Stratigraphy and Paleontology of the Gilmore City Formation of Iowa

L. R. Laudon

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The Stratigraphy and Paleontology of the Gilmore City Formation of Iowa

by

LOWELL R. LAUDON

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THE STRATIGRAPHY AND PALEONTOLOGY OF THE GILMORE CITY FORMATION OF IOWA

INTRODUCTION

Limestone of supposed Kinderhook age has long been known to be exposed in western Humboldt and eastern Pocahontas counties in north-central Iowa. The surface exposures of this limestone are few and usually more or less obscured by overlying glacial drift. It has been only within the last few years that extensive quarrying in the region has exposed considerable sections of the limestone. Most of the fauna with which this paper deals was collected in two of these quarries which are located about one mile northwest of Gilmore City, Iowa. The term Gilmore City is hereby proposed for the rock formation lying unconformably below the St. Louis limestone in the vicinity of Gilmore City, Iowa.

LOCATION OF THE AREA

The exposures of the Gilmore City formation are confined to two localities. The most important are located in western Hum-

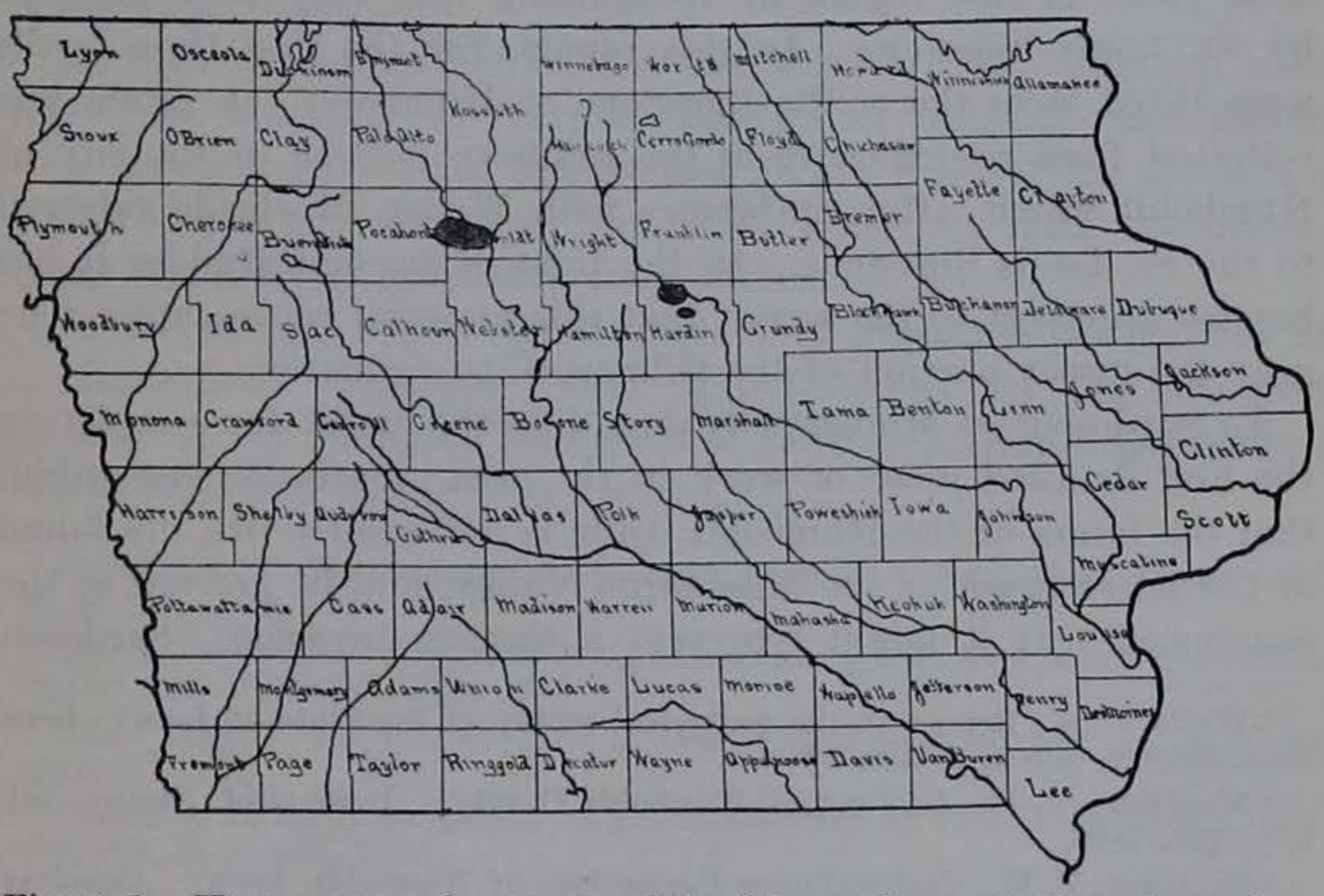

Figure 1. Known areas of exposure of the Gilmore City and Alden formations in Iowa.

boldt County along the Des Moines River valley and in the adjacent highland to the south of the river between Humboldt and Gilmore City. The best exposures of the formation are in the Gilmore City quarries which are located in the southwest portion of Sec. 25, T. 92 N., R. 31 W., in Pocahontas County. The other exposures in Pocahontas County are located within a few square miles in the immediate vicinity of Gilmore City.

The second locality in which this formation is exposed is in Hardin County along the Iowa River in the vicinity of Alden. In this area the exposures are limited to about five miles of the river valley.

PREVIOUS WORK

The first work in the area was done in 1870 by White[1] for the Iowa Geological Survey in which he reports "subcarboniferous" limestone of Kinderhook age along the Des Moines River near Humboldt. The St. Louis limestone which is also exposed in this region was considered by White to be of Kinderhook age. The exposures in Pocahontas County at the site of the present quarries at Gilmore City also were visited, and it was predicted that at some future time the rock would be an important source of lime.

In 1899 T. H. Macbride[2] limited the areal extent of the Kinderhook rocks in this region by recognizing that they were overlain by St. Louis limestone. In this report, for the first time fossils were listed from the oölitic limestone at Humboldt. A fauna was collected from an exposure in the southern portion of the city of Humboldt which, after conference with Weller, Macbride referred to the St. Louis limestone. In the light of present studies, it has become apparent to the writer that this material represents a zone near the upper portion of the Gilmore City formation.

To Sardeson[3] of Minneapolis should go the credit for completing the first detailed piece of work in the area. Sardeson recognized that the fauna of the Humboldt oölite is not exactly like the fauna of the Kinderhook of the Mississippi Valley, and he arrived at the conclusion that it might represent a western invasion. Sardeson

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1 White, C. A., Report on the geological survey of the State of Iowa: Iowa Geol. Survey, vol. 1, p. 218, 1870.

2 Macbride, T. H., Geology of Humboldt County: Iowa Geol. Survey, vol. 9, p. 123, 1899.

3 Sardeson, F. W., Carboniferous Formations of Humboldt, Iowa: American Geologist, vol. 30, p. 300, 1902.

remained until very recently the only worker who realized that this fauna was not the typical Kinderhookian fauna of the Upper Mississippi Valley. However he apparently followed Macbride and Weller in interpreting the fauna of the St. Louis limestone, when he collected fossils from the exposure of supposed St. Louis limestone in Mr. Peckham's quarry in the southeastern portion of the city of Humboldt and referred them to the St. Louis limestone.

In the report on the Geology of Pocahontas County, Macbride[4] mentioned that Kinderhook limestone is overlain by the St. Louis limestone in the eastern portion of Pocahontas County. At the present time no exposures of the St. Louis limestone are known in Pocahontas County.

In 1906 Beyer and Williams[5] refer to the St. Louis limestone overlying the Kinderhook limestones in Humboldt and Pocahontas counties. Many of the exposures of limestone considered to be of St. Louis age in their report are now known to belong to the upper zones of the Gilmore City formation.

In the report on the Mississippian of Iowa by Van Tuyl[6] the possibility of correlating the Humboldt oölite with the Alden limestone of Hardin County was suggested. The fauna of the Humboldt oölite was considered to be Kinderhook in age but no direct correlations were made with the type Kinderhook section of the Mississippi Valley.

In 1932 the writer[7] correlated the Gilmore City limestone with the Alden limestone of Hardin County and removed the Gilmore City formation from the Kinderhook on the basis of the sharp unconformity which separates the Alden limestone from the underlying Kinderhook beds near Iowa Falls.

In the present report the Gilmore City limestone is regarded as a Kinderhook formation lying unconformably on the youngest member of the Hampton formation of Iowa and beneath the earliest strata referable to the Osage series.

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[4] Macbride, T. H., Geology of Pocahontas County: Iowa Geol. Survey, vol. 15, p. 227, 1905.

[5] Beyer, S. W., and Williams, I. A., Limestone Quarries of Iowa: Iowa Geol. Survey, vol. 17, p. 425, 1906.

[6] Van Tuyl, F. M., Mississippian of Iowa: Iowa Geol. Survey, vol. 30, p. 99, 1922.

[7] Laudon, L. R., Stratigraphy of the Kinderhook of Iowa: Iowa Geol. Survey, vol. 35, p. 417, 1932.

TOPOGRAPHY AND DRAINAGE

The area of exposure of the Gilmore City formation lies entirely within the drift plain of the Wisconsin Glacier. The area around Gilmore City is a rolling plain with little relief. In the immediate vicinity of Gilmore City the drift mantle, overlying the bed rock, is very thin and at the site of the two main quarries at Gilmore City the bed rock is essentially at the surface.

The Wisconsin drift plain of this area is cut by two branches of the Des Moines River. These rivers have cut shallow, comparatively wide, valleys in the drift and throughout the distance from Bradgate to Humboldt, the west fork of the river flows essentially on the upper surface of the Gilmore City formation. From Rutland to Humboldt the river has cut a shallow valley into the upper portion of the formation, producing low cliffs on the outside of the meanders. South and east of Humboldt the only exposures visible on the bank of the river are of later age.

GENERAL GEOLOGY

The formations exposed in the Gilmore City area are confined to two geologic periods. The Gilmore City formation is the oldest horizon exposed in the region and consists almost entirely of gray, white, or blue cross-bedded limestone. It is unconformably overlain by the St. Louis limestone, and the contact of the two is usually leached. The St. Louis formation consists of brown dolomite at the base followed by gray brecciated limestone. Occasional lenses of shaly blue or green sandstone are to be found in the lower portion.

The St. Louis limestone is unconformably overlain by shales and sandstones of Pennsylvanian age. Several exposures showing the contact of the two formations may be seen along the Des Moines River valley near Humboldt.

ACKNOWLEDGMENTS

To one great student in the field of crinoidal structure, the writer is forever indebted. Almost all of the spare time throughout one complete year was spent by the late Professor A. O. Thomas of the State University of Iowa in study and in preparation for study of many of the specimens which are figured in this report. The writer owes almost all of his training in the field of crinoidal structure to Professor Thomas. To those who knew Dr. Thomas

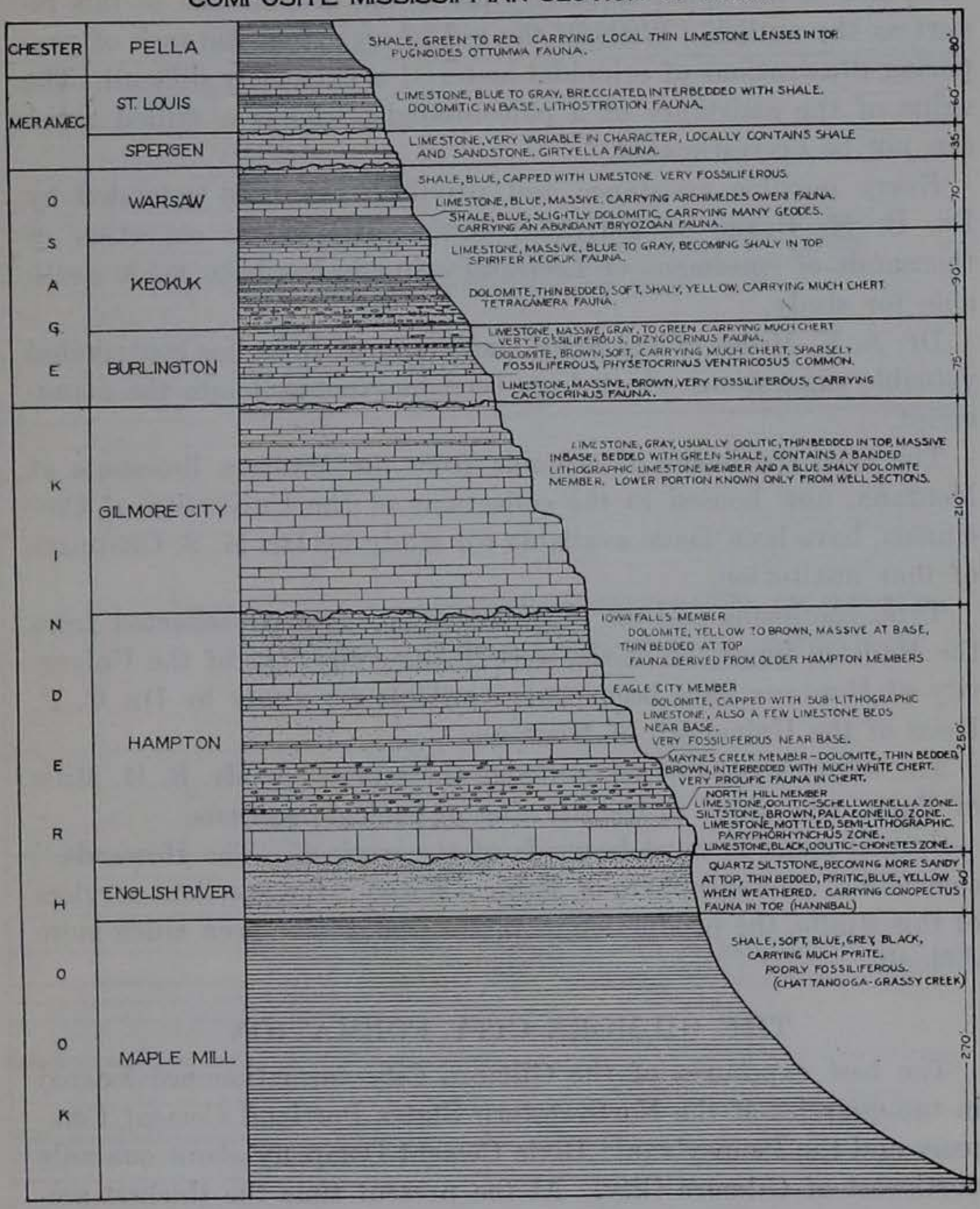

Figure 2. Composite Mississippian section of Iowa.

and knew of his intense interest in crinoids, this report will mean more.

Mr. C. T. Kohn, paleontologist and geologic artist for the Mid-Continent Oil Corporation of Tulsa, drew all of the illustrations which appear in the plates of this report. Through two years of study Mr. Kohn has become an excellent student of crinoidal struc-

ture, and he has spent as much time in the preparation of this report as the author. Without the aid of an artist, the task of preparing illustrations of crinoidal material is extremely difficult. The value of the assistance of a paleontologist who is a skilled artist can not be overestimated.

Every possible assistance and privilege has been extended by Dr. B. H. Beane of LeGrand, Iowa. His entire collection of thousands of specimens of LeGrand crinoids has been made available for study.

Dr. A. K. Miller of the State University of Iowa has contributed valuable suggestions which have been incorporated into the manuscript.

The type specimens of crinoids from the Madison limestone of Montana, now housed in the collections of the University of Cincinnati, have been made available for study by Dr. M. S. Chappars of that institution.

