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CRINOIDS FROM THE ANCHOR LIMESTONE (LOWER MISSISSIPPIAN) OF THE MONTE CRISTO GROUP SOUTHERN NEVADA[1]

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Abstract.—A silicified crinoid fauna from the Anchor Limestone of the Monte Cristo Group (Lower Mississippian) is described. Specimens are from the Meadow Valley Range of southern Nevada and adjacent areas. The fauna is primarily from the upper and lower members of the Anchor Limestone. The upper member is judged to be early Osagean in age, based on crinoids and conodonts, whereas the lower member is late Kinderhookian to earliest Osagean. The fauna is thought to fill a gap in the Mississippian crinoid record represented by unconformity in the standard Mississippian section. Although many taxa are unique and new, the crinoids most nearly resemble specimens from the Chouteau Limestone and lower Burlington Limestone. The several typical western European species found in the fauna provide evidence that southern Nevada was in the path of westward flowing equatorial currents.

The fauna is dominated in numbers, genera, and species by camerates, specifically the Actinocrinitidae. Among inadunates, the disparids are dominant. The fauna is thought to represent two communities that have been mixed by carbonate debris flows. A deeper water, base-of-slope fauna of disparid inadunates is near living sites, whereas shallow water platform camerates have been transported.

A total of 42 taxa is recognized. One new family, Sunwapticrinidae (camerates), is proposed. The new family includes two new genera, *Displodocrinus* (*D. monticulus,* n. sp.) and *Dilatocrinus* (*D. apricus,* n. sp.). The family Coelocrinidae includes the new genus *Tarantocrinus* (*T. typus,* n. sp.) as well as *Agaricocrinus acugalerus,* n. sp. The Actinocrinitidae includes the new genus *Ancalocrinus.* A new flexible crinoid, *Ancoracrinus* (*A. typus,* n. sp.), is also proposed. Other new species include *Amphoracrinus repinus, Actinocrinites anchorensis, Aacocrinus enigmatus, Cusacrinus viaticus, Physetocrinus majusculus, Sunwapticrinus nevadensis, Eretmocrinus aridus, Oenochoacrinus limbus, Celonocrinus nodulus,* and *Wachsmuthicrinus corrugatus.*

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The first crinoids reported from southern Nevada, *Actinocrinus viaticus* and *Platycrinus vexabilis,* were found at Mountain Springs Pass and described by C. A. White in 1877. These specimens are from what has since been named the Anchor Limestone (Hewett, 1931). Nearly a century later Lane (1964), Lane and Webster (1966), and Webster and Lane (1967, 1970) described crinoids from Nevada and adjacent states, but all were from Paleozoic strata younger than the Anchor Limestone. This report describes and analyzes the crinoid fauna from the Anchor Limestone collected between 1964 and 1985 at numerous localities (see locality register) in the Arrow Canyon Range and southern part of the Meadow Valley Range, Clark County, Nevada (Fig. 1).

A total of 42 taxa from the Anchor is recognized here at the familial, generic, or species level. Of these, one family, four genera, and 14 species are new.

The fauna is dominated by monocyclic camerates, which account for 66 percent of both the genera and species. The family Actinocrinitidae is especially conspicuous.

Stratigraphy

The Anchor Limestone was named by Hewett (1931) for exposures in the Goodsprings area, southern part of the Spring Mountains, Clark County, Nevada. Originally designated a member of the Monte Cristo Formation, the Anchor Limestone was distinguished from the underlying Dawn and overlying Bullion limestones by its abundant nodular and discontinuous chert bands. The chert weathers with a dark ferruginous-brown gossan that contrasts with the gray-weathering Dawn and Bullion limestones.

Although generally referred to as a formation within the Monte Cristo Group, the Anchor Limestone has been referred to as a member by various workers in the past (McKee and Gutschick, 1969, among others).

The Anchor Limestone is widespread in the southern part of the Great Basin. It covers approximately 45,000 km^2 not considering telescoping by thrust faulting. It occurs in a northeastward trending elongate belt from the Providence Mountains in southeastern California to the Beaver Dam Mountains in south-

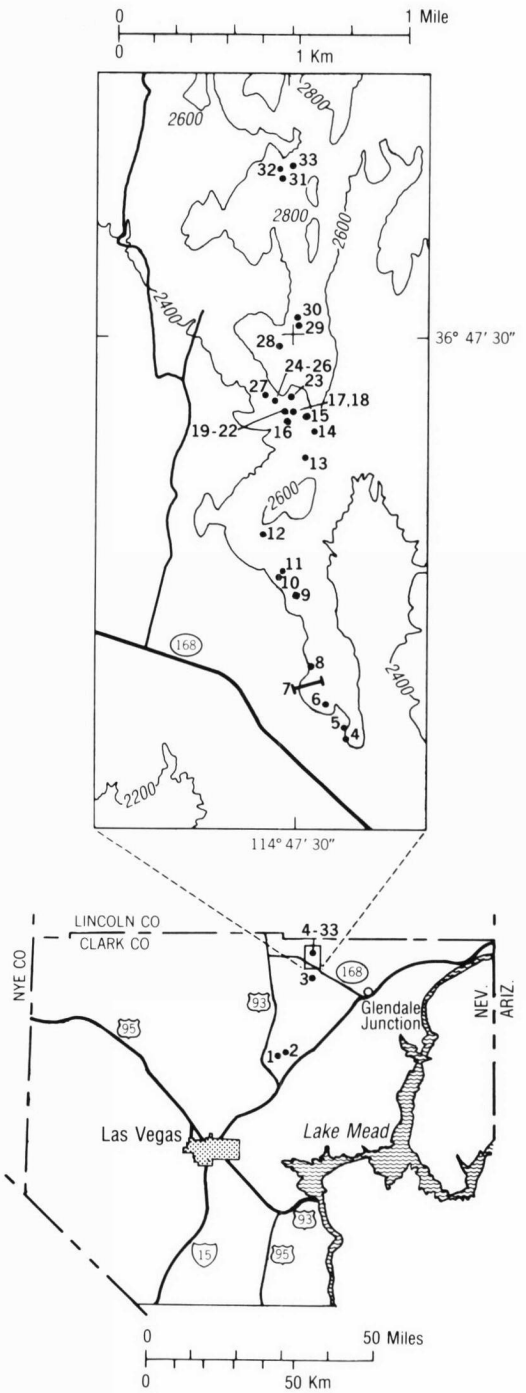

Fig. 1. Map of northeastern part of Clark County, Nevada with enlargement of part of the Meadow Valley Range showing collecting localities listed in locality register. Solid line at locality 7, measured section. Arrow Canyon Quadrangle, 200-ft. contour interval.

eastern Utah. This belt corresponds to the southeastern margin of the Great Basin and western edge of the Colorado Plateau.

The Muddy Mountains are included within the depositional belt of the Anchor Limestone. In the Muddy Mountains, Mississippian limestones have been referred to the Rogers Spring Limestone and Blue Point Limestone (Longwell, 1928). The Rogers Spring Limestone is equivalent to the Monte Cristo Group and the formational subdivisions, including the Anchor Limestone, are recognizable within it. Although the Rogers Spring Limestone (Longwell, 1928) has precedence over the Monte Cristo Group (Hewett, 1931), the latter has been applied throughout much of Clark County. Use of the term Rogers Spring Limestone should be suppressed in favor of the Monte Cristo.

Thickness of the Anchor Limestone is not uniform. Longwell and others (1965) reported a range of 20 to 122 m throughout Clark County, whereas Langenheim and others (1962) gave the range as 80 to 246 m. Brenckle (1973) measured 204 m at Arrow Canyon, Pierce and Langenheim (1974) 60 m at Tungston Gap, and we measured 54.5 m in the southern Meadow Valley Range (loc. 7).

The reference section measured in the southern Meadow Valley Range for this study allows subdivision of the Anchor Limestone into three informal members, as follows (Fig. 2).

Lower Member.—Packstone to grainstone, medium light gray to medium gray (N7–N6), weathering same, medium- to coarse-grained, general increase in grain size upward, graded beds increasing in abundance upward, thin discontinuous irregular ferruginous-brown weathering chert beds and nodules up to 8 cm thick, thin to medium bedded, up to 17 cm thick, poorly exposed in lower 3 m, brachiopods and solitary corals at 14 m above base. Thickness 24 m.

Middle member.—Wackestone to packstone, light blue-gray to light gray (5B7/1–N8), becoming lighter upward, weathering same, fine- to coarse-grained, argillaceous, ferruginous-brown weathering chert nodules and thin discontinuous to irregular chert bands up to 5 cm thick, not as abundant as in underlying or overlying units, thin to medium bedded, up to 15 cm thick. Thickness 11.5 m.

Upper member.—Packstone to grainstone,

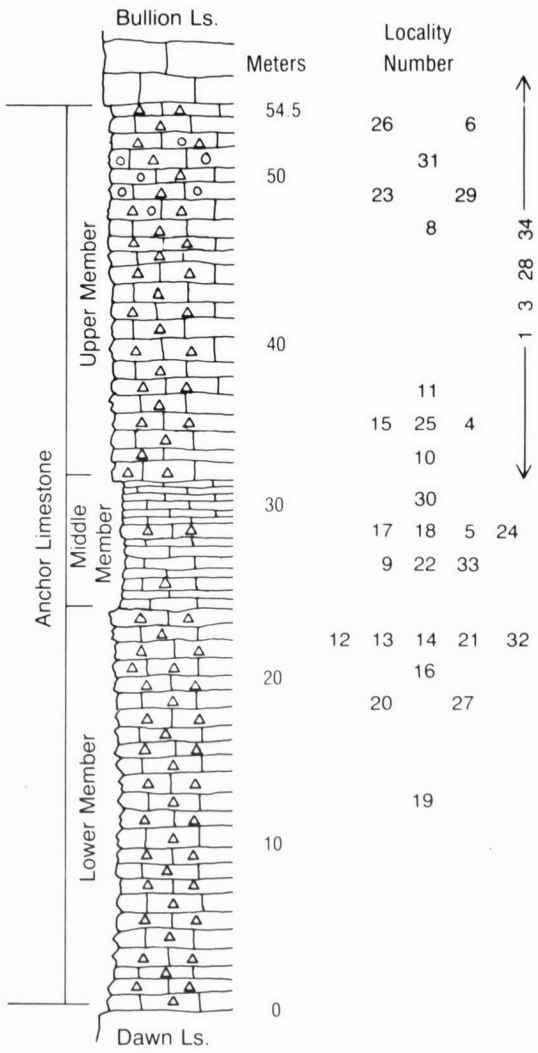

Fig. 2. Columnar section of Anchor Limestone at loc. 7 (see Fig. 1). Upper, middle, and lower members are shown. Stratigraphic positions of crinoid collecting localities are shown at right; stratigraphic position of locs. 1, 3, 28, and 34 includes all of the upper member. Refer to Fig. 1 for geographic location of localities.

light to medium gray (N7–N5) weathering medium light gray to yellow-gray (N6–5Y7/1), fine- to coarse-grained, abundant dark ferruginous-brown weathering chert nodules and discontinuous beds up to 10 cm thick, some units cross-bedded, graded beds up to 10 cm thick increasing in abundance upward, thin to medium bedded, up to 14 cm thick, scattered crinoid ossicles, solitary corals, and brachiopods. Fining upward, coarse to very coarse-

grained grainstone in basal 4 m. Phosphatic and iron oxide nodules in upper 6 m. Laterally this unit may become entirely chert. Thickness 19.5 m.

Crinoids were collected throughout the southern Nevada outcrop belt of the Anchor Limestone, and the three members described in the measured section were recognizable throughout the area. Brenckle (1973) initially described them in the Arrow Canyon Range, and they are present but not obvious in the stratigraphic column of Pierce and Langenheim (1974, fig. 2). A low-angle unconformity separates the middle and upper members in the Las Vegas Range approximately 5 km northwest of locality 1.

The members of the Anchor Limestone should probably be recognized formally, but will be referred to as the lower, middle, and upper members in this report. Recognition of the members supports recognizing the Anchor Limestone as a formation and the Monte Cristo as a group. A regional study of the Anchor Limestone is needed to evaluate fully the sedimentological and stratigraphical relationships of the formation.

Depositional Environments

Limestone beds of the Anchor Limestone show evidence of deposition in a high-energy setting. We believe that the fauna is a mixed one and includes faunal elements of two distinct environments.

Elsewhere in the Lower Mississippian (Kammer and others, 1983), bases of delta slopes include such dominant disparid crinoids as *Halysiocrinus, Synbathocrinus,* and *Catillocrinus.* In the Anchor fauna these crinoids and a flexible crinoid, *Ancoracrinus,* n. gen., are the only ones that have portions of the arms attached. This fact suggests that they were buried close to their living sites. The abundant camerate crinoids, from which the stout, closely interlocked, biserial arms are always missing in the Anchor fauna, are regarded as transported elements that lived on a shallow platform and were transported to their burial sites by carbonate debris flows that also deposited graded limestone beds. Thus, the Anchor fauna represents a low-diversity disparid community that lived at the base of slope and a high-diversity camerate community that lived on a carbonate platform. Conodont faunas in the Anchor Limestone suggest deposition on the lower slope.

Correlation and Age of the Anchor Limestone

The age of the Anchor Limestone has generally been considered to be Early or Middle Mississippian, but differences of opinion exist (Fig. 3). Conodonts and smaller foraminifera have been the major fossil groups used previously to date the Anchor Limestone.

In the western U.S., the Kinderhookian-Osagean boundary has commonly been placed at the last occurrence of the conodont genus *Siphonodella* and the first occurrence of *Gnathodus typicus* (Sandberg, 1979; Lane, Sandberg, and Ziegler, 1980; Wickwire, Davis, and Webster, 1985). The name bearers, however, are facies controlled and are absent or rare in many sections. Where they are absent, the zones are commonly recognized on species found in association with the name bearers in other facies.

Pierce and Langenheim (1972, 1974) placed the Kinderhookian-Osagean boundary within the Anchor Limestone based on the occurrence of *Pseudopolygnathus marginatus* in the upper part of the unit and the appearance of *Polygnathus communis carina* in the upper part of the lower member as we recognize it. Their interpretation follows the conodont sequence recognized in southwestern Missouri by Thompson and Fellows (1970). Sandberg (1979) questioned the use of *P. communis carina* to mark the boundary because he considered its range to extend below the boundary in the western U.S. We found the first occurrence of *P. communis carina* 5 m above the base of the Anchor Limestone in the reference section. This level is lower than that found by Pierce and Langenheim (1974) but still in the lower member. R. H. Lane (pers. comm., 1986) found this subspecies in the base of the Anchor Limestone at Arrow Canyon.

In a recent study of post-*Siphonodella* conodonts, Lane, Sandberg, and Ziegler (1980) placed *Pseudopolygnathus marginatus,* as recognized by Pierce and Langenheim (1974), in synonymy of *P. oxypageus* and considered it to be of Osagean age, upper *Gnathodus typicus* Zone. We found *P. oxypageus* only in the upper member of the Anchor Limestone. We also found *Pseudopolygnathus pinnatus,* a form reported from the uppermost part of the *G. typicus* Zone through the *anchoralis-latus* Zone (Lane, Sand-

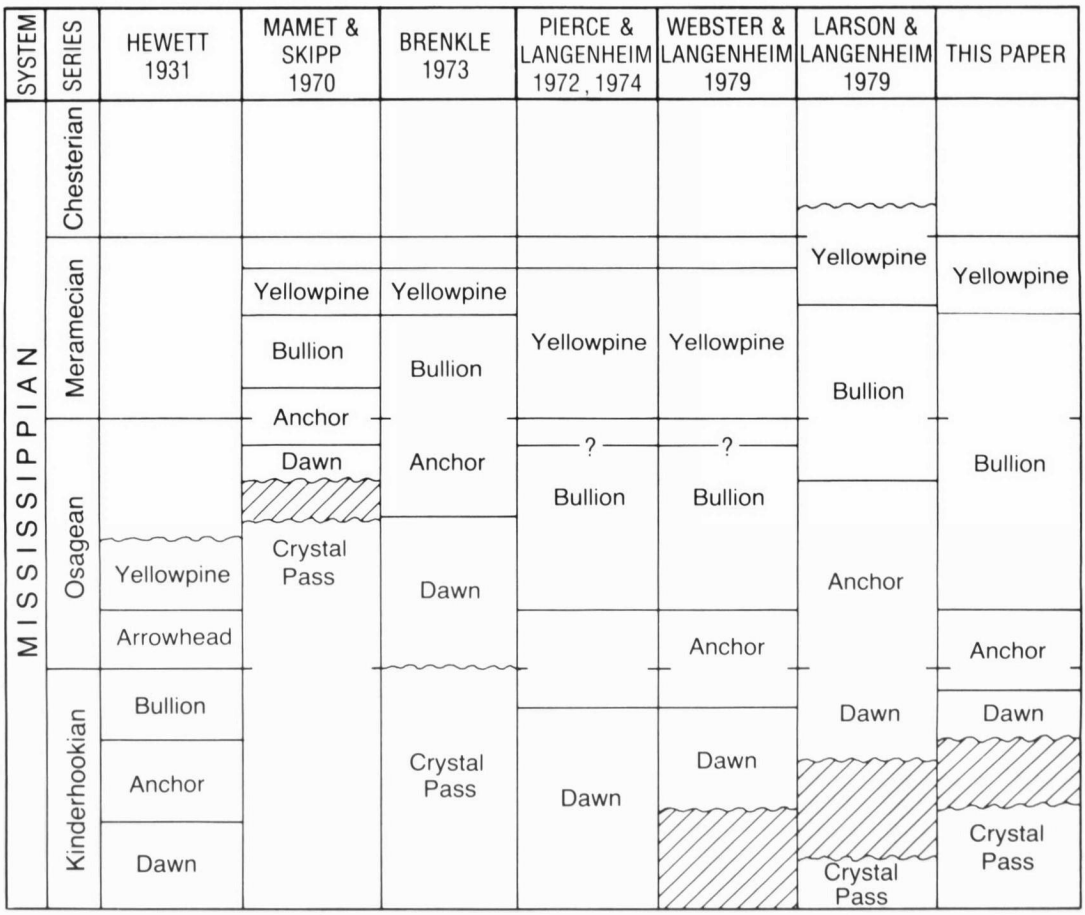

Fig. 3. Chart showing age assignments of formations of the Monte Cristo Group by various authors.

berg, and Ziegler, 1980), in the upper 15 m of the upper member.

Lane, Sandberg, and Ziegler (1980) placed *Pseudopolygnathus dentilineatus,* as recognized by Pierce and Langenheim (1974), in synonymy of *Pseudopolygnathus multistriatus* and showed that *P. multistriatus* ranges from the late Kinderhookian into the Osagean above the *G. typicus* Zone. We found *P. multistriatus* to range throughout the Anchor Limestone, as reported by Pierce and Langenheim.

We recognize the *Gnathodus typicus* Zone and basal part of the *anchoralis-latus* Zone in the Anchor Limestone, based on forms associated with the zonal fossils but not the name bearers. The base of the *G. typicus* Zone is currently not defined and could occur within, at the base of, or below the lower member of the Anchor. The upper part of the *Siphonodella isosticha* Zone may be present in the lower member of the Anchor Limestone.

Foraminifera of the Anchor Limestone were studied by Brenckle (1973) from a composite section of the Monte Cristo Group in the Arrow Canyon Range. He considered the base of the Anchor Limestone as questionably coinciding with the base of Mamet's foraminiferal zone 9. Furthermore, Brenckle (1973:16, fig. 8) recognized no diagnostic faunas within the Anchor or Bullion limestones and listed them together, representing foraminiferal zones 9 through 12, late Osagean to late Meramecian. Brenckle (pers. comm., 1986) considers that the late Osagean to Meramecian age of the Anchor Limestone may need to be revised downward after study.

Laterally the Anchor Limestone interfingers with the Joana Limestone to the north in the northern part of the Meadow Valley Range, the Horseshoe Mesa Member of the Redwall Formation to the east in northwestern Arizona (McKee and Gutschick, 1969), and into the Eleana Formation to the west near the Mercury test site.

Both the crinoids studied here as well as conodonts obtained from acid residues of the Anchor Limestone support a late Tournaisian age. We believe that the formation probably straddles the Kinderhookian-Osagean boundary and records a time interval represented by disconformity in the standard Mississippian section (Thompson, 1979).

The crinoids reported here support this view. They show closest relationship to crinoids from the Chouteau Limestone (upper Kinderhookian) and the Lower Burlington Limestone (lower Osagean). For example, species of *Actinocrinites, Aacocrinus, Sampsonocrinus,* and *Pleurocrinus* are all most closely allied to Chouteau species (see Systematic Paleontology). On the other hand, specimens of *Displodocrinus, Dilatocrinus, Eretmocrinus, Halysiocrinus,* and *Catillocrinus* all have Lower Burlington affinities. The latter two genera are confined to the upper member of the Anchor and suggest strongly that the upper member is Osagean. The lower member is probably latest Kinderhookian and earliest Osagean, containing the boundary. The middle member is too poorly fossiliferous for crinoids to be helpful in more precise age determination.

Surprisingly, the fauna has relatively little similarity to the Redwall and Lake Valley crinoid faunas that are geographically closest to the Anchor. Only *Physetocrinus copei* is common to the Redwall, Lake Valley, and Anchor. This lack of similarity may be partly due to the fact that both the Redwall and Lake Valley faunas are judged to be somewhat younger than the Anchor fauna. *Sunwaptacrinus,* a Kinderhookian form, is the only crinoid with northern Rocky Mountain Mississippian affinities.

Representatives of the Rhenocrinidae and *Oenochoacrinus* are Devonian holdovers that have survived into the Mississippian.

Faunal Analysis

Articulated crinoid material occurs at several localities along a southwest-to-south trend within the Anchor Limestone. This trend extends from the Meadow Valley Range in the north, southwest through the Arrow Canyon Range to the Spring Mountains in Nevada, then south to the Providence Mountains in southeastern California.

The best preserved and most abundant specimens were from the Meadow Valley and Arrow Canyon ranges. A few poorly preserved specimens were found at Mountain Spring Pass in the Spring Mountains. Abundant but metamorphosed nonsilicified specimens, which were generally not collectable, were found in the Providence Mountains.

Specimens weathered out along the upper surface of thin- to medium-bedded packstones and grainstones. Silicification and dolomitization of the crinoidal plates ranges from none to nearly complete with extremes occurring in the same bed within a few meters laterally. Four specimens (three disparid inadunates and one flexible) have articulated arms. A fifth specimen, a cladid inadunate, has the base of the arms attached. Several camerate and flexible calices have one to three proximal columnals articulated. No holdfasts were found.

Several specimens of such flexibles as *Wachsmuthicrinus corrugatus,* n. sp., and an unidentified genus were found disarticulated.

Compaction of many specimens is obvious from the lateral compression of some cups and calices, inward folding of the tegmen on several camerates, and compression of some pluricolumnal segments. Four echinoid coronas with associated spines were crushed where buried.

Specimens do not show abrasion but commonly show solution weathering. The loss of some cup or calyx plates often limits the identification of the reclaimed specimens and sometimes hinders the attempt to reclaim the specimen.

Search of residues from blocks with cups and calices in them yielded a number of additional small cups, especially of *Synbathocrinus,* that were not exposed on the surface. In addition, loose radial plates as well as other cup, thecal, brachial, and stem plates in the residues suggest that the platycrinitids, flexibles, and inadunates are definitely underrepresented in the articulated fauna. Flexible radials and columnals and platycrinitid basal circlets, radials,

and columnals are present in nearly every residue from each locality. At least five and probably six other inadunate genera are believed to be represented in the disarticulated material as well as six and perhaps 13 additional species of platycrinitids. Two other camerates are represented by crushed incomplete calices.

Combining the genera represented by crushed calices and disarticulated plates, we estimate that close to 10 unidentified genera and more than 20 species occur in the Anchor fauna. At the species level the described fauna represents a maximum of 68 percent of the total fauna.

Paleobiogeography

During Early Mississippian time North America was widely covered by a shallow epicontinental sea (Fig. 4). Crinoids have been described from numerous localities in the midwestern, southwestern, and northwestern U.S. and southwestern Canada. These provide a biogeographical setting for the southern Nevada crinoids described here.

The midwestern area from which most known Early Mississippian crinoids have been described was a marine embayment that was largely isolated from major marine oceanic currents by barriers: land on three sides and a deep-water trench on the other (Fig. 4). The rising Appalachians to the south, the Canadian shield to the east, and the Transcontinental arch to the north were all land areas at this time (Gordon, 1986). The west side of the embayment, which we here term the cratonic endemic embayment, was formed by the Ouachita trough. This elongate area of deep water formed a barrier to shallow-water, attached invertebrates like crinoids.

The endemism of this embayment has two aspects. First, many genera that evolved within the area failed to spread outside the embayment. Genera of the family Batocrinidae are especially conspicuous in this regard. These crinoids are dominant in numbers in many beds of the Burlington Limestone, yet they are rare or absent outside this area. Other crinoids, especially camerates like *Dorycrinus,* for instance, are also endemic to the area.

