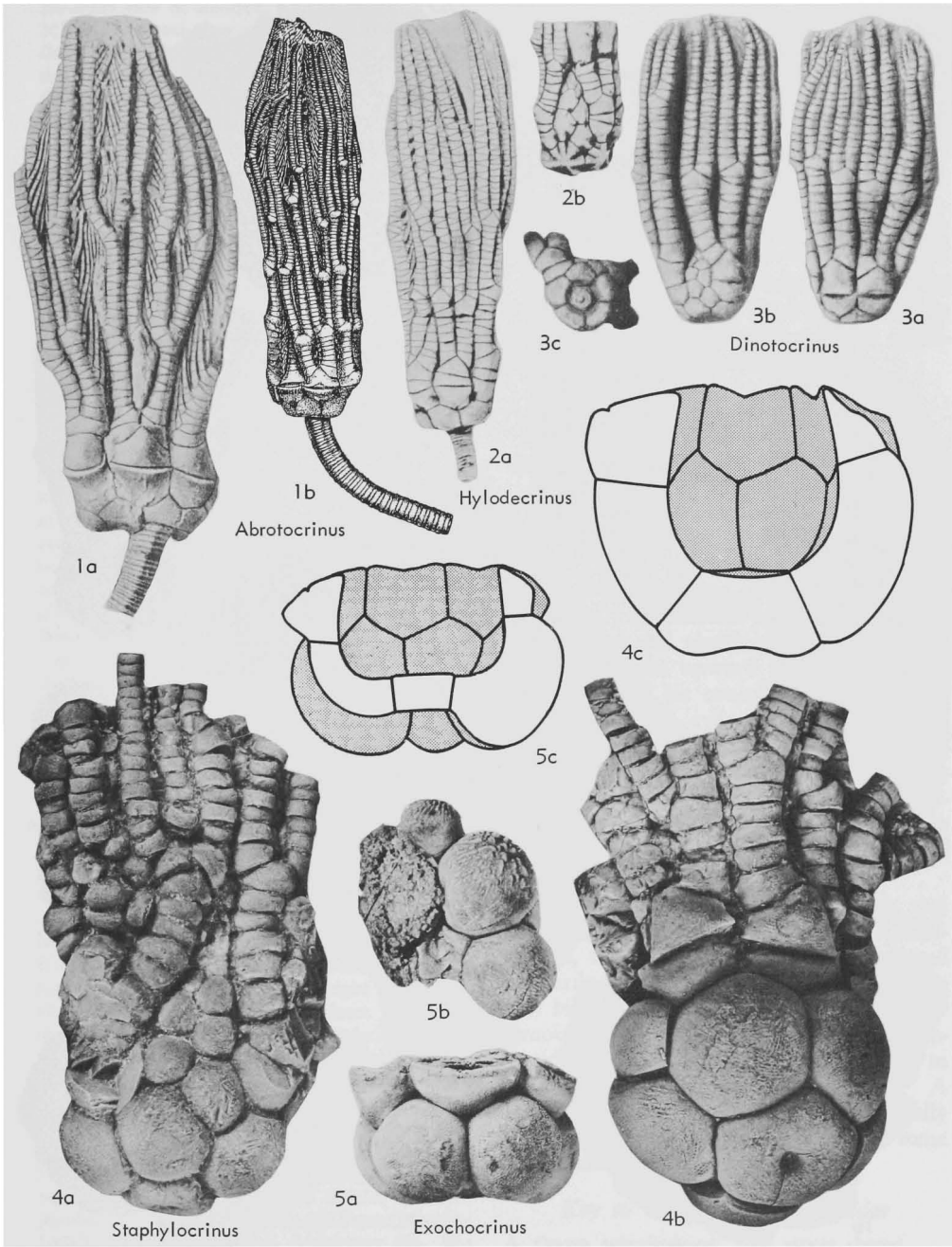


FIG. 493. Staphylocrinidae (p. T743-T747).

pinnules relatively long and stout. Stem transversely circular, with prominent nodals and internodal series. *L.Carb.*, G.Brit.(Eng.); *L.Miss.-U. Miss.*, N.Am.(Can.-USA).——FIG. 493,*3*. **D. compactus*, U.Miss.(Ste. Genevieve), Ala.; *3a-c*, holotype, ant., post., and dorsal views, ×1.5 (Kirk, 1941).

Exochocrinus BURDICK & STRIMPLE, 1969, p. 12 [**Eupachycrinus tumulosus* S. A. MILLER, 1892b, p. 680; OD]. Cup moderately deep, truncate bowl

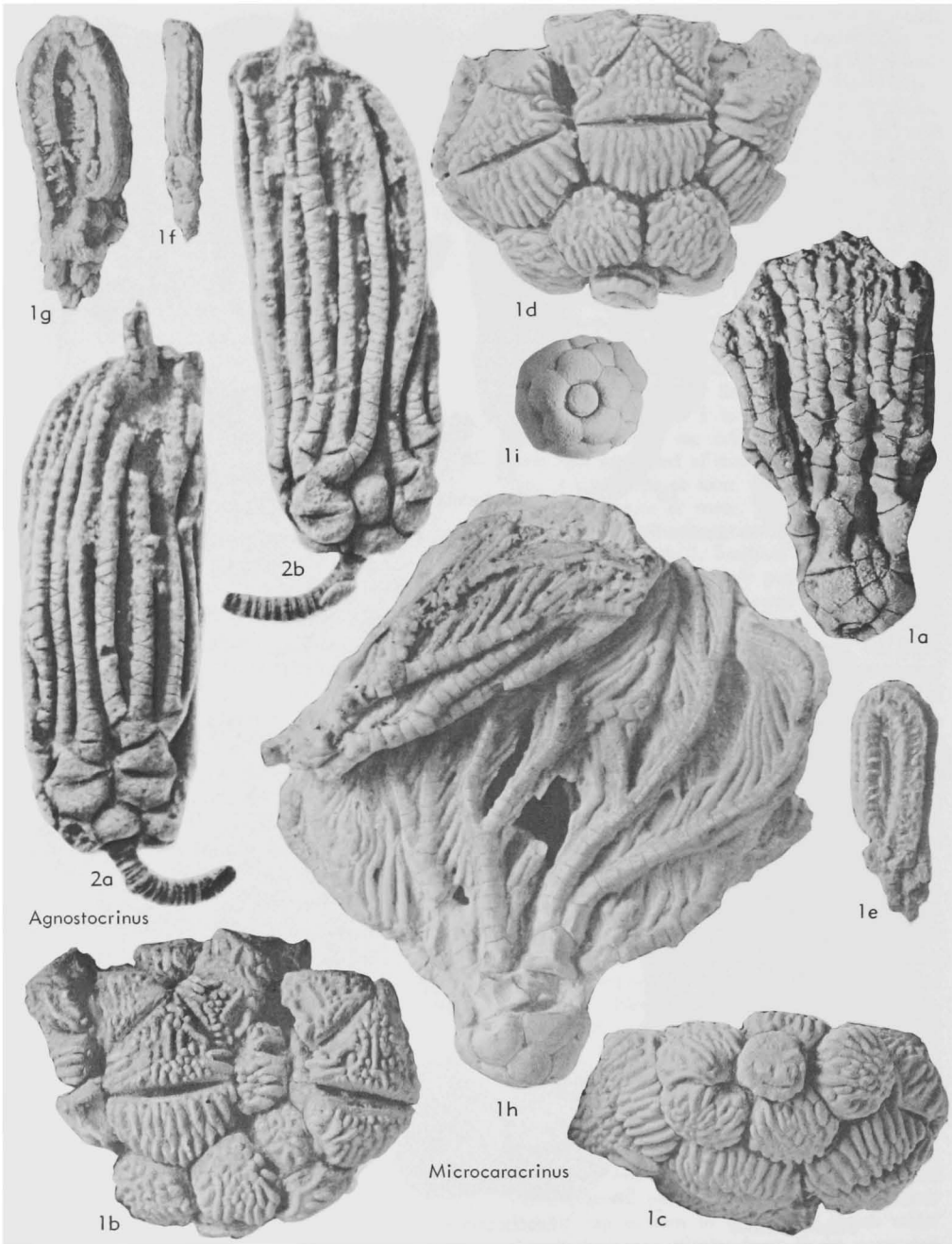


FIG. 494. Staphylocrinidae (p. *T744*, *T747*).

shaped, all plates much thickened, rotund; small infrabasal circlet solidly fused, forming flat pentagon disposed horizontally, located in concavity at base of cup, sides of which consist of upflared proximal parts of extremely tumid basals; radials low, wide, strongly convex, much smaller than basals; 3 anals in cup. Arms unknown. Rudimentary stem indicated by diminutive impression on infrabasal circlet. *U.Miss.(Chester.)*, USA(Ill.-Ky.-Ala.).——FIG. 493,*5*. **E. tumulosus* (MILLER);

5a, A-ray view of holotype, Ky.(Breckinridge Co.), ×1.3; *5b,* dorsal view of cup from Ill.(Randolph Co.), ×0.8; *5c,* diagram. vert. sec. of cup (portions beyond section shaded) (based on holotype) (Burdick & Strimple, 1969).

