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SYNOPSIS: Iowa Mississippian rocks, rich in fossil crinoidea, lend themselves excellently for stratigraphic zonation. Zone index fossils have been chosen in the basis of stage of evolution and abundance of occurrence. The following crinoid zones are established: North Hill formation, *Aacocrinus chouteauensis* (Miller), Hampton formation, *Rhodocrinites kirbyi* (Wachsmuth and Springer), Gilmore City formation, *Rhodocrinites serpens* (Laudon), Burlington formation, Dolbe Creek member, *Cactocrinus proboscidialis* (Hall), Haight Creek member, *Agaricocrinus planoconvexus* Hall, Cedar Fork member, lower part, *Azygocrinus rotundus* (Yandell and Shumard), upper part, *Dorycrinus quinquelobus* (Hall), Keokuk formation, transition beds, *Eutrochocrinus trochiscus* (Meek and Worthen), main limestone unit, *Actinocrinites lowei* (Hall), Warsaw formation, *Barycrinus spurius* (Hall), St. Louis formation, *Dichocrinus ornatus* Wachsmuth and Springer and Ste. Genevieve formation, *Taxocrinus huntsvillae* Springer.

INDEX DESCRIPTORS: Mississippian Crinoids, Iowa Crinoids, Crinoids.

CRINOID ZONATION IN THE MISSISSIPPIAN ROCKS OF IOWA

The Mississippian rocks of Iowa lend themselves excellently to crinoid zonation. They are composed predominately of relatively shallow water carbonate rocks that accumulated on shelf areas adjacent to the craton. Most of them are in part crinoidal and in large parts of the section the rocks are composed almost exclusively of disarticulated crinoidal remains. Well preserved crinoid remains are sufficiently abundant in much of the section to make them by far the best zone fossils.

Perhaps of most importance, sufficient time elapsed during the accumulation of the Mississippian rocks in Iowa to record the explosive evolution of crinoids that culminated during the deposition of the Kinderhookian and Osagean rocks. A very large number of Osagean genera became extinct before the transgression of Meramecian seas. Zonation, to be of most value, must be based on knowledge of crinoid evolution and not on chance preservation of a few fossils.

Zonation based on a single index species for which the zone is named becomes more valuable when a faunal assemblage is also taken into account. When faunal assemblage is coupled with the knowledge of the stage of evolution of the various genera within the assemblage a remarkably precise stratigraphic location within the various Mississippian carbonate sequences in Iowa can be determined. In general the more primitive stages of evolution present in the lower parts of the section tend to survive longer while specialized and exotic forms are short lived.

The crinoid zonation adopted in this paper can also be used quite successfully in the Mississippian strata exposed in northeastern Missouri and adjacent parts of Illinois. The Missouri area south of St. Louis, the Springfield area in southwestern Missouri, northern Arkansas and adjacent northeastern Oklahoma contain rocks stratigraphically older than the Burlington limestone and younger than the youngest rocks classed as Kinderhook in age in Iowa. Large faunas from the Fern Glen formation of southeastern Missouri, and the St.

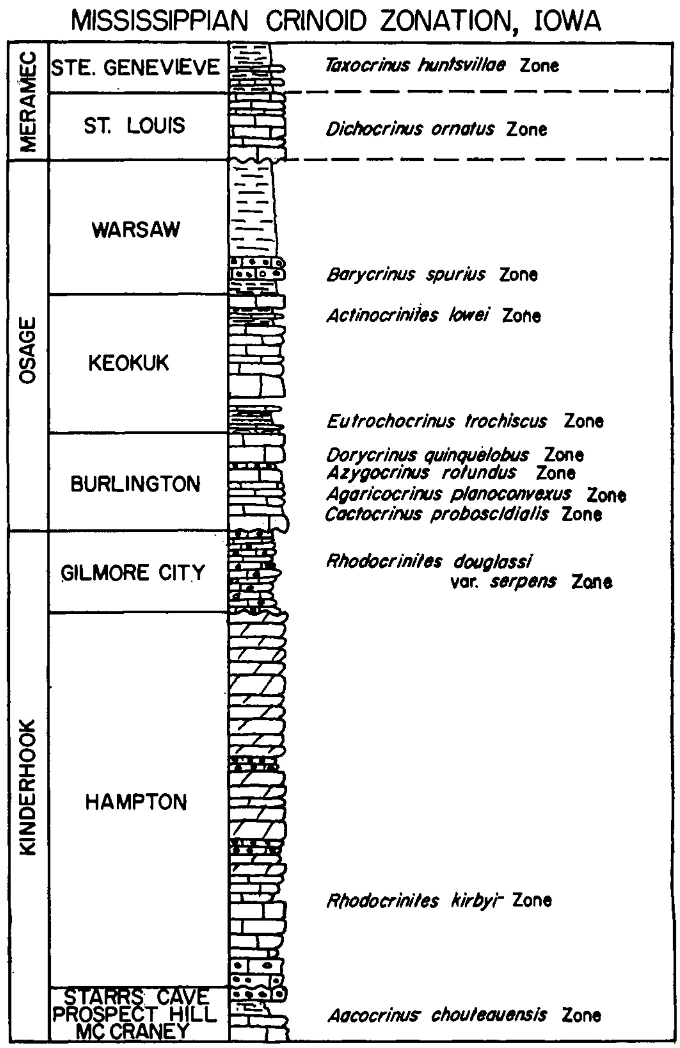

Figure 1. Mississippian crinoid zonation in Iowa.

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Joe formation of northern Arkansas and northeastern Missouri now in our collections remain undescribed. Ancestors of a very large number of the common Burlington genera are present in these undescribed faunas.

The Mississippian seas transgressed against the cratonic area of North America from both west and east so extensively that only small parts of the southern part of the craton in New Mexico and Colorado remained permanently above water during the Mississippian.

The Iowa area lying as it does along the east side of the cratonic high received only comparatively thin wedges of lower Mississippian Kinderhookian sediments. The thin wedge of McCraney limestone, a correlative of the Chouteau formation of Missouri, rests unconformably on the English River formation, now classed as late Devonian in age. The McCraney and Chouteau limestones are correlatives of the Caballero silty limestone beds of New Mexico and all three represent sedimentary wedges deposited by the early Mississippian sea against the southeast side of the craton. Faunas from all three are closely similar.