Secondly, widespread genera found elsewhere either do not occur or are rare and short-

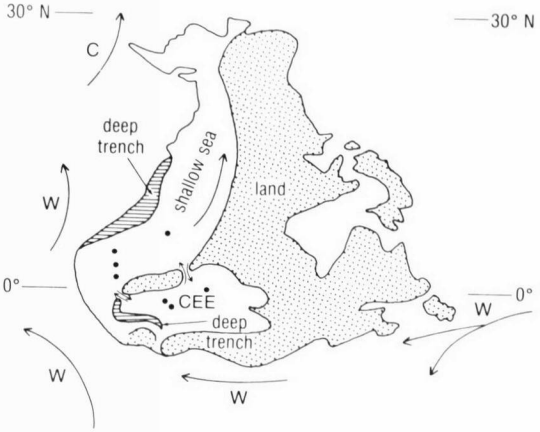

Fig. 4. Lower Mississippian paleogeography of North America. Warm (W) and cold (C) oceanic currents are shown. CEE, cratonic endemic embayment; stippled pattern, land; ruled pattern, deepwater trenches; white, shallow seas. Dots indicate Lower Mississippian crinoid localities. Areas of faunal exchange shown by double arrows. (Modified from Gordon, 1986, and Dewey, 1985.)

lived within the endemic embayment. Examples include *Amphoracrinus, Poteriocrinites,* and the Sunwaptacrinidae. Some exchange did occur between the endemic embayment and sites to the north and west in what is now the western U.S. and Canada. We postulate that there were two places where faunal interchange of crinoids took place. One was an eastern sag in the Transcontinental arch, where crinoid species spread between Iowa, Montana, and Alberta, Canada. This faunal province included crinoids from the Hampton, Lodgepole, and Banff formations. Generic composition and abundance are similar in all of these faunas, which are dominated by small *Platycrinites* and *Rhodocrinites* as well as numerous small inadunates. Several species, or closely comparable species, are shared by these areas.

A more westerly area of interchange extended from the Chouteau and Lower Burlington limestones of Missouri around the western terminus of the Transcontinental arch into the Lake Valley area of New Mexico, the Redwall Limestone of Arizona, and the Anchor Limestone of Nevada. Faunas from these areas are dominated by camerate crinoids, especially members of the Actinocrinitidae. The rhodocrinitid-platycrinitid assemblage of the more eastern Banff-Lodgepole-Hampton province is absent or inconspicuous.

The differences in these two faunas may be due to differences in climate or water depth, resulting in differences in water temperature. The more southern area was close to the Early Mississippian equator (Fig. 4) and therefore tropical. The Montana-Alberta-Iowa crinoids were somewhat north of the equator, perhaps in subtropical environs, and lived in water that may have been somewhat deeper and cooler. Cool water currents, however, did not extend this far south according to Dewey (1985).

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SYSTEMATIC PALEONTOLOGY

Terms used in the descriptions follow the *Treatise on Invertebrate Paleontology* (Moore and Teichert, 1978) with the following modifications. Theca is applied to all calyx plates below the ambulacral tracts excluding plates on arm lobes obviously extended away from the calyx. Thecal rim refers to the upper limit of the theca where the arms become free. Cup or dorsal cup is restricted to the calyx plates between the proximal columnal and the radial facets.

Abbreviations used in the descriptions and measurements are as follows.

amb, ambb—ambulacral, ambulacrals
B, BB—basal, basals
Br, Brr—brach, brachs
d—diameter
IAx, IAxx—primaxil, primaxils
IB, IBB—infrabasal, infrabasals
IBr, IBrr—primibrach, primibrachs
IIBr, IIBrr—secundibrach, secundibrachs
IIIBr, IIIBrr—tertibrach, tertibrachs
IVBr, IVBrr—quartibrach, quartibrachs
iBr, iBrr—interbrach, interbrachs
iIBr, iIBrr—interprimibrach, interprimibrachs
iIIBr, iIIBrr—intersecundibrach, intersecundibrachs
O, OO—oral, orals
R, RR—radial, radials
RA—radianal

Subscript numbers immediately following any of the brach or interbrach terms refer to order; for example, IBr_1 is the first primibrach, IBr_2 is the second.

All measurements are in millimeters. Specimens are deposited in the United States National Museum and identified by USNM numbers.

The following is a complete list of taxonomic categories of which members are described or discussed in this paper.

Subclass Camerata Wachsmith and Springer, 1885
Order Monobathrida Moore and Laudon, 1943
Suborder Compsocrinina Ubaghs, 1978
Superfamily Periechocrinacea Bronn, 1849
Family Amphoracrinidae Bather, 1899
Amphoracrinus Austin, 1848
A. rupinus, n. sp.
Family Actinocrinitidae Austin and Austin, 1842
Subfamily Actinocrinitinae Austin and Austin, 1842
Actinocrinites Miller, 1821
A. anchorensis, n. sp.
Aacocrinus Bowsher, 1955
A. enigmaticus, n. sp.
Sampsonocrinus Miller and Gurley, 1895
Sampsonocrinus sp.
Steganocrinus Meek and Worthen, 1866
Steganocrinus sp.
Ancalocrinus, n. gen.
A. spinobrachiatus (Hall, 1860)
Subfamily Cactocrininae Ubaghs, 1978
Cusacrinus Bowsher, 1955
C. viaticus (White, 1874)
Cactocrininae? sp.
Subfamily Physetocrininae Ubaghs, 1978
Physetocrinus Meek and Worthen, 1869
P. cf. *P. copei* (Miller, 1881)
P. majusculus, n. sp.
Physetocrinus? sp.
Family Sunwaptacrinidae, n. fam.
Sunwaptacrinus Laudon, Parks, and Spreng, 1952
S. nevadensis, n. sp.
Displodocrinus, n. gen.
D. divergens (Hall, 1860)
D. monticulus, n. sp.
D. monticulus?
Dilatocrinus, n. gen.
D. apricus n. sp.
Superfamily Carpocrinacea de Koninck and Le Hon, 1854
Family Coelocrinidae Bather, 1899
Agaricocrinus Hall, 1853
A. acugalerus, n. sp.
Tarantocrinus, n. gen.
T. typus, n. sp.

Family Batocrinidae Wachsmuth and Springer, 1881
Eretmocrinus Lyon and Casseday, 1859
E. aridus, n. sp.
Eretmocrinus sp.
Superfamily Hexacrinitacea Wachsmuth and Springer, 1885
Family Dichocrinidae Miller, 1889
Subfamily Dichocrininae Miller, 1889
Dichocrininae indet.
Suborder Glyptocrinina Moore, 1952
Superfamily Platycrinitacea Austin and Austin, 1842
Family Platycrinitidae Austin and Austin, 1842
Platycrinitidae sp. 1
Platycrinitidae sp. 2
Platycrinitidae sp. 3
Platycrinitidae sp. 4
Platycrinites Miller, 1821
P. vexabilis (White, 1874)
Pleurocrinus Austin and Austin, 1843
P. formosus (Miller and Gurley, 1895)
Pleurocrinus sp.
Oenochoacrinus Breimer, 1962
O. limbus, n. sp.
Subclass Inadunata Wachsmuth and Springer, 1885
Order Disparida Moore and Laudon, 1943
Superfamily Calceocrinacea Meek and Worthen, 1869
Family Calceocrinidae Meek and Worthen, 1869
Halysiocrinus Ulrich, 1886
Halysiocrinus sp.
Superfamily Allagecrinacea Carpenter and Etheridge, 1881
Family Catillocrinidae Wachsmuth and Springer, 1886
Catillocrinus Shumard, 1865
Catillocrinus sp.
Family Synbathocrinidae Miller, 1889
Synbathocrinus Phillips, 1836
Synbathocrinus sp. 1
Synbathocrinus sp. 2
Order Cladida Moore and Laudon, 1943
Suborder Cyathocrinina Bather, 1899
Superfamily Cyathocrinitacea Bassler, 1938
Family Cyathocrinitidae Bassler, 1938
Cyathocrinites Miller, 1821
Cyathocrinites sp. 1
Cyathocrinites sp. 2
Cyathocrinites sp. 3
Cyathocrinites sp. 4
Suborder Poteriocrinina Jaekel, 1918
Superfamily Poteriocrinitacea Austin and Austin, 1842
Family Poteriocrinitidae Austin and Austin, 1842
Poteriocrinites Miller, 1821
Poteriocrinites sp.
Superfamily Rhenocrinacea Jaekel, 1918
Family Rhenocrinidae Jaekel, 1918
Rhenocrinidae sp. 1
Rhenocrinidae sp. 2
Family Stellarocrinidae Strimple, 1961
Celonocrinus Lane and Webster, 1966
C. nodulus, n. sp.
Subclass Flexibilia Zittel, 1895
Order Sagenocrinida Springer, 1913
Superfamily Sagenocrinitacea Roemer, 1854
Family Dactylocrinidae Bather, 1899
Wachsmuthicrinus Springer, 1902
W. corrugatus, n. sp.
Family Euryocrinidae Moore and Strimple, 1973
Ancoracrinus, n. gen.
A. typus, n. sp.

Subclass CAMERATA Wachsmuth and Springer, 1885

Genus AMPHORACRINUS Austin, 1848

Diagnosis.—Calyx low to high, rounded or conical, $IIBrr_1$ fixed in each half-ray; primanal typically followed by 2 or rarely 3 plates. Tegmen usually higher than theca, but equal to or less than this, tapering upward and prominently lobed but not spinose, summit generally flat, occupied by 5 OO, 4 of these forming semicircle around larger posterior O; anal tube eccentric, on posterior side of CD O.

Remarks.—The diagnosis of *Amphoracrinus* in the *Treatise* (Moore and Teichert, 1978) indicates that the shape of the calyx may vary considerably. A literature review of the species assigned to the genus suggests that all of the forms from England, Ireland, and Morocco conform to the diagnosis. Previously assigned American species do not because of differences in features of the calyx. Four American species initially identified as *Actinocrinus* (sic), *A. divergens* Hall, 1860, *A. spinobrachiatus* Hall, 1860, *A. inflatus* Hall, 1860, and *A. viminalis* Hall, 1863, were transferred to *Amphoracrinus* by Meek and Worthen (1873), Wachsmuth and Springer (1881), or Whitfield (1893). Their assignment was accepted by Wachsmuth and Springer (1897) and Bassler and Moodey (1943). *Actinocrinus divergens* and *A. spinobrachiatus* have very low to disc-shaped cups with elongate tegmens terminated distally by spines; we believe them to represent new genera. *Actinocrinus inflatus* agrees with the general calyx description of *Amphoracrinus* but has stellate ridge ornamentation and a tegmen capped by a spinose ring of oral plates. *Actinocrinus viminalis* has a lobed, bowl-shaped calyx, and the arms are free above the axillary second primibrach; it also probably belongs to a new genus. Another American species, *Amphoracrinus blairi* Miller and Gurley, 1896, has a moderately high bowl-shaped cup, a low gently arched tegmen composed of a few

large plates, and prominent brachial lobes subhorizontally projecting with the axillary second primibrach. We tentatively assign *A. blairi* to *Sampsonocrinus*.

The tumid but not spinose orals and their position at the flattened top of the tegmen of *Amphoracrinus* are considered to be stable features of the genus. The orals are homologous with the orals in *Ectocrinus* and *Neoplatycrinus* among the camerates, and with those in allagecrinids, belemnocrinids, and codiacrinids among the inadunates.

The neotype of *Amphoracrinus gilbertsoni* illustrated in the *Treatise* (Moore and Teichert, 1978), as well as holotypes and paratypes of several other species of *Amphoracrinus* illustrated by Wright (1955a), show only the first secundibrach fixed in the calyx.

Wright (1955a) illustrated many species of *Amphoracrinus* from Britain and reported numerous specimens of some species. A statistical study of the Coplow Knoll material might show that some species have considerable morphologic variability and that combination of some species may be in order.

AMPHORACRINUS RUPINUS, n. sp.

Fig. 5,*3–7*

Diagnosis.—Calyx tuliform, cup shallow bowl, primanal followed by 3 plates in second tier; tegmen twice cup height, tegmenal plates small to large, rather regularly arranged; arms free above $IIBr_1$, 2 ambulacral tracks per ray; stem and lumen circular.

Description.—Calyx intermediate in size, tuliform in lateral outline, pentagonal in oral or aboral view, sutures impressed, coarse granular ornament on all calyx plates. Theca wide shallow bowl; basal circlet hexagonal, horizontal, projecting slightly below RR, distal tips barely upflared, divided into 3 equal parts, sutures in B and E rays and CD interray, shallow basal impression for stem articulation. RR 5, hexagonal, nearly half again wider than long, gently convex transversely, largest in A ray, progressively smaller toward posterior interray. IBrr 5, rectangular, nearly twice as wide as long, not quite 0.8 width of RR, gently convex transversely and longitudinally, proximal and distal sutures convex. Axillary $IBrr_2$ pentagonal, wider than IBrr, strongly convex transversely, gently concave longitudinally, with an increasing outward flare distally. $IIBrr_1$ horseshoe-shaped, very short, bearing free arms. Primanal hexagonal, in line with and slightly smaller to slightly larger than RR; anitaxis 1:3:2, in contact with superjacent tegmenal plates. $iBrr_1$ large, octagonal, longer than wide, concave transversely, convex longitudinally, distal tips projecting above IAx into interradial notches, followed by 2 elongate plates extending above ambulacral openings in contact with superjacent tegmenal plates.

Tegmen approximately twice thecal height, gently tapering distally to midlength of OO, then sharply incurving; capped by 5 OO, centrally positioned blunt-noded posterior O largest, in contact with 4 tumid OO anteriorly and laterally, anal tube on posterior side. Three circlets of smaller plates separating OO from ambb positioned at top of ambulacral openings. Anal tube not preserved. Facet for stem attachment circular, weakly impressed in basal circlet, lumen circular.

Measurement of:	Holotype	Paratype
	407341	407342
calyx height (less anal tube)	28.9	32.5
width	26.0	30.0
theca height	9.0	10.0
BB circlet d	8.3	8.0
BB length	3.6	~4.3
width	6.0	6.9
RR length	5.0	~4.0
width	7.3	7.4
IBr_1 length	2.5	2.9
width	5.8	5.8
IAx length	2.6	2.9
width	7.2	7.4
primanal length	4.5	~4.7
width	5.0	5.1
iBr_1 length	6.0	7.3
width	4.2	4.2
stem impr d	5.2	~5.5
lumen d	1.5	1.5

Remarks.—*Amphoracrinus rupinus,* n. sp., is the first true *Amphoracrinus* reported from North America. It is distinguished from the European and African forms by its more regularly plated tegmen.

Etmology.—The species name *rupinus* is Latin for rocky chasm and refers to the locality where the holotype was found.

Material.—Holotype, 407341 (loc. 3); paratypes, 407342 (loc. 7 + 54), 407343 (loc. 10).

Family ACTINOCRINITIDAE Austin and Austin, 1842

Remarks.—Modern concepts of the Actinocrinitidae began with Moore and Laudon (1943) and continued with papers by Bowsher (1955), Wright (1955a), and Brower (1965, 1967, 1969). Brower (1967, 1969), noting the close relationship of the Actinocrinitidae to some presumed ancestors in the Pereichocrinidae, recognized four subdivisions in the Actinocrinitidae. These were formally named by Georges Ubaghs as subfamilies in the *Treatise* (Moore and Teichert, 1978). Brower considered the major difference between the two families to be the loss of one of the three anal plates in the second series of plates in the anitaxis. He also recognized that many abnormal actinocrinitids have three plates above the primanal. Within the Actinocrinitidae, Brower considered the Eumorphocrininae to have the most primitive features, namely, many fixed brachs retained in the cup and the arms strongly grouped but not protuberant. We concur with his analysis of the Actinocrinitidae, and we would emphasize the evolution that occurred in the simplification of the tegmen, reduction of fixed brachs, and modification of thecal shape, each of which characterize genera in the Actinocrinitidae.

The Actinocrinitidae evolved in the latest Devonian or earliest Carboniferous, perhaps polyphyletically and perhaps repeatedly, well into the Early Carboniferous. They quickly diversified in the mid-Tournaisian and continued a major radiation in late Tournaisian time. Species dominate or are major elements in many crinoid faunas of middle and late Tournaisian time in parts of England (Wright, 1955a), Iowa (Hall, 1858, 1860; Wachsmuth and Springer 1897; Miller and Gurley, 1896, 1897), Illinois (Meek and Worthen, 1873), Missouri (Keyes, 1894; Miller and Gurley, 1891, 1895, 1896, 1897; Peck and Keyte, 1938), New Mexico (Laudon and Bowsher, 1951), Arizona (Brower, 1969) and Nevada (this paper).

As knowledge of the group has accumulated, generic concepts within the Actinocrinitidae have been refined and genera have come to be recognized on the basis of variable morphological features that evolved rapidly. Generic distinctions are typically subtle, and great care must be taken in identification. Many species are based on a few specimens, and genera have not been statistically evaluated. Enough specimens of a few genera (i.e., *Actinocrinites,* at Coplow Knoll, Scotland, and the Burlington Limestone, Iowa and Missouri) are known to provide the basis of such a study, which could greatly enhance understanding of this important group of crinoids. A key to the subfamilies and genera is given below.

Key to subfamilies and genera of the Actinocrinitidae

I. Fixed portions of arms strongly grouped
  A. Brachial lobe in each ray protuberant . . . Actinocrinitinae
    1. Calyx high conical to high bowl-shaped
      a. Tegmen convex, with anal tube
        1, Tegmenal plates small, 6 arms per ray, arms flaring with IIBr or IIIBr . . . . . *Actinocrinites*
        2, Tegmenal plates large, 2–4 arms per ray, arms flaring at IAx or IIBr . . . . . *Aacocrinus*
      b. Tegmen low or flat, without anal tube
        1, With 2–4 arms per ray, cup more conical, arms flaring at IIBr . . . . . *Diatorocrinus*
        2, With 2 arms per ray, cup more bowl-shaped, arms flaring with IAx . . . . . *Abactinocrinus*
    2. Calyx discoid to low conical to bowl-shaped
      a. BB upflared distally
        1, Calyx low cone to bowl-shaped, arms flaring with IBr_1, 2 ramule-bearing arms per ray . . . . . *Steganocrinus*
        2, Calyx low bowl, arms flaring with IAx, 4 arms per ray . . . . *Sampsonocrinus*
      b. BB forming flat disc
        1, Calyx low bowl, 4 arms per ray, RR upflared, arms flaring with IAx. . . . . *Blairocrinus*
        2, Calyx discoid, 4 or more arms per ray, RR subhorizontal, arms flaring with IBr_1 . . . . . *Ancalocrinus*, n. gen.
  B. Brachial lobes never protuberant . . . Eumorphocrininae

1. With 2 or 1 ambulacral openings per ray
   a. With 1 ramule-bearing arm per ray *Cytidocrinus*
   b. With 2 ramule-bearing arms per ray . . . . . *Manillocrinus*

II. Fixed portion of arms weakly grouped or not grouped
A. Anal tube present . . . . . Cactocrininae
1. iIBrr not connected with tegmen
   a. Flange at base of free arms absent
      1, Arms free above IIBrr. . . . . *Cactocrinus*
      2, Arms free above IIIBrr or IVbrr *Ilmocrinus*
   b. Flange at base of free arms present *Teleiocrinus*
2. iIBrr connected with tegmen
   a. Free arms branched. . . *Dialutocrinus*
   b. Free arms unbranched
      1, With 4 arms per ray . *Nunnacrinus*
      2, With more than 4 arms per ray *Cusacrinus*

B. Anal tube absent . . . . . Physetocrininae
1. Flange at base of free arms absent *Physetocrinus*
2. Flange at base of free arms present *Strotocrinus*

Subfamily ACTINOCRINITINAE Austin and Austin, 1842

Remarks.—Members of the Actinocrinitinae are easily separated from those of other subfamilies by the presence of a protruding lobe for each ray. The shape and position of the lobes are important in the recognition of genera within the subfamily. Their shape is controlled by the convexity of the proximal axial plates of the lobe. That is, if the axial plate is gently convex transversely, the lobe is relatively wide; if the convexity is acute, the lobe is narrow. The point at which the lobe begins to develop, or where the outflaring begins, as well as the length of the plates in the theca below the outflaring, control the relative height of the theca. Two other factors affect the width of the lobe at the thecal rim. These are the number of fixed brachs and intersecundibrachs. The more of these plates in the theca, the wider the lobe. The number and width of interradial plates affect the relative spacing of the lobes and the relative widths of lobes and calyx. The greater the number of interradial plates, the wider the interray, resulting in more widely spaced lobes. The lobes appear narrower where widely spaced.

Genus ACTINOCRINITES Miller, 1821

Type species.—*Actinocrinites triacontadactylus* Miller, 1821.

Diagnosis.—Calyx low to moderately high, bowl- to cone-shaped, tegmen convex, bearing subcentral anal tube; basal circlet low, distal tips upflared, visible in lateral view, RR largest plates in theca, primanal in radial circlet followed by 2 plates; IIBr axillary, rarely 2 IIBrr per ray; fixed brachs commonly including $IIIBr_1$ to $IIIBr_3$; arms strongly grouped into protruding lobes, some lobes beginning with IIBrr or IIIBrr; free arms 4 or 6 per ray at thecal rim, in some branching distally, uniserial proximally, biserial distally; iIBr number variable, commonly 5 to 7 below ambulacral tracts, in contact with tegmenal plates distally; iIIBrr present or not; tegmenal plates small, undifferentiated; anal opening at distal end of slender anal tube. Stellate ridge and ray ornamentation common on theca, nodes or short blunt spines common on some tegmenal plates. Stem round; lumen pentalobate.

Remarks.—*Actinocrinites* has been one of the most abused generic names in the crinoid literature. It was introduced early (Miller, 1821), and the initial type material includes forms that are today assigned to two genera and isolated cup and stem elements that might belong to any of several genera (Wright, 1955a). The generic concept was loosely interpreted, and since 1821 more than 300 species have been assigned to *Actinocrinites* or the incorrect spelling *Actinocrinus*.

Bassler and Moodey (1943) listed 91 species that they accepted as belonging to *Actinocrinites,* 25 species that they or other authors transferred

Fig. 5. Amphoracrinidae, Actinocrinitidae.—*1, 2. Sampsonocrinus* sp., basal and A ray views, 407353.—*3–7. Amphoracrinus rupinus,* n. sp., 3–5, oral, A ray, and basal views, respectively, holotype 407341; 6, 7, AB interray and D ray views, paratype 407342.—*8–11. Actinocrinites anchorensis,* n. sp., 8–10, oral, A ray, and basal views, respectively, holotype 407344; 11, basal view, paratype 407346.—*12–16. Aacocrinus enigmaticus,* n. sp., 12–15, oral, A ray, posterior, and basal views, respectively, holotype 407347; 16, basal view, paratype 407348. All views ×1.

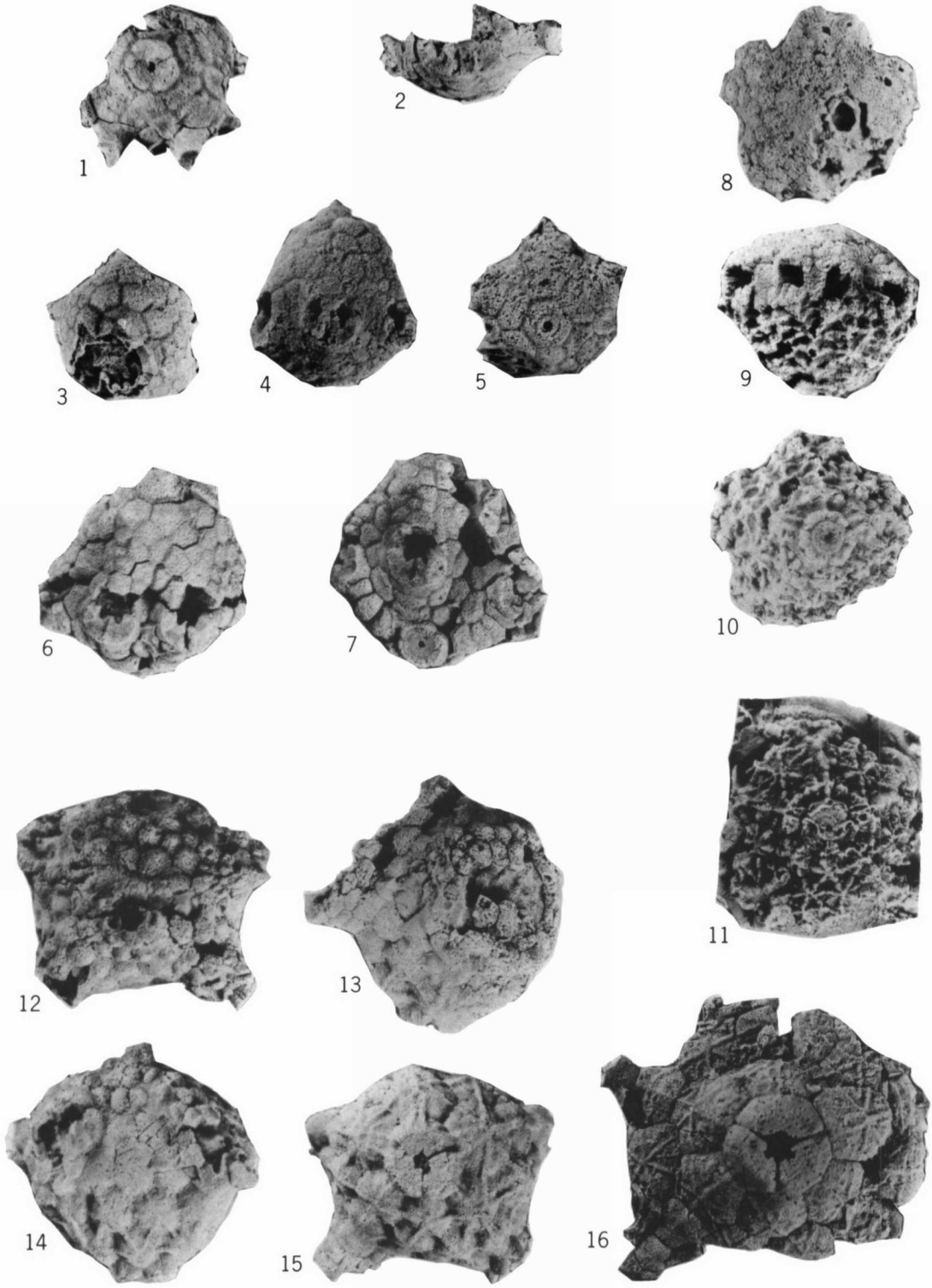

Fig. 5. For explanation, see facing page.

to other genera, and 3 species that did not belong but were not transferred. In addition, they listed 231 species under *Actinocrinus* of which 8 were assigned to *Actinocrinites* and the remainder to other genera. Webster (1973) listed 18 species assigned to *Actinocrinites* between 1951 and 1965, and 28 species were transferred from *Actinocrinites* during the same time. We believe that at least 8 other species should be transferred to other genera.

