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FAUNAL STUDIES OF THE TYPE CHESTERAN, UPPER
MISSISSIPPIAN OF SOUTHWESTERN ILLINOIS

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PART 1

AMMONOIDS FROM THE MIDDLE CHESTER BEECH CREEK
LIMESTONE, ST. CLAIR COUNTY

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ABSTRACT

The index goniatite *Lyrogoniatites* has been discovered in the Golconda Group, Hombergian Stage, middle Chester Series, of the type area. This ammonoid, *L. hartmani* FURNISH & SAUNDERS, n. sp., is comparable to species known elsewhere in America; it indicates a correlation with the Oklahoma Caney Formation (Delaware Creek Member) and equivalents in Georgia, Alabama, Arkansas, Texas, Utah, Nevada, and Alaska. An equivalent faunal zone occurs in the upper Viséan Series of Europe, below the usual boundary between Upper and Lower Carboniferous. Strata just below the Chester Series in southwestern Illinois contain the *Prolecanites monroensis*—*Goniatites greencastleensis* fauna of late middle Viséan age, the only known true Meramecan ammonoids in America.

INTRODUCTION

In 1951 ALBERT E. HARTMAN found a single goniatite within an abandoned quarry about one-half mile west of Richland Creek, in southwestern St. Clair County, Illinois, north of the town of Hecker (SW $\frac{1}{4}$ SW $\frac{1}{4}$ Sec. 27, T. 2 S., R. 8 W.). Mr. HARTMAN, who is a refinery engineer with Socony Mobil, was raised in this area and has collected fossils from the vicinity for many years so he recognized that the goniatite was unique. Additionally he was accompanied at the time by HAROLD H. BEAVER, who substantiated the conclusion that it was an important discovery, the first such fossil in the type Chester. Although loose on the surface, this goniatite was found on

a block of limestone near a face in the main quarry bed, so the source is known rather precisely. Nevertheless, several attempts to duplicate the discovery, even with HARTMAN's assistance, have been unsuccessful. During the fall of 1969, DENNIS W. BURDICK found an additional ammonoid in a currently active quarry, about a mile to the northwest of the original locality. This find initiated the thought that still more would be found there, a forlorn hope. The second specimen was associated with highly fossiliferous argillaceous material used as fill for a roadway within the quarry, but can be traced to a section in the quarry face. It is apparent that the two goniatites came from

beds in the Beech Creek Limestone and were separated by no more than about ten feet vertically. Also, the specimens appear to be conspecific and here are described as holotype and paratype of *Lyrogoniatites hartmani* FURNISH & SAUNDERS, n. sp.

STRATIGRAPHY

Chester formations have been subjected to as intense scrutiny for biostratigraphic analysis as any comparable section in America. The work of such eminent authorities as STUART WELLER (1914, 1920a) and BUTTS & ULRICH (1917) on rocks of the Eastern Interior Basin is classic. Large-scale petroleum development, particularly about 30 years ago, accentuated interest in these strata and provided much additional information. Southwestern Illinois is probably the most important area for studies of Late Mississippian rocks and fossils in this country; a radius of a few tens of miles here encompasses the type localities of many standard Chester divisions (SWANN, 1963). Although most of the rock-unit names have become relatively stable in this area, comparable time subdivisions are not well formalized. SWANN (*ibid.*) has recommended that Genevievean, Gasperan, Hombergian, and Elviran Stages be employed in a "provincial" sense. Above the Ste. Genevieve, these terms correspond to lower, middle, and upper Chester "groups" of STUART WELLER (1920a), who also used Okaw for the middle portion. In 1939, J. M. WELLER proposed New Design, Homberg, and Elvira as group names, and they have been used in a variety of publications including the *Mississippian Correlation Chart* (WELLER *et al.*, 1948).

There has also been variability in defining the boundary between lower and middle Chesteran stages (Gasperan and Hombergian). For the most part, differences involve assignment of the Beech Creek Limestone (SWANN & ATHERTON, 1948; SWANN, 1963), a relatively thin carbonate rock which is the source of the two goniatites from St. Clair County. The name Beech Creek was derived from southcentral Indiana, near Bloomington, but the same thin carbonate beds have been designated basal Golconda Group in southwestern Illinois (SWANN, 1963). STUART WELLER (1926) identified this part of the section on the basis of a wide-ranging fossil as his *Pterotocrinus capitalis* Zone (SUTTON, 1934). Conodonts of the *Gnathodus bilineatus*—*Cavusgnathus cristata* As-

semblage Zone characterize the entire Golconda as a middle Chesteran unit, according to COLLINSON, SCOTT, & REXROAD (1962). Faunal evidence contradicts SWANN's reassignment of the Gasper-Homberg boundary; even his own comments suggest that the Beech Creek is a part of the Hombergian, rather than marking the top of the Gasperan Stage in the lower Chester, as he indicated. For example, according to SWANN (1963, p. 79) *Pterotocrinus* (such as some of those in the Beech Creek) with "Large, simple, and forked blades as well as heavy massive plates characterize the Hombergian." Also, it is stated (*ibid.* p. 83) that the *Talarocrinus* Range Zone (defined by WELLER, 1926) is equivalent to "all fossiliferous Gasperian [Gasperan] rocks except the Beech Creek Limestone." From our own observations and on the basis of the restricted occurrences of both these crinoid genera, assignment of the Beech Creek to the Hombergian is logical.

TIME CORRELATION

No apparent effort has been made to employ Chesteran stages in the usual sense as broadly recognizable time-stratigraphic subdivisions. The stage names proposed for "middle Carboniferous" units in western Europe, such as Bollandian, Pendleian, and Arnsbergian, have similarly received relatively little attention. The most widely used classification scheme for the European Carboniferous has been based upon fossils; for example the *Posidonia* (P_1 and P_2) Zone [= "*true-Goniatites*" Zone and upper *Dibunophyllum* (D_2 and D_3) Zone]. Symbols and mapping units have also been designated, but such numbers and letters have a meaning only in terms of an individual author or country. Viséan (Lower Carboniferous) and Namurian (Upper Carboniferous) are most often employed in a worldwide sense as series names; with lower, middle, and upper corresponding to stage subdivisions. An agreed-upon boundary between Lower and Upper Carboniferous (JONGMANS *et al.*, 1928) generally has been attributed to fall within the Chester Series in North America (*e.g.*, MOORE, 1937; MILLER & FURNISH, 1940).

Over a period of years, the British Viséan and Namurian goniatite zones have been defined in a precise manner (BISAT, 1924; HUDSON, 1945) and their equivalents have been recognized widely in Eurasia and Africa. Nearly identical faunal rela-

tionships are also apparent in the southern Midcontinent (MILLER & FURNISH, 1940), Great Basin (YOUNGQUIST, 1949), and Alaska (GORDON, 1957).

In North America, the greatest problem in Upper Mississippian correlation has existed in attempting to bridge the gap between type Chesteran in the Eastern Interior Basin and strata in the southern Midcontinent. Although exposures of the Upper Mississippi Valley province lie just across the Ozark Uplift about 150 miles from strata of comparable age in northcentral Arkansas, faunas of the two areas are quite different, the Arkansas sections containing dark shales rich in ammonoids. Consequently, assignments of the Meramecan-Chesteran boundary in Arkansas (ULRICH, 1904; GIRTY, 1911; MILLER & FURNISH, 1940; GORDON, 1944; McCaleb, QUINN & FURNISH, 1964; FURNISH, QUINN, & McCaleb, 1964; and GORDON, 1965) have been either vague or contradictory. The most comprehensive and significant review of this correlation problem was presented by MOORE (1948) who surveyed the various faunal elements. His conclusion, the same as that presented earlier (MOORE, 1937) was that the typical *Goniatites* faunas in America were of early Chesteran age, rather than Meramecan. About ten years ago, it became apparent to FURNISH that MOORE's interpretation was the correct one. A number of discoveries have substantiated this conclusion. Field studies in association with H. L. STRIMPLE were most significant, for he has secured sequential crinoid faunas from critical areas for comparison. Discovery of an upper Viséan goniatite in the type Chester substantiates these correlations.

Mississippian strata in southeastern Kentucky to northern Alabama have provided some close ties with the Illinois Basin, because of a general similarity in lithofacies. A common set of terms has been employed in the two areas by BUTTS (1922) and McFARLAN & WALKER (1956). One critical faunal occurrence in the Knobs region south of Lexington was recorded by S. A. MILLER (1889) from near Crab Orchard, Kentucky; the type locality for *Goniatites kentuckiensis*, *Neoglyphioceras subcirculare*, and *Girtyoceras limatum*. As far as known, the goniatites from this locality were collected by MAURITZ FISCHER, a consulting geologist working in the area about 80 years ago. FISCHER's notes delimit the site to a small area near the Lincoln-Rockcastle County line; he also

stated that it is the only spot where he observed these particular fossils in hundreds of exposures examined. An intensive search in the vicinity has failed to reveal any of these goniatites or other Mississippian fossils and the locality is still enigmatic. The entire area was mapped by McFARLAN (1929) and in greater detail by GUALTIERI (1967) but their work shows no rocks of Late Mississippian age where FISCHER indicated that the fossils had been found. Originally, the layer was identified as St. Louis (in an unrestricted sense to include the Ste. Genevieve); beds of this age are exposed extensively only two or three miles to the east. Still farther east in the limestone plateau, fossiliferous limestones occur in the upper Newman Formation (GUALTIERI, 1967) of early and middle Chesteran age according to GORDON WEIR (personal communication) and various authors. The reported site of the goniatite locality lies approximately adjacent to a major east-west fault at Gum Sulphur. The preservation, silicified residuum in a red clay, even suggests that the matrix may be cavern fill. Possibly FISCHER's description deliberately misrepresented the occurrence.

Over the years, SMITH (1903), ULRICH (1904), GIRTY (1911, 1915), and others adopted the St. Louis (including Ste. Genevieve) assignment for the Crab Orchard fauna and believed it to be representative of Meramecan goniatites. GIRTY (1911, p. 23) noted that some species in a comparable fauna, the Moorefield, "are definitely suggestive of a higher horizon . . . Kaskaskia [= Chester]." Still, as recently as 35 years ago, the consensus of such authorities as BUTTS, FOERSTE, and McFARLAN was that FISCHER's collections had probably come from true St. Louis (MILLER & FURNISH, 1940); so this concept persisted. Comparable *Goniatites*-Zone cephalopod faunas were ascribed to the Meramec Series by MILLER & YOUNGQUIST (1948), YOUNGQUIST (1949), MILLER, YOUNGQUIST & NIELSEN (1952), etc. Additionally, it was reported that the index fossils *Goniatites* and *Eumorphoceras* had been found in direct association within the Barnett Shale of central Texas (MILLER & YOUNGQUIST, 1948, p. 652, 653) and all were considered to be of Meramecan age. CLOUD & BARNES (1948, p. 59) even concluded that all of the Barnett faunas were "entirely pre-St. Louis, if not pre-Spergen." As recently as 1955, MILLER & FURNISH (p. 463) stated that "the sequence of middle Carboniferous ammonoid zones established in

Britain can not now be applied literally to American strata."

This low ebb in the level of understanding regarding Middle Carboniferous faunal relationships was soon alleviated to a considerable degree. COLLINSON (1955) redescribed WORTHEN's *Goniates monroensis* (1890) from Illinois as a late middle Visean *Prolecanites* and identified the stratigraphic level as Ste. Genevieve. RUZHENTSEV (1956) and LIBROVICH (1957) then recognized lower Namurian globose goniatitids in the southern Urals and defined *Platygoniatites* (type, *P. molaris* RUZHENTSEV) and *Dombartites* (type, *D. tectus* LIBROVICH). GORDON's (1960) description of similar globose forms from a comparable horizon in the Fayetteville Shale and upper Barnett Shale as *Paracravenoceras* (type, *P. ozarkense* GORDON) was an important contribution. GORDON (1957) had already recorded a series of ammonoid faunas in Alaska, largely from the Brooks Range, without any indication of mixing in standard zonation. In the Alaska monograph, no ties with the Upper Mississippian series were proposed, but on the basis of this presentation and other data, SELLERS & FURNISH (1960) listed early *Goniates* from western Canada as an index of lower Chesteran. A study of mature *Girtyoceras* and *Eumorphoceras* (MCCALEB, QUINN, & FURNISH, 1964) reestablished the similarity of the type species of these two genera, which clearly are related but have different stratigraphic occurrences (Fig. 1). Other authorities, for example SCHMIDT (1925) and E. W. J. MOORE (1946), had recognized the differences between the taxa and the fact that they provided a basis for distinguishing upper Visean and lower Namurian goniatite faunas in Europe. Differentiation of the forms now identified as *Arcanoceras* RUZHENTSEV, 1966 (type, *Girtyoceras burmai* MILLER & DOWNS, 1950) added another critical taxon in the *Eumorphoceras* Zone (SAUNDERS, 1964), which had caused confusion in earlier studies.

Another recent development has aided in an understanding of Meramec-Chester relationships. In checking the source of WORTHEN's cephalopods east of Waterloo, Monroe County, Illinois (COLLINSON, 1955) we found that the locality is on the Hartman homestead, about a mile from the place indicated by WORTHEN's description. A ledge with abundant cephalopods is still exposed in the headwaters of Walters Creek near an old quarry and the remains of a lime kiln, where small-scale

operations could have existed about 80 years ago. A moderate amount of stone was removed from this quarry in 1915 (ALBERT E. HARTMAN, personal communication). The exposure is about 200 yards below a culvert on State Highway 156 at 590 feet elevation on a 120-hectare plot not covered by land survey (projected to the NE¼ NE¼ Sec. 31, T. 2 S., R. 9 W.). In addition to the species of *Prolecanites*, *Acanthonautilus*, and "*Temnocheilus*" described from here, *Goniates greencastlensis* MILLER & GURLEY, 1896, and *Bollandites?* sp. were found in association. Collectively, this assemblage is known from exposures on the far side of the Eastern Interior Basin just west of Greencastle, Putnam County, Indiana, a fact recognized by WORTHEN and others who identified both localities as upper St. Louis Limestone. As noted by COLLINSON (1955) the strata near Waterloo lie within a belt of Ste. Genevieve exposures; however, the cephalopod bed is a dense carbonate associated with ledges bearing *Lithostrotionella "canadensis"* and more closely resembles the St. Louis Formation (WELLER, 1926). In the same vicinity, STUART WELLER (manuscript) identified Aux Vases Sandstone resting directly upon St. Louis, with Ste. Genevieve missing. The type Greencastle Limestone is a local development of fossiliferous oolite that has been correlated by different authorities with the various Meramecan units; it was determined by BIEBER (1958) to lie "at or near the contact of the Salem and St. Louis formations." The problem of correlation appears to have been solved by discovery on an identical cephalopod assemblage, including *Goniates greencastlensis* MILLER & GURLEY, 1896, and *Prolecanites monroensis* (WORTHEN, 1890) [= *P. americanus* MILLER & GARNER], within the classic section at Bedford, Lawrence County, southern Indiana. This occurrence was called to our attention by N. GARY LANE in 1964; after verification by HARRELL L. STRIMPLE, the fauna was collected by a field party from the University of Iowa. REXROAD (personal communication) has identified the cephalopod layer at Bedford as Upper St. Louis Limestone on the basis of conodonts.

In summary, these diverse records indicate that the only known true Meramecan goniatite fauna in America occurs in the St. Louis Limestone. The so-called "St. Louis" cephalopod fauna of eastern Kentucky and the "Meramecan" goniatites of the southern Midcontinent and Western Interior (MILLER & FURNISH, 1940) are actually

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of Chesteran age. GORDON (1965, p. 78-79) has stated that firm placement of the Greencastle fauna would alter his concept of regional correlations with respect to the Arkansas section. If such an early *Goniatites* fauna actually is present within the Boston Mountains, south flank of the Ozarks, it will be found to occur above the Boone Formation but three stages below the Moorefield fauna (instead of as a Moorefield correlative as shown on GORDON's chart, 1965, Table 9). In the zonation of northern England, these Meramecan goniatites, or closely similar species, occur in the upper *Beyrichoceras* Zone (B_2), also designated as lower *Dibunophyllum* (D_1).

MISSISSIPPIAN-PENNSYLVANIAN BOUNDARY

The southwestern Illinois region represents an area in which classic Mississippian-Pennsylvanian boundary relationships exist. That is, a profound regional unconformity is present between formations above and below the contact. This hiatus, together with the pronounced contrast in faunal and lithic types, effectually precludes assignment of these strata to a single "system" in the traditional sense. Although no conclusions are to be drawn from our studies that will alter such a concept, the new information does reemphasize that valid correlations can be established with "Carboniferous" in Eurasia.

It now appears that the Elviran Stage and the upper part of the Hombergian Stage (upper half of the Chesteran) correspond to lower Namurian-A, Pendleian and Arnsbergian Stages (E_1 and E_2) in Europe. That is, the Lower-Upper Carboniferous boundary in the southwestern Illinois section falls within the Golconda Group, above the Beach Creek Limestone (Fig. 1). The so-called "lower Fayetteville Limestone" of GIRTY in northern Arkansas (GORDON, 1965; GORDON *et al.*, 1969) also contains Lower Carboniferous fossils and should be associated with the Moorefield-Hinds-ville; true Fayetteville faunas are basal Upper Carboniferous, Pendleian Stage (E_1).

The Mississippian-Pennsylvanian systematic boundary in the southern Midcontinent must be selected almost as arbitrarily as the Lower-Upper Carboniferous contact in Europe. In Oklahoma and Arkansas there are both younger Mississippian and older Pennsylvanian strata than are present in Illinois. For example, the cephalopod

fauna of the Imo Formation and the Rhoda Creek Shale (FURNISH, QUINN, & McCaleb, 1964; SAUNDERS, 1966; LANE, 1967, 1969; STRAKA, 1969) is post-Chesteran in a strict sense and probably correlates with the upper Arnsbergian-lower Chokierian Stages of HODSON (1957) in Europe. Also, the faunal resemblances (*Pentremites* spp.) and lithic similarities between type Morrowan beds (Lower Pennsylvanian) and Illinois Chesteran strata have been noted historically. However, the Morrowan Series correlates with Kinderscoutian (R_1), Marsdenian (R_2), and Yeadonian (G_1) according to QUINN & SAUNDERS (1968) and QUINN (1970).

Any prospect of securing an international agreement in this boundary dilemma is complicated by still another interpretation in eastern Europe and Asia. The Soviet authorities prefer that a considerable portion of the Namurian (A and B) be placed in the Lower Carboniferous (STEPANOV, 1969); these strata are late Chesteran and early Morrowan in age.

Sufficient data now establish intercontinental correlation within reasonable limits. The most logical action would be to accept an arbitrarily designated horizon for reference; base of the occurrence of *Cravenoceras leion* in northern England (BISAT, 1930) has precedence. The inconvenience of such a definition would be offset by the advantage of a less cumbersome time terminology. In much of North America, such a boundary would effect no change in mapping, for late Chester strata are missing. Other areas on this continent have less of a natural break, and one definition will serve nearly as well as another.

SYSTEMATIC PALEONTOLOGY

Family GONIATITIDAE de Haan, 1825

Subfamily NEOGLYPHIOCERATINAE Plummer & Scott, 1937

DIAGNOSIS.—Representatives of the Neoglyphioceratinae are characterized by a coarsely lirated test with slightly sinuous growth lines and constrictions. The shells appear to have attained only moderate size, reaching maturity at about 30-40 mm diameter, in contrast with *Goniatites*, which in many cases reached 50-100 mm in size. The conch is also more nearly discoidal in cross section than are the true subglobular goniatitids. Sutures of the Neoglyphioceratinae are relatively primitive,

with a small ventral lobe, shallow median saddle, and rounded lateral saddles (Pl. 1).

DISCUSSION.—Several generic names have been proposed for representatives of the subfamily Neoglyphioceratinae, but some are objective synonyms. The group has been discussed at length, particularly by BISAT (1955) and PAREYN (1961). These same authors have questioned the generic distinction of various elements. In the case of *Lyrogoniatites*, definition must be rather arbitrary to differentiate the species from those in *Neoglyphioceras*, for some intermediate forms are known. Still, the usual occurrence normally falls in one group or the other; an evolute broad whorl (*Lyrogoniatites*) or a subdiscoidal narrowly umbilicate conch (*Neoglyphioceras*). Most occurrences do not contain the two in association. Within the "lowermost Namurian" faunas of the Aktyubinsk region in the southern Urals, V. E. RUZHENTSEV has obtained abundant representatives of both forms; he has stated (personal communication) that he considers the generic distinction to be valid.

OCCURRENCE.—The coarsely lirate widely umbilicate goniatitids referred to *Lyrogoniatites* are characteristic of the upper *Goniatites* Zone, lower and middle Chesteran part of the Upper Mississippian. The genus has been found to occur widely with ammonoids of the *G. granosus* group, together with advanced representatives of *Girtyoceras*. Some authorities have recorded neoglyphioceratins near the Viséan-Namurian boundary, but within the upper strata (e.g., PAREYN, 1961; LIBROVICH, 1962; RUZHENTSEV, 1965). This discrepancy may be partly a problem of definition, as well as one of detailed correlation, for the strigate goniatitids have not been found associated with true *Eumorphoceras* in America. However, the ranges of these "boundary markers" may not be entirely discrete. For example, extremely large collections of the *Goniatites granosus* fauna from the Moorefield Shale in Arkansas contain a few specimens of *Cravenoceras*, the lower Namurian index.

Genus LYROGONIATITES Miller & Furnish 1940

TYPE-SPECIES.—*L. newsomi georgiensis* MILLER & FURNISH, 1940.

DIAGNOSIS.—This genus comprises lirate goniatitids closely related to *Neoglyphioceras*, but

distinguished from that genus by the low broadly rounded whorl outline and a relatively large umbilicus. Although many forms included in *Lyrogoniatites* are variable in conch proportion and ornamentation, they are sufficiently distinct from *Neoglyphioceras* to warrant separate generic designation (Fig. 2). The differences are reflected by the umbilicus-to-diameter and width-to-diameter ratios, averaging 0.37 and 0.57 at approximately 24 mm diameter in *Lyrogoniatites*. By contrast, these proportions are 0.23 and 0.43 at an equivalent conch diameter in *Neoglyphioceras*.

DISCUSSION.—Almost a dozen species have been referred variously to *Lyrogoniatites* or *Neoglyphioceras*. Some should be regarded as synonyms, but their evaluation is complicated by poorly preserved type material or inadequate descriptions and illustrations. For example, the sutural outlines of *L. claudi* MILLER & YOUNGQUIST, 1948; *L. hyatti* (GORDON, 1960); *L. crebriliratus* (GORDON, 1965); and *N. spirale* (PHILLIPS, 1841) are unknown. The sutures of *L. newsomi* (SMITH, 1903) and *N. caneyanum* (GIRTY, 1909) are too immature for specific comparison, and the only illustrated suture of *L. newsomi georgiensis* MILLER & FURNISH, 1940, is modified as a result of mature septal crowding. On the basis of conch proportions and number of lirae, however, four distinct groups can be recognized within *Lyrogoniatites*; sutural information distinguishes one additional form (Fig. 2). Taxonomically, it seems realistic to consider the five as distinct species. Taxa within these groups will be regarded as subspecies, with realization that some of them are probably synonyms.

The holotype of the type-species of *Neoglyphioceras* (*Goniatites spiralis* PHILLIPS, 1841) has been lost. A lectotype and paralectotypes were designated by BISAT (1955) but they are crushed and the suture is unknown. Therefore, the existing concept of this genus is based largely upon the ubiquitous form *N. subcirculare* (MILLER, 1889). *N. caneyanum* (GIRTY, 1909) is essentially the same in all respects as *N. subcirculare*, and is regarded as a synonym of that taxon.

The following are treated as subspecies of *Lyrogoniatites newsomi*: *L. claudi* MILLER & YOUNGQUIST (1948), from the Barnett Shale, 2.5 miles southeast of San Saba, Texas; *L. utahensis* MILLER, YOUNGQUIST, & NIELSON (1952), from the Chainman Shale, 4 to 5 miles east-southeast of Cowboy Pass, Confusion Range, central western

Utah; and *L. newsomi georgiensis* MILLER & FURNISH (1940), from the Floyd Shale, Floyd County, Georgia. All of these fit into a broad group characterized by 23 to 40 longitudinal lirae, and U/D and W/D ratios which average 0.38 and 0.60 at approximately 20 mm of conch diameter. The suture, which is best known from specimens of *L. utahensis*, consists of a deep narrow ventral lobe with slightly swollen flanks, narrow flaring ventral prongs, and a shallow funnel-shaped median saddle. The first and second lateral saddles are rounded; the lateral lobe is widely acuminate with sinuous sides (Fig. 3,b). *L. newsomi* is highly variable and widely distributed in equivalent strata throughout North America and parts of Europe; the "subspecies" probably represent provincial variants.

Lyrogoniatites hyatti (GORDON, 1960) may be a distinct species, characterized by its wide evolute conch (U/D 0.55, W/D 0.55) and 20 strong longitudinal lirae. This taxon is known only by HYATT's single specimen collected 80 years ago from the Barnett Shale, bank of Espey Creek, 5 miles southwest of Lampasas, Lampasas County, central Texas, where *L. newsomi claudi* also occurs.