Type specimens and all other crinoidal material collected from the Madison limestone of the west in the collections of the University of Montana have been made available for study by Dr. C. F. Deiss of the University of Montana.

The writer wishes to acknowledge the services of Mr. B. H. Mills of Tulsa, who aided in the drawing of geologic sections.

Special mention must be made of the work of "The Howards," commercial photographers of Tulsa. Without the excellent services of this studio, the production of plates would have been much more difficult.

THE GILMORE CITY FORMATION

The best exposures of the Gilmore City formation are located in the quarries of the Northwestern States Portland Cement Company and the Pennsylvania Dixie Cement Company about one mile northwest of Gilmore City. At the present time the thickest section consisting of 57 feet of limestone is exposed in the northwestern corner of the Pennsylvania Dixie Quarry and is here designated as the type section of the formation. The uppermost beds of the formation are missing from this section, due to erosion, but are well exposed along the Des Moines River in the vicinity of Humboldt. The lower portion of the formation is not exposed in Iowa and is known only from well borings.

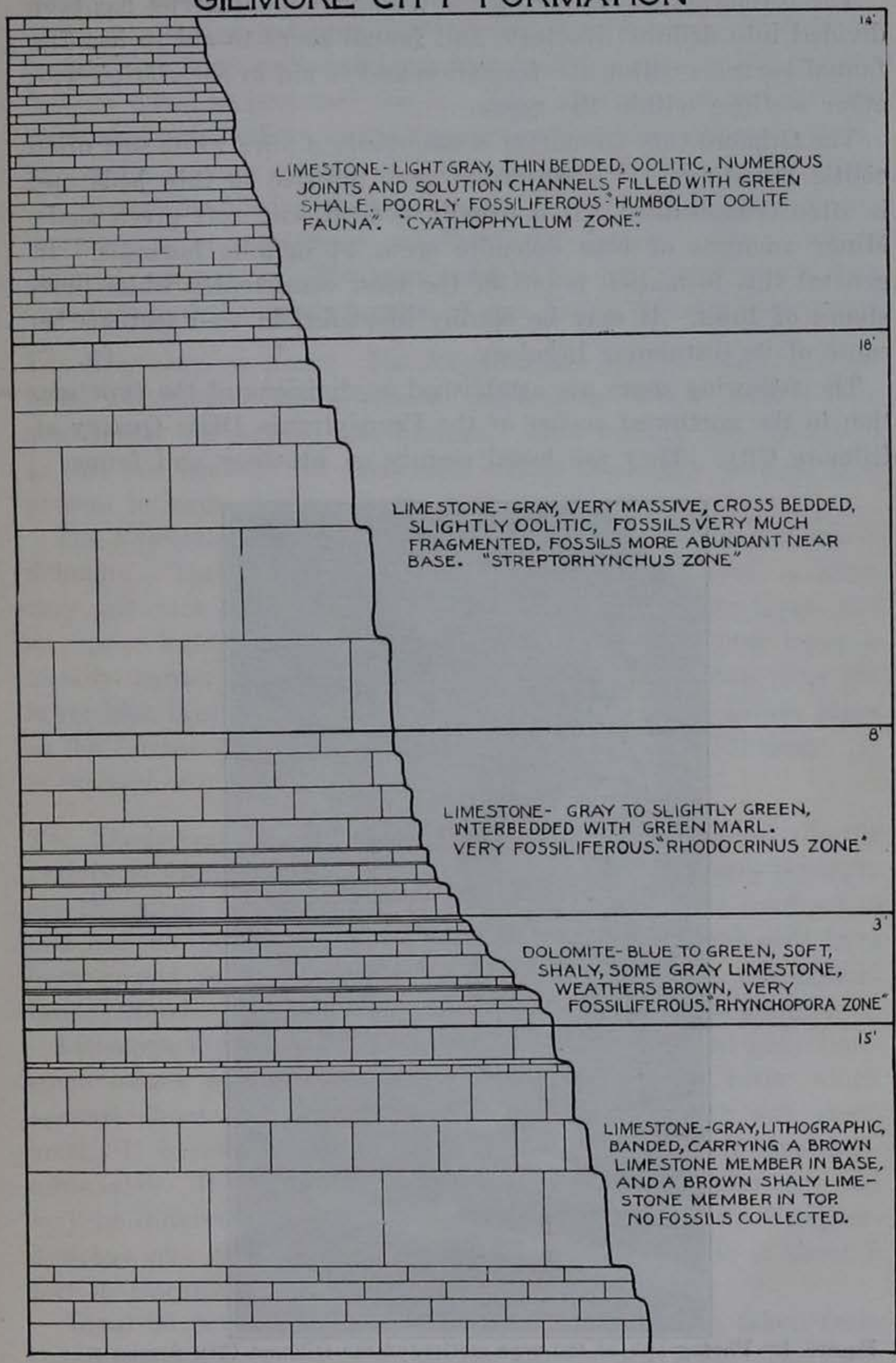

Figure 3. Type section of the Gilmore City formation.

LITHOLOGIC CHARACTER

The formation as exposed in the Gilmore City quarries has been divided into definite lithologic and faunal zones to aid in locating faunal horizons within the formation and to aid in correlation with other sections within the region.

The Gilmore City formation is essentially a pure white soft often oölitic limestone. It varies from very massive to thin beds and is often cross-bedded. It is usually bedded with soft green shale. Minor amounts of blue dolomite occur at definite horizons. In general this formation is one of the most consistently white limestones of Iowa. It may be readily identified in well sections because of its distinctive lithology.

The following zones are established as divisions of the type section in the northwest corner of the Pennsylvania Dixie Quarry at Gilmore City. They are based mainly on lithology and fauna.

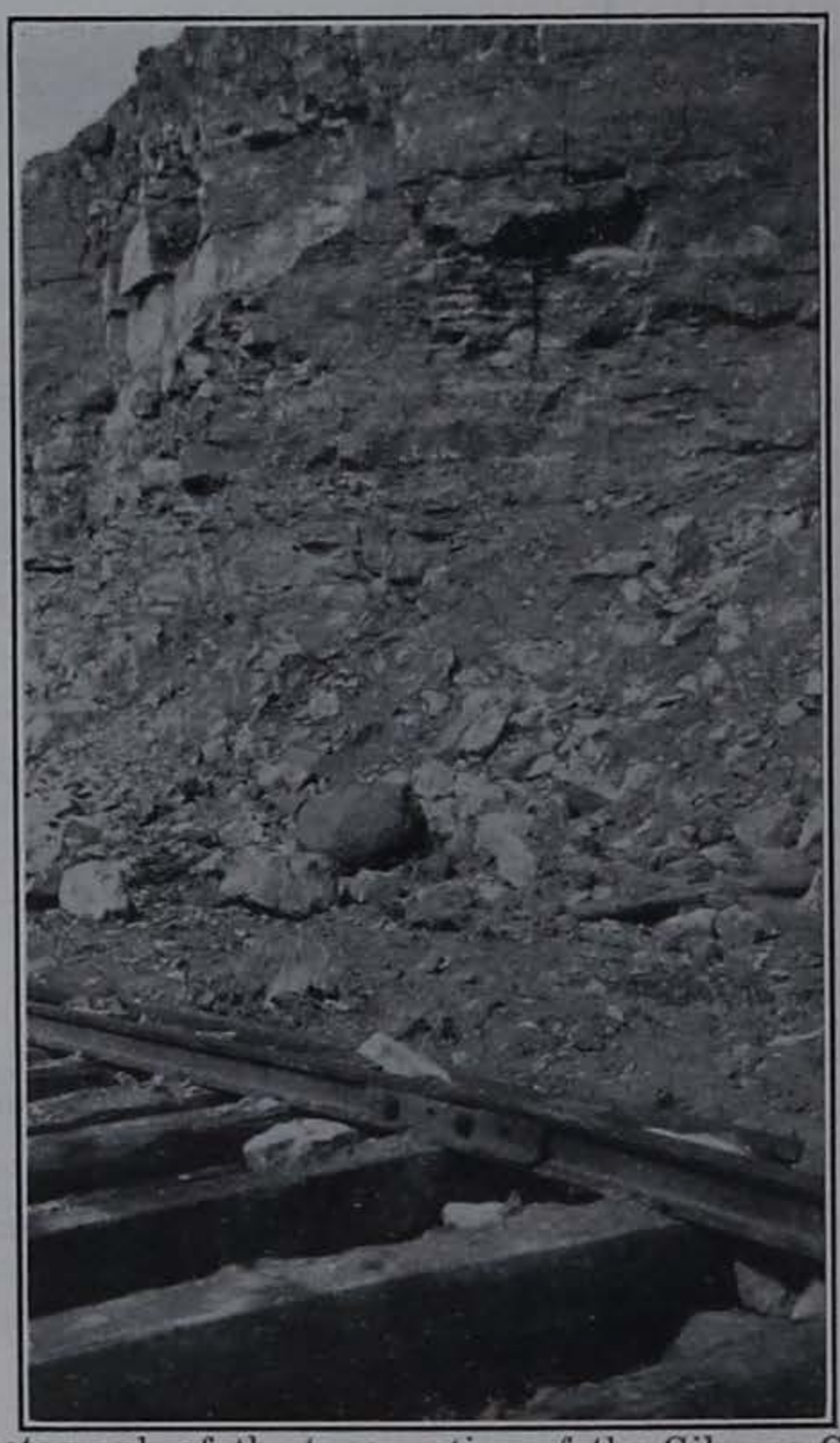

Figure 4. Photograph of the type section of the Gilmore City formation.

Lowermost Zone (Unnamed): The Pennsylvania Dixie Company opened a lower horizon in the quarry late in the summer of 1931 which has not as yet been well studied. At the present time no fossils have been collected from this horizon, and because of this fact no name is proposed for it. This zone may be readily distinguished from others in the formation of its distinctive lithology. The major portion consists of delicately banded gray semi-lithographic limestone filled with large masses of calcite. Banding in the limestone is in some cases parallel to the bedding and in others definitely concentric. The basal ledge of the zone consists of brown limestone and the upper portion of soft brown dolomitic limestone.

The Rhynchopora Zone: The *Rhynchopora* zone is named for the fossil brachiopod *Rhynchopora cooperensis* which occurs very abundantly throughout the horizon. This form is not restricted to this one zone in the formation and is used only because it is present in large numbers in the zone.

The *Rhynchopora* zone consists of about 5 feet of blue soft marly dolomite. There are usually three portions to the zone: a lower very soft dark blue layer, a central hard gray limestone layer, and an upper lighter blue dolomitic layer. This upper blue layer is usually harder, thinner bedded, and carries more lime than the lower blue layer. This zone would make an excellent datum plane in the formation because of its distinctive color and lithology. It is exposed only in the quarries at Gilmore City.

The Rhodocrinus Zone: The *Rhodocrinus* zone is named for the variety of species of *Rhodocrinus* which occur abundantly throughout the entire horizon. The genus *Rhodocrinus* is not confined to this horizon, but it is rare in others. This zone might well have been named for a number of forms which occur in the crinoid fauna; *Rhodocrinus* however was chosen because of its abundance.

Lithologically the *Rhodocrinus* zone consists of hard gray limestone ledges which are often slightly oölitic. The beds, which average about one foot in thickness, are bedded with soft green marl. It is rather sharply defined beneath by the soft blue dolomitic layer. It grades into the overlying *Streptorhynchus* zone and may be differentiated from it only by the fact that the *Streptorhynchus* zone is more massive. The *Rhodocrinus* zone is about 8 feet in thickness.

About 95 per cent of the crinoids which have been taken from this formation were found within the *Rhodocrinus* zone. The lime-

from Rutland to Humboldt. The St. Louis formation retains its usual wavy, thin-bedded appearance in this region and may be easily recognized by its lithological character alone. The basal beds are usually brown dolomite and are followed by typical gray, brecciated, sub-lithographic limestone. A good exposure of the unconformable contact may be seen about 200 feet downstream from the dam at Rutland on the north bank of the river. Other good exposures of the contact may be seen at intervals throughout the distance from Rutland to Humboldt. A very good exposure showing this contact may be seen in an old abandoned quarry in the extreme southern portion of the city of Humboldt.

The lower three zones of the Gilmore City formation are exposed only in the quarries at Gilmore City. The *Streptorhynchus* zone is exposed in one or two abandoned quarries in the immediate vicinity of Gilmore City. Most of the exposures in the region consist of a portion of the *Cyathophyllum* zone. Numerous exposures of this zone may be seen in sink holes in both Humboldt and Pocahontas counties. All of the exposures along the Des Moines River from Bradgate to Humboldt represent some part of this zone.

SUBSURFACE STRATIGRAPHY

The Gilmore City formation may be traced in deep well sections very successfully because of its distinctive lithology. It is a pure soft white often oölitic limestone which usually carries very little chert. The Osage formations which would naturally overlie this formation are everywhere characterized by great amounts of chert. The St. Louis formation may be easily recognized because it consists of alternating beds of dolomite, limestone, and shale with considerable chert. The underlying Kinderhook formations are dolomitic or shaly in their nature.

The following data have been taken from Norton's[9] interpretations of the deep well sections of Iowa. The well cuttings have not been seen by the author and the following interpretations are based entirely on the original descriptions of Norton.

Deep wells at Fort Dodge in Webster County show a thickness of 210 feet of material which may be referred to the Gilmore City formation. The Gilmore City is overlain by the St. Louis lime-

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[9] Norton, W. H., Underground Water Resources of Iowa: Iowa Geol. Survey, vol. 21, 1913, vol. 33, 1930.

stone and underlain by the cherty dolomites of the Hampton formation. The upper contact of the formation was reached at 200 feet and the lower contact at 420 feet. The lowermost shaly material in the Mississippian section as designated by Norton in this well should probably be referred to the Sheffield formation.

At Gowrie in the southern portion of Webster County the thickness of the Gilmore City has increased to 250 feet. It is overlain by the St. Louis limestone and underlain by 90 feet of material which probably should be referred to the Hampton formation. The Hampton formation gradually undergoes changes toward the south and becomes more sandy and shaly.

The Gilmore City formation is 280 feet in thickness in the deep well at Denison in Crawford County and is overlain by a very thick section of the St. Louis limestone. It is questionable whether or not the Hampton formation is present at all in this section. The Gilmore City-St. Louis contact is found at a depth of 490 feet.

At Audubon in Audubon County the Gilmore City formation is 285 feet in thickness. Nearly 100 feet of strata representing the Hampton formation occur below the Gilmore City formation. At least 50 feet of Chattanooga shale is present at the base of the Mississippian section in this well. The upper contact of the Gilmore City is found at 660 feet and the lower contact is located at 945 feet.

At Dunlap in Harrison County the formation is 265 feet in thickness. At Logan in the same county it is 280 feet in thickness. At California, also in the same county, about 254 feet of limestone of Gilmore City age are present. The descriptions of the soft white oölitic limestone in these wells make its identity almost certain.

At Holstein in Ida County the St. Louis limestone is underlain by 60 feet of limestone and dolomite which should probably be referred to the Gilmore City formation. At Sioux City the St. Louis is again underlain by 60 feet of limestone which seems certainly to represent a portion of the Gilmore City formation. It is very apparent that the Gilmore City formation thins rapidly to the north.

A thickness of 140 feet is assigned to the Gilmore City formation in the well at Rippey in Greene County. It is overlain by 100 feet of St. Louis limestone and is underlain by 140 feet of beds which may be referred to the Kinderhook. The upper contact is located at 430 feet and the lower contact at 570 feet.