About 75 species are now assigned to *Actinocrinites*. Nearly 40 of these are from three stratigraphic units. These are: 12 species from the Burlington Limestone (middle Tournaisian) of Missouri and Iowa; 15 from the Keokuk/Ft. Payne Chert (early Visean) of Illinois, Indiana, Kentucky, and Tennessee; and 12 from the Coplow Knoll deposits (early Visean) of Scotland. We believe that only three to five species from each of these deposits are valid and that the others are synonyms. In addition, we believe that most species from the Burlington and Keokuk/Ft. Payne Chert represent an unnamed genus, not *Actinocrinites*. We also consider that at least four of the seven Permian species of *Actinocrinites* are synonyms and belong to an unnamed genus. These suggestions are beyond the scope of this paper and await further study.

Evolution of *Actinocrinites* occurred in the early part of the Carboniferous, and the genus spread across northwestern Europe and the U.S. It became extinct in the U.S. in the middle Tournaisian but continued to evolve in northwestern Europe until the early Visean.

ACTINOCRINITES ANCHORENSIS, n. sp.

Fig. 5,*8–11*

Diagnosis.—Calyx broadly turbinate, tegmen convex, theca bowl-shaped, basal flange scalloped, ornament sharp, stellate, 6 arms per ray.

Description.—Calyx small, broadly turbinate, tegmen convex, arms grouped, lobes protuberant, blocky pentagonal in oral view; sharp stellate ridge ornament on all cup plates through IIBrr, double and triple ridges between BB and RR, single thereafter. Theca bowl-shaped, moderately high, walls gently convex, upflared at 45°, all plates tumid. Basal circlet hexagonal, shallowly concave on base for stem attachment, distal tips upflared, visible in lateral view; BB nearly twice as wide as long, scalloped transverse ridge forming flange at base of theca. RR hexagonal, wider than long, largest plates in theca. $IBrr_1$ rectangular, wider than long, all sutures convex. IBr_2 axillary, rarely hexagonal, commonly septagonal, wider than long, adjoined laterally by $iIBrr_1$ and $iIBrr_2$. IIBr septagonal, wider than long, axillary, flaring distally, supporting iIIBr on inner upper shoulder. Inner IIIBr of each half-ray axillary, outer IIIBr not axillary. Six arms per ray at thecal rim, arms free with $IIIBr_1$, distal arms unknown.

iIBr octagonal, wider than long, following plates smaller, equidimensional; series 1:2:2, ending at bases of ambulacral tracts, separating arm lobes, in contact with tegmenal plates distally. iIIBrr hexagonal, narrow, much longer than wide, separating half-ray ambulacral tracts. Ambulacral tracts oval, elongate, inner tract of each half-ray slightly larger, providing tracts for 2 arms. Primanal in radial circlet, hexagonal, slightly longer than wide to wider than long, supporting 2 smaller plates distally; anitaxis 1:2:4, in contact with tegmen distally but plates lost by weathering. Tegmenal plates small to intermediate, gently tumid, commonly 3 plates more strongly tumid to nodose above lobes. Surface of tegmen convex, bearing 5 troughs originating between rays and shallowing upward. Anal tube slightly posterior of center, distally unknown. Stem round; lumen pentalobate.

Measurement of:	Holotype	Paratypes	
	407344	407345	407346
calyx height	19.0	...	...
width	20.5	...	...
theca height	11.2	...	...
BB circlet d	16.0	8.1	6.2
BB length	2.9	3.5	2.6
width	4.3	6.4	4.6
RR length	3.0	4.5	3.0
width	4.9	6.3	5.6
IBr_1 length	2.4	3.5	2.5
width	4.1	4.0	4.0
IAx length	3.0	...	3.2
width	4.0	5.2	4.4
iBr_1 length	3.7	...	2.5
width	4.0	...	4.0
primanal length	3.8	4.5	...
width	3.4	5.0	...
stem impr d	3.6	...	...

Remarks.—*Actinocrinites anchorensis* is most

similar to *A. albersi* (Miller and Gurley, 1895) from the Chouteau Limestone in Missouri and *A. lowei* (Hall, 1858) from the Keokuk Limestone in Illinois. The calyx of *A. albersi* is a higher cone with a higher tegmen that has many nodose plates, and the interradial areas are narrower and less deeply developed than on *A. anchorensis*. The calyx of *A. lowei* is a higher cone, the basal circlet is relatively higher, the arm lobes flare to become nearly horizontal, and more distal brachs are fixed in the lobes than on *A. anchorensis*. The basal flange occurring on the low basal circlet is not typical of *Actinocrinites*.

Etymology.—The species name is derived from the formation in which the specimens were found.

Material.—Holotype, 407344 (loc. 7 + 51); paratypes, 407345 (loc. 22), 407346 (loc. 29).

Genus AACOCRINUS Bowsher, 1955

AACOCRINUS ENIGMATICUS, n. sp.

Fig. 5,*12-16*

Diagnosis.—Calyx wide, bowl-shaped, nearly equidimensional, tegmen small plated, arms 10, ornament stellate ridge, anal tube subcentral.

Description.—Calyx large, wide, bowl-shaped, nearly equidimensional, pentagonal in oral view, walls convex, brachial lobes sharply extended, flaring out at base of axillary IBr, widely separated by iBrr, 2 arms per ray at thecal rim, distal arms unknown.

BB 3, equal in size, large, forming upflaring base with gentle impression for circular stem attachment, some bearing weak flange. RR 5, hexagonal, largest plates in calyx, wider than long, strongly convex transversely and longitudinally, A largest, B and E slightly smaller, C and D smallest. IBrr wider than long, hexagonal or octagonal, strongly convex transversely, gently convex longitudinally. IBr_2 axillary, nearly twice as wide as long to longer than wide, septagonal, widely flared, 23° above horizontal, with isotomous subdivision distally. $IIBrr_1$ and $IIBrr_2$ fixed in brachial lobes, no other brachs preserved. Primanal in line with RR, slightly smaller than C and D RR, anitaxis series 1:2:3:2, plates decreasing in size and exterior convexity. $iBrr_1$ large, slightly longer than wide, strongly convex longitudinally and transversely; iBr series 1:3:2 or 1:2:1, in contact with tegmenal plates distally.

Tegmenal plates numerous, size intermediate to small; weakly to strongly tumid with faint elongate ridge generally developed; 5 OO largest, small anal tube central or subcentral. Primary ambb slightly smaller, most adjacent to OO. Anal tube obvious, only small-plated base preserved.

Rounded stellate ornamentation confined to theca, ridges radiating from centers of RR, $iBrr_1$, primanal, and 2 following anal plates onto all adjacent plates; may be 2 or 3 ridges between each R and adjacent B or BB. Stem impression round; lumen probably pentalobate, partly destroyed in etching or silicification; outer part of crenularium formed of radiating fine crenulae.

Measurement of:	Holotype	Paratype
	407347	407348
calyx height (less anal tube)	37.6	....
width	37.8	....
theca height	21.7	....
BB circlet d	13.8	13.0
BB length	7.6	
width	11.0	14.4
RR length	11.0	13.7
width	13.3	15.7
IBr_1 length	7.7	9.0
width	9.7	11.0
IAx length	4.0	11.2
width	7.5	7.2
iBr_1 length	9.9	13.2
width	8.7	12.3
stem impr d	8.1	....

Remarks.—*Aacocrinus enigmaticus* is readily distinguished from all other species of the genus by the relatively smaller, more numerous plates in the tegmen. Oral and ambulacral patterns as noted by Brower (1967) in various species of 10-armed *Aacocrinus* are recognized. The ray structure of hexagonal primibrachs and septagonal axillary primibrachs was considered primitive by Brower (1967) and suggests close relationship with the Eumorphocrininae. The protuberant arm lobes, however, clearly indicate that *A. enigmaticus* belongs to the Actinocrinitinae. Brower noted that when the rare condition of a hexagonal primibrach and a septagonal axillary primibrach is present, all interbrachs are small, with the third level interbrachs reaching the level of the secundibrachs. In contrast, *A. enigmaticus* has quite large first interbrachs and the third level interbrachs extend distally to the top or slightly above the

ambulacral opening, well above the secundibrachs.

Variation noted among the specimens studied includes the lack or weak development of a flange on the basal circlet and relative size of the tegmenal plates. The tegmenal plates are definitely larger on the largest specimens. Although the plates are described as small to intermediate, this is relative to the sizes of the calyx and thecal plates. Comparable plates in other described species of *Aacocrinus* would be considered large. *A. enigmaticus* includes the largest known specimens in the genus.

Aacocrinus enigmaticus belongs to the 10-armed group of aacocrinids. The calyx is more bowl-shaped than in most species, showing an advanced morphology, whereas the somewhat smaller plates of the tegmen would normally be considered a primitive condition in camerate crinoids. Small-plated tegmens are common in the physetocrinids and eumorphocrinids (Brower, 1967) and are typical of *Abactinocrinus* and *Diatorocrinus*.

Brower (1967) thoroughly reviewed all species of *Aacocrinus* and discussed their stratigraphic distribution. He noted that all species are from the Compton and Chouteau and related formations in Missouri (mostly the central part of the state), all named species are of Kinderhookian age, and only one unnamed species occurs in the Osagean. This is the first report of *Aacocrinus* from another region.

Etymology.—The species name is from the Latin term *aenigma* meaning something obscure, a riddle or mystery, and refers to the phylogenetic relationship of this species.

Material.—Holotype, 407347 (slightly distorted calyx, loc. 19); paratypes, 407348 (loc. 18), 407349 (silicified partial calyx, disarticulated and reconstructed, loc. 7 + 48.5). Other specimens, 407350–407352 (3 crushed partial calices, locs. 7 + 45, 7 + 51, and 8).

Genus SAMPSONOCRINUS Miller and Gurley, 1895

Remarks.—*Sampsonocrinus* was placed in synonymy with *Actinocrinites* by Moore and Laudon (1943). Wright (1955a), however, accepted the genus, recognizing that only the primibrach remained in the thecal wall, the theca was decidedly more bowl-shaped, and the radials were larger than in *Actinocrinites*. His analysis was accepted by Brower (1967) and followed in the *Treatise* (Moore and Teichert, 1978).

SAMPSONOCRINUS sp.

Fig. 5,*1,2*

Description.—Theca low bowl-shaped, with prominent wide lobes, sutures slightly impressed, no surface ornament below thecal rim; hexagonal basal disc with distal tips upflared; RR not as high as wide but largest plates in theca; $IBrr_1$ rectangular; axillary $IBrr_2$ convex transversely, in thecal wall but forming proximal end of lobes; iIBr series 1:2:2, in contact with superjacent tegmenal plates; primanal slightly higher but not so wide as RR, anitaxis series 1:2:3, in contact with tegmenal plates distally. Stem impression round; lumen round.

Measurements.—Theca height 11.5, width 27.0; BB circlet d 10.4; BB length 7.5, width 4.3; RR length 4.8, width 8.6; IBr length 3.4, width 6.1; iIBr length 6.3, width 5.4; IAx length 3.0, width 9.4; primanal length 5.0, width 5.9. Theca slightly distorted, height and width approximate; RR and IBr measured on E ray.

Remarks.—The partial theca of *Sampsonocrinus* (407353, loc. 3) consists of the basal disc, all radials, three rays, one interray, and the anitaxis. It represents a new species, for it lacks the stellate ridge ornament of *S. hemisphericus* Miller and Gurley, 1895, the granular ornament of *S. westheadi* Wright, 1947, and the globular shape of *S.? globosus* (Wachsmuth and Springer, 1897). The only other species referred to the genus, *S. loricatus* (Schlotheim, 1820), referred by Wright (1955a), has a high conical theca and probably does not belong to *Sampsonocrinus*. The Anchor Limestone specimen is not of sufficient quality to serve as a holotype.

Genus STEGANOCRINUS Meek and Worthen, 1866

STEGANOCRINUS sp.

Fig. 6,*9–12*

Remarks.—*Cytidocrinus* and *Steganocrinus* have ramule-bearing arms. The ramules develop on each brachial, on alternating sides, in *Steganocrinus*. In *Cytidocrinus,* every other brachial lacks

a ramule; that is, alternating ramules occur on every second brachial.

Three partial arm segments referred to *Steganocrinus* sp. (407354-407356, loc. 28) were found in one small block of limestone in the upper member; however, a calyx referable to *Steganocrinus* has not been found in the Anchor Limestone. The arm segments show some differences in the ramule branching pattern. One segment has alternating ramule bases on every brachial. Another segment shows the same pattern except that it is anomalous at the proximal end; one ramule is not developed where it would normally have been expected. The third segment has two ramule bases for every three brachials. All segments are short and do not represent complete arms. Because the arms are delicate and were found in close proximity, they are believed to show some of the variation of the ramule branching pattern on one arm or variation within one specimen.

On each of the three segments, a spine is developed on the oral side of the arm directly above each ambulacral opening. Distally each spine enlarges and branches into multiple short spines, producing a clavate appearance. Wachsmuth and Springer (1897, pl. 61, fig. 1e) illustrate sharply pointed spines on specimens of *S. sculptus* (Hall, 1858). It is not known if the difference in spine shape is of specific significance.

Genus ANCALOCRINUS, n. gen.

Type species.—*Actinocrinus spinobrachiatus* Hall, 1860, here designated.

Diagnosis.—Crown elongate; calyx strongly lobate; theca discoid to wide shallow bowl-shaped; tegmen stout, highly arched, summit spinose; generally 4 free biserial arms per ray, no distal branching; stem round, lumen pentalobate.

Description.—Crown elongate, calyx not visible in lateral view if arms preserved; calyx strongly lobate, bell-shaped in lateral view, pentalobate in basal view; theca discoid to wide shallow bowl-shaped, lobes declining distally to level of BB; tegmen highly arched, summit bearing spinose OO; anal tube short, eccentric, directed obliquely upward.

Basal circlet hexagonal, horizontal, impressed for stem attachment; 3 equal BB, sutures in B and E rays and CD interray. RR hexagonal, wider than long, weakly upflared distally, bearing transverse ridge ornamentation. $IBrr_1$ octagonal, wider than long, strongly convex transversely, horseshoe-shaped in transverse section, subhorizontal to moderately downflared, bearing transverse ridge and node ornamentation. $IBrr_2$ septagonal, wider than long, axillary, strongly convex transversely, downflaring, bearing transverse ridge and node ornamentation. IIBr axillary, wider than long, strongly convex transversely, bearing transverse ridge and node ornament. $iIBr_1$ large, followed by 2 smaller plates, in contact with tegmenal plates distally. Primanal hexagonal, longer than wide; anitaxis series 1:2:3, in contact with tegmen distally. Tegmen large plated, sculptured by wide interradial notches extending nearly to oral summit. Arms free with IIIBrr, 4 per ray, retaining width until near distal ends, distally every sixth Br bearing a laterally directed spine, no distal branching. Stem round; lumen pentalobate.

Remarks.—The strongly grouped arms that form extended lobes on *Ancalocrinus* are similar to those of *Steganocrinus* and *Sampsonocrinus*. The thecae of these latter two genera have upflaring basals and are conical or bowl-shaped. *Blairocrinus* is the only other actinocrinitine with a flat basal disc; however, it has a bowl-shaped theca with the radials forming low subvertical walls. Also the lobes are not as extended on *Blairocrinus* as they are on *Ancalocrinus*. We consider *Ancalocrinus* to represent the extreme flattening of the theca that occurred in the Actinocrininae. This morphological condition is homologous with that developed in *Displodocrinus,* n. gen., in the Sunwaptacrinidae.

Etymology.—The generic name is derived from *ancala,* which is Greek, meaning the bent arm, and refers to the recurved arms in this crinoid.

ANCALOCRINUS SPINOBRACHIATUS (Hall, 1860), n. comb.

Fig. 7,*11-13*

Actinocrinus spinobrachiatus Hall, 1860:6, text fig.
Amphoracrinus? spinobrachiatus (Hall). Meek and Worthen, 1873: 389, pl. 6, figs. 5a-c. Wachsmuth and Springer, 1897:478, pl. 62, figs. 1-4.

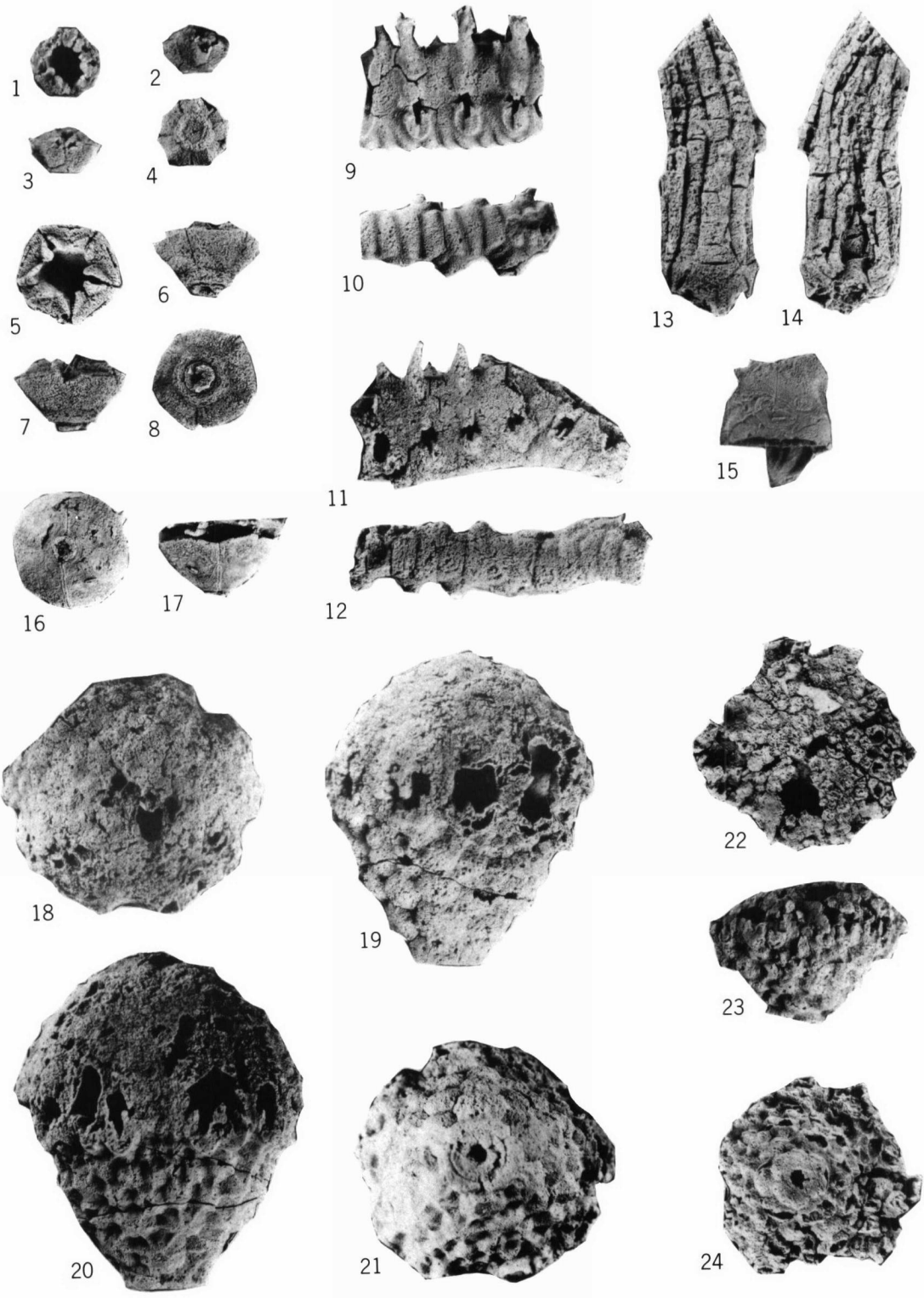

Fig. 6. For explanation, see facing page.

Description.—See Hall, 1860; Wachsmuth and Springer, 1897.

Remarks.—The coarse, wavy, transverse ridge and node ornamentation of *A. spinobrachiatus* is distinctive. Stellate ridges between thecal plates and ray ridges are the most common form of ornamentation in the Actinocrinitidae. Variation is noted on the Anchor specimens. One form (Fig. 7,*11*) has thin high transverse ridges across the radials, less high ridges on the first primibrachs, and a longitudinally high ridge on the primanal. Similar ornament but only somewhat wavy and not so highly elevated occurs on another specimen (Fig. 7,*13*). On a third specimen (Fig. 7,*12*) the ridges are crenulate with subridges at the apices of the crenulations and accessory nodes on some plates. Similar ornamentation is also present on the axillary primibrachs, secundibrachs, interprimibrachs, and distal plates in the anitaxis series. The same types of ornament and variation are present on specimens illustrated by Wachsmuth and Springer (1897, pl. 62, figs. 1-4) and on identified specimens in the biological collection of the Springer collection at the United States National Museum. Generally more coarsely ornamented forms have nodose tegmenal plates and more finely ornamented forms have smooth but tumid tegmenal plates. In addition, the shape of the base of the theca varies from gently convex to flat to slightly concave.

Material.—Five specimens, 407357-407361 (locs. 3, 11, 12, 22, and 10).

Genus CUSACRINUS Bowsher, 1955

CUSACRINUS VIATICUS (White, 1874)

Remarks.—Bowsher (1955) reassigned *Actinocrinus viaticus* White, 1874 to *Cusacrinus*. Stellate ornament is obvious on an otherwise poorly preserved crown with six arms per ray. The preservation of the specimen is such that the species should probably be restricted to the type.

Cusacrinus viaticus was found at Mountain Spring Pass in the early 1870's on the geographical surveys west of the 100th meridian. The specimen occurs on a small slab in association with *Platycrinites vexibilis*.

CACTOCRININAE? sp.

Remarks.—A crushed calyx (407582, loc. 7 + 54) from the upper upper member of the Anchor Limestone is questionably referred to the Cactocrininae. The medium-sized specimen has a conical theca, moderately inflated tegmen, weakly protruded brachial lobes, interprimibrachs in contact with the tegmen distally, well-developed stellate ornament on thecal plates, tegmenal plates that are nodose close to the thecal rim and distally slightly tumid, the second primibrach and only secundibrach axillary, four arms per ray at the thecal rim, and one thecal pore per arm. The anal tube, arms, and stem are unknown. The posterior interray is crushed, and some plates are missing. Although dislocated slightly, the primanal was followed by three plates in the second tier.

This specimen represents another genus of the Actinocrinitidae in addition to those described. It is probably a *Cusacrinus* or *Nunnacrinus*. The presence of three plates in the second row of the anitaxis we consider to be anomalous.

Genus PHYSETOCRINUS Meek and Worthen, 1869

PHYSETOCRINUS sp. cf. P. COPEI (Miller, 1881)

Fig. 6,*22-24*

Remarks.—Two specimens referred to *Physetocrinus* sp. cf. *P. copei* from the lower member of the Anchor Limestone are poorly silicified; one lacks the tegmen and the other is partly crushed. Both have conical cups, scalloped basal flanges, tumid cup plates with weakly developed stellate ridge ornament, and the four arms grouped and weakly protuberant. The small-

Fig. 6. Actinocrinitidae, Dichocrininae, disparid inadunates.—*1-4. Synbathocrinus* sp. 2, oral, A ray, posterior, and basal views, respectively, 407463, ×2.0.—*5-8. Synbathocrinus* sp. 1, oral, A ray, posterior, and basal views, respectively, 407444, ×1.5.—*9-12. Steganocrinus* sp., 9, 10, lateral and basal views, 407355, ×1.5; 11, 12, lateral and basal views, 407354, ×1.5.—*13-15. Halysiocrinus* sp., 13, 14, E ray and BC ray views, 407441, ×1.5; 15, E ray view, 407442, ×1.5.—*16, 17.* Dichocrininae indet., basal and lateral views, 407410, ×1.0.—*18-21. Physetocrinus majusculus,* n. sp., oral, A ray, posterior, and basal views, respectively, holotype 407364, ×1.0.—*22-24. Physetocrinus* cf. *P. copei,* oral, posterior, and basal views, respectively, 407362, ×1.0.

plated tegmen is low but definitely convex, and all plates are weakly to moderately tumid. The anal opening occurs on the surface, with no trace of an anal tube.

Brower (1969) remarked on the considerable variation in tegmen convexity, cup shape, and ornamentation of *P. copei* in the Nunn Shale and Redwall Limestone. He considered the Redwall Limestone specimens to represent a variety with a convex tegmen, conical cup, weakly developed ornament, and anal opening on a short rudimentary anal tube. Specimens from the Anchor Limestone agree with the descriptions and illustration of *P. copei* except for the presence of a small basal flange and lack of a rudimentary anal tube. The state of preservation and the differences noted preclude a positive identification.

Measurements.—Calyx height 23.4, width 29.5; theca height 15.0; BB circlet d 9.8; BB length 4.2, width 7.5; RR length 5.5, width 7.2; IBr_1 length 3.4, width 5.2; IAx length 3.8, width 5.0; iBr_1 length 4.6, width 5.1; iBr series 1:2:2; primanal length 5.2, width 4.8; anitaxis series 1:2:3:3:2; 4 arms per ray.

Material.—407362, 407363 (loc. 20).

PHYSETOCRINUS MAJUSCULUS, n. sp.

Fig. 6,*18-21*

Diagnosis.—Calyx large, conical turbinate, tegmen inflated, plates moderate sized; 4 arms per ray, weakly grouped, slightly protruded; iIBrr in contact with tegmen; stellate ridge ornament; stem round, lumen pentalobate.