GORDON (1965) described *Lyrogoniatites crebriliratus* in association with *Girtyoceras*, from the "basal Fayetteville Shale" (= Moorefield-Hinds-ville-Batesville of authors, e.g., GARNER, 1967) north slope of Round Mountain, Independence County, northern Arkansas. This taxon differs

from the others by its relatively thin conch (U/D 0.42, W/D 0.48) which is covered by numerous closely spaced lirae (44-47 per whorl). None of the type specimens of GORDON's species portrays sutures, for only external molds are known; some uncertainly exists as to their generic assignment.

A form from Viséan-Namurian boundary strata in the southeastern Verkhoyansk region, Soviet Union, in our opinion represents an additional discrete species of *Lyrogoniatites*. This taxon is being described by Dr. YU. N. POPOV, Leningrad, so will not be considered in detail here. The Hecker Quarry specimen from the Golconda Group of St. Clair County, Illinois, is remarkably similar to the Soviet specimen in external morphology. However, on the basis of their considerably different sutures, the Hecker specimen appears to represent a distinct species.

LYROGONIATITES HARTMANI Furnish & Saunders, new species

Figure 2,3c; Plate 2, Figures 6-9

DIAGNOSIS.—This species is characterized by a relatively thin conch and a moderate-sized umbilicus. Sculpture consists of about 50 lirae per whorl. The suture outline is typical of the genus, with a long narrow ventral lobe and flaring ventral prongs; the lateral lobe is wide and V-shaped.

DESCRIPTION.—Although *Lyrogoniatites hartmani* is based upon only two specimens, they supplement one another and indicate that the form is distinct from all previously described species.

EXPLANATION OF PLATE 1

Representative Neoglyphioceratinae.

FIGURE

- 1-5. *Lyrogoniatites newsomi utahensis* MILLER, YOUNGQUIST, & NIELSEN, 1952, from the middle Chesteran portion of the Chainman Shale at the original locality, Confusion Range, W. Utah.—1-2. Dorsal and septal views of a whorl fragment (SUI 34394), showing external ornament of preceding whorl impressed onto the dorsal surface and the internal sutures, X3.—3-4. Lateral and cross sectional views of a smaller specimen (SUI 34393), X3 and X4.—5. Lateral view of the largest paratype (SUI 1906), X1.3.
- 6-7. *L. newsomi* (SMITH, 1903) from the Bollandian Stage of N. Eng. (SUI 34395), X2.
- 8-16. *Neoglyphioceras subcirculare* (S. A. MILLER, 1889). —8-9. Lateral and sectional views of speci-

men (SUI 34396) from the same general locality as that shown in Fig. 1-5, included for comparison with Fig. 4, X3.—10. Lateral view of specimen (SUI 13729) from the Bollandian of Dinckley Ferry, Lancashire, X2.5.—11. Lateral view of specimen (SUI 33823) "from lowermost Namurian" of Dombur R., Aktyubinsk District, W. Kazakhsk S.S.R., X2.—12-13. Lateral views of topotypes (SUI 34397) probably from FISCHER's original collection, middle Chesteran portion of the Newman Formation near Crab Orchard, SE Ky., X2.5.—14-16. Ventral and lateral views of one specimen and lateral view of another (SUI 12266) from the Moorefield Formation in large gully called "Buffalo Wallow," about 2 miles south of Moorefield, Independence Co., Ark., X2.

The holotype (SUI 34386) is a somewhat eroded calcitic cast that preserves details of shell morphology and suture outline. The paratype (SUI 34387) is an internal mold of about one-third volution within the body chamber that shows the overall nature of the shell sculpture.

At a diameter of 23 mm, the conch is thickly subdiscoidal. Its proportions are height/diameter, 0.45; width/diameter, 0.54; and umbilicus/diameter, 0.22. The whorls are somewhat flattened laterally but rounded ventrally. The umbilical shoulder is distinct.

The outer volution of the holotype is nearly smooth, an observation that originally caused some doubt regarding proper generic reference. However, longitudinal lirae are visible on the shell surface at the umbilicus and are also exposed in cross section at the juncture of the dorsal surface with the preceding whorl. The paratype represents an incomplete whorl section but has 45 lirae spaced rather uniformly, about 0.3 mm apart on the ventral region at 20 mm diameter. Three shell constrictions that form slight lateral and ventral sinuses occur on each whorl.

The suture of *Lyrogoniatites hartmani* is nearly identical to that of *L. newsomi utahensis* MILLER, YOUNGQUIST, & NIELSEN (1952) (Fig. 3,b-c), but slight differences in width of the ventral lobe and in sinuosity of the lateral lobe are observed.

DISCUSSION.—Conch proportions serve to distinguish *Lyrogoniatites hartmani* from most other representatives of the genus. The whorl outline is considerably narrower and the umbilicus is

smaller than in the nearest related form, *L. newsomi utahensis*. In addition, *L. hartmani* has about 50 longitudinal lirae per whorl, in contrast to the 23-40 lirae in *L. newsomi*. The conch form of *L. hartmani* is essentially identical to that of an undescribed Verkhoyan form ("*L. n. sp.*"), but the suture outlines are different, that of *L. hartmani* being more or less typical of the Neoglyphioceratinae, whereas the Soviet taxon shows features more nearly characteristic of some Namurian forms, such as *Cravenoceras* and *Reticuloceras*. That is, the ventral lobe is wider, the ventral prongs are relatively large, and the median saddle is higher (Fig. 3,a).

Recently, JAMES A. DRAHOVZAL, of the Alabama Geological Survey, secured several specimens of *Lyrogoniatites* in association with *Goniatites* sp. and *Girtyoceras* sp. from the Pride Mountain ("Gaspar") Formation, 60 feet above the Tusculumbia Formation, Colbert County, Alabama. These are similar to both *L. hartmani* and *L. newsomi* in suture outline, but the low, wide whorls and larger umbilicus indicate an identity with *L. newsomi utahensis*.

OCCURRENCE.—The two specimens of *Lyrogoniatites hartmani* FURNISH & SAUNDERS, n. sp., were secured from the upper Beech Creek Limestone, Golconda Group, near Hecker, Illinois. The vicinity is characterized by a surface of low relief, but irregularity at the pre-Pennsylvanian unconformity apparently accounts for such local exposures of Mississippian limestones in relatively small inliers. Limestone strata in the Hecker area,

EXPLANATION OF PLATE 2

Representative middle Chesteran *Lyrogoniatites*, X2.

FIGURE

1-4. *Lyrogoniatites newsomi utahensis* MILLER, YOUNGQUIST, & NIELSEN (1952), from the middle Chesteran portion of the Chainman Shale, Confusion Range, W. Utah.—1-2. Lateral and apertural views of paratype (SUI 1906).—3-4. Apertural and lateral views of holotype (SUI 9805).

5. *L. newsomi claudi* MILLER & YOUNGQUIST (1948). Lateral view of fragmentary specimen from middle Chesteran portion of Helms Formation (Barnett Shale) at base of the Sierra Diablo Escarpment about one-half mile north of Mine Canyon, westernmost Culberson Co., Texas.

6-9. *L. hartmani* FURNISH & SAUNDERS, n. sp.—

6-7. Ventral and lateral views of fragmentary paratype (SUI 34387).—8-9. Lateral and septal views of holotype (SUI 34386). Both specimens are from the middle Chesteran Beech Creek Limestone, north of Hecker, St. Clair Co., S.W. Ill.

10-13. *Lyrogoniatites* n. sp. Views of two specimens (Geol. Survey Canada Coll.) from near the Visean-Namurian boundary (C₁), South Verkhoyansk Range, Tompo River Basin, S.E. Yakutsk, A.S.S.R. This material is being studied by Yu. N. Popov and duplicates were provided by The Central Scientific Geological and Prospecting Museum of Leningrad to W. W. NASSICHUK.

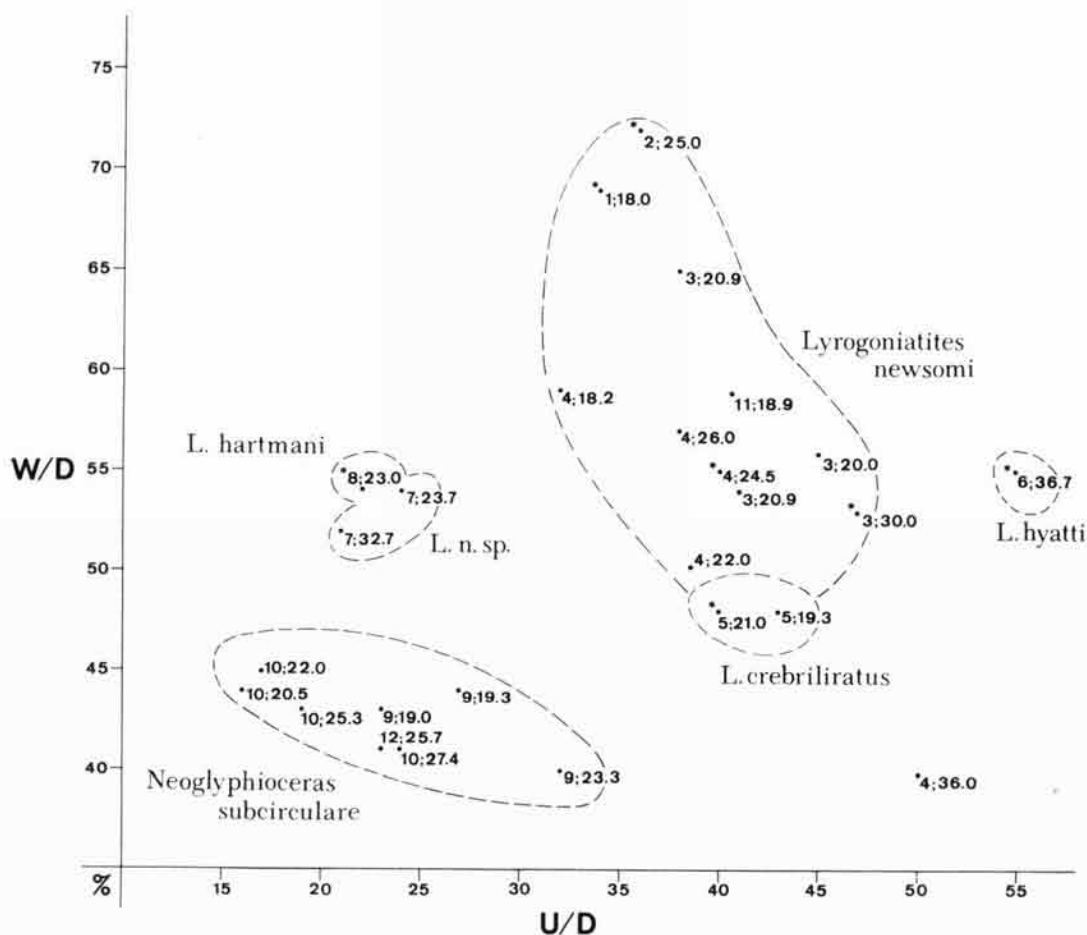
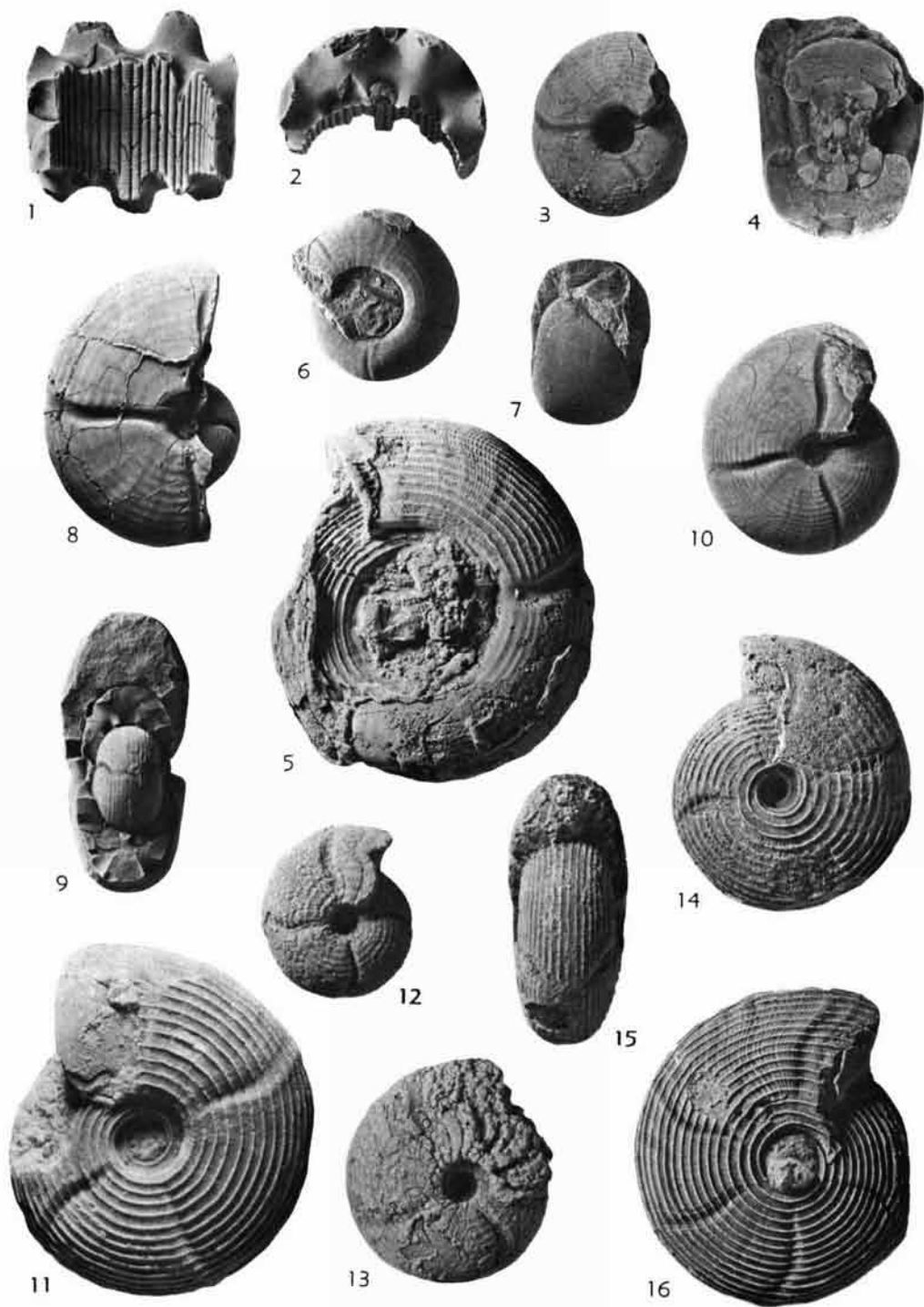
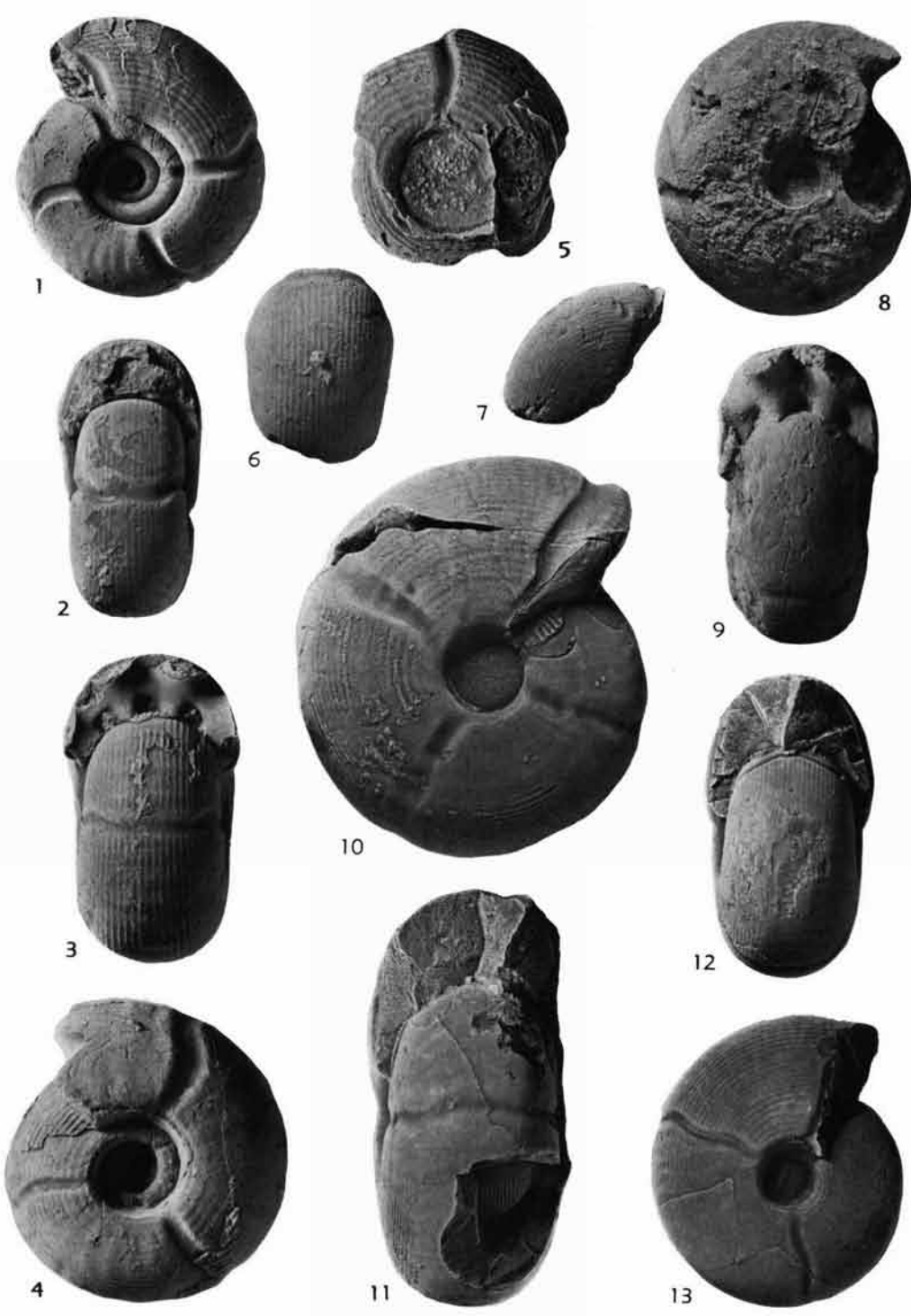


FIG. 2. Scatter diagram showing distribution of width/diameter and umbilicus/diameter ratios of component species of *Neoglyphioceras* and *Lyrogoniatites* at approximately equivalent conch diameters (mean diameter is 23 mm). Specimens showing the three largest U/D ratios reflect their considerably larger size (greater than 30 mm). For comparative purposes, the proportions of a single large specimen of *L. newsomi utahensis* are plotted. Taxonomic subdivisions are also based on sutural information (e.g., *L. hartmani* and *L. n. sp.*, Fig. 3) and number of lirae per whorl [*L. newsomi* (23-40), *L. crebriliratus* (44-47), and *L. hyatti* (20)]. Asterisks indicate type-specimens; prefixes 1-12 designate species and subspecies, and are accompanied by the conch diameter of each specimen.

1. *Lyrogoniatites newsomi newsomi* (SMITH, 1903), Moorefield Shale, Independence Co., Ark.
2. *L. newsomi georgiensis* MILLER & FURNISH (1940), Floyd Shale, Floyd Co., Ga.
3. *L. newsomi claudi* MILLER & YOUNGQUIST (1948), Barnett Shale, southeast of San Saba, Texas.
4. *L. newsomi utahensis* MILLER, YOUNGQUIST & NIELSON (1952), Chainman Shale, Cowboy Pass, W. Utah.
5. *L. crebriliratus* (GORDON, 1965), Moorefield Shale, Independence County, Ark.
6. *L. hyatti* (GORDON, 1960), Barnett Shale, Lampasas Co., Texas.
7. *L. n. sp.*, Visca-Namurian boundary (C_1), Verkhoyansk Range, Southern Yakutsk.
8. *L. hartmani*, n. sp., Beech Creek Limestone, St. Clair County, Ill.
9. *Neoglyphioceras subcirculare* (S. A. MILLER, 1889) [= *N. caneyanum* (GIRTY, 1909)], Batesville Sandstone, Independence Co., Ark.
10. *N. subcirculare*, Moorefield Shale, Independence Co., Ark.
11. *Lyrogoniatites newsomi claudi*, Helms Formation, Culberson Co., Texas.
12. *N. subcirculare* "lowermost Namurian," Dombar R., W. Kazakhsk S.S.R.





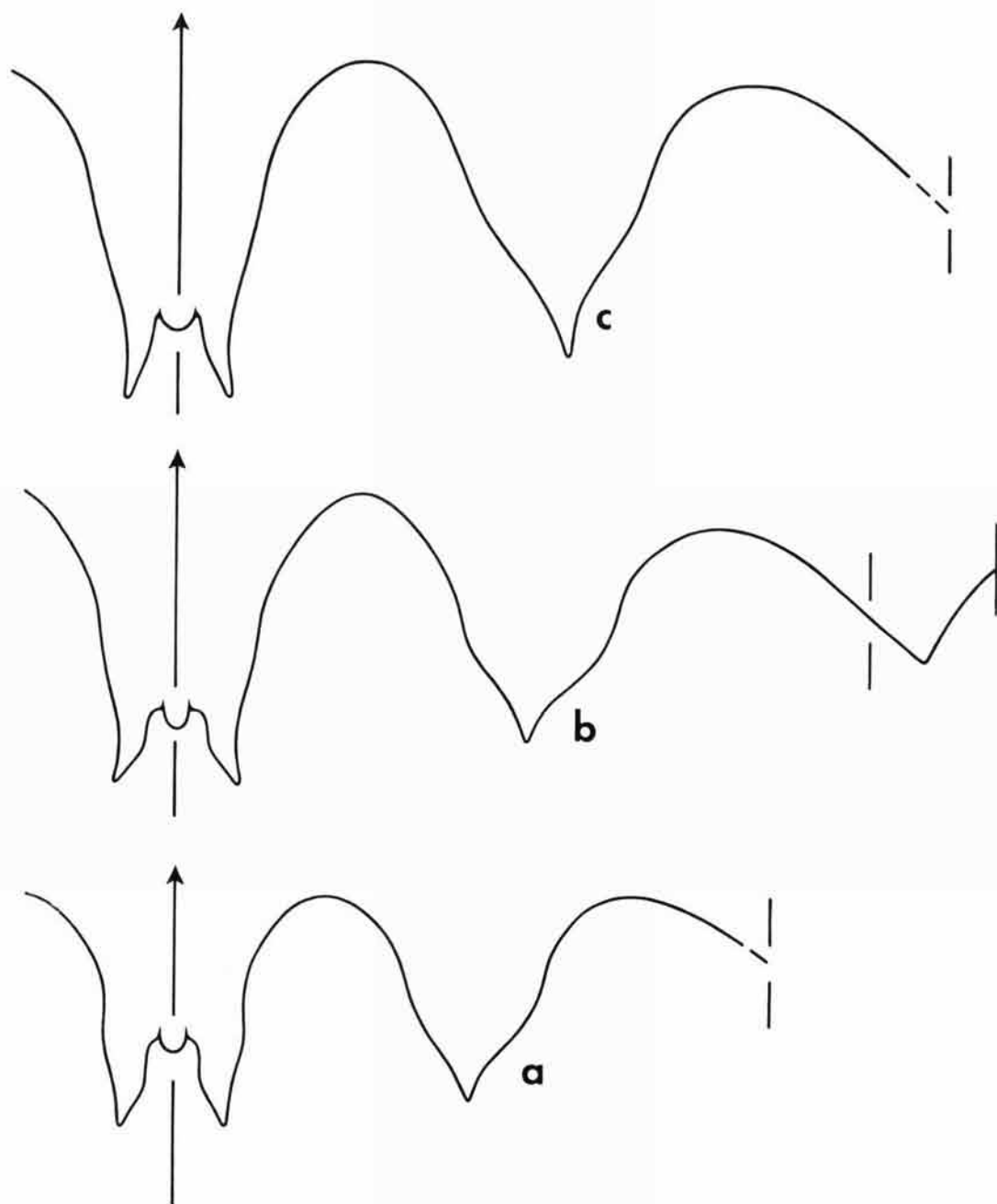


FIG. 3. Diagrammatic representation of external sutures of *Lyrogoniatites*.——*a.* *L. n. sp.* (Geol. Survey Canada Coll.), Viséan-Namurian Boundary (C_1), Verkhoyansk Range, Southern Yakutsk, at 15 mm of conch diameter, approx. X10.——*b.* *L. newsomi utahensis* (MILLER, YOUNGQUIST & NIELSON, 1952) (SUI 9807), Chainman Shale, Cowboy Pass, W. Utah, at 15 mm of conch diameter, approx. X13.——*c.* *L. hartmani* n. sp. (SUI 34386), Beech Creek Limestone, St. Clair Co., Ill., at 16 mm of conch diameter, approx. X10.

southwestern St. Clair County, have been quarried for many years, so exposures are extensive. The main excavation lies within an area mapped by STUART WELLER during the field seasons of 1911-13 (WELLER & WELLER, 1939, pl. 1) and is located nearly midway between St. Louis and Ste. Genevieve, and only about 30 miles north of Chester. The older Hecker Quarry, locality for the holotype, was noted by SHAW (1921) to be characterized by a distinctive translucent yellow fossiliferous limestone. This exposure is about 1.25 mi. north-northeast of Hecker, Prairie du Long Township (SW $\frac{1}{4}$ SW $\frac{1}{4}$ Sec. 27, T. 2 S., R. 8 W.). There are a series of quarry workings on both sides of a small tributary to Richland Creek, which lies a half-mile farther east, and these quarries are just north of State Highway 156. The quarry, presently active, owned by Quality Stone Company, is about a mile to the west of the former operations (includes the common $\frac{1}{4}$ -corner of Sec. 28 & 29, T. 2 S., R. 8 W., New Athens West 7 $\frac{1}{2}$ -minute Quadrangle, 1954).