In the Stuart well in southern Guthrie County 100 feet of lime-

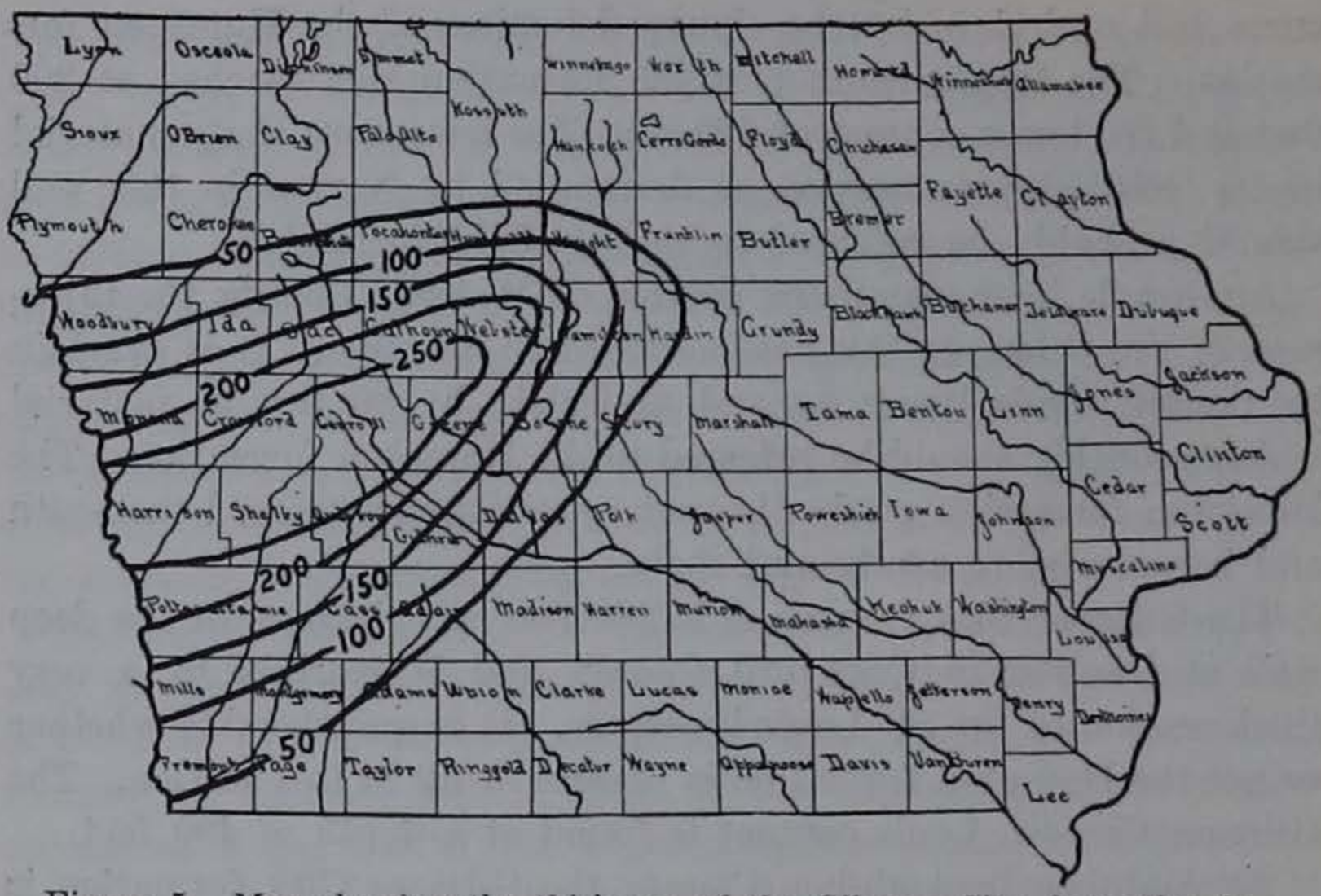


Figure 5. Map showing the thickness of the Gilmore City formation in western Iowa.

stone may be referred to the Gilmore City formation. It is overlain by St. Louis limestone and underlain by Hampton. The base of the Mississippian section is marked by the Chattanooga black shale.

At Atlantic in Cass County it is quite difficult to separate the Gilmore City formation from the overlying beds of the Osage series. The formations have been logged showing a considerable amount of chert throughout the entire Mississippian section. The presence of much chert in the Gilmore City formation is unusual. It seems probable however that much of this chert might have come from the overlying Osage formations. A green shale bed between the Gilmore City and the chert horizons probably represents the St. Joe formation of Missouri, Kansas, and Oklahoma. The Gilmore City appears to be about 170 feet in thickness in this well.

At Council Bluffs and Omaha, wells have been drilled which show nearly 200 feet of limestone underneath the green shale horizon at the base of the Osage series. Above the green shale horizon some 200 feet of cherty limestone has been logged which represents the Osage-Boone series of Missouri, Oklahoma, and Kansas.

South of Omaha the Gilmore City formation thins quite rapidly so that at Glenwood it is represented by only 105 feet of strata.

It is again overlain by green shale of the basal Osage and underlain by Kinderhook shales, the lower portion of which are probably Chattanooga in age. The upper contact of the Gilmore City formation is located at 1668 feet and the lower contact at 1765 feet.

In the deep well at the city of Bedford in Taylor County the Osage series is represented by over 300 feet of cherty limestone. At the base of this cherty limestone, a bed of soft white oölitic limestone has been logged. This oölitic limestone is underlain by the Chattanooga black shale. It may be that this thin layer represents a southern extension of the Gilmore City formation or it may represent some portion of the Chouteau formation of Missouri.

The Gilmore City formation is present throughout the north central basin from Gilmore City to Alden. In the Webster City well in Hamilton County the Gilmore City formation is over 100 feet in thickness and is apparently overlain by a few thin beds of St. Louis limestone. The St. Louis is exposed in the valley of the Boone River a short distance south of Webster City. In this well the Gilmore City is underlain by 180 feet of dolomitic limestone which should be referred to the Hampton formation. The Hampton formation is underlain by the Sheffield formation of Upper Devonian age. The Gilmore City-Hampton contact is at 230 feet.

At Boone only 30 feet of material can be referred to the Gilmore City formation. It is overlain by the St. Louis formation and underlain by 20 feet of shale which lies above the typical Hampton dolomites. The base of the Hampton formation in this section is marked by the oölitic *Schellwienella* zone which marks the base of the formation at LeGrand, Iowa. The Hampton formation is underlain by the Chattanooga shale which is in turn underlain by the Sheffield shales of Devonian age. The true relation between the Sheffield and Chattanooga is shown in this section. The black shales of Chattanooga age are deposited on the uppermost limestone beds which occur at the top of the Sheffield section. The upper contact of the Gilmore City formation is placed at 470 feet and the lower contact at 500 feet.

The Gilmore City formation thins rapidly toward the south and east and is not recognized in the wells at Des Moines.

The distribution of the Gilmore City formation in Iowa shows that a basin of deposition existed in late Kinderhook times with its deepest portion running from Fort Dodge southwest through northeast Greene, central Carroll, southeastern Crawford, northwestern

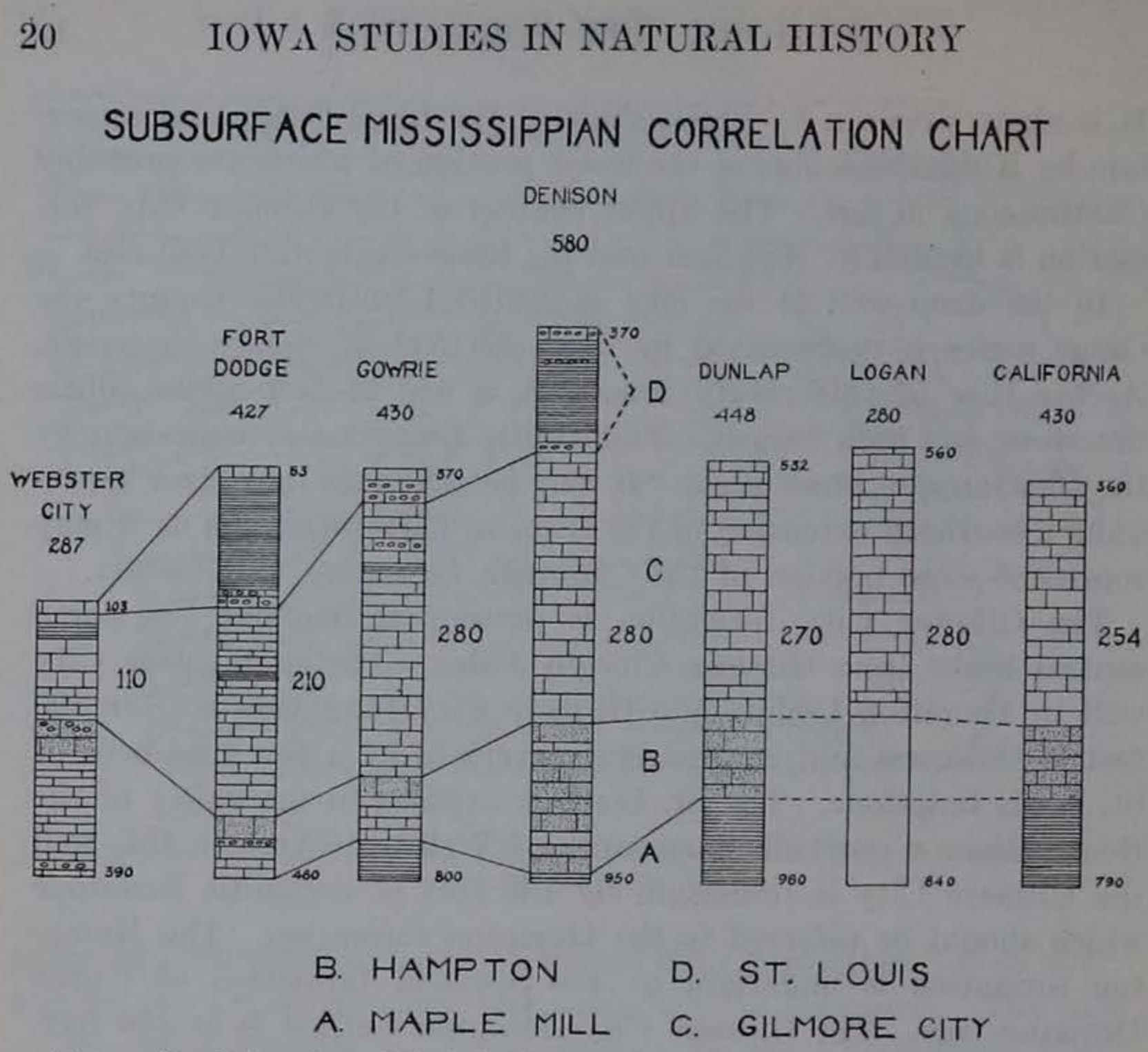


Figure 6. Subsurface Mississippian correlation chart for western Iowa.

Shelby, and central Harrison counties. The formation thins rapidly to the north from this axis and is overlain by the St. Louis formation. Southward from this axis it also thins quite rapidly but is overlapped by the cherty Osage limestone formations.

STRUCTURE

Because of the mantle of glacial drift which obscures the region, it is difficult to determine the type of structure which brings the Gilmore City formation to the surface. Since the formation is exposed at the grass roots in many places in the type area, it becomes evident that this region was a topographic high at the time of the glacial invasion.

The dip of the formation at Gilmore City is to the northeast at a low angle. The direction of dip changes to east a short distance to the east of Gilmore City. At Humboldt the direction of dip is to the southeast. These surface relations would suggest either a low fold with an axis to the south of the Gilmore City area or a

fault trending northwest southeast located somewhere to the south of the Gilmore City area.

The area immediately around Gilmore City has long been known for its sink holes. The area at one time had a large number of sinks scattered over the surface, but it becomes very questionable as to whether the topographic features referred to in this region at the present time as sinks are correctly named. Certainly their origin is slightly different from the origin of the usual sink hole.

At one time the surface of the limestone in this region was well covered with sink holes which led downward to a very well defined subterranean drainage system. It seems probable that the region was at one time underlain by extensive caverns. This underground drainage system is still present as evidenced by the fact that the farms of the region are drained into these sinks. At the time of heavy rains a downward suction may be observed in almost all of the larger holes. Quarrying in the region has been hindered by these large sink holes which are now filled with marine muds and shales. In addition to the sink holes, large numbers of underground channels filled with marine shale and having no immediate connection to the surface may be seen in the quarry faces.

The features referred to as sinks in this region have had their origin in somewhat this manner. These old sink holes filled with marine shale were covered with glacial drift. Ground water percolating down through the drift has gradually reopened some of the connections to the old underground drainage system. The drift immediately overlying the opening has gradually been carried down into the underlying limestone and deposited in the crevices in the rock. The sinks themselves consist of a crater-like depression in the glacial drift ending in a leached crevice in the limestone surface. The origin of these sink-like depressions has been mainly a mechanical process rather than a chemical process. There are often as many as a dozen of these depressions to the square mile in the immediate vicinity of Gilmore City.

Sink holes and caverns are not usually developed in a region which is not well dissected by an extensive river system. In 1928 a deep well was drilled at Manson in Calhoun County some twenty miles southwest of Gilmore City. The drill should have entered the Mississippian limestone about 300 feet beneath the surface. Instead the well was drilled for 1211 feet without penetrating anything but arkose and shale. The well was stopped while still drill-

ing in arkosic material. The drill should have entered the lower Ordovician strata at this depth. The material represented in this well has apparently been deposited in a deep river valley cut into the upper surface of the Paleozoic beds. The sinks and caverns in the Gilmore City limestone were very likely formed in connection with this river system.

There are two possibilities for the age of the shales and arkoses found in the Manson well. Gilmore City and Manson are both within the area of deposition of the Pennsylvanian and Cretaceous. Dr. A. C. Tester of the University of Iowa has made a very extensive study of Cretaceous sediments in Iowa and has expressed the opinion through personal communication that the highly arkosic sediments found in the lower portion of the Manson well are not Cretaceous in age. Since Pennsylvanian sediments exposed in the region are often coarsely clastic and Cretaceous sediments are usually shales, it would appear that the deep river valley at Manson was cut before Pennsylvanian times. This would make the uplift which developed the extensive caverns and sink holes in the region post-Kinderhook pre-Pennsylvanian in age. All of the shales which are found in the sink holes at Gilmore City need not necessarily be of Pennsylvanian age however since the Cretaceous sea undoubtedly covered the area.

Additional evidence supporting the Pennsylvanian age of the uplift which formed the sink holes may be found in the vicinity of Alden in Hardin County. The Alden limestone correlates with the Gilmore City limestone and is of the same lithologic character. Sink holes filled with marine shale are found in the quarry at Alden. These sink holes are almost identical in appearance with those of the Gilmore City area. Since the Pennsylvania sediments are exposed in the immediate vicinity of Alden and the nearest exposure of the Cretaceous is a considerable distance to the west, it would seem likely that the shales in the sink holes at Alden are of Pennsylvanian age.

PALEONTOLOGY

Approximately 70 species of marine invertebrates have been collected from the Gilmore City limestone in the past three summer field seasons. Taken as a whole the formation is not particularly fossiliferous although a few zones will yield a fairly large fauna. The fauna is distributed in the following proportions: Coelenterata 6, Echinodermata 32, Molluscoidea 15, and Mollusca 21.

The Rhynchopora Zone: Fossils are exceptionally abundant in the blue shaly dolomite of the *Rhynchopora* zone. Slabs of the stone from the upper portion of the zone are often well covered with brachiopod shells and bryozoans. The following fauna was collected from the quarries at Gilmore City.

Corals

Cyathophyllum glabrum Keyes
Michelinea placenta White

Crinoids

Rhodocrinus cavanaughi n.sp.
Rhodocrinus douglassi var. *constrictus* n.var.
Rhodocrinus douglassi var. *serpens* n.var.
Dichocrinus multiplex n.sp.
Culmicrinus thomasi n.sp.