Description.—Calyx large, turbinate, tegmen inflated, slightly higher than theca. Theca steeply conical, walls straight to weakly convex, slope 60° above horizontal, base flat. Basal circlet hexagonal, shallow-concave proximally, subvertical to weakly flared distally; sutures notched, in normal position in B and E rays and CD interray; BB equal in size, wider than long, with small central notch. RR large, hexagonal, wider than long, steeply upflared, tumid. $IBrr_1$ smaller than RR, hexagonal, wider than long, steeply upflared, tumid. Axillary IBr_2 commonly pentagonal, rarely hexagonal or septagonal, wider than long, tumid. Axillary IIBrr septagonal, strongly convex transversely, gently convex to concave longitudinally, distal tips flaring outward in some. IIIBrr rectangular, much wider than long, strongly convex transversely, upflaring to horizontal, 1 or 2 per arm fixed in calyx. Arms free above $IIIBr_1$ or $IIIBr_2$, 4 per ray.

$iIBr_1$ large, hexagonal, approximately equidimensional, tumid; series commonly 1:2:2:2, rarely 1:3:2:3:2 to base of ambulacral tracts, in contact with tegmenal plates distally. One narrow iIIBr per ray, in contact with tegmenal plate near top of ambulacral openings. Primanal in radial circlet, approximately size of RR, wider than long to longer than wide; anitaxis series 1:2:4:3:2, in contact with tegmenal plates distally. Ambulacral tracts elongate longitudinally; openings in each half-ray separated by 1 elongate plate; openings in adjacent half-rays separated by 3 elongate plates parallel to one another; openings in adjacent rays separated by 2 ranges of 2 or 3 plates. Tegmen formed of moderate-sized plates, faintly to gently tumid, OO on anterior side of anal opening, CD O surrounded by half circlet of others, slightly larger than other tegmenal plates; shallow interradial depressions or troughs extending 0.50 to 0.67 distance to summit, anal interray though slightly wider, extending to slightly eccentric anal opening. Anal opening probably flush posteriorly, weakly rimmed anteriorly.

Cup ornament stellate ridges radiating across all cup plates to IIBrr, less pronounced triple and double ridges from BB to RR and primanal along ray axes. Stem circular, proximal columnals thin; lumen pentalobate.

Measurement of:	Holotype	Paratype
	407364	407365
calyx height	51.9	...
width	43.0	...
theca height	24.9	...
BB circlet d	13.6	9.6
BB length	6.0	...
width	10.4	8.9
RR length	7.3	5.5
width	9.5	8.5
IBr_1 length	5.6	5.0
width	7.7	6.7
IAx length	4.9	...
width	6.9	...
IIAx length	4.0	...
width	6.3	...
iBr length	6.8	5.9
width	6.7	5.9
primanal length	8.2	~5.3
width	7.9	~7.5
stem impr d	8.3	7.4
lumen d	...	1.8

Remarks.—The presence of relatively strongly grouped arms, four arms per ray, and relatively large tegmen plates on *P. majusculus* shows relationship to primitive forms of the genus as recognized by Brower (1969). The arms are not as strongly lobed as those in *P. sampsoni* Miller and Gurley, 1896 from the Chouteau Limestone in Missouri or *P. smalleyi* Weller, 1909 from the Fern Glen Formation in Missouri.

The inflated tegmen of *P. majusculus* is distinctive. Only *P. smalleyi* has an inflated tegmen relatively as large as that of *P. majusculus*. The low cup and flaring arms of *P. smalleyi* suggest relationship to *Blairocrinus*.

P. majusculus is closely related to *P. copei*. *P. majusculus* differs by having a more highly inflated tegmen and a higher conical theca. The arms flare out to produce a weak overhang but not a solid rim at the base of the arm lobes; fewer plates separate the ambulacral tracts between rays and half-rays, and tegmenal plates are of a more uniform, intermediate size.

Etymology.—The species name *majusculus* is Latin, meaning somewhat larger or greater, and refers to the large size and inflation of the tegmen.

Material.—Holotype, 407364 (loc. 34); paratype, 407365 (loc. 11).

PHYSETOCRINUS? sp.

Fig. 7,*19-21*

Description.—Calyx large, turbinate, irregular pentagonal in oral view, tegmen inflated, approximately height of theca, lobes slightly protruded. Theca wide, bowl-shaped, walls gently convex to distal tips of axillary IIBrr, outflaring at distal tips; prominent stellate ridge ornament on all thecal plates to base of ambulacral tracts, ridges triple and double to distal center of axillary IIBrr, single to ambulacral tracts, all thecal plates large and tumid. Basal circlet scalloped hexagonal, forming base of calyx, impressed distally for stem attachment, sutures in normal position, B and E rays and CD interray; BB wider than long, flat proximally, distal tips upflared. RR wider than long, hexagonal, or septagonal if adjoined by 2 BB. $IBrr_1$ wider than long, hexagonal in E, A, and B rays, pentagonal in C and D rays, laterally adjoining only 1 plate of anitaxis and 2 iIBrr on opposite side. Axillary $IBrr_2$ longer than wide, pentagonal or hexagonal depending on number of interradial plates adjoined. Axillary IIBr hexagonal or septagonal, supporting iIIBr distally on inner shoulder. Inner IIIBr of each half-ray axillary. Outer IIIBr of each half-ray and $IVBrr_1$ of inner half-ray supporting free arms; 6 arms per ray.

iIBrr hexagonal or septagonal, wider than long; series 1:2:2:2 to base of ambulacral tracts, adjoining tegmenal plates distally. iIIBrr small, adjoined by 2 narrow elongate plates, extending between ambulacral tracts to adjoin tegmenal plate distally. iIIIBr narrow, extending distally between ambulacral tracts to adjoin tegmenal plates. Tegmen moderately arched, surface scalloped by interradial troughs extending as far as can be seen on part preserved; secondary depressions originating between half-rays extending onto lower 0.34 of tegmen; all plates small, numerous, not ornamented. Primanal in radial circlet, slightly wider than long; anitaxis series 1:3:4:2:2 to base of ambulacral tracts, adjoining tegmen distally. Anal opening or tube not preserved. Stem impression round; lumen not preserved.

Measurements.—Calyx height 43.4 (incomplete), width 50.3 (avg); theca height 22.3; BB circlet d 13.5; BB length 4.8, width 9.5; RR length 7.5, width 10.8; IBr_1 length 7.9, width 4.5; IAx length 9.1, width 7.6; iBr length 7.4, width 9.1; primanal length 8.4, width 8.7; stem impr d 6.5.

Remarks.—This specimen may represent a new genus intermediate between the Pereichocrinidae and Actinocrinitidae. As discussed under the Actinocrinitidae, some actinocrinitids are morphologically like some of the younger pereichocrinids from which the actinocrinitids were derived. *Physetocrinus*? sp. could be classified in the Pereichocrinidae because it has three plates above the primanal. The moderately arched tegmen and presence of intertertibrachs support this classification. The axillary single secundibrach and occurrence of the base of the free arms with the first tertibrach or quartibrach support assigning the form to the Actinocrinitidae.

We have questionably assigned this form to *Physetocrinus,* considering the occurrence of three plates in the second row of the anitaxis to be an abnormality. Actinocrinitids, including *Physetocrinus,* normally have only two plates

immediately above the primanal, but exceptions have been reported (Brower, 1969). The ornamentation, moderately arched tegmen, and six arms per ray are features found in the physetocrinids. The small-plated tegmen and six arms per ray are advanced features, whereas the moderately arched tegmen, protruded lobes, and presence of intertertibrachs are primitive features of *Physetocrinus* (Brower, 1969). *Physetocrinus* lacks an anal tube; it is not known if this form has an anal tube.

Physetocrinus? sp. may be ancestral to younger physetocrinids with more than four arms per ray.

Material.—407366 (loc. 17).

Family SUNWAPTACRINIDAE, n. fam.

Type genus.—*Sunwaptacrinus* Laudon, Parks, and Spreng, 1952.

Diagnosis.—Crown elongate, calyx lobed, theca discoid to shallow bowl-shaped, tegmen elevated, anal tube stout, with or without spinose termination; BB 3, equal, $IBrr_1$ quadrangular or hexagonal, IIBrr and IIIBrr not fixed in some genera, $iIBr_1$ large, followed by a few smaller plates in contact with tegmenal plates distally; primanal in radial circlet, followed by 3 plates; anitaxis wide, in contact with tegmen distally. Arms biserial just beyond calyx, branching isotomously more than once distally, all bifurcations high above theca. Column round; lumen pentalobate.

Remarks.—When *Sunwaptacrinus* was named by Laudon, Parks, and Spreng, they recognized that it was intermediate between the Coeleocrinidae and Batocrinidae but placed it in the Batocrinidae because it has a stout, elongate anal tube. At the same time they stated (1952:570), "*Sunwaptacrinus,* although temporarily placed in the Batocrinidae, will eventually have to be placed in a new family." Lane (1963) removed *Sunwaptacrinus* from the Batocrinidae because the free arms branch above the theca. Ubaghs (in Moore and Teichert, 1978) placed *Sunwaptacrinus* in family uncertain, noting the desmidocrinid affinities.

We consider the Sunwaptacrinidae to have evolved from *Desmidocrinus* in Late Devonian or Early Carboniferous time. The sunwaptacrinids extended the tegmen into a stout anal tube, lowered the cup, and developed distal arm branching. The distal arm branching is variable but typically occurs twice or three times. Branches may divide again or remain single. Thickness of the arms remains uniform until tapering at the tips. In addition to *Sunwaptacrinus,* the family contains *Displodocrinus,* n. gen., and *Dilatocrinus,* n. gen.

The observed geographic distribution of the family is restricted to North America. The earliest known form, *Sunwaptacrinus,* occurs in the upper crinoid zone of the Banff Formation, of middle Tournaisian age, in Alberta, Canada. The occurrence of *Displodocrinus* and *Dilatocrinus* with *Sunwaptacrinus* in the Anchor Limestone in southern Nevada in the latest middle Tournaisian and earliest late Tournaisian is the next youngest occurrence. The family apparently terminated with *Displodocrinus* and *Dilatocrinus* in the lower Burlington Limestone in Iowa in late Tournaisian time.

Genus SUNWAPTACRINUS Laudon, Parks, and Spreng, 1952

SUNWAPTACRINUS NEVADENSIS, n. sp.

Fig. 7,*1-5*

Diagnosis.—A *Sunwaptacrinus* with lobes flaring with the axillary IBr_2, impressed sutures, stellate ornament lacking, and 12 arms at thecal rim.

Description.—Theca discoid in immature forms, shallow bowl-shaped in adults, wider than high, strongly lobate; tegmen unknown, sutures impressed. Basal circlet horizontal, hexagonal, base gently excavated for stem attachment, distal edges vertical, visible in lateral view of calyx, sutures moderately deeply notched, in normal position in B and E rays and

Fig. 7. Sunwaptacrinidae, Actinocrinitidae.—*1-5. Sunwaptacrinus nevadensis,* n. sp., 1, 2, A ray and basal views, holotype 407377, ×1.5; 3, 4, B ray and posterior views, paratype 407378, ×1.0; 5, basal view, paratype 407379, ×1.5.—*6-9. Displodocrinus monticulus,* n. gen., n. sp., 6, 7, posterior and basal views, holotype 407381, ×1.0., 8, basal view, paratype 407382, ×1.5; 9, basal view, paratype 407383, ×1.0.—*10. Displodocrinus monticulus*?, lateral view, 407386, ×1.0.—*11-13. Ancalocrinus spinobrachiatus,* n. gen., 11, basal view, 407357, ×1.0; 12, basal view, 407358, ×1.0; 13, basal view, 407359, ×1.0.—*14-18. Dilatocrinus apricus,* n. gen., n. sp., 14, 15, posterior and basal views, paratype 407388, ×1.0; 16, basal view, paratype 407389, ×1.0; 17, 18, posterior and basal views, respectively, holotype 407387, ×1.0.—*19-21. Physetocrinus*? sp., posterior, basal, and A ray views, respectively, 407366, ×1.0.

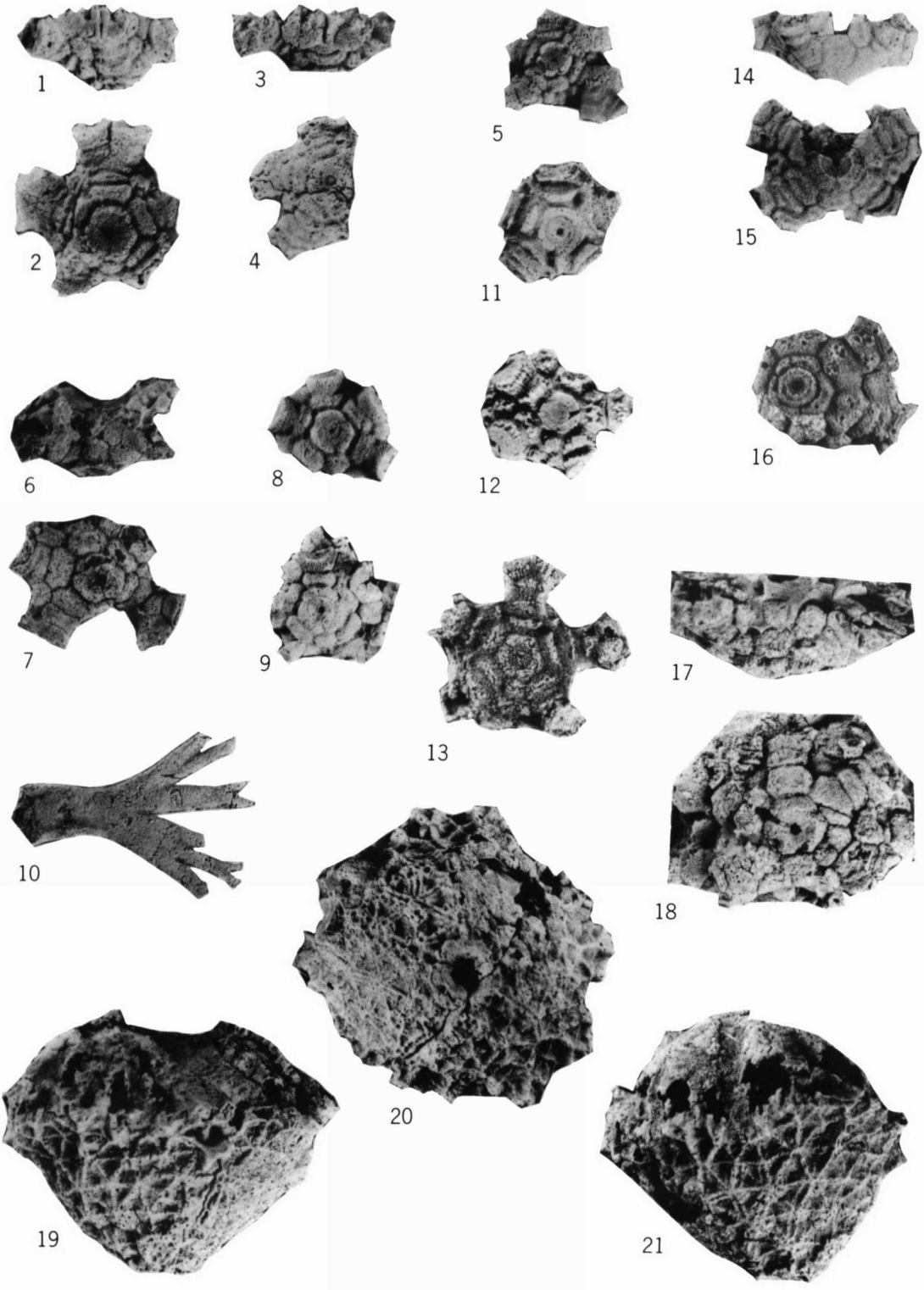

Fig. 7. For explanation, see facing page.

CD interray; BB 3, equal, approximately twice as wide as long, gently convex transversely, slightly concave to convex longitudinally. IBr_1 rectangular, 2 to 4 times wider than long, moderately convex transversely, gently convex longitudinally, all sutures convex. IBr_2 septagonal, axillary, strongly convex transversely, gently convex longitudinally, flaring subhorizontally, adjoining $iIBr_1$ and $iIBr_2$ laterally. IIBrr wider than long, proximal 1 to 3 fixed, becoming biserial immediately, facets deep. C and D ray $IIBr_1$ axillary on inner half-ray; 12 arms at thecal rim, distal arms unknown.

$iIBrr_1$ large, octagonal, longer than wide, gently convex transversely and longitudinally, series 1:2, second tier plates smaller, distally adjoining tegmenal plates. Primanal in radial circlet, septagonal, slightly wider than long; anitaxis 1:3:4 or 1:3:5, wide, adjoining tegmenal plates distally; interradial areas wide, moderately deep. No ornamentation, plates appearing tumid with impressed sutures. Stem round; lumen pentalobate.

Measurement of:	Holotype	Paratypes		
	407377	407378	407379	407380
theca height	...	...	3.3	...
BB circlet d	6.0	7.5	3.6	7.9
BB length	2.7	3.5	1.8	3.9
width	4.5	6.3	2.8	6.3
RR length	2.7	3.3	1.5	3.0
width	5.0	6.5	3.0	6.3
IBr_1 length	1.6	2.5	0.6	...
width	3.9	5.3	2.8	...
IAx length	2.0	2.5	1.4	...
width	5.3	6.8	4.1	...
iBr length	3.1	3.8	2.3	...
width	2.9	2.7	1.3	...
primanal				
length	2.7	...	1.9	4.0
width	3.0	...	2.3	4.0
stem impr d	4.5	3.8	2.5	5.8
lumen d	0.9	...	0.6	1.5

Remarks.—A growth series is represented in the four specimens of *S. nevadensis*. These specimens show that the theca is discoid in immature forms and becomes a very shallow bowl with growth. The basal disc remains horizontal throughout growth, whereas the radials curve upward as they increase in size. The lobes are well developed on the smallest specimen with the axillary second primibrach downflaring. In adult specimens the upflaring of the radials results in the elevation of the axillary primibrachs into a subhorizontal position. First primibrachs in immature forms are much wider than long, a nearly 4:1 ratio; with growth the length increases more rapidly than the width so that in adults the width is only about twice the length. The tegmen would probably have been somewhat expanded as there is no indication of incurving of the thecal rim.

The holotype of the type species of *Sunwaptacrinus, S. brazeauensis,* is of late Kinderhookian age, from the Banff Formation, Alberta, Canada. *S. nevadensis* lacks the stellate ornament of, and has fewer arms per ray at the thecal rim than *S. brazeauensis*.

Etymology.—The specific name is derived from the state of Nevada where the specimens were found.

Material.—Holotype, 407377 (loc. 28); paratypes, 407378 and 407379 (loc. 28), 407380 (loc. 27).

Genus DISPLODOCRINUS, n. gen.

Type species.—*Actinocrinus divergens* Hall, 1860, here designated.

Diagnosis.—A Sunwaptacrinidae with horizontal basal circlet, theca discoid to wide shallow bowl-shaped, calyx strongly lobed, lobes outflaring with IBr_1, declining to IIIBrr, upflaring when free; arms branching distally 2 or more times; tegmen stout, with spinose termination.

Description.—Crown nearly as wide as long, arms spreading widely, incurving at summit, calyx not visible in lateral view; theca discoid to shallow bowl-shaped, strongly lobate with deep wide interradial areas; tegmen stout with spinose oral ring, anal tube extended with terminal spine ring in most species. Arms biserial, 3 to 5 per ray where free, branching 2 or more times distally, retaining width until near distal ends.

Basal circlet horizontal, formed of 3 equal plates, sutures in B and E rays and CD interray. RR hexagonal or heptagonal, wider than long, subhorizontal to gently upflared. IBr_1 hexagonal, subhorizontal to declined, much wider than long, strongly convex transversely, forming base of lobes. $IBrr_2$ axillary, declined, much wider than long, strongly convex transversely. IIBr wider than long, commonly axillary, declined. $IIIBr_1$ or $IIBr_2$ fixed. iIBrr elongate, extending upward between lobes to adjoin 2 plates in base of tegmen. Arms retaining width

distally nearly to terminus before tapering; distal branches isotomous. Primanal in radial circlet, followed by 3 plates adjoining tegmenal plates distally.

Tegmen formed of intermediate to large plates, OO large, spinose in some forms; anal tube eccentric, narrower than tegmen. Theca commonly ornamented. Stem round; lumen pentalobate.

Remarks.—We have been unable to locate Hall's (1860) type of *Actinocrinus divergens.* Wachsmuth and Springer (1897:591) recorded it in the Worthen collection at the Illinois State Museum at Springfield. Richard Leary, curator at the museum, informed us (pers. comm., Feb. 1986) that they have no accession record of the specimen.

Hall's (1860) description is adequate, and we consider part of the specimens illustrated by Wachsmuth and Springer (1897:588, pl. 62, figs. 6, 8–10 only) to be correctly identified. Our concept of *Displodocrinus* is based on these specimens. Because the type specimen of *A. divergens* is lost, the specimen illustrated by Wachsmuth and Springer (1897: pl. 62, fig. 6) is here designated as the neotype. This specimen is in the Springer collection in the USNM.

Displodocrinus differs from *Sunwaptacrinus* by having a much lower theca with more pronounced lobes and drooping arms proximally. In addition to *D. divergens,* n. comb., and *D. monticulus,* n. sp., the genus includes *D. viminalis* (Hall, 1863), n. comb. The genus is known only from North America, from the Waverly Group and the Anchor and Burlington limestones. It is of middle and late Tournaisian age.

Etymology.—*Displodocrinus* is derived from *displodo,* Latin, meaning spread out, and refers to the discoid shape of the theca and spread out nature of the crown.

DISPLODOCRINUS DIVERGENS (Hall, 1860), n. comb.

Actinocrinus divergens Hall, 1860:36, text-fig.
?*Actinocrinus quadrispinus* White, 1865:15.
Amphoricrinus divergens (Hall, 1860). Wachsmuth and Springer, 1881:155. Whitfield, 1893:21, pl. 2, figs. 12, 13. Wachsmuth and Springer, 1897:588 (part), pl. 62, figs. 6, 8–10 only.

Remarks.—Wachsmuth and Springer (1897) interpreted *Amphoracrinus divergens* (Hall, 1860) loosely, illustrating forms with flat basal discs (pl. 62, figs. 6, 8–10) and upflared basal discs (pl. 62, figs. 5, 7). Other obvious differences in ornamentation, number of primibrachs, cup shape, and arms on the same illustrations separate these specimens. Species that they included in the synonymy have such distinct differences as only two plates in the second tier of the anitaxis (i.e., *Actinocrinus planobasilis* Hall, 1860). Wachsmuth and Springer (1897:588) commented on the variation in the theca and tegmen; but apparently placed more emphasis on the branching pattern of the arms for taxonomic purposes. We consider the branching of the arms important, but not to the exclusion of other morphologic features of the theca that have been shown to be of value (Brower, 1967, 1969).

DISPLODOCRINUS MONTICULUS, n. sp.

Fig. 7,6–9

Diagnosis.—A *Displodocrinus* with impressed sutures, tumid RR, and granular ornament.

Description.—Theca discoid to wide shallow bowl-shaped; strongly lobate with lobes declining distally below base of theca. Basal circlet hexagonal, gently impressed for stem attachment; commonly projecting below RR, visible in lateral view of calyx, normally notched by sutures in B and E rays and CD interray; BB 3, large, nearly twice as wide as long. RR 5, hexagonal, large, approximately half again wider than long, subhorizontal to gently upflared, convex transversely and longitudinally. $IBrr_1$ hexagonal, strongly convex transversely, transverse cross section horseshoe-shaped, much wider than long, declined to subhorizontal, forming base of lobes. IBr_2 axillary, pentagonal or hexagonal, strongly convex transversely, much wider than long, declined with distal tip near level of base of theca. IIBrr wider than long, 1 per half-ray, axillary, declined. $IIIBr_1$ fixed, wider than long, declined.

iIBrr hexagonal or heptagonal, large, elongate, widely separating rays, adjoining 2 plates distally. Primanal in radial circlet, septagonal, approximately equidimensional, supporting 3 plates in second tier, anitaxis adjoining teg-

menal plates distally. Tegmen and distal arms not preserved. Thecal plates bearing poorly preserved granular ornament. RR bearing tumid transverse ridges. Column round; lumen pentalobate.

Measurements of:	Holotype	Paratypes			
	407381	407383	407384	407382	407385
calyx width	25.5[a]	...	...	...	...
theca height	5.2	2.7	7.4	...	...
BB circlet d	8.0	7.5	8.5	4.6	7.8
length	4.0	3.6	4.2	2.2	3.7
width	7.2	5.8	7.1	3.7	6.0
RR length	4.9	2.9	4.8	2.0	3.8
width	7.6	5.7	6.6	3.8	7.3
IBr_1 length	3.1	2.2	3.6	1.8	...
width	6.8	6.8	6.8	4.0	...
IAx length	3.3	...	2.6	...	...
width	6.7	...	7.0[a]	...	...
iBr length	4.9	4.3	5.6	3.1	...
width	4.4	2.6	3.5	2.2	...
primanal length	4.4	...	4.8	3.0	...
width	5.0	...	4.0	3.0	...
stem impr d	4.7	3.9	5.0	2.8	5.7
lumen d	...	1.0	1.0	0.7	1.8

a. Incomplete.

Remarks.—The immature specimen of *Displodocrinus monticulus* (Fig. 7,*8*) has a nearly flat theca. The radials barely upflare and the first primibrachs downflare. The intermediate-sized specimen (Fig. 7,*9*) has slightly more upflared radials with the first primibrachs strongly downflared. The first primibrachs are subhorizontal on the holotype and an unillustrated large paratype (407384). These specimens form a growth series that shows the change from a nearly flat discoid theca in immature forms to a wide shallow bowl-shape in adults.