Hylodecrinus KIRK, 1941, p. 85 [**H. sculptus*; OD]. Crown compact, subcylindrical, arms approximately 9 or 10 times height of cup. Cup cyathiform, with flattened base, formed of heavy tumid plates; infrabasals small, not visible in lateral view, mostly covered by column; basals large, forming lower part of cup as seen in side view; radials large, articular facets full width of radial, sutures gaping; anal plates 3, radianal pentagonal, resting almost equally on *BC* and *CD* basals, anal *X* large, rising above radials, right tube plate reaching well up on *C*-ray primaxil. Anal sac relatively slender, reaching nearly to tips of arms, recurved, with cluster of small spines at flattened apex. Stem stellate in section in proximal part, becoming pentagonal below. Arms uniserial, stout, endotomous, with 2 primibrachs in each ray and 2 bifurcations above primaxils except in anterior ray which usually has single isotomous division above first dichotom, axillaries nodose, and usually small node on each brachial, giving crown a rough, uneven appearance; brachials with slightly sloping articular faces, and long, stout pinnules. [Resembles *Pachylocrinus* in general habit but has stout arms with few divisions, a long ventral sac, and a pentastellate to pentagonal stem.] *L.Miss.(up. Borden Gr.),* USA(Ind.-Ky.).——FIG. 493,*2*. **H. sculptus,* Keokuk, Ind.; *2a,b,* ant. (*B*-ray) and post. views of crown, ×0.7 (Kirk, 1941b).

Microcaracrinus STRIMPLE & WATKINS, 1969, p. 201 [**M. delicatus*; OD]. Crown tall, slender. Cup shallow bowl shaped, with narrow basal concavity; infrabasals small, confined to basal concavity; large basals tangent to basal plane of cup; large radials wider than high, articular facets filling distal face of radials; 3 anals, radianal in posterior position, anal *X* and right tube plate above with confluent distal surfaces. Anal sac short, sharply looped. Arms slender, uniserial, with well-rounded exteriors, not abutting, pinnules stout; first branching on primibrachs *1* in all rays and a second branching higher, a third bifurcation may take place in some inner half-rays only (exotomous). Column transversely round. *M.Penn. (Atokan)-L.Perm.(Wolfcamp.),* USA(Midcontinent reg.); *M.Carb.,* USSR.——FIG. 494,*1a. M. conjugulus* STRIMPLE & MOORE, U.Penn.(Missour., LaSalle Ls.), near Pontiac, Livingston Co., Ill.; holotype crown from post. side, ×4 (Strimple & Moore, 1971a).——FIG. 494,*1b-d. M. bellirugosus* (MOORE), U.Penn.(Virgil., Wabaunsee Gr.), near Emporia, Kans.; holotype from post., dorsal, and ant. sides, ×2.7 (Moore, 1939c).——FIG. 494,*1e-i. M. colubrosus* (MOORE), L.Perm.(?Ft. Riley Ls.), near Augusta, Kans.; *1e,f,* anal sac of paratype from left and ant. sides, ×2.7; *1g,* same from right side, ×3.2; *1h,i, AB*-interray and dorsal (anal series directed upward) views of holotype crown, ×2.7 (all Moore, 1939c).

Superfamily ZEACRINITACEA Bassler & Moodey, 1943

[*nom. transl.* MOORE & STRIMPLE, 1973, p. 31 (*ex* Zeacrinitidae BASSLER & MOODEY, 1943, *nom. correct. pro* Zeacrinidae KIRK, 1942a)] [Materials for this superfamily prepared by R. C. MOORE, N. GARY LANE, & H. L. STRIMPLE]

Concave to flat-based low saucer-shaped cup with one to three anal plates, mostly mushroom-shaped tall anal sac and multiple uniserial arms. *L.Miss-U.Perm.*

Family ZEACRINITIDAE Bassler & Moodey, 1943

[Zeacrinitidae BASSLER & MOODEY, 1943, p. 17 (*nom. correct. pro* Zeacrinidae KIRK, 1942a, p. 382)]

Crown compact, cylindrical or flaring upward. Cup low, with prominent but shallow basal concavity; radial articular facets wide, sloping outward-downward (declivate); three anals in cup, variable in relative size and position, solidly joined to form prominent upward projection of cup summit. Anal sac conspicuous, variable in form, pyramidal, cylindrical or mushroom shaped. Arms uniserial, branching endotomously, bi-endotomously, or isotomously in early forms; brachials pinnulate or hyperpinnulate, with two or four pinnules to each brachial except axillaries. Stem round transversely. *L.Miss.-U.Perm.*

Possibly related to the pirasocrinids and comparable to them in evolutionary specialization, the Zeacrinitidae are differentiated primarily by suppression of some isotomous arm bifurcations so as to produce an endotomous structure, like that of the Cercidocrinidae. The zeacrinitids are thought to be derivatives of the cercidocrinids. A peculiarity of many crinoids of this family is the firm attachment to the cup of some anal plates above radial summits.

Key to Genera of Zeacrinitidae

A. Crown subcylindrical. Cup saucer shaped, with basal concavity, arms uniserial .....
  I. Concavity wide, including proximal extremities of plates in all circlets (formula in terms given for proximal tips of plates in Pirasocrinidae, ---), arms branching endotomously .....
    a. Anal sac short, pyramidal; arms

narrow ..... *Zeacrinites*
b. Very numerous wide arms concealing anal sac ..... *Parazeacrinites*
c. Anal sac tall, club shaped .... *Alcimocrinus*

II. Concavity wide, including proximal extremities of infrabasals and basals, those of radials in basal plane of cup (formula, −−0) .....
a. Anal sac tall, club shaped .. *Eratocrinus*
b. Anal sac slender, planospirally coiled ..... *Linocrinus*
c. Anal sac short and stout ..... *Sarocrinus*
d. Anal sac mushroom shaped, with laterally directed spines bordering widened summit ..... *Tholocrinus*

III. Cavity chiefly consisting of sharply depressed stem attachment area on infrabasals but including proximal tips of basals, those of radials above basal plane on outer side of cup (formula, −−+); arms branching endotomously ..... *Neozeacrinus*

Zeacrinites Troost in Hall, 1858, p. 544 [*Z. *magnoliaeformis* Troost in Hall, 1858b, p. 684; SD Wachsmuth & Springer, 1880, p. 128] [=*Zeacrinus* Hall, 1858b, p. 546 *(nom. van.)*]. Crown compact. Cup low, broad, with wide basal concavity; infrabasals small, mostly covered by stem; basals small, spear shaped, rather widely separated by proximal parts of large radials which form solidly joined distally projecting part of cup; radianal may separate *CD* basal and anal *X*. Anal sac short, pyramidal, tapering distally. Arms broad and closely appressed; uniserial, primibrach *1* axillary in all but *A* ray, which may have 2 or, less commonly, 3 primibrachs; 2 to 4 higher divisions of arms endotomous; each brachial with 2 pinnules, one on each side. Stem transversely round. *U.Miss.(Chester.), ?M.Penn.,* USA(Ill.-Ky.-Ala.-Ind.-Va.-Mo.-Texas).——Fig. 495,*1a-f*. *Z. *magnoliaeformis,* U.Miss., Ala.; post. and ant. views of crown, 2 dorsal, oblique, and ventral views of cup, ×1 (Springer, 1926b).——Fig. 495,*1g*. *Z. *wortheni* (Hall), U.Miss., Ky.; post. view of crown, ×0.7 (Springer, 1926b).

Alcimocrinus Kirk, 1938, p. 162 [**Zeacrinus girtyi* Springer, 1926b, p. 83; OD]. Crown subcylindrical, slightly expanding upward. Cup low, with broad, shallow basal concavity; infrabasals small, covered by stem; basals and proximal edges of radials within basal concavity; anal sac elongate, somewhat club shaped. Arms stout, uniserial brachials low and broad; primibrachs *2* axillary; 6 to 8 endotomous branches in each half-ray above primaxil. *U.Miss.(Chester.)-M.Penn.(Atokan),* USA (Okla.).——Fig. 495,*3*. **A. girtyi* (Springer), L.Penn., Okla.; *3a,b,* post. and ant. views of crown, ×1 (Springer, 1926b).

Eratocrinus Kirk, 1938, p. 165 [**Zeacrinus elegans* Hall, 1858b, p. 547; OD]. Crown tall, slightly pear shaped. Cup shallow saucer shaped; basal concavity narrow and shallow; small infrabasals confined to center of concavity; distal parts of basals, and radials, visible in side view; 3 anal plates in cup. Anal sac elongate, and club shaped, some species with large polygonal plates in vertical row on posterior side and at summit. Arms uniserial, appressed; with large first primibrachs axillary in all but *A* ray, which may have 2 to 5 primibrachs; 3 or 4 endotomous divisions in each half-ray. Stem subpentagonal in outline proximally, becoming round distally. *L.Miss.(Osag.)-U.Miss.(Warsaw),* USA(Iowa-Mo.-Ind.-Ill.).——Fig. 495,*2a,b*. **E. elegans* (Hall), L.Miss., Iowa; *C*-ray and *EA*-interray views of crown, ×1 (Springer, 1926b).——Fig. 495,*2c,d*. *E. *commaticus* (S. A. Miller), U.Miss.(Chester.), Mo.; post. and *E*-ray views of crown showing pinnulate arms and anal sac, ×1 (Springer, 1926b).