Brachiopoda

Chonetes multicosta Winchell
Productus sedaliensis Weller
Rhynchopora cooperensis (Shumard)
Spirifer centronatus Winchell
Spiriferina solidirostris Winchell
Eumetria verneuiliana (Hall)
Cliothyridina obmaxima (McChesney)
Cliothyridina incrassata (Hall)

Two species of echinoids and one starfish from the *Rhynchopora* zone are now being described by Dr. G. A. Cooper of the United States National Museum.

Rhynchopora cooperensis and *Spirifer centronatus* are the most commonly occurring brachiopods in the zone. One species of echinoid and *Rhodocrinus douglassi* var. *serpens* also occur fairly abundantly in the zone. The lower portion is usually crowded with fucoids.

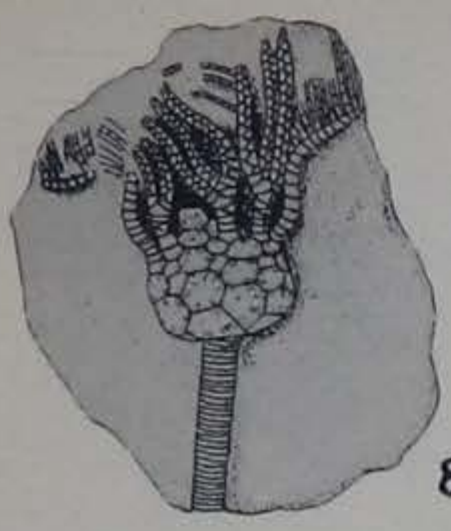
The Rhodocrinus Zone: The crinoid "nests" are all located within this zone. Most of the other fossils that have been collected from this zone have been associated with the crinoids. The most nicely preserved fossils in this zone are obtained in green shale lenses between the massive beds of gray limestone. Fossils may be obtained by breaking the gray limestone but their preservation does not compare with that of the shale partings. The following fauna has been collected from the *Rhodocrinus* zone in the two quarries at Gilmore City.

Corals
Cyathophyllum glabrum Keyes
Michelinea placenta White
Blastoids
Orophocrinus sp.
Cystoids
Agellacrinites sp.
Crinoids
Rhodocrinus watersianus Wachsmuth and Springer
Rhodocrinus douglassi Miller and Gurley
Rhodocrinus douglassi var. *serpens* n.var.
Rhodocrinus douglassi var. *multidactylus* n.var.

EXPLANATION OF PLATE I

GILMORE CITY FORMATION

Plate I



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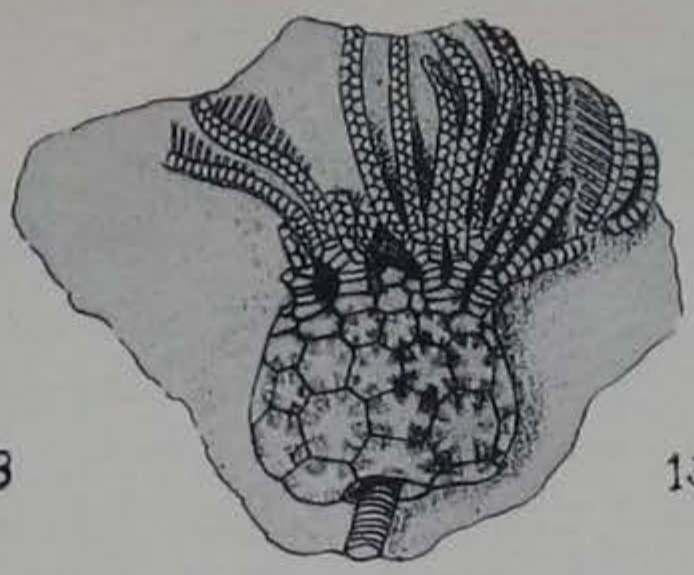

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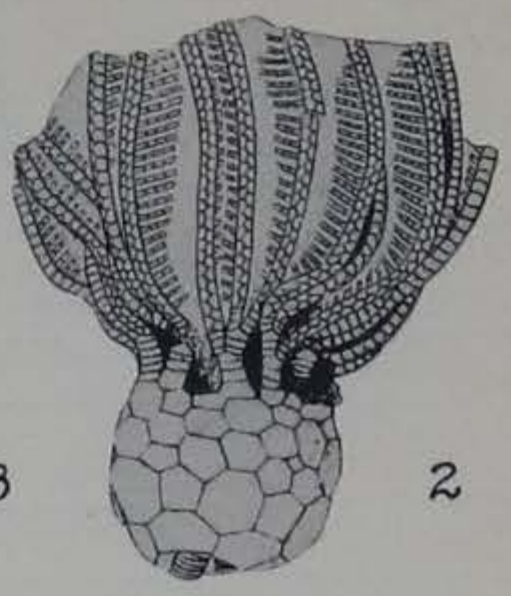

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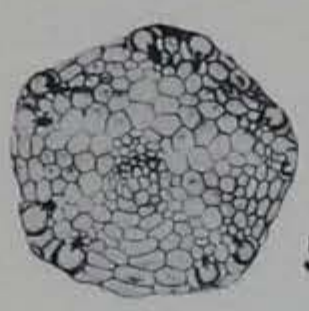

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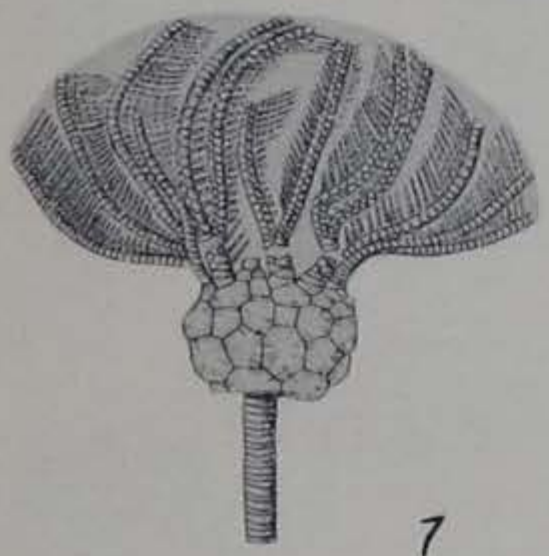

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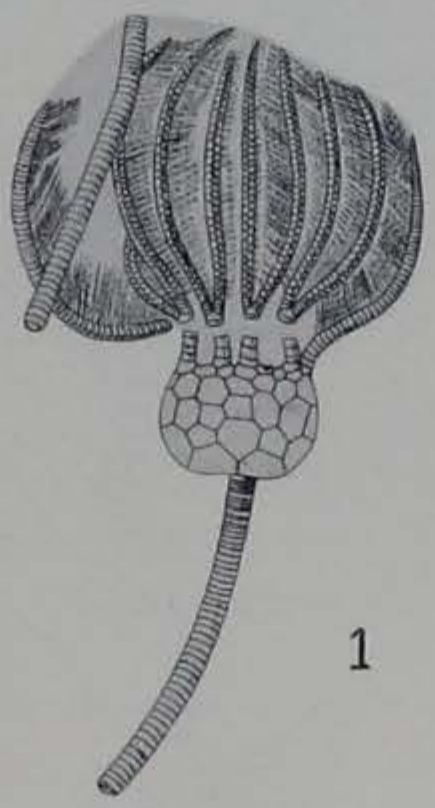

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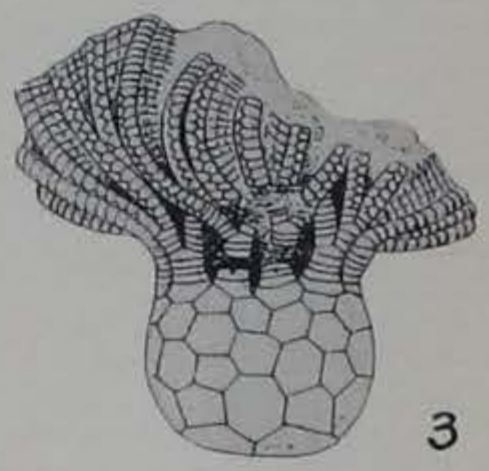

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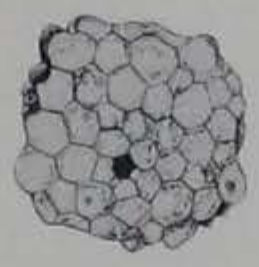

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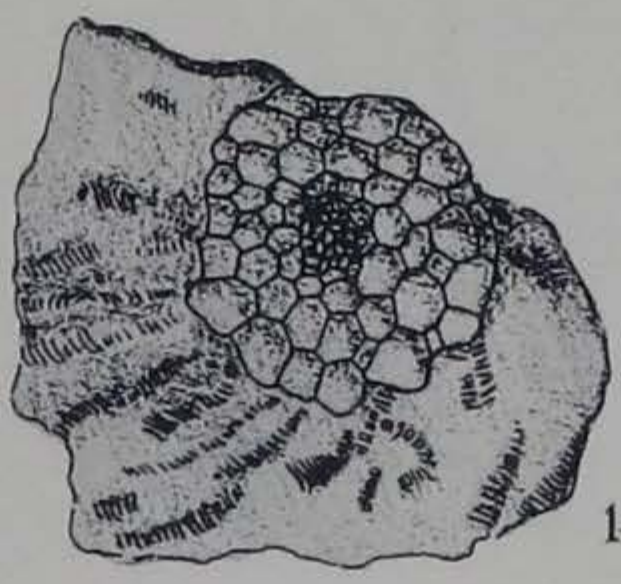

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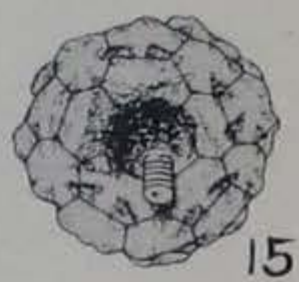

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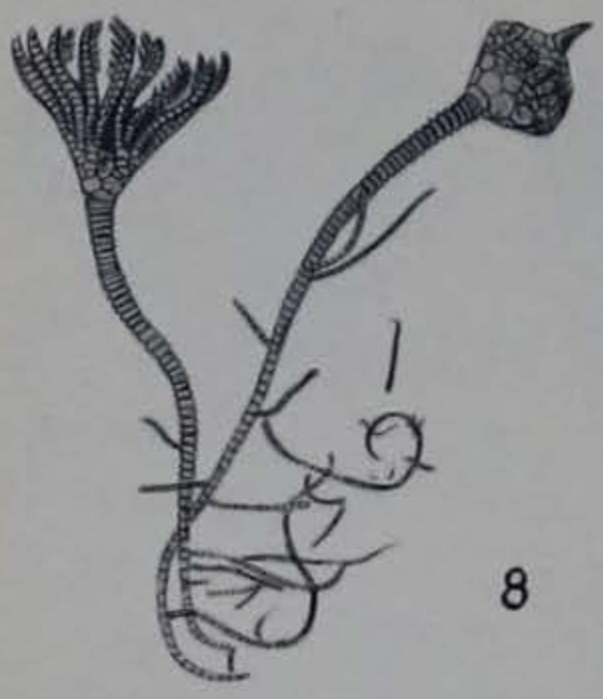
C. T. Kohn, del.



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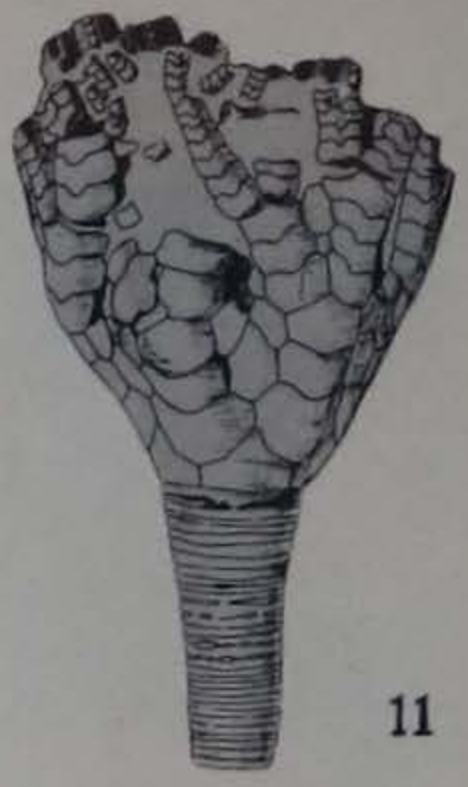

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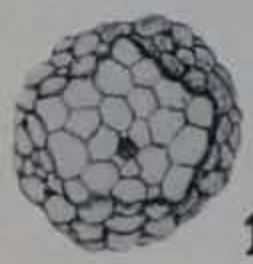

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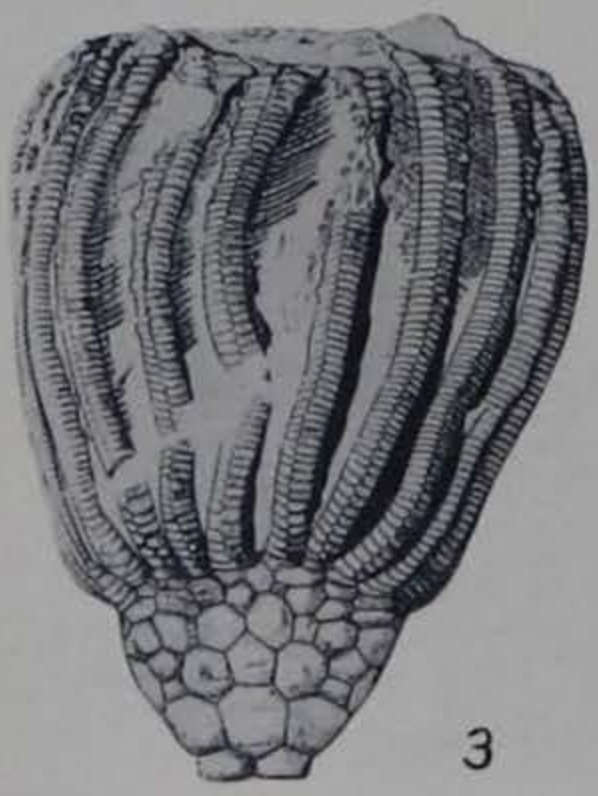

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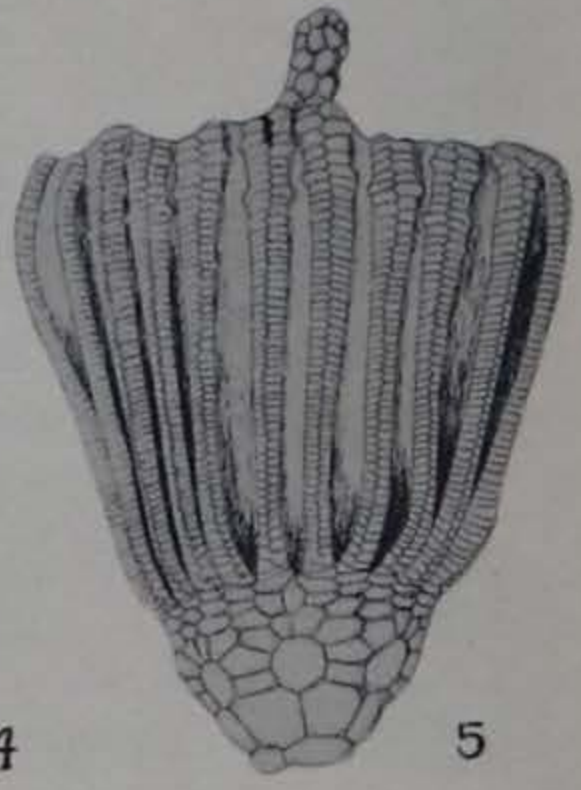

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C. T. Kohn, del.