The Prospect Hill formation, disconformable on the McCraney formation, represents a thin overlap wedge of the more extensively developed Sedalia formation of Missouri. The overlying Starrs Cave unit represents a comparatively local shore zone oolite that marked the beginning of the transgression of the sea that deposited the Hampton formation. Local deposits of oolite of approximately the same age are present in the Chapin area in central Iowa and at LeGrand, Iowa.

The spectacularly crinoidal Gilmore City formation in north central Iowa represents a post Hampton accumulation of oolitic limestone that was deposited in shallow water. The oolitic limestones at Humboldt and probably the oolitic limestone at Alden are correlatives of the Gilmore City.

Erosion followed the deposition of the Gilmore City formation in Iowa during which time the lower part of the New Providence formation in Kentucky and Tennessee, the Fern Glen formation of southeastern Missouri and adjacent Illinois, and the St. Joe formation of northern Arkansas, southwestern Missouri and northeastern Oklahoma accumulated.

Thick sections containing excellently preserved crinoid faunas accumulated in the Alamogordo and Lake Valley areas in New Mexico during this time.

The basal parts of the Burlington limestone in the Hannibal area in Missouri and in the Springfield area in Missouri are older than any part of the basal Burlington section in Iowa.

The Burlington seas transgressed against the underlying Hampton formation in Iowa from the southeast toward the northwest bringing successively younger zones in contact with the underlying Hampton strata northward in Iowa.

Similar transgression of the Mississippian seas is present in the New Mexico area where marvelously fossiliferous crinoid bearing strata crop out in the Sacramento Mountains, the San Andres Mountains and in the Lake Valley area. The Lake Valley strata encompass the interval from earliest Osage equivalents, such as the Fern Glen and St. Joe limestones, through the Lower Burlington. Late Burlington age faunas and Keokuk faunas are not present at Lake Valley.

Kinderhookian faunas containing excellently preserved fossils are also present in the deposits laid down along the western side of the cratonic area in Colorado, Utah, Wyoming, Montana and Alberta. The Lodgepole formation of Montana, Wyoming and Utah contains Kinderhook crinoid genera closely comparable to the Mississippi valley faunas. Similar closely related faunas of Kinderhook age are present in the Banff formation in the Alberta front ranges.

It appears now that essentially continuous sedimentation took place in this western area from the earliest Kinderhookian transgression through the Osage and perhaps in part into the Meramec.

Because of the unusually large number of crinoid genera and species involved in the text of this paper it is deemed undesirable to include the direct reference for each in the body of the text. All are figured in the references included in the bibliography. In most cases the original references were not consulted but rather large monographs such as *Crinoidea Camerata* by Wachsmuth and Springer, 1897, were used. All genera and species used can be found in the papers listed in the bibliography.

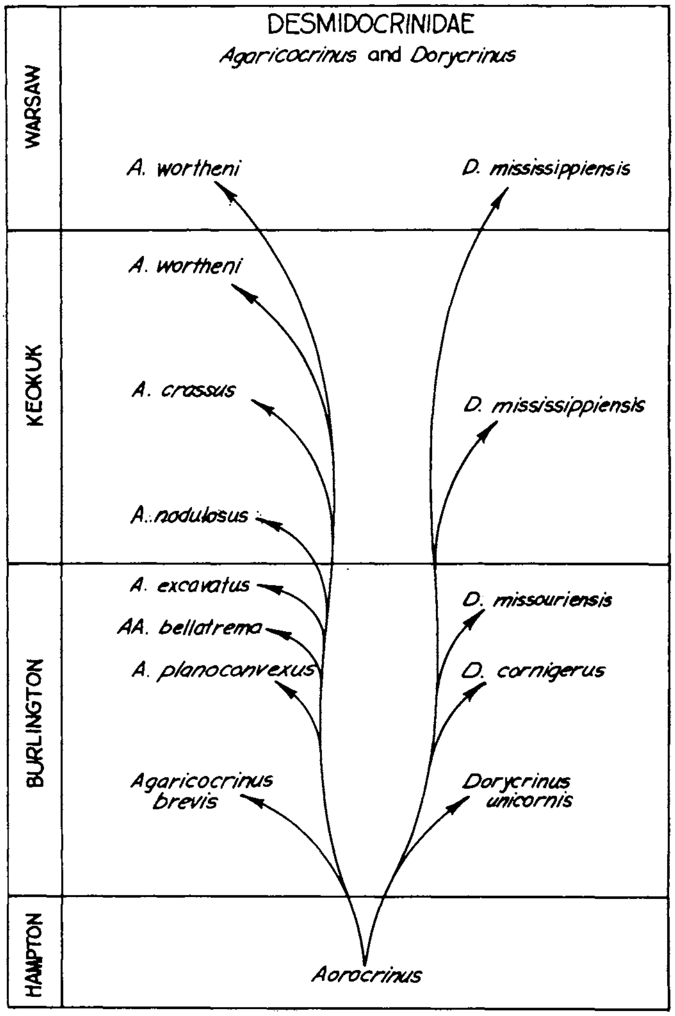

Figure 2. Evolution of desmocrinid genera *Agaricocrinus* and *Dorycrinus*.

CRINOID ZONATION IN IOWA KINDERHOOKIAN ROCKS
AACOCRINUS CHOUTEAUENSIS ZONE

Crinoids have not been found as yet in the McCraney limestone, the Prospect Hill siltstone and the Starrs Cave oolitic limestone. This is almost certainly due to the lack of quarry development in rocks containing these formations. Disarticulated plates of several species of *Platycrinites* (Bassler 1938) and also of stellate radial plates from *Aacocrinus* (Bowsher 1955) are present along the bedding planes of the McCraney limestone in the Burlington area.

Because of the presence of several species of *Platycrinites,* excellently preserved, and also several species of *Aacocrinus* in the quarries in the Chouteau limestone in the Newark, Missouri area a short distance south of the Iowa line we are assigning the common species *Aacocrinus chouteauensis* (S. A. Miller 1892) as the zone index fossil of the McCraney formation in southeastern Iowa.

Fourteen species of *Platycrinites* have been described from the Chouteau formation of Missouri. All have moderately steep cups and a tegmen composed of a few relatively large plates. The Chouteau forms can be assumed to be the probable ancestors of the platycrinitids in the early Mississippian rocks of Iowa.