Linocrinus Kirk, 1938, p. 168 [**L. wachsmuthi*; OD]. Crown subcylindrical. Cup low, broad, with shallow basal concavity; infrabasals concealed by stem; basals angularly tumid, radials with strong radiating ridges, sutures with first primibrachs gaping; anal sac large, elongate, planispirally coiled distally, with anal opening on anterior side below spiral. Arms uniserial, composed of wedge-shaped, nodose brachials; first primibrachs large, with strong median keel, axillary in all but anterior ray, which has 3 to 5 primibrachs; arms branching endotomously 2 or 3 times above primaxils. Stem round transversely. *L.Miss.(Kinderhook.)-U.Miss.(Chester.),* USA(Ind.-Iowa-Ill.-Ala.-Okla.-Ga.-Mo.-Mont.)-Can.(Alta.).——Fig. 496, *2a-c*. **L. wachsmuthi,* U.Miss., Ala.; *B-, C-,* and *B*-ray views of crown, ×1.3 (Springer, 1926b). ——Fig. 496,*2d*. *L. *arboreus* (Worthen), U. Miss., Ala.; *D*-ray view of partial crown showing spirally coiled distal part of anal sac, ×1.8 (Springer, 1926b).

Neozeacrinus Wanner, 1937, p. 144 [**N. peramplus*; OD]. Crown moderately tall, ovoid. Cup low, saucer shaped, with narrow basal concavity consisting of stem impression, confined to infrabasals; basals and radials slightly tumid; anal sac not known. Arms broad and compact, uniserial brachials wide and low, primibrachs *1* axillary in all rays; arms branching isotomously on secundibrachs and endotomously 3 or 4 times above secundaxils, producing bi-endotomous arms; brachials with 4 pinnules each, 2 on each side. *M. Penn.-U.Perm.,* USA(Texas)-Indon.(Timor).—— Fig. 497,*1a,b*. *N. uddeni* (Weller), L.Perm., Texas; post. and dorsal (*CD* interray directed upward) views of cup, ×1 (Moore and Plummer, 1940).——Fig. 497,*1c*. *N. praecursor* Moore & Plummer, M.Penn.(Desmoines.), Texas; *D*-ray view of crown, ×0.7 (Moore & Plummer, 1940). ——Fig. 497,*1d-g*. **N. peramplus,* U.Perm., Basleo, Timor; *1d-f,* post., dorsal, and ventral

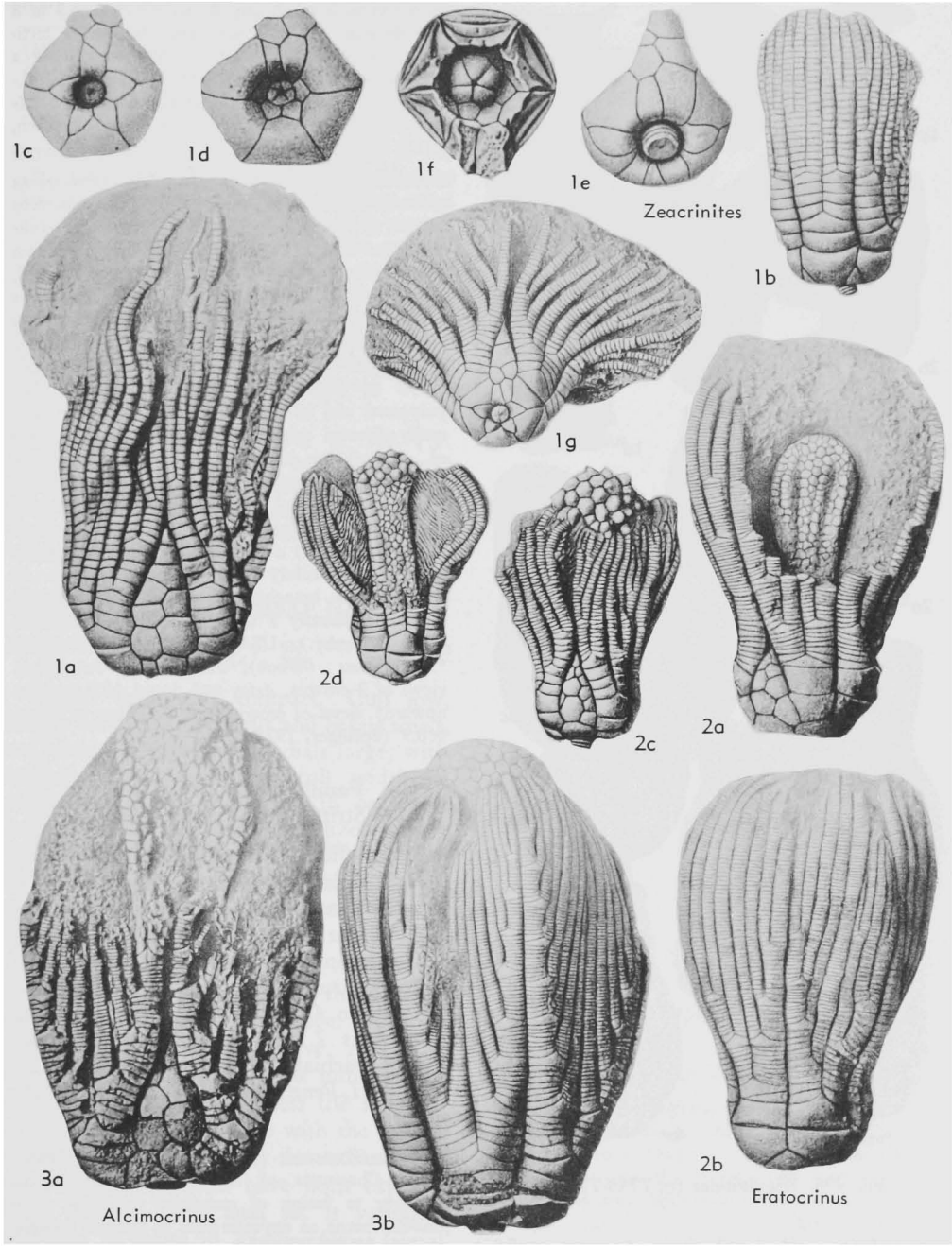


FIG. 495. Zeacrinitidae (p. T748).

views of holotype crown, ×1; *1g*, lat. view of *B* arm from primibrach *2* to tertibrach *4* with pinnules, ×2 (Wanner, 1937).

Parazeacrinites BURDICK & STRIMPLE, 1971, p. 25 [**Zeacrinus koninckí* BATHER, 1912, p. 73; OD]. Crown pear shaped, narrowing upward. Like *Zeacrinites* except that brachials are thinner and each bears single pinnule on alternate sides of successive brachials. *L.Carb.(Visean)*, Eu.(Eng.). ——FIG. 496,*4*. **P. koninckí* (BATHER); *4a-c, E-*

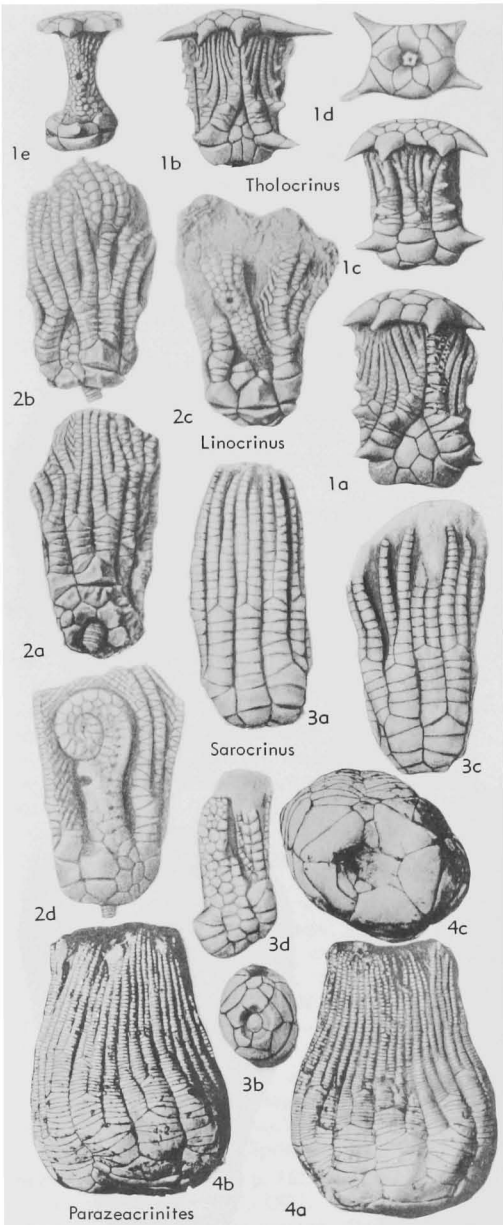


FIG. 496. Zeacrinitidae (p. T748-T750).

ray, *C*-ray, and dorsal views of crown, ×0.9 (Wright, 1952a).

