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Notes Concerning *Delocrinus* and *Graffhamicrinus* (Crinoidea: Inadunata)H. L. STRIMPLE¹

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The purpose of the present study is to describe an historically important crown (cup with arms attached) of *Delocrinus hemisphericus* from Virgilian strata in Taylor County, Iowa, collected by C. A. White sometime during his tenure as State Geologist of Iowa (1866-1869), and to clarify the present status of the genus *Delocrinus*. Several crowns of *D. hemisphericus*, one crown of *Graffhamicrinus nodosarius* (Strimple), and a divergent form described as *Delocrinus elongatus* n. sp. from the Virgilian of Oklahoma are illustrated. Possible

Because of the large number of crinoids of Pennsylvanian age which are known only from dorsal cups, there has been some confusion through the years in attempting to group them into higher taxa. Many genera are little more than groups of superficially similar appearing species which may or may not be closely related. Many higher taxa are in the same category. The search for morphological features which might serve as consistent taxobases among closely comparable forms has not been fully successful as yet and is not anticipated by the present writer in the foreseeable future. In the meantime, considerable progress is being made as more and better preserved material is found and evidence of phyletic lineages is accumulated. One of the most common and long ranging genera known among Pennsylvanian crinoids is that commonly called *Delocrinus* Miller and Gurley, 1890, which has included at one time or another as many as 73 described nominal species.

Associated with and probably related to *Delocrinus* in some manner are numerous other genera, the most pertinent to the present study being *Diphuicrinus* and *Graffhamicrinus*. An attempt is made to delineate the various lineages and to evaluate some dissenting views.

THE GENUS *DELOCRINUS* MILLER & GURLEY

The genus *Delocrinus* was restricted to the type species, *Poteriocrinus hemisphericus* Shumard, 1858, *nomen nudum* and the genus referred to *nomen dubium* by Knapp (1969). This action was taken because the type specimens of *P. hemisphericus* were lost and presumed to be destroyed by fire. Full details were given by Knapp (1969, p. 367, 368). An alternative line of action was taken by Moore and Strimple (1970) with a petition to the International Commission on Zoological Nomenclature for fixation of a neotype of *Poteriocrinus hemisphericus* from among specimens actually used by Miller and Gurley (1890) when they proposed the genus *Delocrinus*. A favorable ruling (1974, Opinion 1006) was subsequently made by the International Commission on Zoological nomenclature. Thus this subsequent concept of the genus *Delocrinus* must include characteristics of the type species as defined and illustrated by Moore and Strimple (1970): "Dorsal cup subcircular in outline, low (height approximately one-third of diameter), with narrow, moderately deep basal concavity containing diminutive infrabasal circling of five down-flared plates; basal plates strongly curved longitudinally, forming part of basal concavity and lower outer sides of cup; radial plates notably wider than high nearly vertical at summit of cup, with broad subhorizontal articular facets of muscular type; single anal plate between posterior radials,

phylogenies are discussed with emphasis on the genera *Delocrinus*, *Graffhamicrinus*, and *Diphuicrinus*.

INDEX DESCRIPTORS: Crinoids (*Delocrinus*, *Endelocrinus*, *Graffhamicrinus*, *Palmerocrinus*, *Diphuicrinus*; *Delocrinus hemisphericus*, and *Delocrinus elongatus* n. sp.); Chesterian (Lower Carboniferous); Pennsylvanian (Morrowan, Atokan, Desmoinesian, Missourian, Virgilian), Upper Carboniferous; Nodaway Coal; Coal Creek Limestone; Fremont County, Iowa; Taylor County, Iowa; Washington and Osage Counties, Oklahoma; Lower Permian (Wolfcampian).

with outer surface curved inward; first arm plate (primibrach) in form of long spine directed horizontally outward, with two upper facets for articulations with pair of arms (Fig. 1, 1-3)."

"Figure 1" above is Plate 4 in the document (B. Z. N., v. 27). "1-3" represents the three figured specimens consisting of the neotype, one dorsal cup and a single primaxil. The description can be enlarged to note a smooth cup exterior, a small, round stem with minute circular lumen; proximal ends of radials slightly above the basal plane in the neotype and apparently entering the basal plane in the figured specimen; distal portion of anal plate erect with a single distal facet in the neotype but elongated and inclined with two small facets on the distal termination in the figured specimen. It is possible the basal plates have been pressed upward by compaction and that proximal ends of radials do not actually enter the basal plane as appears in the figured specimen as preserved (Moore and Strimple 1970, plate 4, figs. 2a-c), but the narrow, sharply inclined anal plate of *Delocrinus* with two facets for reception of tube plates is identical to the anal plate arrangement in several species of *Diphuicrinus* of Atokan and Desmoinesian age.