The Beech Creek Limestone, lower Golconda Group, is about 25 feet thick in this general area and consists of an upper and lower carbonate unit separated by a few feet of shale. WELLER (1920a) noted that this part of the section was more abundantly fossiliferous than any other por-

tion of the Chester. The fauna includes various echinoderms, brachiopods, trilobites, bryozoans, and coelenterates. Ostracodes, foraminifers, and conodonts are known as microfauna from this unit. The most conspicuous fossils are the axes and fronds of *Archimedes*, calyces of *Pentremites*, bases of *Agassizocrinus*, and plates of *Pterotocrinus*. In general, molluscs are uncommon; a few cephalopods were observed, including poorly preserved orthocones and the nautilicone *Stroboceras*. The latter is a small evolute discoidal shell, which occurs with Upper Mississippian goniatites in the shale facies of the southern and southwestern states.

REPOSITORY.—The holotype (SUI 34386) and paratype (SUI 34387) are in the University of Iowa collections.

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PART 2

CRINOIDS FROM THE BEECH CREEK LIMESTONE, LOWER
GOLCONDA GROUP, ST. CLAIR COUNTY, ILLINOIS

D. W. BURDICK and H. L. STRIMPLE

ABSTRACT

A crinoid fauna from the Beech Creek Limestone (lower Golconda Group), Chesteran, is described from southwestern Illinois, and is compared with faunas from the Fraileys Shale in Kentucky, the Glen Dean Limestone of southern Indiana and Kentucky, and the lower Fayetteville Formation in Oklahoma. Components of all three faunas are compared with genera and species known from Viséan and Namurian strata in Great Britain and Morocco. Consideration of common genera, and of the evolutionary grade achieved by the species of these genera suggests that the Viséan-Namurian boundary occurs below the Glen Dean Limestone in the type Chester region.

Fifteen genera of crinoids are known from the Beech Creek Limestone. They are represented by the species, *Acrocrinus constrictus* BURDICK & STRIMPLE, n. sp., *Agassizocrinus occidentalis* (OWEN & SHUMARD), *A. papillatus* WORTHEN, *Aphelocrinus oweni* KIRK, *A. sp. cf. A. popensis* (Worthen) BURDICK & STRIMPLE, n. comb., *Camptocrinus sp.*, *Dasciocrinus sp.*, *Exochocrinus sp.*, *Intermediocrinus asperatus* (WORTHEN), *I. hinmani* BURDICK & STRIMPLE, n. sp., *Onychocrinus distensus* WORTHEN, *Pentaramicrinus sp. cf. P. altonensis* (Miller & Gurley) BURDICK & STRIMPLE, n. comb., *P. bimagnaramus* BURDICK & STRIMPLE, n. sp., *Pterotocrinus armatus* SUTTON, *P. sinuosus* BURDICK & STRIMPLE, n. sp., *P. sp.*, *Rhopocrinus sp. cf. R. proboscoidalis* (WORTHEN) *Taxocrinus sp. cf. T. whitfieldi* (HALL), and *Zeacrinites sp. cf. Z. wortheni* (HALL). *Acrocrinus* is emended; species which were formerly assigned to *Zeacrinites* from British Viséan strata are referred to *Parazeacrinites* BURDICK & STRIMPLE, n. gen.

INTRODUCTION

The primary purpose of the present study is to document occurrences of crinoids from the Beech Creek Limestone (lower Golconda Group) of the Chester Series at two localities in southwestern Illinois. Many crinoid species have been described from the Chester Series in the Illinois Basin and the eastern interior region of the United States, but only a few are recognized as having restricted stratigraphic distribution. The present authors believe that many of these species can be used as stratigraphic indices when their geologic ranges are better documented. Research is presently hindered because most described Chesteran crinoid specimens lack adequate stratigraphic and geographic records.

Most previous crinoid workers have failed to examine the stratigraphic succession of their faunas from Chesteran formations east of the Mis-

issippi River. Except for a report by Horowitz (1965) on the Glen Dean fauna of southern Indiana and Kentucky, no published investigations have dealt with the total crinoid fauna of an individual Chesteran formation. Composite faunal lists such as those presented by Bassler & Moodey (1943) cannot be considered valid because many of the reported occurrences were neither documented adequately in the literature nor in repository holdings.

The majority of known Chesteran crinoids were described in the late 19th century in a number of voluminous and classic works by S. A. Caseday, W. F. E. Gurley, James Hall, S. S. Lyon, F. B. Meek, S. A. Miller, D. D. Owen, B. F. Shumard, Frank Springer, A. G. Wetherby, Charles Wachsmuth, and A. H. Worthen. Specimens were described in order of

acquisition so that reports commonly involve a melange of material from widely separated geographic regions and stratigraphic horizons. Due to a jealous guarding of favorite collecting sites, or lack of adequate stratigraphic and geographic information, many records of localities and horizons are ambiguous. Species reported in a single volume as being from the "Chester Series, Chester, Illinois" could have come from any of the several formations exposed in that region.

Twentieth century writers such as EDWIN KIRK, and A. H. SUTTON and co-workers have contributed greatly to our present comprehension of Chesteran crinoids. These workers concentrated mostly on systematics, establishing and refining genera. However, species discussed or described by them were based on specimens collected by previous researchers. Consequently, taxa described by those authors lack adequate occurrence data.

Large collections of Chesteran crinoids are presently being accumulated at The University of Iowa, and we anticipate that detailed examination of the crinoid faunas will result in refinement of specific ranges and recognition of faunal successions. Comments relating to some of the materials are included within the generic discussions given in this paper.

LOCALITIES

Crinoids used in this study were obtained from the Beech Creek Limestone (lower Golconda Group) in two quarries located a few miles north of Hecker, Illinois. The Beech Creek Limestone in this vicinity is about 25 feet thick, and consists of an upper and lower carbonate unit separated by a few feet of fossiliferous shale. During the quarrying process the shaly material is removed and dumped in abandoned portions of the quarry. Specimens described in this report were procured from these shale dumps. Well-preserved specimens are quite rare, but certain elements, such as infrabasal cones of *Agassizocrinus* and wing plates of *Pterotocrinus*, are very abundant. Coquinas composed almost exclusively of the abraded ossicles of these genera are found in the spoil heaps and can be traced back to the fossiliferous shale zone in the quarry faces.

Some of the materials were collected from an inactive quarry about 1.5 miles north-northeast of Hecker, Prairie du Long Township (SW $\frac{1}{4}$, SW $\frac{1}{4}$, sec. 27, T. 2 S., R. 8 W.). Other materials

were collected from an active quarry, operated by the Quality Stone Company, about 2 miles north of Hecker (NW $\frac{1}{4}$, NW $\frac{1}{4}$, SW $\frac{1}{4}$, sec. 28 and NE $\frac{1}{4}$, NE $\frac{1}{4}$, SE $\frac{1}{4}$, sec. 29, T. 2 S., R. 8 W.). The quarry foreman at this operation reported (personal communication) that a core below the quarried limestone penetrated 10 feet of unfossiliferous blue-gray shale and 10 feet of maroon shale.

REPOSITORIES

Material referred to in the present study is located in 1) the Repository, Department of Geology, The University of Iowa (SUI), Iowa City; 2) Department of Geology, Indiana University (IU), Bloomington; 3) Geological Survey of Alabama Type Collection (GSATC), University; 4) Springer Collection, U.S. National Museum (USNM-S), Washington; 5) Walker Museum collections (WM), now repositied at the Field Museum, Chicago.

ACKNOWLEDGMENTS

ALBERT E. HARTMAN of Waterloo, Illinois, and ALAN S. HOROWITZ, Indiana University, informed us of the echinoderm fauna in the Beech Creek Limestone at the localities included in this study, and during the past several years many expeditions to the localities have been made by various staff members and graduate students from The University of Iowa. E. E. HINMAN, Cornell College, Mt. Vernon, Iowa, found the excellent crown of *Intermediocrinus hinmani* BURDICK & STRIMPLE, n. sp., on one of the expeditions. KENT MADENWALD, of New Baden, Illinois, was kind enough to donate one of the spectacular crowns of *Zeacrinites* sp. cf. *Z. wortheni* to the study. AMEL PRIEST of Peru, Iowa, donated the figured specimen of *Acrocrinus constrictus* BURDICK & STRIMPLE, n. sp., from the lower Fayetteville Shale (Chesteran) of Oklahoma. E. R. POHL of Horse Cave, Kentucky, loaned us a closely related crinoid fauna (listed under North American Faunal Correlation in this paper) from the Fraileys Shale, near Millerstown, Grayson County, Kentucky. M. R. MCGINNIS, currently in the U.S. Army, stationed in California, donated another excellent crown of *Zeacrinites* sp. cf. *Z. wortheni*. Excellently preserved specimens of *Acrocrinus shumardi* discussed in this paper were obtained from collections made by members of the SPENCER WATERS family of Moulton, Alabama, and A. W. BEINLICH

and his wife of Sheffield, Alabama. Problems encountered in this study have been discussed with W. M. FURNISH and B. F. GLENISTER, The University of Iowa. The manuscript was typed by

Miss SHIRLEY STREEBY, and assistance in obtaining needed references was given by Miss VERA BACON, Librarian, Geology Department, The University of Iowa.

NORTH AMERICAN FAUNAL CORRELATION BASED ON CHESTERAN CRINOIDS

The crinoid fauna of the Beech Creek Limestone has not been reported previously, and correlation of it is hindered because similar faunas have not been documented in the literature. Correlation within the Chesteran strata of the Illinois Basin region is hindered because only a few crinoid range zones are reported from these rocks and none extend into the lower Golconda Group. The *Talarocrinus* Range Zone "is equivalent to beds from the Shetlerville through the Ridenhower, that is, to all fossiliferous Gasperian rocks except the Beech Creek Limestone" (SWANN, 1963, p. 83). The occurrence of certain short-ranged crinoid species such as *Pterotocrinus acutus* WETHERBY (1879), *P. bifurcatus* WETHERBY, (1879), and *P. capitalis* (LYON, 1857) occur above the lower Golconda Group. The first two species are reported to range through the Glen Dean Limestone, and the latter to "approximately the lower half of the Fraileys Shale" (SWANN, *ibid.*, p. 79). Detailed examinations of the strata, both in the field and laboratory have failed to detect the presence of these common and diagnostic taxa in the Beech Creek Limestone near Hecker, Illinois.

Nineteen species of crinoids representing 15 genera are known from the lower part of the Golconda Group near Hecker, Illinois. The recognized forms are listed in Table 1. Of these genera, *Agassizocrinus* OWEN & SHUMARD (1852a), *Dasciocrinus* KIRK (1939), *Exochocrinus* BURDICK & STRIMPLE (1969), *Intermediocrinus* SUTTON & WINKLER (1940), *Pterotocrinus* LYON & CASSEDAY (1859), and *Zeacrinites* TROOST in HALL (1858) are thought to be restricted to Chesteran strata. All except *Exochocrinus* and *Intermediocrinus* are thought to occur throughout Chesteran strata. Species known from the Beech Creek Limestone such as *Acrocrinus constrictus* BURDICK & STRIMPLE, n. sp., *Onychocrinus distensus* WORTHEN (1882), *Intermediocrinus himani* BURDICK & STRIMPLE, n. sp., *Pterotocrinus armatus* SUTTON (1934), *P. sinuosus* BURDICK &

STRIMPLE, n. sp., and *Taxocrinus* sp. cf. *T. whitfieldi* (HALL, 1858) are considered as useful diag-

TABLE 1. *Late Mississippian Crinoid Genera from the Beech Creek Limestone (St. Clair County, Illinois), Type Chester Region, and Their Occurrences Elsewhere in North America and Europe (Great Britain).*

GENERA REPRESENTED IN THE BEECH CREEK LIMESTONE, HECKER, ILLINOIS	Fraileys Shale, Millerstown, Kentucky,	Lower Fayetteville Fm., Vinita, Oklahoma (STRIMPLE, 1948-69)	Glen Dean Limestone, Southern Indiana and Kentucky (Hosowitz, 1965)	Visean, England and Scotland (WRIGHT, 1950-60)	D. Hill's Coral Zone 3, England, Visean-Samarian boundary (WRIGHT, 1950-60)	Namurian, England and Scotland (WRIGHT, 1950-60)
<i>Acrocrinus</i> YANDELL, 1855	X	X	..	X	..	..
<i>Agassizocrinus</i> OWEN & SHUMARD, 1852a	X	X	X	..	..	..
<i>Aphelecrinus</i> KIRK, 1944a	X	X	X	X	X	..
<i>Camptocrinus</i> WACHSMUTH & SPRINGER, 1897	..	..	..	X	X	..
<i>Cymbiocrinus</i> KIRK, 1944b	..	X	..	..	..	..
<i>Dasciocrinus</i> KIRK, 1939	..	X	..	..	..	..
<i>Exochocrinus</i> BURDICK & STRIMPLE, 1969	..	..	..	X	..	..
<i>Intermediocrinus</i> SUTTON & WINKLER, 1940	X	..	..	..	..	..
<i>Onychocrinus</i> LYON & CASSEDAY, 1860	..	..	X	X	X	..
<i>Pentamerocrinus</i> SUTTON & WINKLER, 1940	..	..	..	X*	..	..
<i>Phacelocrinus</i> KIRK, 1940b	X	..	..	X?	..	..
<i>Pterotocrinus</i> LYON & CASSEDAY, 1860	..	..	X	..	..	..
<i>Rhopocrinus</i> KIRK, 1942b	..	..	..	..	..	..
<i>Taxocrinus</i> PHILLIPS in MORRIS, 1843	..	X	..	X	..	..
<i>Zeacrinites</i> TROOST in HALL, 1858	X	X	X	..	..	..

* Reported in this paper.

nostic elements which are stratigraphically restricted and can be recognized easily in other regions. The first two species are known from lower Chesteran strata (Fraileys Shale and lower stratigraphic units). The remainder are known only from the lower part of the Golconda Group (Fraileys Shale and Beech Creek Limestone).

Exochocrinus is most common in the *Talarocrinus* Range Zone. Disarticulated plates thought to represent *Exochocrinus* from above that zone are uncommon and are much smaller in size. Occurrences of *Exochocrinus* are not adequately documented at this time.

Intermediocrinus is presently thought to range from basal Chesteran through the lower Golconda (Beech Creek and Fraileys equivalent). Specimens referred to *Intermediocrinus hinmani* BURDICK & STRIMPLE, n. sp., represent the highest known occurrence of that taxon. Specimens described in this paper are from the Beech Creek Limestone near Hecker, Illinois. Dorsal cups which cannot be distinguished from the type specimens are also known from a shale horizon between the Beech Creek Limestone and the Big Clifty Sandstone (Fraileys Shale) near Millers-town, Kentucky. Above this horizon closely related species are referred to *Eupachycrinus* (see discussion under *Intermediocrinus* in this paper).

Acrocrinus constrictus BURDICK & STRIMPLE, n. sp., as presently known in the United States, is represented only in lower Chesteran strata (*Talarocrinus* sp. Zone [Gasperan] through Fraileys Shale [middle Golconda]). *Acrocrinus alvestonensis* WRIGHT (1958), a closely related species, is from the Viscean (S_2 zone) of southwestern England. These species represent a primitive lineage of acrocrinids and are probably only of limited stratigraphic significance.

Species of *Onychocrinus* LYON & CASSEDAY (1860) are axillary on primibrach 4 in the lower Chesteran strata and on primibrach 3 by upper middle Chesteran time (upper Glen Dean). Specimens referable to *Onychocrinus* from the Beech Creek Limestone are axillary on primibrach 4 and are referred to *O. distensus*. Specimens described herein represent the latest reported occurrence of that taxon.

Species of *Taxocrinus* PHILLIPS (1843) are axillary on secundibrach 3 in lower Chesteran strata (up through the Paint Creek Formation) and secundibrach 2 by upper middle Chesteran (Glen Dean). Specimens collected from inter-

mediate strata are axillary on secundibrach 2 or 3 within rays of a single individual. A specimen referable to *Taxocrinus* from the Beech Creek Limestone exhibits the variable ray structure of the intermediate zone.

Aphelecrinus KIRK (1944a), *Camptocrinus* WACHSMUTH & SPRINGER (1897), *Cymbiocrinus* KIRK (1944b), and *Phacelocrinus* KIRK (1940b) are not restricted to Chesteran strata. Species assigned to those genera are not adequately documented in the literature and consequently discussion of them at this time would be inappropriate.

Pterotocrinus LYON & CASSEDAY (1860) is represented in the Beech Creek Limestone by "wing-plates" that have long distinct petioles (proximal shafts) and greatly expanded vertical blades. Such types of blades characterize Chesteran strata equivalent to the Paint Creek Formation through the Glen Dean Formation. *P. armatus* SUTTON (1934) and *P. sinuosus* BURDICK & STRIMPLE, n. sp., are reported herein from the Beech Creek Limestone. The former species is reported from the "Golconda limestone in western Kentucky" (SUTTON, 1934, p. 407). The latter species also occurs in the lower Bangor Limestone near Moulton, Alabama. These species are presently thought to be restricted to Golconda age strata.

Zeacrinites is discussed in some detail within the generic remarks of that taxon. The low dorsal cup and elongate basals of specimens referred to *Z. sp. cf. Z. wortheni* (HALL, 1858) in this paper are most commonly observed in specimens from the Golconda Group of the Illinois Basin region.

An undescribed crinoid fauna from the Golconda Group is known to the writers through a collection made by Dr. E. R. POHL of Horse Cave, Kentucky. The fauna was collected about 4 miles south-southwest of Millerstown, Grayson County, Kentucky, "In a road cut, Broadford to Broadford Church junction at elevation 620-630 near south border of Millerstown, Kentucky 7.5 minute Quadrangle." The "specimens all occur in the lower ten feet of a thirty-foot shale bed which rests conformably on the Beech Creek limestone. This shale grades above into the Big Clifty sandstone" (E. R. POHL, personal communication to H. L. STRIMPLE, 1962). This horizon is equivalent to the Fraileys Shale. The materials are to be repositated at Vanderbilt University, Nashville, Tennessee. The following species are known from this locality: *Acrocrinus constrictus* BUR-

DICK & STRIMPLE, n. sp.; *Agassizocrinus* sp. cf. *A. occidentalis* OWEN & SHUMARD (1852a), or *A. laevis* ROEMER (1852); *Aphelecrinus* sp.; *Intermediacrinus hinmani* BURDICK & STRIMPLE, n. sp.; *Phacelocrinus* sp.; *Phanocrinus bellulus* (MILLER & GURLEY, 1894a); and *Zeacrinites* sp. cf. *Z. wortheni* (HALL, 1858). Material referable to *Phanocrinus* is not known from the Beech Creek Limestone near Hecker, Illinois. All other specimens collected from the Fraileys by POHL are referable to species reported herein from the Beech Creek. Genera in common with those of the Beech Creek Limestone are listed in Table 1.

Since 1948, STRIMPLE has reported 12 crinoid species from a single locality in the dark shaly facies of the lower Fayetteville Formation between Afton and Vinita, Oklahoma. Because these species comprise a single fauna, we have composed a list of documented taxa from that locality in order to make it readily available for reference. Previously reported crinoid species are: *Alcinoecrinus ornatus* STRIMPLE (1949); *Aphelecrinus exoticus* STRIMPLE (1951c); *A. planus* STRIMPLE (1951c); *Chlidonocrinus trinodi* STRIMPLE & WATKINS (1969); *Cymbiocrinus gravis* STRIMPLE (1951a); *Dasciocrinus aulicus* STRIMPLE (1963); *Heliosocrinus aftonensis* STRIMPLE (1951b); *Phanocrinus alexanderi* STRIMPLE (1948); *P. cylindricus* (MILLER & GURLEY, 1894b); *Scytalocrinus aftonensis* STRIMPLE (1951c); *Ulrichicrinus chesterensis* STRIMPLE (1949); and *Zeacrinites peculiaris* (MILLER & GURLEY, 1896). Additionally, *Acrocrinus constrictus* BURDICK & STRIMPLE, n. sp., and *Taxocrinus* sp. cf. *T. whitfieldi* (HALL,

1858) are reported herein. The specimen referred to *P. cylindricus* has long arms like the types of that species but the basal and radial plates are not as tumid. Also the radial plates of the types are more erect. The cup of the described specimen more closely resembles the types of *P. formosus* (WORTHEN, 1873), *P. alexanderi*, and undescribed specimens from the upper Fraileys Shale or lower Haney Limestone near Anna, Illinois. *A. constrictus* as reported herein is known only from middle Chesteran and upper lower Chesteran rocks. *Taxocrinus* sp. cf. *T. whitfieldi* is known only from rocks approximately equivalent to those of Golconda age. Occurrences of other species identified by STRIMPLE are not amply documented at this time. Genera in common with those of the Beech Creek Limestone in Illinois are listed in Table 1.

The Chesteran crinoid fauna reported by HOROWITZ (1965) occurs higher (Glen Dean) in the geologic section than that described in this paper, and diagnostic Golconda elements are absent. Most of the species of *Zeacrinites* reported by HOROWITZ have smaller basal plates than most Golconda species. He also reports three species of *Eupachycrinus* MEEK & WORTHEN (1865). That genus is not known to occur below the Fraileys Shale. *Onychocrinus pulaskiensis* MILLER & GURLEY (1895a) has a primibrach series composed of three brachials, a reduced number from earlier species which had four. *Pterotocrinus* wing plates figures by HOROWITZ do not have the long shaft type of petiole and greatly expanded vertical blade characteristic of many earlier forms.

WISEAN-NAMURIAN FAUNAL CORRELATION

Studies now being carried out by us indicate that classifications of Upper Mississippian and Visean-Namurian crinoid taxa are in great need of refinement. Until this has been accomplished, a comprehensive analysis of the faunas cannot be presented. At present we can only provide comments on our finds which may serve as a basis for future investigations.

Except for specimens referred to *Phanocrinus formosus* (WORTHEN, 1873) by TERMIER & TERMIER (1950, p. 226, pl. 221, fig. 1-8) no species represented in the Chester Series of the United States are known to occur elsewhere in the world. The specimens figured by those authors are re-

ported from the upper Visean, 5 kilometers southwest of d'Igli, Morocco. PAREYN (1962) has interpreted beds at this locality as uppermost Visean, P₂. Unfortunately the occurrence of the holotype of *P. formosus* is recorded only as "Chester division of the Lower Carboniferous Series, Chester, Illinois" (WORTHEN in MEEK & WORTHEN, 1873, p. 549). Specimens which closely resemble *P. formosus* are known to occur in lower Chesteran strata and range upward through the Glen Dean (middle Chesteran). *P. alexanderi* from the lower Fayetteville Formation near Vinita, Oklahoma, and undescribed forms from the lower and middle Bangor Limestone in Alabama also appear to

be closely related to *P. formosus*. The occurrence of *Phanocrinus* and particularly *P. formosus* in the upper Viséan of Morocco, and the abundance of species assigned to that genus suggest that the uppermost Viséan (P_2 Zone) correlates within the lower or middle Chesteran of the United States. Additionally, HOROWITZ & PERRY (1961, p. 867) have reported that *Aphelocrinus oweni* KIRK (1944a), and *Onychocrinus pulaskiensis* MILLER & GURLEY (1895a), from the Glen Dean are "very similar" to the British upper Lower Carboniferous (P_2 - E_1) species, *A. dilatatus* WRIGHT (1945), and *O. liddensis* WRIGHT (1954). *A. oweni* also occurs in the Beech Creek Limestone.

Species of *Onychocrinus* from the United States have four primibrachs per ray in lower Chesteran strata and have reduced their number to three in Glen Dean age equivalents (upper middle Chesteran). Species from lower horizons commonly have even more primibrachs. Species of *Onychocrinus* from near the Viséan-Namurian boundary (P_2 - E_1) of Britain have three or four primibrachs per ray, indicating an approximate evolutionary stage equivalent to those from Chesteran strata of the United States.

Viséan crinoid species from the British Isles that were assigned to *Eupachyrinus* MEEK & WORTHEN (1865) were removed from that taxon by us (1969) because the species did not have the small downflared infrabasals which characterize *E. quatuordecembrachiatus* (LYON, 1857), the type-species. *E. macneanensis* WRIGHT (1951) has large infrabasals which are visible in a side view. That taxon is herein tentatively referred to *Manikisocrinus* STRIMPLE (1951b). *Eupachyrinus vapidus* WRIGHT (1951), has been referred to *Exochocrinus* BURDICK & STRIMPLE (1969), because it has a nearly flat infrabasal circlet and swollen basal plates bearing granular ornamentation. That species is reported from the Viséan of northern Ireland. *Exochocrinus* is locally common in lower Chesteran beds of the United States but may range into middle Chesteran strata. Occurrences of that genus are not adequately documented. Correlation based on *E. vapidus* would not be considered justified at this time because that species bears only slight resemblance to the type species of *Exochocrinus*.