Silicification has apparently preserved the granular ornamentation in a somewhat random manner on the five specimens. It is best preserved on the primibrachs and interprimibrachs. The smallest specimen has from wavy ridges to a shagreen ornamentation on some plates and a faint granular ornamentation on others. The shagreen ornament may be the result of acid etching.

Differences between *D. monticulus* and *D. divergens* are the presence of granular ornament, relatively larger radials, and slightly more upflaring theca on *D. monticulus*.

Etymology.—The species name, *monticulus,* Latin, means little mountain and refers to the mountains where the specimens were found.

Material.—Holotype, 407381 (loc. 27); paratypes, 407383, 407384 (loc. 11), 407382, 407385 (loc. 14).

DISPLODOCRINUS MONTICULUS?

Fig. 7,*10*

Remarks.—*Displodocrinus divergens* has terminal tegmen spines that are digitate as illustrated by Wachsmuth and Springer (1897, pl. 6, fig. 6). Digitate tegmen spines were found in several blocks of the Anchor Limestone during etching for cups or calices. One spine (407386, loc. 27), found in association with the holotype of *D. monticulus,* is divided into five branches distally. At least four of the branches divide into a dual spine at the distal end. These spines are large (35.3 mm long, 25.0 mm wide) and when spread around the tegmen terminus would make a formidable barrier for predators.

Genus DILATOCRINUS, n. gen.

Type species.—*Amphoracrinus multiramosus* Meek and Worthen, 1866, here designated.

Diagnosis.—A sunwaptacrinid with BB upflaring, theca low bowl-shaped, calyx strongly lobate, arms drooping proximally, with multiple isotomous branches distally, tegmen stout with extended anal tube bearing terminal spines.

Description.—Crown nearly as wide as long, arms widely spread and incurving distally, base of calyx visible in lateral view; theca low shallow bowl-shaped, wider than long, strongly lobate with deep wide interradial areas; tegmen stout, extended into elongate anal tube; tube spinose medially and distally. Arms biserial, drooping proximally, 2 to 4 per ray at thecal rim, branching isotomously 2 or more times distally, retaining width until near distal end. Thecal plates with or without granular ornament, sutures impressed.

Basal circlet truncate proximally, upflaring distally, formed of 3 equal plates, sutures in B and E rays and CD interray. RR 5, large, hexagonal, upflaring, wider than long. $IBrr_1$ hexagonal, upflared proximally to subhorizontal distally, wider than long, convex transversely, concave longitudinally, forming base of lobes. IBr_2 axillary, horizontal to declined, much wider than long. IIBr pentagonal, wider

than long, commonly axillary. $IIIBr_1$ and $IIIBr_2$ fixed, $IIIBr_2$ axillary in some rays; brachials free and biserial thereafter. iIBrr large, extending upward, between bases of lobes, adjoining 2 plates distally. Primanal in radial circlet, smaller than RR, followed distally by 3 plates. Stem round; lumen pentalobate.

Remarks.—*Dilatocrinus* is intermediate between *Displodocrinus* and *Sunwaptacrinus*. In *Dilatocrinus* the base of the theca is visible in lateral view and the basal circlet is upflaring, not flat, with the theca not visible in lateral view as in *Displodocrinus*. The arms droop proximally and the theca does not upflare as much in *Dilatocrinus*; in *Sunwaptacrinus* the arms do not droop and there is a greater amount of upflare in the theca.

Meek and Worthen (1873) suggested the name *Amphoracrinus multiramosus* under *A. divergens,* stating that the specimen their description was based on was probably a distinct species, and noting differences in tegmenal spines and arm branching. Apparently they considered the thecal differences mere variations, making no mention of them.

Dilatocrinus is known only from North America. It is of middle and late Tournaisian age. In addition to the type species *D. multiramosus,* n. comb., the genus includes *D. apricus,* n. sp.

Etymology.—*Dilato* is derived from *dilatus,* a Latin term meaning spread or expanded, and refers to the spread out nature of the theca.

DILATOCRINUS APRICUS, n. sp.

Fig. 7,*14-18*

Diagnosis.—Theca low bowl-shaped, strongly lobate, arms downflaring on distal part of lobes; BB upflared, sutures impressed, unornamented plates gently to moderately elevated above impressed sutures.

Description.—Theca low shallow bowl-shaped, tegmen and free arms unknown. BB 3, equal, much wider than long, with sutures in normal position on B and E rays and CD interray, gently upflared, distally visible in lateral view of theca, proximally gently impressed for stem attachment. RR 5, large, hexagonal, normally not quite twice as wide as long, gently convex transversely and longitudinally, upflared at approximately 45°. $IBrr_1$ small, rectangular, nearly twice as wide as long, gently convex transversely and longitudinally, with sutures convex, subhorizontal, forming initial base of lobes. IBr_2 pentagonal or rarely hexagonal, axillary, moderately convex transversely, gently convex longitudinally, downflared distally. $IIBrr_1$ fixed, much wider than long, gently convex transversely; more distal Brr not preserved.

iIBrr octagonal or nonagonal, large, longer than wide, supporting 2 plates, series distally in contact with tegmenal plates. Primanal septagonal, in line of RR, slightly longer than wide; anitaxis 1:3, more distal plates unknown. Arms 10 at thecal rim, free arms unknown. Sutures impressed, no other ornament. Stem round; lumen pentalobate.

Measurement of:	Holotype	Paratypes			
	407387	407388	407389	407390	407391
calyx width	27.5[a]	25.8[a]	....	...	...
theca height	6.6	9.7	13.7	...	...
BB circlet d	9.4	8.7	10.2	8.9	9.8
BB length	4.5	8.7[b]	4.7	4.3	4.7
width	7.5	6.4	8.2	7.0	7.2
RR length	4.7	4.4	5.0	5.3	5.3
width	7.7	6.3	9.0	8.8	8.2
IBr_1 length	2.8	2.7	4.3	3.4	...
width	6.0	5.6	7.4	6.6	...
IAx length	2.7	2.7	2.4	3.1	...
width	8.3	7.2	9.3	8.1	...
iBr length	6.5[a]	5.9	6.9	6.4	...
width	6.1[a]	4.0	6.2	5.6	...
primanal					
length	4.9	5.3	6.0	6.4	5.4
width	5.9	5.5	6.9	6.7	5.9
stem impr d	....	4.6	7.0	6.9	5.7
lumen d	2.2	1.1	1.7	1.5	1.5

a. Incomplete.
b. E-BC plane.

Remarks.—The degree of impression of the sutures among the five specimens of *Dilatocrinus apricus* ranges from slight to moderate. The basal circlet of paratype 407390 is abnormal in the position of the basal sutures, which are in the E and A rays and CD interray.

Dilatocrinus apricus is similar to *D. multiramosus* but lacks granular ornament.

Etymology.—The species name *apricus* is Latin meaning exposed to the sun or lying open and refers to the desert environment where the specimens were found.

Material.—Partial calices. Holotype, 407387 (loc. 11); paratypes, 407388, 407391 (loc. 11), 407389 (loc. 26), 407390 (loc. 6).

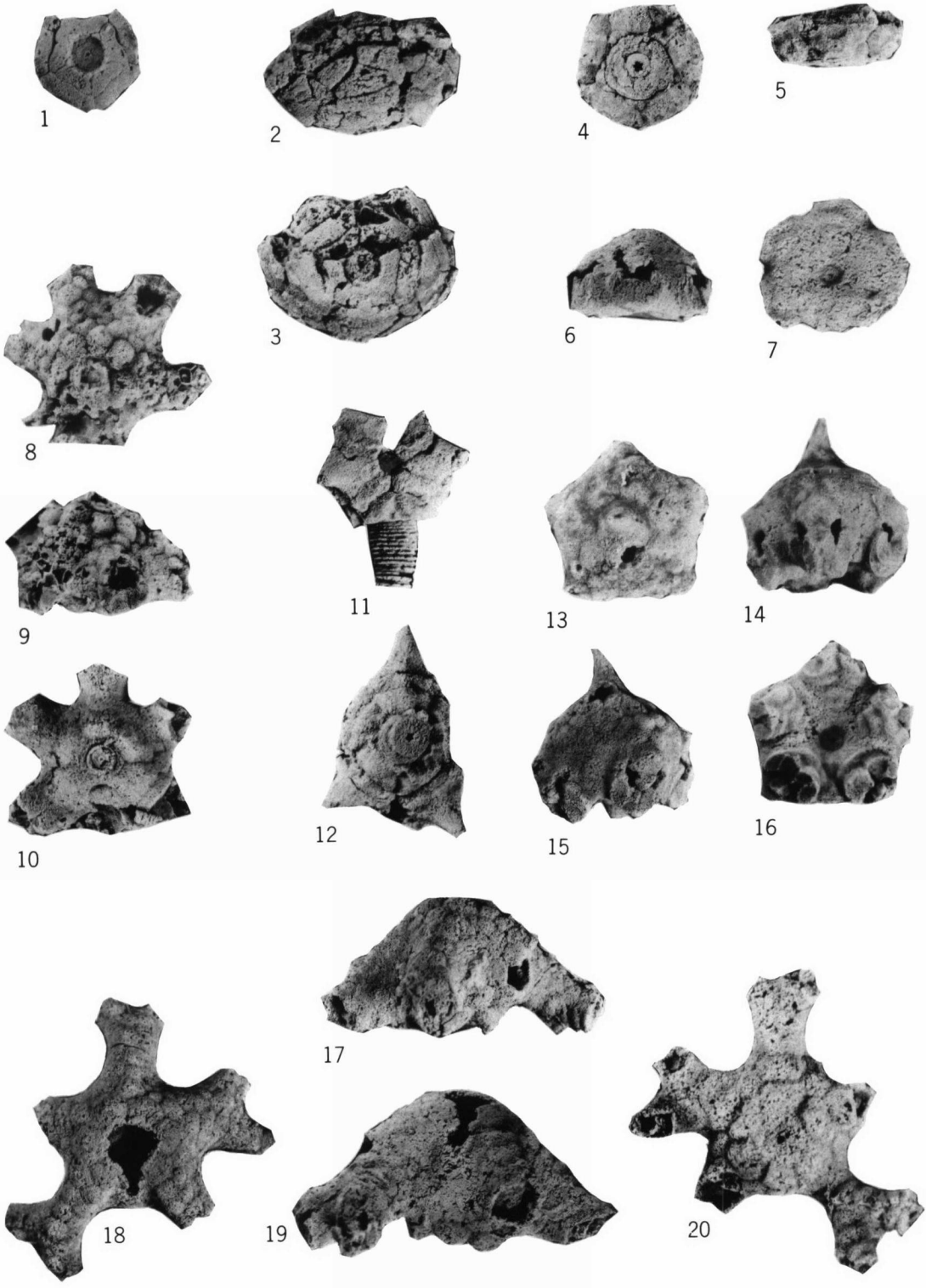

Fig. 8. For explanation, see facing page.

Genus AGARICOCRINUS Hall, 1858

Diagnosis.—Calyx small to large, flattened biconvex to inverted conical; base slightly to deeply concave, BB and RR commonly not visible in lateral view; iIBrr and primanal elongate. Tegmenal plates commonly large, tumid or nodose; CD O commonly bearing large node or spine. Anal opening near top of tegmen posterior to CD O, may be on short anal tube. Free arms long, deep plated, commonly 10, or up to 4 arms in each but A ray.

Remarks.—Since 1900, *Agaricocrinus* has been reviewed three times, primarily from literature study. Klem (1900) considered that only 10 of the 42 assigned species were valid, the others being junior synonyms. Bassler and Moodey (1943) recognized 41 valid species and 10 junior synonyms. Ehlers and Kesling (1963) considered 39 species to be valid, and they named another. Klem's work was apparently overlooked by Bassler and Moodey and by Ehlers and Kesling.

Although we agree with part of the synonymies of each of the earlier works, we believe that a definitive investigation of the genus is needed, the available types of all species should be studied, and variation of the abundant forms from the Keokuk, Fort Payne, and Burlington formations should be investigated.

Species of *Agaricocrinus* are of stratigraphic value in the midcontinent. Some generalities are of use.

1. Younger forms usually, but not always, increase in size (Ehlers and Kesling, 1963).

2. Primitive species have no more than 10 arms (Klem, 1900). This group includes species from the Chouteau and lower Burlington Limestone. Ten-armed forms persist in some younger species.

3. Primibrachial plates are present in two lineages. Both lineages extend throughout the observed range of the genus and both develop more than 10 arms (Ehlers and Kesling, 1963). In one lineage, short, quadrate first primibrachs do not extend beyond the theca. In the other, the elongate first primibrachs extend upward, displacing the second primibrachs out of the theca.

4. Two types of tegmens are recognized and both extend throughout the range of the genus. With the large-plated tegmen, oral and ambulacral plates are associated with a few smaller plates. With the small-plated tegmen, oral and ambulacral plates are associated with many small plates.

5. Two types of anal series are developed in the tegmen. In species with large-plated tegmens, anal series plates are smaller than normal tegmenal plates and adjoin them without any major change in curvature of the tegmen wall, or depression, or marked elevation; a primitive condition. In species with small-plated tegmens, anal series plates are much smaller than normal tegmenal plates and adjoin them with marked depressed grooves or elevations; an advanced condition (Klem, 1900).

6. Two general calyx shapes are recognized. With an inverted conical calyx, the tegmen is high and moderately to highly arched. With a flattened biconvex calyx, the tegmen is low and gently convex and the theca is low.

AGARICOCRINUS ACUGALERUS, n. sp.

Fig. 8,*6, 7, 13-16*

Diagnosis.—Calyx small, basal invagination including IAxx; arm facets downflaring to upflaring; inflated tegmen forming most of calyx; tegmen plates large, slightly tumid, posterior O projecting as prominent spine; anal opening small, at top of tegmen on posterior side.

Description.—Calyx small, approximately equidimensional, resembling spiked helmet in lateral view, pentagonal in oral or aboral view. Basal invagination variable, shallow to moderately deep, always including proximal parts of IAxx, may include $IIBrr_1$ and $IIBrr_2$. Basal plane formed by IAxx or IIBrr. Basal circlet small, horizontal, hexagonal, nearly covered by stem impression, formed of 3 equal plates, sutures in B and E rays and CD interray; BB

Fig. 8. Coeleocrinidae, Dactylocrinidae, Euryocrinidae.—*1-3. Ancorachrinus typus,* n. gen., n. sp., 1, basal view, paratype 407479, ×1.5; 2, 3, lateral and basal views, holotype 407478, ×1.5.—*4, 5, 11, 12. Wachsmuthicrinus corrugatus,* n. sp., 4, 5, basal and lateral views, paratype 407476, ×1.0; 11, 12, lateral and basal views, holotype 407475, ×1.0.—*6, 7, 13-16. Agaricocrinus acugalerus,* n. sp., 6, 7, A ray and basal views, paratype 407371, ×1.5; 13-16, oral, A ray, posterior, and basal views, respectively, holotype 407367, ×1.5.—*8-10, 17-20. Tarantocrinus typus,* n. gen., n. sp., 8-10, oral, B ray, and basal views, paratype 407376, ×1.5; 17-20, A ray, oral, posterior, and basal views, respectively, holotype 407374, ×1.0.

wider than long. RR hexagonal, half again wider than long, downflared. IBr_1 quadrangular, short, nearly 3 times wider than long, gently convex transversely, sutures convex. Axillary IBr_2 pentagonal, more than twice as wide as long, moderately convex transversely, smooth or tumid. $IIBr_1$ uniserial, short, strongly convex transversely, gently convex longitudinally, facets deep, sloping downward, vertically, or upward. $IIBrr_2$ biserial; 10 arms at thecal rim. iBrr narrow, 2 to 3 times longer than wide, extending to base of ambulacral openings. Primanal in radial circlet, approximately twice as long as wide, extending to level of IAxx, adjoining RR, both IBrr, and 3 superjacent plates of anal series.

Tegmen highly arched, walls convex, formed of large slightly tumid plates; ambb and OO easily recognized and arranged typically; ambb moderately tumid to nodose; 5 OO centrally positioned, posterior O surrounded laterally and anteriorly by other OO, projected into prominent spine extending well above small anal opening on posterior side of tegmen. Anal series formed of plates slightly smaller than normal tegmenal plates, opening at apex of slight protrusion. No ornamentation except for nodose IAxx and ambb and spinose posterior O. Stem round; lumen pentalobate.

Measurement of:	Holotype	Paratypes			
	407367	407368	407369	407370	407371
calyx height	18.6	13.0	~13.8	....	~9.8
width	18.7	17.4	17.6	18.4	13.5
theca height	3.7	4.8	4.9	4.8	3.8
BB depth invag	4.4	1.9	3.3	2.2	1.7
circlet d	2.5	....	2.7	....	1.7
BB length	1.0	....	1.4	....	1.0
width	1.8	....	....	....	....
RR length	1.8	....	1.6	....	1.9
width	3.0	....	2.8	....	2.8
IBr_1 length	1.2	....	1.3	1.5[a]	1.5
width	2.8	....	3.2	....	3.0
IAx length	2.0	....	3.1	2.7	2.0
width	4.8	....	5.4	5.6	3.8
iBr length	4.6	....	3.9	....	4.7
width	1.5	....	1.9	....	2.4
primanal					
length	3.4	....	....	....	2.5
width	1.7	....	....	....	1.6
stem impres d	2.4	2.6	2.8	2.0	2.2
lumen d	0.4[b]	....	0.8	0.6	0.3

a. B ray.
b. Incomplete.

Remarks.—*Agaricocrinus acugalerus* is easily recognized in the Anchor fauna by the small size, basal concavity, and sharply pointed oral spine. It is most comparable in shape to *A. brevis* (Hall, 1858), *A. gracilis* Meek and Worthen, 1861, and *A. stellatus* (Hall, 1858). *A. brevis* has stellate ridge ornament, a narrower basal cavity including only the radials, and the small-plated anal series, none of which occur on *A. acugalerus*. *A. gracilis* differs by having strongly nodose primibrachs and interprimibrachs and strongly nodose orals and ambulacral plates. *A. stellatus* differs from *A. acugalerus* by having a lower arched and inverted conical shape, quadrate interprimibrachs, all tegmenal plates tumid, and a short blunt CD oral spine.

Etymology.—The species name is derived from the Latin *acua,* pointed, and *galerus,* helmet. It refers to the resemblence of *A. acugalerus* to a spiked helmet.

Material.—Holotype, 407367 (loc. 22); paratypes, 407371 (loc. 11), 407368 (loc. 3), 407370 (loc. 10), 407372 (loc. 30), 407369, 407373 (loc. 28).

Genus TARANTOCRINUS, n. gen.

Type species.—*Tarantocrinus typus,* n. sp., here designated.

Diagnosis.—A coelocrinid with strongly lobed calyx, elongate lobes beginning with IBr_1, fixed brachs declining to $IIIBr_1$, arms free after $IIIBr_2$.

Description.—See description of *Tarantocrinus typus.*

Remarks.—Among the Coelocrinidae *Tarantocrinus* is most closely related to *Agaricocrinus.* Both genera have similar plate structure in the invaginated bowl-shaped theca, elongate interprimibrachs, and three plates following the primanal. Also both have a convex tegmen, generally higher than the theca, with four large orals adjacent to the larger posterior oral and deep facets on the rounded brachials. The major difference in the two genera is the elongate declined lobes of *Tarantocrinus.* The lobes with their covering plates are similar to the basal part of the arms of such genera as *Steganocrinus* and *Physetocrinus* in the Actinocrinitidae.

Etymology.—The calyx of *Tarantocrinus* vaguely resembles the large-bodied desert tarantula. The generic name is derived from *tarantola,* Italian for a large spider.

TARANTOCRINUS TYPUS, n. sp.

Fig. 8,*8-10,17-20*

Diagnosis.—Calyx strongly lobate, lobes elongate, declined to $IIIBrr_1$, theca low, shallowly invaginated; tegmen highly arched, OO large, forming semicircle around larger CD O; most thecal and tegmenal plates tumid; 10 arms at thecal rim; stem round, lumen pentalobate.

Description.—Calyx moderate sized, of inverted expanded bowl shape in lateral view, strongly pentalobate in oral view with deep, wide, interradial areas; lobes extending below base of theca. Theca widely expanded, shallowly invaginated bowl-shape. Tegmen highly arched, 3 times thecal height.

Basal circlet hexagonal, horizontal; BB nearly twice as wide as long, extending slightly beyond stem, not visible in lateral view. RR large, hexagonal, strongly convex longitudinally, proximally in basal invagination, distally outflaring to form base and walls of theca, strongly tumid. $IBrr_1$ large, hexagonal, widely outflaring, forming base of lobes, strongly convex transversely, straight to gently convex longitudinally. $IBrr_2$ axillary, large, septagonal, sloping gently downward, strongly convex transversely, slightly tumid. Fixed IIBrr 1 per half-ray, axillary, wider than long, slightly tumid. Fixed IIIBrr 1 per quarter-ray, wider than long; arms free with $IIIBrr_2$. All Brr with deep facets having horseshoe-shaped transverse cross section. Arms 10 where free, distal arms unknown.

iIBrr septagonal, large, elongate, followed by 1 plate in base of tegmen. Primanal large, septagonal, in radial circlet, followed by 3 plates distally in contact with basal tegmenal plates. Tegmenal plates large, weakly to moderately tumid, summit formed by 4 OO adjacent to larger strongly tumid or spinose posterior O. Anal opening below summit in posterior interray. Interradial areas deep, wide, continuing onto tegmen as wide shallow invaginations reaching to base of oral circlet. Stem round; lumen pentalobate.

Remarks.—Without the stem, the calyx of *T. typus* would have rested on the distal extremity of each arm lobe, in particular the first tertibrachs. Were the stem very short or small, *T. typus* could have rested on the substrate on the base of the extended lobes. However, the stem impression is moderately large, suggesting that *T. typus* was an elevated filter feeder.

Measurement of:	Holotype	Paratypes	
	407374	407376	407375
calyx height	23.9	11.5	15.6
width	46.5[a]	20.6[b]	28.2[b]
theca height	7.1	2.5	4.6
BB circlet d	5.9	3.5	5.3
BB length	3.2	1.9	....
width	5.9	3.4	....
RR length	6.0	2.8	3.9
width	7.4	4.7	5.2
IBr_1 length	4.5	....	3.2
width	8.2	....	....
IAx length	4.3	....	2.6
width	7.9	....	....
iBr_1 length	6.5	....	4.6
width	3.8	2.2	3.2
primanal length	5.6	....	....
width	6.2	4.4	....
stem impr d	....	2.8	....
lumen d	1.0	0.1	....

a. Measured at branching of arms on lobes.
b. Incomplete.

Etymology.—This is the first species assigned to the genus, therefore *typus,* Latin, meaning example, is proposed.

Material.—Holotype, 407374 (loc. 27); paratypes, 407376 (loc. 19), 407375 (loc. 20).

Family BATOCRINIDAE Wachsmuth and Springer, 1881

Remarks.—Lane (1963, fig. 1), summarizing the phylogeny of the Batocrinidae, considered them to be polyphyletic, having evolved between the Late Devonian and the Middle Mississippian from coelocrinid ancestors. Only two genera, *Eretmocrinus* and *Abatocrinus,* are known to occur in strata older than Osagean. *Abatocrinus* is thought to have been derived from *Aorocrinus* in latest Devonian or earliest Mississippian time. *Eretmocrinus* was considered to have been derived at the same time from *Dorycrinus* (Lane, 1963). Devonian species previously assigned to *Dorycrinus* have been transferred to such other genera as *Stamnocrinus* and *Thamnocrinus.* We propose that *Eretmocrinus* was derived from a *Stamnocrinus*-like ancestor by expansion of the basal circlet to form a distinct rim or flange at the flat base of the theca and reduction of the number of plates in the interradial and anitaxis series so that fixed brachs roof over the interprimibrachs in most rays and the anitaxis.

Genus ERETMOCRINUS Lyon and Casseday, 1859

ERETMOCRINUS ARIDUS, n. sp.

Figs. 9; 10,*22-33*

Diagnosis.—A turbinate form, theca lacking ornamentation, basal flange weakly developed, tegmenal height approximately equaling thecal height, tegmenal plates tumid.

Description.—Calyx intermediate sized, asymmetrical turbinate, thecal plates lacking ornamentation; tegmenal plates tumid, anal tube posterior of center of tegmen. Theca asymmetric bowl-shaped, walls concave in immature forms, straight to convex in adults, flaring upward at 18 to 36°, lower in immature forms, posterior steeper than anterior. Basal circlet small, weakly flanged or straight or with a steep upward flare distally, definitely constricted at distal tips; notched or unnotched sutures in normal position in B and E rays and CD interay; overhanging proximal columnal; BB not quite twice as wide as long. RR hexagonal, nearly 3 times wider than long, gently convex transversely, straight longitudinally, flaring abruptly outward from BB. $IBrr_1$ rectangular, wider than long, gently convex transversely, straight longitudinally, all sutures gently convex. Axillary $IBrr_2$ pentagonal, twice as wide as long, gently convex transversely, straight longitudinally. IIBrr 2, wider than long, gently convex transversely, axillary $IIBr_2$ larger. Fixed IIIBrr 2, wider than long, gently convex transversely, convexity increasing longitudinally, adjoining adjacent IIIBrr laterally.

$iIBrr_1$ nonagonal, wider than long to longer than wide, adjoined on each side by RR, IBrr, and $IIBrr_1$, followed by 1 (most common) or 2 elongate single plates, series roofed by IIIBrr. Primanal in radial circlet, wider than long, all following plates smaller; anitaxis series commonly 1:3, roofed by fixed brachs. Ambulacral openings 4 per ray, may be 1 additional in C and D rays; 20 to 22 free arms. Thecal pores small, connected to or separate from ambulacral opening, on upper outer side of opening, associated with all openings or with only a few. Tegmen asymmetric conical, all plates tumid, moderate sized, OO larger; posterior O largest, adjoined laterally and anteriorly by other 4 OO. Anal tube narrow, posterior of center. Stem impression round; lumen pentalobate.