It is difficult to determine why and particularly when spinose primaxils developed in the catacrinid lineage. A phanocrinid genus *Idosocrinus* Wright, 1954, is the oldest (Viséan, Lower Carboniferous) related genus known in which some primaxils project in a horizontal manner as pronounced spines. Very similar spines are known in Morrowan strata and some have been illustrated by Moore and Plummer (1938, fig. 33) as *Delocrinus? pendens* Moore & Plummer and *Delocrinus? sp. A, B, C*. *Delocrinus matheri* Moore and Plummer (1938, fig. 32) was also illustrated but the holotype of this species is small and is poorly represented in the Morrowan and has subsequently been referred to *Endelocrinus* Moore and Plummer (1938) by Strimple (1960). It is possible that *Delocrinus? sp. A* is conspecific with *Endelocrinus matheri*. Spines identified by those authors as *Delocrinus? pendens*, *Delocrinus? sp. B*, and *Delocrinus? sp. C* are all large and are found associated with the prolific *Arkaocrinus dubius* to which they are probably related. *Arkaocrinus* Knapp (1969) has a highly advanced (specialized) cup and is not thought to have survived into Atokan time. If its progenitor is *Bronaughocrinus* Strimple of late Chesterian age, as I believe, it is a divergent end member of the phanocrinid lineage and as such is then related to diphuicrinids-catacrinids.

Based on presently known material, *Delocrinus* is thought to have evolved from *Diphuicrinus*, perhaps through *Graffhamicrinus*. *Delocrinus* flourished in Missourian and Virgilian time and continued as a viable genus into the Permian. Several divergent genera are involved (e.g., *Arrectocrinus* Knapp, 1969, *Pyndaxocrinus* Knapp, 1969). The unusually large *Delocrinus vastus* Lane & Webster (1966) is Wolfcampian (Lower Permian) in age and the primaxils lack spinose extensions. Loss of spinosity of primabrachs in *Delocrinus* is also found in *Delocrinus elongatus* n. sp. (Fig. 1B, C), *D. brownvillensis* and *D. vulgatus*

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of Virgilian age. Whether this change represents a homogenous group has not been established.

Commonly occurring with *Delocrinus* is the closely related genus *Graffhamicrinus*, which is most readily identified through possession of an ornamented exterior. *Graffhamicrinus* is stratigraphically older than *Delocrinus*; however, in Missourian time *Delocrinus* becomes the most prolific of the two genera. Knapp (1969) concluded that such features as arms, presence or absence of an anal plate, and surface ornamentation were not usable as taxobases at the generic level. He also concluded that it was impossible for a lineage to progressively evolve the base of the cup from a flat, or planate, base to a basal invagination. Many detailed observations made by Knapp may be verified by examination of the specimens involved but some of his major interpretations have been discredited or revised. Presently acceptable taxon are listed by Moore, Lane and Strimple (1973) except that *Parallelocrinus* has subsequently been synonymized with *Diphuicrinus*.

Small specimens of *Delocrinus* fall in the size range of medium to large specimens of *Endelocrinus*. This has led to speculation on the probability that some species of *Endelocrinus* may in fact be the young of *Delocrinus* (see Strimple, 1950). Because of close relationship, *Endelocrinus* is considered here in some detail.

Eupachycrinus fayettensis Worthen (1873) is the type species of *Endelocrinus* Moore & Plummer (1940) and is considered to be Missourian in age (Moore & Plummer, 1940, p. 299). Some character states ascribed to the genus, such as "strong transverse as well as longitudinal convexity of the basals (BB) and radials (RR), which makes these plates appear distinctly bulbous; or by sharp inflexions of the borders of the basals (BB) and radials (RR) at angles where they meet —", are actually weakly developed in the holotype and the hypotype (which is on the same block of matrix). The bulbosity of cup plates is no more pronounced than found in *Apographiocrinus* or in some species of *Contocrinus*; however, both of those genera have uniserial arms. Some other species ascribed to *Endelocrinus* have distinctly bulbous plates, e.g., *E. tumidus* (Strimple, 1939). *Delocrinus* s. s. does not have bulbous cup plates. *E. fayettensis* has non-spinose, somewhat elongated, primaxils (actually of unequal lengths) and the lower one-third of the arms are uniserial, becoming biserial above.