Of the 15 crinoid genera known from the Beech Creek Limestone in Illinois (Table 1), eight are known to occur in the Viséan of Britain.

Pentaramicrinus SUTTON & WINKLER (1940) is herein reported for the first time from the British Viséan (see remarks under that taxon). *Pentaramicrinus* contains several generalized species which reflect little evolutionary change and are not considered as significant stratigraphic indices. British species formerly placed in *Zeacrinites* TROOST (in HALL, 1858) are herein referred to *Parazeacrinites* BURDICK & STRIMPLE, n. gen. The latter genus is comprised of less advanced species than the former. *Parazeacrinites* bears a pinnule on alternating sides of consecutive brachials, whereas *Zeacrinites* has two pinnules per brachial, one attached to each side, probably representing fused brachial couplets. *Parazeacrinites* occurs in the P_2 - E_1 Zone of Britain. The primitive characters of that genus do not allow correlation with the Chester Series.

British Viséan and Namurian species of *Campocrinus* and *Taxocrinus* are not well known and their status precludes comparison with similar species from Chesteran strata in the United States. Species of *Phacelocrinus* discussed by WRIGHT (1951) from Britain are from Tournaisian strata and are axillary on primibrach 2 or 3. Those found in the Chester Series are more advanced and have only one primibrach per ray, although rare examples of two primibrachs in one or two rays of an individual are known. A specimen described as *Phacelocrinus*? sp. is reported from the Viséan (S_2) of Britain (WRIGHT, 1960, p. 330, pl. A, fig. 9). That specimen is axillary on primibrach 2 and is therefore more primitive than species from the Chester Series.

Acrocrinus is known from the Viséan (S_2) of Britain and the Genevievean and Chesteran of the United States (see discussion under Acrocrininae). *A. alvestonensis* WRIGHT (1958), from Britain represents a primitive stock which evolved into several diagnostic North American species but also maintained a primitive lineage that leads to *A. constrictus* BURDICK & STRIMPLE, n. sp. At present, occurrences of the primitive lineage are not adequately documented and are therefore not of stratigraphic significance.

Species referable to *Agassizocrinus*, *Cymbiocrinus*, *Dasciocrinus*, *Intermediocrinus*, *Pterocrinus*, and *Zeacrinites* are known only from the United States, where, except for *Cymbiocrinus*, they are restricted to Chesteran strata.

Based on taxa discussed above and on correlations suggested by such workers as WELLER *et al.*

(1948), MOORE (1948), and HOROWITZ & PERRY (1961), the present authors believe the Visean-Namurian boundary falls within the Chester Series of the Illinois Basin below the Glen Dean horizons. Many of the British crinoids species reported by WRIGHT as being from the Visean-Namurian transition (P_2-E_1 or D. HILL's Coral Zone 3) exhibit characters which are more primitive than those of related species found in the Chester Series of the United States. These factors

intimate that the British species may be older or that species in the United States may have evolved more rapidly. Additionally, species of such genera as *Platycrinites* MILLER (1821), and *Mespilocrinus* DEKONINCK & LEHON (1853), are reported from the P_2-E_1 Zone by WRIGHT. Representatives of these genera are not known to extend upward into the Chester Series of the United States, although *Platycrinites* does occur in the Pennsylvanian.

SYSTEMATIC DESCRIPTIONS

Subclass INADUNATA Wachsmuth & Springer, 1885

Order CLADIDA Moore & Laudon, 1943

Family ZEACRINITIDAE Moore & Laudon, 1943

Genus ZEACRINITES Troost, in Hall, 1858

TYPE-SPECIES.—*Zeacrinites magnoliaeformis* TROOST, in HALL, 1858, p. 543; by original designation.

DIAGNOSIS.—Cup flat to low bowl-shaped with deep basal invagination and commonly one to three anal plates in *CD* interray. Infrabasals small, downflared, occupying just the most proximal portion of basal invagination. Rays endotomous, all in lateral contact, first axillary on primibrach *I*, except ray *A* which has extra primibrachs. Non-axillary brachials quadrangular from back view, on interior they bear a pinnule on each side. Anal sac stout, distally bears an elongate spine. Column with circular cross section.

REMARKS.—SPRINGER (1926, p. 79) considered *Zeacrinites* as ranging "through the entire Lower Carboniferous, beginning in the Kinderhook, culminating in the Chester, and passing up into the Pennsylvanian." Various species were subsequently removed, and SUTTON & HAGAN (1939, p. 85) recognized "no species of *Zeacrinus* younger than Mississippian." Several of the species attributed to *Zeacrinites* by SUTTON & HAGAN, previously were excluded from that genus by KIRK (1938, p. 165, 166) and placed in *Eratocrinus*, KIRK. After publication of SUTTON & HAGAN's paper on *Zeacrinites*, KIRK (1939, p. 470) again affirmed his ascription of the species to *Eratocrinus*. Later KIRK (1942a, p. 382-383) described *Sarocrinus*, and removed some other forms from

Zeacrinites. Species from rocks older than Chesteran are not considered to belong to *Zeacrinites*, and were discussed by HOROWITZ (1965, p. 13), who stated that "With these emendations, the described species of *Zeacrinites* in North America are reported only from rocks of the Chester Series and from rocks of middle Pennsylvanian age in Texas."

Species of *Zeacrinites* reported from rocks of Pennsylvanian age are not well established and most of them have been assigned to other genera. *Zeacrinites? sellardsi* MOORE & PLUMMER (1940) from Middle Pennsylvanian rocks of Texas is questionably assigned generically. For its high stratigraphic occurrence, the sides of the cup seem too high. The anal series is advanced and most likely this species does not belong in *Zeacrinites*. The cup may be referable to *Sciadiocrinus* MOORE & PLUMMER (1938).

Tundracrinus polaris YAKOVLEV (1928) from Permian strata was assigned to *Zeacrinus* (*Zeacrinites*) by YAKOVLEV & IVANOV (1956). The species has a cone-shaped cup which bears no resemblance to that of *Zeacrinites*.

Zeacrinites is herein restricted to species having a pinnule on *each side* of a single brachial. Species from Visean strata of Europe formerly placed in the genus have a pinnule on only one side of a brachial (but in alternating consecutive positions) and herein are placed in *Parazeacrinites* BURDICK & STRIMPLE, n. gen. Unquestionable species of *Zeacrinites* are known only from Chesteran strata in the United States.

Species assignments of individuals referable to *Zeacrinites* are difficult because populations exhibit great variation in the selected characters upon which many species are based. Characters used by other workers, such as exact number and ar-

range of anal plates in the *CD* interray, were not considered significant by SPRINGER (1926, p. 81-84, text fig. 1-9; pl. 22, fig. 1-12; pl. 23, fig. 1-8) and WRIGHT (1926, p. 156, text fig. 61-88; pl. 15; 1952, p. 109, 115, pl. 34, fig. 44-49, 51-55, 57-62, 64-68, 70). SUTTON & HAGAN (1939) also included the number of primibrachs in ray *A* as a diagnostic species character. The above features used singly or in combination do not seem to be diagnostic for specific differentiation. Using the above criteria it was necessary for HOROWITZ (1965, p. 13-22, pl. 1, fig. 1-19; pl. 2, fig. 1, 2) to assign nine specimens from Glen Dean horizons in Indiana and Kentucky to eight species, three described species, and five undescribed species. HOROWITZ (1965, p. 14) stated that only one specimen "shows very close resemblance to a holotype in all features that can be compared."

Several populations from different Chesteran horizons reposit at The University of Iowa indicate that species identification based solely on the characters discussed above would cause division of apparently conspecific populations. Within a population common tendencies can be observed but many variations exist. Characters such as depth of the invagination, whether wide or narrow, diameter of the basal plane, relative width of the basal plates, how far they extend distally (to or past the basal plane), whether the radial plate is nearly flat or arched, how far the radial extends proximally (within invagination), and the number of secundibrachs within a series, should also be taken into account. These features are also somewhat variable, but one or a combination of them is sometimes conspicuous within a population. Species identification is also hindered because evolutionary characters cannot be studied due to the poor recording of horizons and localities for many of the holotype specimens. The present writers agree with HOROWITZ (1965, p. 14) that "Until larger collections are studied so that structural variability can be evaluated, variation in the characters of *Zeacrinites* will probably be conducive to the erection of spurious species."

Other than the characters given in the diagnosis above, *Zeacrinites* represents a highly variable genus of crinoids. All rays are axillary on primibrach 1, except the *A* ray which commonly is axillary on primibrach 2, and less so on primibrach 3. Generally at least two axillaries occur above primibrach 1, their position varying in each half ray and in different rays of the same speci-

men, but the arms have an endotomous character. Populations show a general tendency to be axillary on certain brachials, but exhibit a great deal of variance.

Characters of the anal interray are also highly variable. Shape, arrangement, size, and number of plates in the *CD* interradius show a multitude of variations within a population from a given locale and horizon. As with the brachials, population variances show tendencies and norms. Basal and radial plates also vary in size and shape, but again norms and tendencies are observed.

Described species are based on individual specimens and variations cannot be studied. Research is further hindered by lack of stratigraphic and locality data on most of the holotype specimens. Evolutionary tendencies cannot be discerned from these specimens.

It is beyond the scope of this paper to discuss each species presently assigned to *Zeacrinites*. *Zeacrinites* should prove to be a stratigraphic aid, especially where populations are discovered. Comments included below are based on some type specimens, and populations from known horizons. The material discussed includes populations from the Golconda Group near Anna, Illinois, Glen Dean Limestone of Pulaski County, Kentucky, Renault Limestone near Waterloo, Illinois, and two horizons in the Monteagle Limestone (Gasperan), near Huntsville, Alabama.

Specimens from lower stratigraphic horizons (lower Gasperan) most commonly have four or five secundibrachs and those from higher horizons three or four secundibrachs. Branching of the *A* ray on primibrach 2 or 3 is not, by itself, considered a valid criterion for distinguishing species of *Zeacrinites*; the *A* ray of this genus most commonly has two primibrachs. Specimens with three primibrachs are considered to exhibit a primibrach trait suggesting that *Zeacrinites* evolved from forms with more numerous primibrachs in the *A* ray.

The dorsal cups from lower Chesteran strata are proportionally higher than those from younger deposits. The basals of early forms (lower Gasperan) are very long and narrow, being visible in side view of the cup. In higher strata (Golconda) they are wider, and still visible in a side view. In specimens from the Glen Dean, the basals are smaller, and are not readily visible in side view.

Within a population, characters of the anal interray are highly variable, but a tendency toward elongation of the anal *X* and right tube plates is noticeable in forms from successively higher stratigraphic intervals. This is observed in examples which have three anal plates within the cup. The plates should be in normal "primitive" position. In many of the forms from lower Gasperan strata in Alabama, and the Renault of Illinois, anal *X* and the right tube plate measure slightly wider than high, or are nearly equidimensional. Forms from the Golconda are slightly longer than wide. In specimens from Glen Dean horizons, the plates are easily observed as being longer than wide.

OCCURRENCE.—Upper Mississippian (Chesteran) and Middle Pennsylvanian?, North America (USA).

ZEACRINITES sp. cf. **Z. WORTHENI** (Hall, 1858)

Figure 4; Plate 3, figures 1, 3, 5-6, 8, 10, 12-13, 15

Zeacrinus wortheni HALL, 1858, p. 683, text fig. 111;

SUTTON & WAGNER, 1931, p. 32, text fig. 1-C.

DESCRIPTION.—Crown compact, 1.4 as long as maximum width. Cup flat bowl-shaped, 5.3 as wide as high, with deep proximal invagination which is about 1.4 as deep as cup is wide; basal plane 0.6 as wide as cup; interbasal, basal-radial, and anal plate sutures deeply impressed; on basals and radials within invagination are evenly spaced circular impressions which circumscribe the stem. Infrabasal not visible. Basals, proximal portion not visible, at least 1.4 as long as wide, widest portion across distal ends of interbasal sutures, strongly downflared but not vertical, becoming less downflared and then horizontal at basal plane, distal tips barely visible in side view of cup. Radials largest plates of cup, about 2.1 as wide as long, widest across distal ends of inter-radial sutures, mostly visible in side view of cup, wholly visible in basal view, proximal tip extending past basal plane and well into basal invagination; articular facet occupies full distal width of radial, sloping upward and outward at about 70 degrees from cup summit. Two plates of anal series lie within *CD* interray; radianal is quadrangular, in contact with *C* radial, *CD* basal, anal *X*, and right tube plate; anal *X* is in contact with the radianal, *CD* basal, *D* radial, right tube plate and one other tube plate; right tube plate lies above the cup summit but one corner touches upper left corner of *C* radial; anal sac large, with blunt spine at summit; a strengthened longi-

tudinal flange extends between each ray, but is not visible when arms are closed. Portion of anal sac exposed in *D* ray exhibits proximal anal element resting on an inwardly extended flange of secundibrach 2 of *E* ray, an arched opening above articular facet of *D* radial passing into the cavity, and a depressed slot in mid-portion of the anal sac starting at about one-third the length of sac. Within the slot are subhorizontal slits sloping inwardly and passing into the cavity. Proximal portion of the stem is in the invagination; stem cross section is circular.

Rays are in close lateral contact all around, lateral edge of arm impressed on the adjacent arm or portion of anal sac where they are in contact. Brachials bear a groove along their outer distal margins. The groove does not extend to the lateral edges. Primaxil *A* is small and the secundibrach 1 on each of its shoulders is in contact with the nonaxillary primibrach below the primaxil. Brachials of ray *D* are not preserved. Secundibrachs above secundibrach 2 in the right half of ray *E* are abnormal, secundibrach 3 is too long and misshaped and there are small fragmentary or unfused brachial segments above secundibrach 3. For brachial arrangement see Figure 4.

REMARKS.—The most distinct features of the crown (SUI 34402) are the impressed sutures of the cup, and the transverse groove on the brachials. The greatly accentuated sutures appear modified on this specimen, in that other cups found in the same horizon are smoother or have barely impressed sutures. The transverse grooves on the brachials most likely represent ligament areas which are not pronounced on other specimens referred to species of *Zeacrinites*. Another peculiarity of the specimen is the nature of the laterally appressed arms. *Zeacrinites* characteristically has arms in lateral contact but their margins are straight. The margins of the specimen described here are somewhat irregular and bear mutual impressions where they are in contact with one another, or plates of the anal tube. The circular impressions within the basal invagination and encircling the column cross plate boundaries with very evenly spaced regularity. The rings probably were caused by nodals of the column rubbing against sides of the invagination during life. The resulting irritation possibly arrested secretion of calcite by the dermal cells. The regularity and depth of the rings could not have been achieved after the death of this organism.

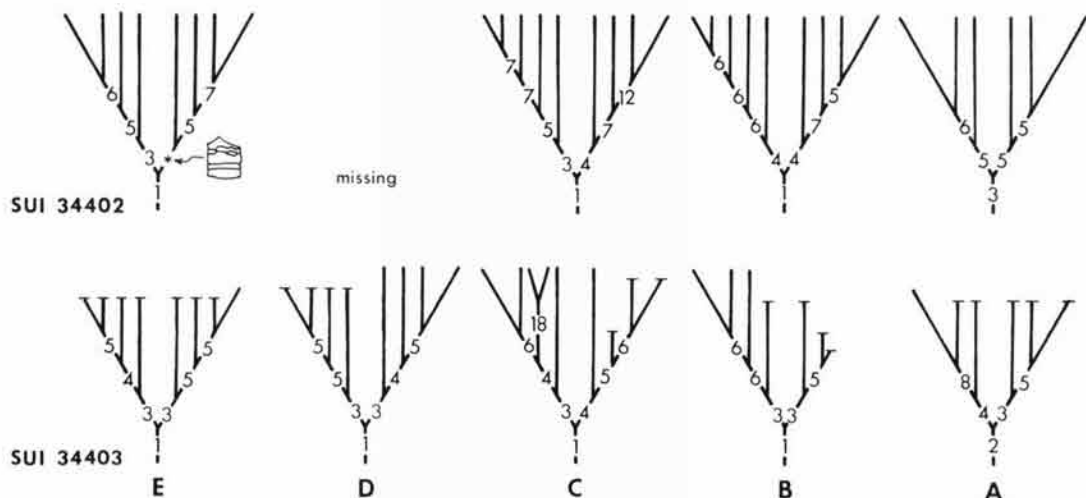


FIG. 4. Arm structures of two specimens (SUI 34402, 34403) of *Zeacrinites* sp. cf. *Z. wortheni* (HALL, 1858) from the Beech Creek Limestone, lower Golconda Group, Chesteran, about 2 miles north of Hecker, Ill. Letters indicate Carpenter designations of rays. Numbers indicate the number of brachials within a series. A horizontal bar over an arm indicates the number of distal brachials is obscured or not preserved. The right secundibrach series in ray E of specimen SUI 34402 is abnormal.

Such rings also occur on the holotype of *Intermediacrinus variabilis* SUTTON & WINKLER (1940). The impressed sutures are presently interpreted as due to physiological or chemical interaction within the dermal layers, causing sensitive areas in which calcite deposition was arrested or hindered. This interpretation is thought to be a unique peculiarity not related to any particular genus or species.

Several dorsal cups and a nearly complete crown (SUI 34403) which are referable to *Zeacrinites* were collected from the same horizon as that of the specimen described above. These are thought to be conspecific with the described specimen. Cups of similar size to that of the crown have proportional components, especially the wide invagination, elongate basals, and proximally elongate tip of the radials. Also the anal series is relatively primitive and plates of the CD interray are large and longer than wide. The described crown differs from other specimens in that its impressed sutures are more easily discerned.

The smallest cup collected is less than 7 mm in diameter and has radial plates which just reach the basal plane. The cup has a circular column, elongate anal plates, elongate basals, and a heavy nonaxillary primibrach preserved adjacent to ra-

dial A. Other preserved primibrachs are also heavy, but are axillary.

The other nearly complete crown (SUI 34403) is about the same in size as the described specimen. The crowns are most alike in sharing the character of having distinct gaps between brachials. Also, the arms commonly are axillary on secundibrach 3 or 4, tertibrach 5 (50%), and quartibrach 5 or 6 (Fig. 4). The crowns differ in that cup sutures of the second crown are not as impressed, the basals do not extend as far beyond the basal plane, and the radianal is in contact with the BC basal. Ray A of the second specimen is axillary on primibrach 2 instead of 3.

The impressed sutures and notched brachials of the specimens of *Zeacrinites* described in this paper are diagnostic but do not seem to warrant a new species designation because of characters presented above. The crown is ascribed to *Z. wortheni* because it has a similar anal series, positioning of the basal plane, number of primibrachs, and number of secundibrachs.

Certain features observed on the crown are not considered characteristic. The primaxil of ray A of the first described specimen is undersized and allows the secundibrach series to be in contact with the next lower primibrach. Secundibrach 3 of the right half of ray E is proportionally

long and ossicles above that brachials are small and irregular (Fig. 4). The irregular brachial segments somewhat resemble those found in biserial arms. The condition possibly represents an unfused brachial (each segment bears a pinnule; normal brachials of *Zeacrinites* bear two pinnules, one on each side).

MATERIAL AND OCCURRENCE.—Described crown, SUI 34402 collected by J. CANGE; comparative crown, SUI 34403, collected by M. R. MCGINNIS, while a graduate student at Iowa State University, Ames, Iowa; juvenile and mature cups figured herein, SUI 34429 and 34539, respectively; and other cups, SUI 34417, from the Beech Creek Limestone, 2 miles north of Hecker, Ill. Other material from inactive quarry in the same horizon 1.5 miles north-east of Hecker is SUI 34418.

MEASUREMENTS IN MILLIMETERS.—Described specimen, length of crown, 46; maximum width of crown, 33; maximum width of cup (measured *BC* to *DE*), 19.1; height of cup, 3.6; diameter of basal plane, 12; diameter of stem, 3.5; width of *AB* basal, 3.2; width of *A* Radial, 10.5; length of *A* radial, 5.0; length of *AB* interrational suture, 4.0.

Genus *PARAZEACRINITES* Burdick & Strimple, new genus

TYPE-SPECIES.—*Zeacrinus konincki* BATHER, 1912, p. 73; designated herein.

DIAGNOSIS.—Similar to *Zeacrinites*, but with shorter brachials, each bearing a single pinnule attached on alternating sides within brachial series.

DESCRIPTION.—See WRIGHT, 1952, p. 107 (description of *Zeacrinites konincki*).

REMARKS.—*Parazeacrinites* BURDICK & STRIMPLE, n. gen., probably represents a more primitive stock of zeacrinids than does *Zeacrinites* TROOST (in HALL, 1858). A pinnule is attached to each side of a single brachial in *Zeacrinites*. In *Parazeacrinites* the brachials are much thinner and bear just one pinnule. Pinnules of the latter genus are attached in an alternating fashion within each brachial series. *Zeacrinites* probably evolved from *Parazeacrinites* by early fusion of two brachials to form one, thus achieving two pinnules per brachial. Some of the specimens of *P. konincki* (Bather, 1912) BURDICK & STRIMPLE, n. comb., figured by WRIGHT (1952, pl. 32, fig. 15, 17; pl. 33, fig. 1, 2) show cuneate and biserial brachials and indicate the early attempt to achieve a greater concentration of pinnules along the arms.

OCCURRENCE.—Lower Carboniferous (upper Viséan), Europe (Britain).

INCLUDED SPECIES.—*Parazeacrinites konincki* (Bather, 1912) BURDICK & STRIMPLE, n. comb., and *P. impressus* (M'Coy, 1851) BURDICK & STRIMPLE, n. comb.

Family EUPACHYCRINIDAE Miller, 1889

Genus *INTERMEDIACRINUS* Sutton & Winkler, 1940

TYPE-SPECIES.—*Eupachyrcrinus asperatus* WORTHEN, 1882; by original designation.

DIAGNOSIS.—Cup medium bowl-shaped, with deep proximal invagination; two or three anal plates in *CD* interray. Anal sac elongate, usually terminated by single elongate spine. Rays with two to four biserial arms (*C* ray most commonly with 4 arms and *A* ray 2 arms); primibrach *I* axillary in all rays; secundibrach *I* axillary in some rays.

REMARKS.—*Intermediacrinus* has recently been reviewed and emended by BURDICK & STRIMPLE (1969, p. 6-8). The genus is very closely related to *Eupachyrcrinus* MEEK & WORTHEN (1865). Because of the designated type-species for each genus, the two genera may be considered synonymous by some authors. In general some characters occur more commonly in one genus than the other. Species assigned to *Intermediacrinus* commonly have four arms in ray *C*, usually have more tumid basal and radial plates, and occur stratigraphically below species assigned to *Eupachyrcrinus*. The latter genus has only three arms in ray *C*, and commonly has a smoother cup.

The above differentiation is generally correct for species included in each genus. The type-species of each genus, *Intermediacrinus asperatus* (WORTHEN, 1882) and *Eupachyrcrinus quatuordecimbrachialis* (LYON, 1857), differ essentially only in the number of arms in ray *C*. The holotypes of each species have tumid basals, radials, and primaxils, and have a prominent longitudinal groove along the proximal length of each basal plate. The biserial character of the arms in *I. asperatus* does not extend proximally as far as *E. quatuordecimbrachialis*, but the former species is smaller and may not be as mature as the latter.

Based on general cup similarities and on difference in arm structure, it seems possible that *Eupachyrcrinus quatuordecimbrachialis* evolved from the lineage which produced *Intermediacrinus asperatus*. Unfortunately, the stratigraphic occurrence of the two species is not well enough documented to enable the evaluation of such a state-

ment. *I. pentalobus* (HALL, 1858) is also probably closely affiliated with the two species discussed above. *I. pentalobus* lacks the longitudinal grooves on the proximal portions of the basal plates.

OCCURRENCE.—Upper Mississippian (Chesteran), North America (USA).

INTERMEDIACRINUS ASPERATUS (Worthen, 1882)

Plate 3, figures 9, 11, 14

Eupachyrcrinus asperatus WORTHEN, 1882, p. 34; —, 1883, p. 311, pl. 29, fig. 4.

Intermediacrinus asperatus (Worthen). SUTTON & WINKLER, 1940, p. 561, pl. 67, fig. 1-2; BURDICK & STRIMPLE, 1969, p. 2, 4, 7-8.

DIAGNOSIS.—Diameter of basal plane nearly equal to that of cup. Basals and radials extremely tumid; broad longitudinal depression extends along portion of each basal plane within proximal invagination.

DESCRIPTION.—Crown medium length and compact. Cup medium bowl-shaped, about 2.25 as wide as high, with broad and moderately deep basal invagination. Depth of invagination equivalent to about 0.3 height of cup. All cup plates, except infrabasals, extremely tumid; each suture, except within proximal invagination, accentuated by sharply depressed and evenly concave groove. Diameter of basal plane about 0.7 that of cup.