Sarocrinus KIRK, 1942, p. 382 [**S. nitidus*; OD]. Crown small, cylindrical. Cup very low saucer shaped with deep, narrow basal concavity confined to infrabasals and proximal edges of basals. Anal sac short, stout, composed of numerous small polygonal plates. Arms uniserial, branching on primibrachs *2* in all but *A* ray, which has 3 to 8 primibrachs; all branches isotomous, with tertibrachs present in all but *A* ray, which has a single division. *L.Miss.(Osag.)*, USA(Iowa-Ind.-Mo.).——FIG. 496,*3*. **S. nitidus*, Ind.; *3a-d*, *A*-ray, dorsal, *BC*-interray, and post. views of crown, ×1.3 (Kirk, 1942a).

Tholocrinus KIRK, 1939, p. 479 [**Hydreionocrinus spinosus* WOOD, 1909; p. 93; OD] [=*Xystocrinus* MOORE & PLUMMER, 1938, p. 27 (type, *Zeacrinus depressus* HALL, 1858b, p. 546; OD)]. Crown short and compact. Cup rounded saucer shaped, with narrow, deep basal concavity; infrabasals concealed by stem; anal sac elongate, higher than arms, narrowed medially, composed of numerous small plates below large, expanded summit composed of large plates, those of central area polygonal and of periphery comprising long, laterally directed spines; anal opening at midheight of sac. Arms composed of uniserial strongly wedge-shaped brachials proximally, becoming biserial distally; distal tips of arms preserved under expanded distal part of anal sac; primibrachs *1* axillary in all but *A* ray, which has several primibrachs; all axillary plates strongly nodose to spinose; arms branching isotomously on primaxils and endotomously 2 to 6 times above primaxils. *U.Miss.(Chester.)*, USA(Ill.-Ky.).——FIG. 496,*1*. **T. spinosus* (WOOD), U.Miss., Ky.; *1a-e*, post. views of 2 crowns, *A*-ray and dorsal (*CD* interray upward) views of crowns, and ant. view of theca, ×0.9 (Springer, 1926b).

Family EXOCRINIDAE Strimple & Watkins, 1969

[Exocrinidae STRIMPLE & WATKINS, 1969, p. 183]

Small crinoids with multiple slender uniserial arms and low bowl-shaped cup which is flat to faintly convex or concave at base, main cup plates being radials with plenary articular facets; 3 anals in cup. Arms 30 to 40, branching isotomously on primibrachs *1* and at higher levels, pinnulate; brachials commonly keeled longitudinally. *L.Penn.(Morrow.)-L.Perm.(Wolfcamp.)*.

Exocrinus STRIMPLE, 1949, p. 9 [**E. multirami*; OD]. Characters of family with pronounced tendency to fusion of successive brachials with pinnules borne on opposite sides of arms as though the individual brachials were still divided; radianal directly above *CD* basal followed by anal *X* and right tube plate with confluent distal edges. Anal sac short, cylindrical, composed of longitudinal rows of polygonal plates. Arms branching on elongate primibrachs *1*, secundibrachs *2* or *3*, and tertibrachs *3-5*. Stem transversely round, noncirriferous. *L.Penn.(Morrow.)-L.Perm.(Wolf-*

camp.), USA(Kans.-Okla.-Texas-Ill.-Neb.-Nev.). ——FIG. 498,*1. E. wanni* STRIMPLE, U.Penn. (Missour., LaSalle Ls.), Livingston Co., Ill.; *1a, C*-ray view of crown, ×2.4; *1b, B*-ray view of crown, ×2; *1c, C*-ray camera lucida drawing of crown, ×4 (Strimple & Moore, 1971a).

Oxynocrinus STRIMPLE & WATKINS, 1969, p. 184 [**O. spicata*; OD]. Crown short and broad. Cup low bowl shaped with gently convex base; radial articular facets plenary; 3 anal plates in normal (primitive) arrangement in cup. Arms approximately 40, branching isotomously on primibrachs *1,* secundibrachs *2* or *3,* and tertibrachs *4* or *5,* pinnulate. Stem transversely round, noncirriferous. *L.Penn.(Morrow.),* USA(Texas).——FIG. 498,*2. *O. spicatus,* Marble Falls Ls., Lampasas Co., Texas; post. view of holotype crown, ×1.85 (Strimple & Watkins, 1969).

Petalambicrinus STRIMPLE, 1976, p. 867 [**P. craddocki*; OD]. Shallow cup with shallow basal invagination; anal plates advanced, as in *Exocrinus*; radial articular facets large, plenary; proximal columnal large, transversely round. *U.Penn.(Missour.),* USA(Texas).

Family TIMORECHINIDAE Jaekel, 1918

[Timorechinidae JAEKEL, 1918, p. 63] [=Timorocrinidae WANNER, 1916, p. 283]

Crown short and compact. Cup low, basally concave, infrabasals and basals small, not visible in side view; radials large, with articular facets occupying full width of plates; one small anal plate in or above cup. Anal sac stout and specialized, where known. Arms composed of uniserial medium high or elongate brachials, short, stout, primibrachs *1* axillary, heterotomous. *U.Perm.(Basleo beds).*

Rather strangely specialized crinoids of zeacrinitid type are included in the Timorechinidae, of Upper Permian age. The cup is very low and basally concave. Advanced evolution of the anal series is indicated by absence of a radianal, unless the so-called *X* plate that occurs in line with the radials of some genera is actually the radianal. In some genera all anals have been expelled from the cup. The anal sac is variously modified in form; in *Timorechinus* lateral projections of the sac make partitions between the arms in a manner strongly suggesting the separate arm compartments of *Eucalyptocrinites,* among the camerates. The strange calyx of *Timorechinus* was not at first suspected of being that of a crinoid.

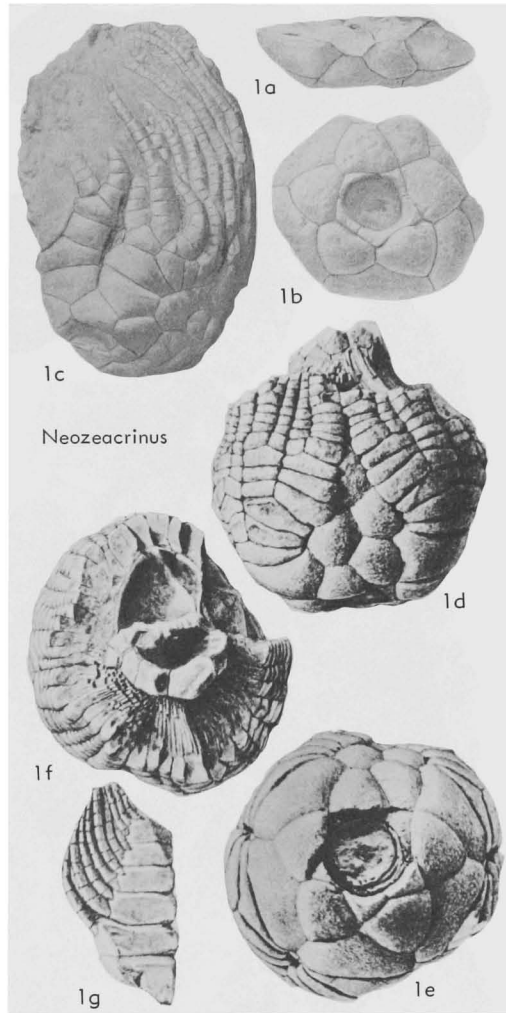


FIG. 497. Zeacrinitidae (p. T748-T749).