Remarks.—The 14 specimens of *E. aridus* vary in shape of the basal circlet, number of arms, number of thecal pores, and number of plates in the interradial series. Variation in the number of arms in other genera of the Batocrinidae was discussed by Lane (1963), and the addition of one arm in each of the posterior rays, as in *E. aridus,* is not uncommon. Variation in the number of plates in the interradial series is also common among the

Measurement of:	Holotype	Paratypes				
	407392	407395	407396	407397	407393	407394
calyx height	18.7	....	....	15.9	....	11.7
width	20.5	21.5[a]	21.6	19.0	19.7	12.9
theca height	9.7	9.5	8.8	7.3	9.7	5.8
BB circlet d	6.3	6.9	6.4	....	6.5	4.2
BB length	....	3.0	2.6	....	2.5	2.0
width	4.4	5.5	5.1	....	4.7	3.1
RR length	....	1.5	1.8	....	1.8	....
width	....	4.1	4.6	....	4.2	....
IBr_1 length	1.3	1.4	1.0	....	1.6	....
width	2.3	2.8	4.1	....	3.0	....
IAx length	2.0	1.6	2.0	....	2.0	....
width	3.5	3.4	4.2	....	3.8	....
iBr length	....	2.8	3.8	....	....	....
width	....	3.4	3.3	....	....	....
primanal						
length	....	2.7	....	....	....	....
width	....	3.6	....	....	....	....
stem impr d	2.9	2.2	1.8	....	3.0	2.1
lumen d	0.5	0.7	0.5	0.4	0.5	0.3

a. Slightly crushed or distorted.

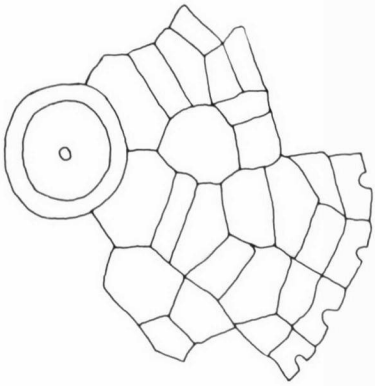

Fig. 9. *Eretmocrinus aridus,* n. sp., paratype 407404, ×8, part of aboral cup, orientation uncertain, showing parts of two rays and interrays.

Batocrinidae. The additional plates in the interprimibrachial series or another tier of plates in the anitaxis, as in *E. aridus,* is to be expected. The significance of the variation in the number of thecal pores is not known. Haugh (1978) interpreted thecal pores as part of an integrated current-sensing system.

Variation in the shape of the basal circlet of *E. aridus* is perhaps significant. Without the arms, one of the morphologic features used for generic identification of *Eretmocrinus* is the presence of a basal flange. Forms lacking the flange are referred to *Abatocrinus.* The flange is present on all specimens from the Anchor Limestone in which the theca is preserved. The development of the flange ranges from obvious to weak. Part of this variation could be the result of silicification and etching during preparation.

Most other species of *Eretmocrinus* have calices that are considerably wider at the base than that of *E. aridus* or are higher, cone-shaped, and ornamented. The calyx shape of *E. aridus* is most like that of *E. parvus* Rowley, 1902 and *E. nodosus* Rowley, 1900. Both of these forms, however, have more slender calices and strongly nodose plates on both the theca and tegmen. The relatively wider theca and lack of ornament on the theca of *E. aridus* distinguish it from these forms.

It is possible that *E. parvus* from the lower Burlington (Rowley, 1902) and *E. nodosus* from the upper Burlington (Rowley, 1900) are variants of one species. If so, the name *E. parvus* would prevail since *E. nodosus* is previously occupied by a different form, *E. calyculoides* var. *nodosus* Wachsmuth and Springer, 1897 [*E. calyculoides* (Hall, 1860)].

Etymology.—The species name *aridus* is Latin, meaning arid, and refers to the climate of the area where the specimens were found.

Material.—Holotype, 407392 (loc. 3); paratypes, 407393, 407394, 407400-407402 (loc. 3), 407398, 407399 (loc. 28), 407403-407405 (loc. 7 + 51), 407396, 407406 (loc. 29), 407397 (loc. 11), 407395 (loc. 34).

ERETMOCRINUS sp.

Fig. 10,*14-19*

Description.—Calyx low, inflated mushroom-shaped in lateral view, notched pentalobate in basal view, more nearly circular in oral view, thecal plates smooth. Theca low, walls concave, arm lobes weakly upflared to recumbent distally. Basal circlet large, notched, with well-developed flange; sutures in normal position in B and E rays and CD interray; 3 BB equal, wider than long. RR hexagonal, much wider than long, gently convex transversely, flaring out distally. $IBrr_1$ rectangular, flaring outward to subhorizontal, more than 3 times wider than long, gently convex transversely, proximal suture convex, distal suture concave or convex. Axillary $IBrr_2$ pentagonal, up to 3 times wider than long, gently convex transversely, horizontal to slightly upflared.

IIBrr short, wide, deep, arms free with $IIBrr_2$ or $IIIBrr_2$; $IIBr_1$ adjacent to CE inter-

Measurement of:	Specimen		
	407409	407408	407407
calyx width	33.0[a]	21.4[a]	14.3
theca height	11.5	6.5	5.7
BB circlet d	15.5	10.4	6.4
BB length	7.1	4.5	3.0
width	12.8	8.6	5.2
RR length	2.2	1.8	....
width	7.8	5.5	....
IBr_1 length	1.5	0.8	....
width	4.9	3.7	....
IAx length	3.2	1.4	....
width	5.5	4.3	....
iBr length	5.8	5.1	....
width	5.3	3.9	....
primanal length	3.1	2.5	....
width	6.2	4.7	....
stem impr d	5.0	3.2	1.8
lumen d	1.5	0.8	0.6

a. Incomplete.

radial axillary. Distal parts of arms unknown, probably 12 total, 2 each in A and B rays, 3 in C ray; E ray probably with 2 and D ray with 3. $iIBrr_1$ large, octagonal or nonagonal, longer than wide, may be followed by 1 plate, commonly roofed by fixed Brr, rarely extending to tegmenal plates. Primanal septagonal, large, in radial circlet, wider than long, longer than RR; anitaxis series 1:3:1 or 1:3:2, in contact with tegmenal plates distally. Tegmenal plates of variable size, larger plates strongly tumid, OO and anal tube unknown. Stem impression round, 0.34 to 0.25 d of basal circlet; lumen small, weakly pentalobate.

Remarks.—The three specimens form an excellent growth series. They show that thecal shape changes little from the smallest to largest form and that thecal walls may be reflexed slightly to gently upflared distally. The basal flange is well developed at an early stage as is a third arm in the C ray. Arm facets may be vertical or slightly upflaring. Roofing of the interrays is incomplete in the smaller forms but complete in the largest specimen except for the anitaxis.

The tegmen is greatly inflated with tumid large plates. One very tumid first ambulacral plate occurs in the second row of plates above the ambulacral openings. Secundibrachials and tertibrachials have deep facets similar to those in *Agaricocrinus* and *Alloprosallocrinus.*

The incomplete roofing of the anitaxis and small number of arms per ray (less than four) in this form are judged to be primitive characters. The large basal flange is similar to that of *E. magnificus,* which has nodose interprimibrachials and ray ridge ornament, and *E. rugosus,* which has coarse nodes on the radials, primibrachials, and interprimibrachials. Both *E. magnificus* and *E. rugosus* are from Osagean strata in the Mississippi Valley region.

None of the specimens is complete or of sufficient quality to serve as a holotype. Although a new species is believed to be represented by these specimens a name is not proposed.

Material.—407407 (loc. 3), 407408 (loc. 7 + 49), 407409 (loc. 34).

DICHOCRININAE indet.

Fig. 6,*16,17*

Remarks.—This bowl-shaped, moderately large, upflared basal circlet, 19 mm wide and 9.0 mm high, consisting of two equal plates that adjoined six plates distally, is referred to the Dichocrininae. The surface is covered with liesegang rings from the silicification that destroyed any possible ornamentation. The attached proximal columnal is small, thin, and circular in transverse section.

The dorsal cup structure is similar on most genera in the Dichocrininae (Broadhead, 1981). Lacking the tegmen and arms, it is impossible to identify most basal circlets at the generic level. This specimen is quite large for the dichocrinids. The specimen is illustrated for stratigraphic purposes.

Material.—407410 (loc. 29).

Family PLATYCRINITIDAE Austin and Austin, 1842

Remarks.—Most platycrinitids have similar cup structure, and generic distinctions are based on arm structure, anal position, and tegmenal plate arrangement. A cup recovered without tegmen and arms may be of little value, for the missing parts severely limit the identification of the specimen. Crowns in which the arms cover the anal opening and tegmen also may be of limited use.

We believe that the Platycrinitidae are of stratigraphic use but in need of a thorough revision. Until a taxonomic and stratigraphic study is completed, most newly found forms

Fig. 10. Batocrinidae, Rhenocrinidae, Cyathocrinitidae.—*1-4. Cyathocrinites* sp. 2, oral, A ray, posterior, and basal views, respectively, 407467, ×1.5.—*5, 6. Cyathocrinites* sp. 4, posterior and basal views, respectively, 407469, ×1.5.—*7-9.* Rhenocrinidae sp. 1, A ray, posterior, and basal views, respectively, 407472, ×1.0.—*10-13. Cyathocrinites* sp. 1, oral, A ray, posterior, and basal views, respectively, 407466, ×1.0.—*14-19. Eretmocrinus* sp., 14, 15, basal and B ray views, 407407, ×1.0; 16, 17, basal and posterior views, 407408, ×1.5; 18, 19, C ray and basal views, 407409, ×1.0.—*20, 21.* Rhenocrinidae sp. 2, A ray and posterior views, 407473, ×1.0.—*22-33. Eretmocrinus aridus,* n. sp., 22-24, oral, posterior, and basal views, respectively, paratype 407394, ×1.5; 25-28, A ray, posterior, oral, and basal views, respectively, holotype 407392, ×1.5; 29, 30, B ray and basal views, paratype 407404, ×1.5; 31-33, A ray, posterior, and basal views, respectively, paratype 407395, ×1.5.

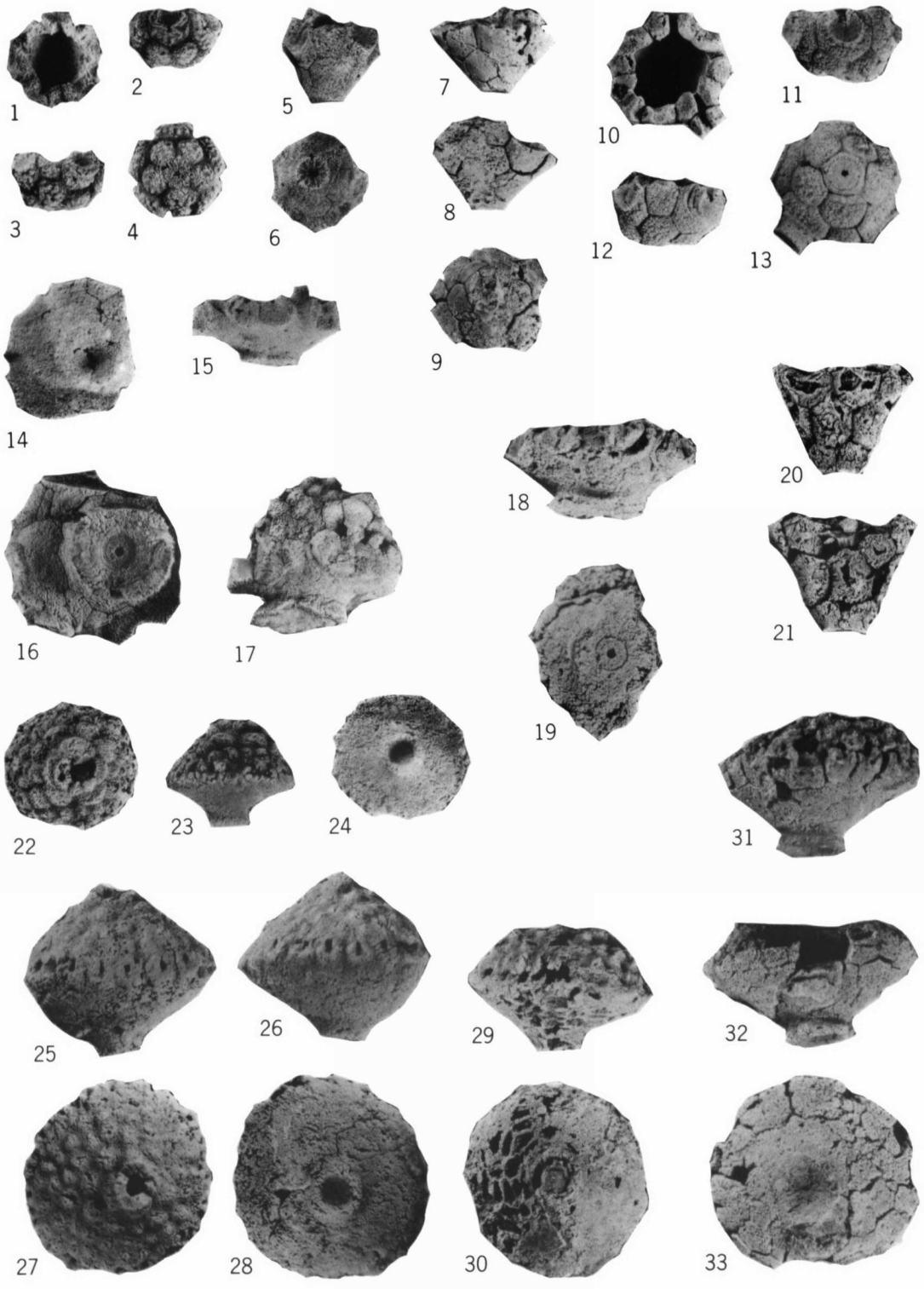

Fig. 10. For explanation, see facing page.

should be left in open nomenclature. We are describing and illustrating the following four species for reference.

PLATYCRINITIDAE sp. 1

Fig. 11,*6,7*

Description.—Dorsal cup bowl-shaped, wider than high, base truncate, walls flaring outward at 50°, tegmen and arms not known. Basal circlet forming base of cup, proximally concave for stem attachment, distally upflared, visible in lateral view, sutures difficult to recognize where preserved. RR wider than long, gently convex transversely and longitudinally, radial facets angustary, slightly over 0.34 radial width, sloping outward steeply, width twice depth, intermuscular furrow wide shallow V-shape. Facets on C and D RR offset toward one another. RR thickened internally below facet; radial notches wide, shallow, not developed on C and D mutual shoulders. No ornament; stem impression round.

Measurement of:	Specimen	
	407411	407412
cup height	7.3	5.0
width	15.0	12.9
BB circlet d	9.7	5.8
RR length	6.4	5.4
width	8.3	7.3
stem impr d	2.3	2.1

Remarks.—The posterior interray is easily recognized by the lack of a radial notch. On the smaller specimen the C and D mutual shoulders are elevated slightly. Unfortunately, the tegmen is not preserved, and the position of the anal opening cannot be determined.

This form belongs to the low bowl-shaped group of platycrinitids such as *P. truncatulus* (Hall, 1858) from the lower Burlington Limestone in Iowa. Platycrinitidae sp. 1 differs by having a higher basal circlet, less nearly vertical walls, and deeper radial notches.

Material.—Figured specimens 407412 (loc. 28), 407411 (loc. 34).

PLATYCRINITIDAE sp. 2

Fig. 11,*2,3*

Description.—Dorsal cup low, shallow bowl-shape, pentalobate in oral view, base truncate, walls flaring up at 40°, incurving distally, no ornament. Basal circlet large, forming base of cup, proximally concave for stem attachment, distally upflared, visible in lateral view, only 1 suture preserved. RR about twice as wide as long, gently convex transversely and longitudinally. Radial facets angustary, protruding, circular, more than 0.5 radial width, subvertical, intermuscular furrow a deep V-shape. Radial notches wide, shallow. Arms and tegmen unknown. Stem impression round, poorly preserved.

Measurements.—Cup height 7.8, width 16.9; BB circlet d 8.5; RR length 7.4, width 8.7.

Remarks.—This form differs from Platycrinitidae sp. 1 by having subvertical, circular radial facets; the anal interray is not recognizable on the dorsal cup.

Material.—407413 (loc. 23).

PLATYCRINITIDAE sp. 3

Fig. 11,*4,5*

Description.—Dorsal cup bowl-shaped, wider than high, of medium height, pentagonal in oral view, base truncate, walls subvertical distally, sutures slightly impressed. Basal circlet forming base of cup, concave proximally for stem attachment, flaring up distally, visible in lateral view. BB 3, 2 equally large, 1 small. RR equidimensional, gently convex transversely and longitudinally, incurving slightly distally. Radial facets angustary, 0.4 radial width, elliptical, long axis transverse, sloping steeply outward, shallowly concave, intermuscular furrow a wide rounded V-shape. Radial notches wide, shallow. Anal interray recognized by assumed AE position of small B. Stem facet circular. No ornament; arms and tegmen unknown.

Measurements.—Cup height 6.0, width 10.2; BB circlet d 6.3; RR length 4.8, width 4.8; d stem impr 2.3.

Remarks.—Some variation in the walls is noted in the three specimens of Platycrinitidae sp. 2. In the smallest form the walls flare out slightly. In the intermediate-sized form the walls are subvertical, and in the largest form they remain subvertical but the distal incurving is not present. Preservation of these specimens is poor and better specimens are needed for further study.

This form is related to the medium bowl-

shaped platycrinitids such as *P. symmetricus* (Wachsmuth and Springer, 1897) from the Hampton Formation at Legrand, Iowa.

Material.—407415 (loc. 12), 407414 (loc. 28), 407416 (loc. 34).

PLATYCRINITIDAE sp. 4

Fig. 11,*1*

Remarks.—A disarticulated dorsal cup (407417, loc. 29) from the lower part of the upper member, which was partly destroyed by weathering, yielded parts of four radials. The most complete is widest medially (15.8 mm) and nearly as long (13.0 mm). Sutures are impressed and beveled. The radial facet is angustary, protruded, less than half the radial width, circular, with a deep, rounded, V-shaped intermuscular furrow. Coarse nodes are present below the facet and above the proximal edge of the radial. Radial notches are wide and moderately deep.

Radials of this general type are common on such discoid or low bowl-shaped dorsal cups as *Platycrinites yandelli* (Owen and Shumard, 1850) and *P. subspinosus* (Hall, 1858), both from the lower Burlington Limestone in Iowa.

Genus PLATYCRINITES Miller, 1821

Type species.—*Platycrinites laevis* Miller, 1821.

Remarks.—*Platycrinites* is the major nomenclatorial quagmire in the Platycrinitidae. The genus was named early (Miller, 1821) and has a long geologic range, Devonian to Permian. About 190 species are currently assigned to the genus (Bassler and Moodey, 1943; Webster, 1973). Nearly 150 of the Early Carboniferous species are from northwestern Europe and the eastern U.S.

Wright (1938, 1955b) recognized two groups of platycrinitid species in Britain. The *P. laevis* group has a tegmen produced into an anal tube opening at the terminus or at a constriction below the summit. Brower (1969) assigned three American species to this group. The *P. bollandensis* group lacks an anal tube, and the anal opening is near the summit of the tegmen or on its side. If it is on the side, the primanal is equal in size to the interprimibrachs. Brower (1969) assigned 13 American species to the group.

Unfortunately many species of *Platycrinites* are based on cups lacking the tegmen, and some species are identified on crowns with arms covering the tegmen and anal opening. A cursory study of species of *Platycrinites* in the Springer collections at the USNM and University of Iowa and a literature review of some species suggest two other morphologic features that might be of value in a systematic treatment of the genus. These are cup shape and features of the radial facet.

The shape of the cup ranges from a flat-based bowl to a high cone. Radial facets vary considerably in size (relative to the radial), shape (elliptical to circular), slope (subvertical to horizontal), and surface morphology (concavity and size and shape of the intermuscular furrow). A multivariant analysis of the species of *Platycrinites* is needed, using cup shape, radial facet features, ornamentation, tegmenal characteristics, anal opening position, anal plates, and arm morphology. Such a study will undoubtedly lead to the recombination of some species. It should, however, show that others are of significant stratigraphic and paleontologic value.

Undoubtedly some of the abundant disarticulated columnals and cup plates in the acid residues of the Anchor Limestone belong to *Platycrinites*. We recognize at least six and perhaps 13 undescribed species from the residue specimens, in addition to the described forms listed under Platycrinitidae. These specimens are mostly basal circlets and isolated radials, some of which could belong to the same species.

Several different types of platycrinitid columnals that probably belong with some of the isolated plates and to described forms can be recognized. Most of the columnals are of the typical, smooth-walled elliptical form with the articular ridges offset at a slight angle on apposing facets. This offset produces the twist in the articulated stem. Some forms are ornamented with coarse nodes on the lateral walls of the columnal. A few specimens have rectangular outline with the apposing facets offset by several degrees. These forms were described from Early Permian deposits in southern Nevada by Webster and Lane (1967, pl. 1, fig. 5) and assigned to *Platyplateium* by Moore and Jeffords (1968). The Anchor specimens are the oldest known occurrence of the *Platyplateium* type of columnal.

The twisted stem is restricted to the Platycrinitacea in the Paleozoic. We suggest that the platycrinitid stem acted as a wind vane. As the current pushed against it, some water was deflected along the stem; when it came against a twisted columnal or the crown, it provided a small amount of lift. This lift helped the crown maintain its elevation above the substrate.

PLATYCRINITES VEXABILIS (White, 1874)

Remarks.—*Platycrintes vexabilis* was found at Mountain Spring Pass, Nevada, along the Old Mormon Road on the U.S. geographical surveys west of the 100th meridian in the early 1870's (White, 1874, 1877). The exact locality and horizon are uncertain. The lithology of the block of limestone that the specimen is on, however, suggests the Anchor Limestone. The Anchor Limestone is well exposed on the west side of the pass, just west of Mountain Spring, Nevada. We have collected the site and found some additional crinoidal material in the Anchor Limestone, but it is weathered and poorly preserved.

The holotype (8526) of *Platycrinites vexabilis* was studied in the USNM. The specimen is small and not well preserved. It has an invaginated cup, the cup plates are not definable, and there is an extended tegmen shorter than the arms. The arms are uniserial and branch at least once distally; brachial plates are narrow and elongate, and no pinnules are present. It is not a platycrinitid and may not be a camerate crinoid. We consider the specimen unidentifiable and the species restricted to the type, a *nomen dubius*.

Genus PLEUROCRINUS Austin and Austin, 1843

Diagnosis.—Like *Platycrinites* except anal opening lateral on tegmen just above RR with or without primanal, which, when present, may be followed by a row of small plates.

Remarks.—*Pleurocrinus* occurs in the Lower Carboniferous in northwestern Europe and the U.S. and in the Permian of Timor. Wright (1938, 1955b) recognized two groups in the genus. The *P. mucronatus* group has an anal opening separated from the radials by a primanal smaller than the interprimibrach and it may be overlain by a range of small irregular plates. Brower (1969) assigned seven species of North American *Platycrinites* to the group. The *P. coplowensis* group has the anal opening directly on the C and D radials without intervening plates. Brower (1969) recognized *Pleurocrinus* sp. from the Redwall Limestone in Arizona as belonging to the group.

The primanal or other small irregular plates between the anal opening and the C and D radials may be lost in preservation of the calyx. If they are very small it is difficult to recognize that they were ever present. We question the use of this subdivision of *Pleurocrinus* in taxonomy and believe that further investigation is needed.

A fourfold subdivision of *Pleurocrinus* is possible on the basis of cup shape. (1) A flat-based bowl shape with the basals not visible in lateral view, as in *P. formosus* and *P. quinquenodus*. (2) A low bowl shape with the basals visible in lateral view, as in *P. mucronatus* and *P. coplowensis*. (3) A high conical shape with the basals strongly upflared and the radials tending to be elongate, as in *P. halli* and *P. pileiformis*. (4) A globose to globose-conical shape with the basals moderately upflared, as in *P. globosus* and *P. depressus*.

All European species belong to the second group. North American species are found in each of the first three groups. Timor species belong to the third and fourth groups.

Shapes of the radial facets differ noticeably among species of *Pleurocrinus:* they range from circular to elliptical. Also notable are differences in the relative size and slope of the radial facet, which probably reflect differences in the arm structure. Without the arms, *Pleurocrinus* and *Eucladocrinus* appear to be indistinguishable.

A systematic study is needed of all of the morphologic features of *Pleurocrinus* discussed above in addition to arm branching patterns and tegmenal characteristics before the genus can be of significant stratigraphic value.

PLEUROCRINUS FORMOSUS (Miller and Gurley, 1895)

Fig. 11,*24-27*

Platycrinus formosus Miller and Gurley, 1895:72, pl. 4, figs. 20, 21. Miller, 1897:750, fig. 1376.

Platycrinus formosus var. *approximatus* Miller and Gurley, 1896: 60, pl. 4, figs. 8–11.
Platycrinites formosus (Miller and Gurley). Bassler and Moodey, 1943:620.
Platycrinites formosus approximatus Miller and Gurley. Bassler and Moodey, 1943:620. Brower, 1969:520.

Remarks.—A single calyx (407440, loc. 34) of *Pleurocrinus formosus* from the upper member is well silicified but slightly crushed on the A and B rays. The basal circlet flares down, is not visible in lateral view, and bears a single node at each of the tips of the circlet. Three nodes are present on the proximal end of each radial and two faint nodes occur on each side. The tegmenal plates are large, each with a node. A single primanal smaller than the interprimibrach occurs below the laterally located anal opening. Measurements are: calyx length 12.0 (distorted), width 16.5 (avg); d basal circlet 7.5; RR length 6.0, width 7.8.