Infrabasals pushed inside cup and not visible; basal-infrabasal sutures on basals indicate that they were small, confined to the proximal portion of the invagination, nearly covered by the column, and downflared. Basals large, slightly wider than long, length from proximal tip to basal plane greater than that from basal plane to distal tip; portion of basal within invagination bears a shallow longitudinal depression. Proximal portion of each basal inclined to 30 degrees upward from basal plane to the infrabasals; distal portion extends upward to about 0.6 height of cup. Radials largest elements of cup, about 1.5 as wide as long, length equivalent to about 0.8 height of cup, having articular facets across full distal width of each. Two plates of anal series within *CD* interray; radianal quadrangular, in contact with *C* radial, *BC* and *CD* basals, and anal *X*; within cup anal *X* in contact with *C* and *D* radials, radianal, and *CD* basal.

Primibrach *I* of all rays axillary; strongly tumid, rising straight up from articular facet before becoming tumid; all extend the full distal width of the radial, lateral edges in close contact

with each other, *C* and *D* abutting tightly against anal *X*. Anterior positions of rays *B*, *C*, and *E* are axillary on secundibrach 2. Ray *A* and posterior positions of rays *B* and *E* exhibit no evidence of being axillary within the secundibrach series. Other brachial series not preserved intact. Arms narrow and taper distally above axillaries. Column composed of nodals and internodals, having a round cross section (possibly incipiently pentagonal.)

REMARKS.—The specimen described above closely resembles *Eupachyrcrinus quatuordecimbrachialis* (LYON, 1857) but exhibits characters which more closely resemble *Intermediacrinus asperatus* (WORTHEN, 1882). The latter species has four arms in ray *C*, whereas the former has three. Also the longitudinal groove along the proximal portion of each basal in *I. asperatus* does not extend far enough distally to be visible in side view of the cup; the groove in *E. quatuordecimbrachialis* does. The number of arms in ray *C* of the presently described specimen is not known, because the posterior half of the ray is not preserved. The anterior half bore two arms, a character shared with both of the species discussed. The posterior half of the primaxil in the described specimen has a relatively long suture, indicating that this side possibly supported an axillary secundibrach. Such interpretation would mean that ray *C* had four arms. The primaxil of ray *D* has a short facet on the posterior half, indicating that it supported a single arm. The anterior half has a long facet on the anterior half, indicating that it supported an axillary secundibrach.

The broad longitudinal grooves on the basals of the described specimen are not visible in a side view, except on the *AB* and *EA* basals, which are weathered and eroded. The exact tumidity of plates and characters of the grooves on basal plates are not considered by us as fully valid distinguishing characters and are discussed for comparative purposes only. *Intermediacrinus pentalobus* (HALL, 1858) has a cup very similar to the other species discussed, but does not have the pronounced longitudinal grooves on the basal plates.

The arms of *Eupachyrcrinus quatuordecimbrachialis* are more biserial on lower brachials than those of *Intermediacrinus asperatus*. The type of the former is larger than the latter and the nature of the biserial arms could be interpreted as a mature development. The specimen described in the present report is larger than the holotype of

either species and displays the "mature" type of arms of the former species.

MATERIAL AND OCCURRENCE.—Partially preserved crown, SUI 34425, active quarry in the Beech Creek Limestone, 2 miles north of Hecker, Ill.

The holotype, and only other known representative of *Intermediacrinus asperatus* is reported from the "Chester Series," Monroe County, Ill. Other related forms: *I. pentalobus* (HALL, 1858), Chester Series, Pope County, Ill.; *Eupachycrinus quatuordecimbrachialis* (LYON, 1857), "calcareous beds, near the base of the millstone grit of Crittenden county, associated with *P. [Pentremites] obesus*, *Asterocrinus [Pterotocrinus] capitalis*, *A. [Pterotocrinus] coronarius*, etc. Ranging higher in the bed than either of the others" (LYON, 1857, p. 478-479) (brackets inserted by present authors). SWANN (1963, p. 79) reports that *Pterotocrinus capitalis* occurs approximately in the lower half of the Fraileys Shale. This unit occupies a position just above that of the specimen described in the present paper. Apparently the character which differentiates *Intermediacrinus* and *Eupachycrinus* was introduced during the time when intervening strata were deposited. Because of genetic variation, populations from such intervening strata should yield specimens which exhibit characters attributed to both genera.

MEASUREMENTS IN MILLIMETERS.—Length of crown, as preserved, 51; width of cup, maximum, 27.5, minimum 23.9; height of cup, 10.8; width of basal plane, 18; length of *EA* basal, 9.5; width of *EA* basal 9.9; height of *EA* basal, 6.3; length of *E* interbasal suture, 6.1; width of radial *A*, 12.6; length of radial *A*, 8.6; length of *AB* interradsial suture, 4.4; maximum diameter of column, 4.0; depth of proximal invagination, 3.8.

INTERMEDIACRINUS HINMANI Burdick & Strimple, new species

Plate 4, figures 3-5, 11, 14, 16, 19-22

Eupachycrinus boydii (Meek & Worthen), Wood, 1909, p. 95, pl. 7, fig. 1-5.

DIAGNOSIS.—Basals and radials moderately tumid. Distal half of radials nearly erect (not greatly constricted distally). Proximal portion of each basal abruptly flexed into basal invagination; distal diameter across flexure of the basals is three times greater than column diameter; portion of each basal within basal invagination has a longitudinal groove or pit which does not extend beyond flexure.

DESCRIPTION.—Cup medium bowl-shaped, about 2.6 as wide as high, with deep basal invagination, which is equivalent to or greater than 0.5 height of the cup. Except within basal invagination, cup plates moderately tumid, sutures somewhat impressed. Diameter of basal plane about 0.5 that of cup.

Infrabasals small, downflared, confined to most proximal portion of basal invagination. Basals large, proximal portions forming steep basal invagination, distal portions extending to greater than 0.5 height of cup; in longitudinal cross section, proximal portion of outline nearly straight and steeply downflared, then abruptly flexed outward just above basal plane, distal portion evenly convex; proximal portion bears distinct longitudinal groove or pit; only a very short portion of the interbasal suture visible in side view of cup. Radials large, about 1.7 as wide as long, extending almost to the basal plane. Three plates of anal series within *CD* interray, in normal position; nature of anal sac unknown.

Arms 15, with brachial series axillary only in proximal portions; primibrach 1 axillary in all rays; secundibrach 1 axillary on right side of *B* ray, right and left sides of *C* ray, and left side of *D* ray; secundibrach 2 axillary on left side of *E* ray; remainder of brachial series unbranched, except for few proximal segments biserial, brachial series all tapering distally.

Column with circular cross section, composed of alternating large and small columnals, penetrated by quinquelobate axial canal.

REMARKS.—The description of the arms of *Intermediacrinus hinmani* BURDICK & STRIMPLE, n. sp., is based on one of the paratypes. The fact that the left half of ray *E* is axillary on secundibrach 2, is abnormal. Both secundibrachs are unusually short and it is thought that these represent an unfused couplet. Their composite length is about the same in length as secundibrach series which are axillary on secundibrach 1. Except for this unfused brachial series the nature of arm branching is the same as that of *I. davidsoni* BURDICK & STRIMPLE (1969), a closely related species. The latter does not have longitudinal grooves on the proximal portions of the basals and the basal and radial plates are not as tumid.

Intermediacrinus hinmani also bears some resemblance to *Eupachycrinus spartarius* MILLER (1879), and *E. boydii* MEEK & WORTHEN (1870). All three species have a longitudinal groove on the proximal portion of each basal but the basal invagination of the first species is distinctly wider than in the latter two. Additionally, the summit of the cup of *E. boydii* is greatly constricted, whereas the summits of the other two species are not.

Since the completion of this manuscript, two crowns of *Intermediacrinus hinmani* have been studied. Both have four arms in ray C, verifying assignment of this species to *Intermediacrinus*. The specimens are in private collections, but a cast of one of them is deposited at The University of Iowa (SUI 34540).

NAME.—The new species is named for Prof. EUGENE E. HINMAN, of Cornell College, Mt. Vernon, Iowa, who collected one of the paratypes.

MATERIAL AND OCCURRENCE.—Types are from the Beech Creek Limestone near Hecker, Ill. Holotype (SUI 34426) and paratype (SUI 34427) are dorsal cups from the active Quality Stone Company quarry 2 miles north of Hecker. Paratype SUI 34428, is a crown with slightly crushed cup, from the inactive quarry 1.5 miles northeast of Hecker. Four well-preserved cups assignable to *I. hinmani* were collected from a shale of middle Golconda age, south of Millerstown, Kentucky, by E. R. POHL of Horse Cave, Ky. That locality was discussed earlier in this paper.

A specimen referred to *Eupachycrinus boydii* by WOOD (1909, p. 95, pl. 7, fig. 105) closely resembles *I. hinmani*. The specimen is reported to come from Decatur County, Tenn., although that region does not have Chesteran strata. The locality is also refuted by WOOD.

Other closely related species and their occurrences are: holotypes of *Eupachycrinus spartarius* and junior synonyms *E. durabilis* (MILLER & GURLEY, 1895a), *E. germanus* MILLER (1879), and *E. irregularis* SUTTON & WINKLER (1940), "Chester Series of Pulaski County, Kentucky"; holotype of *E. boydii*, Chester Series, Randolph County, Illinois. HOROWITZ (1965, p. 34-37) recorded hypotypes of the above species from the upper Glen Dean Limestone of southern Indiana and Kentucky.

MEASUREMENTS.—See Table 2.

TABLE 2.—Measurements in Millimeters for *Intermediacrinus hinmani* Burdick & Strimple, n. sp.

	HOLOTYPE SUI 34426	PARATYPE SUI 34427	PARATYPE SUI 34428
Length of crown	----	----	61
Width of cup	22.5	17.9	23
Height of cup	8.5	6.9	8
Depth of basal concavity	5.4	3.4	----
Diameter of basal plane	12.0	10.0	11.0
Width of A radial	11.0	8.5	11.0
Length of A radial	6.3	4.4	6.9
Width of AB basal	7.5	6.9	7.6
Height of AB basal	4.9	4.3	----
Diameter of column	----	----	4.2

Family PHANOCRINIDAE Knapp, 1969

Genus PENTARAMICRINUS Sutton & Winkler, 1940

TYPE-SPECIES.—*Cromyocrinus gracilis* WETHERBY (1880); by original designation.

DIAGNOSIS.—Cup low bowl-shaped, with deep, commonly narrow, basal invagination, and bearing five to 10 uniserial arms; rays that branch axillary on primibrach I; three anal plates in CD interray; radial plates vertical or nearly vertical, not extending to basal planes; infrabasals completely within invagination; two rows of spines extending over distal portion of anal sac.

REMARKS.—A comparison made by us of the width/height ratios of type specimens of *Phanocrinus* KIRK (1937) and *Pentaramicrinus* SUTTON & WINKLER (1940), figured in the latter writers' paper, shows that cups of *Pentaramicrinus* are proportionally deeper than those of *Phanocrinus*. Ratios for species presently referred to *Pentaramicrinus* range from 1.6 to 2.5; those of *Phanocrinus* range from 2.6 to 3.0.

In a recent review of *Pentaramicrinus* by BURDICK & STRIMPLE (1969), the genus was reported only from Upper Mississippian (Chesteran) strata of North America (USA). A specimen now available (SUI 34213) documents the occurrence of the genus in Europe. The specimen is from the Lower Carboniferous ("Viscan, C2S1") at Coplow Quarry, Clitheroe, Lancashire, Scotland. The specimen is slightly crushed but clearly exhibits nearly erect radials, a deep basal invagination, an anal sac terminated by lateral rows of small spines, and ten uniserial arms. The study by BURDICK & STRIMPLE included mostly North American species and types of included European species were not examined. Some of the European species previously referred to *Phanocrinus* may be referable to *Pentaramicrinus*.

A recently described species, *Phanocrinus trulleum* STRIMPLE & WATKINS (1969), may not be a true representative of its assigned genus. The species has a cup which is proportionally deeper than most other described species of *Phanocrinus*. The width/height ratio of *P. trulleum* is 2.1, falling within the variance exhibited by *Pentaramicrinus*. The species differs from typical members of *Pentaramicrinus*, however, by being larger than any other known representatives and by possessing biserial brachials in the distal portions of the arms. The species is referred to the latter genus as

Pentaramicrinus? trulleum (Strimple & Watkins, 1969) BURDICK & STRIMPLE, n. comb., herein.

Recent collections of crinoids from the *Platycrinites penicillus* Zone in the Monteagle Limestone in the vicinity of Huntsville, Alabama, contain many specimens referable to *Pentaramicrinus*. The zonal name-bearer is confined to rocks of Ste. Genevieve age equivalent. Uncatalogued specimens are available at The University of Iowa and Indiana University.

OCCURRENCE.—Upper Mississippian (Genevievean-Chesteran), North America (USA); Lower Carboniferous (Viséan), Europe (Scotland).

PENTARAMICRINUS sp. cf. **P. ALTONENSIS**

(Miller & Gurley, 1895)

Plate 7, figures 7, 20, 23

Poteriocrinites altonensis MILLER & GURLEY, 1895b, p. 62, pl. 4, fig. 3, 4; MILLER, 1897, p. 751, fig. 1384.

Phanocrinus fragosus SUTTON & WINKLER, 1940, p. 557, pl. 67, figs. 5, 6.

Pentaramicrinus fragosus (Sutton & Winkler) BURDICK & STRIMPLE, 1969, p. 3-4, 9.

DIAGNOSIS.—A 10-armed species; sides of cup flare somewhat outward, distal parameter of radials not constricted. Proximal tips of radials not noticeably curved toward basal plane and not extending to basal plane.

DESCRIPTION.—Cup medium bowl-shaped, with deep, narrow basal invagination, about 2.5 times as wide as high; sides extend slightly outward, forming an angle of about 60 degrees with basal plane; diameter of basal plane just less than 0.5 that of the cup; plates thick, smooth, and slightly tumid. Infrabasals not preserved. Basals large, occupying most of basal view, proximal portions narrow, confined to the invagination and vertically downflared, the curving out of invagination, widening, and extending to about 0.5 height of cup; width of each about 0.75 that of a radial. Radials about 0.6 as long as wide, length equivalent to about 0.8 height of cup, fully visible in side view of cup, not extending to basal plane, widest across distal portion; articular facet occupies full width of radial. Three plates of the anal series in *CD* interray in normal (primitive) position.

Primibrach *I* of rays *A*, *D*, and *E* are axillary; other brachials not preserved.

REMARKS.—In a recent publication BURDICK & STRIMPLE (1969, p. 3-4, 9) referred *Phanocrinus fragosus* SUTTON & WINKLER (1940) to *Pentaramicrinus*. Recent investigations of two similar species, *Poteriocrinites altonensis* MILLER & GURLEY

(1895b) and *Poteriocrinites similis* WORTHEN (1882), have revealed that one of them, the former, is a senior synonym of *P. fragosus*. The latter has high primaxils that appear to have spines and cuneiform brachials. The latter species is herein referred to *Dasciocrinus* KIRK (1939) as an immature and somewhat nondescript species. The arms of *D. similis* (Worthen) BURDICK & STRIMPLE, n. comb., have not achieved great enough length to attain distinct axillaries.

The specimen described in the present paper is referred to *Pentaramicrinus* because of its deep and narrow proximal invagination. Because the radials slope somewhat outward, the cup most closely resembles *P. altonensis*. *P. altacalyx* SUTTON & WINKLER (1940) also has sides which slope outward, but in that species the cup is proportionally higher than in *P. altonensis*. The arms of *P. altacalyx* are not known; *P. altonensis* has ten. The specimen described in this paper has three axillary primibrachs which are not in place but preserved at the top of the cup above *A*, *D*, and *E* radials, and it is assumed that the specimen had ten arms.

The cup is larger than that of other specimens assigned to *Pentaramicrinus altonensis*, and most closely resembles that of *Pentaramicrinus* from the Monteagle Limestone in the vicinity of Huntsville, Alabama. Specimens from Alabama also have ten arms and come from that portion of the Monteagle Limestone which is a Ste. Genevieve age equivalent (associated with *Platycrinites penicillus*). The cup also closely resembles that of an undescribed species of *Pentaramicrinus* from the Bangor Limestone (Chesteran) in Alabama which has only five arms.

MATERIAL AND OCCURRENCE.—Cup free of matrix (SUI 34212), Beech Creek Limestone, 2 miles north of Hecker, Ill.

MEASUREMENTS IN MILLIMETERS.—Width of cup, minimum 8.1, maximum, 9.2; height of cup, 3.8; diameter of basal plane, 4.0; diameter of basal invagination at proximal tips of basals, 1.8; depth of invagination to proximal tips of basals, 1.5; width of *AB* basal, 2.0; width of *A* radial, 4.8; length of *A* radial, 3.0.

PENTARAMICRINUS BIMAGNARAMUS

Burdick & Strimple, new species

Plate 4, figures 2, 6, 18

DIAGNOSIS.—Cup constricted distally, bearing ten arms, of which the left side of ray *B* and right side of ray *E* are greatly enlarged.

DESCRIPTION.—Crown slender and compact.

Cup smooth, medium bowl-shaped with deep basal invagination, constricted distal parameter, about twice as wide as high; diameter of basal plane about one half that of the cup. Infrabasals restricted to proximal portion of invagination; not visible. Basals very large, occupying most of basal view, proximal portions narrow, confined to the invagination, vertically downflared within invagination, then curving out from it, widening and extending upward to about 0.6 height of cup. Radials fully visible in side view, about 0.7 as long as wide, widest across proximal tips of inter-radial sutures, length equivalent to about 0.7 height of cup; articular facet occupies full width of distal portion of each radial. Three plates of anal series in normal position within *CD* inter-radius.

Arms ten, with each ray axillary on primibrach *I*; left side of *B* ray and right side of *E* ray are greatly enlarged. Secundibrach series uniserial, and except for the two enlarged series are thin and taper from secundibrach *I* or *2*; enlarged arms swell to mid-length and then taper distally. Pinules attached in normal alternating positions on brachials. Stem small, with circular outline.

REMARKS.—*Pentaramicrinus bimagnaramus* BURDICK & STRIMPLE, n. sp., is assigned to *Pentaramicrinus* because of its deep, narrow basal invagination, erect radials, and proportional height of the cup. The greatly enlarged arms of the species, although unique to *Pentaramicrinus*, are not unknown among inadunate crinoids. *Anartiocrinus* KIRK (1940a) was described for Chesteran species with "hypertrophied" arms and up-flared infrabasals. A new genus is not proposed for the new species at this time because the cup resembles others presently assigned to *Pentaramicrinus* [*P. compactus* (SUTTON & WINKLER, 1940) and *P. basalis* (SUTTON & WINKLER, 1940)]. *P. compactus* is a nine-armed species which has a

double row of low spines over the distal portion of the anal sac, a character thought to distinguish *Pentaramicrinus* from *Phanocrinus*, which has but a single, greatly enlarged spine at top of the anal sac.

The enlarged or "hypertrophied" arms found in species of *Anartiocrinus* are in the same positions as those found in *Pentaramicrinus bimagnaramus* BURDICK & STRIMPLE, n. sp., which except for its two hypertrophied rami has relatively small arms in relation to size of the cup. This unique condition probably represents some type of specialization. The living crinoid, *Comatula purpurea*, is reported by HYMAN (1955, p. 102) to have long arms for "reaching out and grasping an object, and pulling the animal along, while the short arms are employed in pushing from behind." The elongate arms of *C. purpurea* differ from those of the inadunate forms discussed in that they occupy an anterior position rather than opposite sides of the dorsal cup. The stem of the Paleozoic species would seem to inhibit a free-crawling existence. The stem of these forms could possibly have been nonfunctional. It seems most likely that the arms could have swelled to serve as some sort of support for the other arms to keep them from becoming injured in a wave-disturbed environment.

Pentaramicrinus inflatoramus (SUTTON & WINKLER, 1940) is a nine-armed species in which each arm is somewhat enlarged. Besides the difference in arm numbers, the above species does not have a constricted distal parameter of the radial circle which is found in *P. bimagnaramus*.

MATERIAL AND OCCURRENCE.—Holotype (SUI 34210), a well-preserved crown, and partial cup (SUI 34211) are from the Beech Creek Limestone, 2 miles north of Hecker, Ill.

Two specimens preserved on a single slab (IU 5618) from the Golconda Formation in Indiana, may be conspecific with *Pentaramicrinus bimagnaramus*.

EXPLANATION OF PLATE 3

Figures approximately X1.3, unless stated otherwise. All specimens from the Beech Creek Limestone, north of Hecker, Illinois.

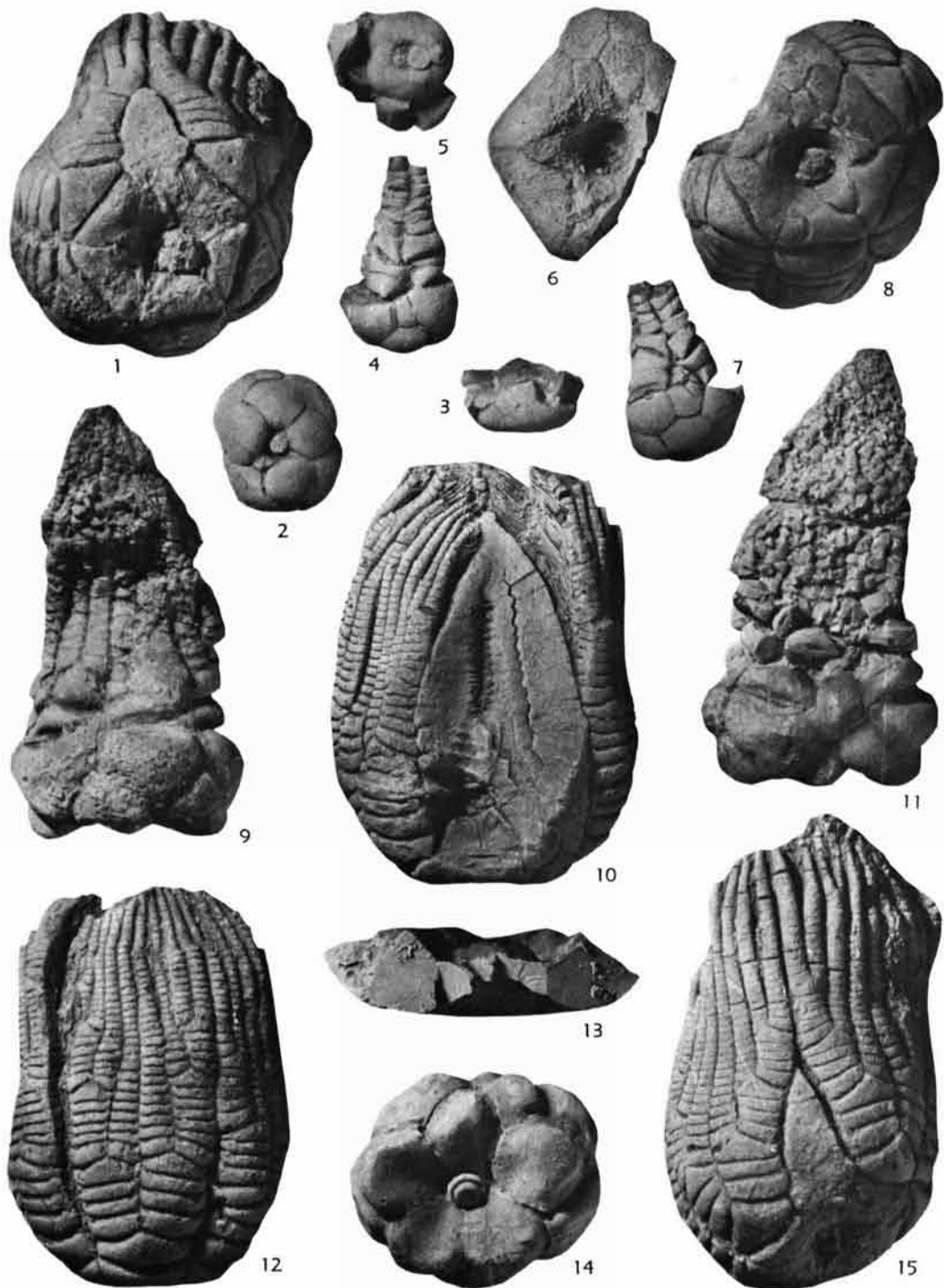
FIGURE

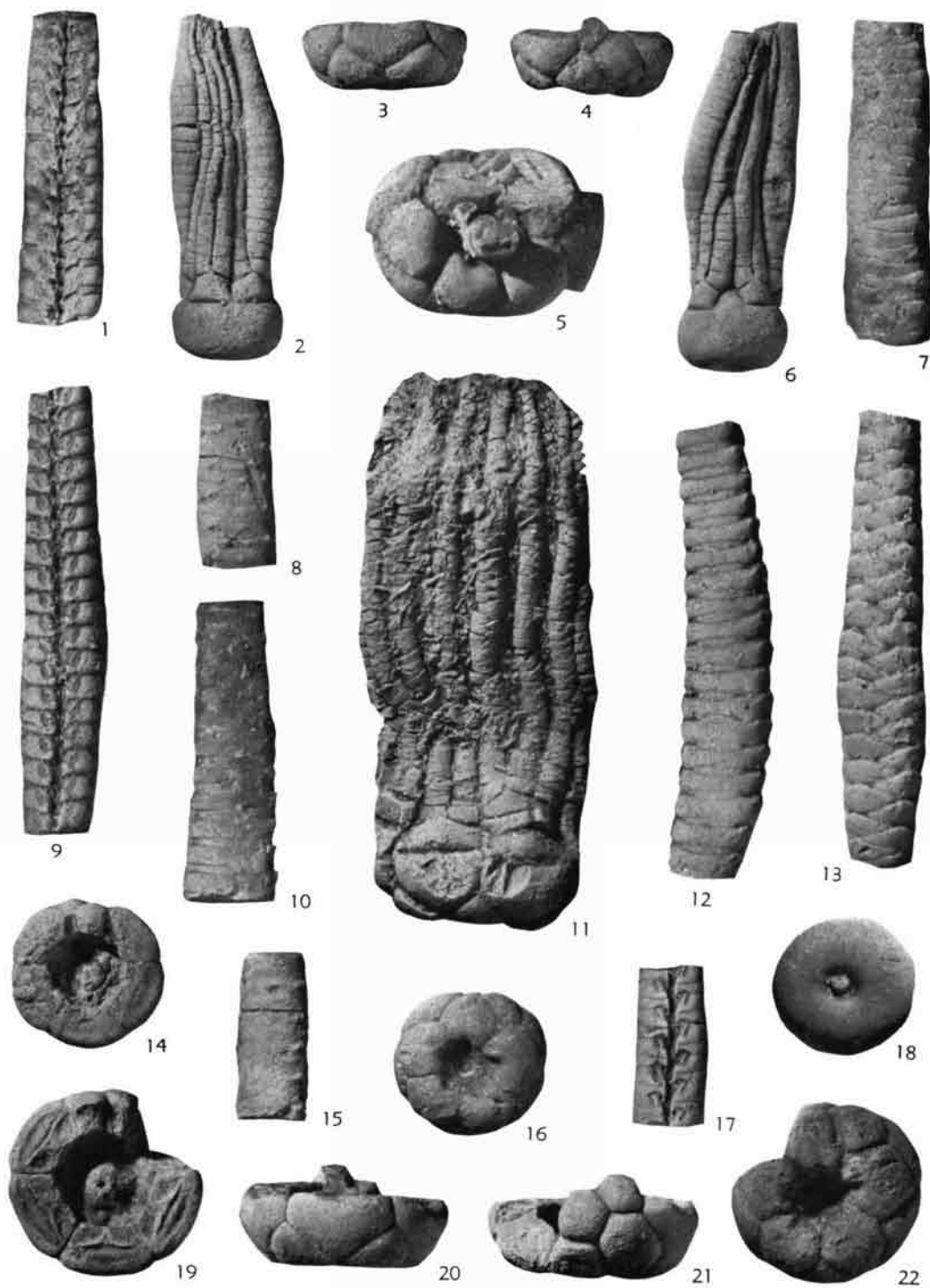
1, 3, 5-6, 8, 10, 12-13, 15. *Zeacrinites* sp. cf. *Z. wortheni* (HALL, 1858).—1, 15. Basal and *CD* interray views (SUI 34403).—3, 5. *CD* interray and basal views of immature specimen (SUI 34534), X2.4. —6, 13. Basal and broken cross section view showing marginal portion of wide invagination (SUI

34429), X1.8 and X2.2.—8, 10, 12. Basal, *D* ray and *B* ray views (SUI 34402).