Aacocrinus, the ancestor of *Actinocrinites* (Bassler 1938) in later Mississippian rocks, is present in the Chouteau rocks of Missouri in several closely related species. All are comparatively simple, with steep cups, and comparatively large tegmen plates. They may be considered as the ancestors of the later Mississippian species of *Actinocrinites.*

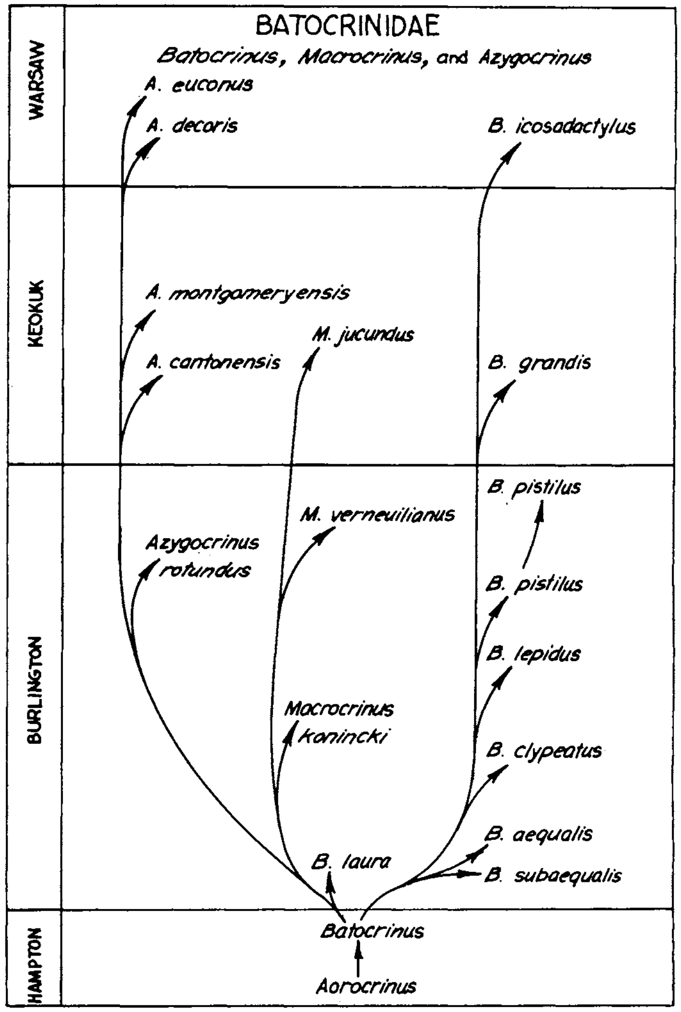

Figure 3. Evolution of batocrinid genera *Batocrinus, Macrocrinus* and *Azygocrinus.*

RHODOCRINITES KIRBYI ZONE

Rhodocrinites kirbyi (Wachsmuth and Springer) is one of the most abundantly occurring crinoids in the crinoid colonies at LeGrand, Iowa in the Hampton formation. It is chosen for the zone index fossil for the LeGrand crinoid faunas because of the very primitive nature of the anal series which was apparently inherited from some of its remote Ordovician ancestors. The anal series is composed of a very large number of small plates with a median row of plates running up the central part of the series. The tegmen plates are very small, much more primitive, than those exhibited on any other species of Mississippian *Rhodocrinites* (Miller 1821). The cup is conical, expanding gradually upward to the arm bases rather than round and globular such as characterizes most younger species of *Rhodocrinites.*

R. douglassi var. *serpens* (Laudon) the zone index fossil for the Gilmore City formation has a round globular cup and a flat tegmen composed of comparatively large plates.

Continued evolution of the rhodocrinitids led eventually to the development of the highly specialized genus *Gilbertsocrinus* (Phillips 1836). *G. reticulatus* (Hall) from the Lower Burlington beds already had developed the laterally directed arms and flat tegmen. *G. typus* (Hall) from the upper Burlington limestone greatly deepened the cup, developed downward projecting spinose basal plates, a widely expanded tegmen, laterally directed arms and a flat tegmen. *G. tuberosus* (Lyon and Cass) from the Keokuk represented the maximum specialization of the genus with its bizarre, highly specialized, tube-like tegmen extensions in addition to small arms.

Associated with *R. kirbyi* (Wachsmuth and Springer) in the LeGrand fauna are other crinoid species exhibiting primitive stages of evolution so important in understanding stratigraphic position of a given formation. In the Actinocrinitidae two species *Cusacrinus arnoldi* (Wachsmuth and Springer) and *C. nodobrachiatus* (Wachsmuth and Springer) have grouped arms with interbrachial plates in contact with tegmen plates. *Cusacrinus* (Bowsher 1955) is ancestral to the genus *Cactocrinus* (Wachsmuth and Springer) so abundant in the Burlington formation.

In the Desmidocrinidae, *Aorocrinus immaturus* (Wachsmuth and Springer) descended from Silurian *Desmidocrinus* Angelin 1878 and differing only in that the arms of *Aorocrinus* are biserial instead of uniserial, is one of the most common crinoids in the LeGrand fauna. *Aorocrinus* is the direct ancestor of the flat based agaricocrinids so abundant in Burlington and Keokuk rocks. *Aorocrinus* also gave rise to the very large family, the Batocrinidae Wachsmuth and Springer 1897. *Dichocrinus* Munster 1837 evolved from the Hexacrinidae Bassler 1938, is also abundant in the LeGrand fauna. *Taxocrinus* Phillips 1843 and *Eutaxocrinus* Springer 1906, ancestors of the explosively evolving onychocrinids of the Keokuk formation were present in the LeGrand faunas.

It is probable that an additional crinoid zone should have been established for a single crinoid colony that was found in the LeGrand beds approximately 11 feet above the base of the formation in the south end of the main quarry. This small colony contained mainly delicate inadunate crinoids. *Pachylocrinus spartarius* (Miller and Gurley) was most abundant and was associated with *Graphiocrinus longicirrifer* Wachsmuth and Springer and *Scytalocrinus Maccabei* Wachsmuth and Springer. Camerate crinoids were entirely absent in this colony.

The genus *Platycrinites* (Bassler 1938), so greatly varied in later Mississippian rocks, is represented by only one primitive species *P. symmetricus* Wachsmuth and Springer in the LeGrand fauna. *P. symmetricus* with its steep primitive cup, very small tegmen plates, raised ambulacral areas on the tegmen and large oral plates is instantly separable from all other Mississippian species on the basis of the tegmen alone. Its closest relative is *P. bozemanensis* (Miller and Gurley) from the Lodgepole formation of Montana.