Endelocrinus is stratigraphically older than *Delocrinus*. *Endelocrinus matheri* (Moore & Plummer, 1938) is known from Morrowan rocks of Oklahoma and Arkansas (Strimple, 1960). *E. matheri* has uniserial lower arms (distal portions are not known) and weakly defined bulbosity of BB and RR as well as slight depressions at apices of those plates. The species is closely similar to *E. fayettensis*, both possessing a shallow basal concavity and tall, non-spinose primaxils. *E. grafordensis* Moore & Plummer (1940) from the Missourian of Texas follows the same pattern and the three species (*E. fayettensis*, *E. matheri*, *E. grafordensis*) are considered here to represent the primary lineage (*Endelocrinus* s. s.).

A species described as *Delocrinus titicara* Strimple & Moore (1971) is from Wolfcampian (Lower Permian) of Bolivia, S. A. The type locality is at the world renowned Lake Titicaca, which was accidentally misspelled in the specific epithet throughout the study as published. Rules of Zoological Nomenclature (I. C. Z. N., Art 32c) allow for correction of an obvious mistake in spelling and the name should be *D. titicaca*. The basals and radials have sharp inflexions at angles where

they meet, the primibrachs 1 are non-spinose and show inequality in length (however, they are somewhat shorter than in species of *Endelocrinus* s. s.) but the arms cease to be cuneate with secundibrachs 2-3. The species is retained in *Delocrinus* at this time pending completion of ontogenetic studies which are underway.

Endelocrinus transitorius Strimple & Moore (1971) from the Lane Shale, Missourian, in Kansas City, Kansas, has all the characteristics of *Endelocrinus* s. s. except for the primaxils, which are short and spinose, as in *Delocrinus* s. s.

Endelocrinus tumidus spinosus Strimple (1950) belongs to the group of species presently assigned to *Endelocrinus* which do have decidedly convex or timid basals and radials. It is a small species (youthful?) with tall, spinose primaxils of unequal lengths. Because of the spinose protrusion of primibrachs 1 the possibility is entertained that it might represent a youthful stage of *Delocrinus* s. s.

At this time there is ample evidence to conclude that a highly complex group of relatively simple appearing crinoids are included in *Delocrinus* s. l. and that relationship with *Endelocrinus* s. l. is even closer than previously considered.

DELOCRINUS HEMISPHERICUS FROM IOWA (FIG. 1A)

Delocrinus hemisphericus has been reported from the Coal Creek Limestone (Virgilian) of Fremont County, Iowa, by Pabian & Strimple (1974, p. 21). A closely related form is described from the same exposure as *Paradelocrinus thurmanensis* Pabian & Strimple (1974, p. 22). Both specimens are represented by crowns. To this is now added a crown of *Delocrinus hemisphericus* from Virgilian rocks of Taylor County, Iowa (Fig. 1A). The crown was no doubt found by White during the geological survey of Iowa which he conducted while he was State Geologist from 1866 to 1869. According to his report (White, 1870) there were only two areas in Taylor County with exposed rock at that time, one of which was near Bedford and the other in the northwest corner of the county at Foster's Coal Bank (sec. 29, T. 70, R. 35). The exposures were primarily for mining Nodaway coal (Wabausee Group) for local sale.

