Echinoderm Faunas of the Decatur Limestone and Ross Formation (Upper Silurian to Lower Devonian) of West-Central Tennessee

Craig R. Clement and Carlton E. Brett

Bulletins of American Paleontology

Number 388, January 2015
BULLETINS OF AMERICAN PALEONTOLOGY
Established 1895

Paula M. Mikkelsen   Warren D. Allmon
Editor-in-Chief   Director

EDITORIAL BOARD

JASON S. ANDERSON, University of Calgary
KENNETH ANGIELCZYK, Field Museum of Natural History
RITUPARNA BOSE, City University of New York
CARLTON BRETT, University of Cincinnati
ANN F. BUDD, University of Iowa
PETER DODSON, University of Pennsylvania
DANIEL FISHER, University of Michigan
DANA H. GEARY, University of Wisconsin-Madison
PETER J. HARRIES, University of South Florida
JOHN POJETA, United States Geological Survey
CARRIE E. SCHWEITZER, Kent State University
GEERAT J. VERMEIJ, University of California at Davis
EMILY H. VOKES, Tulane University (Emerita)
WILLIAM ZINSMEISTER, Purdue University

BULLETINS OF AMERICAN PALEONTOLOGY is published semiannually by Paleontological Research Institution. For a list of titles and to order back issues online, go to http://museumoftheearth.org. Numbers 1-94 (1895-1941) of BULLETINS OF AMERICAN PALEONTOLOGY are available from Periodicals Service Company, Germantown, New York, http://www.periodicals.com. Subscriptions to BULLETINS OF AMERICAN PALEONTOLOGY are available in hard-copy and electronic formats to individuals or institutions; non-US addressees pay an additional fee for postage and handling. For current rates, additional information or to place an order, see http://museumoftheearth.org or contact:

Publications Office
Paleontological Research Institution
1259 Trumansburg Road
Ithaca, New York 14850-1313
Tel. (607) 273-6623, ext. 20
Fax (607) 273-6620
publications@museumoftheearth.org

This paper meets the requirements of ANSI/NISO Z39.48-1992 (Permanence of Paper).
Echinoderm Faunas of the Decatur Limestone and Ross Formation (Upper Silurian to Lower Devonian) of West-Central Tennessee

Craig R. Clement and Carlton E. Brett
ECHINODERM FAUNAS OF THE DECATUR LIMESTONE AND ROSS FORMATION (UPPER
SILURIAN TO LOWER DEVONIAN) OF WEST-CENTRAL TENNESSEE

CRAIG R. CLEMENT
248 Best Drive, Berea, Ohio 44017, U. S. A., scypho@sbcglobal.net

AND

CARLTON E. BRETT
Department of Geology, University of Cincinnati, Cincinnati, Ohio 45221-0013, U. S. A., brettce@ucmail.uc.edu

ABSTRACT
The Decatur Limestone (Pridolian) and Ross Formation (Lochkovian), which crop out in the western valley of the Tennessee River, are a series of fossiliferous bioclastic limestones and fine-grained terrigenous clastic rocks that span the Silurian–Devonian boundary. These formations were deposited at a paleolatitude of 20–30°S on a shallow shelf bounded by the Illinois Basin to the north, the Black Warrior Basin to the south, the Nashville Dome to the east, and the Ozark Uplift and New Madrid Rift Zone to the west.

The Decatur and Ross formations contain diverse assemblages of echinoderms with a total of 38 genera and 69 species in 7 classes, with the crinoids comprising the greatest number of taxa. Of the crinoids, camerates are most diverse (16 genera, 33 species) followed by disparids (8 genera, 13 species), flexibles (4 genera, 13 species), and cladids (2 genera, 4 species). Among the other echinoderm classes, blastoids are represented by 3 genera and 3 species; rhombiferans, edrioasteroids, cyclocystoids, stylophorans, and echinoids are each represented by a single genus and species.

Preservation of the echinoderms ranges from nearly complete specimens to completely disarticulated debris. Several genera, particularly among the flexibles, are known from nearly complete crowns, whereas the cyclocystoid Sievertsia sp. and the disparid crinoid Pygmaeocrinus sp. are recognized only from isolated ossicles. This style of preservation is interpreted to have been produced by episodic storms. The complete crowns represent living individuals, and the cups represent forms that were somewhat resistant to disarticulation, buried by storm-entrained sediment. The calyces of some of the crinoids, particularly among the camerates, were sufficiently resistant to disarticulation to serve as sites of epibiont colonization. The most abundant identifiable echinoderms occur in several beds of coarse debris within the Decatur Limestone and in the lower Rockhouse Limestone and the upper Birdsong Shale (Bryozoan Zone) members of the Ross Formation.

The echinoderm faunas preserved in the Decatur and Ross formations compare most favorably with those in Oklahoma (17/32 genera in common), Bohemia (13/29), and the Armorican Massif (7/22). These comparisons indicate a greater degree of interchange among the echinoderm faunas of these regions than has been previously reported. Representatives of the genus Pygmaeocrinus are noted for the first time outside of Bohemia. Within the Decatur–Ross interval, Scyphocrinidae and Marsupiocrinus (Amarsupiocrinus) made their last appearance.

Seven new genera and 13 new species of echinoderms are described herein, including Probalocrinus dignis (Strimple, 1963) n. comb., Eudimerocrinus hlabsei n. sp., Dimenocrinites (Dimerocrinites) cheilobathron n. sp., Macroystocrinus tertibrachialis n. sp., Marsupiocrinus (Amarsupiocrinus) devonicus n. sp., Paramarsupiocrinus broadheadi n. gen. et n. sp., Paramarsupiocrinus n. gen. et n. sp., Eodolatocrinus hlabsei n. gen. et n. sp., Eohalysiocrinus broweri n. sp., E. gibsoni n. sp., Ichthocrinus erugatus n. sp., Parahormocrinus decaturensis n. gen. et n. sp., Eohadroblastus inexpectatus n. gen. et n. sp., and Eodevonocystis marilynni n. gen. et n. sp. In addition, the blastoid Leptoschisma lone (Dunbar, 1920) is referred to Decaschisma, and the disparid crinoid Phimocrinus americanus Springer, 1923, is referred to Theloreus. Most previously described taxa have been rediagnosed to emphasize those characters that serve to distinguish them.

INTRODUCTION
The Decatur Limestone (Upper Silurian, Pridoli) and Ross Formation (Lower Devonian, Lochkovian) of west-central Tennessee crop out in a north–south band along the western valley of the Tennessee River and provide an unbroken sequence of marine deposits across the Silurian–Devonian boundary (McComb & Broadhead, 1980, 1995; McComb, 1987; Cappacioli, 1987; Broadhead et al., 1989; Gibson, 1992). They comprise a fossiliferous series of bioclastic limestones and fine-grained terrigenous clastic rocks that contain a diverse and abundant fauna of marine invertebrate fossils. The faunas contained in the Decatur and Ross have been collected...
for more than a century and a half, but except for the brachiopods (Amsden, 1949), they have received relatively little systematic study. This is especially true of the echinoderms.

The two major early works concerning the Decatur Limestone and Ross Formation (Dunbar, 1919; Wilson, 1949) were primarily stratigraphic in nature and only listed the echinoderm taxa from these rocks known to those times. Springer (1917, 1920, 1926a) added several new crinoid taxa to those previously described from the Decatur. Since then, McIntosh (1981) described a new species of *Lecanocrinus* Hall, 1852, and Broadhead & Strimple (1978) described a new rhombiferan cystoid, both from the Ross Formation.

The purpose of this study has been to identify the echinoderms present in the Decatur and Ross formations, determine their stratigraphic and geographic ranges, and interpret the conditions under which they lived, died, and were buried.

**Location of the Study Area**
The study area is located along the western valley of the Tennessee River, in Benton, Decatur, and Perry counties, Tennessee (Text-fig. 1), where several large quarries and other exposures afford excellent opportunities for the collection of fossils of all kinds. Good exposures of Decatur Limestone occur in roadcuts and bluffs along the Tennessee River as well as in the quarries, whereas the Ross Formation is well-exposed only in the quarries. The glade and stream exposures mentioned by earlier workers (Dunbar, 1919; Wilson, 1949; Gibson, 1995a–c) no longer exist, for the most part, due to vegetation of the glades and new construction. The quarries, however, provide better exposures of the Ross Formation than existed when most of the early paleontological works on this area were completed. Principal localities (see Appendix A) collected for this study included three active quarries (PQ, Parsons Quarry; BQ, Benton Quarry; MQ, McClanahan’s Quarry) and four inactive quarries (EQ, Elkins Quarry; AM, Allen’s Mill; Q11, Quarry 11; Q13, Quarry 13). Other exposures include two roadcuts (RCa, RCb) along Tennessee State Route 69 and three natural exposures along the Tennessee River (PVa, Perryville south; PVb, Perryville north; CL, Cherokee Landing/Woodland Acres).

**Stratigraphy and Lithology**
The Decatur Limestone and Ross Formation are part of a nearly continuous series of sedimentary units that begin with the Lower Silurian (Llandovery) Brassfield Limestone and end with the Lower Devonian (Pragian?) Camden Formation (Text-fig. 2). The rocks contained within this interval are primarily limestone with lesser amounts of fine-grained terrigenous lithologies. Dunbar (1919) and Wilson (1949) believed that unconformities existed between the Brassfield and the overlying Wayne Group, between the Brownsport Group and the overlying Decatur Limestone and between the Decatur and overlying Ross Formation. Reid (1983) and McComb (1987) did not recognize an unconformity between the Decatur and Ross. McComb (1987) also found no evidence of unconformity between the Decatur and Brownsport at PQ. Barrick (1983) did not recognize an unconformity between the Wayne Group and the overlying Brownspor Group, but did recognize one between the Wayne Group and the underlying Brassfield Formation. It is interesting to note that Dunbar (1917) believed that there was no unconformity between the Decatur Limestone and Ross formation but later changed his mind (Dunbar, 1919).
Text-fig. 2. Generalized stratigraphic column of the Decatur and Ross formations; thicknesses averaged from those of McComb (1987) and Gibson (1988).

Decatur Limestone

The Decatur Limestone is 15–20m thick (Text-fig. 2) and is composed of gray or brick-red, medium- to massive-bedded wackestone to grainstone (Dunbar, 1919; Wilson, 1949; McComb, 1987; McComb & Broadhead, 1995). It includes fine-grained, sparsely fossiliferous beds interlayered with coarse-grained beds that contain more abundant identifiable remains (see Dunbar, 1919; Wilson, 1949). Echinoderm ossicles are the most common identifiable allochems (McComb, 1987; McComb & Broadhead, 1995). In most outcrops, large-scale sedimentary structures, other than horizontal bedding, are not apparent; but in BQ, there are large-scale cross-beds and megaripples evident in the lower portion. McComb (1987) recognized four lithic subunits in the Decatur at PQ, but this formation is not subdivided here.

Ross Formation

Rockhouse Limestone Member

The Rockhouse Limestone Member is 4–5m thick (Text-fig. 2) at all outcrops where it can be recognized and conformably overlies the Decatur Limestone (Reid, 1983; McComb, 1987; Gibson, 1988, 1995a). Reid (1983) subdivided the Rockhouse Limestone at the three localities that she studied (BQ, PQ, AM) into three informal units: (1) a thin (0.61–0.73 m) basal unit composed of thin-bedded limestone and shale partings with a thin (10 cm) shale bed at the base; (2) a thick (2.17–3.55 m) unit of alternating shale and limestone; and (3) a variably thick (0.83–1.44 m) unit of medium-bedded limestones and thin shales. Bryozoan-dominated carbonate mudmounds have been described from the lower Rockhouse at PQ (Gibson et al., 1988, 1989). Mudmounds do not occur at other exposures of the Rockhouse Limestone, although Reid (1983) recognized a cystoporate bryozoan-rich zone in the lower Rockhouse at AM. Nonetheless, Reid’s units 1 and 2 appear to be recognizable as partial lithic equivalents of phase I and phases II–IV of Gibson et al. (1989), respectively. These units were not identified, in most cases, in this study.

In the southern outcrops of the study area (southern Decatur County), the Rockhouse Limestone can be divided into two informal units of approximately equal thickness. The lower unit, at most outcrops, comprises thin- to medium-bedded limestone (wackestone to grainstone) interbedded with thin shale units, which are commonly green. Bryozoan mudmounds occur in this unit at PQ, extending through its thickness (Gibson et al., 1988, 1989).

The upper unit comprises thin- to medium-bedded limestone (wackestone to grainstone) interbedded with shale beds of approximately the same thickness. These shale beds are a dark blue-gray, with more comminuted fossil debris than is seen in the shales of the lower unit. There is a zone (approximately 1m thick) at the top of this unit that is composed of medium-bedded limestones with thin shale interbeds. This probably corresponds with unit P4 (Rockhouse unit 3) of Reid (1983). The lithologies and fossils occurring in the upper unit are very similar to those in the overlying Birdsong Shale. The upper unit of the Rockhouse is distinguished from the lower part of the Birdsong only by the greater abundance of limestone layers in the former. In the quarries, blocks from these two units were not distinguishable, and the upper Rockhouse–lower Birdsong interval is treated here as an informal unit.

In the northern outcrops, the Rockhouse has a somewhat different character. At AM, it comprises a thin interval (87 cm) of thinly-bedded limestone (possibly corresponding with unit A2 of Reid, 1983) followed by a zone ca. 1.5 m thick, composed of medium-bedded limestone and shale beds in ap-
proximately equal proportion. This is overlain by an upper horizon, slightly more than 2 m thick, comprising medium to thick-bedded limestones separated by thin shale partings. At BQ, the Rockhouse is not well defined, the Decatur presumably grading directly into the overlying Birdsong Shale. However, the shales in the lower part of the Rockhouse are green, whereas the shales in the upper part are dark blue-gray as seen at other localities.

**Birdsong Shale Member**

The Birdsong Shale Member, with a maximum thickness of 19.4 m (Text-fig. 2) and a minimum thickness of 4.5 m (Dunbar, 1919; Wilson, 1949; Reid, 1983; Gibson, 1988, 1995a, b), comprises alternating beds of argillaceous limestone and calcareous shale that are filled with comminuted fossil debris. The member can be divided into two informal units in all outcrops examined. The lower unit was called the "Brachiopod Zone" by Dunbar (1919) and is of variable thickness with a maximum of 15 m (MQ) and a minimum of 2.5 m (EQ) (Gibson, 1988, 1995a, b).

The lowest meter of the Brachiopod Zone (sensu Wilson, 1949; unit 1 of Gibson, 1988) contains beds of limestone that are similar to those in the upper Rockhouse and, in practice, are indistinguishable from them. This thin unit is hereafter considered under an informal unit encompassing the upper Rockhouse Limestone and lowest Birdsong Shale and is not included within the Brachiopod Zone.

The limestone beds in the Brachiopod Zone (as defined here; units 2 and 3 of Gibson, 1988, 1995a, b) decrease in thickness and number higher in the section. The Brachiopod Zone is capped by a 1-m-thick shale unit (unit 3 of Gibson, 1988) that contains only thin (less than 1 cm), discontinuous limestone beds. Brachiopods are the predominant fossils in this lower unit.

The upper unit of the Birdsong Shale (units 5 and 6 of Gibson, 1988, 1995a, b) is composed of thin-bedded limestone and shales, packed with ramose bryozoans and echinoderm debris, and is called the Bryozoan Zone. It is separated from the underlying Brachiopod Zone by a thin (ca. 20 cm), highly bioturbated, limestone layer that Gibson (1988) termed the transition zone (unit 4 of Gibson, 1988). The Bryozoan Zone is ca. 4.75 m thick at BQ and PQ, 3.5 m thick at MQ, and 2 m thick at EQ (Gibson, 1988).

This stratigraphic sequence is examined in all outcrops but is less obvious at BQ. There, there are more thin beds of limestone in the Brachiopod Zone, a character that does not allow easy discernment of the various units. The units that Reid (1983) described in the Birdsong Shale were not recognized in this study.

**PALEOGEOGRAPHY AND DEPOSITIONAL ENVIRONMENTS**

The Decatur Limestone and Ross Formation were deposited on a shallow, fully marine shelf, at ca. 25°S latitude (Heckel & Witzke, 1979; Scotese et al., 1985; Gibson, 1988, 1992, 1995a, b; Scotese & McKerrow, 1990; Woodcock, 2000), which was bounded on four sides by large-scale structural features (Text-fig. 3). To the north, the Illinois Basin was apparently not simply a depocenter, but it was a deepwater basin (Heidlauf et al., 1986, fide Gibson, 1988; Illinois State Geological Survey, 1985). To the south was the Black Warrior Basin. To the east was the Nashville Dome, which was probably no more than barely emergent, and to the west was the Ozark Uplift, which was mountainous, shedding sediments into the western Illinois Basin (see Gibson, 1988; Broadhead et al., 1989). Buschbach (1985) and Braile et al. (1984, fide Gibson, 1988) hypothesized a down-dropped zone on the site of the Reelfoot Rift, connecting the Illinois Basin with the ocean waters to the south. During most of Ross Formation deposition, the shelf dipped gently toward the Illinois Basin, as suggested by aggradation of the Ross Limestone Member to the south (Broadhead et al., 1989).

The shelf bounded by these structural features (termed the Ross Shelf by Gibson, 1988, 1995a, b) was the site of primarily carbonate deposition throughout most of its existence (Early Silurian to Early Devonian) with only intermittent influxes of fine terrigenous clastics. During Decatur deposition, the shelf received very little terrigenous material, the rock being almost entirely carbonate. The Ross in the northern outcrops (Rockhouse Limestone and Birdsong Shale) contains much fine-grained terrigenous sediment and represents a large-scale influx of terrigenous muds onto the carbonate shelf, shutting off carbonate production for a time. The Ross in the southern outcrops is composed of various, mostly carbonate units representing different facies that formed in shallow to shoaling water near the edge of the Black Warrior Basin (Broadhead et al., 1989). The Camden Formation represents a return to clear water conditions and resumption of carbonate production. The Camden in most outcrops is a unit of brecciated chert with contorted bedding. Gibson (1988) interpreted this unit as a siliceous limestone that was altered by dissolution and replacement of the carbonate by silica, probably during subaerial exposure prior to deposition of the Chattanooga Shale (Late Devonian to Early Mississippian), which overlies it. This is interpretation is supported by the occurrence of Chattanooga Shale over brecciated Camden (Gibson, 1988: 67).

**ENvironments of deposition**

The Decatur Limestone and Ross Formation were deposited on a shallow marine shelf, mostly at or below normal wave base and above storm wave base (Reid, 1983; McComb,
The Decatur in the vicinity of Parsons, Tennessee, was studied by McComb (1987) who recognized four successive subenvironments: (1) subtidal, below wave base; (2) tidal channels and shoals; (3) subtidal, at or below wave base; and (4) subtidal, at or above wave base. He based his interpretations primarily on the abundance of micrite in the limestone layers, with more (wackestone and packstone) indicating quieter conditions, and less (grainstone) indicating greater wave or current activity. McComb’s (1987) environment 2 contained oolite beds as well as skeletal grainstone, prompting his tidal channel interpretation. He interpreted graded bedding as storm deposits. The identifiable echinoderms in the Decatur during this study came from several units of coarse-grained limestone in the middle and upper portions (environments 3 and 4).

The Rockhouse Limestone Member of the Ross Formation was studied by Reid (1983), McComb (1987), and Gibson (1988, 1996a, b). Both Reid (1983) and McComb (1987) believed the Rockhouse to have been deposited in relatively quiet water below normal wave base, but subject to episodic currents and wave activity. Gibson et al. (1988, 1989) reported bryozoan dominated mudmounds in the lower Rockhouse at PQ. The intermound areas are ripple-laminated grainstone. Many of the fossils in the lower Rockhouse are broken and abraded. This suggests that current and/or wave activity was prevalent during the deposition of the lower Rockhouse. The depositional environment of this part of the Ross Formation was probably not too different from that of the upper part of the underlying Decatur Limestone, which McComb (1987) interpreted as at or above wave base (Broadhead et al., 1989).

The principal difference between the upper Decatur and lower Rockhouse is the increase of fine, terrigenous clastics in the latter. This increase heralded the overwhelming of the carbonate shelf by the influx of siliciclastic mud characteristic of the majority of the Ross Formation. Gibson et al. (1989) noted that the bryozoan mudmounds, which grew during the deposition of the entire lower Rockhouse, terminated at the base of the more shale-rich portion of the Rockhouse (upper Rockhouse). This level corresponds to an abrupt increase in the rate of terrigenous influx. This rate increased until shale deposition was predominant (lower Birdsong Shale, Brachiopod Zone).

The Brachiopod Zone of the Birdsong Shale Member of the Ross Formation is predominantly fine-grained, terrigenous clastics, although there is a great deal of carbonate skeletal sediment as well. Gibson (1988, 1995a) interpreted the majority of beds in this unit as graded and deposited by storm events. The limestone beds were produced by the winnowing of the substratum, which concentrated the calcareous material. Many of the beds in this interval are replete with well-preserved brachiopods, suggesting a water depth below normal wave base, which would protect the fossils from current or wave action that would tend to break or abrade them. Well-preserved echinoderms are rare, whereas comminuted debris is not, suggesting low abundance and considerable time between storm events. Bioturbation also played a large role in the disarticulation of the echinoderms. During deposition of this interval, the maximum influx of terrigenous clastics occurred, and at the top of the Brachiopod Zone there is a 2-m-thick bed with little carbonate. Above this bed is a thin
transition zone with numerous burrows and few fossils other than finely comminuted echinoderm debris (Gibson, 1988, 1995a).

The upper Birdsong Shale (Bryozoan Zone) comprises interbedded thin limestone and shale with an abundance of thin, ramose bryozoans and large, stoloniferous crinoid stems. This zone was deposited below normal wave base and is interpreted as commonly quiet water conditions, as indicated by several zone was deposited below normal wave base and is interpreted as commonly quiet water conditions, as indicated by several

The episodic nature of terrigenous influx throughout the deposition of the Ross is further demonstrated by the abundance of epibiontic overgrowths on many of the echinoderm specimens (Springer, 1926; Pl. 3, Fig. 6; Thalamocrinus elongatus Springer, 1926, Pl. 10, Fig. 4) that disarticulated in place. The shelf during deposition of the upper Birdsong Shale was also subject to episodic storm events as evidenced by the well-preserved echinoderm specimens in the middle of the unit and oriented tentaculitids.

The episodic nature of terrigenous influx throughout the deposition of the Ross is further demonstrated by the abundance of epibiontic overgrowths on many of the echinoderm specimens and other fossils (Gibson, 1995b). Epibionts, such as bryozoans, are on crinoid calyces (both inside and outside) in all parts of the Ross and on the stoloniferous holdfasts in the Birdsong Zone. The epibionts grew only on exposed surfaces, which indicates that the echinoderm remains were not buried immediately, but instead lay on the sea floor for a period of time long enough for epibiont larvae to settle and grow.

**Previous Reports of Echinoderms**

There have been relatively few works that have reported echinoderms from the Decatur–Ross interval. Safford (1869) reported Aiptocystites anna Sanford, 1869, from the Ross Formation, which in early reports was called the "Lower Helderberg." Foerste (1903) reported Camarocrinus Hall, 1879 (the bulbous root of Scyphocrinites Zenker, 1833), from the Ross, which was then called the Linden.

Springer (1917) named and described three species of Scyphocrinites from the Ross Formation: S. spinifer, S. mutabilis, and S. pyburnensis. He stated that S. mutabilis also occurs in the Decatur Limestone, marking the first time that an echinoderm species was noted as occurring specifically in the Decatur. Springer (1917) also listed the genera Lecanocrinus, Pisocrinus de Koninck, 1858, Eucalyptocrinites Goldfuss, 1831, Marsupiocrinus Morris, 1843, Clonocrinus Quenstedt, 1876, Desmidocrinus Angelin, 1878, and Gazacrinus Miller, 1892, as co-occurring with S. mutabilis in the Decatur Limestone. However, Springer (1920, 1926a) failed to describe any species of Lecanocrinus, Pisocrinus, Marsupiocrinus, or Gazacrinus from that unit. Springer (1917) noted the occurrence of Stereocrinus sp. (now Dolatocrinus Lyon, 1857) and Phimocrinus sp. from the Linden (= Ross Formation).

Dunbar (1919) repeated Springer’s (1917) list of genera from the Decatur, but noted only Marsupiocrinus tennesseensis (Roemer, 1860) and Camarocrinus in his descriptions from that unit. Dunbar (1919) did not separate the northern facies of the Ross Formation into members, referring to it as the Birdsong Formation. From this unit, he listed Codaster lorae Dunbar, 1920 (= Decaschisma lora n. comb. herein), Edriocrinus sp., E. adnascens Dunbar, 1919, E. pyramidatus "Springer MS," Stereocrinus sp. (= Dolatocrinus), Phimocrinus sp., Scyphocrinus pyburnensis, S. pratteni McChesney, 1860, S. mutabilis, and Camarocrinus (= Scyphocrinites) sp.

Springer (1920) described new species of crinoids from the Linden, including Ichthyocrinus devonisicus, and three new species of Edriocrinus Hall, 1858: E. occidentalis, E. explicatus, and E. adnascens (now E. adnascens). In the same work, Springer (1920) noted the occurrence of E. pocilliformis Hall, 1859, but did not include Tennessee in its range. It is likely that the specimens that Dunbar (1919) called E. pocilliformis were ascribed to a different species, possibly E. explicatus by Springer (1920). The name E. pyramidatus, which Dunbar (1919) attributed to a Springer manuscript, never published by Springer and should be regarded as a nomen nudum.

Springer’s (1926a) work on the Silurian crinoids of America was the last major addition to knowledge of echinoderm taxa occurring in the Decatur Limestone and Ross Formation. From the Decatur, he described Mariocrinus rotundus (= Elpidocrinus rotundus), Clonocrinus occidentalis (= Eucalyptocrinites occidentalis n. comb.), Aerocrinus nodosus (= Stipectocrinus nodosus n. comb.), Eucalyptocrinites pereodorus, E. sculptilus, and Cremacrinus decatur; from the Ross he described Gazacrinus stellatus, Thalamocrinus elongatus, and Myelodactylus schucherti.

The last additions to these faunas are two articles, one by Broadhead & Strimple (1978) describing the rhombiferan Tyrriocrinites chelyon, and the second by McIntosh (1981) describing the flexible crinoid Lecanocrinus lawsonae.

**Occurrence of Echinoderms**

Identifiable echinoderms occur only sporadically within the Decatur–Ross interval, although disarticulated ossicles are ubiquitous (Table 1). The identifiable remains from the Decatur come from layers with coarse-grained echinodermal debris but are evident only after weathering etches the limestone, leaving the remains in relief. Two of these layers were collected extensively, in bluff sections, roadcuts, and older parts of quarries. The lower of the two beds occurs ca. 9 m below the top; the upper bed occurs 1.5 m below the top. Both are ca. 2 m thick. The upper unit is exposed at BQ, PQ, MQ, Q13, EQ, RCa, RCh, and PVa. The lower unit is exposed at AM, BQ, PQ, PVb, CL, and Q11, but was collected only from PVb and CL, which are outcrops along the western bank of the Tennessee River, and Q11.

The most commonly articulated remains of crinoids are the cups and calyces. Only rarely do specimens preserve the
arms, and these usually have the proximal stem preserved as well. Blastoids occur with the crinoids, but only the thecae are preserved. The beds between the coarse-grained layers are finer grained and contain relatively few identifiable fossils, such as brachiopods, and, more importantly, large dendritic radix holdfasts (sensu Brett, 1981) of unidentified crinoids. Identifiable echinoderm remains in these fine-grained layers are rare. Root bulbs (“Camarocrinus”) and plates of Scyphocrinides are in both fine- and coarse-grained layers.

The lower Rockhouse Limestone contains beds with identifiable echinoderms, mostly crinoids, some of them well preserved (Table 1). However, most of these were from the northern outcrops (BQ, AM), being most abundant at AM. At BQ, crinoids occur in interbedded thin limestone and green shale, mostly on the bases of limestone beds. At AM, numerous crinoids are in two units. The first is a thin (87 cm) zone of very thinly bedded (1 cm) limestone, which contains abundant Lecanocrinus pisiformis (Roemer, 1860) (e. g., Pl. 9, Figs 8, 12). The next zone is ca. 1.5 m thick and comprises interbedded shales and limestones, each bed several centimeters in thickness. It contains a variety of crinoids and also has the edrioasteroid Pyrgocystis Bather, 1915. Lecanocrinus menicus Springer, 1920, occurs at the northern roadcut on Tennessee Route 69 (RCb) on the underside of a limestone bed (Pl. 10, Fig. 2). Scyphocrinides spp. is common in this zone.

The upper Rockhouse Limestone and lowermost Birdsong Shale are treated here as a unit, being indistinguishable as blocks on quarry spoil piles. This interval comprises interbedded limestone and dark gray shale. In the Rockhouse portion, limestone beds are more prevalent whereas the Birdsong portion is shale-dominated. Recognizable echinoderm remains are not rare in this zone, but the diversity is low (Table 1). The most common echinoderm is the crinoid Scyphocrinides. Specimens of this genus were found in situ in the lowest Birdsong at MQ but are not known higher in the Birdsong. Most of the identifiable crinoids in the upper Rockhouse and lower Birdsong are preserved as cups and calyces only.

The remainder of the lower Birdsong Shale comprises thick, dark gray shale interbedded with medium-bedded, argillaceous limestone. This is the “Brachiopod Zone” of Dunbar (1919), as restricted herein. Identifiable echinoderms are rare in this zone, but isolated ossicles from washings of disaggregated shale indicate a greater diversity than is otherwise apparent (Table 1). Identified ossicles from this zone belong to the cyclocystoid Sieversia Smith & Paul, 1982 (Pl. 12, Figs 5–7), the calceocrinid Eohalysiocrinus Prokop, 1970 (Pl. 7, Fig. 9), and the homocrinid Theloreus Moore, 1962. Echinoid spines and plates are also present (Pl. 12, Figs 2, 11). Edrioocrinus adnacens (Pl. 11, Figs 2, 7) occurs throughout this zone, but it is known only from calyx bases, which are usually attached to brachiopods.

The upper Birdsong Shale comprises thin-bedded (ca. 1 cm thick) limestone and shale. It is replete with small ramose bryozoans, earning the name “Bryozoan Zone” by Dunbar (1919). Echinoderm remains, both articulated and disarticulated, are very common in this zone (Table 1). In the center of this zone at BQ is a series of thicker limestone beds that preserve complete or nearly complete crinoids including Lecanocrinus menicus (Pl. 10, Figs 3–4), Stiptocrinus nodosus (e. g., Pl. 2, Fig. 9), and Thalamocrinus elongatus (Pl. 9, Fig. 2).

Also occurring in abundance at BQ is the blastoid Decaschisma lorae (Pl. 11, Figs 8–9). Echinoid remains are from EQu in this zone (Pl. 12, Figs 1, 3–4). A characteristic fossil of this zone is a large, recumbent, stoloniferous holdfast belonging to a crinoid of uncertain affinity (Clement et al., 1987). These are common throughout the Bryozoan Zone. The camerate Dolocrinus helderbergensis (Springer, 1921) (Pl. 6, Figs 5–6, 8) is known only from this zone, marking the first appearance of this genus. At the top of the Bryozoan Zone at PQ, the new carpod species Eodevonocystis marilynni n. sp. (Pl. 12, Figs 8, 12–15) occurs in a buff-colored silty shale along with complete enrolled trilobites. Scyphocrinides is not known from the upper Birdsong Shale. The lack of specimens of this genus strongly suggests that it had become extinct, at least locally, by the time of deposition of the upper Birdsong.

MATERIALS AND METHODS

The echinoderm specimens collected during this study were acquired in two ways. Articulated and partially articulated specimens were located by careful search of spoil blocks and in situ strata, then removed using hammer and chisel. Most of the specimens from the Decatur were collected in situ from the bluffs, roadcuts, and older quarries, with a few specimens collected from slump blocks. In contrast, most of the specimens from the Ross Formation were collected from spoil pile blocks in the major quarries (BQ, PQ, MQ, EQ) and only a few specimens were found in situ. The blocks of Ross could be placed in an approximate stratigraphic position by using their lithology and paleontology. In most cases, a given block could only be placed within one of the informal units previously described (e. g., Brachiopod Zone). However, in EQ, the stratigraphic position of the blocks, particularly those of the Brachiopod Zone, could be determined very accurately, due to the condensed nature of this section.

Twenty-two samples of the Ross Formation were disaggregated by boiling in a solution of the industrial surfactant Miramine OC-ES. The fossil debris resulting from the disaggregation of the shales was sieved using 5-, 12-, 25-, 35-, 60-, and 120-mesh sieves, which correspond to 4000-, 1410-, 710-, 500-, 250-, and 125-μm opening sizes, respectively, then examined for identifiable echinoderm remains (Table 2). Most of the samples were examined only to the 25-mesh
Table 1. Distribution of echinoderm species through the Decatur and Ross formations. (A) Species found during this study. (B) Species previously reported, but not found during this study. For Decatur Limestone and Rockhouse Limestone member of the Ross Formation: L = lower; M = middle; U = upper; R/B = upper Rockhouse Limestone and lowest meter of Birdsong Shale (upper Rockhouse and lowest Birdsong differentiated only in situ, see text under Stratigraphy and Lithology for explanation). For Birdsong Shale Member of the Ross Formation: L = lowest meter of Birdsong; Br = Brachiopod Zone; By = Bryozoan Zone; X = specimen collected from outcrop; W = specimen found in washings of disaggregated shale samples. Modified from Clement & Broadhead (1994).

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>Decatur</th>
<th>ROCKHOUSE</th>
<th>R/B</th>
<th>Birdsong</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L/M</td>
<td>U</td>
<td>L</td>
<td>U</td>
</tr>
<tr>
<td>Eucalyptocrinites pernodosus</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. sp. A</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. sp. D</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paramarsupicrinus broadheadi</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marsupicrinus excavatus</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M. tennesseensis</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parapilocrinus sphaericus</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protocrinus. sp. A</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polydolitooides enodatus</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elpidocrinus tholiformis</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lampterocrinus tennesseensis</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hexacrinites adaensis</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scyphocrinites elegans</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stiptocrinus benedicti</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eucalyptocrinites sp. B</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. sp. C</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parahormocrinus decaturensis</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hexacrinites carinatus</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lecanocrinus pisiformis</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L. pusillus</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eudimerocrinus hlabsei</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lecanocrinus sp. A</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Macrostylocrinus tertibrachialis</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M. cf. laevis</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M. cf. pustulosus</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parapatelliocrinus broweri</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thalamocrinus robustus</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ichthyocrinus erugatus</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Edriocrinus cf. pyriformis</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pyrgocystis sp.</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scyphocrinites pratteni</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>S. stellatus</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Lecanocrinus lawsonae</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Etriocrinus adnascens</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Edodolocrinus hlabsei</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tyrriocrinus chelyon</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pygmaeocrinus sp.</td>
<td>W</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stiptocrinus nodosus</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thalamocrinus ovatus</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Myelodactylid sp.</td>
<td>X</td>
<td>W</td>
<td>W</td>
<td>W</td>
</tr>
<tr>
<td>Probalocrinus dignis</td>
<td>X</td>
<td>W</td>
<td>W</td>
<td>W</td>
</tr>
<tr>
<td>Thalorinus americanus</td>
<td>X</td>
<td>W</td>
<td>W</td>
<td>W</td>
</tr>
<tr>
<td>Crinobrachiatus sp.</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thalamocrinus elongatus</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lecanocrinus meniscus</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eohalysicrinus broweri</td>
<td>X</td>
<td>W</td>
<td>W</td>
<td>W</td>
</tr>
<tr>
<td>Sievertasia sp.</td>
<td>X</td>
<td>W</td>
<td>W</td>
<td>W</td>
</tr>
<tr>
<td>Eohalysicrinus gibsoni</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kallimorophocrinus sp.</td>
<td>W</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Echinoid</td>
<td>W</td>
<td>W</td>
<td>W</td>
<td>W</td>
</tr>
</tbody>
</table>
sieve size due to time considerations, but several to the 60-mesh size, and one to the 120-mesh size were examined. The stratigraphic distribution of echinoderms recovered both by disaggregation and from outcrop collections is presented in the biostratigraphy section.

Twelve of the disaggregated samples came from a detailed stratigraphic sampling of the Birdsong Shale at MQ. These were collected by Michael Gibson for his dissertation work (Gibson, 1988) and were offered by him for use on this project. The samples were taken at 0.0 (sample M2), 0.2 (M4), 1.6 (M14), 3.7 (M22), 6.6 (M2A), 9.1 (M31), 11.0 (M37), 13.0 (M48B), 13.6 (M48I), 14.0 (M48T), 14.2 (M51), and 14.9 (M54) m above the base of the Birdsong and were chosen to provide coverage of the entire Birdsong, with empha-

Table 1 (continued).

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>Decatur</th>
<th>ROCKHOUSE</th>
<th>R/B</th>
<th>Birdsong</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L/M</td>
<td>U</td>
<td>L</td>
<td>U</td>
</tr>
<tr>
<td>Decaschisma lorae</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eodevonocystis marilynni</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dimerocrinites cheilobathron</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. sp. A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dolatocrinus helderbergensis</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marsupiocrinus devonisus</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amphisterocrinus typus</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eohadrobastus inexpectatus</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eucalyptocrinites occidentalis</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. sculpitis</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. sp. E</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cremacrinus decatur</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gazacrinus stellatus</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scyphocrinites spinifer</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Myelodactylus schucherti</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ichthyocrinus devonicus</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Edriocrinus dispersus</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. explicatus</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. occidentalis</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Distribution of echinoderm species in shale washings from Ross Formation.

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>AM</th>
<th>PQ</th>
<th>uR</th>
<th>M 2</th>
<th>M 4</th>
<th>M 14</th>
<th>M 22</th>
<th>M 2A</th>
<th>M 31</th>
<th>M 37 b</th>
<th>M 48 m</th>
<th>M 48 t</th>
<th>M 48 B</th>
<th>M 48 I</th>
<th>M 48 T</th>
<th>M 51</th>
<th>M 54</th>
<th>PQ uB</th>
<th>EQ B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eohalysiocrinus broweri</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Myelodactylid</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Scyphocrinites sp.</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Echinoid</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Blastoid</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Theloreus americanus</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Sievertsiella sp.</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Hyperpinnulate brachial</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Edricrinus adnascens</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Cinothelocrinus sp.</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Probalocrinus dignis</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Flexible brachial</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Eodevonocystis marilynni</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Pygmaeocrinus sp.</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Kallimorphocrinus sp.</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Lecanocrinus sp.</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
sis both on shale beds of differing thicknesses and on stratigraphic position. Samples M48B, -I, and -T were taken from the bottom, middle, and top of the uppermost shale of the Brachiopod Zone, and sample M51 came from the transition zone between the Brachiopod Zone and Bryozoan Zone.

Three shale samples came from PQ, one from the upper Rockhouse Limestone (1.65 m below the Rockhouse–Birdsong contact), and two from the uppermost Birdsong Shale. One came from the lower Rockhouse Limestone at AM (87 cm above the Decatur Limestone). The remaining six samples are only assignable to general intervals. Three are from BQ, two from the upper Rockhouse or lower Birdsong and one from the Bryozoan Zone of the upper Birdsong; two from PQ, one each from the Brachiopod and Bryozoan Zones; and one from the Bryozoan Zone at EQ.

**BIOSTRATIGRAPHY**

Rocks of Late Silurian and Early Devonian age have been studied extensively, and much is known of the stratigraphic distribution of biostratigraphically important groups of organisms, especially graptolites and conodonts. The Silurian–Devonian system boundary was the first major stratigraphic boundary to be formalized by international agreement (Martinsson, 1977). Previous studies of the distribution of echinoderm remains from this time interval have focused on a regional scale, e.g., Podolia (Stukalina, 1977), Bohemia (Prokop, 1987), and Brittany (Le Menn, 1985). Broader syntheses (McIntosh & Brett, 1988, et al.) based predominantly on the published literature have not added to the empirical database but have allowed the development of generalizations concerning distributional patterns.

The Silurian–Devonian section from west-central Tennessee is especially important because it is well documented in terms of biostratigraphic zonation (McComb & Broadhead, 1980, 1995; McComb, 1987; Capaccioli, 1987) and in terms of interpretation of sedimentary environment (Gibson, 1988; Broadhead et al., 1989). More recently, the conodont *Icriodus woschmidtii* Ziegler, 1960, typical of the earliest Devonian, has been reported from the uppermost Decatur and Rockhouse Limestone Member (Harris et al., 1995) placing the Silurian–Devonian boundary very near the top of the Decatur. Further work to identify which subspecies are present will serve to better constrain the position of the boundary. Thus, the interpretation of the stratigraphic significance of the diverse echinoderm fauna is greatly facilitated. The following discussion highlights the details of stratigraphic ranges, both in terms of local occurrences and in terms of regional or global significance.

**STRATIGRAPHIC RANGE EXTENSIONS**

The Decatur and Ross formations have an abundant and diverse echinoderm fauna, which includes 16 genera and 24 species previously reported and 22 genera and 45 species newly reported herein (see also Clement & Broadhead, 1994). Of the echinoderm taxa reported herein, 15 genera and 19 species have been reported previously from rocks of either older or younger age. Most of these species are known from lower horizons, thus extending their ranges upward, but a few have been noted previously only from younger strata, extending their ranges downward.

Two species now reported from the Decatur, *Stiptocrinus benedicti* (Miller, 1892) and *Lecanocrinus pusillus* (Hall, 1863), have been reported previously only from Wenlock age rocks, with *S. benedicti* from the Laurel Limestone (Tennessee) and *L. pusillus* from the Waldron Shale (Tennessee, Indiana) and the Racine Dolomite (Wisconsin). However, the largest number (9) of the echinoderm species newly reported from the Decatur and Ross were originally found in the Brownspoint Group (Tennessee), which underlies the Decatur. These include *Lamperocrinus tennesseensis* Roemer, 1860, *Macrostylocrinus laevis* Springer, 1926, *M. pustulosus* Springer, 1926, *Marsupiocrinus excavatus* Springer, 1926, *Parapistocrinus sphaericus* (Rowley, 1904), *Thalamocrinus ovatus* Miller & Gurley, 1895, *Amperistocrinus typus* Hall, 1879, *Lecanocrinus pisiformis*, and *L. meniscus*. Of these, three are not known higher than the Decatur (*L. tennesseensis*, *M. excavatus*, *P. sphaericus*); two are in both the Decatur and Ross (*T. ovatus*, *L. pisiformis*); *M. laevis* and *M. pustulosus* are only in the Rockhouse Limestone Member of the Ross; *L. meniscus* is in both the lower Rockhouse Limestone and upper Birdsong Shale (Bryozoan Zone); and *A. typus* is only in the Bryozoan Zone.

*Stiptocrinus nodosus*, which was originally reported from the Decatur (Springer, 1926a), is now known from the lower Rockhouse Limestone and upper Birdsong Shale (Bryozoan Zone). Finally, *Marsupiocrinus* (*Amarsupiocrinus*) *devonicus* n. sp. is the first of its subgenus known from Devonian age rocks.

Several crinoid species in the Decatur–Ross interval were previously known only in earlier strata outside Tennessee. Two species, *Crinobrachiatus* sp. and *Thalamocrinus robustus* McIntosh & Brett, 1988, were previously known only in the Rochester Shale (Wenlock) of New York and Ontario. Both species are now known to occur in the lower Rockhouse and *Crinobrachiatus* sp. occurs in the upper Birdsong (Bryozoan Zone) as well. *Hexacrinites carinatus* Strimple, 1963, which was known from the Henryhouse Formation (Ludlow–Pridolian) of Oklahoma, is in the Decatur and lower Rockhouse. *Probolocrinus dignis* (Strimple, 1963) n. comb., another
Henryhouse species, is now also known from the Decatur and upper Birdsong (Bryozoan Zone).

Finally, there are two forms that have been reported previously only from younger strata. *Edriocrinus pyriformis* Hall, 1862, is known from the early Middle Devonian (Eifelian) Onondaga Limestone of New York. The occurrence of this form in the Ross Formation extends its range downward into the Lochkovian. The occurrence of *Kallimorphocrinus* sp. in the Birdsong extends the range of this genus downward from the Mississippian. Ranges for previously described taxa were taken from Bassler & Moodie (1943), Webster (1973, 1977, 1986, 1988, 1993), and primary literature.

### Ranges of Echinoderm Species Within the Decatur and Ross Formations

Within the Decatur–Ross interval, several interesting trends exist in the occurrence of echinoderms. Each unit recognized in this study is characterized by an assemblage of echinoderm species, some of which are restricted to that unit, others also occurring above and below (Clement & Broadhead, 1994; Tables 1, 2 herein). The Decatur Limestone has a fauna of 28 species (17 genera), of which 19 (belonging to 12 genera) occur only within this unit. All species of *Eucalyptocrinites* in this study were confined to the Decatur. Despite their apparent adaptability to muddy substrata (*e.g.*, Waldron Shale), no specimens of *Eucalyptocrinites* have been found in the Ross, not even in the upper Birdsong (Bryozoan Zone), which represents a waning of the mud influx that characterizes the Ross. This suggests local extinction of the genus very near the Silurian–Devonian boundary in west-central Tennessee, although *Eucalyptocrinites* continued to survive in central Europe into the Middle Devonian. Species of the family *Pisocrinidae* have a similar pattern. Also occurring no higher than the lower Rockhouse is the rhombiferan *Tyridoecystis chelyon* is known only from this zone. Remains of *Kallimorphocrinus* sp., *Gyrocystis* sp., myelodactylid sp., *Eohalysiocrinus* broweri n. sp., *Sievertsia sp.*, and echinoid sp. *Scyphocrinites stellatus* was found in place in the lowermost Birdsong at MQ, the highest occurrence of a specimen of *Scyphocrinites* noted in this study. No scyphocrinitid is known in the Bryozoan Zone of the Birdsong, although it is lithologically and faunally similar to the lower Rockhouse, which is replete with *Scyphocrinites* remains.

The Brachiopod Zone of the Birdsong Shale contains a sparse but taxonomically diverse (9 species, 9 genera) assemblage of echinoderms. The crinoid *Edriocrinus adnascens* occurs commonly in this zone but is not known higher. The single specimen of *Eoelodactocrinus blabei* n. sp. was collected from this zone, and the rhombiferan *Tyridoecystis chelyon* is known only from this zone. Remains of *Kallimorphocrinus* sp., *Decaschisma lense*, *Theoreus americanus*, myelodactylid sp., *Eohalysiocrinus broweri* n. sp., *Sievertsia sp.*, *Eodevonocystis marilymnii* n. sp., and echinoid plates and spines occur in washings from this zone and are also in the overlying Bryozoan Zone. A single plate of what might be *Probolarocrinus dignis* was isolated from washings from this zone. Finally, isolated plates of *Pygnaecrinus* sp. are in washings from the uppermost shale bed of the Brachiopod Zone, this being the first report of this genus from North America.

The Bryozoan Zone of the Birdsong Shale contains a diverse assemblage of 21 echinoderm species (18 genera). One of these, *Probolarocrinus dignis* was in both the Decatur and Bryozoan Zone but not in between, with the exception of one fragmentary plate possibly referable to this species. *Stiopocrinus nidosus* and *Thalamocrinus ovatus* are in the Decatur and lower Rockhouse as well as the Bryozoan Zone. *Lecanocrinus meniscus* and *Thalamocrinus elongatus* are known from the lower Rockhouse and the Bryozoan Zone. These species are not in the more shaly parts of the Ross and were presumably prevented from successfully colonizing west-central Tennessee during much of Ross time by the episodic influxes of terrigenous mud.

Four species, *Theoreus americanus*, *Eohalysiocrinus broweri* n. sp., myelodactylid sp., and echinoid remains occur throughout the Ross. *Crinobrachiatus* sp., which is in the lower Rockhouse and Bryozoan Zone, is only rarely encountered in the intervening shales. Three species first appear in the upper Rockhouse to lowermost Birdsong interval: *Eohalysiocrinus gibsoni* n. sp., *Kallimorphocrinus* sp., and *Sievertsia sp.*
Sievertsia sp. is nearly ubiquitous above the lower Rockhouse, whereas E. gibsoni n. sp. and Kallimorphocrinus sp. are rare. Decaschisma lona first occurs in the Brachiopod Zone but is only common in the Bryozoan Zone. Eodevonocystis marilynni n. sp. has a similar pattern.