Eretmocrinus tentor n.sp.
Aorocrinus iola n.sp.
Dichocrinus multiplex n.sp.
Dichocrinus campto n.sp.
Dichocrinus bozemanensis (Miller and Gurley)
Cactocrinus imperator n.sp.
Taxocrinus dero n.sp.
Pachylocrinus fimbra n.sp.
Pachylocrinus cirrifer n.sp.
Zeacrinus compactus n.sp.
Culmicrinus thomasi n.sp.
Decadocrinus douglassi (Miller and Gurley)
Gilmocrinus iowensis n.sp.
Lasiocrinus expressus n.sp.
Goniocrinus maximus n.sp.

Brachiopoda
Productus sedaliensis Weller

EXPLANATION OF PLATE II

occasional specimens of *Cliothyridina obmaxima* and *Spirifer calvini.*

The Streptorhynchus Zone: The fauna of the *Streptorhynchus* zone is not large nor are the individuals abundant within the zone. Had it not been for the fact that blasting in the quarry has prepared a tremendous amount of material from this zone for observation, the number of specimens collected would have been quite limited. The following fauna was collected from this zone in the quarries at Gilmore City.

Corals

Aulopora geometrica Girty
Syringopora sercularia Girty

Crinoids

Rhodocrinus douglassi var. *serpens* n.var.

Echinoidea

Echinoid spines

Brachiopoda

Streptorhynchus ruginosa (Hall and Clarke)
Rhynchopora cooperensis (Shumard)
Spirifer centronatus Winchell
Eumetria verneuiliana (Hall)
Cliothyridina obmaxima (McChesney)
Seminula pussila Girty

Gastropoda

Omphalotrochus springvalensis (White)
Capulus triblosus (White)

The Cyathophyllum Zone: This zone is not an abundantly fossiliferous horizon at any locality. In the Gilmore City quarries it is particularly unfossiliferous. One thin bed about 12 feet above the *Streptorhynchus* zone is filled with slender cyathophylloid corals. This bed is usually within a few feet of the upper surface of the quarry. Cross sections of the corals may be seen on the faces and ends of slabs in great abundance in this one narrow horizon. The following fauna was collected from the zone at Gilmore City.

Corals

Amplexus blairi Miller
Cyathophyllum sp.

Gastropoda

Omphalotrochus springvalensis (White)
Straparollus macromphalus Winchell

The *Cyathophyllum* zone is exposed along the Des Moines River Valley just downstream from the village of Rutland. At this exposure the zone is characterized by exceptionally large oölites. The limestone is very hard and consequently does not offer exceptionally good collecting. *Cyathophyllum* and *Omphalotrochus springvalensis* may be seen quite abundantly in the dense limestone.

About 90 per cent of the fauna known from the *Cyathophyllum* zone has been obtained from one exposure on the north bank of the Des Moines River just downstream from the bridge, on State Highway number 20, in the city of Humboldt. About 15 feet of oölitic limestone is exposed, which for some reason has become very much weathered. The cementing material for the oölites has been removed leaving a crumbling mass. This is the exposure from which Sardeson[10] collected his fauna from the Humboldt oölite. The fossils occur mainly in lenses about eight feet above the level of the water. The following fauna has been collected from the *Cyathophyllum* zone at Humboldt.

Corals

Zaphrestis sp.
Amplexus blairi Miller
Cyathophyllum sp.

Crinoids

Dichocrinus sp.

Brachiopods

Streptorhynchus ruginosa (Hall and Clarke)
Rhynchotreta gibbosum (Greger)
Dielasma sp.
Spirifer centronatus Winchell
Martinia lata Girty
Eumetria perstrialis Rowley

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10 Sardeson, F. W., The Carboniferous Formations of Humboldt, Iowa: Amer. Geologist, vol. 30, p. 300, 1902.

Pelecypods

Macrodon blairi Miller and Gurley
Conocardium cuneatum Hall
Leiopteria subovata Miller and Gurley
Schizodus sedaliensis Miller and Gurley

Gastropods

Bellerophon blairi Miller and Gurley
Bellerophon sublaevis Hall
Bellerophon panneus White
Bellerophon sp.
Pleurotomaria sp.
Worthenia sp
Murchisonia quadricincta Winchell
Omphalotrochus springvalensis White
Straparollus macromphalus Winchell
Strophostylus carleyana (Hall)
Holopea conica Winchell
Platyceras sp.
Loxonema sp.
Eotrochus concavus (Hall)

At first glance one is impressed with the similarity of this fauna with that of the Spergen formation of the Meramec. A close examination of this fauna however will reveal that it is not the Spergen fauna and that it is far older. It has its closest affinities with the molluscan fauna of the Wassonville member of the Hampton formation of Iowa.

CORRELATION

The writer believes that the Gilmore City formation represents an eastward invasion of some portion of the Madison sea of the west. Its stratigraphic position, its fauna, its lithology, and its distribution all point toward this correlation. Should this correlation later prove to be correct, it is obvious that a much more satisfactory basis for determining the correct age of the Madison limestone itself will have been established. The writer is also of the opinion at the present time, although very little evidence could be advanced to support this opinion, that the Madison of the west does not correspond in time interval to as much of the Mississippi Valley Mississippian as has been heretofore supposed. The follow-

ing evidence is presented in support of the Madison-Gilmore City correlation.

Stratigraphic position: Since the lower contact of the Gilmore City formation is not exposed in the type area, the relation of its correlative, the Alden limestone of Hardin County, to the underlying formations becomes important.

The Alden limestone was correlated with the Gilmore City formation by the writer[11] in 1931. The stratigraphic positions of the two formations are identical. Their lithological character is very similar and is entirely different from any other Iowa limestone. The sink holes filled with marine shales are very similar in both limestone formations and are not found in other limestone formations in Iowa. The Gilmore City limestone may be traced continuously in well sections from Gilmore City to Alden.

The Alden limestone lies unconformably on the upper eroded surface of the Iowa Falls member of the Hampton formation. The unconformity is so sharp that the entire thickness of the Iowa Falls member is beveled by the Alden limestone in a distance of about three miles. The lower portion of the Hampton formation of Iowa is correlated zone for zone with the Chouteau limestone of Missouri. The upper three members of the Hampton formation comprising some 200 feet of strata are younger than any portion of the Chouteau of Missouri. The upper portion of the Hampton formation however is not separated from the lower portion by an unconformity and its fauna is definitely derived from the Chouteau fauna. The Gilmore City formation was deposited upon the upper eroded surface of a formation that has heretofore been considered to be the youngest known Kinderhook.

In all of the surface exposures of the Burlington limestone in Iowa its lower contact is marked by an unconformity. In eastern Iowa the Burlington limestone overlaps against the Kinderhook surface and each of the zones of the Burlington may be found in contact with the underlying Kinderhook in definite order towards the north and west. The Fern Glen-St. Joe horizon is entirely missing in the eastern Iowa section. The lower portion of the lower Burlington of Missouri is also missing in the type section at Burlington. In western Iowa the cherty Osage formations definitely overlap onto the Gilmore City surface. The Gilmore City lime-

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11 Laudon, L. R., Stratigraphy of the Kinderhook Series of Iowa: Iowa Geol. Survey, vol. 35, p. 416, 1929.

stone may be seen from these relations to occupy a position between what used to be considered uppermost Kinderhook and the earliest Osage.

Lithologic Character: In the Madison limestone of Wyoming and Montana and in the Pahasapa limestone of the Black Hills, may be seen considerable amounts of pure light gray limestone. The purity and color of the Gilmore City limestone resembles these western limestones very much. Such a lithologic similarity is undoubtedly of little significance when considered over such large distances. However, since these same light gray colors are characteristic of the Madison over tremendous distances, they may be of some value in this case.

Paleontological relationships: An analysis of the Gilmore City fauna yields a tremendous amount of information with regard to its age. In the fauna consisting of some 70 species of invertebrates about 41 may be positively identified. These forms are distributed in the following manner: Kinderhook 19, Madison 19, Osage 16, and Meramec 6. A critical analysis of the fauna would indicate that it was younger than the Hampton of Iowa. The presence of *Rhodocrinus watersianus, Productus sedaliensis, Spiriferina solidirostris, Spirifer centronatus, Spirifer calvini, Eumetria verneuiliana, Cliothyridina incrassata, Macrodon blairi, Liopteria subovata,* and *Straparollus macromphalus* are very characteristic of the Hampton formation. The presence of *Aulopora geometrica, Syringopora sercula, Rhodocrinus douglassi, Dichocrinus bozemanensis, Seminula pussila, Seminula humilis, Spirifer centronatus, Martinia lata,* and *Straparollus ophirensis* suggest very strongly the Madison.

A comparison of the Gilmore City fauna with faunas collected from the Pahasapa limestone of the Black Hills, the Madison limestone of Montana, and the Upper Banff limestone of Lake Minnewanka, Alberta, show that most of the Gilmore City forms may be duplicated in these western formations. Since the western faunas are very incompletely described at the present time, definite comparisons cannot be made.

These western Mississippian formations are all characterized by an abundance of varieties of *Spirifer centronatus*. The Gilmore City fauna is very definitely a *Spirifer centronatus* fauna since that form occurs far more abundantly than any other form. None

of the limestone of Mississippian age in the Mississippi Valley older than Meramec are characterized by large numbers of individuals of the genus *Syringopora*. *Rhynchopora cooperensis* which occurs very abundantly in the Gilmore City formation was identified by the writer as *Camarotoechia metallica* for a considerable period of time. Its external appearance is almost identical with that of *Camarotoechia metallica*. However after sectioning, it appears very definitely to be a form of *Rhynchopora*.

The most conclusive evidence as to the age of the Gilmore City formation is found in the crinoid fauna. Generically it appears very similar to that of the LeGrand crinoid fauna from the Hampton formation. A great number of the forms appear to have been directly descended from the LeGrand species. The *Rhodocrinus douglassi* type with the flat nodose tegmen is directly foreshadowed by an undescribed form in the LeGrand fauna. The smooth plated species of *Rhodocrinus* represented by *R. watersianus* in the LeGrand beds, appear in the Gilmore City fauna with a variety of different types of arm structure. The large *Eretmocrinus* is merely a specialized *Batocrinus* and is probably directly in the line of ancestry with the exceptionally wide armed forms from the Burlington limestone. *Cactocrinus imperator* is a specialized larger form of *C. arnoldi*. *Eutaxocrinus dero* is very closely related to *Eutaxocrinus fletcheri*. *Dichocrinus bozemanensis* with its striated calyx and flaring base is related to *D. cinctus*. *Dichocrinus multiplex* is a smaller, more delicate form of *Dichocrinus inoratus*. The greatest variation is found in the small inadunate crinoids. Such forms as *Culmicrinus* and *Gilmocrinus* have no representatives in the LeGrand fauna.

The fauna may be readily determined to be much older than typical Osage by the lack of such early Osage genera as *Macrocrinus, Agaricocrinus, Uperocrinus,* and *Eutrochocrinus.*

In 1896 and 1897, Miller and Gurley[12] described a group of crinoids from the Madison limestone which were collected by Earle Douglass in Bridger Canyon a few miles north of Bozeman, Montana. In this collection of crinoids were several species of *Rhodocrinus,* a *Batocrinus,* two species of *Dichocrinus,* several species of *Platycrinus,* and several small inadunate crinoids belonging to the family Poteriocrinidae. A recent visit to the area in which these

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[12] Miller, S. A., and Gurley, F. E., New Species of Crinoids, Cephalopods, and other Paleozoic Fossils: Bulletins 10, 12, Ill. State Museum of Nat. History, p. 40, 1897.

forms were collected has added a few more specimens for comparison. The type specimens of this fauna have all been made available for study. Two of the species of *Rhodocrinus* are quite unlike any forms from the Gilmore City. *Rhodocrinus douglassi* however is one of the most commonly occurring Gilmore City species. The flat topped species of *Rhodocrinus* are not found in other Mississippian formations in the Mississippi Valley. *Dichocrinus bozemanensis* is also identical with one of the Gilmore City forms and is so unlike any other forms of *Dichocrinus* that it may be considered a good index fossil. One of the forms was described as *Poteriocrinus douglassi* and upon examination by the writer has turned out to be a species of the new genus *Gilmocrinus*. Since species belonging to the Poteriocrinidae with only five arms are not known in any other Mississippian formations, the presence of this five armed form in the Madison shows a close relationship between the two faunas. The Madison crinoid fauna as a whole, however, carries several forms which are indicative of a slightly younger horizon. A very perfect form which appears to be identical with *Platycrinus burlingtonensis* appears quite commonly. A large form of *Steganocrinus* considerably larger than any of the Burlington species is present in the fauna. The presence of this genus would ordinarily indicate a horizon younger than Kinderhook.

Distribution: The Gilmore City formation may be determined through well sections to be an eastward overlap into Iowa onto the Kinderhook surface. No attempt has as yet been made to trace this formation on west through Nebraska and Kansas. It may curve northward to connect with the Pahasapa limestone of the Black Hills or it may continue directly across Nebraska and Kansas to connect with the Mississippian of the front ranges. There may be no continuous subsurface connections at the present time since known post-Mississippian uplifts in Kansas and Nebraska have caused the removal of considerable portions of the section by erosion. The formation is nearly 200 feet in thickness in many places along the Iowa-Nebraska line from Nebraska City to Sioux City and can undoubtedly be traced into Nebraska for considerable distances.

CONCLUSIONS

It would appear that the entire Madison formation of the west might possibly be post-Hampton in age. It would also appear that great portions of the Madison might possibly be pre-Osage in age.

CHART SHOWING RANGE OF FAUNA

Species that are new and species that cannot be positively identified are not listed.	MADISON	KINDERHOOK	OSAGE	MERAMEC
Coelenterata				
Amplexus blairi			x	x
Cyathophyllum glabrum			x	
Michelinea placenta	x			
Aulopora geometrica	x			
Syringopora sercularia	x			
Echinodermata				
Rhodocrinus watersianus		x		
Rhodocrinus wortheni			x	
Rhodocrinus douglassi	x			
Dichocrinus bozemanensis	x			
Decadocrinus douglassi	x			
Molluscoidea				
Streptorhynchus ruginosa			x	x
Chonetes multicosta		x	x	
Productus sedaliensis		x	x	
Rhynchopora cooperensis			x	
Rhynchotreta gibbosum			x	
Seminula pussila	x			
Seminula humilis	x			
Spiriferina solidirostris	x	x		
Spirifer centronatus	x	x	x	
Spirifer calvini		x		
Martinia lata	x			
Eumetria perstrialis		x	x	
Eumetria verneuiliana	x	x		
Cliothyridina obmaxima	x	x	x	
Cliothyridina incrassata		x	x	
Cliothyridina crassicardinalis	x		x	
Mollusca				
Macrodon blairi		x		
Conocardium cuneatum				x
Leiopteria subovata		x		
Schizodus sedaliensis		x		
Bellerophon sublaevis			x	x
Bellerophon panneus		x	x	
Bellerophon blairi		x	x	
Straparollus macromphalus		x		
Straparollus ophirensis	x			
Murchisonia quadricincta				x
Phanerotrema brazeriana	x			
Omphalotrochus springvalensis		x		
Strophostylus carleyana	x			
Holopea conica		x		
Platyceras triblosus		x		
Eotrochus concavus				x

The old interpretation which suggests that the Madison sea was present in the west during most of Mississippian times may in time prove to be absolutely true. At the present time the writer is in no position to make any statements with regard to the age of the entire Madison formation. The Gilmore City formation is equivalent to some portion of the Madison. Careful zone for zone stratigraphy within the Madison may later allow a closer correlation.