Key to Genera of Timorechinidae

A. Base of cup flat, lacking concavity, anal sac large, longitudinally fluted, with arms fitting in its grooves ..... *Timorechinus*

B. Basal concavity of cup wide and shallow, numerous arms branching endotomously .. .. *Parabursacrinus*

C. Basal concavity of cup wide and deep .....
  I. Radials longitudinally ridged, *CD* basal very elongate ..... *Benthocrinus*
  II. Radials smooth, *CD* basal short .... *Notiocrinus*

D. Basal concavity of cup narrow and deep, anal sac strongly bulging posteriorly .... *Prolobocrinus*

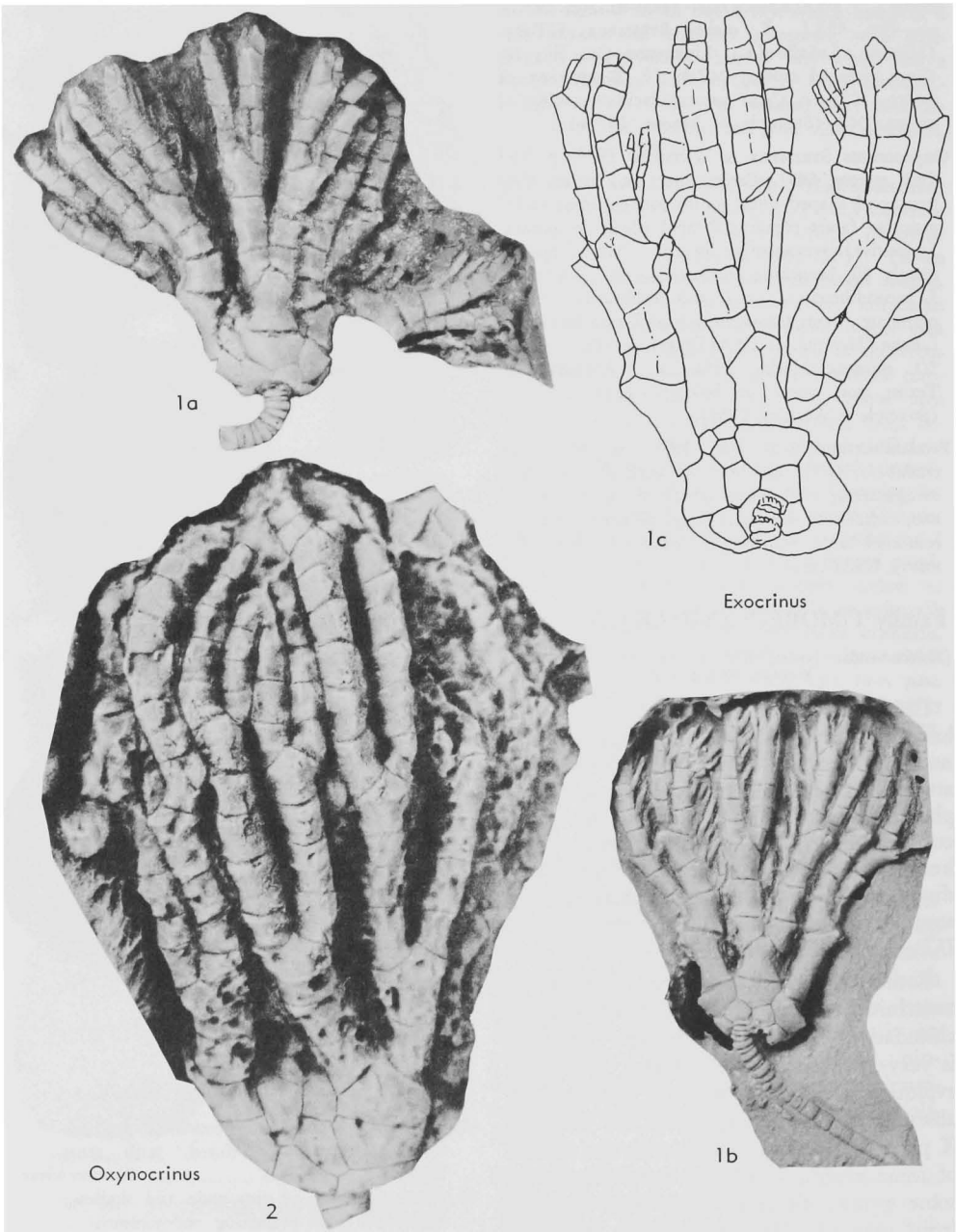


FIG. 498. Exocrinidae (p. T750-T751).

Timorechinus WANNER, 1911, p. 125 [**T. mirabilis*; OD] [=*Timorocystis* LAMBERT, 1911, p. 185 (obj.); *Timorocrinus* WANNER, 1912, p. 599 (obj.)]. Crown ovoid, with greatest width at midheight of arms. Cup low, bowl shaped, with flat base; infrabasals small, confined to stem impression, fused into single plate; basals spear shaped except for *CD* basal, which is very large and projects upward to top of cup; radials small, wider than high; articular facets occupying full width of radials; anal sac massive, with large plate directly above *CD* basal supporting several small

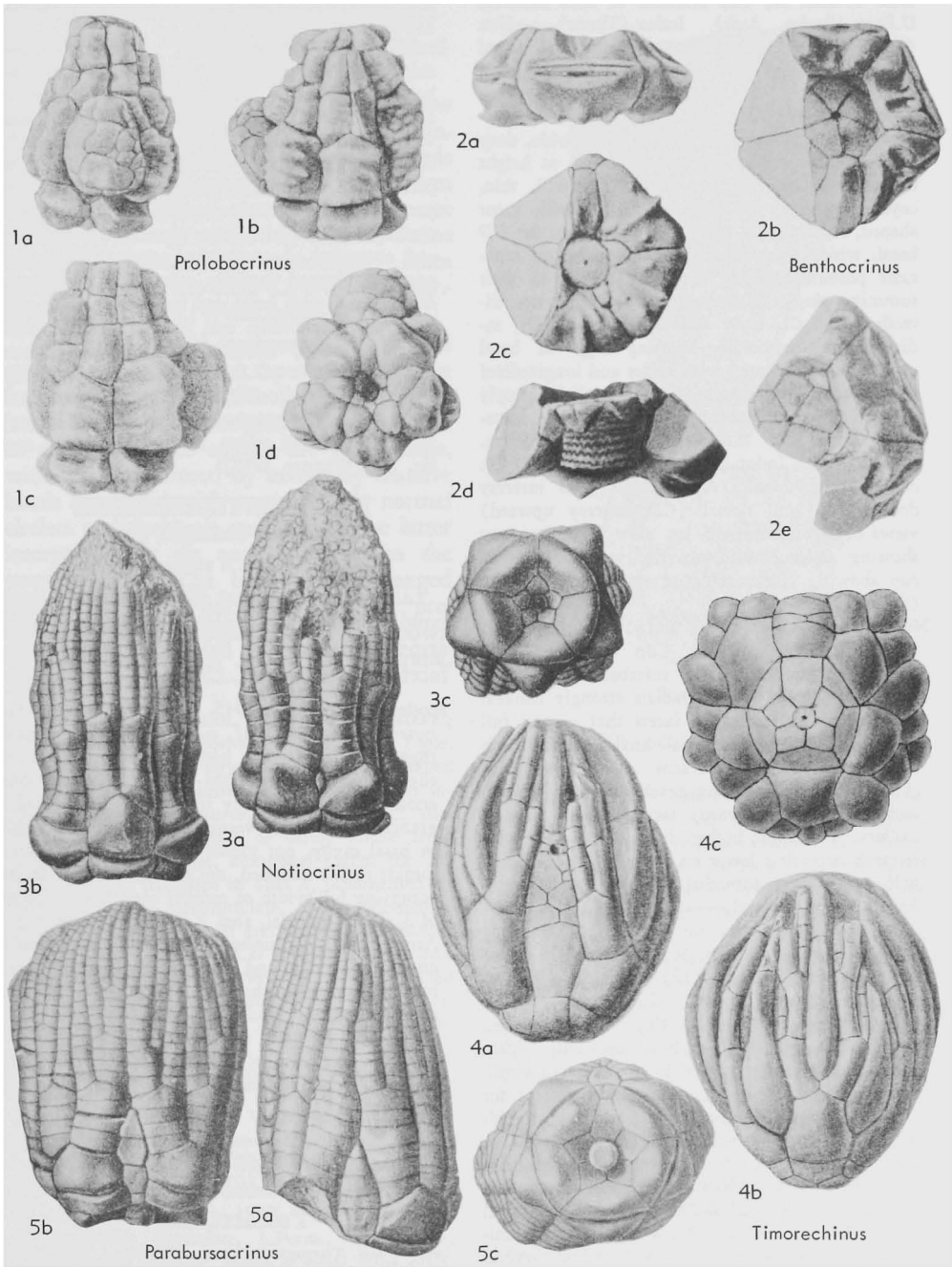


FIG. 499. Timorechinidae (p. *T752-T754*).

plates that surround a small, laterally directed anal opening; summit of sac and interradial and radial areas occupied by large plates that project between the arms and form niches within which arms are placed. Arms short, stout, with large, convex axillary first primibrachs; higher brachials elongate, heterotomous, with ramule on alternate sides of each brachial; tegminal plates separating

arms of each ray and brachials of each half-ray. *U.Perm.(Basleo beds)*, Indon.(Timor).——Fig. 499,*4*. **T. mirabilis; 4a-c*, post., ant., and dorsal (*CD* interray up) views of crown, ×1.5 (Wanner, 1911).