Crinoids have not been found in the upper beds of the Hampton formation other than a few poorly preserved specimens of *Platycrinites*. All have primitive steep-sided cups but without the tegmen and arms are of little value as zone fossils.

RHODOCRINITES DOUGLASSI VAR. SERPENS ZONE

Crinoids in the Gilmore City crinoid colonies essentially all represent stages of evolution beyond those found in the Hampton formation. The excellently preserved crinoids at Gilmore City are distributed mainly through approximately 12 feet of beds below the main upper massive oolitic limestone ledges and above the dark blue shaly limestone beds near the base of the quarry. The crinoids are concentrated in depressions on the limestone surfaces and enclosed in soft, shaly, calcareous muds.

R. douglassi (Miller and Gurley) and four closely related varieties *R. douglassi* var. *serpens*, *R. douglassi* var. *multidactylus*, *R. douglassi* var. *constrictus* and *R. douglassi* var. *excavatus* Laudon 1933 all occur together in the crinoid colonies. *R. douglassi* var. *serpens* is most abundant in the fauna.

The *R. douglassi* group exhibits an advanced stage of evolution beyond that of *R. kirbyi* (Wachsmuth and Springer) from the Hampton formation *R. douglassi* has a round globular calyx and a flat constricted tegmen area composed of much larger plates than *R. kirbyi*. *R. cavanaughi* Laudon 1933, relatively rare in the Gilmore City fauna, exhibits a much more primitive stage of evolution in that its tegmen is composed of many very small plates.

Associated with the *R. douglassi* group in the Gilmore City formation are representatives of most of the families present in the older Hampton beds. The family Desmidocrinidae Angelin 1878 is represented by *Aorocrinus iola* Laudon closely

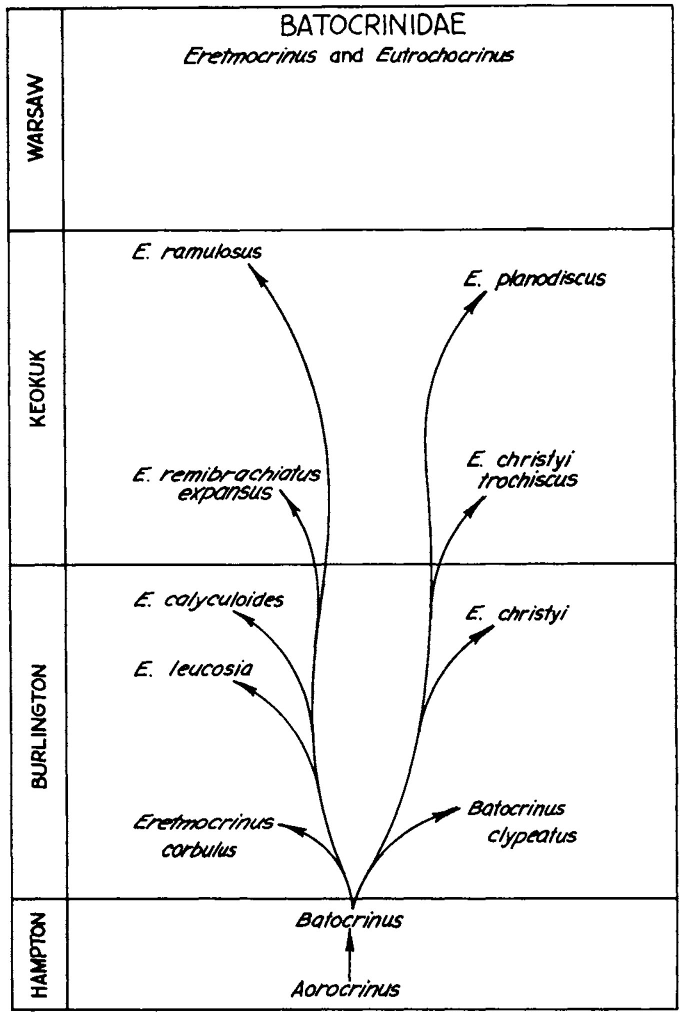

Figure 4. Evolution of batocrinid genera *Eretmocrinus* and *Eutrochocrinus*.

related to *A. immaturus* Wachsmuth and Springer from the LeGrand beds. The family Actinocrinitidae Bassler 1938 is represented by only one species *Cusacrinus imperator* (Laudon), a primitive cactocrinid with six arms separated by interbrachial plates. The family Batocrinidae is represented by one species, *Eretmocrinus tentor* Laudon. The Batocrinidae represent an advance stage of evolution derived from the family Desmocrinidae Angelin 1878 by development of an anal tube instead of having the anus opening directly through the tegmen. *Eretmocrinus tentor* Laudon represents a distinct advance in stage of evolution beyond *Batocrinus macbridei* Miller and Gurley, a very primitive form, from the LeGrand beds. *Platycrinites cranei* Strimple, an advanced species as evidenced by the numerous arms, has been found at Gilmore City. The family Dichocrinidae Miller 1889 is represented by three species *D. multiplex* Laudon, *D. campto* Laudon and *D. bozemanensis* Miller and Gurley an advanced form with a striated cup.

The flexible crinoids are represented by a single species of *Eutaxocrinus* Springer 1936 at Gilmore City. Seven genera of inadunate crinoids are present at Gilmore City, *Gonio-*

crinus, Miller and Gurley 1890, *Decadocrinus,* Wachsmuth and Springer 1879, *Lasiocrinus,* Kirk 1914, *Zeacrinites,* Troost 1858, *Pachylocrinus,* Wachsmuth and Springer 1880, *Culmicrinus* Jackel 1918, and *Gilmocrinus,* Laudon 1933. Two of the commonly occurring species are *Culmicrinus thomasi* Laudon a genus that is normally restricted to the St. Louis limestone and *Gilmocrinus* Laudon 1937 is distinctive in that it has either 5 or 6 long, straight, unbranched arms.