THE CRINOID FAUNA OF THE GILMORE CITY FORMATION

The most striking portion of the invertebrate fauna of the Gilmore City formation is found in the exceptional crinoid fauna. Thousands of specimens of crinoids have been collected from the ledges of the *Rhynchopora* and *Rhodocrinus* zones. A large number are excellently preserved, often showing the most delicate cirri and pinnules. The specimens are preserved in a soft green flour like marl between massive ledges of limestone. Later work in the area may reveal that crinoids showing the arms are more abundant in this formation than they were in the famous Kinderhook crinoid bed at LeGrand, Iowa. At present they are much more widely distributed in the possible area of exposure at Gilmore City than they ever were at LeGrand. The soft nature of the marl in which the specimens occur at Gilmore City makes cleaning and preparation of specimens for study difficult.

A great number of echinoids occur along with the crinoid fauna. They also show the same excellent preservation which characterizes the crinoids. Thousands of specimens of complete echinoids showing all of the spines have been collected from the ledges.

Starfishes are not as common in occurrence but appear occasionally in association with the crinoids and echinoids.

DESCRIPTIONS OF SPECIES

Order CAMERATA Wachsmuth and Springer

Family RHODOCRINIDAE Roemer

Genus *Rhodocrinus* J. S. Miller

Rhodocrinus watersianus Wachsmuth and Springer

Plate I, Fig. 1.

1899. *Rhodocrinus watersianus* Wachsmuth and Springer, Ill. Geol. Surv., vol. 8, p. 184, pl. 12, fig. 16.

1899. *Rhodocrinus watersianus* Wachsmuth and Springer, Harvard Mus. Comp. Zool., Mem. 9. p. 221, pl. 12, fig. 9.

A small smooth form with a rounded globular calyx; averaging

about 30 mm. from base to tips of arms. Dorsal cup typically 9 mm. in width and 7 mm. in height. Arms constricted at their lower portion and flaring at their mid-length.

Dorsal cup. Infrabasals small, hidden in basal concavity. Basals large and curved abruptly inward to form a portion of the basal concavity. Radials heptagonal, smaller than basals, confined to lateral walls of calyx. Costals two, the first usually pentagonal, the second hexagonal, of nearly equal size. Distichals one, followed by five or six free arm pieces before the first bifercation. Normal interbrachial series 1221 or 1222. Primary interbrachial slightly smaller than radials. Anal slightly larger than radials; followed by supplementary pieces which end in an eccentric high pyramid on the tegmen. The anal plate is usually followed by 332 plates in the succeeding cycles.

Tegmen. Inflated, laterally constricted, half the width of the calyx. Posterior oral large. Anus eccentric, in the form of a high rounded pyramid.

Arms. Slender, incurved at tips, four to each ray making twenty for the species. Arms constricted until they branch, above which they flare considerably. Proximal distichal followed by five or six free plates before the arms branch. The change from uniserial to biserial structure is accomplished on the third or fourth brachial above the branching of the arms. Pinnules long, slender, and closely set together.

Column. A typical *Rhodocrinus* stem, with little variation throughout its length. Columnals slightly closer together immediately below calyx. Each columnal is slightly expanded at its mid-portion; however, there is no differentiation in the amount of expansion. The cirri have not been observed.

Relationships. This form is very closely related to *R. coxanus*, *R. wortheni*, and *R. wachsmuthi* but it differs from all members of this group in that it carries only four arms to the ray. Typical forms of *R. watersianus* from both the LeGrand and Gilmore City beds occasionally carry five arms to the ray, thereby showing their afinity to *R. wortheni.* These are apparently transitional forms between *R. watersianus* and *R. wortheni* which carries six arms to the ray. *R. bozemanensis* from the Madison limestone of the West carries only four arms to the ray and differs from *R. watersianus*

in that it has an exceptionally large stem for the size of its calyx and also that its arms are exceptionally small for the size of the calyx.

R. watersianus is not an abundantly occurring form in the fauna. It appeared most abundantly in "nest" No. two in the Pennsylvania Dixie Quarry. It is apparently confined to the *Rhodocrinus* zone.

Occurrence. Gilmore City formation, Gilmore City, Iowa. This species was originally described from the Kinderhook series at LeGrand, Iowa.

Figured specimen. State University of Iowa, No. 2053.

Rhodocrinus wortheni Hall

Plate I, Figs. 2-3

1858. *Rhodocrinus wortheni* Hall, Iowa Geol. Survey, vol. 1, pt. II, p. 556, pl. 9, fig. 8.
1881. *Rhodocrinus wortheni,* Wachsmuth and Springer, Revision of the Paleocrinoidea, pt. II, p. 220.
1897. *Rhodocrinus wortheni* Wachsmuth and Springer, Harvard Mus. Comp. Zool., Mem. 9, vol. 1, p. 220.

This species is very closely allied to *R. watersianus.* It differs mainly in its arm structure and in its greater size. The length of ordinary specimens including arms and calyx is about 38 mm. The height of the calyx to the arm bases is usually 12 mm. Width of the calyx typically 15 mm.

Dorsal cup. Rounded, globose, constricted at upper portion. Infrabasals hidden in basal cavity. Basals comparatively large, approximately 5 mm. in width. Radials higher than wide, averaging 4 mm. in height. First costal wider than high, smaller than radial. Second costal larger than first. Distichals comparatively large. Interbrachial series normally 1222. Primary interbrachial considerably smaller than radial. Normal anal interradius X331.

Tegmen. Unobserved.

Column. As in *R. watersianus* and others of this group.

Arms. Having typically six arms to the ray with the exception of the anterior ray which usually has only four. *R. watersianus,* its closest relative, carries only four arms to the ray. The arms

of *R. wortheni* are long, slender, and uniserial in their lower portion. The change from uniserial to biserial structure takes place on the third brachial above the second branching of the arms.

Relationships. Occasional specimens of *R. watersianus* from Kinderhook beds at LeGrand, Iowa, are found with several of the rays carrying five or six arms. Apparently the variation in arm structure in these smooth plated forms of the genus *Rhodocrinus* was well founded in Kinderhook times.

In the Gilmore City formation there is every variation between the *R. watersianus* type bearing 20 arms and the *R. wortheni* type bearing 28 arms. All forms bearing more than 20 arms are referred in this paper to the species *R. wortheni.* Several new varieties might very easily be erected on the basis of this arm structure. *R. wortheni* is one of the most abundantly occurring fossils in the formation. In one gallon pail of green marl washed from "nest" No. two in the Pennsylvania Dixie Quarry, 123 specimens of this species were found.

Occurrence. Gilmore City formation, Gilmore City, Iowa. This form was originally described from the Lower Burlington beds at Burlington, Iowa.

Figured Specimens. State University of Iowa, Nos. 2054, 2055.

Rhodocrinus cavanaughi n. sp.

Plate I, Figs. 4-6.

Calyx subspherical, averaging about 15 mm. in height and a little less in width. Plates characterized by ridges radiating from their centers. A high anal pyramid appears on the tegmen.

Dorsal cup. Infrabasals large, basal concavity deeply excavated. Basals slightly larger than infrabasals; in contact laterally with the primary interbrachial except in the anal interradius. Radials slightly smaller than basals; in contact laterally with interbrachials. One costal, usually heptagonal. One distichal, above which occur free arm plates. One specimen carries two distichals in the right postero-lateral ray on the side nearest the anal interradius. Primary interbrachial hexagonal; in contact with infrabasal, and followed by 233 plates in the succeeding cycles. Interbrachials in contact with interambulacrals. Anal interradius exceptionally well defined. Anal smaller than basals, hexagonal, followed by supplementary pieces in a continuous row which runs to the base

of the anal pyramid on the tegmen. Anal interradius X3343 in the dorsal cup.

Tegmen. The eccentric anal protrusion is the most conspicuous feature of the tegmen. It is in the form of a rounded node which rises fully two mm. above the general level of the tegmen. Ambulacral plates in a definite series leading from the center of the tegmen to each ray. All plates slightly nodose. Oral plates small and inconspicuous. Arm openings directed slightly outward.

Arms. The arms of this form are unknown.

Column. A few columnals from the upper portion of the stem of this form may be seen protruding from the excavated bases of all of the specimens. As far as can be determined they are typical of the genus *Rhodocrinus.* The columnals are thin, averaging about three to 1 mm. The diameter of the stem is about 3 mm. The lumen is small.

Relationships. This form may be easily recognized from all other species of this genus by its protruding anal pyramid and its exceptionally well defined anal interradius. Most of the features of this form are duplicated in an immature way in an undescribed form of *Rhodocrinus* from the Kinderhook strata at LeGrand, Iowa. The LeGrand form is much smaller but is undoubtedly in the line of ancestry of *R. cavanaughi.*

About 15 specimens of this species were found in a small shaly pocket in the blue dolomite of the *Rhynchopora* zone. The shaly pocket was found in a slab on the floor of the Northwestern States quarry. None have been located at any other place in either of the quarries at Gilmore City.

Occurrence. Gilmore City formation, Gilmore City, Iowa.

Types. State University of Iowa. Holotype No. 2060, Paratypes Nos. 2058, 2059.

EXPLANATION OF PLATE III

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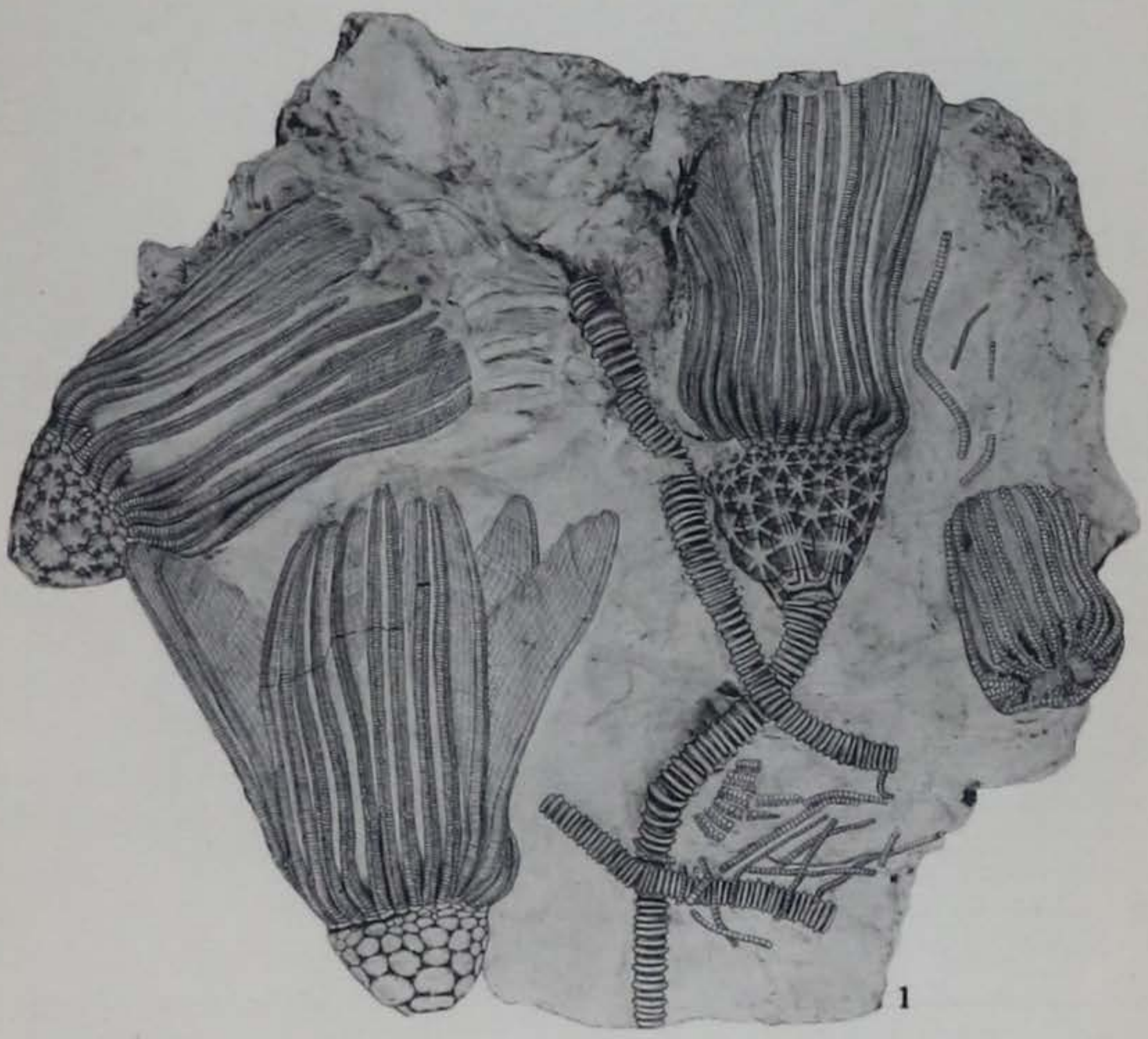
Fig. 1. *Cactocrinus imperator* n. sp. 51
A slab showing the holotype and two paratypes. The holotype shows the character of the stem. A crushed specimen of *Eretmocrinus tentor* n. sp. may be seen on the right margin of the slab. x 3/5.



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Rhodocrinus douglassi Miller and Gurley

Plate I, Figs. 10-11.

1899. *Rhodocrinus douglassi* Miller and Gurley, Illinois State Mus. of Nat. Hist., Bull. 12, p. 39, pl. III, fig. 1.

This species was described from a single badly crushed specimen that had been collected by Earl Douglass in the Madison limestone in the Bridger mountains north of Bozeman, Montana. Later collections in the region have revealed much better specimens than the one figured by Miller and Gurley. Comparison of specimens now in the collection of the University of Montana with specimens from Gilmore City has shown that some are identical and others closely related. The Gilmore City formation has a large number of varieties that are all closely related to *R. douglassi*. The form that is nearest like the specimens of *R. douglassi* from the Madison limestone is not abundant in the Gilmore City fauna.

The calyx of this form is a little less regular than that of the usual *Rhodocrinus*. Width of calyx 15 mm. Height to arm bases 9 mm. Height of entire calyx 15 mm.

Dorsal cup. Infrabasals small, hidden in basal concavity. Basals averaging 4 mm. in width, curving abruptly inward to form the basal concavity. Radials larger than basals, the lower tips of radials curve around base and nearly enter basal concavity. Costals two, hexagonal, considerably smaller than radials. One distichal occupies the constriction just below the abruptly flaring portion of the tegmen. Primarily interbrachial nearly as large as radial, followed by 332 plates in the succeeding cycles. Anal interradius quite wide, normal succession of plates X3332.

Plates marked by regular radiating ridges from an acuminate central node. Ridges not sharply defined in the centers of the plates. Plates of tegmen nodose.

Tegmen. The ventral disk may be used to distinguish this group of crinoids from all other species of *Rhodocrinus*. It is flat on top,

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EXPLANATION OF PLATE IV

Page

Fig. 1. *Dichocrinus multiplex* n. sp. 54
A slab preserving portions of four specimens. The preservation of the long cirri on the lower portions of the stems is excellent on this specimen. x 1.

covered with nodose plates, roughly pentagonal in outline, and meets the lateral walls at an abrupt angle of about 85 degrees. It flares enough so that the arm openings are overshadowed considerably. The plates of the tegmen are much fewer in number in *R. douglassi* than in any of the other varieties which are associated with it with the possible exception of *R. douglassi* var. *constrictus*. The anal opening is not covered by the usual conspicuous pyramid of small plates.

Arms. The arms of this form have not been observed on any of the specimens from Gilmore City. A few small stumps appear on the left antero-lateral ray of the specimen figured in this report. Three arms appear on one side of this ray suggesting a 30 armed form. They branch the first time on the first palmar. The second branching is accomplished on the third brachial of the fourth order.