Finally, six echinoderm species first appear in the Bryozoan Zone of the Birdsong Shale: Dimerocrinites (Dimerocrinites) cheilobathron n. sp., D. sp. A, Dolatocrinus helderbergensis, Marsupiocrinus (Amarsupiocrinus) devonicus n. sp., Ampheristocrinus typus, and Eohydroblastus inexpectatus n. sp. Dolatocrinus helderbergensis is notable in being the earliest dolatocrinid known and is relatively common in this zone. Members of this genus are not seen again until Elfelian time (Onondaga and Jeffersonville limestones, New York and Ohio–Kentucky), raising questions as to where this genus first appeared. Members of this genus are not seen again until Elfelian time (Onondaga and Jeffersonville limestones, New York and Ohio–Kentucky), raising questions as to where this genus first appeared. Members of this genus are not seen again until Elfelian time (Onondaga and Jeffersonville limestones, New York and Ohio–Kentucky), raising questions as to where this genus first appeared.

The remaining 45 species identified during this study have been noted only in the Decatur–Ross interval, with the exception of Marsupiocrinus tennesensis, a form previously reported from the Decatur with antecedents in the Brownsport Group below. Species previously known from the Decatur Limestone and Ross Formations but not encountered during this study were not discussed above due to lack of stratigraphic data. Eucalyptocrinites occidentalis (Springer, 1926) n. comb., E. sculptilis (Springer, 1926), E. sp. E, and Cremacrinus decaturi all occur in the Decatur Limestone and not, apparently, elsewhere. Scyphocrinites dispansus, Myelodactylus schucherti, Ichthyocrinus devonicus, Edriocrinus expansus, E. explicatus, E. occidentalis, and Gazacrinus stellatus are from undifferentiated Ross Formation.

**CONTRIBUTION OF SHALE WASHINGS**

Although most of the echinoderm species reported in this study were collected during field work, several came to light only after the breakdown of shale samples and examination of the resulting debris (Table 2). These included the cyclocystoid Sievertsia sp. (Pl. 12, Figs 5–7), and the crinoids Pygmaeocrinus sp. (Pl. 8, Figs 4, 8) and Kallimorphocrinus sp. (Pl. 8, Figs 5, 7). Marginal plates of Sievertsia sp. are found to be nearly ubiquitous in samples above the lower Rockhouse Limestone. Kallimorphocrinoid and aidemocrinoid stages of an allageocrinoid, herein referred to Kallimorphocrinus sp., are in the smaller size fractions (60-, 120-mesh sizes). Specimens can be more common than the number of individuals reported because most samples were examined only down to the 25-mesh sieve fraction. Specimens of Pygmaeocrinus sp. (isolated radial and IBr2 plates) occurred in only three samples, which were taken from the uppermost shale bed (1 m thick) at the top of the Brachiopod Zone of the Birdsong Shale.

In addition to the three species undetected by field collecting, several other species that were rare in the field were present in most samples taken for washings, filling in otherwise disjoint occurrences. Eohalysiocrinus broweri n. sp., Theloreus americanus, and myelodactylid sp. proved to be more abundant and widespread than first believed. Echinoid remains occurred sporadically in washings from the lower Rockhouse upward, whereas they were only noted in the Bryozoan Zone of the Birdsong from field collecting. Marginal plates from the anomalocystitid Eodevonocystis marilynni n. sp. were also in the Brachiopod Zone, having only been collected in the uppermost layers of the Bryozoan Zone at PQ. The occurrence of identifiable echinoderm remains, such as a common hyperpinnulate brachial plate (Pl. 8, Fig. 11), in washings points out the necessity of this type of collecting in faunal studies. The results of the examination of the washings are summarized in Table 2.

**BIOGEOGRAPHY**

**COMPARISON WITH OTHER AREAS**

There are comparatively few areas that have well-documented echinoderm faunas of Pridolian to Lochkovian age with which to compare the faunas of the Decatur Limestone and Ross Formation (Clement & Broadhead, 1994). The best described faunas from this interval in North America are from the Henryhouse (Ludlovian to Pridolian) and Haragan (Lochkovian) formations of Oklahoma, the Bainbridge (Ludlovian to Pridolian) and Bailey (Lochkovian) formations of Missouri and Illinois, the Keyser Formation (Pridolian to Lochkovian) of Virginia and West Virginia, and the Coeymans and New Scotland formations (Lochkovian) of New York (see Frest et al., 1999, for faunal lists from many of these units). Two European faunas that compare favorably with those in west-central Tennessee are those of the Armorican Massif of France and in the Ludlow–Pridoli interval Bohemian region of the Czech Republic. Comparisons (Table 3) are made at the generic level because (1) there are slight age differences between some of the faunas and (2) there is a strong probability that identical species would not be recognized as such by paleontologists working in North America and Europe. Lower Devonian, especially Lochkovian, faunas are reported to show a high degree of endemism (Witzke et al., 1979; McIntosh & Macurda, 1981). This study suggests that some genera were more cosmopolitan than previously thought.

The Henryhouse Formation (Ludlow–Pridoli) of Oklahoma contains abundant echinoderm remains that were studied by Strimple (1963). Because of its close geographic proximity, it shows the greatest number of common genera.

Strimple (1963) also reported six genera of crinoids from the Haragan Formation (Oklahoma, Lochkovian) of which four (Scyphocrinites, Edriocrinus, Myelodactylus, and Lecanocrinus) also occur in the Ross Formation. Only one species, E. dispansus is present in both formations.

Bassler & Mookey (1943) listed six genera (12 species) from the Bainbridge Formation (Missouri and Illinois, Ludlow–Pridolian) a correlative of the Decatur. Three of those genera also occur in the Decatur or Ross: Thalamocrinus, Lecanocrinus, and Parapisocrinus Mu, 1954. Four species are in common, including Thalamocrinus ovatus, Lecanocrinus pisiformis, Parapisocrinus sphaericus, and P. tennesseensis Roemer, 1860. The Bailey Formation (Missouri and Illinois, Lochkovian) which correlates in part with the Ross, also contains six described genera (seven species) (Bassler & Mookey, 1943), three of which are also in the Ross: Lecanocrinus, Edriocrinus, and Scyphocrinites. Only one species, S. elegans, also occurs in Tennessee, in the upper Decatur.

The Coeymans Limestone (New York, earliest Lochkovian) contains eight genera (Bassler & Mookey, 1943), three of which occur in the Decatur and Ross: Eudimerocrinus Springer, 1926, Myelodactylus, and Scyphocrinites. One species, S. stellatus, is common to all three units. The New Scotland Formation (New York), also of Lochkovian age, contains seven described genera (Bassler & Mookey, 1943), of which four occur in the Decatur or Ross: Lecanocrinus, Edriocrinus, Myelodactylus, and Scyphocrinites. One New Scotland species, E. pocilliformis, was reported from the Ross Formation (Dunbar, 1919), but assignment of specimens from the Ross to this species is probably incorrect (see discussion under Edriocrinus).

The Keyser Formation (Pridolian–Lochkovian; New York, West Virginia) contains numerous echinoderms, including many rhombiferans. However, of the 15 genera listed by Bassler & Mookey (1943) and Springer (1917), only Myelodactylus and Scyphocrinites occur in the Decatur or Ross. Scyphocrinites stellatus is the only species in both the Keyser and the Decatur–Ross interval.

As noted previously, there are two well-described European faunas that can be compared to those in the Decatur and Ross Formations of west-central Tennessee. Although no common species have been confirmed, the congeneric similarity is striking. The Armorican Massif region in France contains fossiliferous Lower Devonian strata (Lochkovian to Pragian) from which numerous crinoids have been reported (Le Menn, 1985, 1987). Le Menn (1985, 1987) described 22 genera of crinoids of Geddinian to Siegenian (Lochkovian to Pragian) which four (Scyphocrinites, Edriocrinus, Myelodactylus, and Lecanocrinus) also occur in the Ross Formation. Only one species, E. dispansus is present in both formations.
the Bohemian region of the Czech Republic is even more striking. Prokop (1962, 1980, 1987), Breimer et al. (1968), and Macurda (1983) reported numerous echinoderms from Pridoli through Pragian strata of Bohemia, and of the 29 genera of echinoderms in those rocks, 13 co-occur in the Decatur or Ross formations of west-central Tennessee. These include ten genera of crinoids (Eucalyptocrinites, Scyphocrinites, Eohalysiocrinus, Parapisocrinus, Pygmaeocrinus Bouska, 1947, Theloreus, Ichthyocrinus, Lecanocrinus, Edriocrinus, Hexacrinites), two genera of blastoids (Polydeltoideus, Decaschisma Fay, 1961),

<table>
<thead>
<tr>
<th>GENUS</th>
<th>OKLAHOMA</th>
<th>MISSOURI</th>
<th>NEW YORK</th>
<th>MARYLAND</th>
<th>BOHEMIA</th>
<th>ARMORIA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CRINOIDEA</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Camerata</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>“Siphonocrinus”</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elpidocrinus</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eudimerocrinus</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dimerocrinites</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lamptercrinus</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gazacrinus</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stiptocrinus</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Hexacrinites</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Scyphocrinites</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Eohalysiocrinus</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pisocrinus</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Myelodactylus</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pygmaeocrinus</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td><strong>Disparida</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Theloreus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Eohalysiocrinus</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pisocrinus</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Myelodactylus</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pygmaeocrinus</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cladida</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thalamocrinus</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Flexibilia</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lecanocrinus</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Ichthyocrinus</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Edriocrinus</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>BLASTOIDEA</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decaschisma</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Polydeltoideus</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td><strong>EDRIOASTEROIDEA</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pyrgocystis</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td><strong>CYCLOCYSTOIDEA</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sievertsa</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
and one genus of cyclocystoid (*Sievertsia* (Prokop, 1962, 1987; Breimer et al., 1968). In addition, *Ramacrinus brevis* Le Menn & Prokop, 1980, which occurs in the Bohemian section, is a species that closely resembles *Theloreus americanus* of Tennessee; these two species are almost certainly congeneric. The number of co-occurring genera suggests strong faunal ties between Bohemia and Tennessee.

It is probable that some oceanic connection existed between these European and Tennessee echinoderm communities during late Silurian to early Devonian times. Both Armorica and Bohemia (Perunica) were relatively small peri-Gondwana terranes during the late Silurian–early Devonian (Scotese & McKerrow, 1990; Woodcock, 2000). Reconstructions by Barrett (1985) (Text-fig. 3) and Morzadec et al. (1989) (Text-fig. 3C) indicate a connection between these regions and eastern Laurentia. The number of genera shared between Bohemia and Tennessee is close to the number of shared genera between the Henryhouse Formation (Oklahoma) and the Decatur and Ross. However, many of the genera in Lochkovian age rocks in Tennessee are not present in Bohemia until the Pragian, which suggests a west-to-east migration route as opposed to the east-to-west route that Witzke (1977) proposed for the migration of *Scyphocrinites*. The former interpretation was also supported by Stukalina (1977), who indicated only Early Devonian occurrences of *S. stellatus-mutabilis* in Europe but Late Silurian occurrences (such as those in Tennessee) elsewhere. The oceanic currents, as reconstructed by Barrett (1985) (Text-fig. 3B), support this alternative view. This difference might, however, reflect conditions in those European regions during Lochkovian times that were not favorable for abundant and diverse echinoderm assemblages.

**Geographic Range Extensions**

Eleven echinoderms reported occur elsewhere in Pridolian to Pragian (Siegenian) age strata. Four species have been previously reported from the Henryhouse Formation of Oklahoma, including *Probolocrinus dignis*, *Hexacrinites carinatus*, *H. adaenisi*, and *Polydeltoideus enodatus* (see Strimple, 1963; Breimer & Macurda, 1972). *Polydeltoideus enodatus* and *H. adaenisi* only occur in the Decatur, *H. carinatus* occurs in the Decatur and lower Rockhouse, and *P. dignis* occurs in the Decatur and upper Birdsong (Bryozoan Zone).

*Scyphocrinites elegans*, a scyphocrinitid common in Pridolian through lower Lochkovian strata of Bohemia, is also present in the Bailey Limestone (Lochkovian) of Missouri and has now been noted from the Decatur Limestone (Pridolian) (Pl. 3, Fig. 1). The genus *Scyphocrinites* occurs almost worldwide during the latest Silurian–earliest Devonian (Haude, 1972). The genus *Eobalysioocrinus*, noted from Wenlock rocks of New York (Brett, 1981) and Pragian to Eifelian rocks of Bohemia (Prokop, 1987), is recorded for the first time from the Lochkovian rocks (Ross Formation) of Tennessee. *Theloreus*, a characteristic Armorican genus (Geddinan to Siegenian; Le Menn, 1985), is noted for the first time in North America with the re-assignment of *Phimocrinus americanus* Springer, 1923, to that genus. *Theloreus americanus* is very similar to *Ramacrinus brevis* and these species are almost certainly congeneric. *Pygmaeocrinus*, until now known only from Lower Devonian rocks of Bohemia (Strimple, 1963; Prokop, 1987), occurs in the upper Birdsong Shale (uppermost Brachiopod Zone) of Lochkovian age. Specimens belonging to the cyclocystoid genus *Sievertsia* occur throughout the upper Rockhouse Limestone to upper Birdsong Shale (Bryozoan Zone) interval and represent the first reported occurrence of cyclocystoid remains from Lochkovian age rocks. The occurrence of *Pyrgocystis* sp. marks the first report of a member of this genus from west-central Tennessee.

As noted in the biostratigraphy section, the forms *Thalamocrinus robustus* and *Crinobrachiatus* sp. have been previously reported only from the Rochester Shale (Wenlock) of western New York State and southern Ontario. Specimens referred to these forms occur in the lower Rockhouse, extending their geographic range as well as stratigraphically. Similarly, specimens referred to *Edriocrinus pyriformis*, a species known from New York (Eifelian, Onondaga Limestone), are in the Ross. Finally, *Elpidocrinus tholiformis*, a species previously reported only from the Henryhouse Formation of Oklahoma, is herein noted for the first time in Tennessee. However, the specimen that Strimple (1963) referred to *Abathocrinus rotundus* (Springer, 1826) is an aberrant *Elpidocrinus* (Broadhead, 1988b) and could belong to *E. tholiformis* (see discussion under *Elpidocrinus*).

**TAPHONOMY**

Taphonomy, the study of the processes affecting the remains of an organism between the time of its death and its discovery as a fossil, has become a major topic of concern for modern paleontologists because it is these processes that determine the final preservational form of a fossil (Fagerstrom, 1964; Lawrence, 1968; Seilacher, 1973; Behrensmeyer & Kidwell, 1985; Kidwell & Baumlle, 1990; Brett & Baird, 1986; Brandt, 1989; Allison, 1988, 1990; Martin, 1999). Biostratinomy, the part of taphonomy that includes the processes occurring between the death and final burial of an organism, is the focus of this discussion. Necrolysis, the processes associated with the decay of the soft tissues, is considered only briefly. Fossil diagenesis, the processes between final burial and discovery by a paleontologist, is not considered here. For a more complete general discussion of taphonomy, see Lawrence (1968), Behrensmeyer & Kidwell (1985), Thomas (1986), Brett &

The kinds of preservation of echinoderms in the Decatur and Ross formations depended on two principal factors: (1) original cohesiveness of the skeleton, which includes interlocking skeletal articulations and the amount and type of connective tissues, and (2) length of exposure before final burial. Although it is commonly difficult to separate the effects of these two processes, some generalizations can be made. Following death, the skeletal elements of the arms usually disarticulated first, followed by the thecal plates, and then (for stalked forms) the stem. The rate of disarticulation was dependent on the kind of connective tissue (muscle or ligament) and kind of articulation (e.g., syzygy) between plates (see Lewis, 1980; Brett & Baird, 1986; Brett, 1995; Thomas, 1986; Ausich, 1993; Ausich & Baumiller, 1998; Ausich et al., 1999; Gahn & Baumiller, 2004; Thomka, 2010; Thomka et al., 2011, 2012, for detailed discussion of echinoderm taphonomy). For example, the arms, being movable, were less tightly bound together, resulting in easier disarticulation compared to thecal plates (Meyer et al., 1989; Brett et al., 1997). The resistance of the various parts of the skeleton to disarticulation was taxon dependent. For example, most blastoids are preserved as whole, uncrushed thecae, which lack stems and brachioles. This suggests a high degree of thecal cohesiveness with low cohesiveness for the stem and brachioles, with the result that the thecae were preferentially preserved. The cyclocystoids, in contrast, are known only from discrete plates, which suggests that their plates were only loosely joined with connective tissue and disarticulated rapidly after death.

Among the crinoids, this resistance to disarticulation varied between different species within a genus (cf. Meyer et al., 1989; Brett et al., 1997; Thomka et al., 2011). For example, the cups of species of Lecanocrinus were more resistant than other parts of the skeleton to the processes leading to disarticulation. Lecanocrinus meniscus, however, is known mostly from crowns (5 of 6 specimens; e.g., Pl. 10, Figs 1, 2–3, 5), and it is likely that the tightly appressed arms of this species allowed greater preservation potential of the upper crown (Pl. 10, Fig. 2). Lecanocrinus pisiformis, on the other hand, is known mostly from cups (33 of 38 specimens; e.g., Pl. 9, Figs 7, 10) suggesting that the connective tissue between the ossicles composing the free arms and attaching them to the cup was not as resistant to decay as that of L. meniscus.

Resistance to disarticulation also could vary within parts of the same structure (i.e., theca). The aboral cup (infracasals, basals, and radials) can be relatively thick, with the remainder of the plates becoming very thin distally. This morphology would make the base of the cup more easily preserved than the more distal parts, and many of the specimens of Probalocrinus dignis are composed primarily of the aboral cup with a small number of more distal plates (Pl. 1, Figs 3, 6).

Length of exposure is the other major factor governing the kind of preservation in the echinoderms of the Decatur and Ross formations (cf. Brett & Seilacher, 1991; Brett et al., 1997; Thomka, 2010). The amount of comminuted debris in the Decatur and Ross indicates that most echinoderms were exposed for periods of time long enough to allow complete or nearly complete disarticulation. With the exceptions of a few forms identifiable from single plates (e.g., the cyclocystoid Sievertsia, Pl. 12, Figs 5–7; plates of the camerate crinoid Dolatoicrinus), only final burial of articulated portions of individuals allowed for preservation of identifiable specimens. Articulated specimens are sufficiently abundant to give a general idea of the diversity of the original echinoderm fauna. However, constructional differences, which affected the likelihood for preservation of articulated remains, are as yet not sufficiently well understood to allow interpretation of original relative abundances.

The few experimental biostratinomic (actualistic) studies that have been done on some modern crinoids (comatulids) demonstrate the rapid onset of disarticulation within one day and almost complete disarticulation within a few days after death (Mayer, 1971; Liddell, 1975; Meyer & Mayer, 1988; Kidwell & Baumiller, 1990; Brett et al., 1997). However, the plate articulations in comatulids are much more muscular than those interpreted for the Paleozoic subclasses (see Breimer, 1978; Ubaghs, 1978b; Ausich, 1993; Ausich & Baumiller, 1998). This difference indicates that comatulids (and probably most other articulates) disarticulate more readily than did most members of the Paleozoic subclasses. The much poorer fossil record of the articulates compared with that of the extinct subclasses also strongly suggests that this is the case.

Most of the crinoid specimens collected during the course of this study are isolated aboral cups. This is true of both the Decatur and Ross and suggests sedimentation and current regimes in which most individuals were exposed long enough to allow disarticulation and separation of arm and stem ossicles. Brett & Baird (1986) and Brett et al. (1997) suggested a time span of weeks to months for this level of disarticulation. Many crinoids buried during storm events undoubtedly were exhumed later by scour, which further advanced disarticulation. Parsons et al. (1989) indicated that exhumation (by scour or other physical process) of previously buried remains was common in shell beds in the Middle Devonian of New York (see also Brett & Baird, 1993; Brett & Allison, 1998). However, “scour burial” is also an effective mechanism for the rapid (few hours) burial of large objects, and might have been important in the burial of completely or partly articulated crinoids (K. R. Walker, pers. comm., 1989).
The rare specimens preserving arms and stem (e. g., *Stiptocrinus nodosus*, Pl. 3, Fig. 8) in the Decatur and Ross formations are thought to have been buried alive by sediments mobilized or deposited during or after storms. This is in accordance with the criteria given by Lewis (1980: 32) for the preservation of whole skeletons: “burial must take place before death or shortly after death…” Lewis (1980: 32) also stated that: ”Storms seem to have been the single most important agent for the preservation of complete echinoderms in shallow shelf environments.” Some specimens of *Lecanocrinus meniscus* (Pl. 10, Fig. 1) exhibit no evidence of disarticulation; the arms are still intact (these parts presumably disarticulated first, having moveable articulations). Such specimens could have been preserved only by burial while still alive or very shortly after death (presumably a few hours) and before significant decay had taken place (Brett & Seilacher, 1991; Brett *et al.*, 1997, 2012; Taylor & Brett, 1998; Thomka, 2010).

Many Paleozoic crinoids did not disarticulate after death as readily as the modern comatulids, as studied by Liddell (1975) and Meyer (1971). Calyces of some camerates apparently sat exposed on the sea floor for as yet undetermined lengths of time (weeks?, months?) during which they were used as substrata by epibiontic organisms. Studies of *Eucalyptocrinites* from the Waldron Shale ( Wenlock) of Indiana and Tennessee (Liddell & Brett, 1982) indicate that cups of this genus were important as islands of hard substrata for epibions, including bryozoans, worms, and holdfasts for other crinoids. Brett & Baird (1986) and Brett *et al.* (1997) suggested that the cups of *Eucalyptocrinites* could have been exposed on the sea floor for time periods on the order of years, as evidenced by the epibions.

The calyces of some of the camerates (particularly those from the Ross Formation), especially *Scyphocrinites* spp., were used as hard substrata by epibiontic organisms (especially bryozoans and spirorbid worms) similar to those on the Waldron *Eucalyptocrinites* as well as those on contemporaneous brachiopods (Gibson, 1992). The calyx of one specimen of *S. stellatus* (Pl. 4, Figs 3, 5–6) has encrusting bryozoans on portions of both the inside and outside calyx surfaces. The position of the bryozoans indicates that the uncruched calyx lay on its side, partially embedded in the mud of the sea floor (Text-fig. 9A), with the exposed portions available for colonization. This calyx was ultimately filled with and covered by terrigenous mud, but not until bryozoan colonies had covered several square centimeters of calyx surface.

The time during which epibiontic larvae could colonize an intact crinoid calyx would have depended primarily on the resistance to decay of the organic fibers connecting adjacent plates (Lewis, 1980; Kidwell & Baumiller, 1990; Ausich, 1993; Ausich & Baumiller, 1998) and the degree to which the skeletal material of adjacent plates interlocked (Thomas W. Broadhead, pers. comm., 1989). Length of time of exposure can be estimated by the degree of colonization of the exposed surface; a more completely covered surface was exposed longer than a less-covered one (Liddell & Brett, 1982; Brett *et al.*, 1997). However, percent coverage depends on the rapidity of growth of the epibions, and availability of larvae, which could have been seasonal. These factors are unknown; therefore, no estimates for the time required for a given amount of encrustation can be given.

Most of the crinoid (mostly camerate) calyces that have epibions are from the Ross Formation, with only a few from the Decatur Limestone. None of the crinoid calyces in this study that were colonized by epibions were completely covered by them, and most had only a few small colonies (e. g., Pl. 1, Figs 9–10), suggesting relatively short periods of exposure before final burial.

There are some isolated problems in understanding the biostratigraphic processes prevalent at the time of Decatur and Ross deposition. A small number of specimens collected from the Ross Formation represent *in situ* disarticulation with little scattering of the ossicles (Pl. 3, Fig. 2; Pl. 9, Figs 8, 12). It is difficult to understand why the ossicles of these specimens were not scattered by the biologic and physical processes that undoubtedly existed at the time and produced the abundant discrete ossicles present in most beds. Even gentle currents would have scattered the separated ossicles, especially any current bringing in the sediment that buried the remains. The lack of scattering also strongly suggests the local absence of large scavengers and deposit feeders (e. g., trilobites, gastropods, polychaetes). Why these groups, which would have scavenged the remains of crinoids and are known to occur in the Ross, did not do so in these cases is an unanswered question. These disarticulated specimens are probably underrepresented in the collections made thus far from the Ross because they are difficult to recognize in the field and are easily overlooked.

**Decatur Limestone**

As described previously, identifiable echinoderm remains in the Decatur Limestone are mostly confined to the coarse-grained layers. These layers probably represent skeletal debris that moved during storms, burying both articulated remains and living echinoderms (*cf.* Type I A or Burlington-type abrasion deposits of Brett & Seilacher, 1991; Brett *et al.* 1997). These layers lack the abundant *in situ* holdfasts present in the fine-grained layers, which most likely were the result of fairweather wave and current action and represent times of echinoderm colonization. Both the fine- and coarse-grained layers in the Decatur are traceable for long distances. The processes that formed these beds were widespread over much of the shelf on which the sediments of the Decatur were deposited. For example, the upper coarse-grained layer in Q13, the
The majority of crinoid specimens in the Decatur are calyces (e.g., Pl. 1, Fig. 2; Pl. 2, Fig. 12), that typically lack arms and stem. Burial, exhumation, and reburial by scour might account for this type of preservation, although abrasion was not noted on the crinoid cups, suggesting little transport (cf. Meyer et al., 1989; Brett et al., 1997). Crossbeds, which indicate sediment movement, are known from the Decatur Limestone (C. Clement, pers. obs.), and McComb (1987) recognized storm beds (e.g., graded beds) in this unit. Sediment movement resulting from such storms would likely bury any echinoderm lying on the sea floor.

The type of preservation in the Decatur, with a great deal of disarticulated debris, relatively few articulated calyces, and rare, well-preserved individuals, is typical of crinoidal sand banks, as noted in the Gasport Limestone (Wenlock) of western New York State and the Coeymans Limestone (Lochkovian) of eastern New York (see discussion by Brett, 1999; Frest et al., 1999).

**Lower Rockhouse Limestone**

The lower Rockhouse Limestone contains thin- to medium-bedded limestone beds alternating with thin shale beds; the depositional environment of these beds has been studied in detail by Gibson (1995a, b). Several partially disarticulated crinoidal calyces were noted from the lower Rockhouse at BQ. The preserved parts of the calyces were found on the lower surfaces of limestone beds, embedded in an underlying shale layer (e.g., Pl. 6, Figs 1–2). Those parts of the cups not embedded in the shale are not preserved intact and either collapsed into the thecal cavity or the plates were scattered over the sea floor (Text-fig. 9B) by current activity. This process left only edges of the cup exposed on the sea floor (now embedded in the limestone). The calyces are filled with a mixture of terrigenous mud and skeletal debris. This mode of preservation is similar to that reported by Brett & Baird (1986) and Brett et al. (1997) for specimens of Eucalyptocrinites from the Waldron Shale in which the buried side was much better preserved than the exposed side.

There are two possible scenarios to explain this mode of preservation. The crinoids might have lived on the sea floor (represented by the mud), died, were partially buried in the mud, exposed parts disarticulated, and the remaining parts were finally buried by skeletal debris (storm or in situ slow accumulation). On the other hand, the cups could have been transported with skeletal debris during a storm, deposited on the mud substratum, allowing disarticulation of the exposed parts, and finally buried by more skeletal debris (another storm or slow autochthonous accumulation). The former scenario is preferred, but it is not possible to distinguish which is correct with the present data.

At PQ and RCB, isolated specimens of Lecanocrinus meniscus preserving arms and proximal stem (e.g., Pl. 10, Fig. 2) were collected from the lower Rockhouse. Another, similar, specimen (Pl. 10, Fig. 1) of L. meniscus found at PQ is probably also from this horizon. These specimens were found in skeletal grainstones, and their preservation strongly suggests that they were buried alive by sediment, probably deposited during a storm.

At AM, the lowest Rockhouse contains numerous Lecanocrinus pisiformis, most of which are preserved as cups, and a few exhibit evidence of in situ disarticulation. One specimen is preserved with arms and proximal stem (Pl. 9, Fig. 12), but the arms are completely disarticulated, lying in a mass at the distal end of the cup. This crinoid must have lain on the sea floor for some time (unfortunately, there is little on which to base estimates of absolute time for rates of disarticulation for the extinct subclasses of crinoids) before burial, allowing it to disarticulate. The lack of scattering of the brachial plates indicates that the crinoid must have been buried by slow accumulation of sediment under conditions lacking significant water movement, scavenging, or bioturbation [cf. taphofacies ID of Brett et al. (1997), which was interpreted by them as reflecting deeper, low energy, but still somewhat storm-influenced, carbonate-shelf taphonomic settings]. This suggests a local environment inhospitable to most organisms, perhaps one arising in the aftermath of a storm event.

**Upper Rockhouse/Lower Birdsong**

The upper Rockhouse Limestone and lowermost Birdsong Shale are difficult to distinguish when dealing with blocks on quarry spoil piles and are thus treated as one unit. They are composed of medium- to thin-bedded limestone with interbeds of shale of similar thickness. This unit contains relatively few identifiable echinoderm remains, the most abundant being specimens of Scyphocrinites spp. At BQ, a nearly complete, although distorted, crown of Lecanocrinus meniscus (Pl. 10, Fig. 4) was in a block from this unit, along with several calyces of S. stellatus (e.g., Pl. 4, Fig. 2). This occurrence suggests that specimens of Scyphocrinites lost their free arms rapidly after death, whereas the crowns of flexibles with tightly appressed arms, such as L. meniscus, were more resistant to disarticulation after death (see also Thomka et al., 2011). Also, numerous, disarticulated marginal ossicles of the cyclocystoid Sievertsia sp. (Pl. 12, Figs 5–7) occur in washings from this and overlying units. No articulated specimens of this cyclocystoid have been found, strongly suggesting that they disarticulated rapidly after death. Similar occurrences of Sievertsia plates are reported from washings from numerous beds in the...
Silurian of North America, such as the Osgood and Waldron Shales (Frest et al., 1999).

Although influxes of terrigenous mud increased during the deposition of this unit, the lack of abundant, identifiable, echinoderm remains suggests that either the rate of deposition was not sufficient to bury the echinoderms before most had disarticulated or subsequent exhumation of previously buried remains, presumably by storms, resulted in few articulated echinoderm remains being preserved.

**BRACHIOPOD ZONE OF THE BIRDSONG SHALE**

The Brachiopod Zone of the Birdsong Shale, which contains the greatest percentage of terrigenous mud of any unit of the Ross Formation, is the zone between the lowest meter of the Birdsong and the overlying Bryozoan Zone. This zone is composed of thick shale beds interbedded with thinner limestone beds, and echinoderm remains are primarily isolated ossicles. Identifiable, articulated remains are rare, and only one crinoid (Dimerocrinites?, BQ, unfigured) that retained the arms was recovered in this unit. This specimen retains the proximal stem, but the calyx is poorly preserved and incomplete, precluding identification; the arms are nearly completely disarticulated. Gibson (1988) reported numerous, graded, limestone-shale couplets in this unit and the succeeding "Bryozoan Zone," which he recognized as storm-produced layers (tempestites). Storm events, which buried the communities that existed during deposition of this unit, must have been infrequent enough to allow complete or nearly complete disarticulation of the echinoderms present. Alternatively, rates of sediment influx were low enough that previously buried echinoderms were exhumed during subsequent storms, and their ossicles scattered. Evidence of bioturbation (burrows, swirled textures; see Gibson, 1988, 1995a, b) suggests that disarticulation and scattering of the ossicles was furthered through biologic means. The recognizable echinoderm remains from this zone were primarily in the shale beds. Gibson (1988: 119) interpreted these shale beds as the "normal" sediment of the Birdsong Shale. He interpreted the fining-upward limestone units as representing deposits winnowed by storm activity (Gibson, 1988: 110).

**BRYOZOAN ZONE OF THE BIRDSONG SHALE**

The Bryozoan Zone is the bryozoan-rich interval (4.5 m) at the top of the Birdsong Shale, which consists of thin limestone beds with thin shale interbeds. Echinoderms from this unit exhibit a wide range of preservational styles. The rocks composing the Bryozoan Zone are, like the rest of the entire Decatur–Ross interval, replete with disarticulated echinoderm ossicles. However, echinoderm thecae are abundant, relative to the rest of the Birdsong. Also, in the middle of this zone at BQ, beds containing complete or nearly complete crinoids are present, including Lecanocrinus meniscus (Pl. 10, Figs 3, 6), Stiportocrinus nodosus (Pl. 2, Fig. 9; Pl. 3, Fig. 8), and Thalamocrinus elongatus (Pl. 9, Fig. 2). These latter beds, which are ripple cross stratified, are almost certainly the result of a storm event, which buried living or recently deceased crinoids. In contrast, specimens of crinoids (e. g., S. nodosus, Pl. 3, Fig. 2) at BQ, completely disarticulated in situ, indicating no appreciable current or wave activity or bioturbation, any of which would have scattered the ossicles. Th e circumstances under which such disarticulated but unscattered remains are preserved are obscure but certainly include quiet water conditions, lack of large scavenging or bioturbating organisms, and perhaps slow burial by mud.

The majority of echinoderm specimens in this unit are calyces or parts of calyces that lay on the sea floor long enough to allow disarticulation of the arms and stalks. Most of the camerate calyces found in this zone have at least some epi- bions attached, indicating exposure at the sediment surface. It seems likely that the sea floor during this time was stirred up and buried only infrequently by passing storms, allowing disarticulation of most echinoderms, but burying and, thus, preserving a few nearly complete individuals.

Following on the work of Speyer & Brett (1988) and Meyer et al. (1989), Brett et al. (1997) developed a model of general echinoderm taphofacies for epeiric seas, in which they used differing levels of four variables (disarticulation, reorientation/sorting, fragmentation, and corrosion) to segregate seven separate facies that in turn reflect amounts of turbulence, sedimentation rate, and oxygen level. Although it is unwise to base paleoenvironmental interpretations on a single group of organisms, some inferences can be made. Th e fossils present in the Decatur/Ross indicate oxygenated conditions, making degree of turbulence and rate of sedimentation the major environmental parameters in relation to this model. Th e environment of the Decatur Limestone most closely approximates carbonate taphofacies IA, "shoal" or "Burlington-type" taphofacies, with high turbulence and low sedimentation rate, as indicated by the high degree of disarticulation, sorting, and fragmentation of the echinoderms. Th e Bryozoan Zone of the Birdsong Shale Member of the Ross Formation exhibits high disarticulation, some reorientation (oriented tentaculitids), low sorting, low fragmentation, and a moderate amount of corrosion, suggesting silicilastic taphofacies IID, storm influenced deeper shelf, or "Waldron-Rochester type." Th e Brachiopod Zone (Birdsong Shale, Ross Formation) with high disarticulation, some reorientation (overturned corals), low sorting, high fragmentation, and low corrosion, is harder to place into a category but is probably taphofacies IIC or IID, as is the upper Rockhouse Limestone/lowest Birdsong Shale (Ross Formation) unit. Th e lower Rockhouse Limestone is more like the Decatur Limestone, with high disarticulation,
high fragmentation, high corrasion, but low sorting, and probably is assignable to taphofacies IC, storm dominated shoal margin/carbonate ramp (Cincinnatian Type).

**SYSTEMATICS**

The order in which the Crinoidea are presented herein is that of the *Treatise on Invertebrate Paleontology*, Echinodermata Part 2(2) (Moore, 1978b). USNM numbers denote specimens from the United States National Museum of Natural History, Washington, DC. All other material assigned PRI numbers in this text is reposited in the collections of Paleontological Research Institution, Ithaca, New York; those specimens lacking PRI numbers are reposited in the collections of the University of Tennessee at Knoxville. All bibliographic indices by Bassler & Moodey (1943), and Webster (1973, 1977, 1986, 1988, 1993, 2003) were used extensively in preparing this section.

**Class CRINOIDEA** Miller, 1821  
**Subclass CAMERATA** Wachsmuth & Springer, 1885

*Diagnosis.*—Crinoids with brachial and interbrachial plates incorporated in cup, dicyclic forms with 5 infrabasal plates.

**Order DIPLOBATHRIDA** Moore & Laudon, 1943

*Diagnosis.*—Dicyclic camerates.

**Superfamily RHODOCRINITOIDEA** Roemer, 1855

*Diagnosis.*—Diplobathrids with radial plates not in lateral contact, or variably separated.

**Family RHODOCRINITIDAE** Roemer, 1855

*Diagnosis.*—Rhodocrinitoideans with interbrachial plates regularly arranged.

**Genus PROBALOCRINUS** n. gen.

*Type species.*—*Siphonocrinus dignis* Strimple, 1963.

*Diagnosis.*—Rhodocrinitid with fixed intertertibrachials, prominent nodes on basal plates, intersecundibrachials (generally) and intertertibrachials in single vertical series.

*Remarks.*—*Probaloecinus dignis*, which was originally attributed to *Siphonocrinus* Miller, 1888, differs from other species of the latter genus in many ways, including having fixed intertertibrachials and not having the calyx asymmetry from the possession of a large anal tube. In addition, *Probaloecinus* n. gen. always has two secundibrachials per half ray whereas *Siphonocrinus* ranges from two and four; all radials are separate, not variably separate as in *Siphonocrinus*; and the tegmen plates of *Probaloecinus* n. gen. are much smaller than those of *Siphonocrinus*. Finally, the anal interarea of *Probaloecinus* n. gen. is differentiated, but not to the extent of *Siphonocrinus*, which has a swollen posterior side, giving members of the genus their characteristic asymmetric shape. Moreover, *Siphonocrinus* tends to be lobate at the cup summit, whereas *Probaloecinus* n. gen. is not. *Acanthocrinus* Roemer, 1850, another closely related genus, differs in having spines on the basals, radials, and tegmen and in having an invaginated base.

*Range.*—Ludlovian (Henryhouse Formation of Oklahoma) to Lochkovian (Birdsong Shale, Ross Formation, west-central Tennessee).

*Etymology of name.*—Probalo (Gr.), any projection, foreland, referring to the nodes on the basals.

*Probaloecinus dignis* (Strimple, 1963) n. comb.  
Pl. 1, Figs 1–3, 6–7, 10; Text-fig. 4

*Siphonocrinus dignis* Strimple, 1963: 73, pl. 3, figs 6–7, text-fig. 20a.

*Diagnosis.*—Same as for genus.

*Description.*—Calyx medium to high, thin-plated, bowl-shaped. Plates smooth; faint ray ridges sometimes present. Infrabasals small, visible from side. Infrabasals and basals relatively thick; remaining calyx plates much thinner. Basals 5, equal, elongate with strong subcentral node. Radials 5, equal. Interadials 2, large, fixed; first primibrachial hexagonal; second primibrachial axillary, pentagonal to heptagonal. Secundibrachials 2, fixed, both hexagonal to heptagonal; second secundibrachial axillary. Tertibrachials 4 or more, fixed. Normal interay plates in 1/2/2–3 plating arrangement; anal interray with 1/3/3/+ pattern. Intersecundibrachials usually in single vertical column 1/1/1/1 or rarely 1/2/1/1; intertertibrachials in single vertical column, number variable. Intersecundibrachials, intertertibrachials, and distal parts of interrays tending to be somewhat depressed. Interbrachial areas connecting with tegmen. Tegmen composed of many, tiny, smooth, polygonal plates. Arms biserial, with some fixed pinnulars at arm bases. Stem and arms beyond proximalmost free brachials unknown.

*Remarks.*—Specimens of *Probaloecinus dignis* have considerable variation in prominence of the basal nodes and development of ray ridges. The nodes range from large, rounded knobs to short spines. Smaller specimens tend to have less...
well-developed nodes. Ray ridges might or might not be present and are rarely prominent in the aboral cup. They are, however, more prominent above the primibrachials. Most known specimens have some abnormalities. Irregularly shaped plates and extra plates are common, particularly in the interrays. The occurrence of *P. dignis* in the latest Silurian (Pridolian) and earliest Devonian (Lochkovian) marks an extension of both stratigraphic and geographic range for this species, which was previously known from the late Silurian (Ludlow, Henryhouse Formation) of Oklahoma (Strimple, 1963).

**Material and Occurrence.**—Three well-preserved cups, three partial cups preserving the proximal part of the cup, one partial cup preserving distal portion of cup and proximal arms and tegmen. Measurements approximate due to crushing and embedding on slabs of specimens. Specimen PRI 53645 cup complete to IIIBr3, embedded in limestone, CD interray exposed, 13 mm high, 15 mm wide; PRI 53646 cup complete to IIIBr4, crushed on shale slab, 48 mm high, 52 mm wide; PRI 53647 cup complete to IIIBr4, crushed on shale slab, with *Dolocrinus hederbergensis*, 43 mm high, 35 mm wide. Specimen PRI 53648 partial cup to IIIBr1; PRI 68231 partial cup to IIIBr1; PRI 53649 partial cup to IIIBr2; PRI 53650 partial cup preserving distal portion of cup, proximal arms and tegmen.

Lower Decatur Limestone, PRI 53645, loc. PVb. Upper Birdsong Shale (Bryozoan Zone), PRI 53646–53649, loc. PQ. Upper Birdsong Shale (Bryozoan Zone), PRI 53650, loc. BQ (Pridoli–Lochkov).

Superfamily **DIMEROCRINITOIDEA** von Zittel, 1879

**Diagnosis.**—Diplobathrids with radial plates adjoining except at CD interray, or variably separated.

**Remarks.**—The diplobathrids have been subdivided on the basis of the separation of the radials, with those crinoids with completely separated radials included within the Rhodocrinitoidea and those with radials adjoining, except on the posterior side, included within the Dimerocrinitoidea. Several genera [*e.g.*, *Lyriocrinus* Hall, 1852, in the Rhodocrinitoidea, *Eudimocrinus* Springer, 1926 (= *Grphocrinus* Kirk, 1945) and *Siphonocrinus* in the Dimerocrinitoidea; Ubaghs, 1978a; Frest & Strimple, 1981a] within both superfamilies have variably separated radials even within a species. This character necessitates a change in the definition of the superfamilies. Frest & Strimple (1981a: 640) believed that the two superfamilies would eventually be synonymized. However, they stopped short of doing so, only stating that, because both taxa were in need of revision, such an action was premature. Witzke & Strimple (1981: 107–108) believed that the Dimerocrinioidea might be polyphyletic. Short of synonymy, the superfamily diagnoses must be modified to consider the variation of radial separation. Because the in-depth investigation of all diplobathrans necessary for synonymy is beyond the scope of this study, this course is taken here. Placement of a particular genus within a superfamily depends on which radial morphology is most prevalent in that genus and in genera that are presumed to be related.

**Family DIMEROCRINITIDAE** von Zittel, 1879

**Diagnosis.**—Dimerocrinitoideans with symmetrical cup, not bulged on posterior side, infrabasals small, visible from side, not confined to basal concavity.

**Genus** **ELPIDOCRINUS** Strimple, 1963

**Synonyms.**—*Abathocrinus* Strimple, 1963; *Pelidocrinus* Frest & Strimple, 1981.

**Type species.**—*E. tholiformis* Strimple, 1963.

**Diagnosis.**—Dimerocrinitid with high, rounded, large-plated tegmen, flat to low, conical cup, 3 ranges of interradials to free arms, and variable separation of radials by interradials.

**Remarks.**—Frest & Strimple (1981) erected the Elpidocrinidae for *Elpidocrinus*, *Cyphocrinus* Miller, 1892, and two new genera, *Pelidocrinus* and *Pidelocrinus*; the family was distinguished from the Dimerocrinidae by cup shape (high conical vs. low conical), interray morphology (depressed or undepressed), and tegmen height. These features are herein considered insufficient for familial segregation, and the Elpidocrinidae is consequently suppressed. The high, rounded, large-plated tegmen and presence of three interradial ranges are the prime distinguishing features of *Elpidocrinus*.

**Pelidocrinus** named by Frest & Strimple (1981), with *E. tholiformis* Strimple, 1963 (Henryhouse Formation, Oklahoma, Ludlow; Frest *et al.*, 1999), as type species, was distinguished from *Elpidocrinus* by calyx outline (pentagonal vs. round), median ray ridges (present vs. absent), and the number of ranges of interradials in each interray (three vs. four). Although the text figures of *E. tholiformis* (Henryhouse Formation, Oklahoma, Ludlow) and *P. exiguus* (Frest & Strimple, 1981: 647, text-figs 3B–C) are drawn with four and three ranges interradials, respectively, their photographs (Frest & Strimple, 1981: pl. 1, figs 1, 3–4, 6, pl. 2, figs 1–3, 5) indicate three ranges up to the free arms in both. This leaves only cup outline and presence of median ray ridges as generic discriminators. Given the variability of these features within the genus, these are judged inadequate for this generic seg-
regation and Pelidocrinus is regarded as a junior synonym of Elpidocrinus.

Pelidocrinus, also erected by Frest and Strimple (1981), has significant differences in the plating of the calyx (two ranges of interradials, elongate first primibrachial) and calyx shape (lobate) and is considered a valid genus. In addition to erecting a new family (Elpidocrinidae, herein suppressed), Frest and Strimple (1981) transferred Elpidocrinus to the Dimerocriinitidae, citing similarities with Cyphocrinus, a genus that had been included in the Dimerocrinitidae. Also, Pidelocrinus has a dimerocrinitoidean radial circlet and has major similarities with E. exigus, from which it presumably arose. These similarities strongly support placement of Elpidocrinus within the Dimerocrinitidae in the Dimerocrinitoide.

Strimple (1963) erected the genus Abathocrinus for Mariacrinus (?). rotundus Springer, 1926 (Decatur Limestone, Tennessee, Pridolian). This crinoid is similar to Elpidocrinus tholiformis except for the aboral cup. It is missing the infrabasal circlet, the basals are confined to a small basal concavity, and the radials are all in contact. As interpreted by Broadhead (1988b), A. rotundus is an aberrant Elpidocrinus, which did not develop the infrabasal circlet and has basals and radials modified to accommodate this loss. Therefore Broadhead (1988b) synonymized Abathocrinus with Elpidocrinus.

Elpidocrinus cf. tholiformis Strimple, 1963
Pl. 1, Fig. 8

Elpidocrinus tholiformis Strimple, 1963: 81, pl. 5, figs 4–7.—Frest & Strimple, 1981: 651, pl. 1, figs 1, 3–4, 6–8.

Diagnosis.—Elpidocrinus with low, conical calyx, circular outline, and smooth, flat plates.

Description.—Calyx low, conical, with smooth plates. Infra-basals 5 (?), small. Basals 5, subequal, slightly smaller than radials, truncated by first interradial. Radials 5, equal, separated by first interradial. First primibrachial hexagonal, primibrachials as large as radial. Secundibrachials 2, fixed. First interradial larger than radial, with 2 plates in second range, as large as first interradial, 3 plates in third range, at level of free arms, as large as basals. CD interray not exposed beyond first primanal. Tegmen approximately as high as cup, with plates as large as proximal interprimibrachials. Free arms and stem not preserved.

Remarks.—Elpidocrinus tholiformis is distinguished by its low, conical calyx, circular outline (oral view), and flat plates. Elpidocrinus tuberosus Strimple, 1963 (Henryhouse Formation, Oklahoma, Ludlow; Frest et al., 1999) has a nearly flat calyx, circular outline, and nodose (or bulbous) plates, whereas E. exigus has a nearly flat calyx, pentagonal outline, flat plates, and weak ray ridges. Both E. tholiformis and E. tuberosus lack ray ridges.

The present specimen differs from published descriptions of Elpidocrinus tholiformis (Strimple, 1963; Frest & Strimple, 1981a) in having a tegmen that is approximately equal in height to the cup. In those descriptions, E. tholiformis has a tegmen that is much higher than the calyx. This difference is not considered to be significant at the species level because tegmen height is prone to taphonomic distortion, therefore the specimen is included within E. tholiformis.