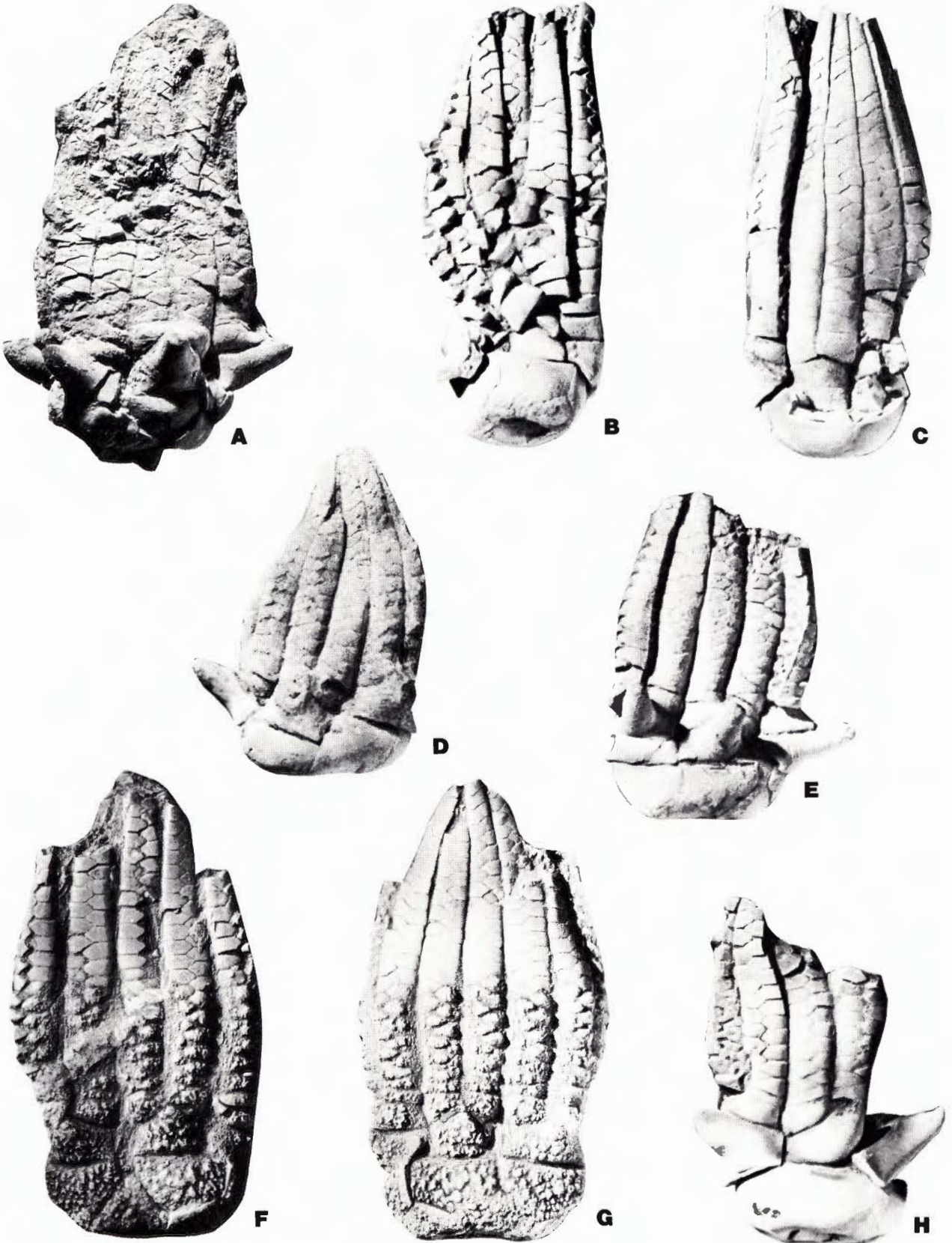
The hypotype crown is deposited in the Geology Repository, The University of Iowa, Iowa City, Catalogue no. SUI 3425. The cup has an estimated diameter of 17 mm, length of arms 50 mm, height of primaxil 6.7 mm, width 10 mm.

DELOCRINUS HEMISPHERICUS FROM OKLAHOMA (FIGS. 1 D,E,H)

Three crowns of *Delocrinus hemisphericus* from the Wann Formation, Ochelata Group, Missourian of Oklahoma, are illustrated for comparative purposes as well as to show selected morphologic features. Two of the specimens (Fig. 1D and 1E) are considered to be typical of the species except that one (Fig. 1E) failed to produce an axillary primibrach 1 but branches on primibrach 2. A similar condition was noted by Pabian & Strimple (1973, p. 18, fig. 16) for a specimen of *D. brownvillensis* Strimple. If the condition is considered to be atavistic it would relate to a distant relative no younger than Osagean (Middle Mississippian) in age. It is considered here to be abnormal.