Column. The stem is not preserved on any of the specimens which have been referred to this species. One or two segments appear at the bottom of the basal concavity in the figured form. They appear to be similar to those which appear on other varieties of this species.

Relationships. This form may be recognized from others of this *R. douglassi* group by its exceptionally wide flaring tegmen, by the large plates which are found in the tegmen, and by the fact that the basals enter into the basal concavity slightly more than usual. The expanded tegmen of this species would suggest the genus *Gilbertsocrinus*. The arms, however, are very definitely not characteristic of the genus *Gilbertsocrinus*. This group of crinoids were foreshadowed in the Kinderhook by an undescribed species of *Rhodocrinus* that is now in the collection of B. H. Beane of LeGrand, Iowa. The LeGrand form is closely related to *R. douglassi* var. *constrictus*. The flat toped tegmen with its pentagonal outline, the laterally directed arms, and the inflated dorsal cup are all present although immaturely developed.

Occurrence. Gilmore City formation, Gilmore City, Iowa. Also found in the Madison limestone of Montana.

Figured specimen. State University of Iowa. No. 2067.

Rhodocrinus douglassi var. *serpens* n. var.

Plate I, Figs. 7-9.

A small form of *Rhodocrinus* with a round globe shaped calyx,

highly sculptured plates, and usually six arms to the ray. Width of calyx averages 9 mm. Height to arm bases 7 mm. The arms are nearly three times the length of the calyx.

Dorsal cup. Infrabasals hidden in a rather large basal concavity. Basals large, curving inward to form the outer portion of the basal concavity. Radials entirely on the lateral wall but very nearly reaching the basal concavity. Radials as large as the basals, averaging 3 mm. in height. Costals two, slightly smaller than radials, supporting a single distichal above which occur free arm plates. Interbrachial series normally 1232 or 1222. Anal interradius carrying a median row of plates with supplementary pieces on either side. Normal anal succession X321.

Tegmen. Flat on the upper surface with a right angled junction with the lateral wall. Arm openings laterally directed. Plates of tegmen nodose. Orals small, differentiated only with difficulty. Anal opening slightly eccentric.

Arms. Slender, branching twice usually, making six arms to the ray and thirty to the species. They branch for the first time on the sixth palmar. The second branching takes place usually on the fourth brachial above the first branch. The palmars are highly cuneiform. The brachials between the first and second branches are a mixture of uniserial, cuneform, and biserial pieces. Occasional forms are found which carry only four or five arms in one or two of the rays.

Column. A typical *Rhodocrinus* stem with the usual monotony throughout its entire length. Columnals slightly closer together near the calyx. Cirri not observed. The stem of this form appears always to be impressed on one of the basal plates. The eccentric emergence of the stem from the basal concavity suggests the possibility that this form might have been a nodding type. A large number of stems of this form have been found coiled up like a serpent with a slight depression in the center suggesting the resting place of the crinoid calyx. It seems likely that the eccentric emergence of the stem was not inflicted after the death of the crinoid, since in all cases it actually displaces and deforms the basal plate against which it rests.

Relationships. This form is the most commonly occurring form in the *R. douglassi* group. It differs from *R. douglassi* in that the

radials are not depressed as far towards the basal concavity, the relative width of the tegmen is considerably less and it does not overhang the arm openings. The tegmen is not quite as flat on top as it is in others of the group, the plates are slightly more nodose, and the anus is more centrally located. Hundreds of specimens have been collected from the *Rhodocrinus* zone in the Pennsylvania Dixie Quarry. It is mainly because of the abundance of this form that the *Rhodocrinus* zone is so named.

Occurrence. Gilmore City formation, Gilmore City, Iowa.

Types. State University of Iowa. Holotype No. 2061; paratypes Nos. 2056, 2062.

Rhodocrinus douglassi var. *multidactylus* n. var.

Plate I, Figs. 12-14.

This form is slightly larger than *R. douglassi* var. *serpens.* It is definitely related to this same group, however. The calyx averages 13 mm. in width and 8 mm. in height from the base to the arm openings. The calyx is relatively wider than that of *R. douglassi* var. *serpens* and the arms are proportionally shorter.

Dorsal cup. Infrabasals small, hidden in the basal concavity. Basals average 5 mm. in width and are abruptly recurved to form the rim of the basal concavity. The lower tips of the radials reach very nearly to the basal concavity making the radials proportionally smaller than in *R. douglassi* var. *serpens.* The radials average 4.5 mm. in width. Costals two, hexagonal, followed by a single distichal, above which there are free arm plates. Primary interbrachial less than half the size of the radial. Normally followed by 232 supplementary plates. The anal plate is followed by a median row of plates with supplementary plates on either side. The normal succession is X3322.

Tegmen. Flat on top with an abrupt marginal angle which gives rise to the laterally directed arm openings. Plates on the lateral edge of the tegmen are more nodose than those of the central plates. Anal pyramid eccentric, raised above the general surface, and composed of many small plates.

Arms. The structure of the arms varies somewhat within this variety. There are usually eight arms to the ray, making forty to the species. However, quite commonly 10 arms are present on each

of the rays that border the posterior interradius. Occasional forms are found with 9 rays to each of the postero-lateral rays. The arms of this form branch quite close to the calyx. When the form carries 10 arms to the ray the first branching takes place on the first palmar. The arms branch for the first time on the third or fourth brachial when only eight arms are found in the ray.

Column. This form exhibits a typical *Rhodocrinus* stem with practically no differentiation throughout its entire length. The stem is impressed in one of the basal plates suggesting a nodding type and showing its affinity to *R. douglassi* var. *serpens.*

Relationships. This form has been derived through a differentiation of the arms of *R. douglassi* var. *serpens.* The large number of arms, the branching of these arms close to the calyx, the greater width of the calyx in comparison to the length, and the depression of the radials toward the basal concavity readily distinguish this form from others of the group. This form occurs chiefly in the *Rhodocrinus* zone and does not occur abundantly in the fauna.

Occurrence. Gilmore City formation, Gilmore City, Iowa.

Types. State University of Iowa. Holotype No. 2065; paratypes Nos. 2063, 2064.

Rhodocrinus douglassi var. *constrictus* n. var.

Plate II, Figs. 1-2.

This form differs from others of the *R. douglassi* group in that it has an exceptionally rounded bottle shaped calyx and a constricted pentagonal tegmen. Height of calyx 16 mm., width 17 mm., width across top of tegmen 11 mm.

Dorsal cup. Base deeply excavated, infrabasals small, confined to bottom portion of basal concavity. Basals large, averaging 5 mm. in width. Radials nearly as large as basals, length 3 mm., width 4 mm. Costals two; first hexagonal, nearly as large as radial; second about half the size of the radial. Distichals one, with the arm openings grooved in their upper surfaces. Interbrachial area well defined, the succession of plates normally being 123221. Primary interbrachial slightly smaller than radial and succeeded by two plates that are equal in size to it. Anal plate large, followed by three irregularly arranged plates. The median row of supple-

Dorsal cup. Sub-oval, height equals width, averages 14 mm. Basal cup shallow, slightly excavated, tending to flare laterally as in a typical *Eretmocrinus.* Interbasal sutures deeply grooved. Radials wider than long, width 6 mm., length 4 mm. Costals two, first quadrangular, second pentagonal, much wider than long. Distichals two, slightly larger than costals, usually hexagonal. Palmars two, except on the postero-lateral rays where on the side nearest the anal interradius only one appears. Brachials of the fourth order appear on the two postero-lateral rays on the side nearest the anal interradius to support the extra arm that usually appears at this position. Anal heptagonal, larger than radials, followed by three plates; from right to left heptagonal, pentagonal, and octagonal. Remaining anal interradius of irregular plates usually 6 or 7 in number. The upper plates of the anal interradius are in contact with the plates of the tegmen. Primary interbrachial large usually 10 sided followed by two plates, occasionally by only one. Interdistichals and interpalmars not present. Surface comparatively smooth, plates slightly raised into low nodes. Occasionally the plates in the upper portion of the dorsal cup are more nodose than those near the base.

Tegmen. Tegmen high, gradually tapering into a long spinose, slightly eccentric, anal tube which in many cases rise more than 10 mm. beyond the arm tips. Spinose radial dome plates appear in groups of three above each ray. Oral plates small, also carrying spines. Arm openings directed laterally causing the arms to flare slightly at their junction with the calyx. Respiratory pores have not been observed.

Arms. Arms biserial, simple, typically 22, four to the ray with the exception of the two postero-lateral rays which carry five each. The extra arm being, in each case, nearest the anal interradius. The number of arms varies, however, from 20 to 23. One form carrying 23 arms has 6 arms in the right postero-lateral ray. Forms having only 21 arms usually carry four instead of five arms on one side of the anal interradius. One specimen bears only 20 arms in which the anterior ray carries only three arms. The arms show a definite transition between typical *Batocrinus* arms and the paddle shaped arms of an *Eretmocrinus.* The bases of the arms are rounded while the upper portions are flattened and definitely much wider. The brachials in the upper portions of the arms give rise to short laterally directed spines about every third to fifth

brachial. The tips of the arms converge inwards around the tube. The pinnulars are of short quadrangular pieces each carrying a short downward directed spine in their central portion.

Column. Columnals averaging 12 to one cm. in the upper portion of the stem and 9 to one cm. in the lower portion. Nodals and internodals alternately arranged throughout the column with every fourth nodal expanded more than the second one. Nodals are much less conspicuous in the lower portion of the column. Stout long cirri characterized by short cirrals are given off at definite intervals from the lower portion of the stem. The lumen is small.

Relationships. A form such as this would be definitely out of place in the earlier Kinderhook strata. The calyx structure resembles very much that of several of the forms of *Eretmocrinus* which are so common in the early Osage formations. Smaller forms of *Batocrinus* had already appeared in the LeGrand beds of the Kinderhook but none of the larger forms with the highly nodose plates were as yet developed. This form marks the first appearance of the genus *Eretmocrinus*. It has not as yet completely developed the features which are so characteristic of the Burlington forms, such as, the eccentric anal tube, the extremely wide paddle shaped arms, and the flaring basal cyclet of plates. The spikes on the upper portion of the arms are developed in exactly the same manner in *Aorocrinus armatus* of the Devonian and in various species of *Dorycrinus* in the Osage.

This is one of the most commonly occurring forms in the fauna. It occurs abundantly in the lower portion of the *Rhodocrinus* zone and has been found in all of the ''nests'' at Gilmore City.

Occurrence. Gilmore City formation, Gilmore City, Iowa.

Types. State University of Iowa. Holotype No. 2070; paratypes Nos. 2068, 2069, 2071.

Genus *Aorocrinus* Wachsmuth and Springer

Aorocrinus iola n. sp.

Plate II, Figs. 7-8.

A small species of *Aorocrinus* measuring 52 mm. from the base of the stem to the arm tips. The calyx measures 7 mm. in length and 8 mm. in width. The arms average 9 mm., and are sharply

incurved at the tips. The calyx expands rapidly, and is widest at the arm bases.

Dorsal cup. Basal cup shallow, basals expanded slightly beyond columnals. Radials large, wider than long, width averaging 2 mm. First costal quadrangular, about one-third of the width of the radial, wider than long. Second costal wider than first. Distichals two, approximately the same size as the second costal. Anal interradius wide. Anal followed by three plates in second cycle and four plates in the third cycle. Primary interbrachial large, followed by two small plates which rest on an almost horizontal surface.

Tegmen. Shorter than the dorsal cup, plates slightly nodose. Interbrachials connected with tegmen plates. The posterior oral plate is raised into a short spine.

Arms. Arms variable in number, between 20 and 22, the extra arms, if present, being introduced next to the anal interradius. The first four brachials of the arms are stout and uniserial. The change to the biserial structure is made on the fifth brachial. The brachials in the uniserial portion of the arms are very large in comparison to the size of the species. The pinnules are short and stout.

Column. The stem of this form is very distinctive. The columnals immediately below the calyx are sharply expanded, but grade rapidly into rounded forms in the lower portion of the stem. The stem tapers very rapidly. The cirri are long and slender, one being 34 mm. in length. At their point of origin on the stem they are nearly as large as the stem itself.

Relationships. The shape of the calyx and of the stem is very similar to that of *Aorocrinus immaturus* of the LeGrand beds. *A. iola* differs from *A. immaturus* in that there are often 5 arms to each of the postero-lateral rays and also in the fact that the arms change from the uniserial to the biserial structure much sooner on *Aorocrinus immaturus.* The type of arm structure appears to be almost identical with that of *Aorocrinus cauliculus* (Hall) of the Devonian suggesting that this form might have its lineage directly from some Devonian form rather than through *Aorocrinus immaturus.* It may be easily differentiated from any

of the Mississippian species of *Aorocrinus* by this arm structure alone.

This form occurs only sparingly in the fauna. It has been collected from both the *Rhynchopora* zone and the *Rhodocrinus* zone. The greatest number of the forms were taken from very thin blue beds in the *Rhynchopora* zone in the southeast corner of the Pennsylvania Dixie Quarry. Both of the type specimens, however, were taken from "nest" No. two in the *Rhodocrinus* zone.

Occurrence. Gilmore City formation, Gilmore City, Iowa.

Types. State University of Iowa. Holotype No. 2076; paratype No. 2072.

Family ACTINOCRINIDAE (Roemer)

Genus *Cactocrinus* (Wachsmuth and Springer)

Cactocrinus imperator n. sp.

Plate II, Fig. 9; Plate III, Fig. 1.

This is the largest and most robust crinoid that occurs in the fauna. The calyx and arms in the larger specimens often reach a length of 95 mm. The average length of specimens is about 90 mm. The calyx averages about 24 mm. in length and 35 mm. in width at the arm bases. The arms average 55 mm. in length.

Dorsal cup. Basals slightly flaring. Basal cup 3 mm. in height. Radials 6 mm. in height and 7 mm. in width. First costal 4 mm. in height and 5 mm. in width. Second costal slightly smaller. Distichals slightly smaller than second costal. Palmars half the size of the distichal. Interbrachial series normally 12222. Primary interbrachial 6 mm. in width and 6 mm. in length. Anal interradius normally 1244321. Anal plate equal in size to radials. Plates marked with sharp radiating ridges, the lower two cycles usually having from 2 to 3 ridges to each side of the plate.

Tegmen. The disk tapers gradually into a very long slender anal tube which rises at least an inch above the arm tips. The plates of the tegmen are small and usually marked with a low node in their center. Oral plates are small and inconspicuous. The ambulacral portions of the tegmen have a tendency to be raised.

Arms. Typically 32, all rays carrying 6 except the two posterolateral rays which carry seven. The extra arm in each case being

nearest the anal interradius. The arms are long, slightly incurving at the tips, and characterized by very small brachials. There are normally about 22 brachials to one cm. The arms average 55 mm. in length and often carry small nodes at regular intervals. The pinnules are characteristic of *Cactocrinus,* having a small spike-like plate on each of the pinnulars.

Column. The stem is stout, consisting of alternately expanded columnals which are thin, usually averaging about 13 to each cm. The lumen is small and round. The edges of the columnals are milled.

Relationships. This form is undoubtedly one of the largest species of the genus *Cactocrinus.* It is equalled in size only by the larger specimens of *Cactocrinus arnoldi* from the LeGrand beds. Several of the lower Burlington species are very nearly as large as this form but none exceed it in size. This form undoubtedly had its origin in the large *Cactocrinus arnoldi* type of the Kinderhook. It differs from *C. arnoldi* mainly in that it has a greater number of arms and its plates are more sharply sculptured. One undescribed form which occurs in the uppermost portion of the LeGrand beds appears to have the same type of ornamentation to its plates.