Material and Occurrence.—One partial calyx, PRI 53651, with B and E rays well preserved, C and D rays embedded in matrix, and A ray eroded. Approximately one third of tegmen exposed; 9 mm high, 7 mm wide. From a block of Decatur Limestone, loc. PVa (Pridoli).

Genus EUDIMEROCRINUS Springer, 1926

Synonyms.—Ambicocrinus Kirk, 1945; Griphocrinus Kirk, 1945.

Type species.—Eudimerocrinus multibrachiatus Springer, 1926.

Diagnosis.—Dimerocrinitids with branching biserial arms.

Remarks.—Eudimerocrinus is distinguished from other dimerocrinitids by its branching, biserial arms. Ptychocrinus Wachsmuth & Springer, 1885, and Macarocrinus Jaekel, 1895, have uniserial arms; Pterinocrinus Goldring, 1923, has unbranched arms with compound brachials. Cyphocrinus has a calyx that curves outward and downward at the top, with the arm bases pointing downward (recurved), presumably with recumbent arms. Dimerocrinites Phillips, 1839, has unbranched biserial arms. Kirk (1945) erected the dimerocrinitid genera Ambicocrinus and Griphocrinus, removing Ambicocrinus from Thysanocrinus Hall, 1852, which is a synonym of Dimerocrinites, and Griphocrinus from Rhodocrinites Miller, 1821. Ambicocrinus was distinguished by its thin plates, lack of ray ridges, nondepressed interray areas and sub-stellate column. Griphocrinus was distinguished primarily on its variably separated radials. Considering that some species of Griphocrinus possess ray ridges and depressed interrays [e.g., G. nodulus (Hall, 1862), Hamilton Group, New York, Givetian; G. ovatensis Breimer, 1962, Spain, Eifelian], whereas others lacked both [e.g., G. halli (Lyon, 1862), Beechwood Limestone, Kentucky, Givetian], it does not seem reasonable to use these features as generic discriminators. This leaves column shape and plate thickness as the distinguishing criteria for Ambicocrinus. These characters are herein not considered to be of generic significance. Likewise, variably separated radi-
Remarks.—All three of these genera have branching, biseria1 arms, a character not shared by other dimerocrinitid genera and the feature that unites them. *Ambiococcus* and *Griphocrinus* are, therefore, synonymized with *Eudimerocrinus*, which has priority.

*Eudimerocrinus hlabsei* n. sp.

Pl. 2, Figs 1, 4

Description.—A *Eudimerocrinus* with ornate, extremely nodose calyx plates.

Remarks.—*Eudimerocrinus* *hlabei* n. sp. is distinguished by its extremely nodose plates. All plates have nodes that project outward, and vary from club-shaped to extremely sculptured with sharp ridges and deep depressions. The variable separation of the radials allies this species with forms previously placed within the genus *Griphocrinus*, which is herein synonymized with *Eudimerocrinus* (see above). Although the holotype is preserved only to the level of the second primibrachial, the primibrachial facets suggest the presence of fixed secundibrachials. Also, the facets above the second range of interprimibrachials indicate at least one more range with three plates. The notches above the second primibrachial suggest that the fixed secundibrachials projected outward from the cup. If so, the proximal parts of the arms also probably projected outward.

*Eudimerocrinus* *hlabei* n. sp. most likely evolved from *E. multifibrachatus* (Beech River Formation, Tennessee, Ludlow) by increases in calyx plate nodosity and minor outward bulges of the calyx, which produced a more bowl-shaped calyx. It probably gave rise to the other Lower and Middle Devonian *Eudimerocrinus* (formerly *Griphocrinus*).

Material.—Seven specimens. Holotype, PRI 53654, preserved to the second primibrachial in two rays, infrabasals covered by bryozoan, primanal only in anal interray; 25 mm high, 27 mm wide. Five fragmentary specimens, PRI 53655 and 68240–68243, consist of infrabasals, basals, and radials, ranging 15–20 mm wide, height not determinable.

*Types and Occurrence.*—The holotype, PRI 53654, is from the lower Rockhouse Limestone, loc. AM; specimens PRI 53655 and 68240–68243 are from a single block of Decatur Limestone (probably upper), loc. MQ. A specimen (PRI 68244) consisting of a few articulated plates, possibly referable to this species, is also known from the upper Decatur Limestone, loc. RCh. Isolated plates are known from many Decatur outcrops (Priddoli–Lochkov).

*Etymology of Name.*—Specific name *hlabei* in honor of Marilyn Hlabse (pronounced Lap’see) Clement who helped immensely in this project.

Genus *DIMEROCRINITES* Phillips, 1839

*Type species.*—*Dimerocrinites* (*Dimerocrinites*) *decadactylus* Phillips, 1839.

*Diagnosis.*—*Dimerocrinitid with cone- to bowl-shaped calyx; biserial arms unbranched when free.*

Remarks.—*Dimerocrinitids are distinguished primarily on calyx and arm morphology.* *Dimerocrinites* differs from other dimerocrinitids in having a cone- to bowl-shaped cup and unbranched, biserial arms. *Eudimerocrinus* (herein containing *Ambiococcus* and *Griphocrinus*) has branched, biserial arms, *Macarocrinus* and *Ptychocrinus* have uniserial arms, *Pterinocrinus* has compound brachials, and *Cyphocrinus* has a recurved calyx and prominent spinose tegmen.

Subgenus *DIMEROCRINITES* Phillips, 1839

*Type Species.*—*Dimerocrinites* (*Dimerocrinites*) *decadactylus* Phillips, 1839.

*Diagnosis.*—*Dimerocrinites with 10 arms.*

Remarks.—*Dimerocrinites was divided into two subgenera, D. (*Dimerocrinites*) Phillips, 1839, and D. (*Eucrinus*) Angelin, 1878, by Witzke & Strimple (1981) on the basis of the number of free arms; D. (*Dimerocrinites*) has ten free arms, D. (*Eucrinus*) has 20. Angelin (1878) had originally called *Dimerocrinites* with 20 arms *Eucrinus*. This genus was later synonymized with *Thysanocrinus* (Wachsmuth & Springer, 1897), which, in turn, was synonymized with *Dimerocrinites* (Goldring, 1923).
**Dimerocrinites (Dimerocrinites) cheilobathron** n. sp.

Pl. 1, Fig. 9

*Thysanocrinus inornatus.*—Wachsmuth & Springer, 1897: pl. 18, figs 6A–D, non 193, pl. 19, fig. 5 (= ?Dimerocrinites sp.).

**Diagnosis.**—Dimerocrinites (Dimerocrinites) with a rimmed base, smooth, flat plates, and broad ray ridges; many (5 or more) fixed secundibrachials; numerous intersecundibrachials.

**Description.**—Calyx thin-plated, conical, with smooth plates and flat-bottomed, rimmed base with circular outline (axial view). Ray ridges broad, becoming more prominent distally; interrays depressed. Infrabasals 5, small, equal, barely visible from side. Base flat, rimmed, composed primarily by infrabasals and small part by basals Basals 5, equal, composing approximately one half of aboral cup height. Radials 5, large, equal, with largest plates in cup, wider than high, in narrow contact with adjacent radials, widely separated on posterior side. Primibrachials 2, large; first primibrachial hexagonal; second primibrachial axillary. Fixed secundibrachials 7 (?). Interray areas wide; normal interradials with 1/2/3/2/+ plating pattern, becoming irregular and variable beyond fourth range, open to tegmen. CD antitaxis in 1/3/+ pattern. Intersecundibrachials numerous. Free arms and stem not preserved.

**Remarks.**—Species of *Dimerocrinites* are differentiated on the basis of plate ornamentation, development of ray ridges, shape of the dorsal cup, and number of fixed secundibrachials. The distinguishing features of *D. (D.) cheilobathron* n. sp. are its rimmed base, smooth, thin plates, broad ray ridges, many (seven or more) fixed secundibrachials and numerous intersecundibrachials.

Wachsmuth & Springer (1897: pl. 18, figs 6A–D) illustrated a specimen of *Dimerocrinites* that they assigned to *D. inornatus* (Hall, 1862) (Waldron Shale, Indiana, Ludlow; Frest et al., 1999) and which closely resembles *D. (D.) cheilobathron* n. sp. Their specimen does not, however, fit their description of *D. inornatus*, which is characterized by nodose basals, no basal rim, and stellate ornament. Springer (1926a: pl. 1, figs 11–12) illustrated the normal appearance of *D. inornatus* with its nodose basals. The specimen that Wachsmuth & Springer (1897) illustrated is not *D. inornatus* but is most likely conspecific with *D. (D.) cheilobathron* n. sp.

**Material and Occurrence.**—Two specimens known (other than that of Wachsmuth & Springer, 1897); the holotype, PRI 53652, crushed on a small slab of shale, preserving two mostly complete rays and parts of another; the CD interray is unexposed. The base is uncrushed, but parts of the exposed calyx are covered by encrusting bryozoan; 25 mm high. Second specimen, PRI 68249, more fragmentary, preserving only the proximal calyx (aboral cup plus the first primibrachial in two rays and interradials in some interrays). It, however, has the proximal posterior side exposed, showing three plates in the anal series. Both specimens from the upper Birdsong Shale (Bryozoan Zone), loc. BQ (Lochkov).

**Etymology of Name.**—Specific name *cheilobathron* (Gr., cheilos, rim; bathron, base), referring to the rimmed base of this species.

**Dimerocrinites sp. A**

Pl. 1, Fig. 11

**Diagnosis.**—Dimerocrinites with low, conical calyx: plates smooth, tumid, with depressed sutures; ray ridges low, broad; basals protruding slightly over infrabasals.

**Description.**—Calyx low, conical, with slightly bulbous plates and somewhat depressed sutures. Infrabasals 5, equal, barely visible from side, mostly composing stem facet. Basals 5, equal, protruding slightly beyond stem facet. CD basal truncated by primanal. Radials 5, wider than high, notched by the first interprimibrachial, in contact except on posterior side. Primibrachials 2; first interradial hexagonal, wider than high. At least two secundibrachials. Regular interradials in 1/2/+ plating pattern. Anal series well-developed with anal ridge; anal interarea in 1/3/5/+ plating pattern. Interrays depressed. Plates beyond the second secundibrachial level, free arms, tegmen, and stalk not preserved.

**Remarks.**—*Dimerocrinites* sp. A differs from associated specimens of *D. (D.) cheilobathron* n. sp. in having tumid plates with depressed sutures, an anal ridge, and basals that protrude proximally over the stem facet. *D. (D.) cheilobathron* n. sp. has a rimmed base with relatively prominent infrabasals, flat plates, and no anal ridge. The subgenus to which this species belongs is uncertain because the only known specimen is preserved only to the first secundibrachial in two rays, with a single, slightly separated second secundibrachial in one of those rays. However, this brachial does not appear to be axillary, suggesting the ten-armed form, *Dimerocrinites (Dimerocrinites)*.

This single specimen might represent a new species. However, considering its incomplete nature, it seems unwise to add to the already considerable number of recognized species of *Dimerocrinites*, some of which will probably be synonymized.

**Material and Occurrence.**—One partial, uncrushed calyx, PRI 53653, preserved to radials in all rays, to the first secund-
brachial in two rays (C, D), with a single, slightly separated second secundibrachial in the C ray. The anal area is preserved to the first secundibrachial level. The specimen preserves surface stereom on some plates in the A and B rays and AE and AB interrays. Calyx approximately 10 mm wide, 6 mm high at first secundibrachial level. Upper Birdsong Shale (Bryozoan Zone), loc. BQ (Lochkov).

Family LAMPTEROCRINIDAE Bather, 1899

Diagnosis.—Dimerocrinotoideaen with pronounced asymmetry of the calyx due to swelling (protrusion) of the anal interray, and possessing a long anal tube.

Genus LAMPTEROCRINUS Roemer, 1860

Type species.—Lampterocrinus tennesseensis Roemer, 1860.

Diagnosis.—Lampterocrinid with 5 uniserial arm trunks.

Remarks.—Lampterocrinus differs strongly from the other member of the family, Siphonocrinus, primarily in the structure of the rays. Lampterocrinus has five free uniserial arm trunks with three or more primibrachials incorporated in the cup, whereas Siphonocrinus has two fixed secundibrachials and can have fixed tertibrachials, depending on the species. These features allow additional interradials and intersecundibrachials, which are not present in Lampterocrinus. Siphonocrinus also is generally much larger than Lampterocrinus. All of the radials in Lampterocrinus are in contact, except on the anal side. This is a variable condition in Siphonocrinus, even within a single specimen, larger specimens tending to have some or all of the radials separated by the first interradial. It is somewhat doubtful that Siphonocrinus even belongs in the Lampterocrinidae, but this issue requires further study.

Lampterocrinus tennesseensis Roemer, 1860
Pl. 2, Fig. 5

Lampterocrinus tennesseensis Roemer, 1860: 37, pl. 4, figs 1a–b.—Wachsmuth & Springer, 1897: 208, pl. 13, fig. 10; Springer, 1926a: 20, pl. 3, figs 1–6.
Lampterocrinus fatigatus Strimple, 1963: 83, pl. 5, figs 1–3.
Lampterocrinus sculptus Springer, 1926a: 21, pl. 3, figs 7–8.

Diagnosis.—Lampterocrinus with stellate ridges, lacking central nodes, on plates.

Description.—Calyx medium cone-shaped with stellate ridges crossing plate sutures, usually single, sometimes multiple, bulging posterior side. Infrabasals 5, equal, visible from side. Basals 5, large, equal, higher than wide, with largest plates in cup. Radials 5, equal, wider than high, smaller than basals. Fixed primibrachials 3 (?), becoming progressively smaller distally; first primibrachial hexagonal. Normal interradials small, with a 1/2/3 pattern to level of free arms; anal interray covered. Tegmen low, asymmetrically dome-shaped, higher in CD interray. Arms and column not preserved.

Remarks.—After examination of the illustrations of the various species of Lampterocrinus, it became obvious that this genus, like so many other multispecific genera, needs revision. It seems likely that Springer’s (1926a) three coeval species are members of a single species that is rather variable in terms of calyx shape and ornamentation. The form of L. roemeri (Beech River Formation, Tennessee, Ludlow) represents one extreme with an elongate calyx and ornament reduced to strong single ridges connecting ray plates, radials and adjacent basals, and basals and infrabasal-infrabasal sutures. Lampterocrinus sculptus (Beech River Formation, Tennessee, Ludlow) represents the other extreme with a wider calyx, weak ray ridges, and stellate ornament consisting of multiple, weak ridges connecting most calyx plates. Lampterocrinus roemeri and L. sculptus are considered to be junior subjective synonyms of L. tennesseensis, which was described from the same formation. Lampterocrinus fatigatus (Henryhouse Formation, Oklahoma, Ludlow) is similar to L. tennesseensis and is considered herein to be synonymous. Lampterocrinus astroferus Prokop, 2004, reported from the upper Ludlow of Bohemia, Czech Republic (Prokop, 2004), is similar to L. tennesseensis but has a lower bowl-shaped calyx and basals higher than radials.

Geologically older species of Lampterocrinus (e. g., L. robustus Weller, 1900, L. subglobosus Weller, 1900) are mostly preserved as dolomitized internal and external molds of Wenlock age from the Racine Formation of the North American midcontinent, and they tend to have tumid or nodose plates. This feature distinguishes them from the younger species, L. tennesseensis, as defined herein.

The single, reasonably complete specimen from the Decatur Limestone is most similar to the "L. sculptus" morphology in that it has a relatively wide cup, stellate ornament, and a low tegmen.

Material and Occurrence.—Four specimens. One mostly complete, somewhat crushed calyx, PRI 53656, missing B-ray primibrachs, interray plates above the first interradial preserved in the BC interray, and tegmen plates above this region to the summit of the calyx. Best preserved calyx 23 mm high, 23 mm wide; second calyx 30 mm high. Also collected several fragments, PRI 68251–68253, consisting of articulated infrabasals and basals.
Upper Decatur Limestone ca. 1.5 m below the contact with the overlying Rockhouse Limestone, PRI 53656, loc. RCa. Articulated infrabasal and basal circlets are from the same horizon and lower levels at several localities: PRI 68253, loc. BQ; PRI 68252, loc. Q13; PRI 68251, loc. RCa (Pridoli).

Family GAZACRINIDAE Miller, 1892

*Diagnosis.*—Dimerocrinitoideans with basal concavity; single interradial in each interray; tegmen composed of few, large, interambulacral plates with ridges; orals 5, large.

Genus GAZACRINUS Miller, 1892

*Type Species.*—Gazacrinus inornatus Hall, 1863.

*Diagnosis.*—Same as for family.

*Gazacrinus stellatus* Springer, 1926

Pl. 1, Figs 4–5

*Gazacrinus stellatus* Springer, 1926a: 19, pl. 2, figs 25, 25a–c.—

Strimple, 1963: 88, pl. 6, figs 3–4.

*Diagnosis.*—Gazacrinus with deep, pentagonal basal cavity; large first primibrachial; ornament consisting of coarse pustules and rugae on calyx plates, and coarse stellate ridges connecting adjacent basals and basals with radials.

*Description.*—Calyx erect bowl-shaped. Calyx plates with coarse pustules and rugae. Stellate ridges connecting adjacent basals and basals with radials. Basal concavity deep, pentagonal. Infrabasals 5, small, at bottom of basal concavity. Basals 5, almost as large as radials, involved in basal concavity. Radials 5, wider than high, largest plates in cup. Radial arm facet smaller than radial width. Primibrachials 2, much smaller than radial. At least 1 fixed secundibrachial. Interradial 1, large. Arms, tegmen and stem not preserved.

*Remarks.*—This species is known from one specimen, which Springer (1926a) described from the lower Linden Formation (= Ross Formation) of Hardin County. Bassler & Mooodey (1943) and Strimple (1963) attributed it to the Decatur Limestone. No specimens of *Gazacrinus stellatus* were found during this study.

*Type and Occurrence.*—Holotype, USNM S139, cup preserved to secundibrachial 1. Lower Ross Formation or Decatur Limestone, Hardin County.

Order MONOBATHRIDA Moore & Laudon, 1943

*Diagnosis.*—Monocyclic camerates.

Suborder COMPSOCRININA Ubaghs, 1978

*Synonym.*—Tanaocrinina Moore, 1952.

*Diagnosis.*—Monobathrids with radial plates adjoining except on posterior side.

Superfamily PERIECHOCRINOIDEA Bronn, 1849

*Synonym.*—Carpocrinacea De Koninck & Le Hon, 1854.

*Diagnosis.*—Compsocrinines with 3 equal or subequal basals; brachial and interbrachial plates incorporated in cup.

*Remarks.*—As defined by Ubaghs (1978a), the superfamilies Periechocrinoidea and Carpocrinoidea are indistinguishable. He cited, "Three equal basals...; first primibrachs hexagonal, but quadrangular in advanced members; primanal heptagonal, followed by three plates in the next higher row, or hexagonal with two plates in second row" (Ubaghs, 1978a: T443) for the Periechocrinoidea. For the Carpocrinoidea he cited: "Basals three, generally equal; first primibrachs ordinarily quadrangular; primanal generally followed by three plates in next higher row" (Ubaghs, 1978a: T462). These descriptions do not distinguish these two groups of crinoids but instead show their essential unity. Witzke & Strimple (1981) detailed the poor differentiation between these two superfamilies and noted that if they were combined, Periechocrinoidea has priority. Ausich (1987) also pointed out the lack of distinction between these superfamilies. It is therefore proposed to synonymize the Carpocrinoidea with the Periechocrinoidea, the latter having priority.

Family CARPOCRINIDAE de Koninck & Le Hon, 1854

*Diagnosis.*—Periechocrinoideans with three or fewer ranges of interradials.

*Remarks.*—The Periechocrinoidea can be divided into two families—Periechocrinidae and Carpocrinidae—based on the number of ranges of interradials present before the arms become free. The periechocrinids have four ranges or more; the carpocrinids have three or fewer ranges. These forms are also characterized by low tegmens composed of numerous small plates. The Periechocrinidae contain most of the genera previously assigned, except *Stiptocrinus*. The Carpocrinidae thus defined comprise the remainder of the Periechocrinoidea.
The Carpocrininae includes those genera presently assigned to the Carpocrinidae (Ubags, 1978a: T462–T466), except Barrandeocrinus Angelin, 1878, and Methabocrinus Jaekel, 1918, which are placed within the subfamily Barrandeocrininae Angelin, 1878.

Of the remaining, mostly geologically younger, periocrinoid groups, the Coelocrinidae (and probable descendant groups Batocrinidae and Paragararicocrinidae), Amphoracrinidae, and two subfamilies (sensu Ubags, 1978a) of Actinocrinitidae (Actinocrininae, Cactocrininae) are considered to be descended from Stiptocrinus (Carpocrinidae, Stiptocrininae n. subfam.). The remaining "actinocrinid" groups (Physetocrininae, Eumorphocrininae) more likely were derived from the Periechocrinidae.

Subfamily **STIPTOCRININAE** n. subfam.

**Diagnosis.**—Carpocrinidae with biserial arms and a lobate calyx.

**Remarks.**—Within the Carpocrinidae, three groups can be segregated using the structure of the arms (uniserial or biserial) and lobation of the calyx. The Stiptocrininae n. subfam. (*Stiptocrinus*) is characterized by biserial arms and a lobate calyx, the Carpocrininae (*Carpocrinus* Müller, 1840, *Acacocrinus* Wachsmuth & Springer, 1897, *Bohemicocrinus* Jahn, 1893, *Cylcocrinus* Miller, 1892, *Desmiodocrinus*) by uniserial arms and a nonlobate calyx, and the Barrandeocrininae (*Barrandeocrinus, Methabocrinus*) by biserial arms and a nonlobate calyx. The tegmen of the barrandeocrinines is also distinct from those of the other groups, being composed of a few, large plates (*Methabocrinus*) or thin intersecundibrachials between fixed brachials (*Barrandeocrinus*).

Genus **STIPTOCRINUS** Kirk, 1946

**Type Species.**—*Stiptocrinus spinosus* Kirk, 1946.


**Diagnosis.**—Same as for subfamily.

**Remarks.**—*Stiptocrinus* was synonymized with *Carpocrinus* by Frest & Strimple (1977a, a view also held by Witzke & Strimple, 1981). Recent finds prove that *Stiptocrinus* possessed unbranched biserial arms as opposed to the uniserial, hyperpinnulate arms of *Carpocrinus*. *Stiptocrinus* is normally lobate (calyx viewed from oral direction) to some degree, and usually possesses nodose to stellate ornament. *Carpocrinus* is not lobate and exhibits only subdued ornament, usually in the form of vermicular ridges, never nodose or stellate. The principal differentiating feature of *Stiptocrinus* is its biserial arms. *Stiptocrinus* is herein considered separate from *Carpocrinus*. *Carpocrinus sablensis* (Saint-Cenere Formation, Armorican Massif, Upper Lochkovian–Pragian) has a slightly lobate calyx, prominent ridged ornamentation, and a large spine on the posterior oral plate, strongly suggesting assignment to *Stiptocrinus*. However, arms are not preserved on Le Menn’s specimen, making assignment tentative.

*Acacocrinus* (probably a form like *A. anebos* Ausich, 1987) was a probable ancestor of both *Stiptocrinus* and *Carpocrinus* during the Llandovery. *Stiptocrinus* arose from *A. anebos* by the development of lobation, an ornamented cup, and biserial arms. *Acacocrinus anebos* (Brassfield Formation, Ohio, Llandovery) is remarkably similar to *C. bodei* from the Hopkinton Formation (Upper Llandovery). However, *C. bodei* is almost certainly a *Stiptocrinus*, possessing the lobate calyx and ornamented cup plates that characterize that genus. However, its arms are not known. It is the earliest known member of the *Stiptocrinus* lineage.

*Stiptocrinus* is a plausible progenitor of two Devonian and Mississippian families, the Actinocrinidae and Coelocrinidae. Brower (1967) considered *Stiptocrinus* to be a possible ancestor to the actinocrinids. The most characteristic features of the *Stiptocrinus* lineage are lobation of the calyx, unbranched biserial arms, and three or fewer ranges of normal (nonanal) interprimibrachials. The Actinocrinidae also have these characters.

*Abactinocrinus* Laudon & Severson, 1953, differs from *Stiptocrinus* only in the possession of two plates in the second range of the anal interray series instead of three as in *Stiptocrinus*. *Aacocrinus* Bowsher, 1955, another actinocrinid, is like *Abactinocrinus* but also has an anal tube. The Amphoracrinidae differ from the lobate actinocrinids only in having a quadrangular first primibrachial rather than a hexagonal one. The Amphoracrinidae undoubtedly evolved from the Actinocrinidae.

*Stiptocrinus* (most likely a taxon like *S. nodosus*, described below) probably gave rise to the Middle Devonian–Mississippian family Coelocrinidae, primarily by adding bifurcations to the rays, within the calyx. *Aorocrinus* Wachsmuth & Springer, 1897, the oldest member of the Coelocrinidae, possesses a lobate calyx, hexagonal first primibrachial, and biserial arms, as in *Stiptocrinus*. Illustrations by Goldring (1923: pl. 35) suggest that the addition of arm bifurcations was produced by differentiation of a proximal pinnule. Brower (1973) and Broadhead (1988a, b) showed this to be a common phenomenon within the Camerata and an easy way to add to the arm system. The coelocrinids, in turn, probably gave rise to another prominent Mississippian family, the Batocrinidae, by development of a quadrangular first primibrachial, an
anal tube and the secondary loss of lobation. Some of the Actinocrinitidae (Actinocrinitinae, Cactocrininae) were either derived from the coelocrinids or could represent direct descent from the original Stiptocrinus lineage through as yet undiscovered intermediates. The close resemblance of these actinocrinids to Stiptocrinus suggests the latter to be the case.

**Stiptocrinus cf. benedicti** (Miller, 1892)

*Pl. 2, Fig. 2*

_Saccorinus benedicti_ S. A. Miller, 1894: 283, pl. 5, fig. 1.—Springer, 1926a: 46, pl. 10, figs 6–14.

_Habrocrinus benedicti_.—Slocom, 1908: 295, pl. 87, figs 6–7; Foerste, 1917: 240, pl. 10, figs 50A–B.

_Habrocrinus farringtoni_ Slocom, 1908: 298, pl. 87, figs 1–5.

_Periechocrinus ornatus_ Wachsmuth & Springer, 1897: 527, pl. 51, fig. 7.

_Periechocrinus chicagoensis_ Weller, 1900: 131, pl. 13, figs 7–8.

_Stiptocrinus benedicti_.—Kirk, 1946: 34.

**Diagnosis.**—Stiptocrinus with ornament consisting of small nodes surrounding a central depression on most calyx plates, 1/2/2 or 3 normal interray series, and 1/3/5 anal interray series.

**Description.**—Calyx conical, nonlobate, with highly weathered ornament of small nodes surrounding central depression; sutures slightly depressed. Basals 5, rimmed. Radials 5, equidimensional. First primibrachial hexagonal, smaller than radial. Normal interrays 1/2/2 to first secundibrachial level; CD interray 1/3/5/7 to first secundibrachial level. Arms, stem, and tegmen not preserved.

**Remarks.**—Species of Stiptocrinus are differentiated on the basis of ornament of the principal cup plates and plating pattern in both the normal and anal interrays. The single specimen assigned herein to _S. benedicti_ is crushed and incomplete but preserves enough features for specific identification. Because the specimen is highly weathered, only a few plates still retain the ornament, but these have the distinctive _S. benedicti_ appearance.

_Stiptocrinus benedicti_ differs from _S. howardi_ (Miller, 1892) (Laurel Limestone, Indiana, Wenlock; Frest _et al._, 1999) by having a 1/3/5 vs. a 1/3/3 CD interray series and a 1/2/2 or 3 vs. a 1/1 normal interray plating series. _Stiptocrinus benedicti_ and _S. carinatus_ Kirk, 1940 (Laurel Limestone, Indiana, Wenlock; Frest _et al._, 1999) have similar interray plating, but they differ in ornament, which in the latter consists of ridges radiating to the corners of the plates. _Stiptocrinus benedicti_ differs from _S. nodosus_ both in ornament and in CD interray structure (1/3/5 vs. 1/3/3). _Stiptocrinus farringtoni_ (Slocom, 1908) (Racine Dolomite, Illinois, Wenlock; Frest _et al._, 1999) and _S. chicagoensis_ (Weller, 1900) (Racine Dolomite, Illinois, Wenlock; Frest _et al._, 1999) might be synonymous with _S. benedicti_ but require restudy. The specimen identified in this study marks the latest occurrence for this species, which is known mainly from Wenlock age rocks.

**Material and Occurrence.**—Single specimen, PRI 53657, crushed but preserving the basal and radial circlets, two rays to the second primibrachial. The anal interray is best preserved through four ranges. The ornament is highly weathered, but is typical of _Stiptocrinus benedicti._ 20 mm high. Upper Decatur Limestone, loc. PQ (Pridoli).

**_Stiptocrinus nodosus_** (Springer, 1926)

*Pl. 2, Figs 3, 6–9, Pl. 3, Figs 2, 8*

_Aorocrinus nodosus_ Springer, 1926a: 47, pl. 10, figs 16, 16b.

_Stiptocrinus nodosus_.—Kirk, 1946: 35.

**Diagnosis.**—Stiptocrinus with ornament composed of strong nodes, stellate ridges, or both; 1/2/3 normal interray series, and 1/3/3 CD interray series.

**Description.**—Calyx open to erect bowl-shaped, slightly wider than high to slightly higher than wide, with low to moderately variegated terminal vault; extremely variable ornament composed of weak to strong nodes, variably developed stellate ridges, or both. Basals 3, low, equal. Radials 5, large, equal, largest plates in cup, separated by primanal. Fixed primibrachials 2, both much smaller than radials; first primibrachial hexagonal. Fixed secundibrachials 2–3, separated by 1 intersecundibrachial. Normal interrays with 1/2/2 or 3 series to the first secundibrachial; CD interray with 1/3/3 series. Arms 2 per ray, biserial, pinnulate, unbranched when free. Tegmen of low to medium height with relatively large plates; can have single, tongue-shaped spine on ?posterior oral, illBr spine can be present. Stem weakly heteromorphic, with nodes and internodes; nodotaxis type 3 of Webster (1973), N3231323. Holdfast not preserved.

**Remarks.**—_Stiptocrinus nodosus_ is characterized by extremely variable ornamentation. This ranges from a single sharp node on each calyx plate (Pl. 2, Fig. 7) to low, but well-defined, stellate ridges that lack nodes altogether (e.g., PRI 53659–53660; Pl. 2, Figs 6, 8). Intermediate forms have both nodes and stellate ridges that are variably developed (Pl. 2, Fig. 9). Several species could easily have been defined based on differences in ornamentation if intermediates were lacking. However, enough specimens have been found to show the extent of the variation in this species.

This species is the latest _Stiptocrinus_ known to date and might be closely related to the progenitor of the later periecho- crinoidean families Coelocrinidae and Actinocrinitidae. The
variation in S. nodosus is perhaps a harbinger of this later radiation.

Material and Occurrence.—Twenty specimens ranging from partial calyces to nearly complete skeletons preserving arms and stem. Three specimens, PRI 53662–53663 and 68259, preserving portions of the arms; three specimens, PRI 53661–53662 and 68260, preserving portions of the stem. Calyces ranging from 8–19 mm high, 12–21 mm wide, with maximum calyx height preserved at 22 mm. Maximum arm length preserved is 70 mm; maximum stem length preserved is 110 mm.


Superfamily HEXACRINITOIDEA
Wachsmuth & Springer, 1885

Diagnosis.—Compocrinines with large radial plates and few or no fixed brachial or interray plates.

Family HEXACRINITIDAE Wachsmuth & Springer, 1897

Diagnosis.—Hexacrinitideans with 3 basal plates; arms free beyond first secundibrachial, occupying only a small portion of radial summit.

Genus HEXACRINITES Austin & Austin, 1843

Type Species.—Platycrinites interscapularis Phillips, 1841.

Remarks.—Although the Hexacrinitidae is a small family (4–5 genera, Ubaghs, 1978a: T473–T475), it is difficult to diagnose Hexacrinites. The type species has a globose calyx with a high tegmen and pustulose ornamentation. Other species within the genus differ considerably in having a low tegmen and a conical cup. Arms are only known from few species. It is probable that Hexacrinites will be split into two genera: those with a globose calyx, high tegmen, and pustulose ornament remaining in Hexacrinites, and those with the steeply conical calyx characteristic of most species being grouped into another genus. Strimple (1963: 96) noted that neither of the two species that he described from the Henryhouse Formation (Ludlow) of Oklahoma (also found in Tennessee) are members of Hexacrinites sensu stricto.

**Hexacrinites carinatus** Strimple, 1963
Pl. 2, Figs 11–12

*Hexacrinites carinatus* Strimple, 1963: 94, pl. 6, fgs 1–2, text-fig. 30.

Diagnosis.—Hexacrinites with a steeply conical cup, strong ridges from basals to radials and primonial (hexagonal base).

Description.—Cup steeply conical. Ornament consisting of strong, sharp ridges radiating from basals to top center of radials and primonial, alternating converging double ridges and single ridges, and finer, transverse ornament connecting adjacent radials. Basals 3, large, equal, composing approximately 40% of cup height. Radials 5, large, larger than wide; arm facets large, horseshoe-shaped, occupying most of radial edge, projecting outward. Primonial larger than radials. Column, arms, and tegmen not preserved.

Remarks.—The steeply conical cup and strong stellate ornament serve to differentiate Hexacrinites carinatus from other species of Hexacrinites (see recent review by Bohaty, 2007). *Hexacrinites carinatus* is fairly common in the middle and upper Decatur Limestone. Although only seven specimens were collected (including one from the lower Rockhouse Limestone), disarticulated plates are common. These compare well with the figures and descriptions of specimens described by Strimple (1963) from the Henryhouse Formation (Ludlow–Pridoli) of Oklahoma, with the exception of having two converging ridges on the primonial versus only one ridge on the Oklahoma specimens.

The occurrence of *Hexacrinites carinatus* in the Decatur and Rockhouse Limestones increases the geographic range from Oklahoma to Tennessee.

Material and Occurrence.—Seven specimens, cups only, partial or crushed. Specimen PRI 53664 most complete, height 19 mm, width 12 mm. Range in height 13–21 mm.

Decatur Limestone, locs. PQ (PRI 53665, 68269), BQ (PRI 53664, 68271), Q13 (PRI 68372), and RCa (PRI 68273); Rockhouse Limestone, loc. AM (PRI 68270) (Pridoli–Lochkov).

**Hexacrinites adaensis** Strimple, 1952
Pl. 2, Fig. 10


Diagnosis.—Hexacrinites with a steeply conical cup and fine, vermicular ornament.
Description.—Cup steeply conical, with fine, vermicular, transverse ridges connecting adjacent radials. Basals 3, sub-equal. Radials 5, higher than wide, equal; arm facet horse-shoe-shaped, occupying most of radial summit, projecting outward.Primanal as large as radial. Small notches for first interradial. Arms, column, and tegmen not preserved.

Remarks.—This species differs from Hexacrinites carinatus primarily in the ornamentation. Macroscopically H. adaensis appears smooth as opposed to the stongly ridged H. carinatus. Strimple (1926a, 1963) described only one specimen of H. adaensis from the Henryhouse Formation, and no further specimens have been reported. The Tennessee specimen increases the stratigraphic range from the Ludlow to the Pridoli, and the geographic range from Oklahoma to Tennessee.

Material and Occurrence.—Single partial cup, PRI 53666, missing one basal, embedded in a small chip of limestone. The primanal is visible. Height 8 mm, width 6 mm. Upper Decatur Limestone, loc. RCa (Pridoli).

Suborder GLYPTOCRININA Moore, 1952

Diagnosis.—Monobathrids with radials adjoining.

Superfamily MELOCINITOIDEA d’Orbigny, 1852

Diagnosis.— Glyptocrinines with four basals.

Family SCYPHOCRINITIDAE Jaeckel, 1928

Diagnosis.— Melocinitoideans with numerous fixed pinnulars.

Remarks.—The Scyphocrinidae at this time contains four genera: Scyphocrinites, Liomolgocrinus Strimple, 1963, Carolicrinus Waagen & Jahn, 1899, and Marhoumacrinus Prokop & Petr, 1987. Scyphocrinites occurs both in Europe and North America. Liomolgocrinus is known only from North America (Oklahoma). Carolicrinus is known only from eastern Europe, and Marhoumacrinus is from North Africa (Algeria, Morocco) (see Haude & Walliser, 1998; Haude, 1992, 1999). Prokop & Petr (1986, 1987, 1994) segregated Scyphocrinites, Carolicrinus, and Marhoumacrinus primarily on the basis of arm type (uniserial or biserial) and presence of intertertibrachials. They did not address Liomolgocrinus, for which arms have not been described. Scyphocrinites possesses uniserial arms and no intertertibrachials, Marhoumacrinus uniserial arms and intertertibrachials, and Carolicrinus biserial arms and intertertibrachials. In these three genera, the distal interbrachial areas are composed of fixed pinnulars, which are variously ornamented. These fixed pinnulars are mostly traceable from the brachial that gave rise to them. Liomolgocrinus, on the other hand, has what are presumed to be fixed pinnulars that are not can be traced, but are indistinguishable from other interbrachial plates. These plates also lack ornament or convexity, which is a characteristic of the other genera.

Marhoumacrinus and Carolicrinus are further differentiated from Scyphocrinites in having a pinnule on the third secundibrachial, which Scyphocrinites does not. Marhoumacrinus also possesses intersecundibrachials in a 1/1 pattern for the first two ranges (Prokop & Petr, 1987); Scyphocrinites, Carolicrinus and Liomolgocrinus have a 1/2 pattern.

Scyphocrinitids have a unique, bulbous, chambered, holdfast, called a lobolith, which was described in older literature as Camarocrinus. Haude (1992) re-established this taxon as a valid genus. These holdfasts are common in carbonate rocks of Pridolian to Lochkovian age, and provide a useful guide fossil (see Springer, 1917; Strimple, 1963; Prokop & Petr, 1986; Haude, 1972, 1999; Haude & Walliser, 1998).

Genus SCYPHOCRINITES Zenker, 1833

Type species.—Scyphocrinites elegans Zenker, 1833.

Diagnosis.—Scyphocrinitids with differentiated pinnulars, uniserial arms, and no intertertibrachials.

Remarks.—Prokop & Petr (1986) examined specimens of Bohemian Scyphocrinites, placing them in two species, S. elegans and S. subornatus Waagen & Jahn, 1899, primarily on the basis of the number of fixed secundibrachials, although there are also differences in ornamentation. They argued that S. elegans occurs only in Bohemia, whereas the American form described by Springer (1917) as S. elegans represents a new species because of differences in secundibrachial number: S. elegans with only 14–15, and "S. elegans" of Springer with 19–20. The ornament in the Bohemian and American forms is remarkably similar. Scyphocrinites subornatus has 12 secundibrachials, which is the primary discriminating characteristic. The plates are convex and smooth, with low, broad crenulations on the margins.

At present there are 15 nominal species of Scyphocrinites (Webster, 2003; see also review by Donovan & Lewis, 2009). Springer (1917) recognized eight species of Scyphocrinites: S. elegans, S. spinifer, S. mutabilis, S. stellatus, S. pratteni, S. pyburnensis, S. ulrichi (Schuchert, 1903), and S. gibbosus. Springer, 1917. He subdivided these into two main groups based on calyx shape. In "group A," the calyx expanded into the secundibrachial level before becoming constricted. In "group B," the calyx expanded to the level of the primibrachials, above which it is constricted and becomes cylindrical.
toward the arm bases. "Group A" consisted of the first four
species listed above, and was subdivided using calyx shape
(height/width ratio) and ornamentation pattern. "Group B,"
containing the last four species listed above, was subdivided
using height/width ratio, plate ornament, and protuberance
of the proximal interray area.

Prokop & Petr (1986) rejected using calyx shape and or-
nament as species discriminators, stating that calyx shape is
highly dependent on the position of the calyx during burial,
and that the ornamentation changes during ontogeny. They
provided little discussion of the American species but indicated
that Scyphocrinites mutabilis is similar to S. subornatus. Prokop
& Petr (1987) also suggested that S. pyburnensis belongs in
Marhoumacrinus. As stated above, they used the number of
secundibrachials as the primary specific discriminator. This
raises questions about the validity of the American species.
The numbers of secundibrachials are as follows: S. stellatus
10, S. gibbosus and Liomolgocrinus dissutus Strimple, 1963 (=
S. ulrichi sensu Springer, 1917) 11, S. spinifer and S. pratteni
Scyphocrinites spinifer and S. pratteni seem very different:
S. spinifer has a nonlobate cup and very spinose ornament,
whereas S. pratteni exhibits a larger, lobate cup, and only low
nodes on the cup plates. Conversely, S. elegans (of Springer,
1917) closely resembles S. cinctus. Furthermore, the ornamen-
tation of S. mutabilis and S. pyburnensis is very similar.

As stated above, Prokop & Petr (1987) suggested that
Scyphocrinites pyburnensis is a member of their genus
Marhoumacrinus, partly based on the 1/1 pattern of the in-
tersecundibrachials. An illustration of S. pratteni by Springer
(1917: pl. 7, fig. 1a) also has a 1/1 pattern. In another illus-
tration, Springer (1917: pl. 6, fig. 2a) illustrated a 1/2 pattern
in S. pratteni. A specimen of S. mutabilis was illustrated with
a 1/1 pattern in one ray and a 1/2 pattern in another (pl. 6,
fig. 3a). If these illustrations are correct, then distinguishing
Marhoumacrinus from Scyphocrinites on the basis of the inter-
secundibrachials pattern is invalid.

Use of the number of secundibrachials does not suffice to
distinguish the American species. Scyphocrinites cinctus, which
is probably identical to S. elegans (of Springer, 1917), has an
extremely variable number of secundibrachials (12–23). Thus,
one is left with Springer’s criteria, namely the level of con-
striction of the calyx, plate ornament, and protuberance of the
interrays as specific discriminators. Unfortunately, the only
clear conclusion about generic and specific subdivisions of the
Scyphocrinitidae is that much more work is needed to deline-
ate the characters necessary to segregate the Scyphocrinitidae
into recognizable genera and species.

In overall aspect, Scyphocrinites elegans (of Springer, 1917)
stands out from other species because of its thin plates with
fine, radiating ridges. Other species have thick plates with
coarse ornament or smooth plates. Likewise, S. pratteni is eas-
ily defined by its large size, typically nonstellate plates with
a node in the center, its highly protuberant interray areas,
and its crown shape, where the calyx expands to approxi-
mately the level of first secundibrachial, then contracts to the
fourth secundibrachial, and becomes cylindrical thereafter.
Scyphocrinites spinifer is probably justified, but Springer’s il-
lustration (1917: pl. 8, fig. 2a) of a specimen that he termed
S. pratteni is highly similar to his illustration of S. spinifer (pl.
9, figs 1a–c), the principal difference being that the former has
a constricted calyx whereas the latter does not.

The primary difference between Scyphocrinites mutabilis
and S. pyburnensis is that the latter has a constricted calyx,
whereas S. mutabilis does not. Both have a varied ornament,
usually with bulbous plates and crenulate margins, but in
some cases, they have subdued stellate ridges. Whether or not
the constriction is a sufficient reason to segregate these forms
is questionable. Scyphocrinites stellatus is almost certainly con-
specific with S. mutabilis, in which case S. stellatus has priority.
Scyphocrinites gibbosus is also probably conspecific with S. stel-
llatus. Strimple (1963) restricted the name S. ulrichi to the bul-
bous root (Camarocrinus) described by Schuchert (1905) and
placed the calyces assigned to S. ulrichi by Springer (1917)
in a new genus, Liomolgocrinus, with L. dissutus as the type
species.

Within the specimens collected during this research from
the Decatur and Ross formations, three forms can be distin-
guished. A single specimen ascribable to Scyphocrinites elegans
(of Springer, 1917) is from the upper part of the Decatur
Limestone at loc. BQ. Four specimens of S. pratteni were
collected from the upper Rockhouse Limestone at the same
locality and a fifth specimen could not be collected. The rest
of the specimens from the Decatur (2) and Ross (27) mostly
lack constrictions, although one specimen is distorted so that
the calyx is partially constricted. The highly variable ornament
ranges from smooth plates with crenulated margins to stellate
plates with central spines. Ornamentation is varied enough
to preclude separating the various specimens of this group.
They possess thick convex plates and lack the fine, radiating
ridges of S. elegans (of Springer, 1917). It is difficult to assign
these specimens to S. mutabilis, S. pyburnensis, or S. stellatus
because they share characteristics attributable to any or all of
these forms. These three "species" are probably synonymous,
and they will, because of priority, be herein assigned to S. stel-
latus.

Finally, a single specimen of a scyphocrinid lacking any
ornamentation was collected in the lower Birdsong Shale
(Brachiopod Zone) at loc. MQ. Its plate arrangement is also
obscure. Whether it belongs to Scyphocrinites, Liomolgocrinus,
or a new genus is uncertain. It is herein considered to be S. stellatus.

Loboliths (= Camarocrinus), the bulbous holdfasts of Scyphocrinites, are abundant in the upper Decatur and lower Rockhouse, but calyx material is less common and usually disarticulated. Calyces are most abundant in the upper Rockhouse, whereas the loboliths are not as noticeable because they have been flattened by compaction. A few calyces have been found in place in the lowest Birdsong Shale at loc. MQ. A few specimens also occur in blocks that are almost certainly from the lower Birdsong. This genus is not known in younger rocks.

Scyphocrinites cf. elegans Zenker, 1833

Pl. 3, Fig. 1

Scyphocrinus elegans.—Quenstedt, 1850: 621, pl. 55, figs 1–3; Springer, 1917: 30–39, pls 1–5.
Scyphocrinites cinctus Strimple, 1963: 99, pl. 7, figs 4–5, pl. 8, fig. 11.

Diagnosis.—Scyphocrinites with thin plates and numerous fine, radial ridges.

Description.—Calyx large, conical; plates ornamented by fine, radiating ridges. Basals 4, subequal. Radials 5, equal. Primibrachials 2, equidimensional, heptagonal. First primibrachial higher than wide. Normal interrays with 1,2,+ pattern. Most of calyx, arms, and tegmen not preserved.

Remarks.—The single specimen, here referred to Scyphocrinites elegans, is certainly conspecific with specimens described as S. elegans by Springer (1917) from the Bailey Limestone of Missouri. The referral of the Missouri specimens to S. elegans has been disputed by Prokop & Petr (1987), who believed that S. elegans was geographically confined to Bohemia, whereas the American forms belong to an unnamed species. The Bohemian form has a maximum of 15 secundibrachials whereas the American form has 18–20 (Prokop & Petr, 1987; Springer, 1917). However, S. cinctus, which is considered conspecific with the Missouri species, has 12 to ca. 23 secundibrachials (Strimple, 1963). It is likely that all three forms can be grouped within a single species, S. elegans, which is characterized by a conical calyx with no constrictions and plates with fine, radiating ridges.

Material and Occurrence.—One specimen, PRI 53667, preserved only to the first primibrach in two rays, interradials to the second range in one interray; height 28 mm. Upper Decatur Limestone, loc. BQ (Pridoli).

Scyphocrinites pratteni (McChesney, 1860)

Pl. 3, Figs 3–4, 9–10

Melocrinus pratteni.—McChesney, 1868: 22, pl. 5, figs 4.
Scyphocrinus pratteni.—Springer, 1917: 50, pl. 7, figs 1a–b, pl. 8, figs 1, 2a–b; Bassler & Moodie, 1943: 675.

Diagnosis.—Scyphocrinites with thick, weakly or unornamented plates below the secundibrachials and strongly protuberant interray areas; calyx constricted above the secundibrachials, becoming cylindrical above the third secundibrachial.

Description.—Calyx very large, expanding to the first secundibrachial, then constricting before becoming cylindrical above the third secundibrach. Plates smooth, thick, noticeably convex, can have central node; proximal plates without crenulate margin; plates above the second secundibrachial beginning to develop stellate ornament with depressed corners. Basals 4, subequal. Radials 5, equal. Primibrachials 2, equidimensional to somewhat elongate. As many as 12 secundibrachials (according to Springer, 1917). Interray plates large, protuberant to the level of the third secundibrachial; proximal interray plates larger than proximal ray plates; normal plate patterns 1/2/3/+; CD interray distinguished only by larger size of plates and greater protuberance. Arms and tegmen not preserved.