CACTOCRINUS PROBOSCIDIALIS ZONE

During the time gap in deposition of Iowa Mississippian strata between the deposition of the Gilmore City formation and the lowermost beds of the Burlington formation enormous crinoid evolution took place. During this interval the New Providence formation of Kentucky, the Fern Glen formation of southern Missouri, the St. Joe formation of northern Arkansas and northeastern Oklahoma and extensive deposits in the lower part of the Lake Valley formation at Alamogordo, New Mexico took place. Our collections from these formations contain a very large number of new undescribed species that represent the transitional evolutionary stages between the Iowa Kinderhook species and those found in the lower part of the Burlington limestone. Detailed studies of faunas from the upper part of the Lodgepole formation of Montana and from the upper part of the Banff formation of Alberta are furnishing us with additional information concerning these transitional stages in the crinoid evolution.

During the interval between the deposition of Gilmore City strata and the deposition of the basal parts of the Burlington limestone in Iowa the actinocrinitids evolved tremendously. All of the lower massive crinoidal ledges of the Burlington limestone of northeastern Missouri and southeastern Iowa contain a number of species of *Cactocrinus* Wachsmuth and Springer 1897 from which *C. proboscidialis* (Hall 1858) the most abundantly occurring species has been chosen to represent this zone. *Cactocrinus* differs from *Nunnacrinus* Bowsher 1954 and *Cusacrinus* Bowsher 1954 from the LeGrand beds in that the arms in *Cactocrinus* are in a continuous ring with interbrachials confined to the cup. *Cusacrinus* has six arms to the ray while *Nunnacrinus* has only four. *Cusacrinus* is present in the LeGrand fauna with three species, *C. arnoldi* (Wachsmuth and Springer), *C. nodobrachiatus* (Wachsmuth and Springer) and *C. ornatissiums* (Wachsmuth and Springer). In the Gilmore City fauna one species, *C. imperator* Laudon is present.

The genus *Actinocrinites* (Miller, 1821) remains primitive in the *C. proboscidialis* (Hall) zone. Small, comparatively primitive *A. scitulus* Meek and Worthen is the only species present. *Steganocrinus pentagonus* Hall, one of the most common species in the Lake Valley limestone in New Mexico, is present in the *C. proboscidialis* zone.

Primitive desmidocrinids are present in the *C. proboscidialis* zone. *Aorocrinus subaculeatus* (Hall) with its short spine at the apex of the tegmen could have evolved directly from *A. immaturus* Wachsmuth and Springer from the LeGrand beds. It has a truncated base and could be ancestral to the primitive species of *Dorycrinus* such as *D. unicornis* (Owen and Shumard) which also occurs in the *C. proboscidialis* zone.

Agaricocrinus Troost 1858, a desmidocrinid characterized by a flattened to concave cup, apparently evolved from *Aorocrinus.* It appears in the *C. proboscidialis* zone with three small, relatively primitive species, *A. brevis* (Hall) and *A.*

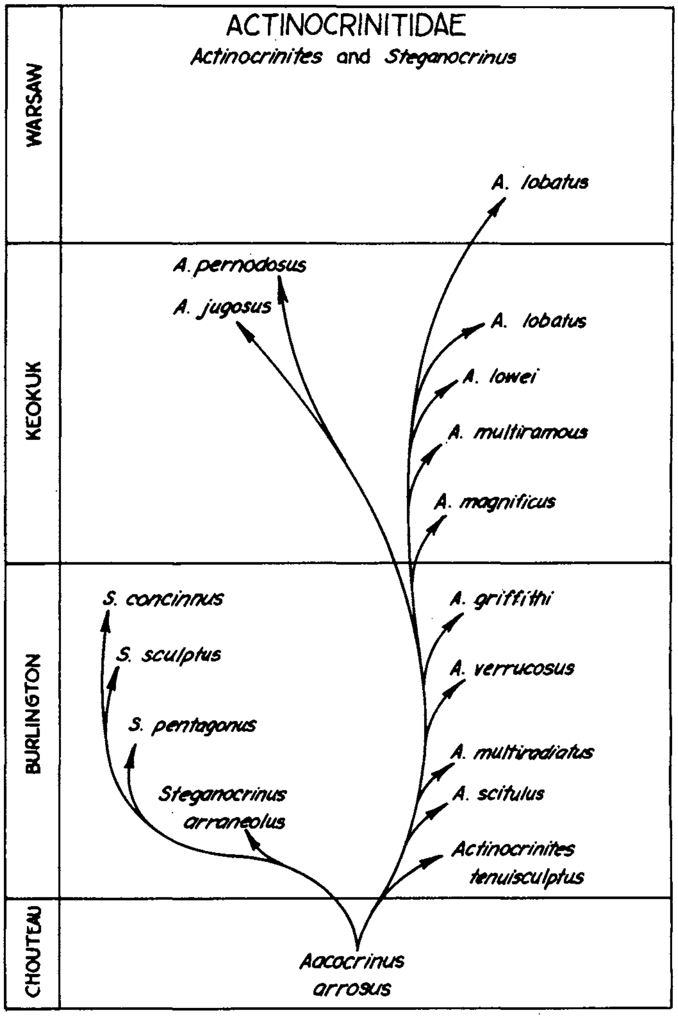

Figure 5. Evolution of actinocrinitid genera *Actinocrinites* and *Steganocrinus.*

fiscellus (Hall) in which the base is not as yet entirely flattened, and *A. pyramidatus* (Hall).

Uperocrinus, with grouped arms inherited from its *Aorocrinus* ancestor, appears in the *C. proboscidialis* zone as *U. longirostris* (Hall). *U. longirostris* is probably the direct ancestor of *Batocrinus* Casseday 1854 and also the ancestor of the highly specialized species of *Uperocrinus* that occur in the upper Burlington and Keokuk beds.

The genus *Batocrinus* Casseday 1854 is present in the *C. proboscidialis* zone in almost prolific numbers. *B. calvini* Rowley appears to be restricted to the lowermost beds. *B. subaequalis* (McChesney), *B. aequalis* (Hall), *B. lepidus* (Hall), *B. turbinatus* (Hall) and *B. cylpeatus* (Hall) are the most common species.

Macrocrinus Wachsmuth and Springer 1897, a relatively small batocrinid with only 12 to 16 arms, much more abundant in upper Burlington and Keokuk beds, is present in the *C. proboscidialis* zone in one abundantly occurring, very distinctive, easily recognized species *M. gemmiformis* (Hall).