Pleurocrinus formosus belongs to the flat-based, bowl-shaped lineage of the genus. Miller and Gurley (1895) based *P. formosus* on a dorsal cup. In 1896 Miller and Gurley described *P. formosus* var. *approximatus* based on a calyx from the Chouteau Limestone at Sedalia, Missouri, where *P. formosus* was found. They recognized that the two forms are very similar. Lacking the tegmen of *P. formosus* and noting slight differences in the sutures and relative heights and widths, they elected to designate the variety. These forms are here judged to be variants of one species.

Occurrence of *P. formosus* in the Anchor Limestone suggests that the Anchor was deposited before the Burlington Limestone and expands the species's geographic distribution to include Nevada.

PLEUROCRINUS sp.

Fig. 11,*8–11*

Description.—Calyx globose, height slightly greater than width, cup plates unornamented, tegmenal plates nodose. Dorsal cup bowl-shaped, base flat, sutures faintly impressed. Basal circlet discoidal bowl, distal 0.34 upflared, visible in lateral view. BB 3, 2 equally large, 1 small, convex transversely and longitudinally. RR 5, wider than long, convex transversely and longitudinally; radial facets circular, angustary, 0.5 radial width, subvertical in immature forms, sloping strongly downward in larger forms, intermuscular furrow wide, semicircular. iIBrr large, hexagonal, extending distally to top of elliptical ambulacral tracts, distally adjoined by 2 tegmenal plates. Tegmenal plates large, nodose, CD O surrounded by semicircle of other OO and small plates above anal opening. Tegmen inflated, equaling dorsal cup height. Anal opening lateral, at base of tegmen above primanal. Secondary anal plates not preserved if present. Arms not preserved. Stem impression circular.

Measurement of:	Specimen	
	407439	407438
calyx height	....	11.4[a]
width	14.0	11.2
BB circlet d	8.0	6.8
RR length	5.5	5.0
width	6.7	6.0
stem impr d	2.8	....

a. Incomplete.

Remarks.—*Pleurocrinus* sp. is intermediate between the flat-based bowl shape and conical lineages of the genus. It is most similar to, but lacks the ornamentation of, *P. turgurium* (Miller and Gurley, 1895) from the Chouteau Limestone at Sedalia, Missouri.

The dorsal cup of *Pleurocrinus* sp. is quite distinctive in the Anchor fauna. The bowl shape is modified by the convexity of the basals and radials, which gives the effect of broadly impressed sutures; actually, the sutures are only faintly impressed along the plate borders. A new species is believed to be represented by these specimens. None, however, are suitable to serve as a holotype.

Material.—407437 (loc. 13), 407439 (loc. 24), 407438 (loc. 3).

Genus OENOCHOACRINUS Breimer, 1962

Diagnosis.—A platycrinitid with an elongate cup, posterior interray wider than others, tegmen composed of 5 central OO, CD O largest, 5 large axillary ambb in radial position.

Remarks.—*Oenochoacrinus* was described from Spain by Breimer (1962). The three species reported (Breimer, 1962) are of Early or Middle Devonian age. Discovery of a species of *Oenochoacrinus* in the Anchor Limestone extends

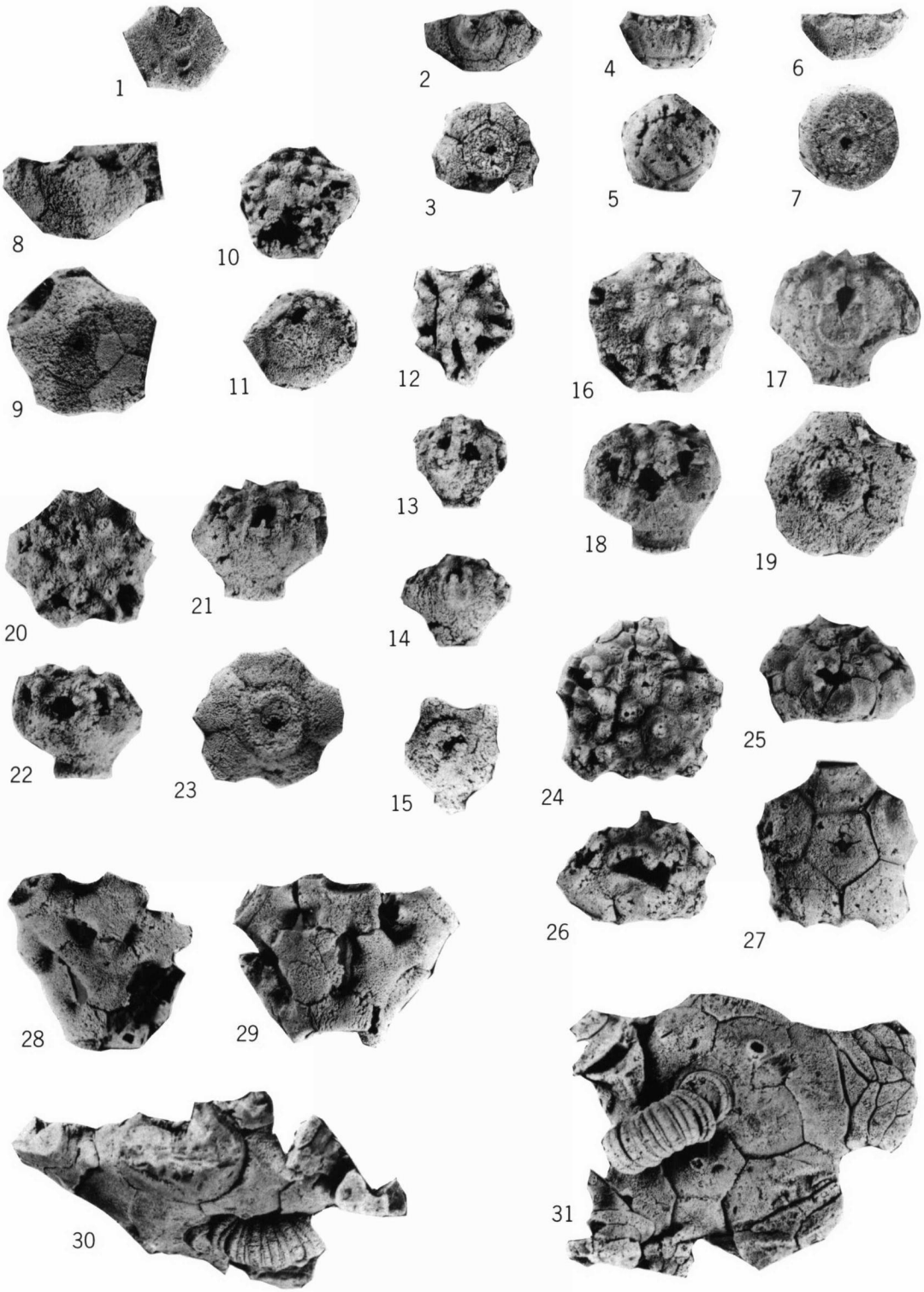

Fig. 11. For explanation, see facing page.

the stratigraphic range into the Carboniferous and the geographic distribution to North America.

OENOCHOACRINUS LIMBUS, n. sp.

Fig. 11,*12-23*

Diagnosis.—An *Oenochoacrinus* with a turbinate dorsal cup with a basal flange.

Description.—Calyx turbinate, pentalobate in oral or basal view, slightly higher than wide, base truncate, with basal flange, tegmen flat to gently convex, dorsal cup plates unornamented, tegmenal plates nodose, posterior interradius slightly wider than others. Dorsal cup conical, walls flaring out at 30 to 46°, less steep on anal side than on anterior, walls straight to concave, flaring to base of radial facets. Basal circlet slightly concave proximally for stem attachment, flanged medially, flange slightly expanded to straight, notched or unnotched, circlet flared up distally. BB 3, 2 equally large, 1 small, smallest in AE interray, fused in some concave, intermuscular furrow a rounded V-shape, depth equaling width. IBrr circular in transverse section, axillary. Ten arms at cup rim; distal arms unknown.

Anal opening directly above C and D RR, in line of ambulacral tracts, followed by series of small irregular plates to CD O. iIBrr large, tumid, as long as wide, widest proximally, tapering distally, extending to top of ambulacral openings, adjoined distally by superjacent O. Tegmenal plates large, regular; 5 OO nodose, CD O largest, adjoined by semicircle of others; ambb 3 per ray, nodose, 2 lateral on sides of ambulacral tract adjoining RR below, iIBrr laterally, and medial amb distally; medial amb axillary, adjoining 2 superjacent OO. Stem impression round; lumen pentalobate.

Remarks.—The basally flanged turbinate shape of *Oenochoacrinus limbus* is more uniformly flared and narrowly turbinate proximally than any of the Devonian species from Spain described by Breimer (1962). It is most similar to *O. princeps* Breimer, 1962, but has a flat instead of inflated tegmen with nodose instead of spinose plates in addition to the difference of cup shape.

Measurement of:	Holotype	Paratypes				
	407418	407419	407420	407422	407424	407426
calyx height	12.3	13.9	13.9	9.9	11.5	10.0
width	14.7	14.4	14.6	9.6	12.6	11.8
BB circlet d	7.3	7.5	8.0	5.8	....	6.1
RR length	6.8	7.3	7.3	5.5	....	5.2
width	6.8	7.7	7.9	5.3	6.4	6.0
stem impr d	....	....	2.2	...	....	2.5
lumen d	....	....	0.1	...	0.2	....

into single large plate. RR 5, slightly longer than wide (immature condition) to slightly wider than long (mature condition), gently convex transversely, straight to slightly concave longitudinally to base of radial facets, subvertical to incurving along radial notches; posterior radial notch noticeably deeper than others. Radial facets angustary, more than 0.5 radial width, elliptical (longest transversely in immature forms) to circular (adult forms), shallowly

Growth stages among the 20 specimens found show a slight change in calyx height to width ratio, with early stages higher than wide and later stages wider than high. The axillary ambulacral plates are not present on small forms and are the last plates to develop in the tegmen. The relative width and length of the

Fig. 11. Platycrinitidae, Stellarocrinidae, Poteriocrinitidae.—*1.* Platycrinitidae sp. 4, lateral view of radial, 407417, ×1.0.—*2, 3.* Platycrinitidae sp. 2, lateral and basal views, 407413, ×1.0.—*4, 5.* Platycrinitidae sp. 3, lateral and basal views, 407414, ×1.5.—*6, 7.* Platycrinitidae sp. 1, lateral and basal views, 407411, ×1.0.—*8-11. Pleurocrinus* sp., 8, 9, lateral and basal views, 407437, ×1.5; 10, 11, oral and lateral views, 407438, ×1.5.—*12-23. Oenochoacrinus limbus*, n. sp., 12-15, oral, posterior, A ray, and basal views, respectively, paratype 407422, ×1.5; 16-19, oral, A ray, posterior, and basal views, respectively, paratype 407419, ×1.5; 20-23, oral, A ray, posterior, and basal views, respectively, holotype 407418, ×1.5.—*24-27. Pleurocrinus formosus*, oral, A ray, posterior, and basal views, respectively, 407440, ×1.5.—*28, 29. Poteriocrinites* sp., posterior and E ray views, 407470, ×1.0.—*30, 31. Celonocrinus nodulus*, n. sp., C ray and basal views, holotype 407474, ×0.0.

radial facets also changes; the facets begin elliptical and become circular. Variation in the basal flange does not appear to be related to growth, but the flange ranges from straight to convex walled with or without sutural notches.

Breimer (1962) reported three small plates between the anal opening and the C and D radials on *Oenochoacrinus*. No plates are present, nor are facets for such plates preserved on any of the specimens of *O. limbus*.

Etymology.—The species name *limbus* is Latin meaning border, fringe, or selvage, and refers to the basal flange.

Material.—Holotype, 407418 (loc. 34); paratypes, 407421 (loc. 7 + 33.5), 407422, 407423 (loc. 10), 407424, 407425 (loc. 13), 407426, 407427 (loc. 14), 407428 (loc. 15), 407429 (loc. 19), 407430–407434 (loc. 28), 407419 (loc. 29), 407420, 407435, 407436 (loc. 34).

Subclass INADUNATA Wachsmuth and Springer, 1885

Genus HALYSIOCRINUS Ulrich, 1886

Remarks.—The discontinuous stratigraphic range of *Halysiocrinus* is Middle Devonian and late Early Mississippian. Devonian species are from the Erian of the Michigan and Illinois basins and Mississippian species are from Osagean strata of the Illinois basin and adjacent areas. Mississippian species of *Halysiocrinus* lack the protruding anal tube and have fewer axil-arms than Devonian species, as noted by Webster (1976). Furthermore, Webster (1976) considered the Devonian forms to represent an unnamed genus that gave rise to the Mississippian forms.

HALYSIOCRINUS sp.

Fig. 6,*13–15*

Remarks.—Two specimens of *Halysiocrinus,* a partial dorsal cup and a crown lacking part of the cup and the tips of the arms, may represent a new species, but neither specimen is suitable to serve as a holotype. The cup consists of the large, wide, moderately high A and D radials, the wide crescent-shaped E ray inferradial, and half of the basal circlet. The deep hinge is wide, nearly full width of the inferradial. The radials are constricted at about 0.75 their length and adjoin medially for slightly over 0.5 their length. The entire cup would have been moderately high.

The partial crown is slender, elongate, somewhat crushed along the E-BC plane of symmetry. The E ray ramules are convex transversely, slightly longer then wide, and unbranched. The five main axils are slender and concavely arched posteriorly. All ramules are gently convex transversely with the first one or two wider than long on the first and fifth axil-arms and longer than wide on all other axil-arms and all succeeding ramules. Heterotomous branching occurs on alpha ramule 6 on axil-arms 1 to 3 and on 5 on axil-arms 4 and 5 and on beta ramule 5 when developed. Anal plates are wide, convex transversely, and laterally enclosed by the axil-arms.

Assuming that these two specimens belong to the same species, they have the covered anal tube and five main axils typical of Mississippian species of *Halysiocrinus*. First branching on the fifth and sixth alpha ramules is higher than in any of the Mississippian species. Lacking additional material, we cannot determine if this is normal for specimens from the Anchor Limestone.

These specimens compare most closely with *H. wachsmuthi* (Meek and Worthen, 1869) in the lack of surface ornament and an unbranched E ray. First branching on the axil-arms of *H. wachsmuthi,* however, is with the third alpha ramule.

The discovery of these specimens extends the geographic range of *Halysiocrinus* and supports an Osagean age for the upper part of the Anchor Limestone.

Material.—Partial crown, 407441 (loc. 25), partial cup, 407442 (loc. 29).

Genus CATILLOCRINUS Shumard, 1865

CATILLOCRINUS sp.

Remarks.—An immature radial identified as *Catillocrinus* sp. (407443) bearing 18 arm facets is reported for stratigraphic purposes. The specimen is small and poorly preserved. Silicification of the plate is incomplete, although the facets are easily recognizable. The steeply sloping walls and small size suggest immaturity. The D and A rays of *Catillocrinus* bear a maximum of 24 and 34 facets, respectively. Thus the 18 facets on this specimen also support our

interpretation of the immaturity of the specimen.

Catillocrinus has been reported previously only from Osagean strata of the Illinois basin region. Thus this specimen, from the upper member (loc. 3), extends the geographic range of the genus and supports an Osagean age for the upper part of the Anchor Limestone.

Genus SYNBATHOCRINUS Phillips, 1836

Remarks.—*Synbathocrinus* is one of the longest-ranging of crinoid genera, found discontinuously from Middle Devonian into the Upper Permian. It was a conservative stock retaining a small cup and five unbranched arms throughout its range. Two lineages within the genus appear to parallel each other. One is characterized by a bowl-shaped cup with transversely rounded radials; the other has a low cup with a medial ridge along the length of the radials. Both may be smooth or granular and both lineages are found in the Devonian and Permian.

The discontinuous stratigraphic range of *Synbathocrinus* includes the Middle Devonian through Middle Mississippian, lower Middle and lower Upper Pennsylvanian, and middle Lower through Upper Permian. The Devonian species are known from the eastern U.S.; Mississippian species from the U.S., British Isles, and Australia; Pennsylvanian species from North America and Russia; and Permian species from Australia and Timor.

Thirteen species of *Synbathocrinus* have been described from Osagean strata of the Illinois basin and surrounding area (Bassler and Moodey, 1943; Webster, 1973). Numerous cups from the New Providence Shale at the Button Mold Knob locality (Kammer, 1984) in Kentucky and Ft. Payne Chert from several localities in Kentucky and cups and crowns from the Burlington Limestone in Iowa and Missouri are in the Springer collections in the USNM and the University of Iowa. Most of these are the bowl-shaped cups with radials that are transversely gently rounded.

These specimens vary in the shape of the cup, ranging from a smooth, steep-walled, truncated cone to a more widely flaring cone, some with slightly impressed sutures and with faintly to moderately transversely rounded radials. Some forms have a constriction at the top of the basal circlet. The basal circlet may be fused into one plate, or more commonly it consists of three plates, two equally large and one small. The anal notch varies from a moderate V-shaped notch equally shared by the C and D radials to a faint notch dominantly on the C radial. A few specimens lack an external expression of the anal notch but show one internally. Brachials on crowns vary from rounded to moderately sharply angular externally in transverse section. Surface ornament, where present, varies from fine papillae to medium granules.

A taxonomic review of *Synbathocrinus* is needed before stratigraphic value of Osagean species can be assessed. Undoubtedly some recombinations are in order.

SYNBATHOCRINUS sp. 1

Fig. 6,*5–8*

Description.—Crown slender, elongate; cup bowl-shaped, width nearly twice height, base truncate, walls flaring upward at 50°, pentagonal in oral view, no ornament. Basal circlet horizontal, slight impression for stem attachment. BB 3 or fused into 1 plate, distal tips upflared. RR 5, pentagonal, wider than long, gently convex transversely; C and D RR sharing shallow anal notch, typically mostly on C R. Radial facets plenary, subhorizontal on outer half, steeply flared down and out on inner half; transverse ridge very low, 0.5 facet width; outer ligament pit 0.4 facet width, deep, sloping inward; muscle area wide, deep, flaring upward, no inner ligament pit, intermuscular furrow narrow, elongate. Arms 5, narrow, unbranched; Brr_1 short, wider than long, all others elongate, longer than wide, bearing faint medial ridge becoming rounded distally. Stem round; lumen pentalobate.

Measurement of:	Specimen				
	407444	407445	407447	407448	407446
crown length	....	...	...	14.5	...
cup height	5.3	3.7	4.8	2.0	2.1
width	10.7	6.9	9.5	2.7	2.8
BB circlet d	6.0	4.3	5.0	1.5	1.4
BB height	1.7	1.2	1.4	0.5	0.4
RR length	4.2	3.0	3.8	1.8	1.7
width	6.2	3.9	5.3	1.7	1.5
stem impr d	3.0	2.4	3.0	0.9	...
lumen d	0.6	0.5	0.5	0.1	0.1

Remarks.—*Synbathocrinus* sp. 1 is one of the most commonly preserved elements in the Anchor faunas and occurs throughout the formation. Variation in the cup shape and anal notch is present in the 32 cups found. The shape ranges from a straight-walled cone to a recurved vase to a convex bowl with or without a constriction at the top of the basal circlet. Radials range from straight to convex to recurved longitudinally. Immature specimens may bear faint longitudinal medial ridges. The anal notch ranges from one lacking external expression (rare) to a shallow notch subequally shared by the C and D radials (rare) to a shallow notch largely on the C radial (common).

Synbathocrinus sp. 1 belongs to the higher bowl-shaped lineage of the genus. Morphotypes in the study material are comparable to several species in the Osagean strata of the Illinois basin and adjacent areas. Until a systematic study of the Osagean species is completed, it is futile to designate a species for the Anchor form.

Material.—407444 (loc. 7 + 49), 407445 (loc. 7 + 51), 407446, 407453 (2 specimens) (loc. 11), 407447, 407448, 407462 (loc. 34), 407449 (8 specimens) (loc. 3), 407452 (loc. 6), 407454 (loc. 12), 407455 (loc. 13), 407456 (3 specimens) (loc. 14), 407457 (loc. 17), 407458 (2 specimens) (loc. 19), 407459 (loc. 20), 407460 (loc. 28), 407461 (loc. 29), 407450 (loc. 7 + 34.5), 407451 (loc. 7 + 45).

SYNBATHOCRINUS sp. 2

Fig. 6,*1–4*

Description.—Cup low, bowl-shaped, width nearly twice height, base truncate, walls flaring upward at 48°, scalloped decahedral in oral view. Basal circlet horizontal, proximally bearing shallow basal impression for stem attachment, forming vertical walls to base of RR. BB 3, 4, or fused into a single plate, distal tips upflared. RR 5, pentagonal, wider than long, bearing broad medial longitudinal ridge. C and D RR sharing shallow anal notch, notch slightly longer on C R. Radial facets plenary, deep, sloping strongly outward; muscle areas wide, deep, flaring upward internally; ligament pit deep, narrow, subvertical, 0.34 facet width; outer ligament furrow not developed; transverse ridge 0.67 facet width. No surface ornament. Stem impression round; lumen pentalobate.

Measurement of:	Specimen		
	407464	407463	407465
cup height	3.4	2.6	3.9
width	6.4	4.8	6.5
BB circlet d	3.8	2.9	4.4
BB height	0.6	0.6	1.4
RR height	2.8	2.2	3.3
width	3.8	2.6	4.4
stem impr d	2.2	1.6	...
lumen d	0.4	0.4	0.6

Remarks.—The medial longitudinal ridges on the radials give the cup a scalloped appearance in aboral view. Sutures are not impressed but appear to be because of the medial ridges.

Synbathocrinus sp. 2 belongs to the low cup, longitudinally ridged, radial forms of the genus such as *S. sulcatus* (Goldring, 1923) and *S. expansus* Goldring, 1935, both of Devonian age from New York, and *S. texasensis* Moore and Ewers, 1942, from the Chappel Limestone of Kinderhookian and Osagean age of Texas. These forms are not so common in the Mississippian as the rounded bowl-shaped forms. *Synbathocrinus* sp. 2 probably represents a new species, but a name is not proposed because the specimens are all small, may be immature, and are not well preserved.

Material.—407465 (loc. 14), 407464 (loc. 10), 407463 (loc. 15).

Genus CYATHOCRINITES Miller, 1821

Remarks.—*Cyathocrinites* is another of the early named crinoid genera that has been grossly abused. Bassler and Moodey (1943) listed 93 recognizable species assigned to the genus, another 21 that had been transferred to other genera, 83 species transferred from the incorrect spelling *Cyathocrinus* to other genera, and 15 species of dubious status assigned to *Cythocrinus* (12 species) or *Cyathocrinites* (3 species). Webster (1973, 1986) listed three species assigned to *Cyathocrinites* named since 1942.

Of the 96 currently recognized species of *Cyathocrinites,* 57 are of Early Carboniferous age; nearly all of these are reported from England and the Illinois basin and surrounding region. Study of Mississippian species of *Cyathocrinites* in the Springer collection of the

USNM and literature review of some species suggest that morphologic differences in the radial facet, shape of the cup, ornamentation, tegmen, and arms offer possibilities for phylogenetic, taxonomic, paleogeographical and stratigraphical studies. Numerous specimens of several species from the Illinois basin and Coplow Knoll in Scotland are available for statistical evaluation.

CYATHOCRINITES sp. 1

Fig. 10,*10-13*

Description.—Cup medium sized, bowl-shaped, base flat, walls subvertical. Infrabasal circlet subhorizontal, forming base of cup. IBB 5, slightly wider than long, distal tips of anterior IBB not visible and posterior IBB barely visible in lateral view of cup. BB 5, pentagonal except posterior B hexagonal, convex transversely and longitudinally, a little wider than long. RR 5, large, U-shaped, equidimensional, convex; radial facets vertical, slightly more than 0.5 width of R, circular, concave, cut by V-shaped ambulacral groove distally. Anal X large, hexagonal, longer than wide, gently convex transversely and longitudinally, distal side in line of distal edge of RR, adjoining 3 plates distally, IBr_1 U-shaped, strongly convex transversely, slightly concave longitudinally, ambulacral groove deep, V-shaped. Granular surface ornament on all cup plates. Stem impression round; lumen weakly pentalobate.

Measurements.—Cup height 10.7, width 15.2; IBB length 2.5, width 2.8; BB length 4.6, width 5.2; RR length 7.3, width 7.2; anal X length 5.0, width 4.5; stem impr d 4.2; lumen d 0.9.

Remarks.—*Cyathocrinites* sp. 1 probably represents a new species. It resembles such bowl-shaped cyathocrinitids with intermediate-width facets as *C. divaricatus*. It differs from *C. divaricatus* by having a more vertical slope on facets and more strongly convex, tumid plates. A species name will not be proposed until a systematic study of the Mississippian species of *Cyathocrinties* can be completed.

Material.—Cup, disarticulated in preparation and reassembled, 407466 (loc. 34).

CYATHOCRINITES sp. 2

Fig. 10,*1-4*

Description.—Cup small, bowl-shaped, base flat, walls flaring out steeply, becoming vertical at radial summit. Infrabasal circlet horizontal, slightly impressed; IBB 5, equidimensional, distal tips upturned, barely visible in lateral view of cup. BB 5, pentagonal except posterior B hexagonal, slightly wider than long, strongly convex transversely and longitudinally, forming base of cup. RR 5, wider than long, horseshoe-shaped; strongly convex transversely and longitudinally; radial facets elliptical, wide, plenary, deep, gently concave, sloping steeply downward, elliptical, cut by intermediate-sized V-shaped ambulacral groove. Anal X broken distally, slightly longer than wide, convex. All cup plates except IBB with coarse granular to short ridge ornament, plates tumid, sutures appearing impressed. Stem impression round; lumen pentalobate. Arms and stem unknown.

Measurements.—Cup height 5.9, width 9.8; IBB length 1.5, width 1.5; BB length 3.1, width 3.7; RR length 4.0, width 4.7; anal X length 2.4 (incomplete), width 2.4; stem impr d 2.4; lumen d 0.5.