Remarks.—Scyphocrinites pratteni is the largest crinoid in the Ross Formation; its large size, smooth plates, and strongly protuberant interray areas distinguish it from any other form. Previously, it was noted only from the Ross Limestone Member of the Ross Formation in Hardin County (Springer, 1917: 52). The present specimens are from the upper Rockhouse Limestone at loc. BQ.

One small specimen (PRI 53668; Pl. 3, Figs 3–4) is most likely a juvenile (subadult) of Scyphocrinites pratteni. The calyx is conical; the radial plates are the largest in the cup; the interray areas protrude slightly in only three interrays; the presumed CD interray bulges most. The calyx plates are bulbous, smooth, and lack marginal crenulations. Pits are developed in the corners of distal plates along with small central nodes or spines. There is some uncertainty about placing this specimen in S. pratteni because of its small size and conical shape. However, the bulging interray areas and ornamentation indicate that assignment to this species is probably correct. Also, Prokop & Petr (1986) noted that the largest plates in cups of juvenile Scyphocrinites are the radials, whereas the first primibrachial and first interradial plate are equal to or larger than the radials in adults; this demonstrates that specimen PRI 53668 is a juvenile.
Material and Occurrence.—Four specimens collected; the two largest preserved only to the third secundibrachial level. The better preserved specimen (from shale) (PRI 53668) lacks basals; the less well-preserved specimen (PRI 68274) is embedded in limestone and is mostly covered with matrix. Specimen PRI 53668 is ca. 75 mm wide and 46 mm high. PRI 68274 is ca. 70 mm wide and 50 mm high. Both specimens are somewhat distorted by compaction. Two other specimens were collected: a large fragment of a calyx (PRI 68275) and a small specimen (PRI 53669), herein considered a juvenile form of Scyphocrinites patteni, 21 mm high and 30 mm wide.

Upper Rockhouse Limestone or lowermost Birdsong Shale at loc. BQ (Lochkov). The exact stratigraphic level is uncertain because the specimens were from spoil piles. The lithology of the surrounding rock is distinctive enough for general stratigraphic placement.

Scyphocrinites stellatus (Hall, 1879)
Pl. 3, Figs 5, 7; Pl. 4, Figs 1–8

Camarocrinus stellatus Hall, 1879: 270, pl. 35, figs 1–8.
Scyphocrinus stellatus.—Springer, 1917: 49, pl. 7, figs 4a, b; Bassler & Moodie, 1943: 676.
Scyphocrinus mutabilis Springer, 1917: 47, pl. 6, figs 3–19, pl. 8, figs 3–5.
Scyphocrinus pyburnensis Springer, 1917: 52, pl. 7, figs 2a–b, 3, pl. 8, figs 6a–b, 7.

Diagnosis.—Scyphocrinus with coarsely stellate plates or smooth, bulbous plates with crenulate margins.

Description.—Calyx medium-sized scyphocrinitid, conical, can have constriction at approximately the first secundibrachial level, otherwise no constriction to arm bases. Ornamentation highly variable, plates usually smooth bulbous with crenulated margins, but sometimes with varying coarse stellate ridges; ornamentation subduced or absent in proximal plates. Basals 4, subequal. Radials 5, equal, equidimensional. Primibrachials 2 per ray, equidimensional to slightly elongate. Approximately 12 secundibrachials. Proximal secundibrachials equidimensional, the last 4 or 5 short and wide. Fixed pinnulars between different rays and between secundibrachials of the same ray. Interray plates typically in 1/2/3+/ pattern, sometimes 1/3/3+. Anal interray not strongly differentiated; plates tending to be somewhat larger than in other interrays. Arms and tegmen not preserved.

Remarks.—Scyphocrinites stellatus has forms with a variety of calyx shapes and ornamentation types. Some specimens have steeply conical calyces, whereas others expand rapidly and then become more or less cylindrical. Ornamentation ranges from bulbous (tumid) plates with crenulated margins to stellate plates that are not noticeably convex. A few specimens have flat, smooth plates without crenulate margins, in the proximal portion of the cup. Most specimens become at least somewhat stellate in more distal parts of the calyx. Ornamentation can make plate boundaries hard to distinguish, especially in higher portions of the fixed pinnulars. Rays can be hard to trace; the secundibrachial axis is deflected adradially below where these plates become thin and wide as with higher brachials. The proximal secundibrachials are like other calyx plates.

Herein, Scyphocrinites mutabilis and S. pyburnensis are synonymized with S. stellatus. Scyphocrinites mutabilis and S. pyburnensis were differentiated primarily on the basis of a constriction at approximately the first secundibrachial level, which is supposedly present in S. pyburnensis but lacking in S. mutabilis. Presence or absence of a calyx constriction was considered by Prokop & Petr (1987) to be a taphonomic effect, a view that is almost certainly correct. Most specimens obtained during this study would be placed in S. mutabilis (sensu Springer, 1917) because they generally lack a constriction. Prokop & Petr (1987) compared S. mutabilis to the Bohemian species S. subornatus. They believed S. mutabilis to be different but did not explain why. Their figures of S. subornatus look very similar to S. stellatus (sensu lato). Scyphocrinites subornatus and S. stellatus are probably conspecific but are left here as separate species pending further comparative study.

One specimen, (PRI 53671; Pl. 3, Fig. 7) from the Birdsong at loc. BQ, has smooth, flat, thin, plates in the proximal part of the cup, whereas plates with a small central node are in the distal portion. This produces a calyx that differs greatly from the typical S. stellatus. This specimen is also abnormal in possessing only one primibrachial in one ray (the other exposed ray is normal). Another specimen (PRI 53675; Pl. 4, Fig. 4) from the lower Birdsong Shale at loc. MQ, has a conical cup with smooth and flat plates. The plates are somewhat irregularly arranged, which makes it difficult to decipher their configuration. Also, the plates have irregularly interdigitating margins; this feature is not in other specimens of Scyphocrinites, which have crenulations that parallel the margins and do not cross them. Whether these specimens are sufficiently different to warrant new specific names or are simply variants of S. stellatus will remain a question until the genus is restudied.

Scyphocrinites stellatus is the most common crinoid in the Ross Formation and is also common in the Decatur Limestone. Most specimens are at least somewhat distorted and crushed owing to compaction, and in only a few preserve the rays to the third terribrachial level.

Material and Occurrence.—Twenty-nine specimens retaining major portions of the cup were collected (PRI 53670–53675, 68276–68297). These range from ca. 25 mm to ca. 70 mm in length. In most cases, the width is unavailable due to crushing, but most are approximately as wide as high.
Upper Decatur Limestone at locs. PQ and BQ; Lower Rockhouse Limestone at loc. AM; upper Rockhouse Limestone or lowermost Birdsong Shale at locs. PQ, BQ, and MQ; lowermost Birdsong Shale at loc. MQ (Pridoli–Lochkov).

**Scyphocrinites spinifer** (Springer, 1917)

_Pl. 3, Fig. 6_

_Scyphocrinus spinifer_ Springer, 1917: 46, pl. 9, figs 1a–c.
_Scyphocrinites spinifer._—Bassler & Moodey, 1943: 676.

**Diagnosis.**—Scyphocrinites with coarse, stellate ornament and a thick, sometimes forked, spine on most cup plates.


**Remarks.**—Springer (1917) assigned a single, spinose specimen of _Scyphocrinites_ to _S. spinifer_, the spines serve to separate this species from all other _Scyphocrinites_. No specimens assignable to this species were found during this study.

**Type and Occurrence.**—Holotype, USNM S332, calyx with proximal arms, proximal stem; specimen 40 mm high, 30 mm wide (illustration from Springer, 1917: pl. 9, fig. 1b). Ross Limestone, Hardin County Tennessee (Lochkov).

Superfamily **EUCALYPTOCRINITOIDEA** Roemer, 1885

Family **EUCALYPTOCRINITIDAE** Roemer, 1885

**Diagnosis.**—Melocritinoideans with large first interradial plate; 2 elongate interradials in second range; first intersecundibrachials large, elongate.

**Remarks.**—The Eucalyptocrinitidae were placed in the superfamily Eucalyptocrinitoidea, along with the Clonocrinidae, Dolatocrinidae, and Polypeltidae by Ubags (1978a). The Dolatocrinidae and Polypeltidae are placed herein in the superfamily Patelliocrinoidea primarily because they possess three unequal basals. The Eucalyptocrinidae and Clonocrinidae are placed within the Melocritinoidea, and Eucalyptocrinitidae is suppressed. This action unites all glyptocrinines with four basals. Witzke & Strimple (1981) suggested a patelliocrinid ancestry for the Eucalyptocrinidae.

Genus **EUCALYPTOCRINITES** Goldfuss, 1831

**Type Species.**—_Eucalyptocrinites rosaceus_ Goldfuss, 1831.

**Diagnosis.**—Eucalyptocrinitids with basal invagination and tegminal partition plates completely separating free arm pairs.

**Remarks.**—The Eucalyptocrinitidae contains four genera. _Eucalyptocrinites_ is distinguished from _Calliocrinus_ d’Orbigny, 1850, by the possession of partition plates, which completely separate adjacent pairs of arms. These partition plates rest on either the two elongate plates of the second range of interray plates or the single intersecundibrachial. In _Calliocrinus_, the partition plates separate the arm pairs only proximally. Both _Eucalyptocrinites_ and _Calliocrinus_ possess a basal concavity, whereas _Archeocalyptocrinus_ Witzke & Strimple, 1981, does not. Eckert & Brett (2001) described a new eucalyptocrinitid, _Aclistocrinus_, which has a basal concavity but partially exert basals.

There are more than 40 described species of _Eucalyptocrinites_ and the calyces of many species are very similar in appearance. In many, the morphology of the calyx above the base of the free arms is diagnostic, making specific identification difficult to impossible with specimens preserving only the calyx.

Six specimens of _Eucalyptocrinites_ were collected during this study; all are from the Decatur Limestone. Of these, only one is identifiable with reasonable certainty, and is referred to _E. pernodosus_ (Springer, 1926); four individuals are moderately conical with variable basal concavities and variously shaped smooth plates; one cup is low and hemispherical with nodose plates and a deep basal concavity. Four distinct morphologies, herein given informal species rank, can be distinguished from the five unassigned specimens, identified by letters A–D. Examination of the type and paratype of _Clonocrinus occidentalis_ reveals that they represent two different species of _Eucalyptocrinites_, not _Clonocrinus_.

_Eucalyptocrinites_ is in great need of revision and many of the species are probably synonymous. Macurda (1968) suggested some synonymies but did not attempt a comprehensive revision. Until such a revision is made, proposing diagnostic specific characters and identifications of many specimens must remain tentative.

_Eucalyptocrinites pernodosus_ (Springer, 1926)

_Pl. 5, Figs 1, 7_

_Eucalyptocrinites pernodosus_, Springer, 1926a: 38, pl. 9, figs 1–4.
_Eucalyptocrinites pernodosus._—Bassler & Moodey, 1943: 466;
Strimple, 1963: 104, pl. 7, figs 1–2.
**Diagnosis.**—*Eucalyptocrinites* with large nodes or blunt spines on calyx plates; basal concavity wide, deep.

**Description.**—Calyx moderately conical with a flat base and wide, deep, pentalobate basal concavity. Large, blunt spines on all plates. Basals 4, confined to lower half of basal concavity, 3 equal, 1 larger. Radials 5, equal, slightly less than half incurved into basal concavity. First primibrachial short (wider than high), approximately half as high as radial; second primibrachial larger; one fragmentary secundibrachial preserved; no further ray plates preserved. First interradial plate large, equidimensional; no further plates preserved. Arms and tegmen not preserved.

**Remarks.**—*Eucalyptocrinites pernodosus* is unique among *Eucalyptocrinites* species in possessing large blunt spines or nodes. This characteristic allows fragmentary specimens, such as the present one (Pl. 5, fig. 7), to be identified. Only one ray is preserved beyond the radials, and it exhibits both primibrachials and a partial secundibrachial. The first primibrachial is incompletely developed, which allows the second primibrachial to join with the radial.

**Material and Occurrence.**—One fragmentary specimen, PRI 53685, showing the inside of the cup, preserving basals, radials, and in one ray, both primibrachials and one partial secundibrachial. Lower to middle Decatur Limestone, loc. PVb (Pridoli).

*Eucalyptocrinites* sp. A

**Pl. 4, Fig. 13**

**Diagnosis.**—*Eucalyptocrinites* with deep, subglobose calyx, vertical-sided, pentalobate basal concavity, and short, wide nodes on major cup plates.

**Description.**—Calyx subglobose with deep, vertical-sided, slightly pentalobate basal concavity. Basals 4, subequal, at bottom of basal concavity. Radials 5, equal, with sharp bend, extending well into basal concavity. First primibrachial small, much wider than high (width:height = 2:1); large truncate second primibrachial supporting large intersecundibrachial. Secundibrachials 2 in each half ray; 1 tertibrachial in each quarter ray. First interradial plate large, somewhat wider than high (width:height = 4:3); large interradials 2 in second range. Arms and tegmen not preserved.

**Remarks.**—This species is distinguished from other Decatur eucalyptocrininits by its subglobose cup shape, deep, narrow pentalobate basal concavity, and calyx plates with long, wide nodes. It differs from *Eucalyptocrinites pernodosus* in having a much narrower base, vertical and narrow basal concavity, and much less-developed ornamentation. The other specimens, described below as *E.* sp. B, C, and D, all have moderately conical calyces and smooth, flat plates.

This specimen is most similar to *Eucalyptocrinites decorus* (Phillips, 1839) (Wenlock Limestone, Dudley, England, Wenlock), which has depressed sutures. It also resembles *E.* rosaceus Goldfuss, 1831 (Eifel, Germany, Eifelian), but that species has a wider base, a larger and less steep basal concavity, and greater development of nodes, including nodes on the inner and intersecundibrachial plates, which are lacking in *E.* sp. A. *Eucalyptocrinites* sp. A could represent a new species.

**Material and Occurrence.**—One partial cup, PRI 53677, preserving all basals and radials, two complete rays and most of a third, and three complete interray areas; 7 mm high, 18 mm wide. Lower to middle Decatur Limestone, loc. PVb (Pridoli).

*Eucalyptocrinites* sp. B

**Pl. 4, Fig. 16**

**Diagnosis.**—*Eucalyptocrinites* with moderately conical calyx; smooth, flat plates; first primibrachial plate nearly equidimensional; first interradial plate elongate; first intersecundibrachial not in contact with the second primibrachial (axillary).

**Description.**—Calyx medium conical, circular in plan view. Basal concavity moderately deep. Basals 4, equal. Radials 5, equal. First primibrachial quadrangular, approximately as high as wide. Second primibrachial approximately as high as wide, not in contact with the intersecundibrachials. First secundibrachial larger than primaxil; second secundibrachial wider than intersecundibrachial. First interradial elongate (width:height = 1.5:1). Second range interradials paired, much larger than intersecundibrachials (width:height = almost 2:1). Arms, tegmen, and stem not preserved.

**Remarks.**—This species is distinguished by its smooth plates, moderately conical calyx, elongate first interray plate, and separation of the primaxil from intersecundibrachials. It is most similar to *Eucalyptocrinites crassus* (Hall, 1863) (Waldron Shale, Indiana, Wenlock; Frest et al., 1999) and might be conspecific. However, before identification can be made, all species of *Eucalyptocrinites* need to be re-examined to detail intraspecific variation.

**Material and Occurrence.**—One partial cup, PRI 53680, preserving all basals, three complete radials plus a partial radial,
two nearly complete rays and most of a third, and two nearly complete interrays; 17 mm high, 21 mm wide. Upper Decatur Limestone, loc. BQ (Pridoli).

**Eucalyptocrinites** sp. C  
Pl. 4, Fig. 15

**Diagnosis.**—*Eucalyptocrinites* with moderately conical calyx, deep basal concavity, wider than high first primibrachial (width:height = 2:1); first interradial equidimensional; second range interray plates and first intersecundibrachials equal in width.

**Description.**—Cup moderately conical. Basal concavity deep, slightly pentalobate. Plates flat, smooth. Basals 4, confined to lower part of basal concavity. Radials 5, equal, with sharp bend, composing most of basal concavity. First primibrachial quadrangular, twice as wide as high; second primibrachial truncate, slightly wider than high, supporting intersecundibrachial. Secundibrachials 2 per half-ray; second secundibrachial pentagonal. One relatively large tertibrachial per quarter ray. First interradial large, equidimensional; second range interradials paired, together nearly as large as first interradial. First intersecundibrachial as wide as paired second range interradials. Arms, tegmen, and stem not preserved.

**Remarks.**—The deep basal concavity, wide first primibrachial, equidimensional first interradial, and relatively wide second range interradials and intersecundibrachials collectively distinguish this form from others in the Decatur Limestone. It is closest in morphology to *Eucalyptocrinites phillipsi* Troost, 1849 (Beech River, Tennessee, Ludlow) (see Wood, 1909). The calyx width expands somewhat faster than the height, which produces slightly concave sides. This feature is similar to the large species *E. magnus* (Worthen, 1875) from the Waldron Shale of Tennessee (Wenlock). The specimen is small and might be a juvenile.

**Material and Occurrence.**—One partial calyx, PRI 53679, preserving basals and radials, two complete rays and one nearly complete ray, two complete interrays, and two incomplete rays; 6 mm high, 12 mm wide. Upper Decatur Limestone, loc. Q13 (Pridoli).

**Eucalyptocrinites** sp. D  
Pl. 4, Fig. 14

**Diagnosis.**—Cup medium conical; shallow basal concavity; plates flat and smooth. Basals 4, nearly flat, subequal, forming top of basal concavity. Radials 5, equal, with sharp deflection, accounting for most of basal concavity depth, most of radial outside of basal concavity. First primibrachial nearly equidimensional, slightly wider than high (width:height = 1.25:1); second primibrachial truncate, supporting intersecundibrachial. Secundibrachials 2 per half-ray; second secundibrachial flat-topped. Tertibrachials small. First interradial slightly elongate to equidimensional; width of paired second interradials greater than first intersecundibrachial. Arms, tegmen, and stem not preserved.

**Remarks.**—The shallow basal concavity, first interradial equidimensional, and high first primibrachial distinguish this form from the other smooth-plated, medium-conical *Eucalyptocrinites* species from the Decatur Limestone. The calyx form is closest to that of *Eucalyptocrinites milliganae* (Miller & Gurley, 1895) (Beech River, Tennessee, Ludlow), but the tegmen is absent, which precludes definite assignment to that species. All species of *Eucalyptocrinites* need to be re-examined, and this is particularly so for those forms with flat smooth plates. Possibly, the proportional variations in cup and plate dimensions described above and elsewhere (Wachsmuth & Springer, 1897; Springer, 1926a) for separating the described species of *Eucalyptocrinites* will prove to be merely intraspecific variation within one or a few species.

**Material and Occurrence.**—Two partial calyces, each preserving at least one complete ray and interray. Specimen PRI 68313, 12 mm high; specimen PRI 53678, 8 mm high. Width measurements are not possible. PRI 68313, lower to middle Decatur Limestone, loc. PVb (Pridoli).

**Eucalyptocrinites occidentalis** (Springer, 1926) n. comb.  
Pl. 4, Figs 9–10

**Diagnosis.**—*Eucalyptocrinites* with smooth, concave cup plates with raised plate sutures.

**Description.**—Calyx open bowl-shaped. Calyx plates smooth, concave, with raised sutures. Basal concavity deep, pentagonal. Basals 4, small, deep in basal concavity. Radials 5, large, involved in basal concavity. Radial-radial sutures forming short projections from base. Primibrachials 2; first primibrachial quadrangular; primibrachials approximately as high as wide; second primibrachial axillary, approximately as high as wide. One interradial, large; two interradials in second range.
One intersecundibrachial. Cup plates beyond second secundibrachial, arms, tegmen, and stem not preserved.

Remarks.—The holotype and paratype of Clonocrinus occidentalis were examined during this study and are considered here to be two different species of Eucalyptocrinites. The original incorrect generic assignment appears to have been the result of misinterpretation of the somewhat fractured second range of interradials. The calyx of the holotype (USNM S213) differs in morphology from that of any other species of Eucalyptocrinites by having shallowly concave plates and raised sutures. This ornamentation gives a scalloped appearance to the radials composing the base, which results in blunt, downward projections formed by the radial-radial sutures. The plate configuration and invaginated basal circllet indicate that these specimens belong to Eucalyptocrinites.

In contrast, the paratype (USNM S5846) has tumid plates, depressed sutures, and ray ridges, features that strongly differentiate it from any other species of Eucalyptocrinites in the Decatur Limestone. This crinoid is removed from E. occidentalis and is referred, herein, to Eucalyptocrinites sp. E. No additional specimens of E. occidentalis were found during the course of this study.

Material and Occurrence.—Holotype, USNM S213, partial cup preserved to the second secundibrachial level. Decatur Limestone, loc. PVa (Pridoli).

Eucalyptocrinites sp. E
Pl. 5, Fig. 2

Diagnosis.—Eucalyptocrinites with smooth, tumid plates, depressed sutures, and ray ridges.

Description.—Calyx low, conical. Plates smooth, tumid; sutures depressed; ray ridges present. Basal concavity shallow. Basals 4, confined to basal concavity. Radials 5, large. Primibrachials 2; first primibrachial quadriangular; second primibrachial axillary. Secundibrachials 2 preserved in each quarter ray. First interradial large; two interradials in second range. One intersecundibrachial in each ray. Calyx distal to first secundibrachial, arms, tegmen, and stem not preserved.

Remarks.—Among species of Eucalyptocrinites from the Decatur Limestone, E. sp. E most closely resembles E. sp. A (of this study) in possessing tumid cup plates, but differs from that species primarily in possessing prominent ray ridges. The only known specimen is the paratype of Clonocrinus occidentalis in the Springer Collection at the USNM, but was not illustrated or described by Springer (1926a; see discussion under E. occidentalis). No specimens of this species were found during this study.

Material and Occurrence.—Partial cup, USNM S5846. Decatur Limestone, loc. PVa (Pridoli).

Eucalyptocrinites sculptilis (Springer, 1926)
Pl. 4, Figs 11–12

Eucalyptocrinus sculptilis Springer, 1926a: 38, pl. 9, figs 5–6a.
Eucalyptocrinites sculptilis.—Bassler & Moodie, 1943: 467.

Diagnosis.—Eucalyptocrinites with a low, open bowl-shaped calyx, wide basal concavity, and slightly tumid plates with fine, radiating ridges that connect with counterparts on adjacent plates.

Description.—Calyx low, open bowl-shaped (nearly conical); calyx plates slightly tumid with fine, radiating ridges that connect with counterparts on adjacent plates. Basal concavity wide. Basals 4, confined to basal concavity. Radials 5, large, composing much of basal concavity. Primibrachials 2; first primibrachial quadriangular, wider than high; second primibrachial axillary. Secundibrachials 2, second axillary. First interradial large; two interradials in second range. One intersecundibrachial in each ray. Arm partition plates flaring outward distally. Column heteromorphic; nodals overlapping internodals.

Remarks.—This species was described by Springer (1926a) from the Decatur Limestone. No specimens were found during this study. Eucalyptocrinites sculptilis differs primarily from other species in the Decatur Limestone by its distinctive ornamentation.

Material and Occurrence.—Syntype, USNM S402, cup. Decatur Limestone, loc. PVa (Pridoli).

Superfamily PATELLIOCRINOIDEA Angelin, 1878

Diagnosis.—Glyptocrinines with 3 unequal basals, rarely five or fused.

Remarks.—The Patelliocrinoidea, as herein defined, contains the Patelliocrinoidea (sensu Ubaghs, 1978a) plus Platyocrinioidea and two families previously placed in the Eucalyptocrinioidea: Dolatocrinidae and Polypeltidae. All of these groups share the characteristic of three unequal basals, two zygous and one azygous. This characteristic distinguishes them from representatives of the Melocrinioidea, which have four basals, and the Glyptocrinioidea, which have five. Because basals are among the first plates formed during ontogeny, variations should reflect basic taxonomic differences. Convergence is possible, but there are no other morphologic...
features to suggest that this was the case. All of the contained
groups, instead, appear to be closely related.

Two major trends are apparent within the Patelliocrinoidea. The first involves the reduction of fixed brachial plates and expulsion of interradials from the cup, ultimately resulting in a cup composed of little more than basal and radial plates. From this trend arose the Marsupiocrinidae, Hapalocrinidae, and Platycrinitidae, as has been noted previously (Brower, 1973; Frest, 1975; Moore & Laudon, 1943; Frest & Strimple, 1977c, 1980). The second trend, heretofore unrecognized, involved increasing calyx size, an increase in the number of fixed brachials, and increasing size and number interradial plates. This trend gave rise to the Polypeltidae, Dolatocrinidae, and Parapatelliocrinidae n. fam.

Brower (1973) used the number of fixed brachials and the number of basals as superfamily- and family-level taxonomic characters, respectively. The number of basals is nearly invariant throughout the families listed above with only one patelliocrinid (Centriocrinus Bather, 1899) and a few platycrinitids (e. g., some species of Platycrinites Miller, 1821) with fused basals. This shared characteristic is obviously a unifying feature for the entire group. The number of fixed brachials and interradials is variable and is significant only at or below the family level.

Superfamily PATELLIOCRINOIDEA Angelin, 1878
Family PATELLIOCRINIDAE Angelin, 1878

Diagnosis.—Patelliocrinoidaeans with aboral cup composing significant proportion (usually > 20%) of calyx height, few fixed brachials, and few interradials in calyx.

Remarks.—The families within the Patelliocrinoidae are distinguished primarily by the degree of inclusion of brachials and interradial plates and, consequently, the prominence of basals and radials in the cup. The Marsupiocrinidae, Hapalocrinidae, and Platycrinitidae are distinguished by a cup mostly reduced to the basals and radials, with the fixed brachials and interradials playing a subordinate role. The Marsupiocrinidae is distinguished by flattened fixed brachials, and the Hapalocrinidae and Platycrinitidae are separated by tegmen structure. The families Prokopicrinidae, Hinacrinidae, and Eutelecrinidae of Frest & Strimple (1977b, 1978b, 1980) all have calyces reduced to basals and radials.

Among the more complexly constructed forms, the Polypeltidae is distinguished by the large number of both fixed brachials and interradials. The Parapatelliocrinidae n. fam. is distinguished by the large number of interradials in conjunction with relatively few fixed brachials.

The Patelliocrinidae, the rootstock of the superfamily, is more difficult to characterize because it contains a greater variety of morphologies. However, it is distinguished by the presence of few interradials and fixed brachials; these plates make up a significant portion of the calyx, thus distinguishing the Patelliocrinidae from those patelliocrinidean families with calyces reduced to aboral cups.

Members of the Dolatocrinidae exhibit similar morphology compared with the Patelliocrinidae. This is particularly true of Dolatocrinus, in which the main distinguishing character is the flattened calyx shape and coincident short aboral cup. Herein, Dolatocrinus is considered to be derived from the Parapatelliocrinidae n. fam. and thus convergent on the patelliocrinid morphology for reasons given under the discussion of the Dolatocrinidae.

Genus MACROSTYLOCRINUS Hall, 1852

Type species.—Macrostylecrinus ornatus Hall, 1852.

Diagnosis.—Patelliocrinids with biserial arms and a differentiated anal area.

Remarks.—Patelliocrinid genera are separated by the nature of the arms, differentiation of the anal region, and, to some degree, calyx shape. Macrostylecrinus is distinguished from other patelliocrinids by its biserial arms and differentiated anal region. Allocrinus Wachsmuth & Springer, 1889, and Briarocrinus Angelin, 1878, have hyperpinnulate, uniserial arms; Eopatelliocrinus Brower, 1973, has normally pinnulate, uniserial arms. Patelliocrinus Angelin, 1878, has biserial arms but lacks a differentiated anal area. The arms of Centriocrinus and Laurelocrinus Springer, 1926, are not known, but Centriocrinus has fused basals and spinose radials; Laurelocrinus has a cylindrical calyx with a depressed base and an undifferentiated anal area. The Hopkinton (Llandovery) genera proposed by Witzke & Strimple (1981), namely Thomasocrinus and Krinocrinus, either lack differentiated CD interrays (Thomascinocrinus) or are differentiated only distally (Krinocrinus). Bolocrinus Witzke & Strimple, 1981, is placed within the Parapatelliocrinidae n. fam., described below.

Macrostylecrinus, with its biserial arms and differentiated anal region, is thought to have given rise to several different lineages whose differentiated anal regions were expelled from the calyx to the tegmen, along with most other interray plates. These include the Hapalocrinidae and Platycrinitidae (Frest & Strimple, 1977b) and the Marsupiocrinidae (Ausch, 1986; Frest, 1975). However, as noted by Witzke & Strimple (1981), Macrostylecrinus encompasses a variety of morphologies and thus is in need of taxonomic revision. Three species of Macrostylecrinus are recognized from the Rockhouse Limestone.
**Macrostyleocrinus tertibrachialis** n. sp.

*Pl. 5, Figs 4, 8*

**Diagnosis.**—*Macrostyleocrinus* with open bowl-shaped calyx, flattened base, and fixed tertibrachials.

**Description.**—Calyx open bowl-shaped; base nearly flat, only slightly convex; radials nearly vertical. Ornament composed of small, sharp ridges connecting adjacent basals and radials, and large granules on and between ridges. Basals 3, unequal, composing nearly flat base, azygous basal in AE interray. Radials 5, equal, slightly wider than high. First primibrachial quadrangular, wider than high, in rounded notch on radial; second primibrachial axillary, wider than high. Secundibrachials 2 per half ray, wider than high. At least 2 fixed tertibrachials per quarter ray, wider than high. Interradial larger than brachials, tumid internally. Interradials 2 in second range, elongate. Anal interray wider than normal interrays; primanal somewhat smaller than normal interadials, followed by 5 plates in next range, 2 of these touching radial shoulders on either side of primanal, and extending toward radials more than half primanal length. One elongate intersecundibrachial. Free arms, tegmen, and stem unknown.

**Remarks.**—Species of *Macrostyleocrinus* are distinguished primarily by calyx shape, ornamentation, and ray structure (Springer, 1926a, b; Witzke & Strimple, 1981). *Macrostyleocrinus tertibrachialis* n. sp. is distinguished from most other species by the possession of fixed tertibrachials resulting in at least 20 free arms. This feature alone separates this form from all others except *M. recumbens* Springer, 1926b (Oriskany Sandstone, Maryland, Emsian). However, *M. recumbens* has 23–25 recumbent arms and a nearly smooth, conical calyx. *Macrostyleocrinus tertibrachialis* n. sp. has a nearly flat base, rounded to nearly vertical radials, and the calyx plates bearing small sharp ridges and large granules. The anal areas of *M. recumbens* and *M. tertibrachialis* n. sp. are very similar. Although the preserved fixed arms flare outward, this is interpreted as being due primarily to taphonomic effects, not a recumbent posture of the arms.

Witzke & Strimple (1981) referred *Macrostyleocrinus*-like forms with only one large interradial or with one or two plates in the second range to *Allocrinus*. Such forms with differentiated anal areas, including *M. tertibrachialis* n. sp., are referred back to *Macrostyleocrinus* because Ubaghs (1978a) correctly described *Allocrinus* as having little or no differentiation in the CD interray. Although free arms are not preserved on the only specimen of *M. tertibrachialis* n. sp. available, given the consistency of arm construction in *Macrostyleocrinus*, it is expected that the arms were biserial, and not hyperpinnulate as in *Allocrinus*.

**Type and Occurrence.**—One specimen, holotype, PRI 53681, preserving basals, radials, rays to the second tertibrachial in two rays (B,C), to secundibrachials in two rays (D,E), to the first primibrachial in one ray (A), and anal interray to second range. The interior is completely exposed; the base and most of one ray (C) are exposed on the exterior. The B and C rays are slightly broken, lying subparallel to bedding. Approximately 11 mm high, 18 mm wide. Lower Rockhouse Limestone, Allens Mill, ca. 87 cm above base (Lochkov).

**Etymology of Name.**—Specific name tertibrachialis, referring to fixed tertibrachials.

*Macrostyleocrinus cf. laevis* Springer, 1926

*Pl. 5, Figs 3, 5*

**Diagnosis.**—*Macrostyleocrinus* with open to erect bowl-shaped calyx, pronounced basal rim, smooth plates, and low ray ridges.

**Description.**—Calyx open to erect bowl-shaped with pronounced basal rim. Plates smooth, wide; shallow ray ridges present. Basals 3, unequal, composing nearly half of cup height. Radials 5, equal, nearly vertical, approximately as high as wide. First primibrachial quadrangular, wider than high; second primibrachial axillary, wider than high. Fixed secundibrachials 2 per half ray. First interradial larger than brachials; 2 plates in second range in normal interrays; anal interray unknown. Free arms, tegmen, and stem not preserved.

**Remarks.**—This species is distinguished by its smooth plates, wide shallow ray ridges and rimmed base. Assignment to *Macrostyleocrinus* is tentative because the anal region is not observable in any specimen collected for this study. If the CD interray was not differentiated, these specimens would have to be reassigned to *Patelliocrinus*. They are not, however *P. laevis* Springer, 1926a, because that species has zero or one interradial in the second range, whereas *M. ? laevis* has two. Also, the brachial proportions are not the same; *P. laevis* possesses nearly equal first secundibrachials, whereas those of *M. ? laevis* are much wider than high. Free arms were probably attached at or immediately above the second or third secundibrachial. Thus, if reassigment of *M. ? laevis* to *Patelliocrinus* becomes necessary, a new specific name will be required to avoid homonymy.

**Material.**—Eleven specimens, all incomplete: specimens PRI 53682–53683 and 68314–68316 with complete basal circlets; PRI 68314 with fragmentary radials; PRI 53683 and 68315, with two complete radials (A, E). Specimen PRI 53682 with three complete radials (A, B, E) and rays A and E preserved to
the second secundibrachial; first interradial preserved in AB, AE, and DE interrays, to second range in AB and AE interrays. Specimen PRI 68316 is disarticulated. Specimens PRI 68317–68318 are fragmentary. PRI 68319 preserves most of the basal circlet and two rays to the first secundibrachial; PRI 68320 is disarticulated but retains stem and disarticulated arms. Specimen PRI 68321 is crushed, preserving basals and interrays; PRI 68322 is weathered, preserving the A ray to the first secundibrachial, with E, A, and B radials exposed. Largest specimen (PRI 68317) 26 mm high to IIBr2; most complete specimen (PRI 53682) 12 mm high to second secundibrachial, 13 mm wide at the first secundibrachial level.

**Occurrence.**—Specimens PRI 53682–53683 and 68314-68318 from the Lower Rockhouse Limestone, loc. BQ. Specimens PRI 68319–68322 from the lower Rockhouse Limestone, loc. AM (Lochkov). A twelfth specimen (PRI 68323), which differs from *Macrostylocrinus laevis* in having a more bowl-shaped calyx (less steeply sloping basals), collected in rip-rap near the Gilmore Street bridge in Lobelville; it is not included here because of uncertainties in stratigraphic position, with the lithology suggesting either lower Rockhouse or Brownsport formation (Ludlow).

*Macrostylocrinus* cf. *pustulosus* Springer, 1926

Pl. 5, Fig. 6

*Macrostylocrinus pustulosus* Springer, 1926a: 26, pl. 4, figs 25, 25a.

**Diagnosis.**—*Macrostylocrinus* with calyx width:height ratio ca. 1:1, open bowl-shaped calyx, and coarse granulose ornament.

**Description.**—Calyx medium, open bowl-shaped. Coarse, granulose ornament, sometimes coalescing to form ridges. Basals 3, unequal, with basal rim. Radials 5, equal, approximately as high as wide. First primibrachial small, quadrangular, strongly protuberant; first interradial relatively small. Rays above the first primibrachial, tegmen, free arms, and stem not preserved.

**Remarks.**—This species is characterized by calyx shape and coarse, granulose ornament. Additionally, the first primibrachial protrudes away from the top of the radial and especially so from the first interradial. It is likely that the second primibrachial is the highest fixed brachial. This form is placed within *Macrostylocrinus* because the CD interray is wider than the others and the adjacent radial shoulders project upward to a greater height. However, cup shape and ornament are closer to that of *Patelliocrinus rugosus* Springer, 1926a (Laurel Limestone, Indiana, Wenlock; Frest et al., 1999). The primibrachials of *M. cf. pustulosus*, however, are quite different, being much narrower and protrusive, as opposed to the wider, nonprotrusive primibrachials of *P. rugosus*.

The present specimens are sufficiently different to warrant a new species; the cup shape and brachials do not match those of *Macrostylocrinus pustulosus*, which has a flat base, wider, less protrusive brachials, and fixed secundibrachials. However, without better-preserved specimens, proposing a new species to accommodate them is not justified.

The three species of *Macrostylocrinus* from the lower Rockhouse Limestone are sufficiently different for easy segregation. However, *M. ? laevis* and *M. cf. pustulosus* are not well enough preserved to be certain of their identities, either as previously known species or as new ones.

**Material.**—Two calyces preserving basals and radials, the larger (PRI 53684) preserving the first primibrachial in two rays (D and E) and the first interradial between them; 1 mm high, 15 mm wide. Smaller specimen (PRI 68324) 9 mm high, 12 mm wide, slightly crushed, with part of base missing.

**Occurrence.**—Lower Rockhouse Limestone, smaller specimen (PRI 68324) at loc. PQ, larger specimen (PRI 53684) from loc. AM (Lochkov).

Family **MARSUPIOCRINIDAE** Bronn, 1855

*Diagnosis.**—Patelliocri­nioideans with calyx reduced mostly to basals, radials, and first interradials; compressed (flattened) proximal secundibrachials in calyx, fixed to level of the first interradial.

**Remarks.**—Marsupiocrinids, known from three genera (*Marsupiocrinus*, *Manticrinus* Ausich, 1986, and *Paramarsupiocrinus* n. gen.) are unique among patelliocri­nioideans in having compressed secundibrachials incorporated within the calyx and fixed by the large first interradial. The fixed secundibrachials are much wider than high and one or more abut the first interradial plate. This feature plus the reduced calyx composed chiefly of basals and radials makes marsupiocrinids unmistakable. Ausich (1986) inferred that *Manticrinus*, a Brassfield marsupiocrinid, was derived from a *Macrostylocrinus*-like patelliocrinid. He suggested that *Manticrinus*, in turn, gave rise to *Marsupiocrinus*. The relationship of *Paramarsupiocrinus* n. gen. to other marsupiocrinid genera is unclear.

Genus **MARSUPIOCRINUS** Morris, 1843

*Type species.*—Marsupiocrinites coelatus Phillips, 1839.

*Diagnosis.*—Marsupiocrinids with undifferentiated anal region and a single, reduced, triangular first primibrachial.
Remarks.—Marsupiocrinus is distinguished by its single, small, triangular primibrachial, and its undifferentiated anal area. *Mannicrinus* has two primibrachials, the second of which closely resembles the single primibrachial in *Marsupiocrinus*; the CD interray is differentiated from the other interrays. The primibrachial of *Marsupiocrinus* is surrounded on two sides by secundibrachials, the sides of which are in wide contact with the radials.

Subgenus *AMARSUPIOCRINUS* Frest, 1975

Type Species.—*Marsupiocrinus* (*Amarsuicioocrinus*) *striatissimus* (Springer, 1926).

Diagnosis.—*Marsupiocrinus* with two arms per ray and basal rim.

Remarks.—Frest (1975: 569) separated *Marsupiocrinus* into two subgenera using calyx shape and the number of free arms. *Marsupiocrinus* (*Amarsuicioocrinus*) has four free arms per ray, no basal rim, a broad basal invagination involving the basals and radials, a gently convex base, and greatly elongated first interradials. *Marsupiocrinus* (*Amarsuicioocrinus*) has two arms per ray, a pronounced basal rim, a nearly planar base, and subquadrate first primibrachials. *Marsupiocrinus* (*Amarsuicioocrinus*) is confined to North America; *M. (Marsupiocrinus)* is mostly restricted to Europe, with *M. (M.)* *tentaculatus* (Hall, 1859) (New Scotland Limestone, New York, Lochkovian) being the sole North American representative.

The specimen described more completely below, under *Marsupiocrinus* (*Amarsuicioocrinus*) *excavatus*, has two arms per ray, a basal rim, but an elongate first interradial and a broad basal invagination involving basals and radials. The two arms per ray and basal rim definitely ally the specimen with *M. (Amarsuicioocrinus)*; this casts doubt on the value of a broad, basal invagination and elongate first interradials as subgeneric discriminators. Another specimen assigned to the same species, with a large, subquadrate first interradial in one ray and much smaller, elongate first interradials in other rays, also raises doubt about the utility of this feature at the subgeneric level. *Marsupiocrinus* (*A. magnificus*) (Troost, 1850) (Beech River Formation, Tennessee, Ludlow), possesses four arms per ray, but has a basal rim, a subquadrate first interradial plate, and no basal invagination; these characters denote assignment to *M. (Amarsuicioocrinus)* (Springer, 1926a; Frest, 1975). Therefore, the two subgenera are divided primarily on the number of arms per ray and the presence or absence of a basal rim. The other characters are somewhat variable. This is consistent with Witzke & Strimple’s (1981) restricted diagnosis of *M. (Amarsuicioocrinus)*. The variable characters, when used in combination with each other, can be helpful in assignment of forms that have variability in the primary characters.

**Marsupiocrinus (Amarsuicioocrinus) cf. tennesseensis**

(Roemer, 1860)

Pl. 5, Figs 9, 12

*Marsupiocrinus tennesseensis* Roemer, 1860: 35, pl. 3, figs 4a–f.

*Marsupiocrinus tennesseensis*.—Wachsmuth & Springer, 1889: 375, pl. 19, fig. 7; 1897: 731, pl. 75, figs 16a–b; Springer, 1926a: 57, pl. 14, figs 1–6a.

*Marsupiocrinus (Amarsuicioocrinus) tennesseensis*.—Frest, 1975: 570.

Diagnosis.—*Marsupiocrinus (Amarsuicioocrinus)* with low, open bowl-shaped calyx; no basal invagination; basal pentagon two-thirds of calyx diameter.

Description.—Cup very low, bowl-shaped; plates smooth or finely striate, Basals 3, large, unequal; basal rim prominent; basal pentagon comprising two-thirds diameter of cup. Radials 5, large, equal, much wider than high (height:width > 2:1). First primibrachial very small, rounded triangular. First secundibrachial relatively large, resting on radials. First interradial large, elongate. Rays beyond the first secundibrachial, tegmen, and stem not preserved.

Remarks.—Species of *Marsupiocrinus (Amarsuicioocrinus)* have been separated primarily using calyx shape, size of the basal pentagon relative to the cup diameter, and ornamentation (Springer, 1926a; Frest, 1975; Witzke & Strimple, 1981). Tegmen convexity and definition of ambulacra are secondary features. As suggested by Strimple (1963), the species contained in *M. (Amarsuicioocrinus)* need to be re-examined. There are certainly synonyms among the 11 species recognized by Springer from the Brownsport Formation of west-central Tennessee, and it is expected that many of these species will be prove to be intraspecific variants.

Material and Occurrence.—Three specimens, severely corroded, preserving basals and radials. One specimen, PRI 68325, preserving the first primibrachial and both first secundibrachials in one ray and one first interradial plate. Specimen PRI 53686 is preserved only to the radials; PRI 53687 has been halved longitudinally and retains some tegmen. PRI 68325 and 53686 are each 33 mm wide, 12 mm high. Specimen PRI 53687 is 30 mm high to tip of tegmen, 35 mm wide at arm level. All specimens are from the lower to middle Decatur Limestone; loc. PVb (Pridoli).

**Marsupiocrinus (Amarsuicioocrinus) cf. excavatus**

Springer, 1926

Pl. 5, Figs 11, 14

*Marsupiocrinus excavatus* Springer, 1926: 60, pl. 16, figs 7, 7b.

*Marsupiocrinus (Amarsuicioocrinus) excavatus*.—Frest, 1975: 569.
**Diagnosis.**—*Marsupiocrinus* (*Amarsupiocrinus*) with broad basal invagination involving radials; 2 large, laterally connected tubercles on radials; first interradial with single large spine; basal pentagon one third diameter of calyx.

**Description.**—Calyx nearly flat, open bowl-shaped, with basal invagination involving radials. Radials with 2 large connected tubercles centered at widest region; first interradial plate with one large proximal spine; scattered small tubercles on rest of cup. Basals 3, unequal; stem cicatrix with large lumen; basal rim weak. Radials 5, large, equal, much wider than high. First primibrachial small, triangular. First secundibrachial large, wide, in contact with radial; other secundibrachs to third. First interradial plate slightly elongate. Free arms, tegmen, and stem not preserved.

**Remarks.**—The two available specimens are closest in morphology to *Marsupiocrinus* (*Amarsupiocrinus*) *excavatus*. However, the dual, laterally connected tubercles on the radials, the spine on the first interradial, and the broad basal invagination involving the radials are not features characteristic of *M. (A.) excavatus*. These characters would be sufficient to recognize a new species based on current taxonomic practice for *M. (Amarsupiocrinus)*. However, we suspect that many of the species now named will prove to be variants of a few species that are more variable than is now recognized. Pending revision of *M. (Amarsupiocrinus)*, it seems best not to add further species. In one specimen, a first interradial is greatly enlarged, and is interpreted as the primanal. The azygous plate would then be in the AE position, which is normal for patellocrinioideans.

**Material and Occurrence.**—Two specimens, both partial calyces. Specimen PRI 53690, crushed calyx preserving secundibrachs in three rays, *ca.* 35 mm wide. Specimen PRI 53689, preserved to first secundibrachial in two rays; 32 mm wide, 8 mm high. Specimen PRI 53690 is from the lower (?) Decatur Limestone at an outcrop on the northeastern corner of the junction of State Route 67 and Cherokee Landing Road, Decatur County. PRI 53689 is from the Decatur Limestone at loc. MQ (Pridoli).

*Marsupiocrinus (Amarsupiocrinus) devonicus* n. sp.

Pl. 5, Figs 10, 13

**Diagnosis.**—*Marsupiocrinus (Amarsupiocrinus)* with low, bowl-shaped calyx, high tegmen, smooth plates, and basal pentagon one third diameter of calyx; ambulacra not distinct on tegmen.

**Description.**—Calyx low, open bowl-shaped; plates smooth except the first interradial, which has small node on proximal part. Basals 3 (?), unequal, with distinct basal rim. Radials 5, equal. First primibrachial small, triangular. Secundibrachials 2; first secundibrachial large in wide contact with radial. First interradial subtriangular (shield-shaped). Tegmen high; most plates with small node; ambulacral regions slightly raised, but plates not differentiated. Free arms and stem not preserved.

**Remarks.**—This species is differentiated by its low bowl-shaped calyx, high tegmen, lack of distinct calyx ornamentation, nondistinct tegminal ambulacra, and relatively small basal pentagon. Unfortunately, the only specimen is badly crushed with the basals and radials pushed deeply into the body cavity and one entire ray is missing. Additionally, the basals and radials are badly fractured, making precise definition of the plate boundaries impossible. Only two plate boundaries are discernable in the basal circlet, but they do not define the azygous plate (which presumably exists). The character of the fixed brachials and tegmen are, however, well preserved. The tegminal ambulacra are not distinct as in *Marsupiocrinus (Amarsupiocrinus) rosaformis* (Troost, 1849) (Beech River Formation, Tennessee, Ludlow) or *M. (A.) stellatus* (Troost, 1850) (Beech River Formation, Tennessee, Ludlow), but the ambulacral areas are raised above the rest of the tegmen. One interambulacral area is swollen and is interpreted as the anal region. This species is closest to *M. (A.) excavatus*, but lacks the ornamentation and has a much more rounded calyx, as opposed to the flat calyx of *M. (A.) excavatus*.

The principal significance of this specimen lies in its stratigraphic position. It is from the upper Birdsong Shale (Bryozoan Zone), making it the latest *Marsupiocrinus (Amarsupiocrinus)* known, and the first reported of Devonian age.