Although attention has not hitherto been directed to the interlocking arrangement of lower brachials of adjacent arms, the condition exists in

Figure 1. A. *Delocrinus hemisphericus* (Shumard), hypotype, SUI 3425, DE interray side view of crown from Taylor County, Iowa, X1.5. B, C. *Delocrinus elongatus* n. sp., holotype USNM S.5743, E ray and C ray views of crown from Washington County, Oklahoma, X1.4 D, E, H. *Delocrinus hemisphericus*, hypotype crowns USNM S.5740, S.5739 and S.5741, CD interray view, D ray view, B ray view, from Osage County, Oklahoma, X1.4, F, G. *Graffhamicrinus nodosarius* (Strimple), metatype USNM S.5742, crown viewed from CD interray and A ray, from Osage County, Oklahoma, X1.4.



both *Delocrinus* and *Graffhamicrinus*. A slightly displaced arm illustrated herein for *Delocrinus hemisphericus* (Fig. 1E, right arm) demonstrates the system of ridges and depressions on an exposed flattened side of the arm.

Another specimen assigned to the species from the same stratigraphic horizon and geographic locality is illustrated (Fig. 1H, left arm) to show a similar structure, but with a different pattern. There are other subtle differences between the two specimens which presumably could represent specific variations. The last mentioned specimen has radials which reach the basal plane of the cup, it has a slight forefacet at the summit of the radials, the cup is fuller or more spherical, and the primaxils are more robust. The first mentioned specimen is by far more representative of specimens of *D. hemisphericus* found at the exposure.

Irregular topography of flattened sides of the arms of *Graffhamicrinus acutus* Strimple, type species of the genus, is illustrated by Strimple (1961, text-fig. 22b, plate 15, fig. 6, right half ray of C ray arm), Arms of both *Graffhamicrinus* and *Delocrinus* commonly expand slightly to just below mid-length and thereafter taper toward the distal termination. Interlocking of adjacent arms is found up into their widest portions. It is conceivable the distal portions of the arms might have been opened on occasion while the proximal portions remained closed, or that the sequence of opening was first distal portions and then proximalward. When closed, the exterior of the arms provided protection from small predators for the thin plated anal tube, anus, and tegmen as well as the soft tissue in the interior of the arms. The anal sac of *Delocrinus* is reported to be a small cylindrical tube usually terminating with an elongated spine (Moore & Strimple, 1941).

THE GENUS *DIPHUICRINUS* MOORE AND PLUMMER

Original definition of *Diphuicrinus* Moore & Plummer, 1938, p. 307, is as follows: "Calyx low basin-shaped, with base sharply and strongly depressed. IBB 3, at bottom of basal concavity of cup, mostly or entirely covered by stem attachment; the small IB in the genotype species is in the left anterior radius. BB 5, nearly equal, proximal parts forming sides of basal concavity of cup, distal parts curving upward to about mid-height of outer wall of calyx; pB [proximal basal] truncated distally for contact with anal X. RR 5, wider than long; articular facets of moderate width, nearly plane. A single anal plate interrupts circle of RR, resting on pB and rising slightly above summit line of RR. In exterior view of dorsal cup, sutures are only slightly impressed; separated plates of the cup show that the face of sutures are more or less deeply excavated, the depressions carrying cross ridges, very pronounced in some examples, for muscular and ligamentous attachment. Arms and tegmen unknown."

Subsequent examination of type and topotype specimens disclosed the existence of five rather than three infrabasals. Although not included in the description the following excerpt from Moore & Plummer's "Remarks" is pertinent: "The shape of the dorsal cup of *Diphuicrinus* is essentially the same as in *Delocrinus*, but the external ornamentation of strong rounded tubercles, is foreign to the latter genus, resembling rather the common type of decoration seen in *Ethelocrinus*."

In light of this and other remarks made by Moore & Plummer (1938), as well as from observations made by subsequent investigators, I disagree with the comment made by Burke (1976, p. 10): "If this species [sic. *Delocrinus aristatus* Strimple, 1949], or any other species of *Diphuicrinus*, is assumed to be either closely related or ancestral to *Delocrinus* (= *Graffhamicrinus*) I fail to find evidence to support that assumption." The fact remains that *Diphuicrinus croneisi* Moore & Plummer is stratigraphically slightly older than any species of *Palmerocrinus* Knapp (1969), *Graffhamicrinus* Strimple (1961), or *Delocrinus* Miller & Gurley (1893), and has all of the morphologic features needed to be closely related or ancestral to all or any of those

genera save in the presence of pustulose surface ornamentation which is a feature shared with *Graffhamicrinus*.

If any species of *Diphuicrinus* are found to have biserial arm structure they should be referred to *Graffhamicrinus*.