2, 4, 7. *Cymbiocrinus* sp. Basal, *A* ray, and *CD* interray views of aberrant individual (SUI 34214).

9, 11, 14. *Intermediacrinus asperatus* (WORTHEN, 1882). *A* ray, *CD* interray, and basal views of specimen (SUI 34425).





MEASUREMENTS IN MILLIMETERS.—Width of cup, minimum 11.0, maximum 12.9; height of cup, 6.9; diameter of basal plane, 7.0; length of crown as preserved, 39.9; width of stem, 1.7; width of *AB* basal, 6; height of *AB* basal, 4.0; width of *A* radial, 6.7; length of *A* radial, 4.7; length of *AB* interradial suture, 2.9.

?*PENTARAMICRINUS* sp. aff. *P. BIMAGNARAMUS*

Burdick & Strimple, new species

Plate 4, figures 1, 7-10, 12, 13, 15, 17

REMARKS.—Several robust arm segments that were collected may have some affinity with *Pentaramicrinus bimagnaramus* BURDICK & STRIMPLE, n. sp. The arms are unique in being thick and ranging in structure from uniserial to biserial. The stout nature of the arms and the fact that they are preserved intact suggests that they were rigid. Uniserial and biserial forms are thought to represent a single species because the arms bear a unique ornamentation and some exhibit an intermediate type of biserial brachial structure.

A series of low nodes is developed on the back of each brachial of the uniserial arms. The nodes are located distally and toward the side of each brachial to which the pinnule was attached. Brachial series with intermediate structure show each series of nodes as a confluent ridge which enlarges distally until it laps over and obscures a portion of the next distal brachial. Arms which appear biserial have the ridges greatly enlarged and extending over several brachials. After this alteration, or possible contemporary with it, the area of pinnule attachment also enlarges until it crowds out the nonpinnular areas above and below, achieving a biserial structure. Biserial arms usually have equidimensional brachials.

The enlarged arms on the holotype of *Pentaramicrinus bimagnaramus* are smaller than

the arm segments discussed above, but they do exhibit a tendency to swell on alternate sides of consecutive brachials. It is possible that the holotype is less mature than the individuals bearing the larger arms.

MATERIAL AND OCCURRENCE.—Figured specimens (SUI 34440-34442), Beech Creek Limestone, 2 miles north of Hecker, Ill.

Family AGASSIZOCRINIDAE Miller, 1889

Genus *EXOCHOCRINUS* Burdick & Strimple, 1969

TYPE-SPECIES.—*Eupachyrinus tumulosus* MILLER, 1892; by original designation.

DIAGNOSIS.—Cup deep, truncate bowl-shaped, and except for infrabasals composed of very tumid plates; infrabasals fused into flat nearly pentagonal disc which lies within proximal invagination formed by protuberant basal plates; basals largest elements of cup; three anal plates in *CD* interray.

OCCURRENCE.—Upper Mississippian (Chesteran), North America (USA); upper Lower Carboniferous (Viscan), Europe (Britain).

EXOCHOCRINUS sp.

Plate 5, figures 10, 12

REMARKS.—Isolated basal and anal plates referable to *Exochocrinus* but not definitely assignable to any species were collected from lower Gollconda Limestone north of Hecker, Illinois. The plates are very tumid, having hemispherical or more rotund cross section, and bear granular ornamentation displayed in a near-radial manner.

MATERIAL AND OCCURRENCE.—Isolated plates free of matrix (SUI 34227), Beech Creek Limestone, 2 miles north of Hecker, Ill. Figured specimen is SUI 34227a.

MEASUREMENTS IN MILLIMETERS.—Figured specimen, length, 7.9; width, 6.9; thickness, 5.7.

EXPLANATION OF PLATE 4

Figures approximately X1.3 unless stated otherwise. All specimens from the Beech Creek Limestone, north of Hecker, Illinois.

FIGURE

- 1, 7-10, 12-13, 15, 17. ?*Pentaramicrinus* sp. cf. *P. bimagnaramus* BURDICK & STRIMPLE, n. sp.; comparative specimens, X2.—8, 15, 17. Outer, lateral and inner views of uniserial arm segment (SUI 34440).—1, 7, 10. Inner, outer, and lateral view of nearly uniserial arm segment (SUI 34441).—9, 12-13. Inner, lateral, and outer view of somewhat biserial arm segment (SUI 34442).
2, 6, 18. *Pentaramicrinus bimagnaramus* BURDICK &

STRIMPLE, n. sp. *A* ray, *CD* interray, and basal views of the holotype (SUI 34210).

- 3-5, 11, 14, 16, 19-22. *Intermediacrinus hinmani* BURDICK & STRIMPLE, n. sp.—3-4, 14, 16. *A* ray, *CD* interray, interior, and basal views of a paratype (SUI 34427).—5, 11. Basal and *EA* interray views of paratype (SUI 34428).—19-22. Interior, *A* ray, *CD* interray, and basal views of the holotype (SUI 34426).

Genus **AGASSIZOCRINUS** Owen & Shumard,
1852

TYPE-SPECIES.—*Agassizocrinus conicus* OWEN & SHUMARD, 1852a; by monotypy.

DIAGNOSIS.—Cup high bowl-shaped, smooth or with moderately tumid elements; infrabasals commonly very thick, fused, resting on basal plane or extending below basals; three or four anal plates in *CD* interray; 10 uniserial arms.

OCCURRENCE.—Upper Mississippian (Chesteran) North America (USA).

AGASSIZOCRINUS OCCIDENTALIS
(Owen & Shumard, 1852)

Plate 5, figures 1-5, 7-9, 11, 13, 15, 16, 22

Poteriocrinus occidentalis OWEN & SHUMARD, 1852a, p. 92, pl. 11, fig. 5a-b; OWEN & SHUMARD, 1852b, p. 596, pl. 5-B, fig. 5a-b.

Agassizocrinus occidentalis (Owen & Shumard). SPRINGER, 1926, pl. 15, fig. 8-9.

Agassizocrinus gibbosus HALL. SPRINGER, 1926, p. 121, pl. 15, fig. 8-9.

REMARKS.—Complete or nearly complete cups assignable to *Agassizocrinus* most closely resemble specimens figured by SPRINGER (1926, pl. 15, fig. 8-9) and referred to as *A. gibbosus* HALL (1858). SPRINGER's specimens are from the "Okaw formation; Chester, Illinois." The lowest portion of that formation is equivalent to the Beech Creek Limestone, to which the specimens collected for this study are referred.

The specimens are classed as *Agassizocrinus occidentalis* in this paper because they share the characters of having slightly tumid basal and radial plates and a smooth infrabasal circlet which is wider than high. The infrabasals of *A. occidentalis* have a central invagination where there was a rudimentary column. It can be demonstrated from several hundred infrabasal circlets collected that many of them also had an invagination that was filled with calcite later in ontogeny (see Pl. 5, fig. 11). When calcite was secreted within the invagination, the circlet became proportionally longer. The sutures between the infrabasals of the type specimen are not distinctly fused. This character is also variable but is more prevalent in infrabasal circlets which have an invagination.

The specimens figured by SPRINGER show a tendency toward characters exhibited by the holotype of *Agassizocrinus gibbosus*, such as a low infrabasal circlet, and tumid radials, but they lack

the distinct vertical radials exhibited by the type. The exact stratigraphic horizon for the type of *A. gibbosus* is not known.

MATERIAL AND OCCURRENCE.—Figured specimens (SUI 34430-34436 and 34535) are from the Beech Creek Limestone in the presently operating Quality Stone Company quarry 2 miles north of Hecker, Ill. Other materials are uncatalogued.

Holotype of *Agassizocrinus occidentalis* (WM 6373) is reported from the Chester series at "Chester, Illinois" (OWEN, 1852, p. 597). Specimens figured by SPRINGER as *A. gibbosus* are from the "Okaw formation; Chester, Illinois." SPRINGER's specimens were not studied. Another infrabasal cone (SUI 32130) referable to *A. occidentalis* is known from the Monteagle Limestone about 40 to 50 feet below the Hartselle Sandstone in Morgan County, Ala. The presence of *Talarocrinus* sp. (SUI 32968) at the last-reported locality indicates a Gasperan age (lower Chester).

AGASSIZOCRINUS PAPILLATUS Worthen, 1882

Plate 5, figures 6, 14, 17-21, 23

Agassizocrinus papillatus WORTHEN, 1882, p. 36; ———, 1883, p. 315, pl. 29, fig. 17; SPRINGER, 1926, p. 54, 57, 63.

Agassizocrinus lobatus SPRINGER, 1926, p. 63, pl. 26, fig. 13-18.

REMARKS.—The types of *Agassizocrinus lobatus* SPRINGER, 1926, were collected from the "Gasper formation at Huntsville, Alabama." Investigations of that region by us and by THOMAS CORNELL, have produced several large infrabasal circlets referable to *A. lobatus* and smaller ones referable to *A. papillatus* WORTHEN (1882). The infrabasals of the larger specimens are fused in their proximal portions, but are individually lobate distally. The infrabasal circlets of the smaller specimens are proportionally shorter, have a proximal invagination, and the full length of each interinfrabasal suture is discernible. Study of these materials lead us to speculate that *A. lobatus* is conspecific with the senior synonym *A. papillatus*.

Collections of similar material from the quarries at Hecker, Illinois, contain lobate infrabasal circlets in all degrees of fusion and seem to verify the former speculation. One infrabasal circlet is about the same in size as the holotype of *Agassizocrinus papillatus*. Larger specimens from Hecker do not exhibit the extreme tumidity of those from Huntsville, but the latter are not all as tumid as those figured by SPRINGER (1926, pl. 26, fig. 13-18). The Huntsville specimens are associated with

Talarocrinus sp., indicating that they are slightly older (Gasparan) than the Hecker specimens. The latter may be gradational with those assigned to *A. occidentalis* (OWEN & SHUMARD, 1852a) in the present investigation. They appear distinct in being lobate, although a few are barely so. If they are proved to be conspecific, at least the character of lobate infrabasals should be given consideration as a stratigraphic tool. The Hecker fauna contains the highest reported stratigraphic occurrence of this character.

The holotype of *Agassizocrinus globosus* WORTHEN (1873) has lobate infrabasals and a small proximal invagination and should be given attention in subsequent studies. That specimen very closely resembles the holotype of *A. occidentalis*. The latter has a small proximal invagination but lacks lobate infrabasals. The cup of the former is about the same in height as the latter, but is slightly wider and has smaller infrabasals. Specimens from Hecker exhibit many variations of height-width proportions and outward slope of the infrabasal-basal facets.

MATERIAL AND OCCURRENCE.—Figured specimens (SUI 34437-34439) are from the Beech Creek Limestone in the presently operating Quality Stone Company quarry 2 miles north of Hecker, St. Clair County, Ill. Other materials are uncatalogued.

Holotype of *Agassizocrinus papillatus* (ISGS 2444) is reported from the Chester Limestone, Monroe County, Ill. Types of *A. lobatus* (USNM S-2792) are reported from the "Gaspar formation," Huntsville, Madison County, Ala. (currently termed the Monteagle Limestone in Alabama and Tennessee). Localities from which Thomas Cornell of Huntsville and we have recently collected comparable specimens near Huntsville, are Garth Mountain, south side of U.S. Highway 431 (SW $\frac{1}{4}$, SE $\frac{1}{4}$, sec. 6, T. 4 S., R. 1 E.) and west slope of Round Top Mountain, north side of U.S. Highway 31 (SW $\frac{1}{4}$, NE $\frac{1}{4}$, SW $\frac{1}{4}$, sec. 5, T. 4 S., R. 1 E.). Collected as silicified residual material with *Talarocrinus* sp. The horizon is probably the upper Monteagle Limestone (lower Chesteran). Holotype of *A. globosus* (UI X-801) is reported from the Chester Group, Chester, Randolph County, Ill.

Family CYMBIOCRINIDAE Strimple & Watkins, 1969

Genus CYMBIOCRINUS Kirk, 1944

TYPE-SPECIES.—*Cymbiocrinus romingeri* KIRK, 1944b; by original designation.

DIAGNOSIS.—Cup low bowl-shaped with proximal invagination; infrabasals small, slightly downflared, confined to invagination; basals and radials

tumid, inornate, visible in side view; column with circular or subpentagonal outline. Rays axillary on primibrach 2. Anal sac oblate-spheroid with two rows of small spines over distal portion.

REMARKS.—Until recently, reported occurrences of *Cymbiocrinus* have been restricted to the Upper Mississippian in North America (USA). A new occurrence is recorded by STRIMPLE & WATKINS (1969, p. 191) from the "Marble Falls Formation, Morrowan?, Pennsylvanian; three miles southwest of Lampasas, Lampasas County, Texas on Espey Creek."

OCCURRENCE.—Upper Mississippian (St. Louis-Chesteran), lower Pennsylvanian (Morrowan?), North America (USA).

CYMBIOCRINUS sp.

Plate 3, figures 2, 4, 7

DESCRIPTION.—Cup medium bowl-shaped, twice as wide as high, widest at distal parameter, sides sloping up from basal plane at about 60 degrees, with proximal invagination; diameter of cup about twice that of the basal plane; basals and radials tumid and inornate. Infrabasals small, confined to invagination, downflared; *A* and *C* elongate to fill void of missing *AB* basal. Basals large, wider than long, width equivalent to about length of radial, occupy most of basal view, strongly downflared from infrabasals, then recurving from basal plane, extending to about 0.5 height of cup. Radials large, fully visible in side view, about 1.5 as wide as long, extending nearly to basal plane; radial *A* underdeveloped, quadrangular, situated between *E* and *B* radials and resting on *EA* basal, radial *B* enlarged to fill in void for missing *AB* basal, and in contact with enlarged *B* infrabasal; articular facet occupies full distal width of radial. Two plates of anal series are within the distal parameter of the cup; one large in normal position on distal part of *CD* basal; small plate rests on right edge of normal plate and is also in contact with *C* radial.

Rays axillary on primibrach 2; primibrach 1, quadrangular, tapers to distal edge; primibrach 2, pentagonal, lateral edges flare to base of secundibrach series, plates of which have gaps along sutures on opposite alternating sides. Column is small, with a circular but incipiently pentagonal outline.

REMARKS.—The described specimen obviously is an aberrant individual in that the *AB* basal did not form and radial *A* is underdeveloped. Other

plates of the cup are disproportional and deformed to occupy those positions.

The gaps between the sutures in each secundibrach series are on alternating opposite sides on the backs of the arms and probably represent agile flexible rays. Gaps on one side would allow an arm to flex back in that direction; gaps on the other side would allow the arm to tip in that direction. The alternating character suggests that the arms could have moved in a circular or arcuate manner.

OCCURRENCE AND MATERIAL.—Cup with proximal portions of rays, free of matrix, SUI 34214, Beech Creek Limestone in the Quality Stone Company quarry 2 miles north of Hecker, Ill.

MEASUREMENTS IN MILLIMETERS.—Height of crown, as preserved 22.0; width of cup, minimum, 13.6; maximum, 15.4; height of cup, 7.2; width of *BC* basal, 5.7; length of *BC* basal, 5.1; height of *BC* basal, 2.8; width of *B* radial, 9.0; length of *B* radial, 5.7; width of column, 1.9; diameter of basal plane, 6.5.

Family SCYTALOCRINIDAE Moore & Laudon, 1943

Genus PHACELOCRINUS Kirk, 1940

TYPE-SPECIES.—*Poteriocrinus wetherbyi* MILLER, 1879; by original designation.

DIAGNOSIS.—Cup medium cone-shaped, bears 10 arms. Rays uniserial, commonly axillary on primibrach 1 or 2, rarely on primibrach 3. Pelma cross section pentagonal.

OCCURRENCE.—Upper Mississippian (St. Louis-Chesteran), North America (USA); Lower Carboniferous (Tournaisian), Europe (Britain).

PHACELOCRINUS sp.

Plate 6, figure 8

REMARKS.—Infrabasal circlets with long, steeply upflared infrabasals and pentagonal proximal columnals are referred to *Phacelocrinus* in this paper, because we do not know of any other genus from Chesteran strata which possesses these characters. Each infrabasal is about as long as wide and flares upward and outward at about 70 degrees. A slight thickening or swelling of the plates occurs along the interinfrabasal sutures where they meet the column. The swelling projects below the proximal columnal. The projections below the column are not uncommon in cups studied that are assignable to *Phacelocrinus*. The columnals are pentagonal to substellate and are penetrated by an axial canal which has a pentalobate cross section.

OCCURRENCE AND MATERIALS.—Two infrabasal circlets, SUI 34228a and 34228b, Beech Creek Limestone in the Quality Stone Company quarry about 2 miles north of Hecker, Ill.

MEASUREMENTS IN MILLIMETERS.—Maximum height of circlet, (a) 3.8, (b) 6.1; distal diameter of circlet, (a) 7.8, (b) 9.9; proximal diameter of circlet, (a) 5.0, (b) 6.4.

Family PELECOCRINIDAE Kirk, 1941

Genus RHOPOCRINUS Kirk, 1942

TYPE-SPECIES.—*Rhopocrinus spinosus* KIRK, 1942b; by original designation.

DIAGNOSIS.—Cup low, cone-shaped, bearing multiple branching arms. Most proximal branching on primibrach 1, 2, or 3; all except primaxils bear a long spine. Interradial suture deeply im-

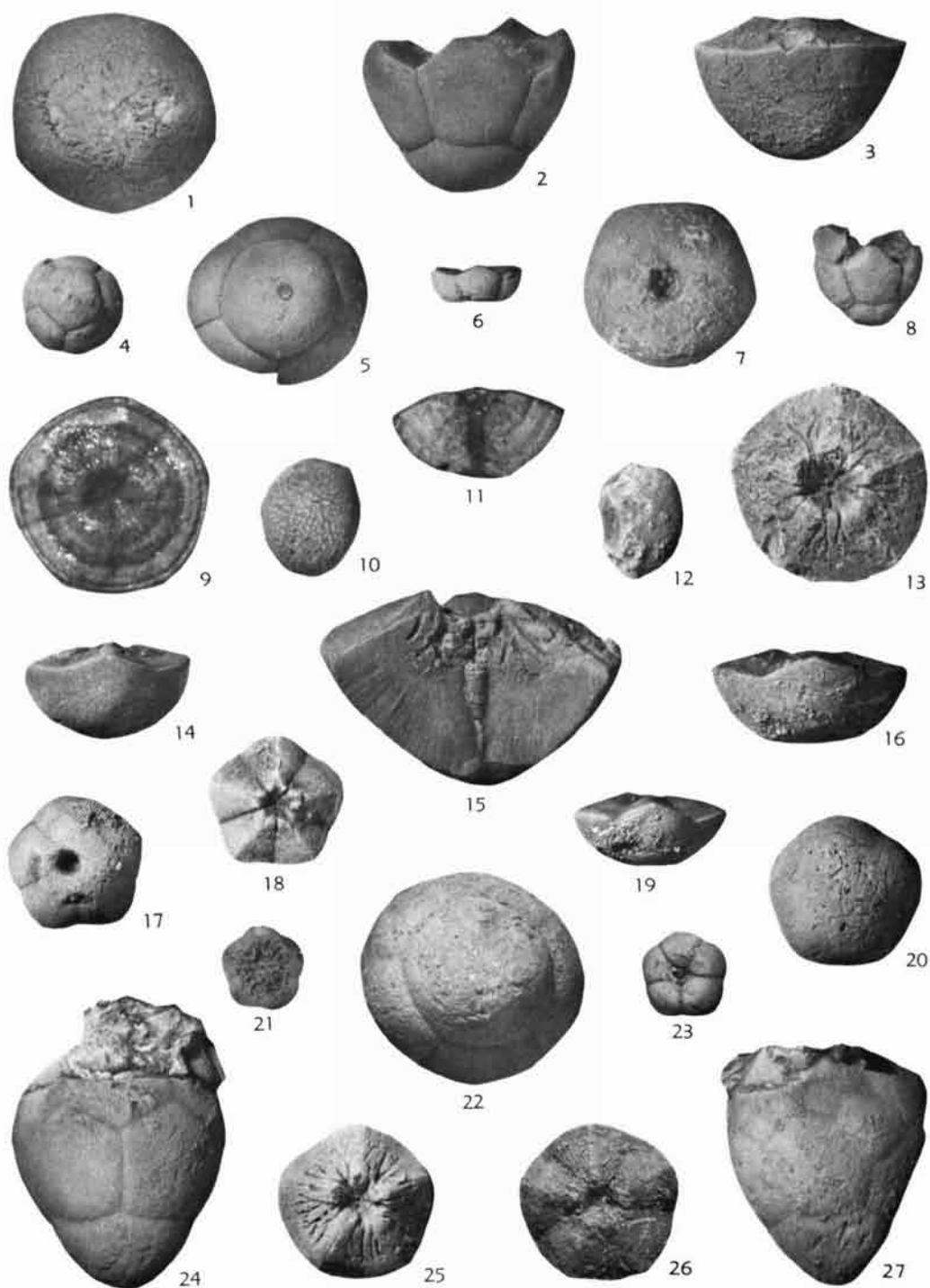
EXPLANATION OF PLATE 5

Figures approximately X2.0, unless stated otherwise. All specimens from the Beech Creek Limestone north of Hecker, Illinois.

FIGURE

1-5, 7-9, 11, 13, 15-16, 22-24, 26-27. *Agassizocrinus occidentalis* (OWEN & SHUMARD, 1852a).——1, 3, 13. Basal, side, and top view of infrabasal circlet (SUI 34430), X2.4.——2, 5. *CD* interray and basal views of partial cup (SUI 34431), X2.9 and X2.5.——4, 8. Basal and side views of a partial cup (SUI 34432).——7, 16, 26. Basal, side, and top views of infrabasal circlet (SUI 34433).——9. Top view of infrabasal circlet which shows concentric outer rims (SUI 34434).——11. Cross section of infrabasal circlet which shows concentric rings to invaginate in earlier growth stages (SUI 34435).