**Type and Occurrence.**—One crushed specimen, holotype, PRI 53688, preserving most of calyx, less D ray, basals and radials crushed inward and badly fractured, secundibrachials preserved in four rays, tegmen apparently uncrushed; *ca.* 28 mm wide, preserved height including tegmen 18 mm. Upper Birdsong Shale (Bryozoan Zone), loc. PQ, found with *Dolatocrinus belderbergensis* and *Stiplitocrinus* sp. (Lochkov).

**Etymology of Name.**—Specific name *devonicus*, referring to the age of the formation in which the specimen occurs.

Genus **PARAMARSUPIOCRINUS** n. gen.

**Type Species.**—*Paramarsupiocrinus broadheadi* n. sp.

**Diagnosis.**—Marsupiocrinid with single, large primibrachial occupying the full width of radial, separating secundibrachials from radial.
Remarks.—Paramarsupiocrinus n. gen. differs from Marsupiocrinus and Manticrinus, the other two marsupiocrinids, in having a single, large primibrachial in each ray that completely separates the secundibrachials from the radial. This difference is considered significant enough to warrant recognition of a new genus. Marsupiocrinus also has a single primibrachial, but it is a small, triangular plate with a wide contact between the first secundibrachial and the underlying radial. Manticrinus (Auszich, 1986) has two primibrachials, with the primaxil being small, triangular, and similar to the single primibrachial in Marsupiocrinus. Marsupiocrinus (Amarsupiocrinus) primaevus Witzke & Strimple, 1981, is most likely a Manticrinus but has a wide second primibrachial. Manticrinus also has a differentiated posterior interradius, a feature lacking in Marsupiocrinus. The state of the CD interray is unknown in Paramarsupiocrinus broadheadi n. sp., because the single known specimen is incomplete. Paramarsupiocrinus n. gen. shares many characteristics with M. (Amarsupiocrinus) such as a flattened calyx, a basal rim, and secundibrachial morphology. Manticrinus has a different secundibrachial morphology and a globose calyx. It is suggested that Paramarsupiocrinus n. gen. evolved from M. (Amarsupiocrinus) because of their shared calyx morphologies. Stratigraphic age (Pridoli) also argues for derivation of Paramarsupiocrinus n. gen. from M. (Amarsupiocrinus).

Etymology of Name.—Para (Gr.), near, plus Marsupiocrinus, alluding to the similarity to that genus in calyx morphology.

**Paramarsupiocrinus broadheadi** n. sp.

Pl. 5, Fig. 15; Text-fig. 5

**Diagnosis.**—Same as for genus.

**Description.**—Calyx low, bowl-shaped, with a shallow basal concavity involving the radials only slightly. Radials, first primibrachials, and first interradials with coarse, corrugate ornament consisting of nodes and/or ridges; nodes connected by ridges; single ridge on the first primibrachial, subparallel to upper boundary. Principal node on radial slightly above center. Low V-shaped ridge on first interradial slightly below center. Fine ridges connecting adjacent plates. Basals 3, unequal, with basal rim. Radials 5, equal, wider than high. One primibrachial in each ray, wider than high, contacting adjacent first interradial. Fixed secundibrachials at least 3 in each half ray; one large, higher than wide interradial. Stem, arms, and tegmen not preserved.

**Remarks.**—See discussion under genus.

---

**Family PARAPATELLIOCRINIDAE** n. fam.

**Diagnosis.**—Patelliocrinoideans with numerous interradial plates, proximally differentiated anal region, and fixed brachials to first tertibrachial.

**Genera included.**—Parapatelliocrinus n. gen.; Bolicrinus; Eodolatocrinus n. gen.; Boliviocrinus McIntosh, 1988.

**Remarks.**—The Parapatelliocrinidae n. fam. comprises a small group of patelliocrinoideans with numerous interradials, a differentiated anal region, hexagonal first primibrachial, small first interradial, and fixed brachials only reaching to the proximal tertibrachials. Most patelliocriniids have few interradial plates except for some Late Ordovician forms, such as Macrostylocrinus cirrifer Ramsbottom, 1961 (see Brower, 1973), and Eopatelliocrinus scyphogracilis Brower, 1973, and Early Silurian forms like Macrostylocrinus silurocirrifer Brower, 1975, and Krinocrinus inflatus Witzke & Strimple, 1981. Krinocrinus also differs in its anal region, which is differentiated only in its distal part. The above species of Macrostylocrinus and *E. scyphogracilis* (Girardeau Limestone, Missouri, Ashgillian) have the large radials typical of patel-
The four genera of parapatelliocrinids contain only a few species, which are based on few specimens. *Bolicrinus* contains two species, *B. globosus* Witzke & Strimple, 1981, and *B. deflatus* Witzke & Strimple, 1981. *Eodolatocrinus* n. gen. contains two species, *E. niagarensis* (Springer, 1921) n. comb. and *E. blalsei* n. sp. The other two genera contain one species each. With the exception of the species of *Bolicrinus*, all species are known from single specimens.

McIntosh (1988), in his discussion of *Boliviacrinus isacsoni* McIntosh, 1988 (Sicasica Formation, Bolivia, Eifelian), and its similarities with *Bolicrinus*, suggested placement of the two genera in a new family if additional forms were found, particularly in Upper Silurian or Lower Devonian strata. With the discovery of forms in the Ross Formation, herein named *Parapatelliocrinus* n. gen. and *Eodolatocrinus* n. gen., and assignment of *Technocrinus niagarensis* Springer, 1921 (Brownsport Group, Tennessee, Ludlow), to *Eodolatocrinus* n. gen., erection of a new family is considered justified.

The Parapatelliocrinidae n. fam. is thought to have arisen from *Eopatelliocrinus* during the Early Silurian (Early Llandovery; McIntosh, 1988), inasmuch as the oldest known parapatelliocrinid is *Bolicrinus* from the Hopkinson Dolomite (Upper Llandovery; Witzke & Strimple, 1981). *Eopatelliocrinus* is the most likely ancestor because of its uniserial arms, a feature shared with *Boliviacrinus*, the only parapatelliocrinid known with arms. Members of Parapatelliocrinidae n. fam. were conservative crinoids that retained several primitive characteristics throughout their stratigraphic range, including hexagonal first primibrachials, and numerous interradial plates.

**Etymology of Name.**—Para (Gr.), near, plus *Patelliocrinus*, noting closeness of this family to the Patelliocrinidae.

**Range.**—Early Silurian (Llandovery) to Middle Devonian (Eifel).

**Genus** *PARAPATELLIOCRINUS* n. gen.

**Type Species.**—*Parapatelliocrinus broweri* n. sp.
as other first interrays; anal interradial pattern 1/3/2/2/1. All interrays open to tegmen. Free arms tegmen and stem not preserved; stem cicatrix circular.

Remarks.—Parapatelliocrinus n. gen. is well distinguished from other parapatelliocrinids. Parapatelliocrinus n. gen. evolved from a Bolicrinus-like form by the incorporation of the first tertibrachial in the calyx and the loss of a secundibrachial. It in turn gave rise to Boliviocrinus by elongation of the cup and addition of a secundibrachial. This parallels the situation seen in Dolatocrinus, in which the earliest species has only one primibrachial, but most later species have two.

Material and Occurrence.—One partial calyx, holotype, PRI 53692, preserving all of the D ray and portions of the C and E rays, and all of the CD and DE interrays. The cup is embedded in a slab of shaly limestone with the D ray well exposed. Although the opposite side is unexposed, other crinoid remains on the same slab indicate that it might be fragmentary or nonexistent due to biostratigraphic effects; ca. 25 mm wide, 13 mm high. Lower Rockhouse Limestone, loc. BQ (Lochkov).

Etymology of Name.—Specific name broweri, in honor of James Brower, Syracuse University, who has contributed much to the understanding of the Patelliocrinoida.

Genus **EODOLATOCRINUS** n. gen.

Type Species.—Eodolatocrinus hlabsei n. sp.

Diagnosis.—Parapatelliocrinid with strongly stellate to nodose ornamentation, single secundibrachial in each half ray, and interrays reduced to three ranges.

Remarks.—Eodolatocrinus n. gen. is most similar to Parapatelliocrinus n. gen. with which it shares a common ray structure. It is distinguished from other parapatelliocrinids by its reduced number of interradial plates (see discussion under Parapatelliocrinus n. gen.). This reduction is convergent back toward a more typical patelliocrinid morphology. As the name implies, Eodolatocrinus n. gen. is thought to have given rise to the Dolatocrinidae, through a form like *E. hlabsei* n. sp. (see below).

Etymology of Name.—Eo (Gr.), dawn, plus Dolatocrinus, alluding to the similarity in structure to and ancestral relationship with that genus.

**Eodolatocrinus hlabsei** n. sp.

Pl. 6, Figs 7, 9; Text-fig. 7

Diagnosis.—Flat-based *Eodolatocrinus* n. gen., without intersecundibrachials.

Description.—Calyx low, erect-sided, flat-based to the first primibrachial, then curving to vertical; strongly ornamented with large central node on each cup plate and stellate ridges connecting with those on adjacent plates. Basals 3, unequal; azygous basal in AE interray; low, rounded pentagonal basal rim encompassing all or most of basal pentagon. Radials 5, small, equal, slightly wider than high. Primibrachials 2; first primibrachials hexagonal, largest plates in calyx after primanal; second primibrachial slightly smaller than first. Single secundibrachial in each half ray, equal in size to radials. Single tertibrachial in each quarter ray. Interrays equal, in 3 ranges in normal interrays, in 1/2/1 pattern, equidimensional. Primanal largest plate in cup, followed by 2 smaller plates; interrays closed from tegmen by first tertibrachial. Free arms and stem not preserved.

Remarks.—The two known species of *Eodolatocrinus* n. gen. are distinguished by calyx shape and presence of intersecundibrachials. *E. hlabsei* n. sp. has a low, erect, flat-based bowl-shaped calyx with no intersecundibrachials. *Eodolatocrinus niagarensis* has a medium bowl-shaped calyx constricted at the first tertibrachial level, and flares slightly above. Each ray in *E. niagarensis* also possesses two disjunct intersecundibrachials.
that are separated by tertibrachials. The interradials are mostly
separated from the tegmen by fixed brachials, but one inter-
ray is narrowly in contact where the arm bases are separated
by one plate.

Material and Occurrence.—Holotype, PRI 53695, well-pre-
served calyx, all rays to first tertibrachial, 13 mm high, 26
mm wide. Lower Birdsong shale (Brachiopod Zone), loc. PQ
(Lochkov).

Etymology of Name.—Specific name *hlabsei*, from the maiden
name Hlabse (pronounced Lap’see) of the senior author’s
wife.

**Eodolatocrinus niagarensis** (Springer, 1921) n. comb.
Pl. 6, Figs 3–4

*Technocrinus niagarensis* Springer, 1921: 14, pl. 5, figs 1–2.

**Diagnosis.**—*Eodolatocrinus* n. gen. with medium bowl-shaped
cup, constriction at first tertibrachial level, and two disjunct
intersecundibrachials.

**Remarks.**—Examination of the holotype, and only specimen,
of *Technocrinus niagarensis* (Decatur Limestone) strongly
suggests that it is not a member of *Technocrinus* Hall, 1859,
but, instead, should be included in *Eodolatocrinus* n. gen.
Unfortunately, the basal circlet is incomplete, which pre-
cludes accurate determination of the number of basal plates:
*Technocrinus* (Melocrinitoidea) is characterized by four, and
*Eodolatocrinus* n. gen. (Patelliocrinoidea) by three. Otherwise,
the cup structure and ornamentation are very similar to that
of *E. hlabsei* n. sp., and *T. niagarensis* is assigned herein to
*Eodolatocrinus* n. gen. Should additional specimens prove to
have four basals, *E. niagarensis* would have to be returned to
*Technocrinus*.

**Material and Occurrence.**—Holotype, USNM S575, well-pre-
served calyx, with part of basal circllet missing. Bob Limestone
(Brownport Group), Hardin County, Tennessee.

Family **DOLATOCRINIDAE** S. A. Miller, 1890

**Diagnosis.**—Patelliocrinoideans with flattened calyces, large,
rectangular first interradial, pentagonal second primibrachial,
and large radial plates.

**Remarks.**—The Dolatocrinidae has been placed within the su-
perfamily Eucalyptocrinoidae (see Ubaghs, 1978a). However,
its three unequal basals ally this family to the Patelliocrinoidea,
into which it is placed herein. The family Polypeltidae also is
placed within the Patelliocrinoidea for the same reason.

The Dolatocrinids arose from either a patelliocrinid or
a parapatelliocrinid ancestor during the Lower Devonian
(Lochkovian). Forms like *Allocrinus* or *Laurelocrinus* could
have been ancestral; both exhibit the large first interradial
characteristic of *Dolatocrinus*, the earliest member of the fam-
ily. *Allocrinus* also has a dorsoventrally flattened cup, which is
characteristic of *Dolatocrinus*. However, *Allocrinus* has unise-
rial hyperpinnulate brachials, whereas *Dolatocrinus* has bise-
rial arms.

The Dolatocrinidae is characterized by a dorsoventrally
flattened calyx and a thick-plated, rigid tegmen. Of the
four genera now placed within the Dolatocrinidae, only
*Comanthocrinus* Springer, 1921, has a differentiated anal re-
region; three plates are present in the second range of the anal
interray, and the tegmen is swollen on the posterior side. For
this reason alone, *Comanthocrinus* should probably be reas-
signed to another patelliocrinoidean family.

**Genus **DOLATOCRINUS** Lyon, 1857

**Type Species.**—*Dolatocrinus lacus* Lyon, 1857.

**Diagnosis.**—Dolatocrinid with biserial arms, and interray
plates connecting to tegmen.
Remarks.—Dolatocrinus is most similar to its probable descendant, Craterocrinus Goldring, 1923, differing from the latter in having its interradial plates connecting to the tegmen, and its flattened calyx. Clarkeocrinus Goldring, 1923, has a higher calyx, branching arms, and uniserial hyperpinnulate brachials. Comanthocrinus has a flat calyx, a differentiated anal area, and uniserial, hyperpinnulate brachials (Springer, 1921). The fixed pinnulars of Comanthocrinus are also much more prominent. The last two genera could represent independent offshoots of the Patelliocrinidae and might not be closely related to Dolatocrinus and Craterocrinus. Stereocrinus Barris, 1878, was synonymized with Dolatocrinus by Kesling & Mintz (1963) because its distinguishing feature, namely the possession of only one primibrachial, varies in some species of Dolatocrinus.

There are several possibilities for the origin of Dolatocrinus. The first is from a patelliocrinid ancestor, such as Patelliocrinus, with which it shares a number of characteristics including large first interradials, a quadrangular first primibrachial, biserial arms, and an anal area that is weakly differentiated. The earliest species, Dolatocrinus helderbergensis, has 20 arms with a single secundibrachial in each half ray. Although Patelliocrinus has only ten arms, it is characterized also by an enlarged pinnule arising from the second secundibrachial (Ubaghs, 1978a; Angelin, 1878). This pinnule could easily have become an arm, as suggested by Brower (1973) and Broadhead (1988a). Patelliocrinus is a possible ancestor of Dolatocrinus. Changes required in the evolution of Dolatocrinus from Patelliocrinus would have included: (1) flattening of the cup; (2) loss of the first primibrachial; (3) loss of the first secundibrachial; (4) enlargement of the first interradial with reduction of remaining interradials; and (5) enlargement of the pinnule on second secundibrachial (which would then become the first secundibrachial and be axillary).

The patelliocrinid Laurelocrinus is another possible ancestor of Dolatocrinus; this change would have required: (1) flattening of the calyx; (2) loss of the first primibrachial; and (3) loss of the first secundibrachial. Hence, it is more parsimonious as an ancestor for Dolatocrinus than is Patelliocrinus. The arms of Laurelocrinus are not known, but there are four arm bases per ray, which indicate that this genus possessed at least 20 arms. It is also stratigraphically more feasible as an ancestor for Dolatocrinus than the first choice, occurring in Ludlow age rocks as opposed to Wenlock age rocks for Patelliocrinus.

A third possible origin of Dolatocrinus is from the paraphelliocrinid, Eodolatocrinus n. gen., which is known from two species. Eodolatocrinus n. gen. is characterized by a flattened calyx, two primibrachials, one secundibrachial, and one tertibrachial, per quarter ray. However, it has approximately equally sized plates with the radials being slightly smaller than the first primibrachials; additionally the latter plates are hexagonal, not quadrangular as in Dolatocrinus. The first interradials are small and approximately equivalent to first primibrachials, whereas the first interradials are the largest cup plates in Dolatocrinus. Finally, the interrays are not in contact with the tegmen due to the first tertibrachials. Evolution of Dolatocrinus from Eodolatocrinus n. gen. would have involved: (1) substantial enlargement of the first interradial to form a quadrangular first primibrachial; (2) enlargement of the radials; (3) reduction of the remaining interradials; and (4) their connection with the tegmen. This transition would not require the elimination of the second secundibrachial. The first primibrachial is lacking in the oldest known species of Dolatocrinus, D. helderbergensis, but is present in many later species. This could indicate that D. helderbergensis, despite its age, represents a derived species; if so, the transition to Dolatocrinus would not have involved the loss of the first primibrachial. Eodolatocrinus n. gen. is closest in age to the oldest known Dolatocrinus, and is considered herein the most likely ancestor of that genus. However, the arms and tegmen of Eodolatocrinus n. gen. are not known. The only paraphelliocrinid for which the arms are known is Boliviacrinus, which has cuneate, uniserial arms (McIntosh, 1988). If Eodolatocrinus n. gen. also has uniserial arms, then the derivation of Dolatocrinus from it is less likely.

Dolatocrinus is exclusively a North American genus. Although it is primarily a Middle Devonian form, it ranges from the Lower Devonian (Lochkovian) to the Upper Devonian (Frasnian). At present, its stratigraphic distribution is disjunct. It first appeared (D. helderbergensis) in the lower Lochkovian Birdsong Shale of west-central Tennessee, but is not seen again until the early Eifelian (Onondaga Limestone, New York; Jeffersonville Limestone, Kentucky). Siegenian and Emsian representatives undoubtedly exist but have not been reported.

Dolatocrinus helderbergensis (Springer, 1921)
Pl. 6, Figs 5–6, 8

Stereocrinus helderbergensis Springer, 1921: 15, pl. 5, figs 3–4.
Dolatocrinus helderbergensis.—Webster, 1973: 244.

Diagnosis.—Dolatocrinus with single primibrachial, plates weakly ornamented with fine, radiating ridges, and 20 arms.

Description.—Calyx flattened with vertical sides. Ornamentation variable; when present consisting of fine, radiating ridges on each cup plate; plates can be smooth, usually slightly convex. Basals 3, unequal. Radials 5, equal. First primibrachial axillary. One secundibrachial per half ray; 2–3 tertibrachials per quarter ray; tertibrachials of adjacent rays nearly meeting above interradials. First interradials largest plates in calyx after radials, supporting 1–2 plates in next
range but typically 2; typically 2 in third range; all interradials above the first very small. Arms and tegmen not preserved.

Remarks.—Dolatocrinus helderbergensis is the earliest known species of Dolatocrinus, and its occurrence in the Birdsong Shale (Bryozoan Zone) is almost certainly at or close to the origin of the genus. It is distinguished from other species of Dolatocrinus by its possession of only one primibrachial per ray, subdued ornamentation, and 20 arms. Other species of Dolatocrinus formerly placed within Stereocrinus have 10 arms.

Material and Occurrence.—Four relatively complete calyces and one partial calyx, ranging from 50–55 mm wide, 25–26 mm high. All specimens found in the upper Birdsong Shale (Bryozoan Zone). One complete calyx, PRI 53693, loc. PQ. One complete calyx, PRI 53694, and one nearly complete, PRI 68327, loc. MQ. One nearly complete calyx, PRI 68328, and one partial, PRI 68329, loc. BQ. Isolated plates and aboral cups are common at all localities with exposed Bryozoan Zone strata (Lochkov).

Subclass DISPARIDA Moore & Laudon, 1943

Diagnosis.—Monocyclic crinoids with few or no fixed brachial or interradial plates.

Order HOMOCRINIDA Ausich, 1998

Diagnosis.—Disparids with compound radial plates.

Superfamily HOMOCRINOIDEA Kirk, 1914

Diagnosis.—Disparids with compound radial plates in B, C, and E rays, or derived from same.

Family HOMOCRINIDAE Kirk, 1914

Diagnosis.—Homocrinoids with all rays similar; B, C, and E radials compound.

Subfamily HOMOCRININAE Warn & Strimple, 1977

Diagnosis.—Homocrinids with atomous arms.

Genus THELOREUS Moore, 1962

Type Species;—Phimocrinus jouberti Oehlert, 1882.

Diagnosis.—Homocrinines are differentiated on a variety of characters including cup shape, ornamentation, number of arms per radial, number of basals, and tegmen structure. Theloreus has a medium to high, conical cup, apparently a single arm per ray, and arm facets the width of the radial. In contrast, Homocrinus Hall, 1852, the earliest homocrinine and presumed ancestral genus (Clement, 1988) has a minute, very high, cone- to vase-shaped cup; Anamesocrinus Goldring, 1923, has multiple arms per radial; Haplocrinites Troost, 1850, has a low cone- to bowl-shaped cup with arm facets restricted to a small part of the radials and a high tegmen. Abyssocrinus Strimple, 1963, has a steeply conical cup with widely flaring distal radials and nearly flat basal-radial sutures (Strimple, 1963). Ramacrinus Prokop, 1969, is distinguished by its low, open bowl-shaped cup, and basal-radial constriction, Juncocrinus Prokop, 1977, by its bulbous plates and vase-shaped cup (radials constricted distally), and Henacrinus Prokop, 1977, by its high conical cup and three basals. These last three are quite small in size (to 4 mm high, Prokop, 1969, 1977). Similar to Abyssocrinus and Ramacrinus, Theloreus has an oral surface composed mainly of radial projections (Pl. 6, Fig. 14).

Theloreus americanus (Springer, 1923) n. comb.

Pl. 6, Figs 10–14


Diagnosis.—Theloreus with broad cup and short basals.


Remarks.—Theloreus americanus was originally described by Springer (1923) as Phimocrinus americanus. Springer (1923) noted the similarity between P. americanus and P. jouberti from the Lower Devonian of the Armorican massif (subsequently reassigned as the type species of the genus Theloreus; Moore, 1962a) but stating that P. americanus did not have compound radials. Re-examination of the holotype in the USNM (Springer collection) indicates three compound radials in the B, C, and E rays. This excludes it from Phimocrinus Schultze, 1867 (Synbathocrinidae), which has five equal, noncompound radials. The infersuperradial sutures have
a symmetrically upward curved shape similar to those of *Abyssocrinus antiquus* Strimple, 1958.

*Theloreus americanus* differs from *T. jouberti* in having a broader cup and shorter basals. *Theloreus jouberti* also typically has a constriction at the basal-radial suture (Le Menn, 1985), a feature lacking in *T. americanus*. The holotype of *T. americanus* has a shape similar to that of *Ramaracrinus brevis* (see Le Menn, 1985), whereas smaller examples have a much steeper cone shape. The two specimens, of markedly different size, collected during this study differ in the proportions of the cup, indicating that it becomes relatively lower and broader through ontogeny.

This report marks the first record of *Theloreus* on the North American continent and strongly suggests biogeographic ties to Armorica and Bohemia.

**Material and Occurrence.**—Two specimens plus several isolated radials. One cup, PRI 53712, slightly compressed, weathered, showing radial platforms, 6 mm high, 6 mm wide. The second specimen, PRI 53713, slightly crushed, with proximal stem, 6 mm high, 6 mm wide. Isolated radials are common in disaggregated samples from the entire thickness of the Ross Formation. Specimen PRI 53712 is from the lower Rockhouse Limestone, loc. AM (Lochkov); PRI 53713 is from the upper Birdsong Shale (Bryozoan Zone), loc. BQ (Lochkov).

Order **CALCEOCRINIDA** Ausich, 1998

Family **CALCEOCRINIDAE** Meek & Worthen, 1869

**Diagnosis.**—Homocrinoids with pronounced flattening of the cup, hinge structure between reduced basals and E inferradial, and reduction or loss of arms in B and C rays.

Genus **EOHALYSIOCRINUS** Prokop, 1970

**Type Species.**—*Eohalysiocrinus convexus* Prokop, 1970.

**Diagnosis.**—Widely separated E-ray inferradial and superradial, lacking B and C inferradials, single fused subanal instead of discrete B and C superradials, and three basal plates.

**Remarks.**—Calceocrinids are distinguished on the basis of cup shape, basal plate configuration, presence of B and C inferradials, separation of E-ray infer- and superradials, and arms (Moore, 1962b). Except for *Eohalysiocrinus (?) typus* (Ringueberg, 1889) (Rochester Shale, New York, Wenlock), the arms of *Eohalysiocrinus* are unknown (Brett, 1981). Prokop's (1970) specimens also lack arms, as do specimens from the Ross. However, *Eohalysiocrinus* is distinguishable from other calceocrinid genera from features of the cup Brett (1981). *Eohalysiocrinus* has widely separated E-ray infer- and superradials, three basals, missing or fused B and C inferradials, a small E inferradial, and three ligamentary fossae on the proximal radials composing part of the basal-radial hinge that are visible on the anterior cup surface. The fossae, which are present on adult specimens of all species thus far reported, are separated by small ridges perpendicular to the hinge. These ridges also mark the boundaries on the hinge between the A and D radials and E inferradial.

The basic cup structure of *Eohalysiocrinus* with its widely separated E-ray radials, three basals and a single posterior plate (subanal), and lack of B and C inferradials is matched by three other described calceocrinid genera: *Halysiocrinus* Ulrich, 1886, *Deltacrinus* Ulrich, 1886, and *Cunctocrinus* Kesling & Sigler, 1969 (see Kesling & Sigler, 1969; Brett, 1981). *Cunctocrinus* was distinguished from *Halysiocrinus* by its lack of B and C inferradials (Kesling & Sigler, 1969). McIntosh (pers. comm., 1981) noted that both *Deltacrinus* and *Halysiocrinus* also lacked B and C inferradials. *Cunctocrinus* and *Halysiocrinus* also have similar arm structure, thus rendering *Cunctocrinus* a junior synonym of *Halysiocrinus* (Brower, 1977). *Deltacrinus* has less well-developed main axils compared to those of *Halysiocrinus* (Moore, 1962b), this being the principal differentiating characteristic between the two genera. Brett (1981) also considered these two genera to be synonymous.

There are further problems with respect to similarities between *Deltacrinus* and *Eohalysiocrinus*. Brett (1981) synonymized *D. contractus* (Ringueberg, 1889) (Gasport Limestone, New York, Wenlock) with *Cunctocrinus hallii* Ringueberg, 1889 (Rochester Shale, New York, Wenlock) and placed it in a new genus, *Catatonocrinus*. In the same paper, Brett strongly suggested that *D. stigmatus* (Hall, 1863) (Waldron Shale, Indiana, Wenlock) be placed within *Eohalysiocrinus*. Ausich (1987) assigned *D. alleni* (Rowley, 1904) (Edgewood Limestone, Missouri, Llandovery) to *Cunctocrinus Hall, 1852. Thus, at present, only the type species *D. clarus* (Hall, 1862) (Hamilton Group, New York, Givetian) and *D. secundus* (Hall, 1872) (Onondaga Limestone, New York, Eifelian) remain within *Deltacrinus*. These species differ from each other in two major aspects. *Deltacrinus clarus* has a very wide E-ray inferradial with no large fossae on the anterior surface. *Deltacrinus secundus*, as illustrated and described by Goldring (1923), has a small E inferradial and three fossae developed on the A and D radials and E inferradial. This makes the cup morphology of *D. secundus* much more like *Eohalysiocrinus* than like *D. clarus*. It is possible that renewed study of *D. secundus* will result in its placement with *Eohalysiocrinus*.

The arms of *Eohalysiocrinus* are known only in *Eohalysiocrinus (?) typus*, a species placed provisionally in this genus by Brett (1981) because of similarities in cup morphology. The original description of *Eohalysiocrinus* (Prokop, 1970)
was based on specimens lacking arms, making comparisons of the type with species retaining arms uncertain. However, the cup of E. (?) typus is very similar to Prokop’s (1970) original type species. Eohalysiocrinus (?) typus has well-developed main axes, a trait shared with Halysiocrinus, but not with either species of Deltacrinus. Halysiocrinus has a wide E inferradial composing most of the radial side of the hinge and lacks fossae on the A and D radials. Eohalysiocrinus has a small E inferradial that makes up half or less of the width of the hinge, and three distinct fossae on the A and D radials and E inferradial.

Deltacrinus clatus and Halysiocrinus share cup morphology, as stated above; the distinguishing characteristics reside in the arms. Deltacrinus secundus, on the other hand, shares cup morphology with Eohalysiocrinus, with a small E inferradial and distinct fossae on the proximal radials, as illustrated by Goldring (1923). Her illustrations also indicate weakly developed main axes similar to D. clatus. This raises the question on whether to use cup morphology or axil development as a generic discriminator.

The occurrence of Eohalysiocrinus in the Lochkovian strata of west-central Tennessee bridges part of the gap between the Wenlock E. (?) typus from New York and Emsian (Zlichovian) and later species described by Prokop (1970), Le Menn & Prokop (1980) and Le Menn (1985) from Czechoslovakia and France (Armorican Massif). This also extends the geographic range of the genus into southeastern North America.

Eohalysiocrinus broweri n. sp.
Pl. 7, Figs 1–2, 5–6, 9–10

Diagnosis.—Eohalysiocrinus with a micropitted surface, cup higher than wide (height:width = 1.25:1), and E superradial protruding above tops of A and D radials and occupying 60% of distal cup width.

Description.—Cup rectangular; anterior surface arched, constricted at or above midpoint; plate sutures depressed; plates with micropitted surfaces (the pitting much larger than the stereomic network). Basals 3, unequal, together making steep-sided trapezoidal unit. DE/AE fused basal small, triangular, composing base of trapezoid, with 3 distinct fossae divided by 2 small ridges perpendicular to hinge; apex not touching stem cicatrix. CD and AB basals as mirror images, composing most of basal unit with stem cicatrix at apex of trapezoid. A and D radials large, in long contact, separating E-ray compound radials, curving adanally to posterior side of cup. Arm facets with aboral fulcral ridge, 2 deep pits (fossae) adoral of ridge. E-ray radials widely separated; superradial protruding above top of A and D radials, with well-developed fulcral ridge and two deep fossae adoral of ridge. E-ray inferradial small, triangular, comprising 40% or less of proximal base width, 50% or less of hinge width. Hinge area with one fossa each in A and D radials and E inferradial. E-ray inferradial fossa largest; fossae separated by two transverse ridges marking boundary between A and D radials and E inferradial; both adjacent plates composing one half of ridge. DE-AE fused basal composing most of basal part of hinge. Trapezoidal subanal (fused B and C superradials) as only posterior plate. B and C inferradials not present; 2 shallow fossae present on distal surface. Arms and stem not preserved.

Remarks.—The species of Eohalysiocrinus are distinguished primarily on cup shape, ornament, and height and width of the E-ray superradial. Compared to E. broweri n. sp., E. convexus (Zlichov Formation, Bohemia, Emsian, Zlichovian) has a higher cup, smooth plates, and wider E-ray superradial; E. latus Prokop, 1970 (Zlichov Formation, Bohemia, Emsian, Zlichovian) has a shorter-than-wide cup with coarse, granular ornament and an E superradial that only comes up to the top of the A and D radials; E. tuberosus Prokop, 1970 (Lodenice Limestone, Bohemia, Pragian) differs in its concentric ornament and wide E superradial; E. cylindricus Prokop, 1970 (Dvorce-Prokop Limestone, Bohemia, Pragian) has an E superradial that is somewhat wider and does not project above the tops of the A and D radials; and both E. reticulatus Prokop, 1970 (Dvorce–Prokop Limestone, Bohemia, Pragian) and E. holynensis Prokop, 1970 (Trebotov Limestone, Bohemia, Emsian, Dalejan) have cups that are much higher than wide. Eohalysiocrinus (?) typus has a shorter (almost square) cup and a much wider E-ray superradial than E. broweri n. sp. Deltacrinus stigmatus, a form that Brett (1981) compared to E. typus, is more similar to E. broweri n. sp., but has an almost square cup and a bilobed subanal, similar to that seen in E. (?) gibsoni n. sp., rather than the typical trapezoid of most Eohalysiocrinus, including E. broweri n. sp.

Brett (1981) compared juvenile E. (?) typus to Prokop’s (1970) species E. reticulatus. He suggested that E. reticulatus and E. cylindricus might be juvenile forms of other species. One specimen of E. broweri n. sp. strongly resembles E. reticulatus and is considered a juvenile form. It is more elongate, and has a narrow base compared with more mature forms. This pattern of ontogenetic change parallels those discussed by Brett (1981) and Brower (1977, 1990).

Types and Occurrence.—Five cups missing arms, stem, and basals: holotype, PRI 53714, 5 mm high, 4 mm wide; para-type, PRI 53715, 5+ mm high (E superradial missing), 4.5 mm wide. Three other small cups: a partial larger one, PRI 53724; a smaller one, PRI 53725, with juvenile characteristics; the latter two from the Birdsong Shale; and a third, PRI
Remarks—Several distinctive characteristics segregate this species from other Devonian calceocrinids. The first is a small E inferradial but no discrete fossae on the anterior base of the cup, as in other species of *Eohalysiocrinus*. Instead, there is a long, apparently smooth, fossa without transverse ridges, contained within the proximal A and D radials and E inferradial. The second is the large A and D radial facets which are approximately 40% of the cup height. In other *Eohalysiocrinus* species, these facets are not as prominent. The third distinct feature is the bilobate subanal (Pl. 7, Figs 7–8), which is dumbbell-shaped with a very thin connecting bar. This contrasts with the trapezoidal shape of the subanal in other species of *Eohalysiocrinus*.

The generic assignment of this species is not entirely clear. *Eohalysiocrinus*, *Deltacrinus*, and *Halysiocrinus* have been considered, but there are problems in considering *E. (?) gibsoni* n. sp. as a species of any of these. *Eohalysiocrinus*, characterized by a small E inferradial, possesses a discrete fossa on the proximal end of each of the anterior radial plates (A, D, E-iR) that is separated from adjacent fossae by small transverse ridges. *Eohalysiocrinus* also has a trapezoidal subanal whereas *E. (?) gibsoni* n. sp. has a thin, bilobate subanal. Species of *Halysiocrinus* differ from *E. (?) gibsoni* n. sp. in having wide E-ray inferradials. However, they do have a single fossa on the proximal radials and a subanal somewhat more similar to that of *E. (?) gibsoni* n. sp. than to those of *Eohalysiocrinus* species. *Halysiocrinus* has a well-developed constriction of the cup, whereas *E. (?) gibsoni* n. sp. is only weakly constricted, if at all. As stated above, *Deltacrinus* is problematical. *Deltacrinus secundus* is probably an *Eohalysiocrinus*, as is *D. stigmatus*, which has a bilobed (but not dumbbell-shaped) subanal and three discrete fossae on the proximal anterior cup. This leaves *D. clarus* as the sole species of the genus. McIntosh (see Brett, 1981) believed *Deltacrinus* and *Halysiocrinus* to be synonymous, the only difference is the nature of the main axils, which are weakly developed in *Deltacrinus*, but extensively developed in *Halysiocrinus*.

*Eohalysiocrinus (?) gibsoni* n. sp. perhaps better belongs within *Halysiocrinus*, but the arms are not known in the former and inclusion in that genus would add a form with a very different cup shape and E inferradial width. This would require the diagnosis of *Halysiocrinus* to be expanded considerably. Inclusion in *Eohalysiocrinus* poses similar but less severe situation because *E. (?) gibsoni* n. sp. lacks the three prominent fossae so characteristic of the radial part of the hinge and possesses a subanal that is very different in shape from that of any other species. The overall cup shape is more similar to *Eohalysiocrinus* than to *Halysiocrinus*, and because of this, *E. (?) gibsoni* n. sp. is tentatively placed within *Eohalysiocrinus*.

Material and Occurrence.—Two somewhat crushed cups missing basals: holotype, PRI 53717, 6.5 mm wide, 7.0 mm high; paratype, PRI 53718, 6.0 mm wide, 5.3 mm high.

Holotype, PRI 53717, from the upper Birdsong Shale (Bryozoan Zone) at loc. PQ; paratype, PRI 53718, from the Upper Rockhouse Limestone or lower Birdsong Shale, loc. BQ (Lochkov).

Etymology of Name.—Specific name *gibsoni*, in honor of Michael Gibson, for his excellent research on the Lower Devonian of Tennessee.
Genus **CREMACRINUS** Ulrich, 1886

*Type Species.*—*Cremacrinus punctatus* Ulrich, 1886.

*Diagnosis.*—Calceocrinids with four arms (A, B, D, E), B and C inferradials, and up to two axillary plates in the main axil (see Brower, 1982, 1987)

*Cremacrinus decatur* Springer, 1926

Pl. 6, Fig. 15

*Cremacrinus* *decatur* Springer, 1926a: 107, pl. 28, fig. 7.

*Diagnosis.*—*Cremacrinus* with massive E-ray arm, large number of A- and D-ray arm branches, and smooth plates.

*Description.*—Cup smooth; sutures slightly depressed. Basals 4. A and D radials large, separated by E inferradial; E inferradial elongate, quadrangular, in wide contact with E superradial; E superradial trapezoidal. B inferradial approximately as large as E superradial. B superradial small. B-ray arm main axil poorly developed with only 2 axil arms, 5–6 axillaries in each axil arm. B-ray arm much smaller than A-ray arm; E-ray arm massive, composed of few large brachials. Proximal stem with barrel-shaped columnals.

*Remarks.*—Only one specimen of this species is known, which was described by Springer (1926a) from the Decatur Limestone of Perry County. It is notable in being the youngest species of *Cremacrinus* (Pridoli). No specimens of this species were found during this study.

*Type and Occurrence.*—Holotype, USNM S2152, crown (illustration from Springer, 1926a: pl. 28, fig. 7). Decatur Limestone, Perry County, Tennessee (Pridoli).

Order **PISOCRINIDA** Ausich & Copper, 2010

Family **PISOCRINIDAE** Angelin, 1878

*Diagnosis.*—Pisocrinids lacking C and E inferradials. B superradial on upper right shoulder of B inferradial. C superradial beveling left shoulder of B inferradial; B, C, and E superradials not in contact with basals.

*Remarks.*—The Pisocrinidae is a group of disparids with a unique cup morphology that probably evolved from a homocrinid ancestor (Moore, 1940; Moore et al., 1978a; Sevastapulo & Lane, 1988; Clement, 1988). Nonetheless, Ausich & Copper (2010: 73) regarded pisocrinids to be sufficiently distinctive and they elevated the superfamily Pisocrinioidea with a single family, Pisocrinidae, to an order of the Disparida.

The ontogeny of the homocrinid *Homocrinus*, as detailed by Sevastapulo & Lane (1988), suggests how the Pisocrinidae probably evolved. The E and C inferradials in juvenile homocrinids are small plates that do not reach the top of the cup. The B inferradial, however, is a large plate equal in size and shape to the A and D radials. The E and C superradials are intercalated between adjacent radials above their respective inferradials. The B superradial is intercalated between the A radial and the B inferradial. During later ontogeny, the superradial migrates toward the distal margin of the B inferradial. The pisocrinids thus, evolved by suppression of the C and E inferradials, and the failure of the B superradial to migrate over the B inferradial during ontogeny (see Sevastapulo & Lane, 1988).

Genus **PARAPISOCRINUS** Mu, 1954

*Type Species.*—*Pisocrinus ollula* Angelin, 1878.

*Diagnosis.*—Pisocrinids with five small basals confined to a basal cavity, and five atomous arms.

*Remarks.*—*Parapisocrinus* is distinguished by its possession of five, unequal, small basals, confined to a basal cavity. *Parapisocrinus* and *Pisocrinus* each have five atomous arms. *Cicerocrinus* Sollas, 1900, the only other pisocrinid with five basals, has branching arms and elongate basals (Moore, 1962a; Moore et al., 1978b).

Ausich (1977) combined *Parapisocrinus* with *Pisocrinus* because the restriction of basals to a basal cavity was judged to have evolved multiple times within *Pisocrinus* and was therefore inadmissible as a generic discriminator. However, restudy by Rozhnov (1981) re-established *Parapisocrinus* as a valid genus. Although Donovan et al. (2009) accepted Ausich’s synonymy, reversing an earlier decision. William Ausich himself (in Ausich & Copper, 2010) followed Rozhnov (1981) in using *Parapisocrinus* as a valid name.

*Parapisocrinus sphacericus* (Rowley, 1904)

Pl. 7, Figs 12–13, 16–17

*Pisocrinus sphacericus* Rowley, 1904: 270, pl. 16, figs 8–9.—Ausich, 1977: 685, fig. 8.


*Parapisocrinus cf. sphacericus.*—Donovan et al., 2008: 50–51, table 1.

*Pisocrinus cf. sphacericus.*—Donovan et al., 2009: 28.

*Diagnosis.*—*Parapisocrinus* with globose cup and circular outline, spear-shaped radial process, basals not visible from side, and no ornamentation.
Description.—Cup globose; basals hidden within deep basal concavity. B inferradial equal or smaller than B and C superradials. Large radials in A and D rays. B, C, and E superradials extending most of way to basals. Radial processes spear-shaped. Free arms, tegmen, and stem not preserved.

Remarks.—Ausich (1977) distinguished the 13 North American *Pisocrinus* species, including forms now assigned to *Parapisocrinus*, primarily on the basis of arm type, cup outline, and the visibility of basals in side view. Cup shape and ornamentation serve to complete segregation. Two arm types were noted, with attendant radial morphologies: (1) long-armed forms with square first primibrachial, and square radial processes, and (2) short-armed forms with trapezoidal first primibrachial and spear-shaped radial processes. The cup outline is either circular or pentalobate, and cup shapes range from globose to conical (Springer, 1926a). A few species [*P. granulosus* (Rowley, 1904), *P. varus* (Strimple, 1963), and *P. spatulatus* (Strimple, 1954)] have granular ornament. *Parapisocrinus sphaericus* is well differentiated by its smooth plates, circular outline, globose cup, basals that are not visible from the side, and spear-shaped radial processes. It has been previously reported from the Bainbridge Limestone of Missouri and the Beech River Formation of Tennessee, both of Ludlow age. A single specimen of pisocrinid from the Leintwardine Formation of Herefordshire, England, was assigned tentatively to *P. cf. sphaericus* by Ramsbottom (1958; see discussion by Donovan et al., 2009).

Material and Occurrence.—Three cups, two preserving the radial processes: PRI 53721, 7 mm wide, 5 mm high; PRI 68333, 5 mm wide, top broken; PRI 53720, 7 mm wide, 5 mm high. Specimen PRI 53721 upper Decatur, loc. PQ; PRI 53720, lower to middle Decatur, loc. PVb (Pridoli).

Genus *PISOCRINUS* de Koninck, 1858

*Type Species.*—*Pisocrinus pilula* de Koninck, 1858.

Diagnosis.—Pisocrinids with five small basals and five atomous arms.

Remarks.—*Pisocrinus* is distinguished from other pisocrinids by its possession of five, often unequal, basals that are visible in profile view and not confined to a concavity. As noted above, we follow Rozhnov (1981) and Ausich & Copper (2010) in distinguishing *Pisocrinus* from *Parapisocrinus*. Both genera appear to be present in the Decatur Limestone.

---

**Pisocrinus** sp. A

*Pl. 7, Figs 11, 15*

Diagnosis.—*Pisocrinus* with basals visible from side and pentagonal outline.


Remarks.—This species differs from *Parapisocrinus sphaericus* in its visible basals, pentagonal outline, and conical cup. However, it is not identifiable, using Ausich’s (1977) criteria, because the radial facets and processes are missing or very poorly preserved. *Parapisocrinus varus* (Henryhouse Formation, Oklahoma, Ludlow–Pridoli) is closest in shape, but it has a granulose cup, whereas *Pisocrinus* sp. A has smooth plates. Although Ausich (1977) classified *P. varus* as having a circular cup outline, Strimple (1963) showed that it has a rounded pentagonal cup outline. This shape is intermediate between the circular form of *P. sphaericus* and the pentalobate form of *P. quinquelobus* Bather, 1893 (Beech River Formation, Bainbridge Limestone; Tennessee, Oklahoma; Ludlow). Ausich (1977) did not discuss this rounded pentagonal shape, apparently because he believed it to be circular. *Pisocrinus* sp. A is distinct from *P. sphaericus* and definitely belongs to the genus *Pisocrinus*, but cannot be assigned to a known species because of poor preservation.

Material and Occurrence.—Two cups with all or most of the radial processes missing: PRI 68334, 4 mm high, 6 mm wide; PRI 53719, 4 mm high, 8 mm wide. Specimen PRI 68334, upper Decatur, loc. PQ; PRI 53719, lower to middle Decatur, loc. PVb (Pridoli).

Order **MYELODACTYLIDA** Ausich, 1998

Superfamily **MYELODACTYLOIDEA** Miller, 1883

Diagnosis.—Disparids with compound radials in C ray only, rarely none.

Remarks.—The Myelodactyloidea contains two families, the Myelodactylidae and Iocrinidae.

Family **MYELODACTYLIDAE** Miller, 1883

Diagnosis.—Myelodactyloideans with coiled, cirriferous stalk of bilaterally symmetrical, crescentic columnals.
Remarks.—Eckert & Brett (1985) strongly suggested using cup morphology for the segregation of the different genera contained within the Myelodactylidae, which is undoubtedly the ideal solution. The stems of myelodactylids, however, are morphologically unique so it is easy to identify even isolated columnals and pluricolumnals to the family level. Only two other groups of crinoids have columns that converge on those of the Myelodactylidae, namely the Camptocrininae (a group of Early Carboniferous to Late Permian camarates (Compocrinina, Hexacrinioidea, Dichocrinidae), and Ammonocrinus Springer, 1926b, a Middle Devonian (Eifelian) flexible (Sagenocrinida, Lecanocrinioidea, Calycocrinidae). Columnals of Ammonocrinus are easy to distinguish from those of myelodactylids because they lack cirri. Stalks of Camptocrinus Wachsmuth & Springer, 1897, are more difficult to distinguish from those of myelodactylids, possessing more nearly elliptical columnals and cirri on the inner side of the coil as in myelodactylids. However, the recurved part of the stalk of camptocrinines is generally not so tightly recurved as that of myelodactylids. Homeomorphy of the stem, the reason that Eckert & Brett (1985) discounted stem morphology as a diagnostic character, is not a major problem in assigning specimens to the Myelodactylidae.

Myelodactylid sp. A

Pl. 7, Figs 14, 18, 20

Description.—Bilaterally symmetrical crescentic stem with paired cirral scars on each columnal; single, slit-like lumen. All other parts not preserved.

Remarks.—Myelodactylid sp. A resembles both Myelodactylus and Herpetocrinus Salter, 1873, which are distinguished primarily on cup and cirral morphology. These genera have paired cirri on each columnal, but Myelodactylus has a cup with five rays and cylindrical cirri, whereas Herpetocrinus has a cup with four rays and rounded, bead-like cirri (Moore et al., 1978b). Unfortunately, neither cup nor cirri are preserved in specimens from the Ross Formation so that generic assignment is not possible.

Material and Occurrence.—Several stem segments: PRI 53722, 10 mm long, 3 mm high, 4 mm wide; PRI 68335, 9 mm long, 5 mm high, 3 mm wide; PRI 68336, 4 specimens ranging from 2–10 mm long, 3 mm high, 4 mm wide; PRI 68337, 28 mm long, 4 mm wide, 5 mm high; PRI 53723, most of proximal coil, maximum diameter 2 mm. Specimen PRI 53722, upper Birdsong Shale (Bryozoan Zone), loc. MQ; PRI 68335, upper Birdsong Shale (Bryozoan Zone), loc. PQ; PRI 68336, upper Birdsong Shale (Bryozoan Zone), loc. BQ; PRI 68337, upper Birdsong Shale (Bryozoan Zone), loc. BQ (Lochkov); PRI 53723, upper Decatur, loc. PQ (Pridoli).