Both *Diphuicrinus* and *Graffhamicrinus* have non-spinose primaxils although some species of *Graffhamicrinus* are now known to produce a blunt, pustule-like node at the summit of the primaxil. In my opinion this only demonstrates the close relationship between the genera involved.

Evidence of diminishing surface ornamentation within the *Diphuicrinus* lineage is afforded by *D. pentanodus* Moore & Strimple (1973) in Morrowan time and is even more readily apparent in species such as *D. dovelyensis* Strimple & Moore (1971) in Desmoinesian time.

A better understanding of the Phanocrinidae from which the Catacrinidae, Diphuicrinidae, Endelocrinidae and allied families probably originated might have helped Burke (1966, 1970, 1976) in his evaluations.

Phanocrinus and the closely allied genus *Pentaramicrinus* are the most common crinoids in Genevevian and Chesterian strata. Their proliferation created a host of slightly divergent forms even in Chesterian time so that it should be no surprise for numerous slightly divergent genera to appear as Pennsylvanian derivatives. Burke (1976) selected observations made by Burdick & Strimple (1973) concerning the incipient change from uniserial to biserial arm structure exhibited by one species, *Phanocrinus cooksoni* Laudon (1941). Burke (1976) cited this as showing that mature *Phanocrinus* attained a degree of incipient biseriality. A primary lineage of *Phanocrinus* maintains uniserial arms into the Imo Formation (uppermost Chesterian) which condition is retained by some Pennsylvanian derivatives (e.g., *Diphuicrinus*). Burke's (1970, 1976) attempt to ascribe a biserial arm structure is unsupported by available specimens. There is no possibility of construing the two known crowns, of *D. faustus*, as being young (small) enough to represent a stage in ontogeny of a biserially armed species in which uniserial brachials are still present. The preoccupation exhibited by Burke (1970, 1976) with this feature is difficult to understand particularly in light of the fact that *Diphuicrinus*, which is an acceptable taxon to him, would be just as vulnerable to synonymy with *Delocrinus* as is *Graffhamicrinus*, if *D. faustus* is judged to have biserial arms.

Two genera proposed by Knapp (1969) are closely related to *Diphuicrinus* and one, *Parallelocrinus*, has been synonymized with *Diphuicrinus* (Moore and Strimple, in press). The cup surface of the other, *Palmerocrinus*, was reported by Knapp (1969) to be either ornate (pustulose) or smooth; however, Strimple and Moore (1971, p. 3) removed the ornate paratype of *P. comptus* (Knapp, 1969, pl. 61, figs. 23-24) from *Palmerocrinus* and referred it to *Parallelocrinus*. As presently defined *Palmerocrinus* has a non-pustulose cup surface.

The arms of *Palmerocrinus comptus*, type species of the genus, are not known but are assumed to be like those of *P. profundus* (see Moore and Strimple, 1973, fig. 5, 3b). The arms differ from those of *Diphuicrinus faustus* in that they become biserial at about secundibrachs 8. The arms of *D. faustus* are cuneate throughout their entire length. *Endelocrinus matheri* has a smooth cup with slight depressions at apices of cup plates and 10 uniserial arms. Relationship between *E. matheri* and *Palmerocrinus* [sic. *P. profundus*] has been suggested by Moore and Strimple (1973, p. 67). All species mentioned in this paragraph are Morrowan age save *P. comptus* which is from the Atokan.

The highly ornate *Diphuicrinus*, as well as the essentially smooth *Palmerocrinus*, are known to occur in post-Morrowan stratum, so it is assumed that *Palmerocrinus* will have biserial arms and *Diphuicrinus* may have very cuneate arms. *Palmerocrinus* is thought to give rise to *Delocrinus* (Catacrinidae) and *Diphuicrinus* to *Graffhamicrinus* (Diphuicrinidae). *Endelocrinus* may also be a derivative of *Palmerocrinus* and the lineage is included in the Catacrinidae.

The species *Delocrinus aristatus* Strimple is Desmoinesian in age and has been referred to *Graffhamicrinus* by Strimple (1961). The oldest known species of *Graffhamicrinus* is *G. antiquus* Strimple & Watkins (1969) of Atokan age but the species is not discussed by Burke (1976). Unless he considers the involved genera and species in total, little credence can be attached to his objections and speculations, in my opinion. A case in point is the attempt to construe the collapse of the basal region of cups as having any significance other than preservational. Innumerable specimens of the genus *Diphuicrinus* are known and recorded which do not display any tendency to collapse. Ligamental fossae are known to exist between cup plates of *Delocrinus* (see Strimple & Moore, 1971, figs. 7, 3-7) as well as *Diphuicrinus*. If the feature is thought to be taxonomically significant then the relationship between *Diphuicrinus* and *Delocrinus* is strengthened rather than weakened.