——15. Natural cross section of an infrabasal circlet which shows a small stem segment fused inside the circlet (SUI 34436), X4.0.——22, 24, 27. Basal, *A* ray, and *CD* interray views of cup (SUI 34535). 6, 14, 17-21, 23, 25. *Agassizocrinus papillatus* WORTHEN (1882).——6, 21, 23. Side, top, and basal views of infrabasal circlet (SUI 34437).——14, 20, 25. Side, basal, and top views of infrabasal circlet (SUI 34438).——17-19. Basal, top, and side views of infrabasal circlet (SUI 34439). 10, 12. *Exochocrinus* sp. Outer and side views of radialial (SUI 34227a), X2.2.





pressed. Three plates of anal series in *CD* inter-ray. Pelma is round.

REMARKS.—The true familial relationship of *Rhopocrinus* is not known at this time. Assignment of the genus to the Pachylocrinidae by KIRK (1942b, p. 151) was followed by MOORE & LAUDON (1943, p. 56, 111). KIRK placed *Rhopocrinus* in the Pachylocrinidae because the arm structures were similar to those of genera of this family and because he believed that the infrabasals of *R. spinosus* KIRK (1942b) were not visible in a lateral view. The arms of *Pachylocrinus* branch endotomously, whereas those of *Rhopocrinus* are of a modified endotomous nature. The cup of *Pachylocrinus* is bowl-shaped and the infrabasals are depressed and not visible in a side view. In the description of the type-species, *R. spinosus*, KIRK (1942b, p. 153) stated that "the IBB are small, not visible in lateral view and almost completely covered by the column." KIRK's specimens are all deformed on planar surfaces. The holotype and one paratype are oriented with the proximal portion of the cup against the matrix with infrabasals not visible. A portion of the proximal region of KIRK's other paratype is exposed. On that specimen the infrabasals appear to be upflared. The holotype of *R. municipalis* (TROOST, in WOOD, 1909) and *R. proboscidualis* (WORTHEN, in WORTHEN & MEEK, 1875), and other specimens referable to the genus and examined for this study have low upflared infrabasals. *Rhopocrinus* is placed in the Pelecocrinidae in the present paper, because it has low upflared infrabasals, a cup shape similar to *Pelecocrinus*, and narrow, cuneiform to biserial brachials, similar to *P. insignis*

KIRK (1941). The latter is the type-species of *Pelecocrinus* KIRK (1941).

Described species of *Rhopocrinus* are axillary on primibrach 2. Specimens referred to *R. proboscidualis* from the lower Chester of Illinois which are repositated at The University of Iowa are axillary on primibrach 2 and 3. An undescribed species from the basal Hartselle Sandstone, at Huntsville, Alabama, is axillary on primibrach 1. Other materials repositated at The University of Iowa and referable to *Rhopocrinus* were collected from two horizons in the Monteagle Limestone near Huntsville, Alabama. Specimens were collected from horizons with *Talarocrinus* sp. and *Platycrinites penicillus* MEEK & WORTHEN (1860), indicating respective lower Chesteran and Genevian age equivalents.

OCCURRENCE.—Upper Mississippian (Genevian-Chesteran), North America (USA).

RHOPOCRINUS sp. cf. R. PROBOSCIDIALIS (Worthen, 1875)

Plate 7, figure 14

Poteriocrinus proboscidualis WORTHEN, in WORTHEN & MEEK, 1875, p. 518, pl. 31, fig. 1.

Poteriocrinus (*Scaphiocrinus*) *proboscidualis* (Worthen). WACHSMUTH & SPRINGER, 1880, p. 114.

Rhopocrinus proboscidualis (Worthen). KIRK, 1942, p. 153.

DESCRIPTION.—Cup low, cone-shaped, with deep interradian furrows; exterior surfaces inornate. Infrabasals low, upflared, about as high as wide. Basals slightly wider than long, with depressed distal tip at beginning of interradian furrow. Radials strongly convex along distal axis, about 1.5 times as wide as long, greatly depressed along lateral facets. Anal series within *CD* inter-

EXPLANATION OF PLATE 6

Figures approximately X2, unless stated otherwise.

FIGURE

1, 4-7, 9, 11, 13. *Acrocrinus constrictus* BURDICK & STRIMPLE, n. sp.—1, 11, 13. Small paratype (SUI 32801), larger partypes (SUI 32802), and holotype (SUI 32253) from upper Monteagle Limestone near Hartselle, Ala., X2.9, X1.3, and X1.3.—4. Radial from shale in lower Hartselle Sandstone, Huntsville, Ala. (SUI 32805).—5. Radial and primibrachs from Beech Creek Limestone, N. of Hecker, Ill. (SUI 34205a).—6, 9. Basal circlet from Beech Creek Limestone, N. of Hecker, Ill. (SUI 34206a).—7. Calyx from lower Fayetteville Formation near Vinita, Okla. (SUI 34385), X1.1.

2, 3, 10, 12. *Acrocrinus shumardi* YANDELL (1855) from Bangor Limestone in Ala.—2. Distal portion of calyx showing wide radials with many brachials in contact with it (SUI 32558) from lower Bangor Limestone, Bangor, Ala.—3, 10, 12. Specimens from lower Bangor Limestone of Colbert Co., Ala., exhibiting a single series of subanal plates. Smallest specimen (fig. 12, X3.4) has only one primibrach in contact with each radial (IU 8962-19); moderate-sized specimen (fig. 3, X3.7) has secundibrach series in contact with each radial (GSATC 188); largest specimen (fig. 10, X1.3) has tertibrach series in contact with each radial (SUI 32558).

ray mostly missing; position of and facets on exposed portion of radial indicate that there were two other plates.

Brachial series mostly displaced; primibrach 1 of ray *E* is nonaxillary; more distal brachials narrow, highly rounded cuneate when viewed from backs, clearly biserial when viewed from sides; observed axillaries each bear a long spine. The round column is composed of well-defined nodals and internodals. It is penetrated by a pentalobate lumen.

REMARKS.—A single crown referable to *Rhopocrinus* and most closely resembling *R. proboscidioides* was collected from a slab of limestone which also contained a specimen of *Intermediocrinus asperatus* (WORTHEN, 1882) and one of *Taxocrinus* sp. cf. *T. whitfieldi* (HALL, 1858). The deep interrational furrows and small upflared infrabasals are readily observable. The arms are somewhat disarticulated but large spines on the axillaries and the cuneate to biserial nature of the other brachials are discernible. A displaced primibrach series (to the left of the infrabasals) is composed of two brachials, the axillary lacking a spine.

Two other species of *Rhopocrinus* are known. The specimen described in this paper differs from *R. municipalis* (TROOST, in WOOD, 1909) in that the latter species appears to lack very spinose axillaries. *R. spinosus* KIRK (1942b) closely resembles the described specimen but representatives of the species described by KIRK are compressed on planar surfaces and appear to have broader cups.

MATERIAL AND OCCURRENCE.—Partially preserved crown, compressed on slab of limestone, SUI 34182, Beech Creek Limestone, 2 miles north of Hecker, Ill.

MEASUREMENTS IN MILLIMETERS.—Width of *E* infrabasal, 1.8; width of *DE* basal, 2.8; length of *DE* basal, 2.5; width of *E* radial, 3.5; length of *E* radial, 2.2; maximum width of column 2.8.

Family PIRASOCRINIDAE Moore & Laudon, 1943

Genus DASCIOCRINUS Kirk, 1939

TYPE-SPECIES.—*Cyathocrinus florealis* YANDELL & SHUMARD, 1847; by original designation.

DIAGNOSIS.—Dorsal cup low bowl-shaped, having a shallow proximal invagination. Infrabasals small, downflared, and confined to the invagination. Arms uniserial, endotomous, and axillary on primibrach 1 in all rays, each axillary bearing a node or spine. Distal plates of the anal sac en-

larged into laterally directed spines, forming a circlet of plates which does not enclose any other plates of the anal series.

REMARKS.—*Dasciocrinus* most closely resembles *Zeusocrinus* STRIMPLE (1961). The distal plates of the anal sac in *Zeusocrinus* form a "circlet of horizontally directed, flat spinose plates surrounding smaller plates" (STRIMPLE, 1962, p. 21). The distal spinose plates in the anal sac of *Dasciocrinus* lack the central circlet of flat, polygonal plates.

Five described species are assigned to *Dasciocrinus*. A study of the type specimens reveals that *D. aulicus* STRIMPLE (1963) commonly branches on secundibrach 6, *D. spinifer* (WETHERBY, 1880) and *D. cachensis* (WELLER, 1920) are commonly axillary on secundibrach 6 to 8, and *D. spinosus* (OWEN & SHUMARD, 1852a) is axillary on secundibrach 8 to 10. The holotype of *D. florealis* (YANDELL & SHUMARD, 1847) could not be located, but it is discerned from the figure given with the original description that the species is axillary on secundibrach 12 to 14. A specimen figured by SPRINGER (1926, pl. 16, fig. 8) and ascribed to *D. florealis* has a similar type of branching. *D. aulicus* is distinguished from other species by its highly tumid and ornate basal and radial plates, and by the long spine characteristic of each primaxil. The backs of the arms of *D. cachensis* are more evenly rounded than those of *D. spinifer*.

We have recently examined the holotype of *Poterocrinites similis* WORTHEN (1882), observing that its primibrachs are very long and have small blunt spines on their outer distal tips similar to species assigned to *Dasciocrinus*. Also the cup is low and the secundibrachs are cuneiform as in *Dasciocrinus*. The specimen is small and is herein referred to the latter genus as an immature representative. The arms are short and thin in *D. similis* (WORTHEN) BURDICK & STRIMPLE, n. comb., and have not attained a great enough length to have distinct axillaries. One arm on the left hand side of the specimen, as it is preserved, may be axillary or it may be a large distal pinnule.

OCCURRENCE.—Upper Mississippian (Chesteran), North America (USA). KIRK's (1939, p. 473) reference to an undescribed species from strata of Genevievean age, near Huntsville, Alabama, cannot be confirmed from materials presently available to us.

DASCIOCRINUS sp.

Plate 7, figure 5

DESCRIPTION.—Cup low basin-shaped, about

one-fourth as high as wide, sides extending upward and outward at about 35 degrees, bearing shallow proximal invagination. Impression of proximal columnal appears to be subpentagonal. Diameter of basal plane measures slightly less than half that of the cup. Infrabasal circlet completely within proximal invagination has diameter about one-fourth that of the cup. Basals are about as long as wide, extending outward and upward from the basal plane to less than half the height of the cup. A small pit is seen at suture intersections, at distal tips of the basals and proximal tips of the radials. Radials are less than half as long as wide and extend proximally to the basal plane. Articular facets slope outward at about 45 degrees, and are slightly separated along the exterior portions by a shallow furrow. Three plates of the anal series occur within the *CD* interray, all being narrow and in normal (primitive) arrangement.

Primibrach *I* is axillary in all rays and each has a prominent spine protruding from its distal tip. Brachials above the primibrachs appear cuneate to biserial.

REMARKS.—The cup here described is referred to *Dasciocrinus* because of its shallow character and proximal invagination, and because of the position of spines on the primibrachs. The specimen cannot be identified to the specific level because the number of brachials within each secundi-brach series is not known. The specimen differs from most species of *Dasciocrinus* in that the radials extend proximally to the basal plane.

MATERIAL AND OCCURRENCE.—Cup with primibrachs SUI 34209, Beech Creek Limestone, 2 miles north of Hecker, Ill.

MEASUREMENTS IN MILLIMETERS.—Diameter of cup, maximum, 7.1, minimum, 6.7; height of cup, 1.9; diameter of basal plane, 3.3; width of infrabasal circlet, 1.8; length of *A* infrabasal, 1.0, width, 0.9; length of *AB* basal, 2.0, width, 1.9; height of *AB* basal above basal plane, 0.9; length of *A* radial, 2.1, width, 3.7; width of stem impression, 1.3.

Family APHELECRINIDAE Strimple, 1967

Genus APHELECRINUS Kirk, 1944

TYPE-SPECIES.—*Aphelecrinus elegans* KIRK, 1944a; by original designation.

DIAGNOSIS.—Cup low to medium cone-shaped, with three anal plates in *CD* interray. Infrabasals upflared, visible in side view, higher than wide. Basals wider than long. Radials wider than long, commonly depressed along lateral sutures. Ar-

ticular facets commonly separated. Rays axillary on primibrach *I*, in some species branching once or twice more distally.

REMARKS.—*Poteriocrinus columbiensis* WORTHEN (1882) and *Scytalocrinus wachsmuthi* WETHERBY (1880) were included as species of *Phacelocrinus* by KIRK (1940b) when he described that genus. They are considered as species of *Aphelecrinus* in the present paper.

Aphelecrinus bayensis (MEEK & WORTHEN, 1865) was assigned to *Aphelecrinus* because KIRK thought the holotype to be incomplete. He stated (1944a, p. 192) "the distal portions of the arms are poorly preserved, and the division may not have been recognized." The holotype has been studied by the first author of this paper, and it is thought that the arms probably were not axillary a second time. The species is still considered to be most closely related to *Aphelecrinus* because it has low infrabasals, a low campanulate-shaped cup, and articular facets separated by an interradial depression. Also, the anal sac of a specimen (SUI 32822) from the Bangor Limestone (Chesteran) of Alabama assigned to the species is large and recurved like that of the holotype of *A. limatus* KIRK (1944a).

The holotypes of *Aphelecrinus bayensis* and *Phacelocrinus wachsmuthi* do not differ appreciably. Both have ten arms, stout primaxils, and a low cone-shaped cup. The former is considered a senior synonym of the latter in this paper. *Phacelocrinus* KIRK (1940b) characteristically has longer infrabasals and a proportionally higher cup which lacks pronounced interradial furrows.

Aphelecrinus columbiensis is thought to be more closely related to *Aphelecrinus* than to *Phacelocrinus*. The proximal columnals are subpentagonal to round, a character shared by both genera. The cup flares outward more and is proportionally shorter than in *Phacelocrinus*. Also, the articular facets of *A. columbiensis* are separated, a character shared with some species of *Aphelecrinus*, and not those remaining in *Phacelocrinus*.

OCCURRENCES.—Mississippian (Kinderhookian-Chesteran). North America (USA): Lower Carboniferous (Viscan), Europe (Scotland).

APHELECRINUS OWENI Kirk, 1944a

Plate 7, figures 2, 3

Aphelecrinus oweni KIRK, 1944a, p. 198, pl. 1, fig. 1-3; HORDWITZ, 1965, p. 25, pl. 2, fig. 15-17.

DESCRIPTION.—Dorsal cup low cone-shaped,

with height about 0.75 of width, flaring upward and outward from the basal plane at about 50 degrees, but flaring outward more from the proximal portion of the radials. Infrabasals about two-thirds as wide as long extend to about one-fourth height of the cup. Basals are longer than the radials and are slightly wider than long. Radials are three-fifths as long as wide and are strongly convex along their vertical axes, which gives the cup a five-sided appearance when viewed from above or below. A distinct furrow separates the outward sloping articular facets. Three plates of the anal series occupy the *CD* interradius. The greatly enlarged radianal is in contact with the *C* and *D* radials, *BC* and *CD* basals, and two other anal plates.

A few proximal columnals are preserved with the cup, one being a nodal and the other an internodal.

REMARKS.—We have not examined the holotypes of all species presently assigned to *Aphelecrinus*. The specimen described above is referred to *A. oweni* because of the pronounced outward flare of its radials. The cup somewhat resembles *A. mundus* KIRK (1944a) but KIRK (1944a, p. 200) stated "The sides of the dorsal cup of *A. oweni* diverge more rapidly than in *A. mundus* and the radials do not have the decided outward flare of the latter species." The specimen described in the present paper most closely resembles one described and figured by HOROWITZ (1965, p. 25, pl. 2, fig. 15-17) under the same specific name. HOROWITZ's specimen has a normal anal series in

the *CD* interray while the anal interray of the specimen described in this paper has the radianal enlarged and in contact with the *D* radial. Positioning of anal plates is not presently considered significant in differentiating species of *Aphelecrinus*.

MATERIAL AND OCCURRENCE.—Dorsal cup, SUI 34207, Beech Creek Limestone, quarry 2 miles north of Hecker, Ill.

MEASUREMENTS IN MILLIMETERS.—Height of cup, 7.4; width of cup, maximum 11.4, minimum 10.0; width of proximal columnal, 3.1; width of *A* infrabasal, 2.8, length 1.9; width of *AB* basal, 3.8, length 3.4; width of *A* radial 4.9, length 2.9.

APHELECRINUS sp. cf. A. POPENSIS (Worthen, 1882)
Burdick & Strimple, new comb.

Plate 7, figure 12

Poteriocrinus popensis WORTHEN, 1882, p. 23; ———, 1883, p. 296, pl. 29, fig. 12.

Scaphiocrinus popensis (Worthen), WACHSMUTH & SPRINGER, 1886, p. 160 (236).

Pachylocrinus popensis (Worthen), BASSLER & MOODEY, 1943, p. 583.

DESCRIPTION.—Crown elongate, flaring upward and outward distally. Cup low, cone-shaped, wider than high, sides flaring upward and outward from the basal plane at about 40 degrees. Crown is preserved on a slab with the *CD* interray exposed and part of *C* ray displaced to the right of the cup. Infrabasals are about four-fifths as long as wide, and extend to about one-third height of the cup. Basals are wider than long, and longer than either the infrabasals or radials.

EXPLANATION OF PLATE 7

Figures approximately X1.3 unless otherwise stated. All specimens are from the Beech Creek Limestone, north of Hecker, Illinois.

FIGURE

- 1, 4, 8, 11, 13, 15-16, 19, 21-22. *Pterotocrinus sinuosus* BURDICK & STRIMPLE, n. sp.—4. Holotype (SUI 34197).—8, 11, 13, 21. Paratypes (SUI 34198a-d).—15-16, 22. Partial interpreted growth series (SUI 34199b-d).—1, 19. Other growth variants (SUI 34199a and 34199d).
- 2-3. *Aphelecrinus oweni* KIRK (1944). *A* ray and *CD* interray views of cup (SUI 34207), X2.0.
5. *Dasciocrinus* sp. Basal view of a specimen with spinose axillary primibrachs (SUI 34209).
- 6, 25. *Pterotocrinus* sp. *A* ray and basal views of calyx (SUI 34204).
- 7, 20, 23. *Pentaramicrinus* sp. cf. *P. altonensis* (Miller &

- Gurley, 1895) BURDICK & STRIMPLE, n. comb. *CD* interray, *A* ray, and basal view of specimen (SUI 34212), X2.2.
- 9-10. *Pterotocrinus armatus* SUTTON (1934). Wingplates (SUI 34203a-b).
12. *Aphelecrinus* sp. cf. *A. popensis* (Worthen, 1883) BURDICK & STRIMPLE, n. comb. (SUI 34208).
14. *Rhopocrinus* sp. cf. *R. proboscidioides* (WORTHEN, 1875) (SUI 34182).
- 17-18, 26. *Onychoecrinus distensus* WORTHEN (1882) (SUI 34179-34181).
24. *Taxocrinus* sp. cf. *T. whitfieldi* (HALL, 1858). *CD* interray view of partial crown (SUI 34178).

Radials are wider than long, length equivalent to about one-third height of the cup. Anal series in the *CD* interray is not preserved, but sutures on adjacent plates indicate presence of three plates within the cup in normal position.

The rays, as far as known, are axillary first on primibrach 1. Second branching occurs on secundibrach 8 on left side of ray *C* and right side of ray *D*, and secundibrach 7 on right side of ray *C*. Third branching occurs on tertibrach 6, 7, or 8. Left side of ray *C* branches a fourth time on quartibrach 3. Branching is endotomous. Brachials are very slightly cuneate.

REMARKS.—Characters of the specimen described above clearly resemble *Aphelecrinus* and correspond most closely to *A. popensis*, n. comb. The species was referred to *Pachylocrinus* WACHSMUTH & SPRINGER (1879) by BASSLER & MOODEY (1943, p. 538). *A. popensis* is herein removed from *Pachylocrinus* because that genus typically branches on primibrach 2, whereas *A. popensis* is axillary on primibrach 1. The species was probably not assigned to *Aphelecrinus* when KIRK originally described that genus because it branched above the second axillary. HOROWITZ (1965, p. 24) has recently ascribed a specimen (IU 5727) to *A. randolphensis* (WORTHEN, 1873, in MEEK & WORTHEN) which branches within the tertibrach series.

MATERIAL AND OCCURRENCE.—Crown partially embedded in matrix, SUI 34028, Beech Creek Limestone inactive quarry 1.5 miles northeast of Hecker, Ill.

MEASUREMENTS IN MILLIMETERS.—Length of crown, 27; height of cup, 4.2; width of column, 2.0; width of *C* infrabasal, 1.6; length of *C* infrabasal, 1.3; length of *DE* basal, 1.6; length of *C* radial, 1.3.

Subclass CAMERATA Wachsmuth & Springer, 1885

Order MONOBATHRA Moore & Plummer, 1943

Family DICHOCRINIDAE Miller, 1889

Genus PTEROTOCRINUS Lyon & Casseday, 1860

TYPE-SPECIES.—*Asterocrinus capitalis* LYON, 1857; by monotypy.

REMARKS.—*Pterotocrinus* is one of the common Chesteran crinoids in the eastern United States. Complete calyxes are rare, but large distinctive plates which were attached to the tegmen of these crinoids are very common in some strata.

The distinctive tegmen plates have been referred to as "wing plates" by recent authors (WELLER, 1920; SUTTON, 1934; SWANN, 1963; GUTSHICK, 1965; HOROWITZ, 1965) and are so designated in this paper.

Described species range from the Renault Formation (SUTTON, 1934) through the Kinkaid Formation (GUTSCHICK, 1965). Lower Chester wing plates are simple, laterally compressed spines which develop wide-bladed ends. By middle Chesteran time, aberrant and heavy forms appeared, while bladed types persisted. Upper Chester forms are dominated by simple elongate and triangular bladed types of wing plates. Since the wing plates are distinctive, and evolved more rapidly than other portions of the calyx, many species of *Pterotocrinus* are described on the basis of wing-plate shape.

Large collections of wing plates generally exhibit a prevalent shape and several less numerous variants of the common form. These populations are best described on the basis of the prevalent forms and mention is made of variants which can be discerned as gradational with the basic stock.

Terminology of the wing plates established by SUTTON (1934), was followed by subsequent researchers (GUTSHICK, 1965; HOROWITZ, 1965) and is adopted in the present paper. The portion of the wing plate that attaches to the tegmen is called the base and the distally expanded portion is called the blade. If a shaftlike area is located between the base and blade, it is called the petiole.

OCCURRENCE.—Upper Mississippian (Chesteran), North America (USA).

PTEROTOCRINUS SINUOSUS

Burdick & Strimple, new species

Plate 7, figures 1, 4, 8, 11, 13, 15-16, 19, 21-22

DIAGNOSIS.—Wing plate with petiole and rapidly expanding blade. In side view, upper portion of petiole convex, changing to concave at junction with blade. Height of blade equivalent to two-thirds length of plate.

DESCRIPTION.—Wing plate laterally compressed, with petiole and rapidly expanding blade. Along upper portion of plate outline, petiole is arched just distal to the base, changing to concave at the blade; lower outline of petiole and blade is concave to the plate. Constriction due to upper and lower concavities occurs proximal to mid-length. Upper portion of blade expands more

rapidly than lower portion. Measured height of the blade is equivalent to about two-thirds length of the wing plate. Distal portion of blade is convex and commonly serrate.

REMARKS.—A selected growth series for *Pterotocrinus sinuosus* BURDICK & STRIMPLE, n. sp., shows that the greatest expansion of the blade occurs in maturity. Most of the smaller and presumably less mature specimens do not have a greatly expanded blade. A similar growth series was demonstrated for *P. armatus* SUTTON (1934, pl. 49, fig. 35-38). *P. sinuosus* most closely resembles *P. armatus*, the former having an arched petiole, whereas the petiole of the latter is nearly straight. *P. armatus* also has a proportionally larger blade. A few specimens of *P. sinuosus* have a blade which expands outward and upward, attaining an angle of less than 90 degrees between blade and petiole. The above character is known in *P. armatus* and *P. arcuatus* SUTTON (1934). The upper outline of the petiole in the latter species is straight and proportionally shorter than that of *P. sinuosus*.

MATERIAL AND OCCURRENCE.—Specimens from the active quarry in the Beech Creek Limestone, 2 miles north of Hecker, Ill. are: holotype (SUI 34197), paratypes (SUI 34198a-d), and miscellaneous plates (SUI 34199a-e and 34202). Those from the inactive quarry in the same horizon 1.5 miles northeast of Hecker are SUI 34200. *Pterotocrinus sinuosus* is also known from the Bangor Limestone near Moulton, Lawrence County, Ala. (SUI 33225-33228, 33230, 33232, 33233).

PTEROTOCRINUS ARMATUS Sutton, 1934

Plate 7, figures 9-10

Pterotocrinus armatus SUTTON, 1934, p. 407, pl. 49, fig. 34-39.

DIAGNOSIS.—Wing plate with petiole and rapidly expanding blade. Upper portion of petiole not strongly arched. Height of blade about equivalent to length of plate; upward expansion of blade attains attitude of approximately 90 degrees of petiole.