The genus *Uperocrinus* Meek and Worthen 1865 with grouped arms and interbrachials in contact with tegmen plates, evolved from *Aorocrinus* Wachsmuth and Springer and differs only in that it has an anal tube. It is present in the *C. proboscidialis* zone as *U. aequibrachiatus* (McChesney). The exact evolution of such specialized forms as *U. pyriformis* (Shumard) present in the Upper Burlington beds and *U. nashvillae* (Troost) from the Keokuk beds is problematical and they may have evolved directly from *Batocrinus*.

Eretmocrinus Lyon and Casseday 1859 differs from *Batocrinus* (Casseday 1854) in that it has developed paddle shaped widening at the arm extremities and tends to have a broad somewhat flattened base. The genus is present most commonly in the upper Burlington beds and ranges on into the Keokuk. *E. leucosia* (Hall) and *E. corbulus* (Hall) are present in the *C. proboscidialis* zone.

Agaricocrinus Planoconvexus Zone

The *Agaricocrinus planoconvexus* Hall zone comprises the upper half of the old lower Burlington as described by Wachsmuth and Springer 1897 in Crinoidea Camerata.

The zone can be easily separated lithologically as well as faunally. The massive, brown, crinoidal limestones, highly resistant to erosion that comprise the *C. proboscidialis* zone are overlain by much thinner bedded, comparatively soft, dolomitic limestone beds that contain much more chert than the beds in the lower part of the section. They normally form a retreating portion of the cliff face below the hard, massive beds of the overlying *Azygocrinus rotundus* zone.

A very persistent chert zone approximately three feet in thickness lies at the top of the old lower Burlington as defined by Wachsmuth and Springer. The more massive, resistant beds of the *Azygocrinus rotundus* zone normally form an escarpment along the valley walls.

Well preserved crinoids are not as abundantly present in the *Agaricocrinus planoconvexus* zone as in either the overlying *Azygocrinus* zone or the underlying *Cactocrinus* zone. The absence of abundant crinoids recovered from this zone may be due in part to the relatively poor exposures that normally develop.

The zone is named for *Agaricocrinus planoconvexus* Hall, a close, but considerably smaller, relative of *A. bellatrema* Hall that occurs abundantly in the overlying *Azygocrinus* zone.

Associated with *A. planoconvexus* in the zone are excellently preserved specimens of *Physetocrinus ventricosus* Hall, slightly smaller and probably ancestral to the larger forms of *P. ventricosus* that are present in the uppermost beds of the Burlington limestone. Also present is *Uperocrinus pyriformis* Shumard, again considerably smaller and probably ancestral to the larger, more robust forms present in the uppermost Burlington beds.

Eutochocrinus lovei (Wachsmuth and Springer) ancestor of *E. christyi* (Shumard), *Batocrinus subaequalis* (McChesney), *B. tuberculatus* (Wachsmuth and Springer), *Periechocrinites whitei* (Hall), *Rhodocrinites barrisi* Hall, *Actinocrinites scitulus* Meek and Worthen and several species of *Platycrinites* are also present in the *Agaricocrinus planoconvexus* zone.

The Azygocrinus Rotundus Zone

This is the zone of the Burlington limestone that has been known to students of paleontology as the *Dizygocrinus* zone. Restudy of the group led Lane, 1963, to subdivide the genus erecting the new name *Azygocrinus* for the Burlington species formerly referred to *Dizygocrinus*. *Azygocrinus* lacks ornamentation and lacks the paired arms arising from a single ambulacral opening.

The *Azygocrinus* zone in Iowa is composed of massive, quite resistant beds of crinoidal limestone rich in fossil brachiopods, corals, bryozoans and crinoids. The nature of the rock is such that with slight weathering it crumbles fairly easily allowing students to break out excellent fossils.

The basal six feet of beds above the chert zone are light colored and fairly massive. Usually they contain many specimens of *Hadrophyllum glans* White. *Azygocrinus rotundus* (Yandell and Shumard) is present sparingly in the lower beds. The light colored basal ledges are overlain by fairly massive beds of green, glauconitic limestone, filled with great numbers of excellently preserved fossils. Best method of collecting the fauna is to find partially weathered ledges, usually in a creek bed, and proceed to break the fossils out of the crumbling mass.

The ledges along Honey Creek adjacent to Morning Sun have produced thousands of excellent crinoids.

Associated with *A. rotundus* (Yandell and Shumard) are excellent specimens of the following: *A. dodeccadactylus* (Meek and Worthen), *Agaricocrinus bellatrema* Hall, *A. inflatus* Hall, *Eutrochocrinus christyi* (Shumard), *Batocrinus laura* (Hall), *Macrocrinus verneuilianus* Shumard, *Eretmocrinus matuta* (Hall), *E. calyculoides* (Hall), *E. cloelia* (Hall), and *E. minor* Wachsmuth and Springer.

Dorycrinus Quinquelobus Zone

The medium bedded, brown, crinoidal ledges that comprise the uppermost beds of the Burlington formation in Iowa contain a group of highly specialized, racially old crinoids. *Dorycrinus quinquelobus* Hall with its distinctive highly spinose tegmen occurs abundantly in this zone. Also present are highly specialized actinocrinids belonging to the genus *Teleiocrinus* Wachsmuth and Springer. *Teleiocrinus umbrosus* (Hall), *T. tenuiradiatus* (Hall), *T. liratus* (Hall) and *T. althea* (Hall) all highly evolved, spinose, gaudily ornamented are present. They differ from cactocrinids in the greater number of arms that arise from the flaring rim of the cup. All appear in this small limited zone at the end of Burlington limestone deposition. A much smaller, less specialized undescribed species of *Teleiocrinus* is present in the *C. proboscidialis* zone.

Associated with the specialized teleiocrinids is *Strotocrinus glyptus* (Hall), evolved from *Physetocrinus*, (Meek and Worthen) characterized by a tremendously wide brim to the cup with multiple arms arising from the edge of the flaring brim. *S. glyptus* shows its *Physetocrinus* ancestry through the minute plates of the tegmen and the anus opening directly through the tegmen.

The *Dorycrinus quinquelobus* zone is marked by other bizarre species, spinose, and racially old. Other actinocrinid species are *Actinocrinites multiradiatus* (Shumard), and *A. verrucosus* (Hall). Specialized desmidocrinids in the zone are *Dorycrinus cornigerus* (Hall), *D. roemeri* (Meek and Worthen), and *D. missouriensis* (Shumard). Specialized agaricocrinids are *Agaricocrinus excavatus* Hall and *A. convexus* Hall. A large highly stellate species, *Physetocrinus ven-*

tricosus Hall also is commonly present in the *D. quinquelobus* zone.