Genus **MYELODACTYLUS** Hall, 1852

Type Species.—Myelodactylus convolutus Hall, 1852.

Diagnosis.—Myelodactylid with five radials, C-radial compound; paired, cylindrical cirri on each columnal.

Remarks.—Although both Myelodactylus and Herpetocrinus have paired cirri on successive columnals, Myelodactylus has five radials and cylindrical cirri, whereas Herpetocrinus has four radials and rounded cirri (see recent review by Donovan et al., 2009). Crinobrachiatus Moore, 1962a, has unpaired, stout cirri, and five noncompound radials.

**Myelodactylus schucherti** Springer, 1926

Pl. 7, Fig. 19

Myelodactylus schucherti Springer, 1926a: 87, pl. 27, fig. 21.—1926b: 21, pl. 5, figs 9–9c.

Diagnosis.—Myelodactylus with a closely coiled column, and short, cylindrical paired cirri.

Description.—Stalk closely coiled; cirri short, paired on each columnal; cirrals cylindrical. Crown and holdfast not preserved.

Remarks.—This species was described from the Linden Formation (= Ross Formation) by Springer (1926a, b). It is distinguished by the close coiling of the stalk and the morphology of the cirri. Whether or not Myelodactylus schucherti is conspecific with “myelodactylid sp. A” discussed previously is not determined because of the lack of large enough stalk segments and cirri in the latter.

Type and Occurrence.—Holotype, USNM 89860, portion of stalk including parts of both proximal and distal stalk. Ross Formation, Benton County (Lochkov).

Genus **CRINOBRACHIATUS** Moore, 1962

Type species.—*Myelodactylus brachiatus* Hall, 1852.

Diagnosis.—Myelodactylid with five radials, none compound; cirri widely spaced, stout, branching; successive cirri on alternate sides of stalk.
Remarks.—Cup morphology serves to distinguish *Crinobrachiatus* from other myelodactylids from which the cup is known. The presence of five radials distinguishes it from *Herpetocrinus*, and its noncompound C ray distinguishes it from *Myelodactylus*. Cups of *Brachiocrinus* Hall, 1858, and *Eomyelodactylus* Foerste, 1919, are not known.

Although cup morphology is rightly used for generic discrimination, the stem morphology of *Crinobrachiatus* is sufficiently distinctive to allow generic identification of stem fragments. *Myelodactylus* and *Herpetocrinus* have paired cirri on each column or a single cirrus per column on alternating sides of adjacent columns throughout most of the length of the stem. *Brachiocrinus* has stout, cirral pairs "borne by two successive columnals which are separated by two to five non-cirriferous columnals," (Moore et al., 1978b: T552). In contrast, *Crinobrachiatus* has stout, branching cirri on alternate sides of the column, each of which are separated by several noncirriferous columnals.

**Crinobrachiatus** sp.

Pl. 8, Figs 1–3, 6

Description.—Cross section of columns rounded triangular to thickened, crescentic. Lumen slit-like, parallel to inner surface. Large cirrus scars on alternate sides of stalk separated by 1–7 columnals that lack cirri; each cirral scar involving several columnals; cirriferous columnal bearing large (relative to columnal thickness) protrusion on side toward outer surface. All other parts unpreserved.

Remarks.—The stem fragments attributed to *Crinobrachiatus* are assigned because of the alternating, unpaired cirrus scars that are separated by several columnals that lack cirri. These columnals are unlike the other myelodactylid stems in the Ross, which have paired, small cirrus scars on each columnal.

Material and Occurrence.—Specimen PRI 53726, with 3 short segments of stalk, 12–14 mm in length, 3 mm high, 3–4 mm wide, two of these with cirrus scars, presumed distal, one without cirrus scars and tapering, presumed proximal; PRI 68338, length of stalk lacking cirr, 30 mm long, 3 mm wide on slab with juvenile *Eohalysiocrinus broweri* n. sp. (PRI 53716); PRI 53727, nearly complete coiled stalk > 110 mm in length, 23 mm wide.

Specimen PRI 53726, upper Birdsong Shale, (Bryozoan Zone), loc. MQ; PRI 68338, lower Rockhouse Limestone, loc. AM; PRI 53727, upper Birdsong Shale (Bryozoan Zone), loc. BQ (Lochkov).
not been widely accepted. The synbathocrinids have been considered to be close to the Homocrinoida (Prokop, 1969, 1977; Sevastopulo & Lane, 1988). Sevastopulo & Lane (1988) demonstrated that the ontogeny of Homocrininae was indistinguishable from that of the allagecrinids and synbathocrinids. They believed that the synbathocrinids and the Homocrinidae were related, and genera with compound radials in the B, C, and E rays were included in the Synbathocrinidae. Clement (1988) removed Abyssocrinus, Ramacrinus, and Theloreus, which have compound radials in the B, C, and E rays, to the Homocrinidae.

The remaining genera—Phimocrinus, Stylocrinus Sandberger, 1856, and Taidocrinus Tolmatchoff, 1924—are similar to Synbathocrinus and presumably have similar ontogenies. Because of the similarities noted above and the inferred relationship, the Synbathocrinidae is herein included within the Allagecrinoidea.

Family **ALLAGECRINIDAE** Carpenter & Etheridge, 1881

**Diagnosis.**—Allagecrinoids with 16 or fewer arms.

**Remarks.**—The principal difference between the Allagecrinidae and Catillocrinidae, the only other family in the Allagecrinoidea, is the number of arms. The greatest number of arms recorded in an allagecrinid is 16 (*Thaminocrinus* Stimpson & Watkins, 1969), whereas the least number of arms for a catillocrinid is also 16 (*Myocrinus* Schultze, 1866) (Moore & Stimpson, 1978: T538). Catillocrinids tend to have a bulbous or flat cup compared with the low, steep, cones of allagecrinids. However, *Catillocrinus* Shumard, 1886, has a low steep, conical cup. The diagnostic characters, as enumerated in the *Treatise on Invertebrate Paleontology* (Moore & Stimpson, 1978: T537, T542) do not fully differentiate the two families.

**Genus** **KALLIMORPHOCRINUS** Weller, 1930

**Type Species.**—*Kallimorphocrinus astrus* Weller, 1930.

**Diagnosis.**—Allagecrinids with bowl-shaped cups, 3 low basals, and tumid radials of uneven width; mature specimens with 6–14 arms, one arm each on C and E radials; anal series with notch on left shoulder of C radial; orals lacking (Lane & Sevastopulo, 1982).

**Remarks.**—The genus *Kallimorphocrinus* contains allagecrinid microcrinoids with three basals, more than five arms, an anal notch, and no orals at maturity (Lane & Sevastopulo, 1982). Those with three basals, five or fewer arms, orals, and no anal notch at maturity were placed in *Litocrinus*. Forms similar to *Litocrinus* with five basals are assigned to *Desmacriocrinus* and those with pouch-like radial extensions are placed in *Trophocrinus*. Early stage *Kallimorphocrinus* are indistinguishable from *Litocrinus*, requiring a growth sequence to allow identification. Also, the anal notch does not appear in *Kallimorphocrinus* until the five-armed stage, after which time the orals are lost. Thus, ontogenetic series of both named genera are not distinguishable prior to the five-armed stage of development.

Lane & Sevastopulo (1982) noted that the genus *Aidemocrinus* Weller, 1930, was simply an early stage of *Kallimorphocrinus*. Arms are mostly lacking and tall radials and prominent orals are present. They even referred to an "Aidemocrinus odiosus stage" (Lane & Sevastopulo, 1982: 247, fig. 1). Because *A. odiosus* Weller, 1930, is the only species of this genus, it is simpler to refer to this growth stage as the "aidemocrinoid stage." Most, if not all, species assigned by Lane & Sevastopulo (1982) to *Kallimorphocrinus* have a stellate stage after the aidemocrinoid stage (see Weller, 1930; Moore, 1940; Webster & Lane, 1970). This might well be termed the "kallimorphocrinid stage," as done by Moore & Strimpson (1978: T539). During this stage, the arms developed and the stellite shape was lost soon after the appearance of five arms. Those species assigned to *Litocrinus* do not have a stellate stage because they retained the aidemocrinoid shape through the five-armed stage (see Lane & Sevastopulo, 1981, 1982). The term "litocrinoid stage" can be used for those non-stellate forms with one to five arms.

**Kallimorphocrinus** sp.

Pl. 8, Figs 5, 7, 15

**Description.**—Cup steep, open-bowl shaped with large protuberant orals. Larger specimens with central ridge on radial, leading to projection at distal edge, giving theca stellate appearance. Sutures on basals not visible; circlet small, low. Radials 5, relatively large, equal, higher than wide. Orals 5, subequal, forming dome; CD oral somewhat larger than others. Stem and arms not preserved.

**Remarks.**—Several specimens of "*Kallimorphocrinus*" sp. were present in washings from the Ross Formation. Four of these are armless, have a steep cup, and represent the "aidemocrinoid stage" (*e.g.*, Pl. 8, Fig. 15). One specimen (PRI 68413) belonging to the "kallimorphocrinid stage" (Pl. 8, Figs 5, 7), has a less steep cup and is stellate, with a ridge that culminates in a projection on each radial. Two of these projections are wider and more blunt than the rest and are interpreted to have had arms attached (C and E).

Many allagecrinoidae have a protuberant basal circlet in early stages, whereas *Synbathocrinus* does not (see Moore, 1940;
Clement & Brett: Echinoderms of West-Central Tennessee

Moore & Ewers, 1942; Lane & Sevastopulo, 1981, 1982). The present specimens are more similar to *Synbathocrinus* in this respect, but *Synbathocrinus* is not known to have a stellate "kallimorphocrinoid stage." Also, no other synbathocrinids or allagecrinoideans are known from the Ross Formation. *Theoreus*, a genus known from the Ross and formerly placed within the Synbathocrinidae because of its radial facet structure, has been reassigned to the Homocrinidae on the basis of its cup with compound B, C, and E radials (see Clement, 1988). It is assumed to have a homocrinid pattern of development with unequal development of the radials in the early stages (see Sevastopulo & Lane, 1988).

The assignment of the present specimens is problematic. If they belong to the Allagecrinoidea, then they are the earliest known representatives of that superfamily. If they are synbathocrinids, they provide a morphological link between that family and the Allagecrinoidea.

**Material and Occurrence.**—Four specimens, PRI 68409–68412, aidemocrinoid stage; one specimen, PRI 68413, kallimorphocrinoid stage.

Specimens PRI 68409–68411 from upper Birdsong Shale (Bryozoan Zone), loc. PQ; PRI 68412, upper Rockhouse Limestone or lower Birdsong Shale, loc. BQ; PRI 68413, upper Birdsong Shale (uppermost Brachiopod Zone), loc. MQ (Lochkov).

Superfamily **BELEMNOCRINOIDEA** Miller, 1883

**Remarks.**—The Belemnocrinoidea, as presently constituted (Moore & Lane, 1978), contains disparids with a variety of morphologies. It is not a natural assemblage, as noted by Sevastopulo & Lane (1988), and further research will probably result in most of the families being assigned elsewhere.

Family **PYGMAEOCRINIDAE** Strimple, 1963

**Diagnosis.**—Belemnocrinoideans with stellate theca with no anal plates in cup, and two primibrachials, First primibrachial in deep notch in radial. Second primibrachial lanceolate, meeting over oral surface, with serrate margins between adjacent second primibrachials and subjacent radial.

**Remarks.**—At present, the Pygmaeocrinidae contains two genera, *Pygmaeocrinus* and *Storthingocrinus* Schultzze, 1867. *Storthingocrinus* is reassigned herein to the Synbathocrinidae. *Pygmaeocrinus* is a unique genus of disparid that can be identified by its distinctive radials and especially by its second primibrachials (see Strimple, 1963; Moore & Lane, 1978: T558–T559). The morphology of these lanceolate plates with their serrate margins is not known from any other Paleozoic crinoid. Similar plates occur in the Applinocrinidae (Mesozoic) (Broadhead & Russell, 1985), but they are first primibrachials, not second primibrachials. The relationship of *Pygmaeocrinus* with other disparids is not known.

**Genus **PYGMAEOCRINUS** Bouska, 1947

**Type Species.**—*Pygmaeocrinus kettneri* Bouska, 1947.

**Diagnosis.**—Same as for family.

**Remarks.**—*Pygmaeocrinus* is known only from the type species, which is from Upper Silurian to Middle Devonian rocks of Bohemia (Prokop, 1987). It has a stellate shape, five small, equal basals with a shallow basal concavity, and five large radials with a deep notch for the insertion of the primibrachials. Two primibrachials are present in each ray. The first primibrachial is small and quadrangular and surrounded on three sides by the subjacent radial. The second primibrachial forms a large lanceolate plate with serrate margins with the adjacent second primibrachials and with the subjacent radial, which projects upward beyond the first primibrachial on both sides. There are no anal plates, and the second primibrachials completely cover the oral surface. The radials and second primibrachials are distinctive, and provide easy identification of fragmentary remains.

**Pygmaeocrinus** sp.

Pl. 8, Figs 4, 8

**Description.**—Small, isolated, deeply notched radials with serrations on adoral edge; lanceolate second primibrachials with serrations on all margins other than the first-second primibrachial sutures.

**Remarks.**—The distinctive isolated radials and second primibrachials from the Birdsong Shale mark the first reported occurrence of *Pygmaeocrinus* outside of Bohemia. These plates cannot be distinguished from those of the type species, *P. kettneri*. Because no complete cups were found, no specific assignment is made.

**Material and Occurrence.**—One radial, PRI 68414; one radial, PRI 68415; 22 isolated radials, two isolated second primibrachials, PRI 68416. Upper Birdsong Shale (uppermost Brachiopod Zone), loc. MQ. The specimens are from the 25-mesh sieve fraction of three disaggregated shale samples from loc. MQ. The samples—M48B (PRI 68414), M (PRI 68415), and T (PRI 68416)—came from a thick shale layer at the top
of the Brachiopod Zone of the Birdsong Shale, immediately below the transition zone that separates the Brachiopod Zone from the Bryozoan Zone (Lochkov).

Subclass CLADIDA Moore & Laudon, 1943

*Diagnosis.*—Dicyclic crinoids with cup composed of basals and radials plus, in most, anal plates, interradial plates in the CD interray only.

*Remarks.*—The cladids are here classified at the subclass level following suggestions by Broadhead (1988a, b) and Ausich (1998). Cladids are less closely related to the disparids than they are to the flexibles and articulate crinoids (Simms & Sevastopulo, 1993).

*Order DENDROCRINIDA* Bather, 1899

*Remarks.*—The cladids are presently divided into three orders, the Cyathocrinida Bather, 1899, Dendrocrinida Bather, 1899, and Poteriocrinida; these were given subordinal rank in the *Treatise on Invertebrate Paleontology* (Moore et al., 1978a), but elevated to orders by Ausich (1998). In addition, certain modern cladistic classifications of crinoids include the Flexibilia as an order of the subclass Cladida (Simms & Sevastopulo, 1993). However, we follow the *Treatise* (Moore, 1978; Ubaghs, 1978c) in treating flexibles as a separate subclass.

In Moore et al.'s (1978a) descriptions of the three cladid suborders (now orders), cup shape, arm morphology, number of anal plates in the cup, and nature of the radial facet were noted as the principal discriminating characteristics. However, considerable overlap in all of these characteristics occurs among the three "suborders." The Cyathocrinida is characterized (Moore et al., 1978a) by species with bowl- to globe-shaped cups, zero to five anals in the cup, uniserial, nonpinnulate arms that are atomous, isotomous, or heterotomous, and angustary radial facets. Species of the Dendrocrinida have cone- to bowl- to discoid-shaped cups, zero to three anals in the cup, uniserial or biserial, pinnulate or nonpinnulate arms that are atomous, isotomous, or heterotomous, and angustary to plenary radial facets. Species of the Poteriocrinida have cone- to bowl- to discoid-shaped cups, zero to four anals in the cup, uniserial or biserial, pinnulate or nonpinnulate arms, and angustary to plenary radial facets.

In addition, the slope of the radial facet and degree of development of the transverse ridge and ligament and muscle fossae are also noted as having taxonomic value. Declivate (outward-downward sloping), planate (horizontal), or sursumate (outward-upward sloping) facetal slopes are noted in both Dendrocrinida and Poteriocrinida. Ubaghs (1978b) did not mention them, but declivate and planate slopes are in the Cyathocrinida as well. Transverse ridges are only poorly developed in the Cyathocrinida and best developed in the Poteriocrinida; Dendrocrinida is intermediate in this respect. The foregoing discussion brings out the lack of truly diagnostic characteristics that can discriminate among the three "orders," and it shows the need of thorough revision at this level. Such a revision is well beyond the scope of this paper and at present, diagnoses of the orders are not given.

*Superfamily DENDROCRINOIDEA* Wachsmuth & Springer, 1886

*Diagnosis.*—Dendrocrinidans with angustary radial facets.

*Family THALAMOCRINIDAE* Miller & Gurley, 1895

*Type Species.*—*Thalamocrinus ovatus* Miller & Gurley, 1895.

*Diagnosis.*—Thalamocrinids with cylindrical cup, smooth, convex plates, and constricted radial circket.

*Remarks.*—As noted by McIntosh & Brett (1988), *Thalamocrinus* and *Bactrocrinites* Schnur, 1849, are closely related and differ primarily in cup shape: *Thalamocrinus* has a constricted radial circket, giving the cup a barrel-shape, whereas *Bactrocrinites* exhibits a steeply conical cup with greatest width at the radial circket. McIntosh & Brett (1988) also noted less developed radial facets in *Thalamocrinus* than in *Bactrocrinites*, but also noted similarity in overall morphology between *Thalamocrinus* and immature *Bactrocrinites*. *Thalamocrinus* differs from all other thalamocrinids (see McIntosh & Brett, 1988, for included genera) by its constricted radial circket. Consequently, the maximum cup width is located at the basal or infrabasal circket, producing a barrel-shaped cup.
**Thalamocrinus ovatus** Miller & Gurley, 1895

*Pl. 8, Figs 9–10, 13–14*


*Cassioocrinus (?) ovatis* Rowley, 1904: 271, pl. 16, figs 13–16.


**Diagnosis.**—*Thalamocrinus* with a moderately elongate cup (width:height = 1:1.4), widest in basal circlet; plates lacking depressed sutures.

**Description.**—Cup elongate, barrel-shaped to nearly cylindrical, with widest part in basal circlet. Infrabasals 5, large, equal, higher than wide, slightly smaller than basals, expanding upward; stem cicatrix wide. Basals 5, large, equal, higher than wide. Radials 5, equal, wider than high; facets peneplenary. Anal plates 2; quadrangular radianal below and to left of C radial; anal X slightly smaller than adjacent radials and same height as radials. Arms, tegmen, and stem not preserved.

**Remarks.**—Species of *Thalamocrinus* are distinguished primarily on the shape of the cup. *Thalamocrinus globosus* Springer, 1926a, is nearly spherical and slightly wider than high (width:height = 1:0.9). *Thalamocrinus cylindricus* (Hall, 1852) and *T. robustus* are slightly higher than wide (width:height = 1:1.1) with *T. robustus* distinguished by depressed sutures. *Thalamocrinus ovatus* and *T. ovalis* are somewhat higher than wide (width:height = 1:1.3–1.4) and were synonymized by McIntosh & Brett (1988). *Thalamocrinus strimplei* McIntosh & Brett, 1988, and *T. elongatus* have elongate cups (width:height = 1:1.8–2.0). *Thalamocrinus elongatus* differs from *T. strimplei* in having the widest part of the cup at the top of the infrabasal circlet and a much wider stem facet.

One specimen of *Thalamocrinus ovatus* (PRI 53731) does not appear to have the radial constriction characteristic of *Thalamocrinus*. However, it is crushed, distorting its original shape. It is here considered a juvenile *T. ovatus* but might ultimately prove to belong to *Bactrocrinites*.

**Material and Occurrence.**—Six cups: two complete (PRI 53728 and 53729), one missing an infrabasal (PRI 53730), and one disarticulated specimen on a slab (PRI 68339). Specimen PRI 53728, 9 mm high, 7 mm wide, uncruushed; PRI 53729, 9 mm high, 8 mm wide, crushed; PRI 53730, 11 mm high, ca. 6 mm wide, crushed; PRI 68339, ca. 10 mm high; PRI 68340, 6 mm high, upper half crushed, radials partially disarticulated; PRI 53731, 4.5 mm high, crushed on limestone chip.

Specimen PRI 53728, lower Rockhouse Limestone, loc. AM; PRI 53729 upper Decatur Limestone, loc. MQ; PRI 53730, 68339–68340 upper Birdsong Shale (Bryozoan Zone), loc. BQ; PRI 53731, upper Birdsong Shale (Bryozoan Zone), loc. MQ (Pridoli–Ludlov).

**Thalamocrinus elongatus** Springer, 1926

*Pl. 9, Figs 1–2, 5*

*Thalamocrinus elongatus* Springer, 1926a: 132, pl. 26, fig. 11.—Strimple, 1963: 66, pl. 3, fig. 5; McIntosh & Brett, 1988: 8.

**Diagnosis.**—*Thalamocrinus* with large, elongate cup (width:height = 1:1.8–2.0) and wide stem facet.

**Description.**—Cup elongate (width:height = 1:1.8–2.0) with widest part near top of infrabasals, narrowing above. Cup plates smooth, without depressed sutures. Infrabasals 5, higher than wide (width:height = 1:1.6); largest plates in cup; circlet expanding slightly distally; stem facet as wide as proximal infrabasals. Basals 5, equal, large, higher than wide (width:height = 1:1.3), somewhat smaller than infrabasals, tapering slightly distally. Radials small, as high as wide (width:height = 1:1), much smaller than basals; peneplenary radial facet at distal end of plate. Quadrangular radial below left side below C radial; anal X similar in shape to and at same height as adjacent radials. Stem circular. Homeomorphic except expanding greatly immediately below cup. Arms and tegmen not preserved.

**Remarks.**—*Thalamocrinus elongatus* is very close in cup morphology to *T. strimplei*. Species of *Thalamocrinus* are distinguished primarily by cup shape, with the cups of *T. elongatus* and *T. strimplei* being greatly elongate relative to other species. Springer (1926a) separated *T. elongatus* from *T. cylindricus* (Hall, 1852) (Beech River Formation, Tennessee, Ludlow) (now *T. strimplei*, see McIntosh & Brett, 1988) primarily on size of the cup and width of the stem facet. *Thalamocrinus elongatus* is much larger than any other *Thalamocrinus* species and has a wide stem facet (70–80% of maximum cup width) with a distally tapering stem. *Thalamocrinus strimplei* is smaller and has a narrower cicatrix, < 50% of maximum cup width.

*Thalamocrinus elongatus* almost certainly evolved from *T. strimplei*. The two species share overall cup shape, massive infrabasals, and wide stem facets. The only changes needed for the evolution of *T. elongatus* from *T. strimplei* would be an increase in the width of the cicatrix and increase in overall size. The stem of *T. strimplei* is unknown, making comparison of this structure impossible.
Specimen PRI 53733 might not belong to *Thalamocrinus elongatus*. It is more nearly cylindrical, and the cup has none of the curvature characteristic of *Thalamocrinus*. It might in fact belong to *Bactrocrinites*. It is included in *T. elongatus* because of its wide stem facet. Also, specimen PRI 53735 might not be properly placed in *Thalamocrinus* because it has flaring radials, unlike the constricted radials of *Thalamocrinus*. However, it is very small (4.5 mm high) and shares the large infrabasals of *T. elongatus*. It is interpreted as a juvenile of that species but could ultimately prove to be a *Bactrocrinites*.

**Material and Occurrence.**—Three specimens: PRI 53734, nearly complete, somewhat collapsed cup missing one radial and preserving the proximal stem (ca. 30 mm long), cup 19 mm high, 9 mm wide; PRI 53733, partial crushed cup preserving only infrabasals and basals; PRI 53735, small cup, 4.5 mm high, 3 mm wide.

Specimen PRI 53734, upper Birdsong Shale (Bryozoan Zone), loc. BQ; PRI 53733, upper Birdsong Shale (Bryozoan Zone), loc. PQ; PRI 53735, Lower Rockhouse Limestone, loc. BQ (Lochkov).

*Thalamocrinus cf. robustus* McIntosh & Brett, 1988  
Pl. 8, Figs 11–12

*Thalamocrinus robustus* McIntosh & Brett, 1988: 5, fgs 1–3, 5–9, 11.

**Diagnosis.**—*Thalamocrinus* with bulbous plates and depressed sutures.

**Description.**—Cup small, somewhat elongate (width:height = 1:1.3), with small, thick, bulbous plates and depressed sutures. Infrabasals 5, small, equal, slightly wider than high; stem facet with pentagonal lumen. Basals 5, equal, somewhat higher than wide. Radials 5, equal, wider than high; radial facet planate, plenary or peneplenary. Anal plates, arms, stem, and posterior side of cup not preserved.

**Remarks.**—*Thalamocrinus robustus* is the only species of *Thalamocrinus* with bulbous plates and depressed sutures. A single specimen from the Ross is referred to *T. robustus* because of its thick, bulbous plates, depressed sutures, and plate proportions. Unfortunately, the anal side is not preserved, and the radials are only slightly constricted, which makes generic identification somewhat uncertain. This occurrence extends both the stratigraphic and geographic range of *T. robustus*; this species was previously known only from Wenlock strata (Rochester Shale) of western New York State (McIntosh & Brett, 1988).

**Material and Occurrence.**—One partial cup, PRI 53732, preserving two infrabasals, two basals, and three radials; anal plates not preserved. Lower Rockhouse Limestone, loc. AM (Lochkov).

Family **EUSPIROCRINIDAE** Bather, 1890  
Genus **AMPHERISTOCRINUS** Hall, 1879

**Type Species.**—*Ampheristocrinus typus* Hall, 1879.

**Diagnosis.**—*Ampheristocrinus typus* Hall, 1879  
Pl. 9, Figs 3–4


**Diagnosis.**—Same as for genus.

**Description.**—Cup medium conical with stellate ornament composed of single ridges connecting adjacent plates. Infrabasals 5, large, equal, visible from side, composing ca. 25% of cup height. Basals 5, large, equal, higher than wide, composing ca. 40% of cup height. Radials 5, large, equal, wider than high, composing ca. 35% of cup height. Arm facets rounded, declivate, angustary. Arms uniserial, isometric; fifth primibrachial axillary; sixth secundibrachial axillary; brachials rounded, approximately as wide as high, but elongate in adoral direction. Proximal tegmen composed of small, irregular plates. Stem transversely round, heteromorphic N212, with faint nodals at intervals. Posterior side covered.

**Remarks.**—The single specimen described here as (?) *Ampheristocrinus typus* is difficult to place within the Cladida due to poor subordinal, superfamilial, and familial diagnoses. It has angustary radial facets, five infrabasals, five primibrachials in each ray, and a tegmen composed mainly of small, irregular plates. The angustary radial facets indicate either a cyathocrinine or dendrocrinine affinity with the closest genera being *Ampheristocrinus*, *Parisocrinus* Wachsmuth & Springer, 1880 (*Euspirocrinidae*, Cyathocrinina), and *Gothocrinus* Bather, 1893 (*Botryocrinidae*, Dendrocrinina). The present specimen appears to have isometric rather than ramulate arms as in *Gothocrinus* (Moore *et al.*, 1978b: T615) and has
coarse, stellate ornament, similar to *Ampheristocrinus* and not
the smooth cups of *Gothocrinus* and *Parisocrinus*. The number of
primibrachials in *Parisocrinus* is questionable, a range of
tree or four was given by Moore et al. (1978a: T585), al-
though the illustration of *P. siluricus* Springer, 1926a (Laurel
Limestone, Indiana, Wenlock) appears to have two primibrach-
chials (Moore et al., 1978a: T584). *Gothocrinus* bears four to
five primibrachials.

Frest & Strimple (1981b) removed *Ampheristocrinus dubius*
Weller, 1900 (Racine Dolomite, Illinois, Wenlock), from
*Ampheristocrinus* because it to has a different plate arran-
gement, which is similar to *Manicrinus* Frest & Strimple, 1978;
they erected a new genus, *Premanicrinus* Frest & Strimple,
1981b, to accommodate *A. dubius*. They also indicated that
*A. calyx* (Hall, 1882) (Waldron Shale, Indiana, Wenlock) was
not recognizable, because known specimens retain only partial
infrabasals rather than five (Springer, 1926a; Frest & Strimple,
1978b). Th e T ennessee specimen closely resembles certain spe-
cies of *Gissocrinus* Angelin, 1878, with many primibrachi-
als. *Gissocrinus macroadactylus* Angelin, 1878, and *G. ludensis*
(Sollas, 1958) (see Ramsbottom, 1958) have medium to high
conical cups, strong stellate ridges, and 3–5 primibrachials.
These species, and perhaps others, should be removed from
*Gissocrinus*, which, according to Moore et al. (1978b: T582),
have a bowl-shaped cup with the first primibrachial axillary.

Springer (1926a) questionably referred a specimen from the
Brownsport Formation of western T ennessee to *Ampheristocrinus
owing to similarities in its cup ornament
and radial facets. However, the posterior side of that speci-
men is embedded in limestone and the number of infrabasals is
uncertain (Springer, 1926a: 132). If this specimen has five
infrabasals, it is probable that it and the Birdsong specimen
are at least congeneric, and possible generic assignments are
either *Gissocrinus* or *Ampheristocrinus*.

**Material and Occurrence.**—One crown, PRI 53736, on lime-
stone slab preserving arms to IIIBr6 in one ray, IIBr in two
other rays to 20 mm, stem to 40 mm, posterior side not ex-
posed, cup 12 mm high, 11 mm wide. Upper Birdsong Shale
(mid-Bryozoan Zone), loc. BQ (Lochkov).

Subclass **FLEXIBILIA** Zittel, 1895

**Diagnosis.**—Dicyclic, nonpinnulate crinoids with proximal
arms loosely incorporated into cup (Lewis, 1981).

**Remarks.**—Diagnosis of primitive members of the different
crinoid subclasses is more difficult than it might seem. This is
primarily due to the somewhat parallel trends toward cup and
arm simplification that are present within each subclass. The
flexibles are dicyclic and have nonpinnulate, uniserial arms in
which the proximal portions are loosely incorporated in the
cup by means of relatively large interradials or small, irregular
plates (perisome) (Lewis, 1981; Moore, 1978a; Springer,
1920). Th ey mostly have three unequal infrabasals, with the
azygous infrabasal in the C ray. However, the infrabasals can
be fused, or missing (resorbed), but the C-ray azygous is
most invariant, with only a few exceptions known (Moore,
1978a).

The looseness and degree of incorporation of the proxi-
mal brachials in the cup is a relative and variable feature. In
some genera, like *Ichthyocrinus*, in which the proximal arms
are rather firmly united to adjacent arms, the degree of flex-
bility between proximal brachials was most likely quite low.
In other genera, such as *Taxocrinus* Phillips, 1843, the arms
are separate and joined only by a flexible perisome. The peri-
osomal connection of the arms to each other and to the rest of
the cup is most often surmised because the perisome is rarely
preserved.

**Order** **SAGENOCRINIDA** Springer, 1913

**Diagnosis.**—Flexibles with anal plates firmly joined to cup
and brachial plates.

**Remarks.**—The Sagenocrinida is separated from the
Taxocrinida primarily on the basis of anal morphology. The
sagenocrinoids have anal plates directly attached to the radi-
als and brachials, without an anal sac, unlike the taxocrinoids
with a single series of anal plates separated from the rays by a
perisome, forming an anal sac (Lewis, 1981; Moore, 1978a).

Superfamily **LECANOCRINOIDEA** Springer, 1913

**Diagnosis.**—Sagenocrinoids lacking nonanal interradials in
lateral interrays and having a prominent aboral cup.

**Remarks.**—Lecanocrinoideans are distinguished from
ichthyocrinoids by the prominence of the aboral cup. Ichthyocrinoids have a small, nonprominent aboral cup,
giving the crown an appearance of being almost entirely com-
posed of arms. Th e sagenocrinotoideans differ from these two
superfamilies in having interradials in all interrays.

Using the presence or absence of nonanal interbrachi-
als in superfamilial classification represents a departure
from traditional criteria, which emphasizes the prominence
of the aboral cup (Moore, 1978a). Th is change necessitates
the removal of the Nipterocrinidae, which have interradials, from the Lecanocrinoidea and their placement within the Sagenocrinoida. Also, Asaphocrinus Springer, 1920, which has been assigned to the sagenocrinoida family Homalocrinidae, is removed from that family and placed within the Nipterocrinidae. This action makes the Lecanocrinoidea a morphologically more homogeneous group. The addition of Asaphocrinus to the Nipterocrinidae does not significantly alter the definition of that family, and likewise the placement of the Nipterocrinidae in the Sagenocrinoida does not require emendation of the superfamilial diagnosis. The presence or absence of interradials, along with the prominence of the aboral cup segregate the Sagenocrinidae into three morphologically distinct groups. The Lecanocrinoidea and Ichtyocrinoidae are well constrained morphologically. The Sagenocrinoida is less well defined and could probably be subdivided with further study.

Family **LECANOCRINIDAE** Springer, 1913

*Diagnosis.*—Lecanocrinoidans with 3 infrabasals and both radianal and anal X in cup.

*Remarks.*—Lecanocrinids differ from mespilocrinids in possessing a radianal as well as an anal X plate; only the anal X plate is present in the mespilocrinids. Gaulocrinus Kirk, 1945 (Gaulocriniidae), lacks anal plates. All three families have three unequal infrabasals, as do most flexibles. The calycocrinids and propyllocrinids have fused infrabasals. Paleoholopodids have no discernible infrabasals or basals, they possess only a fused base below the radials, as in the problematical genus, Edriocrinus.

The lecanocrinids are the most primitive lecanocrinoidans, in that they possess both radianal and anal X plates. The other families originated from this stock through elimination of the anal plates, fusion of the infrabasals to one plate, and reduction of the arms.

Bowsher (1953) proposed the subfamily Lecanocrininae, to include only the genus *Lecanocrinus* and its three subgenera, *L.* (*Lecanocrinus*), *L.* (*Geroldicrinus* Jaekel, 1918), and *L.* (*Miracrinus* Bowsher, 1953). The latter two subgenera were raised to generic status by Strimple (1963). Moore (1978a) included *Lecanocrinus*, *Miracrinus*, *Geroldicrinus*, and *Mysticocrinus* Springer, 1918, in the Lecanocrinidae and did not subdivide the family into subfamilies. Frest & Strimple (1978c) retained generic status for *Geroldicrinus*, reduced *Miracrinus* again to subgeneric level, proposed another subgenus, *L.* (*Alneocrinus*) and erected a new genus, *Nummicrinus*. They used Bowsher’s (1953) subfamilial designation, despite the fact that Bowsher never set up or named another subfamily within the family Lecanocrinidae.

*Mysticocrinus* and *Lecanocrinus* are easily separated. However, *Miracrinus*, *Geroldicrinus*, and *Nummicrinus* are not easily distinguished and they share most characteristics with *Lecanocrinus*. *Nummicrinus* contains species—*N. pisiformis* (Roemer, 1860) and *N. brevis* (Strimple, 1952)—that are close to typical *Lecanocrinus* in cup shape, the main difference being the presence or absence of constricted radials. The morphological characteristics that have been used to separate these genera are considered to be merely extremes in a highly variable genus. Therefore, *Miracrinus*, *Geroldicrinus*, and *Nummicrinus* are herein synonymized with *Lecanocrinus*. Subfamilies are unnecessary with only two genera, *Lecanocrinus* and *Mysticocrinus*, assigned to the family Lecanocrinidae.

Genus **LECANOCRINUS** Hall, 1852

*Synonyms.*—*Geroldicrinus* Jaekel, 1918; *Miracrinus* Bowsher, 1953; *Nummicrinus* Frest & Strimple, 1978.

*Type Species.*—*Lecanocrinus macroptalus* Hall, 1852.

*Diagnosis.*—Lecanocrinids with the radianal below and to the left of the C-ray radial; arms occupying the full width of the radial.

*Remarks.*—*Lecanocrinus* is separated from *Mysticocrinus* by the position of the radianal below and to the left of the C-ray radial and plenary radial facets. *Mysticocrinus*, in contrast, has the radianal directly below the C radial, and each arm occupies a deep cleft that involves only part of the distal width of the radial. *Lecanocrinus*, as defined above, is a highly variable genus that contains a wide variety of morphologies, including variations in cup shape (conical to globose to flat), cup outline (round to pentagonal), crown shape (elongate to nearly spherical), number of arm bifurcations, and degree of basal invagination (Frest & Strimple, 1978c; Strimple, 1952a, 1954, 1963). The genus is in need of major revision. A revision based on consistent morphological criteria that considers intraspecific variation would probably reduce the number of species recognized.

**Lecanocrinus** *cf.* *pusillus* (Hall, 1863)

*Pl.* 9, Figs 13–14


*Lecanocrinus tennesseensis* Miller, 1892: 651, pl. 7, figs 7–8.

*Diagnosis.*—*Lecanocrinus* with a low, erect, bowl-shaped cup; basals large, high; shallow basal concavity; rounded base.
**Description.**—Cup low (width:height = 1:0.6), erect, bowl-shaped with round base and smooth plates. Infrabasals 3, small, unequal; azygous infrabasal in C ray. Shallow basal cavity containing most of infrabasal circle, which is smooth or protruding slightly. Basals 5, large, higher than wide, subequal; CD basal truncate. Radials 5, wider than high, separated in CD interray. Radianal large, quadrangular. Anal X equal; CD basal truncate. Radials 5, wider than high; largest plates in cup, constricted at top; shallow transverse groove toward outside of radial arm facet; radial circle separated by X. Radianal quadrangular, below and to left of C-ray radial. Anal X higher than wide extending to the first secundibrachial. Primibrachials 2, much wider than high. Secundibrachials 3–4; 3 or more tertibrachials; all arms tightly appressed. Stem xenomorphic, with short proximal portion composed of thin columnals, tapering rapidly distally. Remainder of stem composed of thick, higher, cylindrical columnals. Tegmen not present.

**Remarks.**—Lecanocrinus pusillus is described as having fine raised granules as ornament (Springer, 1920). The present specimens are smooth, but their overall appearance is closer to that of L. pusillus than to any other illustrated species. Study of the Lecanocrinus in the Decatur and Ross indicates that there are too many described species, many of which cannot be distinguished. Strimple (1952a, 1954) added six new species. Careful study of all known specimens will surely result in a decrease in the number of recognized species. Past efforts (Strimple, 1963; Frest & Strimple, 1978c) have not resulted in clear-cut specific diagnoses that emphasize the differences between the species.

**Lecanocrinus pusillus** is distinguished from *L. macropetalus*, the most similar species, by having larger basals, a shallow basal concavity, and an erect bowl-shaped cup. *Lecanocrinus macropetalus* has less prominent basals, no basal concavity, and an open bowl-shaped cup. The criteria generally used for distinguishing species of *Lecanocrinus* are cup shape (cuneo to bowl to flat), cup outline (round to pentagonal), base shape (round, flat, or truncate), degree of basal concavity, the height to which the anal X plate extends above the radials, and relative cup plate proportions. However, these described species exhibit variations in these parameters that make certain identification difficult.

**Material and Occurrence.**—Two incomplete specimens: PRI 53743, partial cup missing most radials and anal X, but uncrushed, partially embedded in matrix, 11 mm high, 17 mm wide; PRI 68341, somewhat crushed and distorted partial cup complete only in D ray, retaining RA and X, 12 mm high, 19 mm wide. Specimen PRI 53743 from lower Rockhouse Limestone, loc. AM; PRI 68341 from upper Decatur Limestone, loc. PQ (Pridoli–Lochkov).

**Lecanocrinus pisiformis** (Roemer, 1860)  
Pl. 9, Figs 6–8, 10, 12

**Poteriocrinus pisiformis** Roemer, 1860: 54, pl. 4, fig. 7.

**Lecanocrinus pisiformis**.—Springer, 1920: 135, pl. 1, figs 14–36; 1926a: 65, pl. 20, figs 6–12.

**Nummicrinus pisiformis**.—Frest & Strimple, 1978c: 529.


**Diagnosis.**—Lecanocrinus with small, low, constricted bowl-shaped cup, and rounded base.

**Description.**—Cup low (width:height = 1:0.5–0.7), constricted bowl-shaped, with rounded base and smooth to finely granulose plates. Basals 3, small, unequal; azygous infrabasal in C ray; basal concavity ranging from none to shallow and dish-like, to vertical-sided, all within infrabasal circle. Basals 5, relatively small, equal; CD basal truncated by radianal and anal X. Radials 5, large, wider than high; largest plates in cup, constricted at top; shallow transverse groove toward outside of radial arm facet; radial circle separated by X. Radianal quadrangular, below and to left of C-ray radial. Anal X higher than wide extending to the first secundibrachial. Primibrachials 2, much wider than high. Secundibrachials 3–4; 3 or more tertibrachials; all arms tightly appressed. Stem xenomorphic, with short proximal portion composed of thin columnals, tapering rapidly distally. Remainder of stem composed of thick, higher, cylindrical columnals. Tegmen not present.

**Remarks.**—Lecanocrinus pisiformis is distinguished from other Lecanocrinus species by its small size, rounded base, and constricted radials. It usually has a small, steep-sided basal concavity, but this can be shallow or lacking. The arms form slightly less than half of the crown height. The cup is wider than high, with width to height ratios ranging from 1:0.5–0.7. *Lecanocrinus pisiformis* is the most abundant species of *Lecanocrinus* in the Decatur–Ross interval, being known from 38 specimens collected during this study. With a relatively large number of specimens, intraspecific variation is apparent. One specimen (Pl. 9, Fig. 7) possesses a greatly enlarged radianal, which contacts the infrabasal circle and resembles an unusually small basal. Some specimens have a more elongate cup than is typical (Pl. 9, Fig. 6), whereas others lack a basal concavity (Pl. 9, Fig. 10). However, most specimens fall within a rather restricted range of variation. It is interesting that this species has not been reported previously from the Rockhouse or Decatur limestones, although it is quite common in the underlying Brownsport Group.

**Material and Occurrence.**—Thirty-eight specimens (PRI 53736–53745, 54236–54241, 68342–68366): 5 crowns or partial crowns, 18 cups, and 12 partial cups. Most are at least partially embedded in matrix and range from 4–8 mm high, 7–12 mm wide, maximum crown height 15 mm (PRI 68342).

All specimens collected are from the Decatur Limestone or lower Rockhouse Limestone. The greatest number are from the lower Rockhouse Limestone at loc. AM and include three crowns (all exhibiting some degree of disarticulation; PRI 53738, 53742, 68342), 14 cups, and nine partial cups. Other localities are BQ with one cup (PRI 68360) and three partial cups (PRI 68358–68359, 68364); loc. CL with two partial...


crowns (PRI 53737, 68361); loc. MQ with two cups (PRI 53739, 53744); loc. PQ with one partial cup (PRI 68362); loc. Q13 with one cup (PRI 68363); loc. RCb with one cup (PRI 68366) and one partial cup (PRI 68365). All of the above (except PRI 68364, those from locs. AM and CL) are from the upper Decatur Limestone. The specimens from CL are from the middle Decatur (Pridoli–Lochkov).

**Lecanocrinus meniscus** Springer, 1920

Pl. 10, Figs 1–6


**Diagnosis.**—Lecanocrinus with a low, conical, and truncate base formed by proximal basals and infrabasals.

**Description.**—Cup low (width:height = 1:0.4–0.5), conical, with truncate base composed of infrabasals and proximal basals; sutures strongly depressed to flat; plates thick, smooth to ridged with pits. Infrabasals 3, unequal, confined to base or visible from side, composing 60–90% of base; azegous infrabasal in C ray; circlet nearly covered by stem to extending considerably beyond stem facet. Basals 5, large, equal, wider than high, composing 10–40% of base; CD basal slightly larger than others, truncated distally by anal X. Radials 5, large, equal, wider than high; radial facets (bases of arms) located at noticeably different levels depending on ray; radials separated on posterior side by large elongate anal X. Quadrangular radial below and to left of C radial; large elongate anal X to first secundibrachial. Arms appressed; all brachials much wider than high. Primibrachials 2. Secundibrachials 3–4. Tertibrachials 6 or more, curling inward distally. Stem much less wide than base; proximal stem composed of very thin columnals, with a slight expansion immediately below stem cicatrix; columnals thickening distally. Holdfast disoidal. Tegmen not present.

**Remarks.**—Lecanocrinus meniscus is well segregated from other Lecanocrinus species by its unique, flat, truncate base formed by the infrabasals and proximal basals. The cup is very low with a width to height ratio of 1:0.4–0.5 and makes up only a small percentage (27–29%) of the crown height. Ornamentation is variable from specimen to specimen and ranges from smooth plates, to plates with depressed sutures, to pitted and ridged plates. A shallow basal concavity is present in some specimens. The infrabasals vary in size. Some specimens exhibit a small circlet, nearly covered by the stem and occupying ca. 60% of the base. Others (e.g., PRI 54245; Pl. 10, Fig. 5) have a large circlet that occupies most (90%) of the base and extends far beyond the stem facet and even beyond the base, making up most of the base of the cup and visible from the side. Unlike in most lecanocrinids, the tops of the radials are not at the same level, but differ in each ray. The species was originally described from a single specimen from the Brownsport Formation (Ludlow) of Tennessee; however, these six specimens, all from the Ross Formation, better define the species and extend its range into the Lower Devonian.

**Material and Occurrence.**—Six specimens: five crowns or partial crowns, three with proximal stem, one cup with first primibrachials in four rays, anal X not preserved. Cup height ranging from 4–8 mm, cup width 10.5–15 mm, crown height 14–27 mm. One specimen (PRI 54244) is nearly complete with a partially disarticulated crown, on a slab of limestone with the impression of the stem leading to a preserved holdfast, with a crown 27 mm in height, plus stem 260 mm long.

Specimen PRI 54242 from lower Rockhouse Limestone, roadcut (RCb) along Tennessee Route 69 north of Parsons, Tennessee; PRI 54243 and 68367 from lower Rockhouse Limestone, loc. PQ; PRI 54246, upper Rockhouse Limestone or lower Birdsong Shale, loc. PQ; PRI 54245, upper Rockhouse Limestone or lower Birdsong Shale, loc. BQ; PRI 54244, upper Birdsong Shale (Bryozoan Zone), loc. BQ (cri-noid bed) (Lochkov).

**Lecanocrinus sp. A**

Pl. 9, Fig. 11

**Diagnosis.**—Large, low, bowl-shaped cup with large basal concavity entirely containing infrabasals.

**Description.**—Cup large, bowl-shaped, with large basal concavity, entirely containing infrabasals. Plates smooth. Infrabasals in basal concavity, covered by proximal columnal. Basals 5, large, equidimensional, with largest plates in cup. Radials 5, large, wider than high, somewhat smaller than basals. Radialal elongate, quadrangular, below and to left of C radial; large anal X separating radials. Arms and stem not preserved.

**Remarks.**—This single, severely distorted specimen is quite different from other Lecanocrinus in the Ross or Decatur formations. Its large size and large basal concavity that completely contains the infrabasals are distinctive. Four species of Lecanocrinus that have the infrabasals completely within a basal concavity include *L. (formerly Geroldicrinus) roemerii* Schultze, 1866, *L. (formerly Miradicrinus) perdewi* Bowsher, 1953, *L. invaginatus* Strimple, 1952, and *L. magniradia-lis* (Weller, 1903). *Lecanocrinus roemeri* (Germany, Eifelian) has small basals and pentagonal outline; *L. sp. A* has large basals and, apparently, a circular outline, whereas *L. invagi-natus* (Henryhouse Formation, Oklahoma, Ludlow) also has
relatively smaller basals. Lecanocrinus perdewi (New Scotland Limestone, New York, Lochkovian) has bulbous plates. Whether or not these are all valid specific differences is not clear. The cup of L. magniradialis (New Scotland Limestone, New York, Lochkovian) appears to be more conical, rather than a low bowl shape as in L. sp. A.

Material and Occurrence.—One crushed and distorted cup, PRI 53741, embedded in a shaly limestone matrix, but exposed on most sides, 11 mm high, 24 mm wide (measurements approximate due to crushing). Lower Rockhouse Limestone, loc. EQ (Lochkov).