DESCRIPTION.—Wing plate consists of petiole and rapidly expanding blade. Petiole involves one-third to one-half the length of the plate, upper and lower outlines being nearly straight and subparallel. Base forms an angle of about 70 degrees with the upper outline of the petiole. Height of blade attains dimensions about equivalent to the length of the plate. Upper and lower margins of the blade are widely divergent, upper attaining an attitude of nearly 90 degrees to the petiole and

lower not quite so divergent. Distal margins of the blades are convex and serrated.

REMARKS.—*Pterotocrinus armatus* differs from *P. sinuosus* BURDICK & STRIMPLE, n. sp., in that the former does not have an obvious convex outline along the upper portion of its petiole and the height of its blade is proportionally greater when compared to length of the whole wing plate. Specimens described above most closely resemble a paratype of *P. armatus* figured by SUTTON (1934, pl. 49, fig. 36).

MATERIAL AND OCCURRENCE.—Specimens SUI 34203 figured in this paper are from the active quarry in the Beech Creek Limestone, 2 miles north of Hecker, Ill. The type specimens are from the "Golconda limestone in western Kentucky" (SUTTON, 1934, p. 407).

PTEROTOCRINUS sp.

Plate 7, figures 6, 25

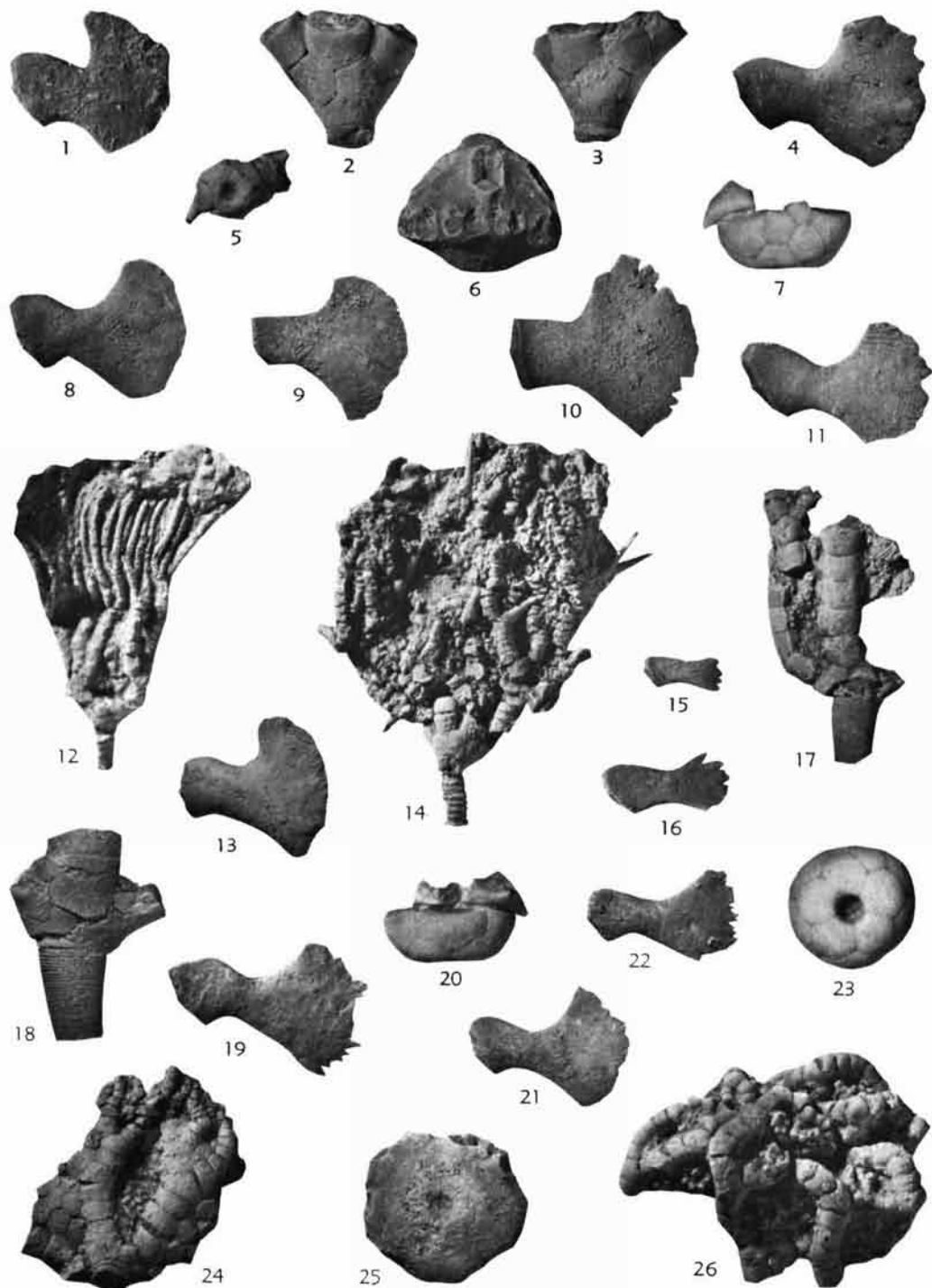
REMARKS.—A single calyx referable to *Pterotocrinus*, but without wing plates was collected. Because wing plates are necessary for specific identification, the cup is not assigned to any described species. The plates of the cup and tegmen are firmly united and the sutures are not easily discerned. The general cup shape and plate arrangement closely resemble that of *P. depressus* LYON & CASSEDAY (1860). The cup is shallow, flaring upward from the basal plane at about 25 degrees and then assumes a more horizontal attitude from the base of the brachial series. The primibrachs are small and triangular. Preserved brachial series within the cup indicate four arms per ray. The anal plate is pentagonal, extending partially between ray C and D, and is in contact with one plate of the tegmen.

Several smooth basal circlets similar to that of the calyx discussed above were also collected. Because no other type of basal circlets was observed, it is probable that the calyx and basal circlets are referable to *Pterotocrinus sinuosus* BURDICK & STRIMPLE, n. sp., which is the most common representative of the genus at localities discussed in this paper.

MATERIAL AND OCCURRENCE.—Figured specimen is SUI 34204, from the active quarry in the Beech Creek Limestone, 2 miles north of Hecker, Illinois.

Genus CAMPTOCRINUS Wachsmuth & Springer, 1897

TYPE-SPECIES.—*Dichocrinus* (*Camptocrinus*) *myelodactylus* WACHSMUTH & SPRINGER, 1897; by original designation.



DIAGNOSIS.—Column coiled, columnals, nodal and internodal, of truncate elliptical shape, paired nodals with inward-directed cirri.

OCCURRENCE.—Lower Mississippian-Permian.

CAMPTOCRINUS sp.

Sieved shale samples have produced several truncate elliptical columnals characteristic of *Camptocrinus*. The materials are not represented well enough to allow specific identification.

MATERIAL AND OCCURRENCE.—Individual columnals, SUI 34443, Beech Creek Limestone, active quarry 2 miles north of Hecker, Ill.

Family ACROCRINIDAE Wachsmuth & Springer, 1885

Subfamily ACROCRININAE Wachsmuth & Springer, 1885

Many excellently preserved acrocrinids have recently been obtained from the lower Bangor Limestone (middle Chesteran) and the lower Monteagle Limestone (Genevievean) in Alabama. The specimens show new details of morphology, as well as ontogenetic stages, and serve as a basis for revision of the generic concept of *Acrocrinus*.

The smallest specimens of *Acrocrinus shumardi* YANDELL (1855) from the Bangor Limestone have only primibrach 1 in contact with the radial (Pl. 6, fig. 12). An ontogenetic sequence of specimens shows that they have progressively more brachials in contact with the radial with increasing size (Pl. 6, fig. 2-3, 10). Each radial is most commonly in contact with four intercalary plates, but individual cases of two and three were also observed. The subanal series in these specimens is the same as that observed in other acrocrinids, a single series of plates consecutively diminishing in size proximally.

About a dozen excellently preserved specimens of *Amphoracrocrinus amphora* (WACHSMUTH & SPRINGER, 1897) were collected from the *Platycrinites penicillus* Zone, in the type area of Huntsville, Alabama. The specimens are partially silicified and occur in a shale. Their state of preservation allows easy preparation which has exposed morphologic details which have not been discussed previously. The radials of larger specimens of this taxon are proportionally wider than those of small ones. Forms with elongate radial plates illustrated by previous researchers are not mature (full-sized) individuals. The vertical grooves sometimes found on sides of the calyx have been

interpreted by some authors as representing resting places for the arms (WACHSMUTH & SPRINGER, 1897, p. 809-810; SPRINGER, 1926, p. 112, 125; MOORE & STRIMPLE, 1969, p. 9). The recently obtained specimens have grooves also, but they are not always oriented longitudinally along the calyx. Grooves are present wherever an arm or a stem crosses the specimen and now are interpreted as due to compaction of the arms against the calyx after burial. Each radial is in contact with 3 or 4 intercalary plates. Specimens most commonly have primibrach 1 reduced in size, with primibrach 2 overlapping the sides of it and in contact with the radial. *Acrocrinus shumardi* commonly has secundibrach 2 or tertibrach 1 in contact with the radial and a single minute triangular primibrach is visible.

Amphoracrocrinus amphora occurs stratigraphically below *Acrocrinus shumardi*. Because the ontogenetic series of the latter species is known to have a stage of brachial development like the former, we consider that *A. shumardi* is a more advanced species than *A. amphora* and judge further that both species should be referred to *Acrocrinus*.

The types of *Acrocrinus alvestonensis* WRIGHT (1958), are poorly preserved but the primibrach series of one paratype is in place. The primibrach series appear to be pentagonal and composed of two brachials. Such an arrangement would mean that the other brachials of an arm were not in permanent contact with the associated radial. The lower stratigraphic occurrence of *A. alvestonensis* (Visean, S₂ Subzone) accords with the early ontogenetic sequence known in *A. shumardi* and supports their assignment to the same genus.

The stratigraphic succession of the species *Acrocrinus alvestonensis*, *A. amphora*, and *A. shumardi* is thought to represent a basic lineage. A new species *A. constrictus*, described herein, retains the coupled primibrach series like *A. alvestonensis*. The new species is known to occur in lower Chesteran strata and has a proportionally narrower articular facet than *A. alvestonensis*.

REPOSITORIES.—Some of the better specimens of *Acrocrinus shumardi* studied were collected by A. W. BEINLICH and his wife, of Sheffield, Ala., and are deposited at the Geological Survey of Alabama (GSATC 188-191). Other materials collected by the SPENCER WATERS family of Moulton, Ala., are deposited at Indiana University. Other materials are deposited at The University of Iowa. Figured radial plate of *A. shumardi* is SUI 32558.

Specimens referred to *Acrocrinus amphora* are reposit at The University of Iowa and Indiana University. These specimens were obtained from a locality discovered by Mrs. MERLE ENGLEBERT of Huntsville, Ala.

Specimens referred to *Acrocrinus constrictus* BURDICK & STRIMPLE, n. sp., are discussed later.

Genus ACROCRINUS Yandell, 1855

Acrocrinus YANDELL, 1855, p. 135.

Amphoracrocrinus MOORE & STRIMPLE, 1969, p. 9.

TYPE-SPECIES.—*Acrocrinus shumardi* YANDELL, 1855; by monotypy.

DIAGNOSIS.—Calyx tall, urn-shaped, with unusually low, wide radials in mature specimens of later species; distal articular facet of radials supporting one primibrach in primitive species, but a minute axillary primibrach 1, secundibrachs and some tertibrachs in latest occurring species; each radial in contact with four or less commonly three intercalaries; 15 or more well- or ill-defined circlets of intercalary plates between basals and radials; primanal large, subanals arranged in single series, each diminishing in size proximally.

REMARKS.—See discussion under subfamily Acrocrininae of this paper.

OCCURRENCE.—Upper Mississippian (Genevievean-Ches-
teran), North America (USA) and Upper Lower Car-
boniferous (Viséan), Europe (England).

ACROCRINUS CONSTRICTUS

Burdick & Strimple, new species

Plate 6, figures 1, 4-7, 9, 11, 13

DIAGNOSIS.—Calyx urn-shaped, widest at summit; basals with prominent basal flange; about 15 circlets of intercalary plates; three or four intercalaries in contact with each radial; articular facet 0.5 as wide as radial, facing outward, and occupying projection of the radial which extends beyond plane tangent to the subradial intercalary plates.

DESCRIPTION.—Calyx tall urn-shaped, expanding fairly evenly from basal circlet, widest at summit, approximately twice as high as wide. Two equal upflared basals, suture common to them extends along plane which intersects middle of radial *A* and anal series; basal circlet widest at summit, about twice as wide as high, with distinct flange on basal plane. About 15 circlets of intercalary plates; most plates hexagonal, minute in proximal circlet, gradually increasing in size distally, proximal intercalaries are about one-half the size of the radials. Radials large, arcuate, in contact except at *CD* interradius, about five-sevenths as high as wide; size of each approach-

ing that of basal circlet; each radial in contact with two interradian and one or two subradial intercalary plates; articular facet narrow, arcuate, about 0.5 as wide as radial, facing outward and somewhat upward and situated on protruding constricted portion of the radial. Primanal large, approximately equal in size to radial; subanal plates arranged in a single series, each plate diminishing in size proximally. Arms biserial, exotomous, and axillary on primibrach 2, secundibrach 2, and tertibrach 2, for a total of 6 arms per ray; composite of axillary brachial series is wider than long and constricted at mid-length, a few appearing fused; only primibrach 1 in contact with the radial. Circular column of thin nodals and internodals of several diameters.

REMARKS.—*Acrocrinus constrictus* BURDICK & STRIMPLE, n. sp., closely resembles *A. alvestonensis* WRIGHT (1958), *A. amphora* WACHSMUTH & SPRINGER (1897), and *A. shumardi* YANDELL (1855). All are similar in shape, approach similar sizes in mature specimens, have about the same number of intercalary plates in contact with the radials, and have a similar number of intercalary circlets. The new species has only primibrach 1 in contact with the radial, like *A. alvestonensis*. The two remaining species have other proximal brachials in contact with the radial (see discussion under Acrocrininae of this paper).

NAME.—The name for this new species is from Latin and refers to the constricted portion of the radial upon which the articulating facet is situated.

MATERIALS AND OCCURRENCE.—*Acrocrinus constrictus* is based on several nearly complete and fragmentary calyces from several localities of approximate geologic time equivalents. Crushed crowns (holotype SUI 32252, paratypes SUI 32801-32804), from which the arm structure is known, were collected *in situ* from the base of a quarry in the Pride Mountain Formation about 10 miles east of Hartselle, Morgan County, Ala. (S $\frac{1}{2}$, SE $\frac{1}{4}$, SE $\frac{1}{4}$, sec. 33, T. 6 S., R. 2 W.). The specimens occur with *Staphylocrinus bulgeri* BURDICK & STRIMPLE (1969) about 50 feet below the Hartselle Sandstone. A weathered cup of *Talarocrinus* sp. (SUI 32968) was collected from loose materials in the quarry.

A single fairly well-preserved calyx (paratype SUI 34385) was collected *in situ* by AMEL PRIEST, of Peru, Ia., from the dark shaly facies of the lower Fayetteville Formation in northeastern Okla. (SW $\frac{1}{4}$, sec. 11, T. 25 N., R. 21 E., Craig County).

A radial plate with four attached intercalary plates (SUI 32805) and miscellaneous basals and radials were collected from a roadcut on the west slope of Round Top Mountain about 2.5 miles east of downtown Huntsville,

Madison County, Alabama (SW $\frac{1}{4}$, NW $\frac{1}{4}$, SE $\frac{1}{4}$, sec. 5, T. 4 S., R. 1 E.), Material was collected from a shaly portion of the lower Hartselle Sandstone, 3 to 12 feet above the Monteagle Limestone. *Talarocrinus* is not known from this exposure but is found about 30 feet below the top of the Monteagle Limestone near this locality.

Another characteristic radial plate collected by E. R. POHL, of Horse Cave, Ky., is from a shale of middle Golconda age, south of Millerstown, Ky. This locality was discussed earlier in this paper.

Material from the Beech Creek Limestone, 2 miles north of Hecker, Ill., consists of radial plates (SUI 34205a,b) and basal circlelets (SUI 34206a,b).

Subclass FLEXIBILIA Zittel, 1879

Order TAXOCRINIDA Springer, 1913

Genus TAXOCRINUS Phillips in Morris, 1843

TYPE-SPECIES.—*Cyathocrinus? macrodactylus* PHILLIPS, 1841; by subsequent designation.

REMARKS.—From stratigraphic collections of Chesteran representatives of *Taxocrinus* available at The University of Iowa the gradual evolution of *Taxocrinus shumardianus* (HALL, 1858) to *T. whitfieldi* (HALL, 1858) is easily discerned. *T. shumardianus* has three brachials in each secundibrach series and occurs in strata of Genevieve and lowest Chesteran age. *T. whitfieldi* has two brachials in each secundibrach series, and occurs in Glen Dean (upper Middle Chester) and higher stratigraphic horizons. Populations from beds intermediate to the horizons reported above include individuals referable to both of the above-mentioned species, as well as individuals which have two secundibrachs in some arms and three in others.

Populations referable to *Taxocrinus* from the Renault and Paint Creek Formations (lower Chester) in Illinois, are assignable to *T. shumardianus*. Almost all of the secundibrach series have three brachials. Rarely, a secundibrach series in these forms shows four or only two secundibrachs. Taxocrinids from the Golconda Group (upper Fraileys Formation), near Anna, Illinois, show a predominance of secundibrach series composed of just two brachials, but many individuals exhibit a prominence of secundibrach series composed of three brachials.

Populations of *Taxocrinus whitfieldi* are represented in collections from the upper Glen Dean (Tar Springs?) in Pulaski County, Kentucky. A few of these individuals have three secundibrachs

in some rays. Specimens from a higher Chesteran unit, the Menard Limestone, near Chester, Illinois, exhibit no variance in the number of brachials within the secundibrach series.

If the population variances discussed above are also reported by subsequent researchers, *Taxocrinus* will prove to be a valuable tool in interpreting Chester stratigraphy. Forms intermediate to *T. shumardianus* and *T. whitfieldi* would then occupy a stratigraphic interval about equivalent to rocks of upper lower Chesteran through middle Chesteran. Variable populations of *Taxocrinus* discussed in this paper are assigned to *Taxocrinus* sp. cf. *T. whitfieldi*.

The holotypes of *Taxocrinus shumardianus* and *T. whitfieldi* have interbrachial series in contact with the basal plates. Populations of taxocrinids from Ste. Genevieve and higher stratigraphic intervals in Alabama show this character to be variable. Many specimens of *T. shumardianus* from lower Chester horizons in Illinois have all interbrachial series in contact with the basals, whereas those from middle Chester strata in the same region exhibit some variation in this character. Positioning of the interbrachials in these populations is considered variable and not of specific importance.

Taxocrinus huntsvillae SPRINGER (1920) is herein judged to be synonymous with *T. shumardianus*. The radials of the former species are not commonly separated by the interbrachial series, whereas those of the latter are separated, with interbrachials series in contact with the basals. This character could be enough to distinguish the species, even though not all specimens assigned to *T. huntsvillae* exhibit the mentioned character. Specimens assigned to *T. shumardianus* also may have one or two interbrachials separated from the basals. Species of *Taxocrinus* from the Chester Series of Illinois most commonly show plates of the interbrachial series in contact with the basals, but those from Alabama have a slightly higher percentage in which this is not true. The variance is found in both *T. shumardianus* and *T. sp. cf. T. whitfieldi*. Since the character discussed only marks interrays of individual specimens, it is not considered to be a criterion for separating species.

Other characters on which *Taxocrinus huntsvillae* has been differentiated are not considered valid. The types of the species come from the Monteagle Limestone (Ste. Genevieve) near Huntsville, Ala. Their small size is probably at-

tributable to some environmental factor and the rounded or arched backs of the arms largely depends on preservation. Well-preserved specimens of *T. shumardianus* also have highly arched brachial series.

OCCURRENCE.—Middle Devonian through Mississippian.

TAXOCRINUS sp. cf. **WHITFIELDI** (Hall, 1858)

Plate 7, figure 24

Forbesiocrinus whitfieldi HALL, 1858, p. 632-633, fig. 104; —, 1860, p. 88; MEEK & WORTHEN, 1865, p. 104; 1866, p. 243.

Onychocrinus whitfieldi (Hall), MEEK & WORTHEN, 1873, p. 552-554, pl. 20, fig. 3.

Forbesiocrinus cestriensis HALL, 1860, p. 68-69.

Forbesiocrinus parvus WETHERBY, 1879, p. 138, pl. 1, fig. 4a-b.

Taxocrinus wetherbyi MILLER & GURLEY, 1895, p. 41-42, pl. 4, fig. 3-5.

Taxocrinus whitfieldi (Hall), SPRINGER, 1920, p. 382, 408-409, pl. 60, fig. 1-11.

REMARKS.—As discussed earlier, *Taxocrinus shumardianus* (Hall, 1858) evolved to *T. whitfieldi* (Hall, 1858) by elimination of one brachial from each secundibrach series. Populations referable to *Taxocrinus* and intermediate to the above species encompass forms assignable to both species, as well as forms in which secundibrach series of a single specimen may be axillary on secundibrach 2 or 3. HALL (1860) described a Chesteran representative of *Taxocrinus* of the latter type as *Forbesiocrinus cestriensis*. In this paper, these intermediate forms are identified as *T. sp. cf. T. whitfieldi*. Populations are necessary to determine whether the secundibrach series are variable. Slight variances (less than 10%) occur in populations of *T. shumardianus*. As far as known, the variable populations of *Taxocrinus* have a stratigraphic range about equivalent to rocks of Golconda age.

A single crown herein referred to *Taxocrinus* sp. cf. *T. whitfieldi* was collected from Chesteran strata considered in the present paper. The crown is flattened and distal portions of the brachial series are missing. The rays are axillary on primibrach 3 of rays A, B, C, and D. Only primibrach 1 of ray E is preserved. The primibrach series of ray C and the right side of ray D are axillary on secundibrach 2. The left side of ray D has only one nonaxillary secundibrach preserved. The left secundibrach series of ray B is not preserved. The right side is slightly disarticulated but apparently

axillary on secundibrach 2. No secundibrachs are in place on ray A but a series of two nonaxillary plates, apparently from the secundibrach series of that ray, is located just above it. (One of the secundibrach series on ray A most likely was comprised of three or more plates.) The basals of the described specimen are not in contact with the interbrachials except in the CD interray.

MATERIAL AND OCCURRENCE.—Partial crown (SUI 34178), collected on slab with *Rhopocrinus* sp. cf. *R. proboscidioides* (SUI 34182) at active quarry in the Beech Creek Limestone, 2 miles north of Hecker, Ill.

Several crowns (SUI 34454) which are thought to be conspecific with the specimen described above are known from the lower Fayetteville Formation, near Vinita, Okla.

Genus ONYCHOCRINUS Lyon & Casseday, 1860

TYPE-SPECIES.—*Onychocrinus exculptus* LYON & CASSEDAY, 1860; by monotypy.

REMARKS.—Four species of *Onychocrinus* have been reported from strata of Genevievean and Chesteran age in the United States. *O. parvus* MILLER & GURLEY (1894) is a young individual with three primibrachs per ray and may be synonymous with *O. pulaskiensis* MILLER & GURLEY (1895a). The latter species is characterized by strong ramules and has three primibrachs per ray. *O. distensus* WORTHEN (1882) and *O. magnus* WORTHEN in WORTHEN & MEEK (1875) have thinner ramules, three or four primibrachs per ray, and are reported from lower Chesteran strata. The rays of *O. magnus* are wider than those of *O. distensus*. Species of *Onychocrinus* which occur in earlier Mississippian strata have as many as six primibrachs per ray. Similar to several other genera, species of *Onychocrinus* exhibit a tendency to branch on lower primibrachs in progressively higher strata.

OCCURRENCE.—Mississippian, North America (USA); Lower Carboniferous, Europe.

ONYCHOCRINUS DISTENSUS Worthen, 1882

Plate 7, figures 17-18, 26

Onychocrinus distensus WORTHEN, 1882, p. 31; —, 1883, p. 307-308, pl. 29, fig. 5; SPRINGER, 1920, p. 421, 436, pl. 73, fig. 5-8.

REMARKS.—Characters which differentiate *Onychocrinus distensus* from similar species are given in generic remarks of the genus concerned.

Several fragmentary crowns were collected. One specimen consists of a cup with two primibrach series preserved. Ray A is axillary on primi-

brach 4 and ray B on primibrach 3. Another specimen consists of a well-preserved portion of the distal arm segments. Many of the distal axillary brachials in the latter specimen bear a short, broad spine. Exteriorly, the brachial series of both specimens are covered with low pustules and granulations. A third specimen consists of a cup with an attached stem and primibrach 1 of rays A and D. Except in the CD interray the

basals of the first-described specimen are not in contact with the interbrachials. Basals AB and DE of the third specimen are enlarged and in contact with the interbrachials.

MATERIAL AND OCCURRENCE.—Cups with primibrach series (SUI 34179) and distal brachial series (SUI 34180), abandoned quarry in the Beech Creek Limestone, 1.5 miles northeast of Hecker, Ill., cup (SUI 34181), active quarry in the Beech Creek Limestone 2 miles north of Hecker, Ill.

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