No claim is made here of having solved all the problems concerning the genera involved but thousands of specimens have been examined and are in the process of being evaluated and re-evaluated. A framework of classification has been proposed (Moore, Lane and Strimple, 1973) and is already in process of revision; however, revisions are based on careful evaluation of all known material and factors.

THE GENUS *GRAFFHAMICRINUS* STRIMPLE

Original description of *Graffhamicrinus* Strimple (1961, p. 123) is as follows: "The dorsal cup is low, truncate bowl-shaped with deep basal concavity. Five IBB occupy the bottom of the basal concavity, are normally mainly covered by the proximal columnal and are downflared. Five BB are elongate, form most of the basal concavity and curve upward to become visible in side view of the cup. Five RR are large, pentagonal elements. There is a single anal plate, normally with the upper half above the summit of the cup and resting upon the truncated tip of the proximal [sic. posterior] basal. The anal plate is succeeded by a single plate above. There are ten biserial arms, bifurcating on the first primibrach in all rays. The primibrachs are usually rather short elements and may be mildly protruded and spine-like, but do not develop long spines, as in *Delocrinus subhemisphericus* [= *D. hemisphericus*]. The exterior of the lower arms are normally mildly rounded but the upper arms are almost flat. The lateral sides of the arms are flat so that the arms abut closely when in repose. All cup plates are marked by ornamentation in the form of pustules, nodes, tubercles, ridges or strong granules, or a combination of any of these features, and the lower arms are also so marked. The column is round."

It has been consistently overlooked by Burke (1966, 1970, 1976) that most species of *Delocrinus* typically and commonly have a strongly protruded, spinose primaxil and that most species of *Graffhamicrinus* do not show a pronounced spine-like primaxil. *Graffhamicrinus* is first recognized as *G. antiquus* in the Bostwick Conglomerate (Atokan) whereas *Delocrinus* has not been recognized with certainty before the Wewoka Formation (Desmoinesian). The genera occur concurrently throughout the Missourian and Virgilian. There are apparently discrete lineages within the broad concept of *Graffhamicrinus* just as there are divergent lineages within the broad concept of *Delocrinus* but this is a matter of refinement and does not warrant rejection of the genus *Graffhamicrinus*.

Surface ornamentation of *Graffhamicrinus antiquus* is pronounced but some Desmoinesian species (e.g., *G. tulsensis* Strimple, 1962b) have more subdued surfaces. *G. nodosarius* Strimple (1939) of Missourian age is highly ornate yet the upper portions of the arms are totally devoid of ornamentation (Fig. 1F,G). *G. magnificus* (Strimple, 1947) of Virgilian age has even more spectacular ornamentation and retains a smooth surface on distal portions of the arms. It is probable that *G. nodosarius* and *G. magnificus* represent a divergent lineage within *Graffhamicrinus* which is thought to be closely aligned with

Diphuicrinus croneisi. *Graffhamicrinus acutus* Strimple (1961), type species of the genus, *G. tulsensis*, and comparable species, are distinct from the more highly ornamented species and probably find their origin in a species like *Diphuicrinus faustus*. These and other possibilities are being explored in other studies.

The arms of *Graffhamicrinus* constrict slightly above secundibrachs I then expand slowly to attain a maximum width at or slightly below mid-length thereafter tapering toward their distal extremity. Ornamentation of the outer surfaces is subdued and does not reach the point of greatest arm width in *G. acutus* but does so in the highly ornate *G. nodosarius* (Strimple, 1939, figs. 1F,G). In *Diphuicrinus faustus* the arms bear small nodes for their entire length and there is no expansion of arms in mid-portions.

Considering that brachials are added at the distal ends of arms during growth of the crinoids the smooth upper brachials are the youngest arm segments and could be expected to reflect youthful or ontogenetic characters. Youthful specimens of *Graffhamicrinus* are not presently recognized but are possibly represented in species of *Tholiacrinus* (Strimple, 1962a, p. 136).