Lecanocrinus lawsonae McIntosh, 1981

Pl. 9, Fig. 9

Lecanocrinus lawsonae McIntosh, 1981: 964, text-figs 1A–B.

Diagnosis.—Lecanocrinus with low, conical cup, considerably wider than high, composed of smooth thecal plates; basal concavity very shallow, barely contacting basal circlet.

Description.—Cup low; plates thick, smooth. Infrabasals 3, small, unequal, visible from side. Basal concavity small, shallow, contained within infrabasal circlet. Basals 5, equidimensional, nearly as large as radial plates. CD basal truncated by radial and anal X. Radials 5, wider than high; largest plates in cup. Radial small, quadrangular, below and to left of C radial. Anal X nearly as large as radial, projecting above first primibrachial. First primibrachial much wider than high, occupying full width of radial facet. Stem and arms not preserved.

Remarks.—This species appears to be different from any of the other lecanocrinids in the Ross Formation. It lacks the radial constriction of Lecanocrinus pisiformis, the wide base of L. meniscus, and the basal cavity morphology and plate dimensions of L. sp. A. Lecanocrinus lawsonae is most similar to L. pusillus, but it differs in having a smaller basal concavity and thicker plates. The shape of L. lawsonae cannot be defined due to crushed and partially disarticulated plates. McIntosh (1981: 964) was wrong in assuming that L. lawsonae and L. anna (Tansey, 1924) were the only smooth-plated species of Lecanocrinus found in Devonian age rocks, considering that both L. meniscus and L. sp. A are smooth-plated. No specimens of L. lawsonae were found during this study.

Type and Occurrence.—Holotype, USNM S305439, crushed cup preserved to IBrr1. Birdsong Shale, Roadcut on Tennessee Route 69 (probably loc. RCB) (Lochkov).

Superfamily ICTHYOCRINOIDEA Angelin, 1878

Diagnosis.—Sagenocrinoids lacking nonanal interradials and without a prominent aboral cup.

Remarks.—Ichthyocrinoids are distinguished by their small aboral cups, which are not distinct from the arms and compose only a small fraction of the crown. Consequently, they appear to be composed entirely of arms. This is distinct from the lecanocrinoids, which have a well-developed cup comprising as much as 30% of crown height. Sagenocrinoids have interbrachials in the lateral interrays, which distinguishes them from the other two superfamilies. Ichthyocrinoids and lecanocrinoids are closely related and probably share a common ancestor (Brower, 1973). The genus Clidochirus Angelin, 1878, presently assigned to the Icthyocrinoida, might have given rise to other early ichthyocrinoids (Clidocrinus Springer, 1920, Icthyocrinus) and also to Lecanocrinus, the most primitive lecanocrinoid, (see Brower, 1973). Clidochirus has a much more prominent cup than later ichthyocrinoids and its morphology is intermediate between typical ichthyocrinoids and lecanocrinoids, as might be expected in an ancestral form.

Clidochirus americanus Springer, 1920 (Brassfield Limestone, Ohio, Llandovery) is the species that gave rise to Lecanocrinus, because of its single anal X and closely abutting arms (Springer, 1920; Ausich, 1984). The species that gave rise to Icthyocrinus is still unclear but might also have been C. americanus. Derivation of Icthyocrinus from that species would involve a reduction in the size or prominence of the cup, and loss of the anal X.

Family ICTHYOCRINIDAE Angelin, 1878

Diagnosis.—Same as for superfamily (the Ichthyocrinoidea contains only the family Icthyocrinidae).

Genus ICTHYOCRinus Conrad, 1842

Type Species.—Icthyocrinus laevis Conrad, 1842.

Diagnosis.—Ichthyocrinids with a single anal plate, and radial situated directly below C radial.

Remarks.—Icthyocrinus is distinguished from other icthyocrinids by its single anal plate, and a radial directly below the C-ray radial. Clidochirus has a more prominent aboral cup than other ichthyocrinids and has a radial directly below the C radial; it differs in the presence of an anal X plate and, in some species, higher anal plates. Clidocrinus is similar to Clidochirus but has a very small aboral cup. Both Synaptocrinus...
Springer, 1920, and *Meticyocrinus* Springer, 1906, lack a radial anal and anal X; *Synaptocrinus* differs by having a greatly enlarged CD basal (Springer, 1920; Moore & Laudon, 1943; Brower, 1973). Although Moore (1978a) illustrated *Synaptocrinus* with an anal X plate, Springer (1920), Moore & Laudon (1943), and Brower (1973) noted the absence of an anal X. No other published work has indicated the presence of an anal X plate, and Moore’s (1978a) illustration is considered a misinterpretation of Springer’s (1920) diagram.

**Icthyocrinus erugatus** n. sp.

*Pl. 10, Figs 7, 10*

**Diagnosis.**—*Icthyocrinus* with a rounded base and smooth plates.

**Description.**—Crown with rounded, wide, bowl-shaped base expanding to top of secundibrachials. Shallow basal concavity involving most of basals. Smooth plates without depressed sutures; sutures straight, not wavy. Wide, low ray ridge not extending beyond second primibrachial. Aboral cup very small, almost horizontal. Stem cicatrix including proximal parts of radials. Infrabasals almost completely resorbed. Basals 5, small, subequal, almost completely within shallow basal concavity. Radials 5, small, subequal, wider than high. Primibrachials 2, expanding; second primibrachial largest plate in crown. Secundibrachials 3–4; at least 3 tertibrachials; all brachials much wider than high. Radianal small, directly below C radial. Stem and distal arms not preserved.

**Remarks.**—Species of *Icthyocrinus* are distinguished primarily on the basis of lower crown shape (conical, bowl), base shape, the prominence of the basals (whether or not visible from the side), and ornamentation. *Icthyocrinus erugatus* n. sp. is distinguished by its bowl-shaped lower crown, rounded base, and smooth plates with undepressed sutures. It also has small basals that are not visible from the side and are only just visible beyond the stem; the proxistele slightly overlaps the radials and probably covered the radianal.

The species most similar to *Icthyocrinus erugatus* n. sp. are *I. phillipsianus* Springer, 1920 (Wenlock Limestone, England, Wenlock), and *I. devonicus* (Birdsong Shale, Tennessee, Geddianin/Lochkovian). Although *I. phillipsianus* has a bowl-shaped lower crown, its base is narrow, unlike *I. erugatus* n. sp., which has a rounded base. *Icthyocrinus devonicus* has a low, cone-shaped lower crown, and both *I. devonicus* and *I. phillipsianus* possess depressed sutures (see Springer, 1920). *Icthyocrinus erugatus* n. sp. is also similar to *I. bohemicus* Waagen & Jahn, 1899 (Koneprusy Limestone, Bohemia, Pragian), which differs in having a narrow-based, bowl-shaped lower theca and prominent basals visible from the side (see Prokop, 1975).

The single specimen of this species is the second *Icthyocrinus* from the Ross Formation, the other being *I. devonicus*, which is also known from one specimen. Despite the paucity of material there is enough morphological difference between these specimens to warrant assignment to separate species.

**Type and Occurrence.**—Holotype, PRI 54247, single, apparently uncrushed, partial crown preserved to first primibrachial in all rays, to the fourth secundibrachial in two rays (A and B) and to the third tertibrachial in a partially preserved ray (E), preserved on small slab of limestone, crown 9 mm high, 19 mm wide. Lower Rockhouse Limestone, loc. AM (Lochkov).

**Etymology of Name.**—Specific name *erugatus* (L.), smooth, referring to the smoothness of the cup and lack of depressed sutures.

**Icthyocrinus devonicus** Springer, 1920

*Pl. 10, Figs 8, 11*

*Icthyocrinus devonicus* Springer, 1920: 290, pl. 35, figs 17a–c.

**Diagnosis.**—*Icthyocrinus* with cone-shaped lower crown, narrow, protrusive base, and depressed sutures.

**Description.**—Crown with narrow, cone-shaped lower crown, expanding to top of secundibrachials. Smooth plates with depressed sutures. Ray ridges lacking. Aboral cup very small. Stem cicatrix involving radial plates. Infrabasals, basals, and radianal covered by proximal columnal. Radials 5, small, wider than high. Primibrachials 2, expanding; second primibrachial largest plate in crown. Secundibrachials 3–7 tertibrachials; 6 or more quartibrachials; all brachials wider than high. Stem not preserved.

**Remarks.**—*Icthyocrinus devonicus* is distinguished from other species of *Icthyocrinus* by its cone-shaped lower crown, narrow, protrusive base, and depressed sutures. In contrast, the co-occurring *I. erugatus* n. sp. has a bowl-shaped lower crown, a rounded base, and sutures that are not depressed. Specimens of *I. devonicus* were not collected during this study, but it is included for completeness and comparison with *I. erugatus* n. sp. It is known from one specimen from the Linden Formation (= Ross Formation) of Benton County.

**Type and Occurrence.**—Holotype, USNM S1706, crown. Ross Formation, Benton County, Tennessee (Lochkov).

Superfamily SAGENOCRINITOIDEA Roemer, 1854

**Diagnosis.**—Sagenocrinoids with nonanal interradials.
Remarks.—As stated under Lecanocrinoidea, emphasis on the presence or absence of nonanal interradials necessitates removal of the Nipterocrinidae from the Lecanocrinoidea and its reassignment to the Sagenocrinoidea, an action that makes the Lecanocrinoidea a more tightly constrained taxon and does not affect the definition of the Sagenocrinoidea.

Family **NIPTEROCRINIDAE** Jaekel, 1918

**Diagnosis.**—Sagenocrinoidea with a prominent aboral cup and numerous, small, irregular, interradials.

**Remarks.**—The Nipterocrinidae is distinguished from other sagenocrinoidean families by the possession of a well-developed aboral cup, and numerous, small, irregular interradials. The Nipterocrinidae and Homalocrinidae are considered here in most closely related because they share a prominent aboral cup, and numerous, small, irregular interradials. Asaphocrinus, previously assigned to the Homalocrinidae (Moore, 1978a; Frest & Strimple, 1978a), is herein reassigned to the Nipterocrinidae. Asaphocrinus probably evolved from Proanisocrinus Frest & Strimple, 1978 (Homalocrinidae) (see Frest & Strimple, 1978a), and might have given rise to other nipterocrinids.

**Genus** **PARAHORMOCRINUS** n. gen.

**Type Species.**—Parahormocrinus decaturensis n. sp.

**Diagnosis.**—Nipterocrinid with single, large interbrachial followed by numerous small plates; radianal below and to left of C-ray radial.

**Remarks.**—Parahormocrinus n. gen. is distinguished from other nipterocrinids in possessing a single, large interradial plate in each interray, which is followed by the usual small, irregular, perisome-like plates, and a large radianal. Two genera of nipterocrinids, Pycnosaccus Angelin, 1878, and Cholocrinus, Springer, 1906, possess a radianal in the same position as Parahormocrinus n. gen. but lack the proximal large interradial plates. Hormocrinus Springer, 1920, is the only other nipterocrinid with large interradials but it lacks a radianal. The species of Hormocrinus have relatively large infrabasals that are visible from the side, and the CD basal is not much larger than the other basals. Conversely, the infrabasals of the single known specimen of Parahormocrinus n. gen. are almost entirely covered by the stem, and the CD basal is much larger than the other basals. These differences clearly differentiate Parahormocrinus n. gen. from other nipterocrinids, including Hormocrinus.

The origins of Parahormocrinus n. gen. are obscure. Derivation of this genus from Hormocrinus would involve the re-evolution of the radianal. Derivation from a genus such as Pycnosaccus with a radianal, would require the formation of a large, regular interradial, either by adding a plate or greatly enlarging a pre-existing perisomal plate. Hormocrinus could have been derived from Parahormocrinus n. gen. by loss of the radianal. However, Hormocrinus is presently known from strata of an earlier age (Ludlow) than Parahormocrinus n. gen. (Pridoli). This stratigraphic arrangement suggests separate derivations of the two genera. It seems more likely that both Hormocrinus and Parahormocrinus n. gen. arose separately from a form like Asaphocrinus, which has a radianal plate, and relatively large perisomal plates.

**Etymology of Name.**—Para (Gr.), near, plus Hormocrinus, denoting resemblance to Hormocrinus.

**Parahormocrinus decaturensis** n. sp.

Pl. 10, Fig. 9; Text-fig. 8

**Diagnosis.**—Same as for genus.

**Description.**—Calyx low, conical. Infrabasals 3, small, unequal, nearly covered by stem; azygous infrabasal in C ray. Basals 5, small, subequal; CD basal much larger than others, all much smaller than radials. Radials 5, large, equidimensional, separated on distal edge by first interradial; C radial pushed distally, with distal edge at level with distal edge of first interradial; radials largest plates in cup and crown. Primibrachials 2, large, wider than high; 2–3 secundibrachials; 3 or more tertibrachials. Radial larger than lateral interray basals, below and to left of C radial; anal X not preserved. First interradials 5, approximately as large as normal basals, extending to midlevel of primibrachials, separating distal edge of radials, followed by small irregular plates to first or second tertibrachial level where adjacent rays adjoin. Proximal stem apparently composed of thin columnals, tapering slowly, distally. Tegmen, most of stem, and arms beyond second tertibrachial not preserved.

**Remarks.**—Two plates are not preserved but almost certainly existed. The more important of the two is the anal X. Although not preserved in the present specimen, facets on the radianal and truncated CD basal attest to its presence. It is inferred that the anal X is a large, elongate plate. Secondly, the facets on the secundibrachials suggest the presence of an intersecundibrachial that began above the first secundibrachial level.
and probably extended to the level of the first tertibrachial. The ornament of the cup and brachials is obscured by secondary overgrowths of syntaxial calcite.

Type and Occurrence.—Holotype, PRI 54248, partial, somewhat crushed crown, preserving rays A, B and C; rays D and E along with the DE basal are missing. Maximum ray preservation to the second tertibrachial. The CD basal and radianal are preserved; anal X is not. Some perisomal plates are apparently preserved in the AB interray. Cup 4 mm high, 8 mm wide; preserved crown height 10 mm; preserved stem length 2 mm. Upper Decatur Limestone, loc. Q13 (Pridoli).

Etymology of Name.—Specific name *decaturensis*, denoting the formation in which the holotype occurs.

Order undetermined
Superfamily undetermined
Family **EDRIOCRINIDAE** Miller, 1889

Diagnosis.—Flexibles without stalk or infrabasals, with four fused basals.

Remarks.—Edriocrinids are an enigmatic group of stalkless crinoids that are characteristic of Lower Devonian echinoderm faunas. They are mostly known from isolated bases that consist of four firmly united basals. Their assignment to the Flexibilia is based on their arms in which the first primibrachial occupies the full width of the radial and bears a striking similarity to lecanocrinoid arms. The arms are well known in only two species, *Edriocrinus sacculus* Hall, 1859 (Oriskany Sandstone, Little Saline Limestone; New York, Missouri; Emsian, Eifelian), and *E. holopoides* Springer, 1920 (Ridgeley Sandstone, Maryland, Emsian), but these are known in abundance. The cup, besides the fused basals, is composed of five radials and an anal X that is the same height as the radials.

Genus **EDRIOCRINUS** Hall, 1858

Type Species.—*Edriocrinus pocilliformis* Hall, 1859.

Diagnosis.—Same as for family.

Remarks.—Springer (1920) gave a good account of both previous work on and morphology of this genus. He divided *Edriocrinus* into two groups, those with little or no trace of attachment, which were presumed to have lived free as adults, and those that were attached to a hard object as adults. Lack of infrabasals and possession of four fused basals makes edriocrinids unique among the flexibles, if this is where they truly belong. Springer (1920) placed *Edriocrinus* provisionally in the Flexibilia, and their phylogenetic position remains uncertain.

*Edriocrinus adnascens* Dunbar, 1919
Pl. 11, Figs 2, 7

*Edriocrinus adnascens* Dunbar, 1919: 52, pl. 2, fig. 10.

Diagnosis.—*Edriocrinus* with a short, permanently attached base that does not expand toward radials.

Description.—Base irregularly circular, much wider than high, with central depression. Basals 4, unequal, with irregular sutures, forming rim around central concavity, spreading slightly toward attachment. Six notches for insertion of radials and anal X. Base permanently attached to hard object. Radials, anal X, and arms not preserved.

Remarks.—*Edriocrinus adnascens* is distinguished from other species of *Edriocrinus* by its permanently attached nature and short base that is wider than high. *Edriocrinus pyriformis* has a much higher than wide base. Although *E. adnascens* and *E. holopoides* overlap with respect to size, the latter is generally larger and has a basal internal cavity that does not become constricted proximally (Springer, 1920), as does that of *E.
Edriocrinus cf. pyriformis Hall, 1862
Pl. 11, Figs 1, 6

Diagnosis.—Edriocrinus with higher than wide, permanently attached base.

Description.—Base elongate, bent, irregular at contact with substratum. Basals 4?, unequal, with irregular suture. Base permanently attached to hard object; plates very thin at center of attachment. Distal parts of basals, radials, anals, and arms not preserved.

Remarks.—The specimens representing this species are distinguished from Edriocrinus adnascens by their cylindrical basal circlot that is higher than wide. The base expands only slightly at the attachment site, and the base of one specimen bends at approximately half the overall height. The two specimens are no longer attached to their original substrata, although the bases retain the impressions of the original attachment. This suggests that individuals of this species were less firmly attached to their substrata than those of E. adnascens, which never occur unattached. If these specimens truly belong to E. pyriformis, this occurrence extends its geographic range from New York and the stratigraphic range downward to the basal Devonian.

Material and Occurrence.—Two specimens, PRI 54249, 68387. Specimen PRI 54249 is 8 mm wide, 11 mm high; specimen PRI 68387, which is less complete, is 9 mm wide, 4 mm high. Both specimens are incomplete, missing the distal basals, radials, and arms. Rockhouse Limestone (lower), loc. RCb (Lochkov).
**Edriocrinus occidentalis** Springer, 1920

*Pl. 11, Fig. 10*

*Edriocrinus occidentalis* Springer, 1920: 445, 449, pl. 76, figs 6–12.—Goldring, 1923: 445, text-fig. 61A.

**Diagnosis.**—Small free-living *Edriocrinus* with rounded base and elongate basals that are constricted below the facets supporting the radials.

**Description.**—Basals 4, elongate, with rounded base. Constriction below facets supporting radials, flaring slightly above. Radials, anal X, and arms not preserved.

**Remarks.**—*Edriocrinus occidentalis* is known only from basal circlets, which are elongate, round-based, and have a constriction below the basal-radial facets. Springer (1920) noted that the specimens are preserved in chert, suggesting that they were from the Camden Formation, which overlies the Ross Formation. No specimens of *E. occidentalis* were collected in this study.

**Material and Occurrence.**—Several specimens in the collection of the National Museum of Natural History; USNM 533993 illustrated (from Springer, 1920: pl. 76, fig. 10). Stewart and Decatur counties (Lochkov?).

**Subphylum BLASTOZOA** Sprinkle, 1978

**Diagnosis.**—Echinoderms with brachioles, subjective structures lacking coelomic extensions.

**Class BLASTOIDEA** Say, 1825

**Diagnosis.**—Blastozoans with hydrospires.

**Remarks.**—Blastoids are also known by having three basals (one azygous), lancet plates, and ambulacra recumbent on the theca.

**Order FISSICULATA** Jackel, 1918

**Diagnosis.**—Blastoids with exposed hydrosphere slits.

**Remarks.**—Blastoids with exposed hydrosphere slits are grouped in the Fissiculata, whereas those with hidden hydrosphere slits or pores and spiracles are assigned to the Spiraculata. Further study (Horowicz et al., 1986; Breimer & Macurda, 1972: 322, 359; Broadhead & Waters, 1984), however, suggested multiple evolution of the spiracular condition, which raises doubt about the usefulness of defining two groups on the basis of this trait. If the spiracular condition arose several times during the history of the blastoids, then it is not of phylogenetic or taxonomic (at the ordinal level) significance, and should not be used as a discriminating characteristic. This would necessitate re-examination of the entire class, to identify phylogenetically sound criteria to subdivide it.

**Family PHAEOSCHISMATIDAE**

Etheridge & Carpenter, 1886

**Diagnosis.**—Fissiculates with prominent ambulacral sinuses and interambulacral pyramids.

**Remarks.**—There have been four major works (Fay, 1961; Fay & Wanner, 1967; Breimer & Macurda, 1972, 1973) concerning familial and generic descriptions and diagnoses of the fissiculate blastoids in the late 1900s. Fay (1961) cited uncertainties with discriminating characteristics at the family level and dealt mainly with the generic level. He proposed a preliminary classification using the number and exposure of hydrosphere slits. Fay & Wanner (1967) formally used these criteria to erect five families.

Breimer & Macurda (1972), in a much more in-depth study, distinguished eight families based on many characters including thecal shape, presence of ambulacral sinuses, morphology of the deltoids, shape of the ambulacra, exposure of the lancet, structure of the hydrospheres, and composition of the anal area. They believed that, by using a large number of discriminating characteristics, their classification more closely approached an evolutionary taxonomy, reflecting the evolution of blastoids (Breimer & Macurda, 1972: 13). This approach, which relies on many variables, could help to understand how blastoids evolved. In practice, their diagnoses are unwieldy and make the placement of new genera or the reasons for placement of known genera within a family uncertain. A classification must be usable to provide an effective communication tool, one of the primary functions of taxonomy. By this criterion, their use of many characters to distinguish individual taxa has failed. The family diagnosis given above is tentative at best, but seems to distinguish those genera that Breimer & Macurda (1972) and Macurda (1983) placed within the Phaenoschismatidae.

The attempts of Fay (1961) and Fay & Wanner (1967) were too simplistic to be an accurate reflection of phylogenetic relationships, but the approach of Breimer & Macurda (1973) is too complex with too many overlapping characters to be usable. A compromise, using fewer, characters, which are truly diagnostic, is needed to produce a truly functional taxonomy of nested, hierarchical diagnoses. Such a compromise can be attained only after further and extensive study of blastoids, and such an undertaking is clearly beyond the scope of this project. Therefore, all familial attributions and diagnoses herein are to be considered tentative.
Genus **DECASCHISMA** Fay, 1961

**Synonym.**—*Leptoschisma* Breimer & Macurda, 1972.

**Type Species.**—*Codaster pulchellus* Miller & Dyer, 1878.

**Diagnosis.**—Phaenoschismatid with 10 hydrospire groups, 3 anal deltoids (super-, sub-, and hypodeltoids), and lancet covered over most of its length.

**Remarks.**—To differentiate the various genera within the Phaenoschismatidae, Fay (1961) and Fay & Wanner (1967) used thecal shape, degree of exposure of the hydrospires, anal deltoid configuration, and amount of exposure of the lancets. In addition to the above characters, Breimer & Macurda (1972) employed the angle of the ambulacral sinus, prominence of the interambulacral pyramids, morphology of the deltoid crest, number of hydrospire groups, shape of the ambulacra, position of the gonopore, and presence of secondary calcite secretions to distinguish the genera. Fay’s (1961) diagnostic criteria are more readily usable and differentiate the genera nearly as well. Additional characters, some of which are typical but not diagnostic, only serve to obscure the features that actually distinguish each genus. Therefore, Fay’s (1961) diagnoses are used here with slight modification.

**Artuschisma** Macurda, 1983, has a superdeltoid and two cryptodeltoids; a hypodeltoid is unknown, but probably is present (Macurda, 1983). *Pentremoblastus* Fay & Koenig, 1963, has super-, sub-, and hypodeltoids, but the lancets are exposed over much of their length (Macurda, 1983).

Careful review of the familial and generic descriptions (Breimer & Macurda, 1972) and specific descriptions (Macurda, 1983) of *Decaschisma pulchellum* (Waldron Shale, Indiana, Wenlock) and *Leptoschisma lorae* (Dunbar, 1920) (Birdsong Shale, Tennessee, Geddinian/Lochkovian) reveal almost complete overlap of the characters cited. Vault height proved to be the most significant difference between these species along with slight differences in the shape of the ambulacra during early stages of ontogeny; juvenile ambulacra are slightly convex in *D. pulchellum*, but petaloid in *L. lorae*. They become linear in adults of both taxa. These differences are not thought to be sufficient to justify segregation of these two species into separate genera; *Leptoschisma* is, therefore, considered to be a junior synonym of *Decaschisma*.

*Pentremoblastus* is closely related to *Decaschisma*; it differs in having an exposed lancet, somewhat wider radial sinuses, and lanceolate ambulacra. Whether these characters are sufficient to define the genera is unclear. Other genera presently placed within the Phaenoschismatidae have different anal structures.

**Decaschisma lorae** (Dunbar, 1920) n. comb.

*Pl. 11, Figs 8–9*

**Codaster lorae** Dunbar, 1920: 119, pl. 2, figs 1–2.

*Leptoschisma lorae*—Breimer & Macurda, 1972: 15, 61, text-fig. 4, pl. 1, figs 4–7; Macurda, 1983: 8, pl. 2, figs 5, 8, pl. 3, figs 1–6, 8.

**Diagnosis.**—*Decaschisma* with moderate vault, and flat facet between hypodeltoid and underlying radial limbs.

**Description.**—Theca elongate, conical in lateral view, rounded pentangular in oral view; vault of moderate height. Ambulacral sinuses deep; interambulacral pyramids short, extending slightly above peristome. Hydrospire slits mostly covered by ambulacra, extending across full width of radial-deltoid suture. Basals 3, unequal; azygous basal in AB position. Pelvis elongate, steep-sided with very small stem facet. Radials 5, equal, with deep ambulacral sinuses. Ambulacra linear. Lancets completely covered except at adoral extremity, resting on deltoid lips and distal radial body. Nonanal deltoids 4, very small, not composing part of outer wall, with small upward trending deltoid crest. Anal deltoids 4; small superdeltoid equal in size to deltoid lips; subdeltoid inverted U-shaped; hypodeltoid missing but facets indicate a triangular shape, similar to that of *Decaschisma pulchellum* (see Breimer & Macurda, 1972). Brachioles and stem not preserved.

**Remarks.**—The primary difference between *Decaschisma pulchellum* and *D. lorae* is the height of the vault, which is somewhat higher in *D. lorae*. The latter also has a pelvic angle (32–44°) that is generally somewhat smaller than that of *D. pulchellum* (40–56°) (Macurda, 1983). These characters give *D. lorae* a narrower, more elongate theca. In addition, Breimer & Macurda (1972: 57, 63) noted that *D. pulchellum* has thick-walled, undifferentiated hydrospires, whereas *D. lorae* has thin-walled hydrospires that are differentiated into lamellae and ducts. Finally, *D. pulchellum* exhibits growth lines paralleling the radial-hypodeltoid suture that form with a distinct radial-deltoid growth front. *Decaschisma lorae* has radial growth lines that are normal to the radial-hypodeltoid suture, suggesting a lack of an external radial-hypodeltoid growth front. This would mean that growth of the CD radial limbs was almost exclusively lateral and parallel to the radial-hypodeltoid suture. The significance of this change is uncertain. The radial-hypodeltoid suture is horizontal in *D. lorae*, whereas it has a shallow V-shape in *D. pulchellum*. This is probably a direct consequence of the change in the mode of growth at this boundary. *Decaschisma lorae* almost certainly evolved from *D. pulchellum* by the elongation of the theca, differentiation of the hydrospires into lamellae and ducts, and reduction of growth normal to the radial-hypodeltoid suture.
Growth of the ambulacra also differs. Decaschisma pulchellum possesses linear or nearly linear ambulacra throughout ontogeny (Breimer & Macurda, 1972), whereas D. lorne has linear ambulacra as an adult but petaloid ambulacra in small juveniles (Breimer & Macurda, 1972). Macurda (1983) described another species, Leptoschisma pentagonum (now Decaschisma pentagonum), which differs from D. lorne in having a lower, more hemispherical vault similar to that of D. pulchellum, and a longer pelvis; otherwise the two species are similar.

Material and Occurrence.—Thirteen thecae, all missing hypodeltoids, most uncruushed (except PRI 68392, 68394, and 68397); PRI 68396 is missing the basal circlet. Maximum dimensions 12.0 mm high, 6.5 mm wide (PRI 68391); minimum 2.5 mm high, 2.0 mm wide (PRI 68397). Complete theca from upper Birdsong Shale (Bryozoan Zone), PRI 68391 and 68398 from loc. MQ (PRI 68398 from washings); PRI 54254, 54256, 68388–68390, 68392, and 68397 from loc. BQ (PRI 68397 from washings). Some washings from the Brachiopod Zone (loc. MQ) have rare isolated basals and radials that are probably assignable to this species (Lochkov).

Genus POLYDELTOIDEUS Reimann & Fay, 1961

Type Species.—Polydeltoideus enodatus Reimann & Fay, 1961.

Diagnosis.—Phaenoschismatids with five anal deltoids.

Remarks.—Polydeltoideus is the only fissiculate with five anal deltoids. It has a typical phaenoschismatid outline with a steeply conical pelvis and low vault having deep ambulacral sinuses and prominent interambulacral pyramids. Decaschisma, the only other Silurian fissiculate, differs in the anal deltoid configuration and in thecal shape; the pelvis is wider, and the ambulacral sinuses narrower. The nonanal deltoids in Polydeltoideus are also more prominent and compose a larger portion of the vault than those in Decaschisma.

Polydeltoideus enodatus Reimann & Fay, 1961
Pl. 11, Figs 12, 15–16


Diagnosis.—Same as for genus.

Description.—Theca elongate, conical in lateral view, pentagonal in oral view, with steeply conical pelvis and short vault; base concave with narrow extension at proximal end. Ambulacral sinuses deep, wide. Large interambulacral pyramids extending considerably above peristome. Hydrospire slits mostly exposed, extending across full radial-deltoid suture. Basals 3, large, elongate, unequal; azygous basal in AB position, with very small stem facet. Radials 5, large, much higher than wide, with short radial limbs. Ambulacra lanceolate; lancet completely covered, resting on deltoid lips and distal radial body. Nonanal deltoids 4, not contributing to outer wall, with prominent deltoid crest, composing significant portion of vault. Anal deltoids 5; small superdeltoid equal in size to deltoid lips; subdeltoid inverted U-shaped; large hypodeltoid composing part of outer wall, with a shallow V-shaped suture where it contacts underlying radial limbs; 2 paradeltoids adanal of and below hypodeltoid. Stem and brachioles not preserved.

Remarks.—One species, Polydeltoideus enodatus, is definitely placed in Polydeltoideus. Another form, P. plasovae Prokop, 1962 (Pridoli Beds, Czechoslovakia, Pridolian), does not preserve the anal deltoids, thus rendering the generic assignment uncertain. According to Prokop (1962), the differences between P. enodatus and P. plasovae are that P. plasovae has a wider theca, narrower ambulacra, narrower sinus angle, and less angular basal-radial sutures.

Macurda (1983) accepted Polydeltoideus plasovae as a separate species pending definite generic identification. The present specimens of P. enodatus have a range of ambulacral sinus angles and thecal widths, which are probably due to allometric growth. Smaller specimens have wider thecae and ambulacral sinus angles compared to larger specimens. All share the angular basal-radial suture pattern typical of P. enodatus. Smaller and presumably younger specimens also have radials that are proportionally wider than larger ones. This ontogenetic change would result in more elongate adults, which is consistent with length-width ratios plotted for Polydeltoideus by Breimer & Macurda (1972: 189, text-fig. 52).

The present specimens of Polydeltoideus enodatus represent the first report of Polydeltoideus from the Decatur (Pridoli) of west-central Tennessee; previously known localities are from the Upper Silurian (Ludlow) Housey Formation of Oklahoma and the Pridoli Beds (Upper Silurian, Pridoli) of Czechoslovakia. Three specimens (PRI 54258, 68400, and 68403; e.g., Pl. 11, Fig. 16) come from the upper Decatur, in a 1-m-thick zone that begins approximately 1.5 m below the top of the unit, placing them close to the Silurian–Devonian boundary (McComb & Broadhead, 1980).

Material and Occurrence.—Seven specimens, only one (PRI 54255) complete or nearly so, but somewhat crushed. All preserve part of the vault. Specimen PRI 54255, 15 mm high, widths for other specimens 6–8 mm.

All specimens from Decatur Limestone. PRI 68399 from lower Decatur, loc. Q11 near loc. Q13; PRI 68400
and 54258 from upper Decatur, loc. RCa,b; PRI 54255 and 68401–68402 from lower to middle Decatur, loc. PVb; PRI 68403, loc. EQ (Pridoli).

Family NEOSCHISMATIDAE Wanner, 1940

Diagnosis.—Fissiculates with large number of nonanal hydrospires, prominent deltoids on the vault, and lacking interambulacral pyramids and sinuses.

Remarks.—Neoschismatids differ from phaenoschismatids in their lack of prominent ambulacral sinuses and interambulacral pyramids and the prominence of the deltoids on the vault. Most phaenoschismatids have an elongate, conical pelvis; the neoschismatids have a variety of thecal shapes but lack an elongate, conical pelvis. The hydrosphere slits of neoschismatids are completely exposed, whereas in most phaenoschismatids, they are at least partly concealed. In orophocrinids, the hydrosphere slits are fully concealed except in Brachyschisma Reimann, 1945, in which the hydrosphere slits are confined to concavities near the ambulacra. The exposed hydrospheres, prominent deltoids, cup shape, and lack of interambulacral pyramids serve to distinguish the neoschismatids from most other fissiculate families except the codasterids. The codasterids differ from the neoschismatids primarily in the prominence of the deltoids and morphology of the hydrospheres. The codasterids have somewhat more prominent deltoids, anal hydrospheres that are strongly reduced to absent, and reduced numbers of hydrospheres in other rays. Conversely, neoschismatids are characterized by small anal hydrospheres, along with a large number of hydrospheres in other rays. These differences are least apparent in the type genus Codaster McCoy, 1849.

The foregoing discussion is based on Breimer & Macurda (1972) and Macurda (1983). These monumental works contain an extraordinary amount of information but are inadequate in one important aspect. As discussed under the Phaenocothematidae, the familial diagnoses, set out by Breimer & Macurda (1972) in the most detailed study to date, failed to clearly define the diagnostic differences that separate the families of the Fissiculata.

Genus EOHAEBROBLASTUS n. gen.

Type Species.—Eohadroblastus inexpectatus n. sp.

Diagnosis.—Neoschismatid with four anal deltoids and covered lancets.

Remarks.—Eohadroblastus n. gen. is placed within the Neoschismatidae because of a strong resemblance to the neoschismatid Hadroblastus Fay, 1962, from which it differs in having four anal deltoids (super-, two crypto-, and hypodeltoids) and covered lancets. Placement of Eohadroblastus n. gen. in the Neoschismatidae requires emendation of the characters defining that family (see Breimer & Macurda, 1972) to include forms with four anal deltoids and covered lancets. All other known neoschismatids have two anal deltoids (epi- and hypodeltoids) and exposed lancets. Placement in the Phaenoschismatidae was also considered but rejected due to the lack of distinct interambulacral pyramids, presence of shallow ambulacral sinuses, and prominence of the deltoids, which compose a significant portion of the vault. These characters, plus the short conical pelvis, preclude assignment to the Phaenoschismatidae but are typical of neoschismatids.

Eohadroblastus inexpectatus n. sp.

Pl. 11, Figs 13–14

Description.—Theca small, conical in lateral view, decagonal in oral view. Pelvis wide, low, conical. Vault low, rounded. Base trigonal. Ambulacral sinuses wide, shallow. Interambulacral pyramids low, indistinct, rising slightly above peristome. Hydrosphere slits completely exposed, occupying most of oral surface, in 10 groups, 6–7 in each normal group; radial-deltoid suture completely occupied by hydrosphere slits; anal hydrospheres reduced, 3 per group, confined to cryptodeltoids. Ornament composed of fine growth lines on basals and radials; Basals 3, unequal; azygous basal in AB position, composing approximately half of pelvic height. Stem cicatrix not visible due to diagenesis. Radials 5, equal, approximately as high as wide, with radial limbs equal in height with radial body. Ambulacra linear, extending to peristome. Lancet completely covered, resting on deltoid lips and radial body. Nonanal deltoids 4, relatively large, near horizontal, with subdeltoid crest sloping slightly upward, composing significant portion of oral surface; deltoid lips small. Anal deltoids 4; superdeltoid small, equal in size to deltoid lips. Cryptodeltoids 2, wedge-shaped, tapering adanally. Hypodeltoid missing, but facets on cryptodeltoids and underlying radial limbs indicating its presence. Stem and brachioles not preserved.

Remarks.—As previously noted, Eohadroblastus inexpectatus n. sp. closely resembles the Mississippian genus Hadroblastus. Its thecal shape resembles that of H. whitei (Hall, 1861) (Burlington Limestone, Missouri and Iowa; St. Joe Limestone, Oklahoma and Arkansas; Lower Carboniferous) (Macurda, 1983), and the deltoids are similar to those of H. kentuckensis (Shumard, 1855) (New Providence Formation, Kentucky and Indiana, Lower Carboniferous). The lancets, however, are completely covered by ambulacral plates, which apparently
extend to the peristome. Also, there are four anal deltoids, compared to two in *Hadroblastus*. The anal region is disrupted but careful preparation and examination revealed a small superdeltoid, two wedge-shaped cryptodeltoids with hydrosphere slits, and a gap that indicates the presence of a hypodeltoid. The superdeltoid is pushed inward as are the two cryptodeltoids and some ambulacral plates of the D ray. The two cryptodeltoids taper adanally, but it is uncertain whether they contacted the superdeltoid. The hypodeltoid is most likely triangular and expands adanally. All hydrosphere slits on the radial limbs can be accounted for as cryptodeltoids.

*Eohadroblastus inexpectatus* n. sp. provides a link between the phaenoschismatids and the neoschismatids. It almost certainly arose from *Polydeltoides* by shortening of the pelvis, enlargement of the deltoids with corresponding reduction of the interambulacral pyramids, decreasing the depth of the ambulacral sinuses, loss of the paradeltoids (which were probably part of the anal pyramid, see Breimer & Macurda, 1972: 315), and conversion of the subdeltoid to two cryptodeltoids. The latter change is present in Devonian phaenoschismatids (Breimer & Macurda, 1972: 315). A form like *Eohadroblastus* n. gen. was predicted by Breimer & Macurda (1972: 348): “A rather good intermediate between *Hadroblastus* and the phaenoschismatids would be a form with superdeltoid, two cryptodeltoids, and hypodeltoid contributing to the external wall of the theca; having wide and shallow ambulacral areas and low interambulacral pyramids, not rising above the peristome and a subhorizontal deltoid crest; with ten hydrosphere groups; the number of hydrosphere slits not or slightly reduced in the anal interarea, and completely or nearly completely exposed hydrosphere slits; with a wide and low pelvis.”

This description fits *Eohadroblastus inexpectatus* n. sp. very well. Breimer & Macurda (1972) expected this intermediate to be from the Upper Devonian rather than the Lower Devonian. It seems unlikely that forms as similar as *Eohadroblastus* n. gen. and *Hadroblastus* developed twice from different immediate ancestors. This suggests that collections of later Devonian blastoids should be examined for forms similar to *Eohadroblastus* n. gen. or *Hadroblastus*, which might be misidentified.

**Type and Occurrence.**—Holotype, PRI 54257, one nearly complete theca slightly crushed and corroded in the CD interray, with anal area disrupted, ambulacra preserved in three rays (B, C, D), 5.5 mm high, 7 mm wide. Upper Birdsong Shale (Bryozoan Zone), loc. MQ (Lochkov).

**Etymology of Name.**—Specific name *inexpectatus* (L.), unexpected, referring to the unexpected occurrence of this morphology in the Lower Devonian.
by large lumen, with thin, raised rim on upper surface near edge of columnal and thin, downward-flaring flange on lower edge of columnal. Distal stem and brachioles not preserved.

Remarks.—*Tyrridiocystis chelyon* is the only rhombiferan cystoid known from the Birdsong Shale, although Safford (1869) listed *Apiocystites anna* (see Broadhead & Strimple, 1978). *Tyrridiocystis chelyon* is rare and is known from seven specimens. Although the present specimen is fragmentary, its plate arrangement and ornament are consistent with *T. chelyon*. This specimen is unique in preserving part of the proximal stem, which is cut almost longitudinally and reveals the internal columnal structure. It is composed of thin, flat disc-shaped columnals, each of which bears a raised rim on the top surface near the edge, and a downward flaring flange on the lower edge. The raised rims provided the stem with flexibility, while the flanges limited the range of motion. *Tyrridiocystis chelyon* probably had a short, wide, proximal stem, and a short distal column of short, cylindrical columnals below as in *Apiocystites*.

Material and Occurrence.—Specimen PRI 54259, one partial, crushed, split almost longitudinally, preserving two basals (B1, B4), two complete infralaterals (IL4, IL5) and a fragment of a third (IL3), and ca. 10 mm of proximal stem (also split longitudinally). Lower Birdsong Shale (Brachiopod Zone), loc. BQ (Lochkov).

Subphylum ECHINOZOA Haekel, 1895
Class EDRIOASTEROIDEA Billings, 1858
Order ISOROPHIDA Bell, 1976

Diagnosis.—Edrioasteroids with a peripheral rim, ambulacra confined to oral surface, and uniserial ambulacral floor plates.

Family PYRGOCYSTIDAE Kesling, 1967

Diagnosis.—Isorophids with elongate, turret-shaped theca, sides composed of upward imbricating plates, and ambulacra confined to upper surface.

Genus PYRGOCYSTIS Bather, 1915

Type Species.—*Pyrgocystis sardesoni* Bather, 1915.

Diagnosis.—Same as for family.

Remarks.—Bell (1975, 1976) re-examined most edrioasteroids and revised their classification (summarized by Bell, 1980). However, he did not study certain minor groups (listed by Bell, 1976), including *Pyrgocystis*, a genus that Kesling (1967b) separated into a distinct family. Bell (1980) placed the pyrgocystids in the Isorophida but did not assign them to a suborder. Further taxonomic assignment remains to be determined pending detailed morphological study.

*Pyrgocystis* sp.
Pl. 12, Figs 9–10

Diagnosis.—*Pyrgocystis* with 8–9 columns of side plates, with indistinct grooves between columns.


Remarks.—Bather (1915) initially defined the pyrgocystids, whereas Regnell (1945) was the last to treat them as a group, recognizing 13 species. These were segregated using thecal shape in transverse section, number of columns of side plates, number of exposed margins of plates per 3 mm, presence and depth of grooves separating columns, and shape of the exposed margins of the side plates, all of which were used to construct a key (Regnell, 1945: 203–204). Rievers (1961) added *Pyrgocystis coronaeformis* Rievers, 1961. Dehm (1961) separated *Pyrgocystis* into two subgenera based primarily on the morphology of the base: *P. (Pyrgocystis)* with a base composed of a few "closely amalgamated plates" (Regnell, 1966: U166) and *P. (Rhenopyrgus* Dehm, 1961) with a base "composed of numerous minute plates scattered in coriaceous skin" (Regnell, 1966: U167). The morphology of the present specimen suggests that it belongs to *P. (Pyrgocystis)*. However, Bell (1976) questioned the taxonomic significance of variations in the arrangement of the plates composing the side of the theca.

The oral surface of the present specimen (PRI 68404) is crushed and preserves few features. Two paraboloid depressions are seen in the cavity where the oral surface was located, but the significance of these is unknown. No unequivocal ambulacra can be seen. The new specimen most likely represents a new species; however, until *Pyrgocystis* is re-analyzed, it seems best to leave it unnamed.

Material and Occurrence.—One specimen, PRI 68406, preserving the base and turret (imbricating side plates), oral surface collapsed, theca 9.0 mm long, 3.5 mm wide. Lower Rockhouse Limestone, loc. AM (Lochkov).
Class **CYCLOCYSTOIDEA** Miller & Gurly, 1895

*Diagnosis.*—Disc-shaped echinoderms, lacking prominent ambulacra, with double layer of small plates inside ring of large, quadrate, marginal ossicles.

Family **CYCLOCYSTOIDIDAE** Miller, 1882

Genus **SIEVERTSIA** Smith & Paul, 1982

*Type Species.*—*Cyclocystoides devonica* Sieverts-Doreck, 1951.

*Diagnosis.*—Cyclocystoids with flat or concave crests on the marginal ossicles.

*Remarks.*—*Sievertsia* is the only genus of cyclocystoid to have marginal ossicles with a flat or concave crest (Smith & Paul, 1982). This allows generic identification of very fragmentary material, including isolated marginal ossicles. It is also the only genus recognized in rocks younger than Wenlock age.

*Sievertsia* sp.

*Pl. 12, Figs 5–7*

*Diagnosis.*—Cyclocystoids with flat crest on marginal ossicles.

*Description.*—Marginal ossicles trapezoidal. Crest flat trapezoidal. Cupules circular, with nearly hemispherical tubercles and thin cupule walls. Cupule zone width less than one-third marginal ossicle length, 2 or 3 cupules per marginal. Lateral margins on ventral surface strongly oblique with large gap between crests of adjacent marginals.

*Remarks.*—The cyclocystoid from the Ross Formation is known only from isolated marginal ossicles, but the flat crest and number of cupules allows assignment to the genus *Sievertsia*. The specimens are closest to *S. devonica* (Sieverts-Doreck, 1951); see key by Smith & Paul (1982: 649–650). However, because of the fragmentary nature of the specimens, there is enough doubt to make specific assignment uncertain. This occurrence marks the first report of cyclocystoids from Lochkovian age rocks. Although cyclocystoids were geographically widespread, the small size of the ossicles and failure of many echinoderm workers to disaggregate large samples of shale and sort through the resulting material, has led to only rare recognition of this group of echinoderms.

*Material and Occurrence.*—88 marginal plates from washings (25–35 mesh sieve). Upper Rockhouse Limestone to upper Birdsong Shale (Bryozoan Zone), locs. BQ, PQ, and MQ. The BQ specimens were from a spoil block that contained remains of *Scyphocrinites* sp., which, including lithology, indicated the general stratigraphic position. The MQ and PQ material came from washings of all samples, and are apparently ubiquitous (Lochkov).

Class **ECHINOIDEA** Leske, 1778

Subclass **PERISCHOECHINOIDEA** McCoy, 1849

*Diagnosis.*—Echinoids with more than two columns of plates in each interambulacrum (Smith, 1984).

Order **ECHINOCYSTITOIDEA** Jackson, 1912

*Diagnosis.*—Echinoids with strongly imbricate coronal plates, lacking enlarged primary spines on interambulacral plates.

Family, Genus, Species Unknown

*Pl. 12, Figs 1–4, 11*

*Description.*—Thin interambulacral plates of uncertain shape, with multiple, small, perforate(?) tubercles; numerous small spines; lantern present, with brace (rotula) and demipyramids identified.

*Remarks.*—Aside from braces of varying size, this echinoid is known from a single small chip of argillaceous limestone with numerous interambulacral plates and spines, plus a rotula and a demipyramid (PRI 54260). All plates are disarticulated, but the interambulacals are imbricate. The interambulacral plates of this species are extremely thin and have stereom preserved on the surface. Each interambulacral has several small tubercles that are apparently perforate. The spines are small, with longitudinally grooved shafts and slightly swollen bases with a socket (acetabulum). The lantern is known from several isolated braces and a single demipyramid (preserved on the chip, PRI 54260). Other plates, as yet unidentified, are also seen on the chip. Unfortunately, no ambulacral plates have been identified, so that identification of this specimen is not feasible, even at the family level.

The specimen has been placed within the Echinocystitoidea because of the apparent imbrication of the interambulacral plates and absence of an enlarged primary spine on the interambulacals, as seen in cidaroids. The size of the plates suggests placement in the Lepidocentridae, but this is not certain. The specimen apparently disarticulated *in situ* with little movement of the various ossicles.

Small (60-mesh sieve size) spines with tripartite ends, which resemble tridentate pedicellaria or secondary spines, are in washings.
Material and Occurrence.—One partial test, PRI 54260, preserving interambulacral plates, spines, demipyramid, and brace; numerous braces, a few spines, and possible ambulacral (containing perforations interpretable as those for tube feet) and interambulacral plates from washings. Specimen PRI 54260 and numerous braces from upper Birdsong Shale, loc. EQ, from washings, demipyramids, braces, ambulacral and interambulacral plates, spines; lower Rockhouse Limestone to upper Birdsong Shale (Lochkov).