Benthocrinus Wanner, 1937, p. 187 [**B. cryptobasalis*; OD]. Cup bowl shaped, with wide, deep basal concavity, stem impression almost at height of radial articular facets; infrabasals small, thin, covered by stem impression; basals small, spear shaped, separated by tips of radials, except for *CD* basal, which is quadrangular, elongate, and separates posterior radials, extending almost to their summits; single elongate anal plate in cup, directly above *CD* basal and separating radials; radials large, proximally forming edge of basal concavity, ornamented with nodes and longitudinal ridges; articular facets as wide as radials, steeply inclined downward-outward with prominent transverse ridge and short ligament pit. *U.Perm. (Basleo beds)*, Indon.(Timor).——Fig. 499,*2*. **B. cryptobasalis; 2a-e*, *D*-ray, ventral (*CD* interray downward), and dorsal (*CD* interray upward) views of incomplete cup, lat. view of broken cup showing deep basal concavity, ventral view of cup showing infrabasals and small basals, ×1.5 (Wanner, 1937).

Notiocrinus Wanner, 1924, p. 181 [**N. timoricus*; OD]. Crown cylindrical. Cup very low, with wide, deep basal concavity; infrabasals and basals not visible in side view; radials strongly convex, pentagonal, with articular facets that occupy full width of radials; single small anal plate in notch between posterior primibrachs. Arms stout, brachials rounded; first primibrachs axillary, convex, and protruding outward; secundibrachs *5* or *6* axillary, isotomous; higher divisions of arms with tertaxils occurring lower on abmedial side of each half-ray than on admedial sides. *U.Perm.(Basleo beds)*, Indon.(Timor).——Fig. 499,*3*. **N. timoricus; 3a-c*, post., ant., and dorsal (*CD* interray upward) views of crown, ×1 (Wanner, 1924).

Parabursacrinus Wanner, 1924, p. 180 [**Bursacrinus procerus* Wanner, 1916a, p. 181; OD]. Crown wide, cylindrical. Cup very low and broad, with wide shallow basal concavity; infrabasals small, largely covered by stem; basals small, not visible in side view, spear shaped except for *CD* basal, which is elongate and projects to mid-height of radials, which are large, convex plates, each with transversely elongate node, articular facets as wide as radials; single small anal plate between posterior radials, supporting longitudinal row of small sac plates. Arms robust, first primibrachs axillary, large, convex and nodose; several endotomous divisions in each half-ray, with admedial branches narrow, elongate, and without higher divisions. *U.Perm.(Basleo beds)*, Indon. (Timor).——Fig. 499,*5a*. **P. procerus* (Wanner); post. views of arms and lower anal sac plates, ×1 (Wanner, 1924).——Fig. 499,*5b,c*. *P. nefotassiensis* Wanner; post. and dorsal (*CD* interray upward) views of crown, ×1 (Wanner, 1924).

Prolobocrinus Wanner, 1937, p. 184 [**P. permicus*; OD]. Crown short and massive. Cup low, bowl shaped, with narrow, deep basal concavity; infrabasals small; basals small, not visible in side view, almost separated by radials and infrabasals; radials large, convex, fluted longitudinally; anal plate small, occupying notch between edges of posterior radials; anal sac swollen globose, protruding backward between posterior arms; short, and composed of numerous irregular plates; anal opening directed laterally toward *C* ray. Arms short, stout, with large gap between massive axillary first primibrachs and radials; several quadrangular, stout, elongate secundibrachs known above primaxils. *U.Perm.(Basleo beds)*, Indon. (Timor).——Fig. 499,*1*. **P. permicus; 1a-d*, post., *B*-ray, *DE*-interray, and dorsal (*CD* interray upward) views of crown, all showing bulged anal sac, ×2 (Wanner, 1937).

Family SCOTIACRINIDAE Moore & Strimple, 1973

[Scotiacrinidae Moore & Strimple, 1973, p. 31]

Like *Zeacrinites* but cup moderately deep bowl shaped and plates tumid, uniserial arms branching on first primibrachs; arm facets plenary. *Up.L.Carb.*

Scotiacrinus Wright, 1945, p. 119 [**Pachylocrinus tyriensis* Wright, 1937, p. 406; OD]. Cup bowl shaped, with narrow basal concavity, plates of cup ridged or corrugated where they join one another, sutures strongly impressed, surface finely granular to coarsely vermiculate; infrabasals small in basal cavity, not visible from side; basals very tumid; radials rounded, not flaring, articular facets occupying full width of radials; anal area normally of 3 plates, radianal, anal *X*, and right tube plate. Arms rather long, uniserial, branching isotomously on primibrachs *1*, and subsequently 2 or 3 times; brachials cuneate, short to rather long, bearing stout pinnules. *Up.L.Carb.*, Eu.(Scot.).——Fig. 500,*1*. **S. tyriensis* (Wright); *1a*, holotype, *C*-ray view of crown, ×0.7; *1b*, paratype, *CD*-interray view oblique from below, ×1.5 (Wright, 1951-54).

Superfamily CALCEOLISPONGIACEA Teichert, 1954

[*nom. transl.* Teichert, in Moore & Strimple, 1973, p. 31 (*ex* Calceolispongiidae Teichert, 1954, p. 70)] [Materials for this superfamily prepared by N. Gary Lane]

Cup large to small, base concave to flat, distinguished mainly by prominent spine- or spadelike projections of basals in most species, arms five obliqui-uniserial. *L.Perm.-U.Perm.*

Family CALCEOLISPONGIIDAE Teichert, 1954

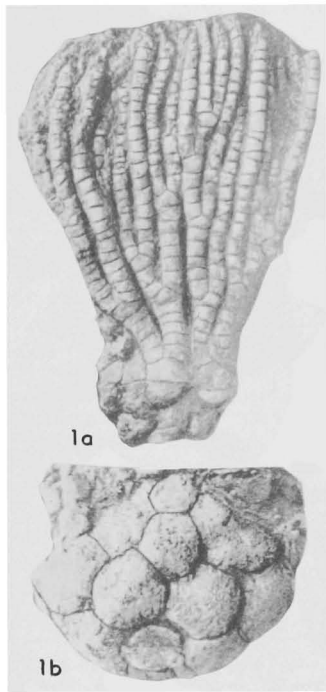
[Calceolispongiidae TEICHERT, 1954, p. 70]

Cup large, bowl shaped, with shallow basal invagination; infrabasals small, concealed by stem, not visible from side; basals large, spinose or tuberculate; radial arm facets wide, inclined outward-upward; one anal plate in cup, separating radials. Arms uniserial, unbranched, pinnulate. Stem small relative to cup size. *L.Perm.(Sakmar.-Artinsk.)-U.Perm.(Word.equiv.).*

Among all cladid inadunates most weird examples of aberrant specialization are found among the Calceolispongiidae, the basals of which were originally misidentified as sponges. Some species are quite large, with the cup formed by extremely massive basals associated with comparatively normal circlets of infrabasals and radials, the latter interrupted by an anal *X* plate on the posterior side. The basals are prolonged laterally by huge horn- or spadelike processes. At present these crinoids are known only from Permian rocks of Australia, Timor, and India.

Calceolispongia ETHERIDGE, 1915, p. 9 [**C. hindei*; M] [=*Dinocrinus* WANNER, 1916a, p. 313 (type, *D. cornutus*)]. Cup large to small, bowl shaped with flat base or shallow basal concavity, and indented basal-radial sutures; infrabasals small, diamond shaped, not visible or barely visible from side; basals very large, hexagonal except for *CD* basal which is truncated by anal *X*, ornamented by large horn-like, mammillate, or spade-shaped spines; radials pentagonal and shorter than basals; separated by anal *X* in *CD* interray; radial arm facets occupying entire width of plates, inclined outward-upward, muscle area long. Arms uniserial, pinnulate; proximal 2 primibrachials large, trapezoidal, distal brachials cuneiform. Stem very small relative to cup size. *L.Perm.(Sakmar.-Artinsk.)-U.Perm.(Word. equiv.),* Australia(W. Australia-Queensl.-New S. Wales-Tasm.)-India (C. peninsular and Assam Himalayas)-Indon.(Timor).——FIG. 501,*1a,b. C. elegantula* TEICHERT, L. Perm., W.Australia; ventral and dorsal views of cup, ×1 (Teichert, 1949).——FIG. 501,*1c-e. C. spectabilis* TEICHERT, L.Perm., W.Australia; inner, ventral, and lat. views of basal spine plate, ×1 (Teichert, 1949).——FIG. 502,*1a,b. C. robusta* TEICHERT, L.Perm., W.Australia; dorsal and *CD*-interray views of crown, ×0.5 (Teichert, 1949).

Jimbacrinus TEICHERT, 1954, p. 71 [**J. bostocki*; OD]. Cup large, bowl shaped with shallow invagination below; basals very large, hexagonal, mammillate; ornamented with 1 to 3 tubercles; radials pentagonal, equal, smaller than basals, bearing one or more tubercles, separated in *CD* interray by anal *X*, radial arm facets form entire upper surface of plates, inclined outward-upward; anal *X* quadrangular, height equal to lateral radial facets, with one to several tubercles. Arms uniserial, pinnulate, primibrachs *1* and 2 trapezoidal, weakly tuberculate, distal brachials cuneiform. Stem small relative to cup size, with alternating long and short columnals. *L.Perm.(Artinsk.),* W.Australia.——FIG. 501,*2. *J. bostocki; 2a-c,* *C*-ray, dorsal and *CD*-interray views of crown, ×1 (Teichert, 1954).