The ornate genus *Tholiacrinus* has been referred into synonymy with *Graffhamicrinus* by Moore, Lane and Strimple (1973, p. 22) without discussion or explanation of the action. It is not clear at this time whether *Tholiacrinus* needs to be retained as a discrete genus or not. Based on present information, a close relationship with *Endelocrinus* Moore & Plummer (1940) is just as possible as with *Graffhamicrinus*. It is possible that smaller species presently assigned to *Endelocrinus* and *Tholiacrinus* are more readily preserved because of a closer union of cup plates. Larger species belonging to *Diphuicrinus*, *Graffhamicrinus* and *Delocrinus* are known to possess ligamental union of cup plates and it is possible that young specimens disarticulated too rapidly at the time of death to be preserved in the fossil record. Current investigations are being directed toward such morphologic details.

Ornamentation has one readily visible function which is to increase the surface area of the animal. Roughness will also provide a better surface for attachment of the thin epidermis. Whatever the function of ornamentation in *Graffhamicrinus*, the need apparently does not extend to the upper arms.

SYSTEMATIC PALEONTOLOGY

- Class CRINOIDEA Miller, 1821
- Subclass INADUNATA Wachsmuth and Springer, 1885
- Order CLADIDA Moore and Laudon, 1943
- Suborder POTERIOCRININA Jaekel, 1918
- Superfamily ERISOCRINACEA Wachsmuth and Springer, 1886
- Family CATACRINIDAE Knapp, 1969
- Genus DELOCRINUS Miller and Gurley, 1890
- DELOCRINUS ELONGATUS Strimple, n. sp.
- Figures 1B, C.

Diagnosis. — Primaxils taller than wide, non-spinose; arms unusually long and lacking pronounced expansion in mid-length; smooth cup surface.

Description. — Dorsal cup is typical of *Delocrinus* and most closely resembles *D. hemisphericus* (see previous description). The arms of *D. elongatus* are longer than those of *Delocrinus hemisphericus* and the absence of spinose primaxils is atypical but not unknown. The possibility is entertained here that *D. elongatus* may be a derivative of *Graffhamicrinus* through suppression of surface ornamentation. The intimate relationship thought to exist between *Delocrinus*, *Graffhamicrinus*, and *Diphuicrinus* has been previously discussed.

Brachials are slow to interlock so that secundibrach 4 is the first to fail to reach the opposite side. The brachials do not attain a fully equibiserial status until about secundibrachs 10. The elongated arms

are more like those of *Erisocrinus* than those usually associated with *Delocrinus* but the primaxils are proportionately taller than found in adult *Erisocrinus*. The dorsal cup with moderately deep basal concavity, single anal plate, and lack of surface ornamentation all link the species with *Delocrinus*. As suggested in the generic discussion, *D. elongatus* may represent a divergent trend within the genus *Delocrinus* followed by *D. brownvillensis*, *D. vulgatus*, and *D. vastus*. The first two species are of Virgilian age and the last is Wolfcampian.

Close affinity may exist between typical *Endelocrinus* (i.e., *E. fayettensis*) and *Delocrinus elongatus*. *E. fayettensis* Worthen (1873) is a small form with depressed areas at the corners of radial and basal plates and the secundibrachs are quadrate until the sixth to ninth segments, thereafter becoming biserial. *D. elongatus* is a much larger species (more mature?) lacking depressed areas at plate corners with most lower brachials interlocked, but not equibiserial until about secundibrachs 10 as previously noted. Both species have moderately tall, non-spinose primaxils and a single anal plate in the cup.

Measurement of holotype in millimeters: length of crown 55.8; height of dorsal cup 7.0, width 16.5; length of BC basal 9.1, width 6.8; height of proximal end of radial above basal plane 1.3; width of E radial 9.5, length 5.2; maximum width of anal \times 3.4, length 4.8; length of D primaxil 6.2, width 8.6; length of C primaxil 6.4, width 8.1; length of A primaxil 8.0, width 8.5.

Occurrence. — Barnsdall Formation, Ochelata Group, Virgilian; abandoned tank dike in hill, NW $\frac{1}{4}$ NW $\frac{1}{4}$ section 10, T. 28 N., R. 13 E., Washington County, Oklahoma.

Holotype. — Revisited in Springer Collection, catalogue USNM S6640A, National Museum of Natural History, Washington, D.C. Collected by H. L. Strimple.

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