The Batocrinidae are also represented with racially old, specialized forms. A very large form of *Uperocrinus pyriformis* (Shumard) with a nodose tegmen is present. The very large variety of *Eutrochocrinus christyi* (Shumard) also is present. Specialized *Batocrinus pistillus* (Meek and Worthen) also occurs only in this zone. Specialized *Eretmocrinus depressus* Wachsmuth and Springer with its unusually wide base occurs only in this zone.

EUTROCHOCRINUS CHRISTYI VAR. TROCHISCUS ZONE

Lying above the brown crinoidal beds of the *Dorycrinus quinquelobus* zone in southeast Iowa is a series of relatively non-resistant, silty, shaly, tan to brown weathering, thin bedded, very cherty strata referred to as the "Transition beds" to the Keokuk formation or the "Montrose cherts." Because of their non-resistant nature they are poorly exposed.

Crinoids are present in this zone sparingly the most common being the unusually large, strange, highly nodose species called *Eutrochocrinus christyi* var. *trochiscus* (Meek and Worthen). Also present is a large species of *Actinocrinites*, a very large spinose species of *Dorycrinus* and a large, very nodose species of *Agaricocrinus*.

ACTINOCRINITES LOWEI ZONE

The Keokuk formation, as it outcrops in Iowa, is composed of medium bedded, blue-gray, crinoidal limestone bedded with thin partings of blue-gray, calcareous shale. The resistant limestone beds of Iowa grade laterally to the southeast into much softer, blue-gray, thicker, calcareous shales in the Crawfordsville, Indiana area and in Tennessee.

Three species of crinoids, all large, heavy plated, and representing late stages in evolution are almost invariably present in any Iowa Keokuk limestone assemblage. They are large, rugose, stellate *Actinocrinites lowei* (Hall) *Dorycrinus missouriensis* (Shumard) with its unusually long tegmen spines, and *Alloprosallocrinus conicus* Lyon and Casseday.

In addition to these commonly occurring forms the genus *Eretmocrinus* Lyon and Casseday is represented by two species both showing markedly advanced stages of evolution, *E. remibrachiatus* (Hall) and *E. magnificus* Lyon and Casseday. Both have markedly nodose, almost spinose cup plates. *Uperocrinus* is represented by the unusually large, spinose form, *U. nashvillae* (Troost) and *Eutrochocrinus* is represented by an equally advanced form *E. planodiscus* (Hall). *Azygocrinus* is also represented by several species with sculptured cup plates, *A. montgomeryensis* (Worthen), *A. indianensis* (Lyon and Casseday) and *A. whitei* (Wachsmuth and Springer) are commonly present.

The Keokuk formation might well have been called the *Agaricocrinus* zone. When the Kentucky, Tennessee, and Indiana forms are included twelve species are recognized. *A. corei* Lyon and Casseday, *A. crassus* Wetherby, *A. wortheni* Hall, *A. elegans* Wetherby, *A. americanus* var. *tuberosus* (Hall), *A. nodulosus* Worthen and *A. whitfieldi* Hall all are present in the Keokuk area. All represent stages of evolution far in advance of the Burlington species.

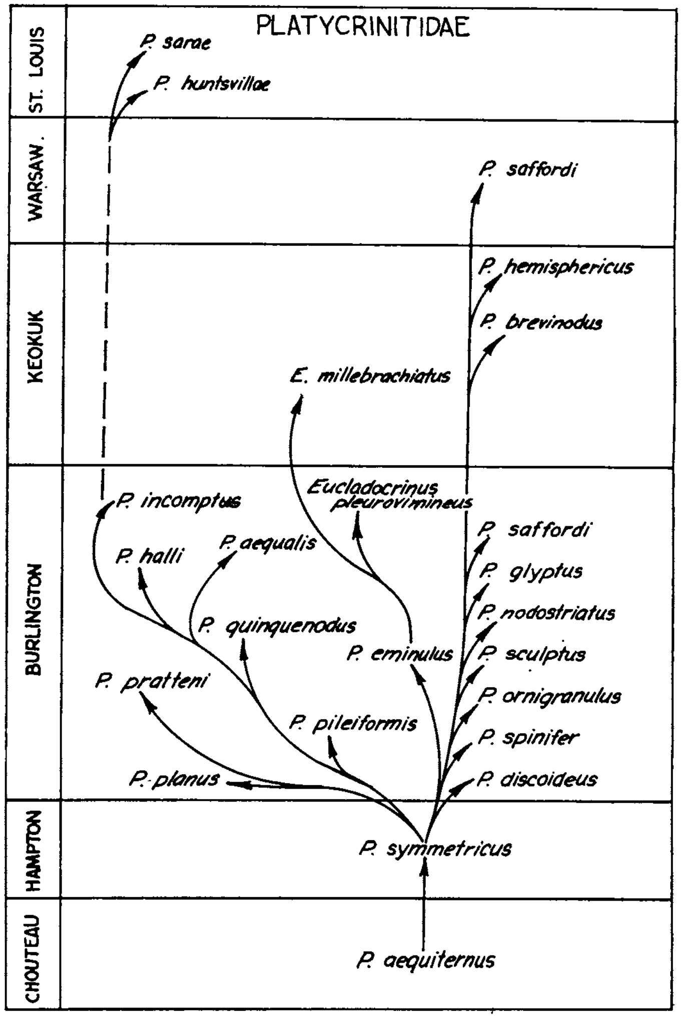

Figure 6. Evolution of the genus *Platycrinites.*

BARYCRINUS SPURIUS ZONE

The comparatively non-resistant shales of the Warsaw formation are not well exposed in southeastern Iowa. Exposures are mainly limited to gully walls adjacent to the Mississippi river. The Soap Creek area in the southern limits of Keokuk has produced the best crinoid faunas. Most of the crinoids in the Warsaw formation are found in the first few feet of calcareous shale just above the Keokuk limestone beds. With the exception of isolated columnals and plates, crinoids are essentially absent above the geode beds.