Scotiacrinus

FIG. 500. Scotiacrinidae (p. T755).

Superfamily and Family UNCERTAIN

[Materials for this superfamily prepared by H. L. STRIMPLE]

Aulodesocrinus WRIGHT, 1942, p. 278 [**A. parvus,* p. 279; OD]. Cup judged to be dicyclic based on proximal sutures on long slender basal plates, with 5 elongate radials, flared distalward, and single elongated anal plate as long as *C* and *D* radials. *L.Carb.(Visean),* Eu.(Scot.).——FIG. 503,*1. *A. parvus; 1a,b,* cup from *AB* interray

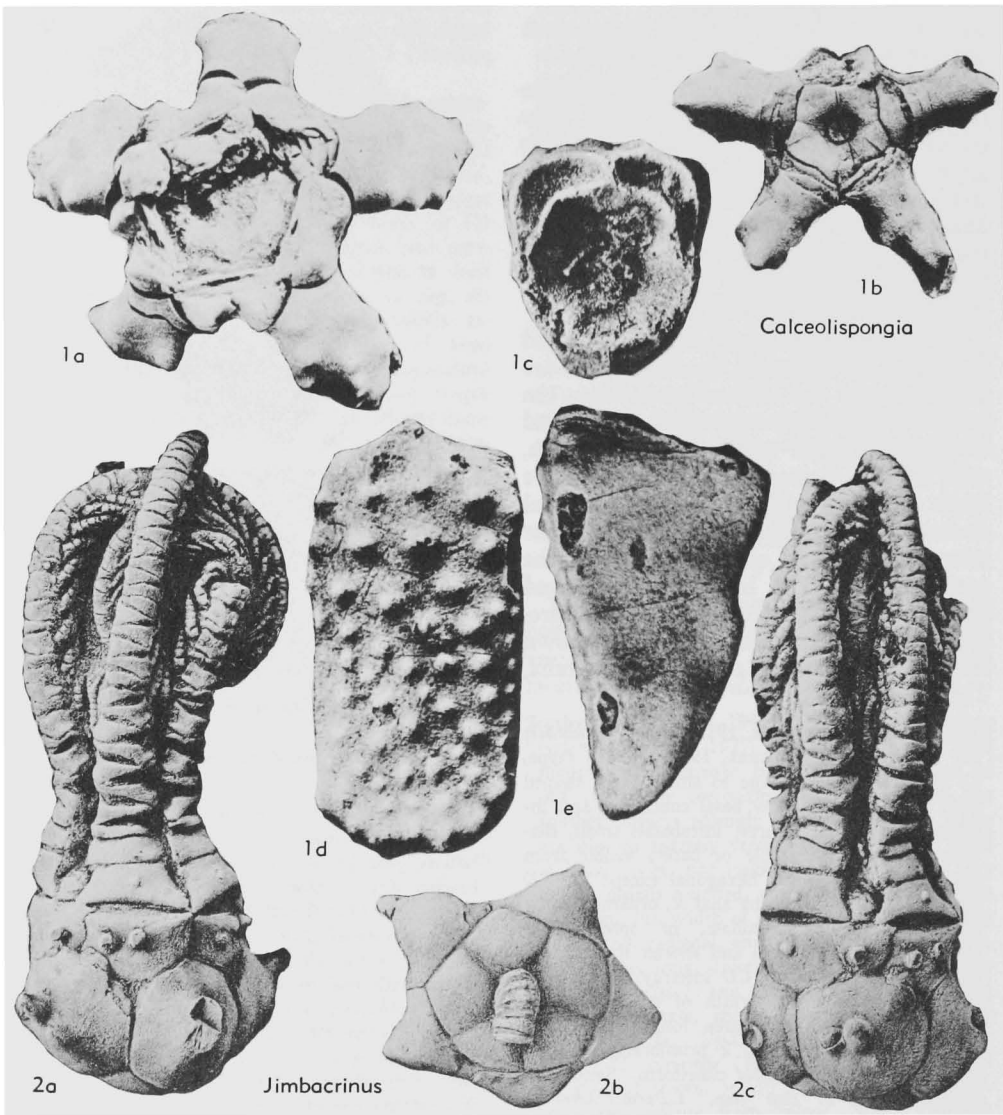


FIG. 501. Calceolispongiidae (p. T755).

and from *D* ray with anal plate to right, ×16.5 (Wright, 1952a).

Carlopsocrinus WRIGHT, 1933, p. 198 [**C. bullatus*; OD]. Crown subglobose; cup with swollen fused infrabasal circlet, minute basals, and large radials in contact with infrabasals, lacking anal plates. Each radial bears large, nonaxillary primibrach *1*, which reduces width and curves inward distally. Columnar facet circular, pierced by minute round lumen. *L.Carb.(Visean)*, Eu.(Scot.).——FIG. 503,*2*. **C. bullatus; 2a,b,* holotype crown from base and side, ×15 (Wright, 1952a).

Order and Superfamily UNCERTAIN

Family PARACTOCRINIDAE Jaekel, 1918

[Paractocrinidae JAEKEL, 1918, p. 25] [Materials for this family prepared by H. L. STRIMPLE]

Small crinoid cups composed of three or more circlets of plates which are only slightly offset rather than alternating. There

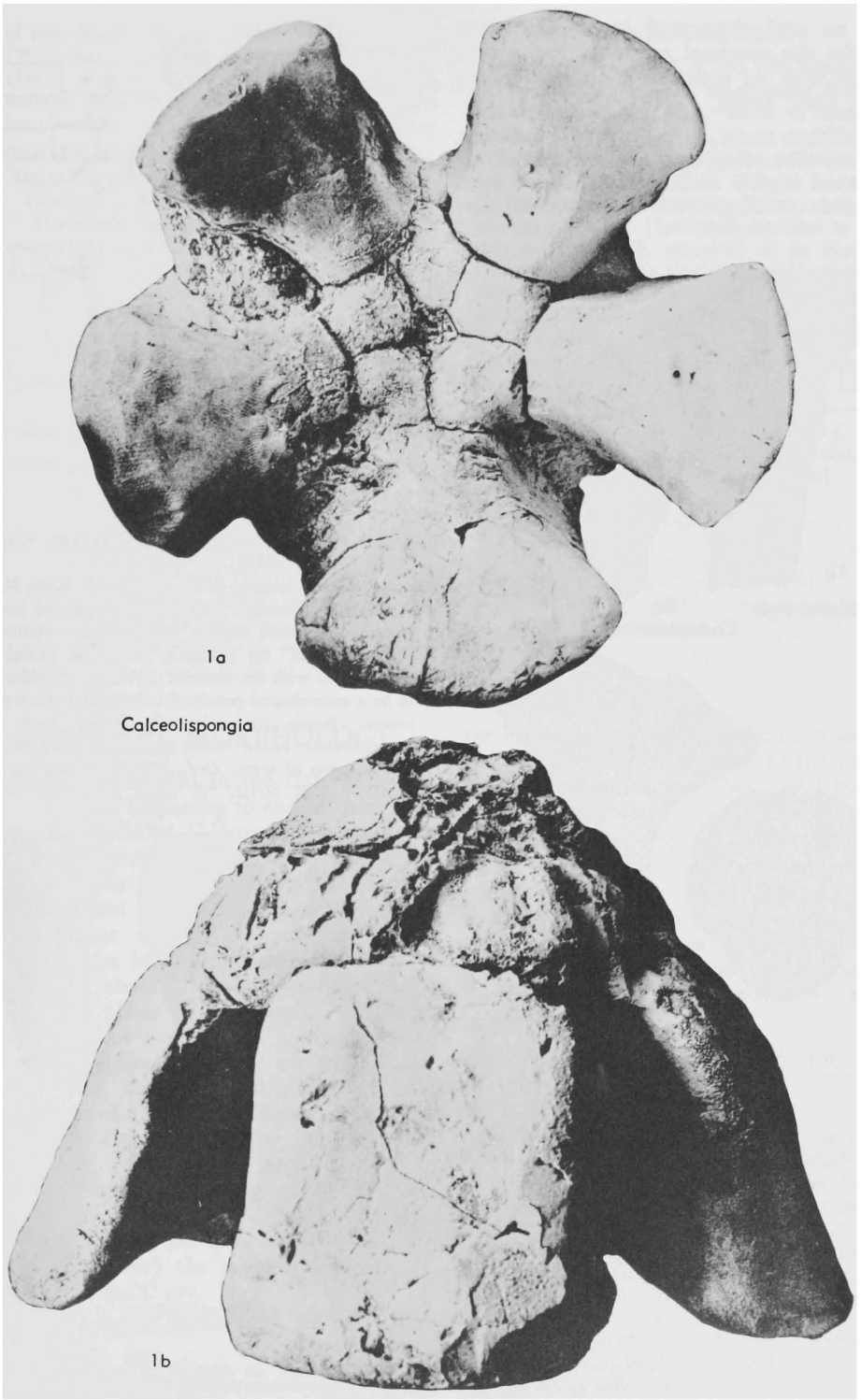


FIG. 502. Calceolispongiidae (p. T755).

are no anal plates and in at least some species the proximal columnal has a cone shape with no facet for additional columnals. *Ord.*, USSR.