Subphylum HOMALOZOA Whitehouse, 1941
Class STYLOPHORA Gill & Caster, 1960

Diagnosis.—Homalozoans with aulacophore.

Order MITRATA Jaekel, 1918

Diagnosis.—Stylophorans lacking numerous pores on upper anterior right corner.

Suborder ANOMALOCYSTITIDA Caster, 1952
Family ANOMALOCYSTITIDAE Bassler, 1938

Diagnosis.—Anomalocystitoids with anomalocystitid plate.

Subfamily PLACOCYSTITINAE Caster, 1952

Diagnosis.—"Anomalocystitids that possess a 'placocystitid' plate and A2 that does not reach the posterior margin, and two or three infracentrals" (Kolata & Jollie, 1982: 640).

Genus EODEVONOCYSTIS n. gen.

Type Species.—Eodevonocystis marilynni n. sp.

Diagnosis.—Anomalocysttid without anterior marginals, large infracentral (I1), and anomalocysttid plate (I2) composing anterior margin; anterior spine bases on M4 and M’4 only; M1 and M’1 marginals with posterior extension separating M2 and M’2 marginals from base.

Remarks.—Eodevonocystis n. gen. is most similar to Rhenocystis Dehm, 1932, in thecal shape, M1 and M’1 proportions, and length of the proximal aulacophore. It differs from all other anomalocystids in several characters. The M1 and M’1 have a narrow lateral extension at the posterior end, separating the M2 and M’2 from the aulacophore. The posterior marginals appear to be missing, with the large infracentral (I1) and anomalocysttid plates (I2) composing the anterior margin. These two plates extend anteriorly to the tip of the fourth marginals (M4, M’4) and are gently inflected toward the superior face at their posterior margins. This is unlike any other anomalocystid. The articulating socket for each exothecal appendage is entirely contained on the top of the fourth marginals. The aulacophorals differ as well. The right and left aulacophorals flare posteriorly, nearly separating the second marginals from the posterior end, and only narrowly separating a tongue-shaped median aulacophoral (A2) from the aulacophore. The third and fourth marginals on the holotype of E. marilynni n. sp. (PRI 54265) are not distinctly separate, but it is assumed that both plates are present. Possession of only three sets of marginal plates would further separate Eodevonocystis n. gen. from other anomalocystids.

The aulacophore is poorly preserved in the holotype of Eodevonocystis marilynni n. sp., with only the proximal portion present. It appears very close in morphology to that of Rhenocystis, to which Eodevonocystis n. gen. appears to be most closely related. A possible distal aulacophore has been recovered, but it is very different from those of other anomalocystid genera, being hollow and imbricate. It might well be a machaeridian instead. Terminology and orientation are from Kolata & Jollie (1982) and Ubaghs (1967).

Eodevonocystis marilynni n. sp.
Pl. 12, Figs 8, 12–15; Text-figs 9A–B

Diagnosis.—Same as for genus.

Description.—Theca rectangular, inferior face flat. M2, M’2, and aulacophorals with faint, wavy ridges. First marginals (M1, M’1) elongate, each one-half of thecal height, one-quarter of thecal width, with thin, posterior flange extending abaxially, separating second marginals (M2, M’2) from inferior face base. Second marginals extending anteriorly to same point as first marginals, with sharp edge where plate is inflected to superior surface. Third and fourth marginals not distinctly separated, together composing one-half of thecal length; articulation socket for exothecal appendage on anterior tip of fourth marginal. Large infracentral (I1) composing one-half of thecal length; anterior tip gently inflected toward superior face. Anomalocystitid plate (I2) small, in left anterior position, with gentle inflection toward superior face, paralleling anterior tip of large infracentral, parallel to thecal margin. Anterior tip of theca elongate, flaring rapidly away from theca. Exothecal appendages, distal aulacophore, and much of superior surface not preserved.
Remarks.—*Eodevonocystis marilynni* n. sp. occurs in the uppermost Bryozoan Zone, in a 10-cm thick, buff-weathering, silty mudstone that contains a large amount of sand-sized carbonate particles, and is overlain by a thin (1–2 cm) limestone (packstone-grainstone) that composes the uppermost bed in the Birdsong Shale at loc. PQ. This lithology is considerably different from other more clay-rich units that make up the shaly beds of the Bryozoan Zone. The associated fauna is diverse, with complete enrolled trilobites, bryozoans, crinoids, corals, and brachiopods.

Material and Occurrence.—Six partial thecae, PRI 54264, 54266, plus several isolated marginals, and a possible distal stele (PRI 54268). The holotype (PRI 54265) is the most complete specimen, preserving an almost complete inferior surface, and the proximal aulacophore. It is crushed, however, and the plates have shifted somewhat. The superior surface is completely collapsed, with what is known of its surface being determined by two other, much less complete, thecae (PRI 54262, 54267). The theca is 14 mm long, 10 mm wide at the middle of the second marginals. Theca plus proximal aulacophore, 19 mm. Other thecae are considerably more fragmentary, mostly preserving the portion nearest aulacophore insertion. Uppermost Birdsong Shale (Bryozoan Zone), loc. PQ (Lochkov).

Etymology of Name.—Specific name *marilynni*, in honor of Marilyn Hlabse Clement, who has made the completion of this work possible.

ACKNOWLEDGMENTS

We thank Drs. Kenneth R. Walker, Robert E. McLaughlin, and James Brower for their comments and criticisms of early drafts of this paper. CC would like to thank his major advisor Dr. Thomas W. Broadhead for support and guidance during a study, which forms the major part of this work. He is especially indebted to Dr. Edward E. C. Clebsch for agreeing to serve on his dissertation committee during the last two months of this project. His action allowed this project to be completed. We thank Dr. Paul Delcourt for providing use of his microscope for photographing some of the tiny remains collected during this project. We especially thank Dr. Michael A. Gibson who worked with CC in the field and provided good counsel and friendship over the course of this study. We thank Vulcan Materials Company for allowing access to their quarries at Parsons and Holladay. Wayne Hollis and Luke Kennon, the foremen at these quarries, permitted easy access during all of our field excursions, and their forebearance is extremely appreciated. David McClanahan gave permission to repeatedly visit his operation and is much deserving of our thanks. We thank Frederick Collier and Craig Warren of the United States National Museum of Natural History who allowed access to the Springer Collection for comparison of collected material with the types.

We thank Paula Mikkelsen and Warren Allmon for encouragement to prepare this monograph and appreciate the comments of outside reviewers including William Ausich, James Brower, Colin Sumrall, and Johnny Waters.

Partial financial support for this dissertation was provided by the Appalachian Basin Industrial Associates (through Dr. Thomas Broadhead) and the UTK Department of Geological Sciences Discretionary Fund.

LITERATURE CITED


APPENDIX A

LOCALITY DESCRIPTIONS

AM, Allens Mill, Benton County
35°55’45”N, 88°05’15”W
Two small, abandoned, quarries on the northern side of Birdsong Creek, the larger exposing ca. 10 m of Decatur Limestone, 6 m of Rockhouse Limestone, and 3 m of Birdsong Shale (Reid, 1983). The smaller quarry exposes ca. 3 m of Decatur Limestone, 5 m of Rockhouse Limestone, and 2 m of Birdsong Shale. Most specimens were collected from a bench 87 cm above the Decatur–Rockhouse contact.

BQ, Benton Quarry, Benton County
35°52’30”N, 88°07’15”W
Large Vulcan Materials Company quarry on Tennessee Route 192 at Holladay, Tennessee, exposing ca. 20 m of Decatur Limestone, 4.1 m of Rockhouse Limestone, and 16.3 m of Birdsong Shale (Reid, 1983). This is a complete section with bedded Camden Chert above the Ross Formation.

CL, Cherokee Landing/Woodland Acres, Decatur County
35°52’00”N, 88°01’30”W
Bluffs on western side of Tennessee River, exposing 10–15 m of Decatur Limestone.

EQ, Elkins Quarry, Perry County
35°37’15”N, 87°59’00”W
Small, recently reopened quarry in western Perry County on northern side of Tennessee Route 20/100, exposing ca. 10 m of Decatur Limestone, 4.3 m of Rockhouse Limestone, 4.5 m of Birdsong Shale (Gibson, 1988)

MQ, McClanahan’s Quarry, Decatur County
35°43’30”N, 88°04’30”W
Active quarry on the southern side of Brodies Landing Road exposing 15–20 m of Decatur Limestone, 6.0 m of Rockhouse Limestone, and 19.4 m of Birdsong Shale (Gibson, 1988). The top of the Birdsong is truncated, with unbedded chert rubble (Camden) above.

PQ, Parsons Quarry, Decatur County
35°41’15”N, 88°06’15”W
Large Vulcan Materials Company quarry on Tennessee Route 69 north of Parsons, Tennessee, exposing 34.5 m of Decatur Limestone (McComb, 1987), 5.1 m of Rockhouse Limestone, and 13.2 m of Birdsong Shale (Reid, 1983). The top of the Birdsong is an erosional surface, with unbedded chert rubble (Camden) above.

PV, Perryville, Decatur County
35°37’30”N, 88°02’00”W
Bluffs along the western side of the Tennessee River at Tennessee Route 20/100 exposing ca. 10 m of Decatur Limestone. PVa is the exposure above bridge, PVb is the exposure below (north) bridge.

Q11 and Q13, Quarry 11 and 13, Decatur County
35°36’00”N, 88°07’00”W
Two small, abandoned quarries on Tennessee Route 69 immediately south of bridge over the Beech River, north of Decaturville, Tennessee, exposing ca. 13 m of Decatur Limestone at Q11 and Q13 and 1 m of Rockhouse Limestone at Q13 (McComb, 1987). Q11 is slightly north of Q13.

RCa, southern roadcut, Decatur County
35°43’30”N, 88°04’30”W
Large roadcut on Tennessee Route 69 north of PQ, exposing 12 m of Decatur Limestone, 1 m of Rockhouse Limestone.

RCb, northern roadcut, Decatur County
35°46’30”N, 88°05’00”W
Northern roadcut on Tennessee Route 69, exposing 5 m of Decatur Limestone, 3 m of Rockhouse Limestone, and 2 m of Birdsong Shale.
PLATES
Measurements are based on the figures; height = maximum vertical measurement; width = maximum horizontal measurement.

Figures

1–3, 6–7, 10. *Probalocrinus dignis* (Strimple, 1963) n. comb. 20
1. PRI 53645; CD interray, height of view 61 mm.
2. PRI 53646; CD interray, height of view 20.2 mm.
3. PRI 53649; base, width 48.6 mm.
6. PRI 53648; base, width 32.6 mm.
7. PRI 53650; top of cup showing tegmen, width 36.6 mm.
10. PRI 53646; normal rays and interrays, height of view 83 mm.

4–5. *Gazacrinus stellatus* Springer, 1926. 26
4. Holotype, USNM S139; side view, width 17.5 mm.
5. Holotype, USNM S139; basal view, height 18 mm.

8. *Elpidocrinus cf. tholiformis* Strimple, 1963, PRI 53651; height 13.3 mm. 22

9. *Dimocrinites (Dimocrinites) cheilobathron* n. sp., holotype, PRI 53652; side view, width of view 34 mm. 24

11. *Dimocrinites* sp. A, PRI 53653; basal view, CD interray up, height of view 17.6 mm. 24
Measurements are based on the figures; height = maximum vertical measurement; width = maximum horizontal measurement.

Figures

1, 4. *Eudimerocrinus hlabsei* n. sp. ................................. 23
   1. Holotype, PRI 53654; side view, height 35 mm.
   4. PRI 53655; basal view, height of view 21.6 mm.

2. *Stiptocrinus cf. benedicti* Miller, 1892, PRI 53657; side view, height 24 mm. .......... 28

   3. Holotype, USNM S4069; side view, height 21.5 mm.
   6. PRI 53659; side view, height 14.6 mm.
   7. PRI 53658; side view, width 25.5 mm.
   8. PRI 53660; side view, width of view 18 mm.
   9. PRI 53661; side view of calyx with proximal stem, showing tongue-shaped tegminal spine, height of view 39.7 mm.

5. *Lampterocrinus tennesseensis* Roemer, 1860, PRI 53656; side view, width of view 30 mm. ..... 25

10. *Hexacrinites adaensis* Strimple, 1952, PRI 53666; side view, height 11.5 mm. ................. 29

   11. PRI 53664; B-ray view, height 20.5 mm.
   12. PRI 53665; C-ray view, height of view 17.3 mm.
Measurements are based on the figures; height = maximum vertical measurement; width = maximum horizontal measurement.

Figures

1. *Scyphocrinites* cf. *elegans* Zenker, 1833, PRI 53667; side view, height 38 mm.


2. PRI 53663; disarticulated crown, width 66 mm.
8. PRI 53662; side view of crown, with proximal stem and arms, height of view 72.5 mm.


3. PRI 53669; juvenile, side view, width 35 mm.
4. PRI 53669; juvenile, basal view, width 38 mm.
9. PRI 53668; side view, width 88 mm.
10. PRI 53668; basal view, width 81 mm.


5. PRI 53670; side view, height 32 mm.
7. PRI 53671; side view, height of view 55 mm.

Measurements are based on the figures; height = maximum vertical measurement; width = maximum horizontal measurement.

Figures

1–8. *Scyphocrinites stellatus* (Hall, 1879). ................................................... 33
   1. PRI 53672; side view, height 60 mm.
   2. PRI 53673; side view, width 53 mm.
   3. PRI 53674; inside view, height of view 42.6 mm.
   4. PRI 53675; specimen lacking ornament, with irregular plate boundaries, basal view, width 57 mm.
   5. PRI 53674; outside view, height 60 mm.
   6. PRI 53674; close-up of encrusting bryozoan, width of view 28 mm.
   7. PRI 53676; basal view, width 41 mm.
   8. PRI 53676; side view, width 42 mm.

   9. Holotype, USNM S213; side view, height 30 mm.
   10. Holotype, USNM S213; basal view, height 33 mm.

   9. Syntype, USNM S402; basal view, width 25 mm.
   10. Syntype, USNM S402; side view, width 24.5 mm.

13. *Eucalyptocrinites* sp. A, PRI 53677; basal view, width of view 22.2 mm. ...... 35

14. *Eucalyptocrinites* sp. D, PRI 53678; side view, width of view 18 mm. .......... 36

15. *Eucalyptocrinites* sp. C, PRI 53679; side view, width of view 15.5 mm. ........ 36

16. *Eucalyptocrinites* sp. B, PRI 53680; side view, width of view 23.7 mm. ........ 35
Measurements are based on the figures; height = maximum vertical measurement; width = maximum horizontal measurement.

Figures

1, 7. *Eucalyptocrinites pernodosus* (Springer, 1926). .............................................. 34
   1. Syntype, USNM S398; crown with stem, height of view 75 mm.
   7. PRI 53685; view of inside of base, width of view 26.5 mm.

2. *Eucalyptocrinites* sp. E, USNM S5846; basal view, height of view 54 mm. ........... 37

   3. PRI 53682; side view, height of view 21 mm.
   5. PRI 53683; side view, width of view 16 mm.

4, 8. *Macrostylocrinus tertibrachialis* n. sp. .......................................................... 39
   4. PRI 53681; inside; cup, B-ray up, width of view 25 mm.
   8. Holotype, PRI 53681; basal view, D-ray up, width of view 21.5 mm.

6. *Macrostylocrinus cf. pustulosus* Springer, 1926, PRI 53684; side view, width 20 mm. .... 40

   9. PRI 53686; basal view, width of view 43 mm.
   12. PRI 53687; beveled calyx showing high vaulted tegmen, width 35 mm.

10, 13. *Marsupiocrinus* (Amarsupiocrinus) *devonicus* n. sp. .................................. 42
   10. Holotype, PRI 53688; basal view, width 28.5 mm.
   13. Holotype, PRI 53688; tegminal view, width 27.5 mm.

   10. PRI 53689; basal view, width of view 34 mm.
   13. PRI 53690; basal view, height of view 41 mm.

15. *Paramarsupiocrinus broadheadi* n. sp., holotype, PRI 53691; side view, width of view 23.5 mm. .... 43
Measurements are based on the figures; height = maximum vertical measurement; width = maximum horizontal measurement.

Figures

1–2. *Parapatelliocrinus broweri* n. sp. ........................................ 44
   1. Holotype, PRI 53692; side view, height of view 32.5 mm.
   2. PRI 53692; side view, wet, height of view 30.5 mm.

   3. Holotype, USNM S575; side view, note constriction at top of cup, width 14 mm.
   4. Holotype, USNM S575; basal view, height 28.6 mm.

5–6, 8. *Dolatocrinus helderbergenis* (Springer, 1926). ..................... 47
   5. PRI 53693; basal view, height 57 mm.
   6. PRI 53694; basal view, height 52 mm.
   8. PRI 53694; side view, width 53 mm.

7, 9. *Eodolatocrinus hlabsei* n. sp. ........................................... 45
   7. Holotype, PRI 53695; side view, width 25.5 mm.
   9. PRI 53695; basal view, height 27.5 mm.

   10. PRI 53712; side view, height 7.1 mm.
   11. PRI 53713; articulation surface of radial, width 8.6 mm.
   12. Holotype, USNM S2011; side view, width 12 mm.
   13. PRI 53713; inside of radial, height of view 7.1 mm.
   14. PRI 53712; oral view, height 6.5 mm.

15. *Cremacrinus decatur* Springer, 1926, holotype, USNM S2152; side view, calyx height 8.5 mm
   (from Springer, 1926a: pl. 28, fig. 7). ...................................... 52
Measurements are based on the figures; height = maximum vertical measurement; width = maximum horizontal measurement; length = maximum measurement of an elongated specimen.

Figures

1–2, 5–6, 9–10. *Eohalysiocrinus broweri* n. sp. ................................................................. 50
1. PRI 53715; anterior side, height 5.3 mm.
2. Holotype, PRI 53714; anterior side, height 5.3 mm.
5. PRI 53715; posterior side showing trapezoidal subanal, height 4.8 mm.
6. PRI 53714; posterior side showing trapezoidal subanal, height 5.1 mm.
9. PRI 53716; basals, from washings, height 1 mm.
10. PRI 53714; oral view, height 4.3 mm.

3–4, 7–8. *Eohalysiocrinus* (?) *gibsoni* n. sp. ................................................................. 51
3. PRI 53718; anterior side showing concentric ridges, width 6.1 mm.
4. Holotype, PRI 53717; anterior side, height 5.3 mm.
7. PRI 53718; posterior side, height 6.3 mm.
8. Holotype, PRI 53717; posterior side, showing thin subanal, width 5.1 mm.

11, 15. *Pisocrinus* sp. A. ........................................................................................................ 53
11. PRI 53719; side view, width 8.6 mm.
15. PRI 53719; basal view, height 7.6 mm.

12. PRI 53720; basal view, width 7.8 mm.
13. PRI 53721; oral view, height 7.2 mm.
16. PRI 53720; side view, width 7 mm.
17. PRI 53721; side view, width 7.6 mm.

14, 18, 20. *Myelodactylid* sp. A .......................................................................................... 54
14. PRI 53722; columnal face, width 4.4 mm.
18. PRI 53722; column showing cirral scars, length 11.1 mm.
20. PRI 53723; proximal coil, height of view 13.5 mm.

19. *Myelodactylus schucherti* Springer, 1926, holotype, USNM 89860; height 14 mm. .......... 54
Measurements are based on the figures; height = maximum vertical measurement; width = maximum horizontal measurement; length = maximum measurement of an elongated specimen.

Figures

1–3, 6. *Crinobrachiatus* sp. ........................................... 55
1. PRI 53726; column showing wide cirral attachment, length 12 mm.
2. PRI 53726; column showing large cirrus scars, length 12.1 mm.
3. PRI 53726; columnal face, width 4 mm.
4. PRI 53727; proximal coil, height of view 27.2 mm

4, 8. *Pygmaeocrinus* sp. ........................................... 57
4. PRI 68414; radial plate, height 1.7 mm.
5. PRI 68414; IBr2, note teeth and sockets, height 1.4 mm.

5, 7, 15. "Kallimorphocrinus" sp. ................................. 56
5. PRI 68409; side view of calyx, width 1.3 mm.
6. PRI 68409; oblique oral view of calyx, width 1.2 mm.
15. PRI 68410; aidemocrinoid stage, height 0.6 mm.

9. PRI 53728; side view, height 9.5 mm.
10. PRI 53730; C-ray up, height 11.6 mm.
13. PRI 53730; disarticulated cup, height of view 12.7 mm.
14. PRI 53731; juvenile?, height of view 5.4 mm.

11. PRI 53732; inner side view, height 6.9 mm.
12. PRI 53732; outer side view, height 7 mm.
PLATE 9
THALAMOCRINUS, AMPHERISTOCRINUS AND LECANOCRINUS

Measurements are based on the figures; height = maximum vertical measurement; width = maximum horizontal measurement.

Figures

1–2, 5. *Thalamocrinus elongatus* Springer, 1926. ................................................................. 59
   1. PRI 53733; partial, cup showing wide stem facet, height 6.3 mm.
   2. PRI 53734; cup with stem, missing radial, height of view 56 mm.
   5. PRI 53735; juvenile?, height 4.8 mm.

3–4. (?) *Ampheristocrinus typus* Hall, 1879. ................................................................. 60
   3. PRI 53736; crown with stem, height of view 65 mm.
   4. PRI 53736; wet crown, height of view 35.7 mm.

6–8, 10, 12. *Lecanocrinus pisiformis* (Roemer, 1860). .................................................. 63
   6. PRI 53737; crown, height of view 12.2 mm.
   7. PRI 53739; abnormal, base (6-sided), width 7.8 mm.
   8. PRI 53738; completely disarticulated crown, note lack of movement of plates, height of view 10.8 mm.
   10. PRI 53740; basal view of specimen with no basal concavity, width 7 mm.
   12. PRI 53742; partially disarticulated crown with stem, height of view 34.5 mm.

9. *Lecanocrinus lawsonae* McIntosh, 1981, holotype, USNM 305439; width 7.6 mm. ........... 65

11. *Lecanocrinus* sp. A, PRI 53741; side view, width 24 mm. ........................................ 64

   13. PRI 53743; basal view, height of view 16 mm.
   14. PRI 53743; side view, width of view 17.6 mm.
Measurements are based on the figures; height = maximum vertical measurement; width = maximum horizontal measurement.

Figures

1–6. *Lecanocrinus meniscus* Springer, 1920. ................................................................. 64
   1. PRI 54243; well-preserved crown with stem, height of view 40.5 mm.
   2. PRI 54242; crown with proximal stem, height of view 37 mm.
   3. PRI 54244; partially disarticulated crown of complete specimen, height of view 24.5 mm.
   4. PRI 54244; holdfast, height of view 40 mm.
   5. PRI 54245; crushed and distorted crown, height of view 28.5 mm.
   6. PRI 54246; basal view of cup, width of view 11.2 mm.

7, 10. *Icthyocrinus erugatus* n. sp. ................................................................. 66
   7. Holotype, PRI 54247; basal view, height 19.5 mm.
   10. PRI 54247; side view, width of view 24 mm.

8, 11. *Icthyocrinus devonicus* Springer, 1920. ................................................................. 66
   8. Holotype, USNM S1706; side view, width 31.5 mm.
   11. Holotype, USNM S1706; basal view of crown, width of view 30 mm.

9. *Parahormocrinus decaturensis* n. sp., holotype, PRI 54248; inside of partial crown, height of view 13.2 mm. ................................................................. 67
Measurements are based on the figures; height = maximum vertical measurement; width = maximum horizontal measurement.

Figures

1, 6. *Edriocrinus* cf. *pyriformis* Hall, 1862. .................................................. 69
   1. PRI 54249; side view showing bend in theca, height of view 12.2 mm.
   6. PRI 54249; basal view showing attachment scar, height of view 11.25 mm.

2, 7. *Edriocrinus* *adnascens* Dunbar, 1919. .................................................. 68
   2. PRI 54253; side view of base on brachiopod, height of view 9.6 mm.
   7. PRI 54253; inside view of base, height of view 18 mm.

3. *Edriocrinus* *dispansus* Kirk, 1911, holotype, USNM 27757; side view of cup, height of view 18.5 mm (from Springer, 1920: pl. 76, fig. 1). .................................................. 69

4–5. *Edriocrinus* *explicatus* Springer, 1920. .................................................. 69
   4. Syntype, USNM S1900; side view of basals, height of view 12 mm (from Springer, 1920: pl. 76, fig. 13).
   7. Syntype, USNM, S1900; top view of basals, width of view 16.7 mm (from Springer, 1920: pl. 76, fig. 15).

8–9. *Decaschisma* *lorae* (Dunbar, 1920) n. comb. ........................................... 71
   8. PRI 54254; oral view, A-ray up, height 6.2 mm.
   9. PRI 54254; side view, height 11.1 mm.

10. *Edriocrinus* *occidentalis* Springer, 1920, syntype, USNM 33993, height of view 12 mm
    (from Springer, 1920: pl. 76, fig. 10). .................................................. 70

11. Hyperpinnulate brachial, PRI 68421; from washings of Ross Formation, height of view 1.3 mm. .................................................. 12

12, 15–16. *Polydeltoideus* *enodatus* Reimann & Fay, 1961. ............................... 72
   12. PRI 54255; oral view, DE interray up, width 8.5 mm.
   15. PRI 54255; side view, height 14.3 mm.
   16. PRI 54258; oral view, A-ray up, height of view 9 mm.

13–14. *Eohadroblastus* *inepectatus* n. sp. .................................................... 73
   12. Holotype, PRI 54257; oral view, A-ray up, width 7.5 mm.
   15. Holotype, PRI 54257; side view, A-ray up, width 8.6 mm.

17–18. *Tyrridiocystis* *chelyon* Broadhead & Strimple, 1978. ............................. 74
   17. PRI 54259; distorted partial theca with stem, height 19.6 mm.
   18. PRI 54259; cross section of stem, height of view 3.3 mm.
Clement & Brett: Echinoderms of West-Central Tennessee
Measurements are based on the figures; height = maximum vertical measurement; width = maximum horizontal measurement.

Figures

1–4, 11. *Echinocystoida* ................................................................. 76
1. PRI 54260; disarticulated theca with imbricate thecal plates and lantern parts (rotula, demipyramid), height of view 21 mm.
2. PRI 54263; plate showing mamelon and pore, length 2.0 mm.
3. PRI 54261; assorted rotulae, height (larger specimen at left) 12 mm.
4. PRI 54261; assorted rotulae, height (larger specimen at left) 5.5 mm.
11. Three-lobed spine (pedicellarium?), PRI 68408; height 1.4 mm.

5–7. *Sievertsia* sp. ................................................................. 76
5. PRI 68406; marginal ossicle with two cupules, height of view 1.8 mm.
6. PRI 68405; marginal ossicle with three cupules, height of view 1.9 mm.
7. PRI 68406; reverse side of marginal ossicle with three cupules, height 1.6 mm.

8, 12–15. *Eodevonocystis marilynni* n. sp. .................................................. 77
8. PRI 54262; adaulacophoral superior face, height of view 10.6 mm.
12. Holotype, PRI 54265; superior face of somewhat disarticulated theca with proximal aulacophore, height 19 mm.
13. PRI 54265; same as Fig. 12, inferior face.
14. PRI 54266; middle part of aulacophore(?), height of view 16.1 mm.
15. PRI 54267; partially disarticulated theca with proximal aulacophore, height of view 13.8 mm.

9–10. *Pyrgocystis* sp. ................................................................. 75
9. PRI 68404; side view of theca, height of view 11.6 mm.
10. PRI 68404; oral view of theca, width at opening 3.8 mm.
INDEX

Acrocrinus Bowsher, 1955 27, 80
Abactinocrinus Lauden & Severson, 1953 27, 80
Abathomcrinus roundus (Springer, 1926) 15, 21–22
Actinocriniidae Austin & Austin, 1842 27
Abysocrinus Strimph, 1963 48–49, 56
antiquus (Strimph, 1952) 49
Acrocrinus Wachsmuth & Springer, 1897 27
anebus Ausich, 1987 27
Acanthocrinus Miller, 1850 20
Aidemocrinus odiosa Weller, 1930 56
Allgeocrinus Etheridge & Carpenter, 1881 55
Allegerinae Caperter & Etheridge, 1881 55–57
Allborinus Wachsmuth & Springer, 1889 39, 46
Amarrapniocrinus Frest, 1975 1, 10, 41–43, 96
Ambiocriste Kirk, 1945 22–23
Amnomicrinus Springer, 1926 54
Amphisterocrinus Hall, 1879 9–10, 12, 60–61, 104
calyx (Hall, 1882) 61
dubius Weller, 1900 61
typus Hall, 1879 9–10, 12, 60, 104
Amphoracrinidae Barther, 1899 27
Anamesocrinus Goldring, 1923 48, 80
Anomalocystitida Caster, 1952 77
Anomalocystitidae Basler, 1938 77
Anocrinus Wachsmuth & Springer, 1897 6, 27–28
Aplocystites anna Safford, 1869 67, 75
Archaeocypctocrinus Witzke & Strimple, 1981 34
Armoricran Massif 1, 5, 12–13, 27, 48, 50, 81–82
Artichasma Macura, 1983 71
Aurhorocrinus Springer, 1920 62, 67
Bactrocristites Schnur, 1849 58–60
Bailey Formation 12–13, 15, 32
Bainbridge Formation 12–13, 53
Baradeocrininae Angelin, 1878 27
Barranocrininae Angelin, 1878 27
Belemnocrinoida Miller, 1883 57
Bentow County 2, 54, 66, 69, 85
biostratigraphy 10, 79–80, 82
biostratigraphy 15, 81–83
bioturbation 5, 18–19
Black Warrior Basin 1, 4
Blasteoida Say, 1825 14, 70, 81
Blastozoa Sprinkle, 1978 70
Bohemia 1, 5, 10, 12, 14–15, 25, 30, 32, 49–51, 57, 62, 66, 79, 83
Bohemicrininae Jahn, 1893 27
Bolocrinus Witzke & Strimple, 1981 38, 43–45
deflatas Witzke & Strimple, 1981 44
globosus Witzke & Strimple, 1981 44
Boliviocrinus McIntosh, 1988 43–45, 47, 82
Brachocrinus Hall, 1838 55
brachiopod 2, 4–5, 7, 17, 69, 78, 83, 108
Brachiopod Zone 4–5, 7–8, 10–12, 15, 19, 31, 46, 57–58, 72, 75
Brachyochisma Reimann, 1945 73
Brassfield Limestone 2
Bracocrinus Angelin, 1878 38, 44
Britany 10
Brownport Group 2–3, 10, 12, 40–41, 44, 46, 61, 63–64, 78
bryozone 3–7, 17, 19, 23–24, 78, 81
Bryozoan Zone 1, 3–4, 6–8, 10–12, 15, 19, 21, 24–25, 29, 42, 48, 51, 54–55, 57–61, 64, 72, 74, 76, 78
Calceocriniidae Meek & Worthen, 1869 49, 82
Calceocrinus bulli Ringueberg, 1889 49
Callocrinididae Bernard, 1895 74, 79
Camocirinus Hall, 1879 6–7, 30–33, 69, 83
Camden Formation 2–4, 70
Camerata Wachsmuth & Springer, 1885 20, 83–84
Campotocrinus Wachsmuth & Springer, 1897 54
Caridocrinus Waagen & Jahn, 1899 30
Carpocrininae de Koninck & Le Hon, 1854 26–27
Carpocrininae de Koninck & Le Hon, 1854 27
Carpocrinus Müller, 1840 27, 80
sablenisi Le Menn, 1987 27
Catatocrinus Brett, 1981 49
Centrocrinus Bather, 1899 38
Chattanooga Shale 4
Cladida Moore & Laund, 1943 14, 58–59, 82
Clarkocrinus Goldring, 1923 47
Cleistocrinus Springer, 1920 65
Clidocrinus Angelin, 1878 65, 79
Clidochirus americanus Springer, 1920 65
Clonocrinus Qwenstedt, 1876 6, 34
occidentalis Springer, 1926 6, 34, 36–37
Codaer McCoy, 1849 6, 71, 73
pulchellus Miller & Dyer, 1878
Coelocrinidae Bather, 1899 27–28
Coeymans Formation 12–13, 18, 79
Comanthocrinus Springer, 1921 46–47
Composocrina Umbags, 1978 26, 54, 79
conodonts 10, 79, 81
Ctenocrinus Goldring, 1923 47
Cremacrinus Ulrich, 1886 6, 9, 11–12, 52, 99
decrat Springer, 1926 6, 9, 11–12, 52, 99
punctatus Ulrich, 1886 52
Crinobrachiatus Moore, 1962 8–11, 15, 54–55, 80, 103
sp. 8–11, 15, 55, 80, 103
Ctenocrinus Kesling & Sigler, 1969 49, 81
Cyclocystoidea Miller & Gurley, 1891 14, 76, 83
Cyclocystoidea Miller, 1882 76
Cylcocrinus Miller, 1892 27
Cypheocrinus Goldring, 1923 21–23
Czech Republic 14, 25
Decachisma Fay, 1961 1, 6–7, 9, 11–12, 14, 71–72, 108
lornae (Dunbar, 1919) 6–7, 9, 11–12, 71, 108
pentagonum Macura, 1983 72
pulchellum (Miller & Dyer, 1878) 71–72
Decatur County 3, 42, 85
Delacrinius Ulrich, 1886 49–51
alieni (Rowley, 1904) 49
cratus (Hall, 1862) 49–50
contractus (Ringueberg, 1859) 49
seconans (Hall, 1872) 49–51
stignatus (Hall, 1863) 50
Dendocrinina Bather, 1879 58–59, 80
Dendocrinoidea Wachsmuth & Springer, 1886 58
Dendrocrinus Strimple, 1956 55–56
Dendrocrinus Angelin, 1878 6, 27
Dimerocrinitidae Zittel, 1879 21–22
Dimerocrinites Phillips, 1839 1, 9, 12–14, 19, 22–24, 88
inornatus Hall, 1862 24
Dimerocrinites (Dimerocrinites) Phillips, 1839 1, 12, 23–24, 88
cheliothoron n. sp. 1, 12, 24, 88
Dimerocrinites (Eucrinus) Angelin, 1878 23
Dimerocrinitoida Zittel, 1879 21–22, 25–26
Diplobathrida Moore & Laudon, 1943 20
Disparida Moore & Laudon, 1943 14, 48, 52, 80, 82
Dolatocrinidae Miller, 1890 34, 37–38, 45–46
Dolatocrinus Lyon, 1857 6–7, 9, 12, 16, 21, 38, 42, 45–48, 81, 83, 99
helderbergensis (Springer, 1921) 7, 12, 47–48, 99
Echinocystitioidea Jackson, 1912 76
Echinoidea Leske, 1778 76
Echinoozoa Haekel, 1895 75
Edrioasteroidea Billings, 1858 14, 75, 79, 83
Edriocrinidae Miller, 1889 68
Edriocrinus Hall, 1858 6–9, 11–15, 62, 68–70, 108
advancus Dunbar, 1919 7–9, 11, 68, 108
dispansus Kirk, 1911 9, 12, 69, 108
explicatus Springer, 1920 69, 108
holopoides Springer, 1920 68
occidentalis Springer, 1920 70, 108
cf. pyriformis Hall, 1862 11, 15, 68–69, 108
saccatus Hall, 1859 68
Eifelian 11, 15, 22, 35, 44, 47, 49, 54, 64, 68
Elpidocrinus Strimple, 1963 6, 8, 13–15, 21–22, 88
exiguus Strimple, 1963 21
cf. thaliformis Strimple, 1963 8, 13, 15, 21–22, 88
tuberosus Strimple, 1963 22
Emsian 13, 39, 47, 50, 68
environments of deposition 4
Eodarwinocysta n. gen. 1, 7, 9, 11–12, 77–78, 111
marriyanni n. sp. 1, 7, 9, 11–12, 77–78, 111
Eodolatocrinus n. gen. 1, 8, 11, 43–47, 99
blabei n. sp. 1, 8, 11, 43–46, 99
niagerensis (Springer, 1926) 45–46, 99
Eosauropalatus n. gen. 1, 9, 12, 73–74, 108
inespectatus n. sp. 1, 9, 12, 73–74, 108
Eosauropalatinus Prokop, 1970 1, 7–9, 11–15, 49–51, 55, 100
broueri n. sp. 1, 9, 11–12, 50, 55, 100
cylindricus Prokop, 1970 50
ghioboni n. sp. 50, 100
bolyneus Prokop, 1970 50
latus Prokop, 1970 50
reticulatus Prokop, 1970 50
tuberosus Prokop, 1970 50
typus (Ringueberg, 1889) 49–50
Eomyelodactylus Foerste, 1919 55
Esapallicrinus Brower, 1973 38, 43–44
iscyphognacili Brower, 1973 43
epibions 6, 17, 19
Euclymocrinoidae Roemer, 1885 34
Euclymocrinoides Goldfuss, 1831 6, 8–9, 11–14, 17–18, 34–37, 95–96
crusta (Hall, 1863) 35
decorus (Phillips, 1839) 35
magnum (Worthen, 1875) 36
milliganae Miller & Gurley, 1895 36
occidentalis (Springer, 1926) 37, 95
permus (Springer, 1926) 34–35, 96
phillipii Troost, 1849 36
roicrus Goldfuss, 1831 34
sculptilis (Springer, 1926) 37, 95
sp. A 35, 95
sp. B 8, 35, 95
sp. C 36, 95
sp. D 36, 95
sp. E 37, 96
Eudimerocrinus Springer, 1926 1, 8, 13–14, 21–23, 91
blabei n. sp. 1, 8, 11, 23, 91
Eudimerocrinus multibrachiatus Springer, 1926 22
Eupachynomorpha Barth, 1890 60
Fissiculata Jaekel, 1918 70, 73
Flexibilia Zittel, 1895 14, 58, 61, 68, 80, 82–83
fossil diagenesis 15
France 12–13, 50, 81–82
Gasport Limestone 18, 49
gastropods 17
Gazacrinidae Miller, 1892 26
Gazacrinus Miller, 1892 6, 9, 12–14, 26, 88
inornatus Hall, 1894 26
stelligatus Springer, 1926 6, 9, 12, 26
Geddiinae 13, 15, 66, 71
Gissocrinus Angelin, 1878 61
ludensis Ramsbottom, 1958 61
macractylus Angelin, 1878 61
Glyptocrinina Moore, 1952 30, 79
Glyptocystitida Barher, 1899 74
Gothocrinus Barher, 1893 60–61
graptoles 10
Griphocrinus Kirk, 1945 21–23
halli (Lyon, 1862) 22
nodulosus (Hall, 1862) 22
oretensis Breimer, 1962 22
Hadroblastus Fay, 1962 73–74
kentuckyensis (Shumard, 1855) 73
whitei (Hall, 1861) 73
Halysocrinus Ulrich, 1886 49–51
Haloplocrinides Troost, 1850 48
Haragan Formation 12–13
Henryhouse Formation 10–13, 15, 20, 22, 25, 29–30, 53, 64, 72, 83
Hepetocrinus Saites, 1873 54–55
Hexacrinites Austin & Austin, 1843 8, 10–11, 13–15, 29–30, 91
adamsii Strimple, 1952 8, 29, 91
carinatus Strimple, 1963 8, 10, 11, 13, 15, 29, 91
Hexacrinidae Wachsmuth & Springer, 1885 29
Hexacrinoida Wachsmuth & Springer, 1885 29, 54
Homaloza Whitehouse, 1941 77
Homacrinidae Angelin, 1878 62, 67
Homocrinidae Ausich, 1998 48, 56–57
Homocrinidae Kirk, 1914 48, 56–57
Homocrininae Warn & Strimple, 1977 48
Homocrinoida Kirk, 1914 48–49, 56
Homocrinus Hall, 1852 48, 52, 56
Hornocrinus Springer, 1920 67
Icthyocrinus Angelin, 1878 65
Icthyocrinoidae Angelin, 1878 61–62, 65
Icthyocrinus Conrad, 1842 1, 6, 8–9, 11–14, 61, 65–66, 107
Icthyocrinus bohemicus Waagen & Jahn, 1899 66
Icthyocrinus devenensis Springer, 1920 6, 9, 12, 66, 107
Icthyocrinus erugatus n. sp. 1, 8, 11, 66, 107
Icthyocrinus phillipsiani Springer, 1920 66
Icriodus woschmidtii Ziegler, 1960 10
Illinois 4, 12, 13, 28, 61, 80–82, 84
Illinois Basin 1, 4, 81
Isorophida Bell, 1976 75
Polydeltoideus Reimann & Fay, 1961 8, 11, 13–15, 72, 74, 83, 108
denatius Reimann & Fay, 1961 8, 11, 13, 15, 72, 108
plasorae Prokop, 1962 72
Pragian 2, 13–15, 27, 50, 66
Premanicrinus Frest & Strimple, 1982 61
Pragian 2, 13–15, 27, 50, 66, 72–73
Proanisocrinus Frest & Strimple, 1978 67
Probalocrinus n. gen. 1, 8–11, 13, 15–16, 20, 88
(digintis (Strimple, 1963) 1, 8–11, 13, 15, 20, 88
Pterinocrinus Goldring, 1923 22–23
Ptychocrinus Wachsmuth & Springer, 1885 22–23
Pygmaeocrinus Bouska, 1947 1, 8–9, 11–12, 14–15, 57, 103
sp. 1, 8–9, 11–12, 57, 103
Pyrgocystidae Kesling, 1967 75
Pyrgocystis Bather, 1915 7–8, 11, 14–15, 75, 80, 83, 111
coronaformis Rievers, 1961 75
sp. 8, 11, 15, 75, 111
Ramacrinus Prokop, 1969 15, 49, 56, 82
brevis Le Menn & Prokop, 1980 15, 49
Reelfoot Rift 4
Rheneocystis Dehm, 1932 77
Rhodocrinites Miller, 1821 22
Rhodocrinitidae Roemer, 1855 20
Rhodocrinitoidea Roemer, 1855 20–21
Rhombifera Zittel, 1879 1–2, 6, 11, 13, 74–75, 79
Rochester Shale 15, 49, 83
Rockhouse Limestone 1, 3–5, 7–12, 15, 18–19, 23, 26, 29, 31–34, 38–40, 45, 49, 51, 55, 57, 59–60, 63–66, 69, 75–77, 80–82, 85
Sagenocrinitida Springer, 1913 54, 61–62
Scilicycstinae Jaekel, 1899 74
Scyphocrinitidae Jaekel, 1928 30–31
Scyphocrinites Zenker, 1833 1, 6–9, 11–15, 17–18, 30–34, 69, 76, 80–81, 92, 95
cinctus Strimple, 1963 31–32
elegans Zenker, 1833 8, 13, 15, 30–32, 92
gibbus Springer (1917) 30–31
mutabilis Springer, 1917 6, 15, 30–31, 33
pratteni (McChesney, 1860) 6, 8, 11, 30–33, 92
pyburnensis Springer (1917) 6, 9, 12, 30–31, 34, 92
stellatus (Hall, 1879) 8, 11, 13, 15, 17–18, 30–33, 92, 95
ubornatus Waagen & Jahn, 1899 30–31, 33
ubrich (Schuchert, 1903) 30–31
Siegenian 13, 15, 47
Stieversia Smith & Paul, 1982 1, 7–9, 11–12, 14–16, 18, 76, 111
devonica (Sievers-Doreck, 1951) 76
sp. 1, 8–9, 11–12, 18, 76, 111
Silurian-Devonian boundary 1, 10–11, 72, 82–83
Siphonocrinus Miller, 1888 14, 20–21, 25
stratigraphy and lithology 2
Stromocrinus Barris, 1878 6, 47–48, 81
Stipitocrinininae n. subfam. 27
Stipococrinus Kirk, 1946 6–8, 10–11, 13–14, 17, 19, 26–28, 42, 81, 91–92
cf. benedicti (Miller, 1892) 8, 10–11, 13, 28, 91
carminatus Kirk, 1940 28
chicagensis (Weller, 1900) 28
farringtoni (Slocum, 1908) 28
howardi (Miller, 1892) 28
nedos (Springer, 1926) 6–8, 10–11, 17, 19, 27–29, 91–92
Sturwingocrinus Schultz, 1867 57
Stylocrinus Sandberger, 1856 56
Stylophora Gill & Caster, 1960 1, 77, 81, 84
surfactant 7
Synapocrinida Springer, 1920 65–66
Synbathocrinus Phillips, 1836 55–57, 82
systematics 20, 79, 82
Taidocrinus Tolmatchoff, 1924 56
taphonomy 15–16, 79–83
Taxocrinus McCoy, 1844 61
Technocrinus Hall, 1859 44, 46
tempestite 19
tentaculitids 6, 19
Thalamoscinidae Miller & Gurley, 1895 58
Thalamocrinus Miller & Gurley, 1895 8, 14, 58, 103–104
cylindericus (Hall, 1852) 59–60, 81
elongatus Springer, 1926 6–8, 11, 13, 19, 59–60, 83, 104
globosus Springer, 1926 59
ovatus (Rowley, 1904) 59
ovatus Springer, 1926 8, 10–11, 13, 58–59, 103
cf. robustus McIntosh & Brett, 1988 8, 10–11, 15, 59–60, 103
strimpel McIntosh & Brett, 1988 59
Theloreus Moore, 1962 8–9, 14, 48, 99
americanus (Springer, 1926) 8–9, 48, 99
Thyamocrinus Hall, 1852 23
trilobites 7, 17, 78
Trichococcus Kirk, 1930 55–56
Tyrreddocrinus Broadhead & Strimple, 1978 6, 8, 11, 74–75, 108
chelyon Broadhead & Strimple, 1978 6, 8, 11, 74–75, 108
Waldron Shale 10–11, 17–19, 24, 35–36, 49, 61, 71, 81
Wayne Group 2, 79
Wisconsin 10
PREPARATION OF MANUSCRIPTS

Bulletin of American Paleontology, the oldest continuously published, peer-reviewed paleontological journal in the Americas, seeks significant, larger monographs (> 50 printed pages, minimum 100 manuscript pages) in paleontological subjects or in neontological subjects that are strongly relevant to paleontological problems. Most contributions focus on systematics, placed in biostratigraphic, biogeographic, paleoenvironmental, paleoecological, and/or evolutionary contexts. Contributions have historically focused on fossil invertebrates, but papers on any taxon of any age are welcome. Emphasis is placed on manuscripts for which high-quality photographic illustrations and the large quarto format are desirable. Both single- and multi-authored (contributed proceedings) volumes are invited.

Submissions are welcome from authors of any institutional or organizational affiliation. Publication costs of the Bulletins are heavily subsidized by PRI, but authors are asked to pay illustration charges ranging from $35 per text-figure to $120 per full-page plate.

Manuscripts must be submitted as electronic copy (preferably pdf) in English, prepared in one of the more widely used word-processing programs. Each manuscript should include Abstract, Introduction, Materials and Methods, Results (flexible format), Discussion, Acknowledgments, Literature Cited, Appendices, Index (subjects only), Tables, Figure and Plate Captions, Text-figures and Plates. The abstract should be informative and include all new taxa, combinations, and taxonomic decisions (e.g., selection of lectotypes); an additional abstract in a second language can be included when appropriate in view of the content or authors. All measurements should be metric, and authorities and dates of all species-level taxa must be provided when first mentioned in the text (although citations need not be included in the Literature Cited). Repositories of types and voucher specimens should be indicated, and nomenclature must be in accordance with the relevant International Code of Nomenclature. All abbreviations and acronyms used in the paper must be explained. Particular care should be paid to formatting the Literature Cited (see full “Instructions” for examples). Comprehensiveness of the Index is at the discretion of the author(s). Illustrations should be prepared as high-resolution, black-and-white digital images, prearranged on plates as appropriate; color reproduction is available but at a substantially higher cost, which must be borne by the author. Low-resolution images are acceptable for initial submission. After review, final submission should include the original (word-processor) text file(s), plus separate table files and a high-resolution image file for each text-figure and plate.

The full “Instructions for Authors” should be consulted during manuscript preparation, and are available from the Editor or online at http://www.museumoftheearth.org/publications/bookstore.php?page=Info_Authors.