Barycrinus spurius Hall and *B. hoveyi* Hall, both heavy

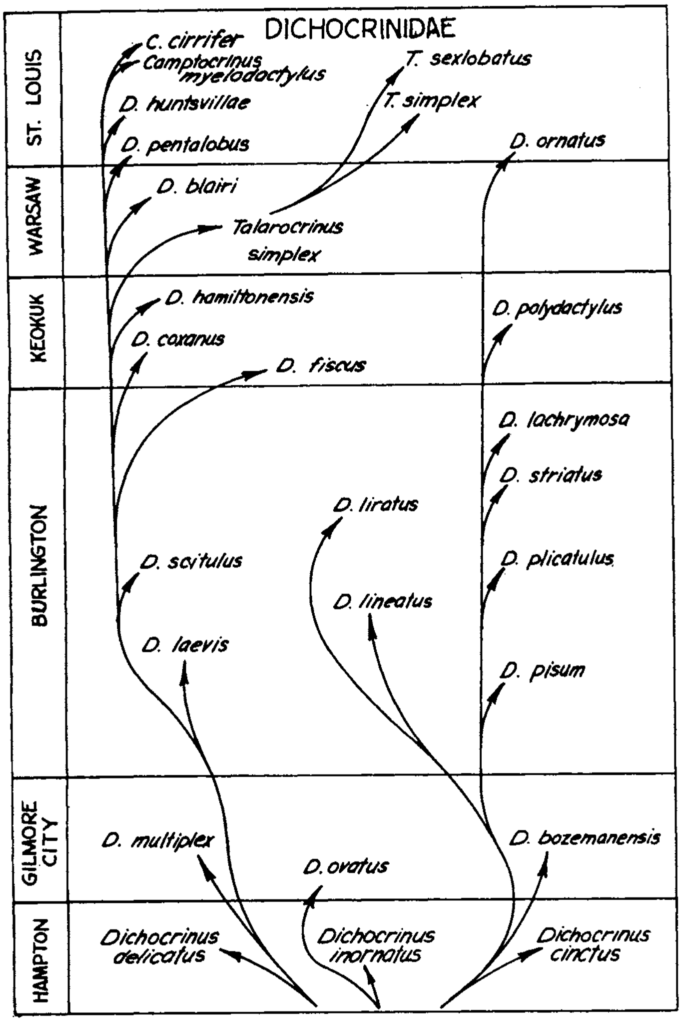

Figure 7. Evolution of the dichocrinid genera *Dichocrinus*, and *Talarocrinus*.

plated species, are present in the shaly beds a few feet above the contact with the Keokuk formation. *Uperocrinus nashvillae* (Hall), *Agaricocrinus wortheni* Hall, *A. americanus* var. *tuberosus* Hall, *Dorycrinus mississippiensis* Roemer, all survivors from the Keokuk fauna, are present. *Cribanocrinus coxanus* (Worthen), a smooth plated rhodocrinitid, represents survival of a primitive type which is hardly different from early Kinderhookian species.

THE DICHOCRINUS ORNATUS ZONE

The St. Louis limestone in Iowa has been tentatively assigned the *Dichocrinus ornatus* zone for the small delicately striated form of *Dichocrinus* which has been found in the *St. Louis limestone* in Iowa.

Fossil crinoids have not been recovered from the St. Louis limestone in Iowa in abundance. *Platycrinites huntsvillae* (Wachsmuth and Springer) the most common crinoid in the St. Louis limestone in the Kentucky-Tennessee area might be expected in the Iowa beds. In the Huntsville, Alabama area the common associates of *P. huntsvillae* are almost entirely delicate inadunate crinoids.

The explosion in crinoid evolution that started in early Kinderhookian time and came to a dramatic climax during the deposition of the Burlington limestone ended abruptly with the deposition of the Warsaw shales. By far the most profound break in invertebrate evolution in the Mississippian takes place before the deposition of the first Meramecian beds in the St. Louis limestone. Meramecian fossils with their diminutive brachiopod fauna, pentremitid blastoid fauna, and delicate inadunate crinoid fauna forecast the faunas that dominate the Chester rocks and in general are more closely related to those of the early Pennsylvanian Morrowan rocks than to their Osagean ancestors.

The presence of angular solution breccias in the basal part of the Iowa Meramec section probably represents collapse breccias that have resulted from solution of evaporites. It is not unusual that this environment is not rich in fossil invertebrates. The dense, white, sub-lithographic limestone of the Iowa St. Louis formation is not a lithologic type in which abundant invertebrate faunas are ever found. It can be assumed that the Iowa St. Louis limestone was deposited in shallow, near shore, evaporating basins contrasting with the more normal highly fossiliferous open marine section as developed in northern Alabama, eastern Tennessee and Kentucky.

The inadunate crinoid genus *Culmicrinus* Jaekel 1918 is present in the St. Louis limestone in the St. Louis, Missouri area to the south quite commonly. It might be expected to be found eventually in the Iowa area.

TAXOCRINUS HUNTSVILLAE ZONE

The Ste. Genevieve formation, originally described as the Pella formation in Iowa, Bain, 1894, rests unconformably on the underlying St. Louis limestone and is commonly marked with a thin basal sandstone. The time lapse between the deposition of the St. Louis limestone in Iowa and the deposition of the Ste. Genevieve is probably not great since throughout eastern Kentucky, Tennessee and northern Arkansas the contact appears conformable. The break can be assumed to represent a minor regression of the sea from Iowa followed by transgression.

The Ste. Genevieve limestone in the Kentucky-Tennessee area is represented by faunas closely related to those of the underlying St. Louis. In general the Ste. Genevieve is much more fossiliferous than the St. Louis and in addition contains a considerable amount of comparatively shallow water oolitic limestone. Small brachiopods, pentremitid blastoids and delicate inadunate crinoids predominate in the southern faunas.

Fragmentary remains of both pentremitid blastoids and crinoids are present in most Ste. Genevieve sections in Iowa.

A single crinoid fauna recovered from the marl beds just above the main limestone bed has been reported to me by Harrell Strimple. On the basis of this we have assigned the zone name *Taxocrinus huntsvillae* Springer for this fauna.

Associated with *Taxocrinus huntsvillae* in this one fauna are the following genera, *Pentarimicrinus* sp., *Phacelocrinus* sp., *Abrotocrinus* sp., *Cymbiocrinus* sp., *Azygocrinus* sp., *Camptocrinus* sp., and two species of *Dichocrinus*.

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