Paractocrinus JAEKEL, 1918, p. 25 [**P. tuberculatus*, p. 22; OD]. Cup erect, almost cylindrical but widened slightly distalward. Lowermost circlet of plates considered to be infrabasals, with broad

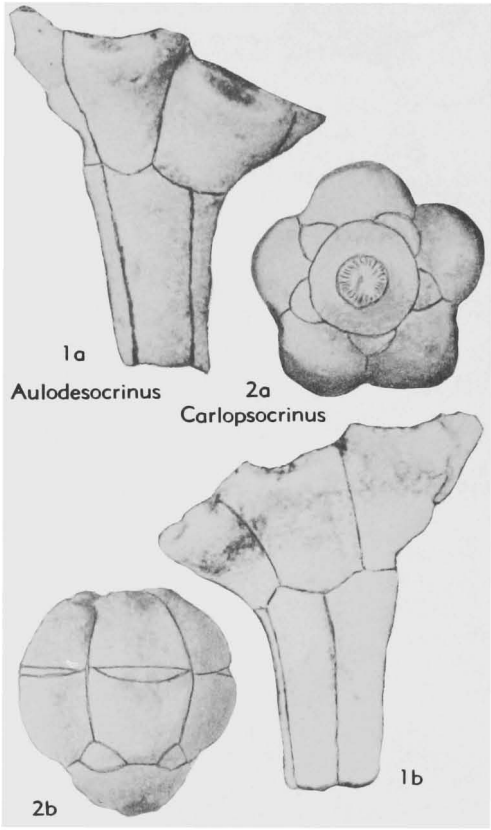


FIG. 503. Superfamily and Family Uncertain (p. T755-T756).

circular columnar cicatrix; next circlet comprised of slightly larger plates, thought to be basals; third circlet in summit view shows no arm facets to indicate radials; in fact, there is no body cavity, but instead a lumen in midportion as evidence of at least one more circlet of cup plates. The poorly preserved specimen described as *Paractocrinus laevis* JAEKEL, 1918, has a cuplike base indicating the presence of a cone-shaped proximal columnal as in *Parorthocrinus*. *Ord.* (*?Vaginatenkalk*), NW.USSR(Leningrad area).——FIG. 504,*1a-c*. **P. tuberculatus; 1a,c,* cup from side and summit, ×2; *1b,* from base, ×1 (Jaekel,

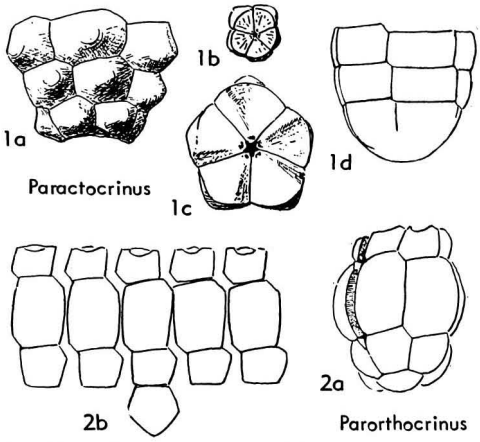


FIG. 504. Inadunata Order Uncertain, Paractocrinidae (p. T758-T759).

1918).——FIG. 504,*1d*. **P laevis* JAEKEL; diag., ×0.7 (Jaekel, 1918).

Parorthocrinus JAEKEL, 1918, p. 25 [**P. liber*; M]. Cup erect, cylindrical with slightly expanded midsection, and small cuplike basal element (termed a "centrobasal" by JAEKEL), which is probably homologous with the element previously considered to be a cone-shaped proximal columnal in *Paractocrinus*. Basals proportionately longer than in *Paractocrinus*; radial circlet appears to have facets for reception of arms. *Ord.*, NW.USSR(Leningrad area).——FIG. 504,*2*. **P. liber; 2a,b,* side view

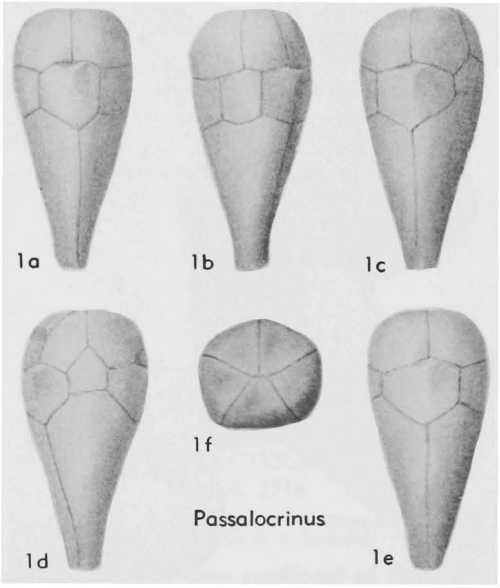


FIG. 505. Inadunata Order and Family Uncertain (p. T759).

of cup, diagram of cup (Jaekel, 1918).
[While this volume was in press, YU. A. ARENDT (1976) proposed a new class of Crinoidea that included the above-mentioned taxa in the following classification:

Class Hemistreptocrinoidea Arendt, 1976
Order Hemistreptocrinida Arendt, 1976
Family Hemistreptocrinidae Arendt, 1976
Hemistreptocrinus Arendt, 1976
L.Ord., USSR(Leningrad area)
Nonparactocrinus Arendt, 1976
L.Ord. or M.Ord., USSR(Leningrad area or Estonia)
Parorthocrinus Jaekel, 1918
L.Ord., USSR(Leningrad area)
Tetractocrinus Jaekel, 1918
L.Ord., USSR(Leningrad area)
Family Paractocrinidae Jaekel, 1918
Paractocrinus Jaekel, 1918
L.Ord. or M.Ord., USSR(Leningrad area or Estonia).—Eds.]

Family UNCERTAIN

Passalocrinus PECK, 1936, p. 292 [**P. triangularis*; OD]. Small, monocyclic, theca shaped like old-fashioned ice cream cone. Basals 3, elongated, equidimensional; radials 5, short, variable sizes and shapes with 3 largest bearing articular facets (*A, B,* and *D* rays); orals 5, *CD* oral the largest. No anal plates or anal opening known. Arms and column unknown. [Specimens described by CRONEIS & GEIS, 1940, purported to be immature representatives of the blastoids *Mesoblastus glaber* and *Pentremites princetonensis,* are remarkably similar to *Passalocrinus.* The ontogeny presented did not show a transition from a *Passalocrinus*-like stage to a recognizable blastoid stage and the matter has not been resolved to date.] *L.Miss.-M.Miss.,* USA(Mo.-Ky.-Okla.-N.Mexico).——FIG. 505,*1*. **P. triangularis,* L.Miss., Mo.; *1a-f,* views of theca from *A, E, D, C,* and *B* rays, and ventral, ×45 (Peck, 1936). [STRIMPLE]

FLEXIBILIA[1]

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GENERAL MORPHOLOGY

Crinoids included in the class Flexibilia display from beginning to end of their long existence (M.Ord.-U.Perm.) a remarkable unity of important morphological characters, which serves to set them well apart from other crinoid groups. Among the features that appear in almost every taxonomic category the foremost are the following:

1) An aboral cup composed of three infrabasal plates (uncommonly reduced to two plates or fused to a single one) combined with five basals and five radials.

2) The infrabasal circlet typically is composed of a small plate (termed *azygous,* unyoked) and two larger ones each formed by fusion of a pair of antecedent small plates (hence termed *zygous,* yoked), uncommonly, all infrabasals are fused together.

3) In all but a few specimens of one genus (*Forbesiocrinus*) the azygous infrabasal is located in the *C* ray.

4) In simpler forms (e.g., lecanocrinids) the basals and radials form the main part of the aboral cup with summits of the radials mostly forming an even horizontal boundary at the arm bases.

5) Relatively large or diminutive anal plates consisting of radianal and anal *X* plate, or of the latter alone, compose posterior parts of most aboral cups, in one group (Taxocrinidae) the linearly arranged anal plates comprise a tube not firmly joined to the posterior basal or either arm of the posterior rays.

6) Observed tegmens of flexible crinoids are mainly built of extremely numerous small plates that in life presumably were buried in a leathery integument that covered and protected the viscera; ambulacral and interambulacral tracts are differentiated, the former leading between medium-sized to large oral plates surrounding the mouth; the posterior oral, exceeding the others in size, is a porous plate that functioned as a madreporite.

7) Position of the tegmen is at the level of radial plate summits in small rotund forms but well above it in larger, many-plated crowns (e.g., *Sagenocrinites,*

[1] In the chapter on Flexibilia the Wenlockian and Ludlovian of Sweden (Gotl.) are bracketed as undifferentiated Upper Silurian, whereas in other parts of this volume the Wenlockian is identified as Middle Silurian.