Remarks.—This form is related to *Cyathocrinites* sp. 1 but differs by having relatively larger radial facets that are elongate transversely, more tumid basals, and coarser ornamentation. It is believed to represent a new species.

Material.—407467 (loc 14).

CYATHOCRINITES sp. 3

Remarks.—A small dorsal cup (407468) from the upper part of the lower member of the Anchor Limestone (loc. 12) is identified as *Cyathocrinites* sp. 3. The infrabasal circlet has been destroyed by weathering and the shape of the base is uncertain, but from the incurving of the proximal parts of the basals it was probably subhorizontal or gently upflared. The basals, radials, and anal X are strongly convex. Apices of the sutures are impressed. The steeply downflared plenary radial facets are elliptical with the longer axis longitudinal; facets occupy approximately half the width of the wide radials. The central part of each basal protrudes as a node with ridges connecting to radials and probably to other basals. Arms and stem are unknown.

This specimen is related to *Cyathocrinites* sp. 1 and sp. 2 but differs from them by having narrower facets that are elongate longitudinally

and impressed sutural apices. It is not suitable to serve as a holotype but is reported for stratigraphic purposes.

CYATHOCRINITES sp. 4

Fig. 10,*5,6*

Description.—Cup conical, wider than high, base flat, basal and radial suture apices gently impressed, no surface ornament. IBB 5, slightly wider than long, proximally horizontal, slightly impressed for stem attachment, distally upflared, visible in lateral view of cup. BB 5, hexagonal except posterior B septagonal, faintly convex to straight longitudinally, gently convex transversely, slightly wider than long. RR 5, horseshoe shaped, wider than long, proximally upflaring, subvertical distally; facets plenary, circular, concave, subvertical, cut by V-shaped ambulacral groove in distal 0.25. Anal X longer than wide, adjoined by 3 plates distally slightly below radial summit. Stem facet circular, forming base of cup; lumen pentalobate.

Measurements.—Cup height 8.2; IBB length 2.2, width 2.6; BB length 4.0, width 4.2; RR (C ray) length 4.9, width 5.5; anal X length 3.6, width 3.3; stem impr d 3.3; lumen d 0.8.

Remarks.—The cup was broken while being collected; most of the E, A, and B radials and part of the EA basal were lost. The remainder of the cup is well preserved and is believed to represent a new species.

This form belongs to the conical group of cyathocrinitids that includes *C. chouteauensis* (Miller and Gurley, 1896) from the Chouteau Limestone of Missouri and *C. marshallensis* (Worthen, 1882) from the Hampton Formation of northern Iowa. It differs by lacking ornamentation and having larger, more down-flared facets than either of these two forms.

Material.—407469 (loc. 25).

Suborder POTERIOCRININA Jaekel, 1918

Remarks.—The suborder Poteriocrinina is a highly diverse group characterized by pinnulate arms. The more primitive forms, in the superfamilies Poteriocrinitacea, Rhenocrinacea, and Scytalocrinacea, typically have a conical cup with a truncate base and upflared infrabasals, three anals in the cup, a tall anal sac, and uniserial arms.

The superfamilies are essentially subdivided on the relative width of the radial facet, with Poteriocrinitacea angustary, Rhenocrinacea peneplenary, and Scytalocrinacea plenary. There are exceptions, however, as *Rhabdocrinus,* assigned to the Poteriocrinitacea, has peneplenary facets and *Maragnicrinus,* currently recognized in the Rhenocrinacea, has angustary facets. Several genera assigned to the Scytalocrinacea have peneplenary, not plenary facets.

In some families the cups are so similar that genera are distinguished on the basis of branching patterns of the arms. In some instances, a cup without the arms cannot be confidently identified below superfamily level. Exceptions noted at the superfamily level compound the dilemma. Until these problems are resolved, the stratigraphical, paleoecological, and paleontological value of these specimens is low. Furthermore, questions arise concerning validity of the current classification followed in the *Treatise* (Moore and Teichert, 1978). These problems point out the lack of known or recognized morphological detail of some forms.

Genus POTERIOCRINITES Miller, 1821

POTERIOCRINITES sp.

Fig. 11,*28,29*

Description.—Cup large, conical, flat based, all plates strongly fluted; flutings aligned to produce ridges connecting plates. IBB 5, short, distal tips upflared, visible in lateral view of cup. BB 5, large, equidimensional, thin. RR 5, large, wider than long, thin, C R elevated above others. Radial facets angustary, approximately 0.67 width of R, sloping steeply outward, slightly elliptical with transverse long axis, concave, bearing gently arched transverse ridge, cut distally by moderately wide V-shaped ambulacral groove. $IBrr_1$ elliptical in transverse section, bearing facets like radial facets. Three anals in cup, right tube plate adjoining RA, anal X slightly below radial summit. Stem round; lumen round, large.

Remarks.—The description is based on two weathered, poorly preserved specimens. One is a disarticulated cup that has been partly reassembled. The other is part of the posterior half of a cup on which weathering has destroyed the distal parts of the radial and anal plates. Nei-

ther specimen is suitable to serve as a holotype, and a name is withheld.

Large conical cups with fluted plates occur in *Barycrinus, Springericrinus,* and *Poteriocrinites. Springericrinus* is closely related to *Poteriocrinites,* differing by having secondary fluting on major cup ridges or flutings. *Barycrinus* has only one or two anal plates with anal X in the radial circlet, whereas *Poteriocrinites* has three anals in the cup. *Barycrinus* lacks transverse ridges on the radial facets, which occur on *Poteriocrinites.* Isolated basal plates of *Barycrinus* and *Poteriocrinites* cannot be distinguished from one another, but radials can. Both genera are widespread in the Lower Carboniferous and care must be taken in their identification on the basis of disarticulated plates. Although both genera are in need of revision, *Poteriocrinites* is in greater need.

Material.—407470, figured (loc. 7 + 52), 407471 (loc. 20).

Family RHENOCRINIDAE Jaekel, 1918

Remarks.—Most genera in the family Rhenocrinidae are of Devonian age. Two genera, *Cydrocrinus* and *Hallocrinus,* are of Early Carboniferous age. If the arms are lacking, it is virtually impossible to assign a dorsal cup to the proper genus.

RHENOCRINIDAE sp. 1

Fig. 10,*7–9*

Description.—Cup low conical, wider than high, base truncate, walls slightly concave, flaring at 48 to 55° above horizontal, plates smooth. Infrabasal circlet low, horizontal proximally, flared up distally; IBB 5, dart-shaped, longer than wide, distal half visible in lateral view. BB 5, hexagonal except septagonal if adjoining anals, slightly wider than long, gently convex transversely, straight to faintly concave longitudinally. RR 5, pentagonal, half again wider than long, gently convex transversely, straight longitudinally. Radial facets plenary in anterior ray, peneplenary in posterior rays with notches between BC and DE rays, with subhorizontal to gentle outward slope; external edge gently convex with nearly right-angle corners, surface concave; transverse ridge extending width of facet from corners; ligament pit shallow, approximately 0.25 facet width; outer ligament ridge very low, same length as pit; outer ligament furrow shallow; outer marginal ridge low; muscle area shallowly concave, deep; intermuscular furrow and central pit narrow, moderately deep; lateral ridge not developed; lateral lobe wide, flared up. Anals 3, in primitive condition; RA pentagonal, approximately size of hexagonal anal X; first tube plate large, proximal half below radial summit. Stem facet circular; lumen pentalobate.

Measurements.—Cup height 11.0, width 16.0; IBB circlet d 6.8; IBB length 3.6, width 3.0; BB length 5.4, width 5.7; RR length 5.2, width 7.9; RA length 5.2, width 4.0; anal X length 4.4, width 3.9; stem impr d 4.2; lumen d 0.7.

Remarks.—Variation in the width of the radial facet makes classification of this form difficult. The plenary facet of the A ray suggests affinity with the Scytalocrinacea, whereas the peneplenary facets on all other rays suggest affinity with the Rhenocrinacea. Since most facets are peneplenary, we have chosen the latter.

Material.—407472 (loc. 10).

RHENOCRINIDAE sp. 2

Fig. 10,*20,21*

Description.—Cup high cone-shaped, slightly higher than wide, base truncate, plates smooth, slight impressions at suture apices. Infrabasal circlet high, subhorizontal proximally, strongly upflared distally, forming lower third of cup; IBB 5, dart-shaped, slightly wider than long, distal 0.67 upflared. BB 5, hexagonal except septagonal if adjoining anals, longer than wide, gently convex transversely, faintly convex longitudinally, largest plates in cup. RR 5, pentagonal, wider than long, moderately convex transversely, straight longitudinally. Radial facets peneplenary, occupying 0.75 radial width, exterior margin gently convex, corners rounded, surface concave. Radial notches shallow, obvious. Anals 3, primitive condition; RA largest, pentagonal; third anal only proximal part below radial summit. Stem impression round.

Measurements.—Cup height 17.5, width 16.0 (avg); IBB length 5.3, width 5.8; BB length 7.9, width 6.5; RR length 6.5, width 7.7; RA length 4.9, width 4.5.

Remarks.—This specimen is crushed, and silicification was incomplete. Details of the radial

facets are not well preserved, but a transverse ridge was definitely present and the intermuscular notch was wide. Anal X and the third anal are not preserved.

Material.—407473 (loc. 20).

Genus CELONOCRINUS Land and Webster, 1966

CELONOCRINUS NODULUS, n. sp.

Fig. 11,*30,31*

Diagnosis.—A *Celonocrinus* with discoid cup, each basal and anal plate bearing a single central node or short spine.

Description.—Crown low, spreading laterally. Cup large, discoid, shallow basal invagination including proximal tips of BB. Infrabasal circlet horizontal, largely covered by proximal columnal, in shallow impression. IBB 5, dart-shaped. BB 5, pentagonal except posterior B hexagonal, wider than long, gently convex transversely and longitudinally, forming base of cup, proximal 0.34 in basal impression, distal 0.34 gently upflared, bearing central node or short spine. RR 5, width more than twice length, gently convex transversely and longitudinally, gently upflared. Radial facet peneplenary, 0.87 radial width, subvertical, flaring downward. One large anal in radial circlet, pentagonal, slightly wider than long, bearing short central spine. Second and third anals with proximal ends in radial circlet, anal X bearing central node.

Brr wider than long, external surface flat, edges angular. IBr axillary, occupying central half of facet. $IIBr_1$ uniserial, much wider than long, outer 0.34 to 0.50 adjoining R in some; all distal IIBrr biserial. Base of flat straplike arms adjoined medially for 3 Brr. Distal arms and tegmen not preserved. Stem round, proxistele heteromorphic, formula N212, symplectic articulation; all proximal columnals wedge-shaped, thicker on AE interray side, most second-order internodals not extending full width of column. Lumen pentagonal.

Measurements.—Cup height 13.4, width 36.5 (incomplete); IBB circlet d 11.6; IBB width 6.9; BB length 11.7, width 13.4; RR length 9.7, width 22.0; anal X length 9.5, width 10.2; proximal columnal d 8.0.

Remarks.—The wedge-shaped columnals create a distinct curvature approaching a right angle in the proximal stem. A short pluricolumnal associated with but not attached to the crown has wedge-shaped second-order internodals that extend the full width of the column; the wedging decreases toward one end, presumed to be distal. This fact suggests that the wedge-shaped columnals are restricted to the proximal part of the stem. If *Celonocrinus nodulus* were a bottom dweller, the stem would serve as a runner-anchor and the right-angle bend in the proximal stem would orient the crown vertically. If the stem were subvertical, the right-angle bend would orient the cup in a near vertical position with the anal interray near the base. Either feeding condition would reduce stress on the proxistele.

Celonocrinus nodulus is distinguished by the node or short spine on each basal and anal plate. Both *C. expansus* Lane and Webster 1966 from the Lower Permian of southern Nevada and *C. angulatus* (Miller and Gurley, 1893) from the Upper Pennsylvanian of Missouri have unornamented cup plates.

Etymology.—The species name *nodulus* is Latin for knot or swelling, and refers to the nodes or short spines on the basal and anal plates.

Material.—Holotype, 407474 (loc. 2). Locality 2 is a fault zone with numerous faults in Devonian and Mississippian strata. It is possible that the specimen is from an incorrectly identified block of younger limestone incorporated in the fault zone.

Subclass FLEXIBILIA Zittel, 1895

Genus WACHSMUTHICRINUS Springer, 1902

Remarks.—*Wachsmuthicrinus* is one of the few flexible crinoids lacking a recognizable anal plate. Ray orientation must be based on the position of the small infrabasal plate when visible. The genus is known from Eurasia and North America. It is restricted to Upper Devonian and Lower Carboniferous strata.

Key to species of *Wachsmuthicrinus* Springer

I. Crown lacking spinose or nodose brachs
  A. Interbrachs few
    1. Ramules small . . . . . *W. dubjanskii*
    2. Ramules large . . . . . *W. ponderosus*
  B. Interbrachs many . . . . . *W. iowaensis*
II. Crown with spinose or nodose brachs

A. Spines or nodes only on axillary primibrachs . . . . . *W. spinifer*
B. Spines or nodes on primibrachs and higher brachs
  1. Spines or nodes only on axillary brachs
    a. Interbrachs present . . . . *W. thiemei*
    b. Interbrachs absent . . . *W. spinosulus*
  2. Spines or nodes on axillary brachs and higher nonaxillary brachs
    a. Many interbrachs, radials not tumid . . . . . *W. bernhardinae*
    b. One or few interbrachs, radials strongly tumid . . . . . *W. corrugatus,* n. sp.

WACHSMUTHICRINUS CORRUGATUS, n. sp.

Fig. 8,*4,5,11,12*

Diagnosis.—A *Wachsmuthicrinus* with irregular rough surface of tumid RR, RR and distal tips of BB connected with ridge ornamentation, axillary Brr and at least 2 distal nonaxillary Brr spinose.

Description.—Crown elongate; cup low bowl-shaped, base flat, walls subvertical. IBB intermediate sized, completely covered by stem. BB 5, hexagonal, distal tips upflared, visible in lateral view of cup, coarsely tumid, surface irregular. RR 5, 1 pentagonal, 4 asymmetric hexagonal overlapping adjacent RR, nearly twice as wide as long, strongly tumid, surface with irregular rough ridges, 2 ridges extending onto each subjacent B; radial facets strongly sloping downward.

IBr_1 much wider than long, bearing transverse ridge with small central node. IBr_2 hexagonal, axillary, bearing coarse, laterally directed spine. Distal Brr wider than long, axillary IIBrr and 2 nonaxillary IIIBrr bearing spines, proximal Brr with irregular wavy transverse ridges with elevated angular central ray ridge. iIBr elongate, probably solitary.

Stem round, largest proximally, formed of heteromorphic thin columnals; crenularium slightly wider than areola; symplectic articulation. Lumen pentalobate.

Remarks.—The holotype of *Wachsmuthicrinus corrugatus* was a mostly disarticulated silicified crown. The cup was articulated, and the proximal columnal was slightly dislocated and embedded in the matrix. Acid etching removed the matrix, and the specimen was partly reconstructed by reattaching the proximal column and primibrachs and a few secundibrachs. Study of the associated brachs provided additional data for the description.

Measurement of:	Holotype	Paratypes	
	407475	407476	407477
cup height	7.3	8.3	8.0
width	16.7	20.9	20.9
BB width	3.8	6.1	5.2
RR length	5.5	6.6	6.5
width	8.9	12.3	11.7
IBr_1 length	5.0	....	....
width	11.5	....	....
IAx length	8.3	....	....
width	10.8	....	....
stem impr d	7.5	10.6	10.2
lumen d	....	1.7	....

Wachsmuthicrinus corrugatus is distinguished from all other species of the genus by the coarsely tumid radials and distal tips of the basals, both bearing ridged surfaces.

Etymology.—The species name *corrugatus* is Latin meaning wrinkled or ridged, and refers to the irregular ridges on the radials.

Material.—Holotype, 407475 (loc. 12); paratypes, 407476 (loc. 10), 407477 (loc. 1).

Genus ANCORACRINUS, n. gen.

Type species.—*Ancoracrinus typus,* n. sp., here designated.

Diagnosis.—A eurocrinid lacking an anal in the cup; anal series cannot be distinguished from interprimibrachial series.

Description.—See description of *Ancoracrinus typus,* n. sp.

Remarks.—The presence of one or two interprimibrachs in each interray, cup configuration, and arm shape and branching pattern show the close affinity of *Ancoracrinus* with *Artichthyocrinus* Wright, 1923. The major difference is the lack of an anal plate in the cup of *Ancoracrinus.* Generally the anal rests on the posterior basal in *Artichthyocrinus;* however, variation occurs and in some specimens the anal rests in a notch in the radials (Wright, 1954). The anal series cannot be distinguished from the interprimibrachial series in *Ancoracrinus.*

Etymology.—*Ancora* is Latin, meaning of an anchor, and refers to the Anchor Limestone.

ANCORACRINUS TYPUS, n. sp.

Figs. 8,*1-3*; 12

Diagnosis.—Crown small, globose; cup plates, Brr, and iBrr firmly fixed; no anal in cup, 1 or 2 iIBrr per interray; arms short, stout, branching isotomously on IBr_2 and once higher, curling in distally; stem round, lumen pentalobate.

Description.—Crown globose, small, slightly wider than high, cup plates, IBrr, and iIBrr firmly fixed in crown. Cup shallow saucer-shaped, more than twice as wide as high. IBB circlet small, entirely concealed by proximal columnal. BB 5, small, equidimensional, distal tips extending beyond proximal columnal. RR 5, more than twice as wide as long, commonly not equal in size, larger RR overlapping adjacent smaller RR on mutual shoulders, when of equal size meeting with no overlap; facets sloping strongly downward, proximal tip normally covered by proximal columnal.

IBrr much wider than long, larger than RR, firmly interlocked with RR. IBr_2 axillary. iIBrr 1 or 2 per interray, resting on notch on mutual shoulder of 2 subjacent $IBrr_1$; $iIBr_1$ hexagonal or septagonal, approximately equidimensional, distally in contact with IIBrr. $iIBr_2$ or if singular only iIBr septagonal or octagonal, elongate, tapering distally, in contact with $IIBr_2$ if singular, $IIBr_3$ if $iIBr_2$. IIBrr wider than long. Each Brr bearing short patelloid process. No ornamentation, all plates above IBB gently convex transversely and weakly convex longitudinally. Stem impression round; lumen pentalobate.

Measurement of:	Holotype	Paratypes	
	407478	407479	407480
crown height	14.3[a]	...	...
width	18.8[a]	...	...
cup height	....	3.0	2.8
width	8.4	8.3	7.9
IBB circlet d	....	...	2.0
BB length	1.4	1.6	1.6
width	....	1.6	...
RR length	2.1	2.3	1.9
width	4.9	5.0	4.4
IBr length	2.5	2.3	2.5
width	7.2	6.6	7.1
IAx length	3.3	...	...
width	6.5	...	...
stem impr d	4.1	4.1	4.1
lumen d	....	0.4	0.4

a. Incomplete.

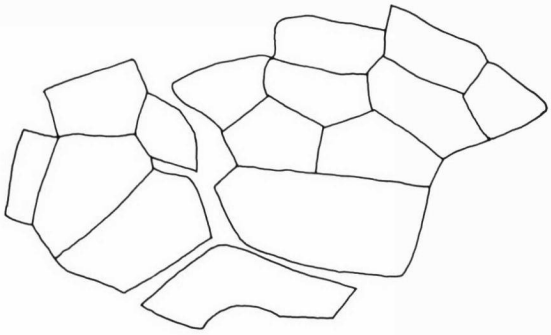

Fig. 12. *Ancoracrinus typus,* holotype 407478, ×8, lateral view showing abnormal two primibrachs above radial plate.

Remarks.—Silicification or loss of the infrabasal circlet in preparation prevented the recognition of infrabasal sutures and subsequent orientation of rays. The circlet is believed to have been formed of three plates, one small and two larger of equal size.

The holotype has one abnormal ray (Fig. 12) in which the first primibrach is axillary followed by axillary first secundibrachs. The two secundibrachs give rise to three tertibrachs, the middle one shared by the two axillary secundibrachs. The right tertibrach of the three is axillary. Brachs beyond the second or third secundibrachs are not preserved or are dislocated in most rays; however, the fourth secundibrach is axillary in one ray. All branching is isotomous.

Etymology.—This is the first species recognized for the genus, thus the Latin *typus,* meaning example, is assigned.

Material.—Holotype, 407478 (loc. 31); paratypes, 407581 (loc. 19), 407479 (loc. 22), 407480 (loc. 13).

LOCALITY REGISTER

1. Upper member, west side of fault block on east side of dry lake; SE SE NW sec. 15, T. 16 S., R. 63 E., Arrow Canyon 15′ Quadrangle.
2. Upper or lower member, exact horizon unknown, in small fault block of Anchor? Limestone in large fault zone; NE NE SE sec. 15, T. 16 S., R. 63 E., Arrow Canyon 15′ Quadrangle.
3. Upper member in fault block cut by calcite-filled fractures and faults; long 36°44′5″, lat 114°47′24″, Arrow Canyon 15′ Quadrangle.
4. Lower part of upper member on southwest-facing slope; long 36°46′18″, lat 114°47′19″, Wildcat Wash SE 7.5′ Quadrangle.
5. Middle member on southwest-facing slope; long 36°46′21″, lat 114°47′20″, Wildcat Wash SE 7.5′ Quadrangle.
6. Four m below top of upper member; long 36°46′24″, lat 114°47′23″, Wildcat Wash SE 7.5′ Quadrangle.
7. Measured section of Anchor Limestone on southwest-facing slope, from top Dawn Limestone, long 36°46′26″, lat 114°47′30″, to base Bullion Limestone, long 36°46′28″, lat 114°47′24″, Wildcat Wash SE 7.5′ Quadrangle. Individual samples from the section are designated with the locality number plus meters stratigraphically above the base of the section (i.e., 7 + 45).
8. Approximately 10 m above base of upper member on south-facing slope of small tributary wash; long 36°46′31″, lat 114°47′28″, Wildcat Wash SE 7.5′ Quadrangle.
9. Middle member on west-facing slope south of small tributary wash; long 36°46′44″, lat 114°47′30″, Wildcat Wash SE 7.5′ Quadrangle.
10. Lower part of upper member on southwest-facing slope; long 36°46′47″, lat 114°47′33″, Wildcat Wash SE 7.5′ Quadrangle.
11. Lower part of upper member on southwest-facing slope; long 36°46′43″, lat 114°47′33″, Wildcat Wash SE 7.5′ Quadrangle.
12. Upper part of lower member on south-facing slope of tributary wash; long 36°46′48″, lat 114°47′35″, Wildcat Wash SE 7.5′ Quadrangle.
13. Upper part of lower member on south side of saddle and west side of strike ridge formed by Anchor and Bullion limestones; long 36°47′8″, lat 114°47′27″, Wildcat Wash SE 7.5′ Quadrangle.
14. Upper part of lower member on north side of saddle along ridge crest; long 36°47′13″, lat 114°47′27″, Wildcat Wash SE 7.5′ Quadrangle.
15. Float from basal part of upper member, north of saddle, west side of ridge crest; long 36°47′15″, lat 114°47′28″, Wildcat Wash SE 7.5′ Quadrangle.
16. Uppermost part of lower member on east side of dry wash; long 36°47′15″, lat 114°47′33″, Wildcat Wash SE 7.5′ Quadrangle.
17. Dip slope on middle member in V between junction of two tributary washes; long 36°47′16″, lat 114°47′32″, Wildcat Wash SE 7.5′ Quadrangle.
18. Same locality as 17, next higher bedding surface in light blue-gray beds.
19. Beds immediately below abundant solitary rugose coral horizon in lower part of lower member along west side of dry wash, above loc. 17; long 36°47′16″, lat 114°47′33″, Wildcat Wash SE 7.5′ Quadrangle.
20. Bedding surface in middle of solitary rugose coral horizon in middle part of lower member; same locality as 19.
21. Top bedding surface of solitary rugose coral horizon in middle part of lower member; same locality as 19.
22. Middle member above cliff of lower member; same location as 19.
23. Float from upper half of upper member on west side near head of dry wash; long 36°47′18″, lat 114°47′32″, Wildcat Wash SE 7.5′ Quadrangle.
24. Float from middle member just east of crest of spur forming west side of tributary wash of loc. 17–22; long 36°47′19″, lat 114°47′34″, Wildcat Wash SE 7.5′ Quadrangle.
25. Basal part of upper member, west side of crest of spur; same coordinates as loc. 24.
26. Uppermost part of upper member, crest of spur; same coordinates as loc. 24.
27. Top bedding surface of first bed immediately above first solitary rugose coral horizon in middle part of lower member on southwest-facing slope; long 36°47′19″, lat 114°47′37″, Wildcat Wash SE 7.5′ Quadrangle.
28. Upper member on west-facing slope; long 36°47′28″, lat 114°47′33″, Wildcat Wash SE 7.5′ Quadrangle.
29. Lower part of upper member on south side of saddle along both sides of ridge crest; long 36°47′32″, lat 114°47′28″, Wildcat Wash SE 7.5′ Quadrangle.
30. Upper part of middle member on south side of saddle, west side of ridge crest; same coordinates as loc. 29.
31. Middle of upper member on north-facing slope in fault block on west side of ridge crest; long 36°47′59″, lat 114°47′32″, Wildcat Wash SE 7.5′ Quadrangle.
32. Top of lower member on north-facing slope in fault block west of ridge crest; long 36°48′00″, lat 114°47′32″, Wildcat Wash SE 7.5′ Quadrangle.
33. Basal beds of middle member on north-facing slope in fault block west side of ridge crest; long 36°48′00″, lat 114°47′28″, Wildcat Wash SE 7.5′ Quadrangle.
34. Upper member both sides of ridge crest; long 36°49′25″, lat 114°47′27″, Wildcat Wash SE 7.5′ Quadrangle.

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