This species is confined to the *Rhodocrinus* zone and has been found in both quarries at Gilmore City. One large slab upon which are preserved several complete specimens rested in the repository at the University of Iowa for a period of over ten years before the main crinoid horizon was located. This slab was taken from the foundation of a barn which had been built from limestone taken from one of the old quarries in the region.

Occurrence. Gilmore City formation, Gilmore City, Iowa.

Types. State University of Iowa. Holotype No. 2074; paratype No. 2077.

Family HEXACRINIDAE Wachsmuth and Springer

Genus *Dichocrinus* Munster

Dichocrinus bozemanensis (Miller and Gurley)

Plate VI, Figs. 1-2.

1896. *Platycrinus bozemanensis* Miller and Gurley. Illinois State Mus. of Nat. Hist., Bull. 10, p. 83, pl. 5, figs. 16, 17.

A rather large form of *Dichocrinus* measuring 13 mm. from the

base of the calyx to the top of the tegmen. This form differs from most forms of *Dichocrinus* in that the lower portion of the basals is expanded into a flaring rim. The calyx expands rapidly and is 11 mm. wide at the arm bases.

Dorsal cup. Basals two, forming a rather deep cup, the lower portion of which is expanded into a flaring rim which is excavated beneath. Interbasal sutures deeply grooved through this rim. Radials 5 mm. high expanding rapidly, 2 mm. wide at the base and 5 mm. wide at top. Costals two, extremely short, united by syzygy, and occupying less than one-third of the upper face of the radials. The costals in this form are free arm plates. Distichals two or three with apparently no regularity. The anal plate is smaller than the radials and does not expand at the upper portion. Except for a slight protrusion toward the basal cyclet, the anal plate appears as a quadrangular piece.

The plates are marked by low, narrow, roughened, parallel ridges which run both transversely and longitudinally on the radials. The transverse ridges are much better defined near the interradial sutures. The number of ridges running longitudinally on the radial plates varies from 3 to 6. These ridges are of the same general character as those which are found on *D. cinctus* of the LeGrand beds.

Tegmen. The highly protruding extremely eccentric anal pyramid is the most conspicuous feature of the ventral disk. It appears well down on the posterior side of the disk between the arms and protrudes almost as far laterally as the arms themselves. The plate structure of the protrusion is irregular and is capped by a number of very small pieces. Ambulacral areas raised into ridges and interambulacral areas deeply depressed. The ambulacral ridges converge at very large spinose posterior oral plate which extends well down the posterior side behind the anal protrusion.

Arms. Only a small portion of the arm structure is preserved on the Gilmore City specimens. The arms branch once on the second costal and then again on the second or third distichal, suggesting that the specimen probably has 20 arms. There are not enough brachials above the last bifercation to determine if the arms are uniserial or biserial. Pinnules consisting of short quadrangular pieces are preserved on two of these lower brachials.

Column. The stem of this form has not been observed on the Gilmore City form.

Relationships. In 1896, Miller and Gurley[13] described this species from the Madison limestone of Montana as *Platycrinus douglassi.* This specimen is not figured by Wachsmuth and Springer in their report on North American Camerate Crinoids because at the time the specimen was unavailable for study. The type specimen is now in the collection of the University of Cincinnati. The species was described from a single specimen which is preserved on a slab so that only the anterior side is exposed. A comparison of the Madison form with the Gilmore City form has shown them to be identical. The occurrence of such a peculiar species of *Dichocrinus* in two widely separated formations should be of considerable significance when their relative ages are considered.

This form may be easily recognized from all other species of *Dichocrinus* by its flaring base, its rapidly expanding calyx, its peculiar plate markings and its highly protruding anal pyramid.

This species of *Dichocrinus* might very easily have been derived from the Kinderhook species *Dichocrinus cinctus.* It is quite definitely different but shows relationships in the type of plate markings. This particular group of striated species of the genus *Dichocrinus* also have descendants in the Burlington in the form of *D. striatus.*

Only two specimens of this form have been found at Gilmore City. They were found together on a slab lying in the bottom of the Pennsylvania Dixie Quarry. Because of this, the horizon from which they came can not be determined with absolute certainty. The character of the slab, however, suggests the thin beds that mark the base of the *Rhodocrinus* zone near the southeast side of the quarry.

Occurrence. Gilmore City formation, Gilmore City, Iowa.

Figured specimen. State University of Iowa. No. 2073.

Dichocrinus multiplex n. sp.

Plate IV, Fig. 1

A large species of *Dichocrinus.* Calyx averaging 12 mm. in length and 10 mm. in width. Stem fully 120 mm. in length, the

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[13] Miller, S. A., and Gurley, W. F., Illinois State Mus. of Nat. Hist., Bull. 10, p. 83, Pl. 5, Figs. 16-17, 1896.

lower portion of which is crowded with long slender cirri. Arms averaging 38 mm. in length.

Dorsal cup. Basals forming a cone shaped cup, expanding gradually until the full width of the calyx is reached at their tops. The height of the basals being 5 mm. Basal suture not sharply defined. Radials twice as long as wide, arm facet occupying about one-third of their upper surfaces. Anal side bulging. Anal plate much wider at the base than at the top.

Tegmen. Consisting of very small plates. Ambulacral plates sharply defined, running in a continuous raised series from the arms to the center of the disk. Oral plates slightly larger than others of the disk. The anus is eccentric and situated on a slight protuberance above the anal interradius. Interambulacral plates situated in depressions between the raised ambulacral rays.

Arms. Slender, uniserial, brachials very short in comparison to their width, cuneform in the upper portion of the arms and averaging five to 1 mm. Pinnules slender, closely packed together, consisting of from 10 to 18 pieces. The bases on which the pinnules rest protrude beyond the general ventral surface of the arms. Since the pinnules arise from every segment from alternate sides of the arms the raised pinnule bases give the ventral surface of the arm a saw tooth appearance. Arms flare laterally at about their mid length and taper to very fine delicate ends. The tips are incurved. The arms branch once on the second costal making 10 arms to each specimen.

Stem. Long slender, sharply differentiated into sharp nodals near the proximal end. Columnals thinner just below calyx and every other segment expanded. This character soon changes and every fourth segment is expanded into a nodal. The nodals become much less prominent towards the distal end of the stem. The lower third of the stem gives rise to a great number of slender curling cirri, many of which measure 30 mm. in length.

The calyx plates are smooth and without markings of any kind.

Relationships. This form is undoubtedly derived from the *D. inornatus* type of crinoid which occurs so abundantly in the Kinderhook at LeGrand. It differs from *D. inornatus* in that it is usually smaller in size, the basal cup does not expand as rapidly and the length of the calyx in proportion to the width is greater than in

D. inornatus. The pinnules and arms are much less coarse and much more delicate on this form. This form compares most closely with that of *Dichocrinus delicatus* of the LeGrand beds. It differs again in the elongation of the base and in the fact that *D. delicatus* has biserial arms.

This form occurs abundantly in both the *Rhynchopora* and *Rhodocrinus* zones of the quarries at Gilmore City. One horizon located near the very upper portion of the *Rhodocrinus* zone is particularly rich in these forms. There are several layers on the west side of the Pennsylvania Dixie Quarry near the north end that are usually well covered with specimens of this form. This particular species because of its delicate arms and pinnules is usually very much broken and fragmented.

Occurrence. Gilmore City formation, Gilmore City, Iowa.

Types. State University of Iowa. Holotype No. 2075.

Dichocrinus campto n. sp.

Plate II, Fig. 10; Plate VII, Figs. 1-2

This is the smallest and most delicate form of crinoid occurring in the entire fauna. The largest specimens will measure about 20 mm. from the base of the calyx to the arm tips. The average sized

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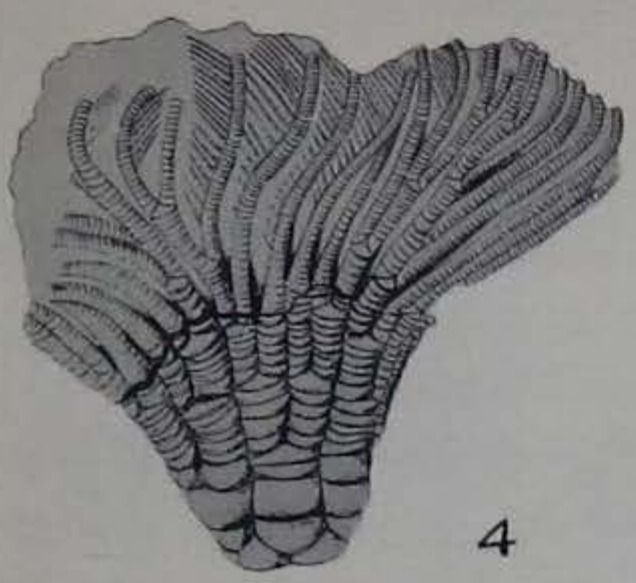
EXPLANATION OF PLATE V

GILMORE CITY FORMATION

Plate V



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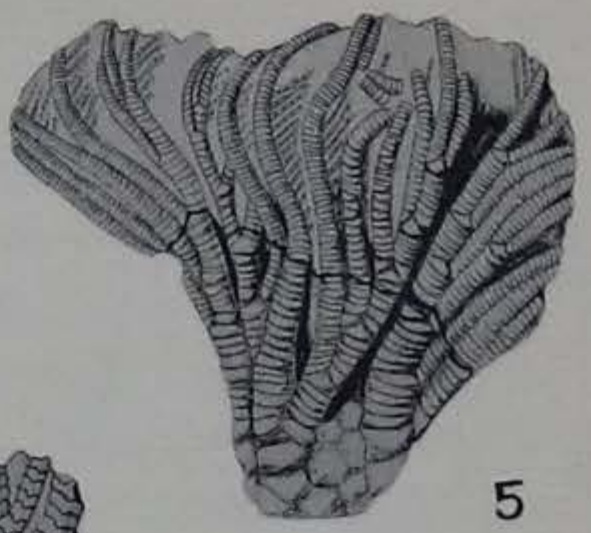

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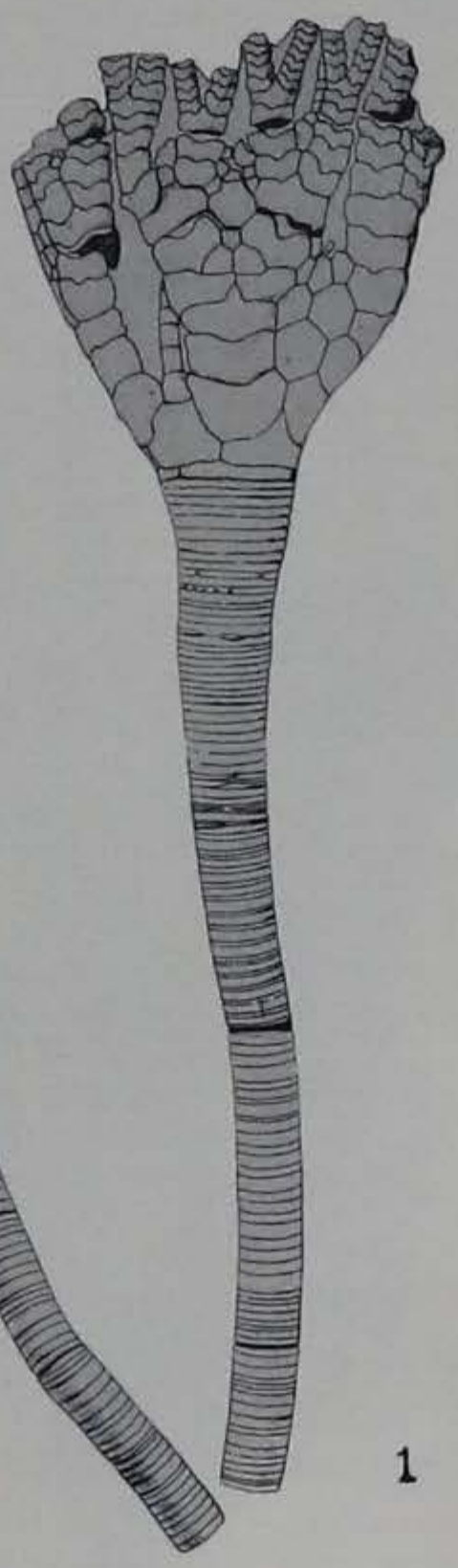

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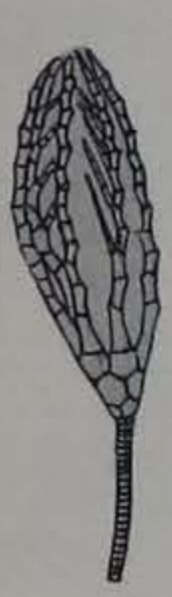

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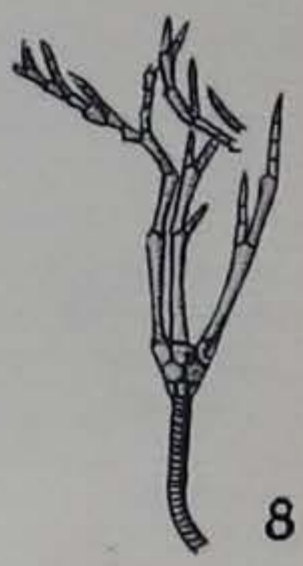

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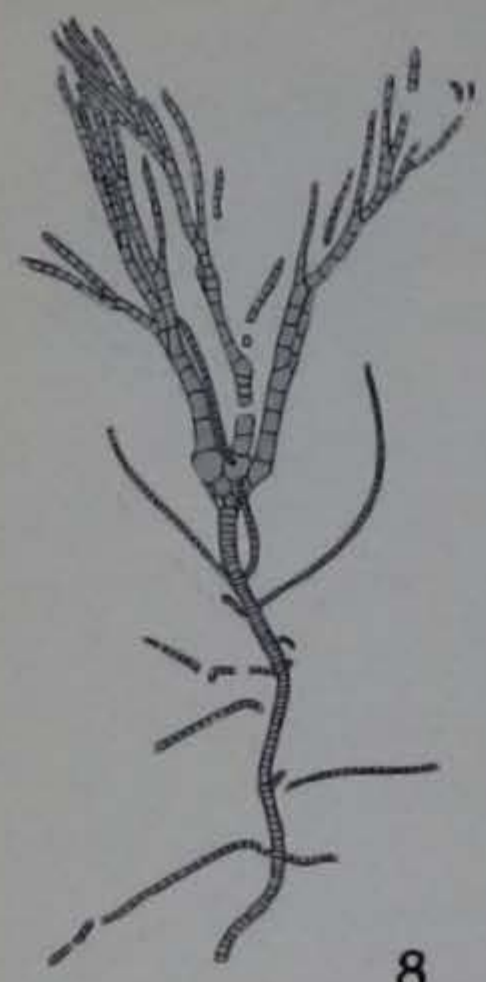
C. T. Kohn, del.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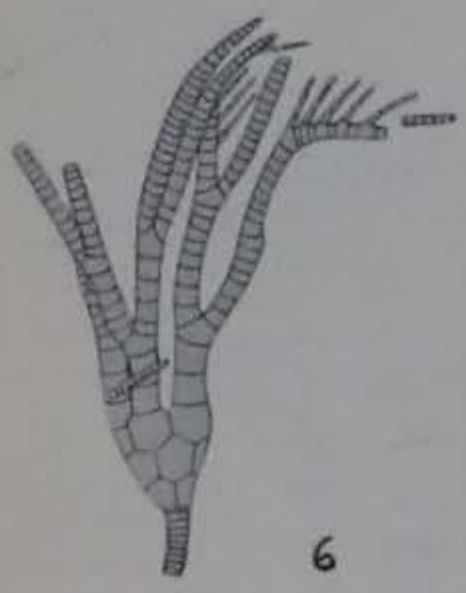
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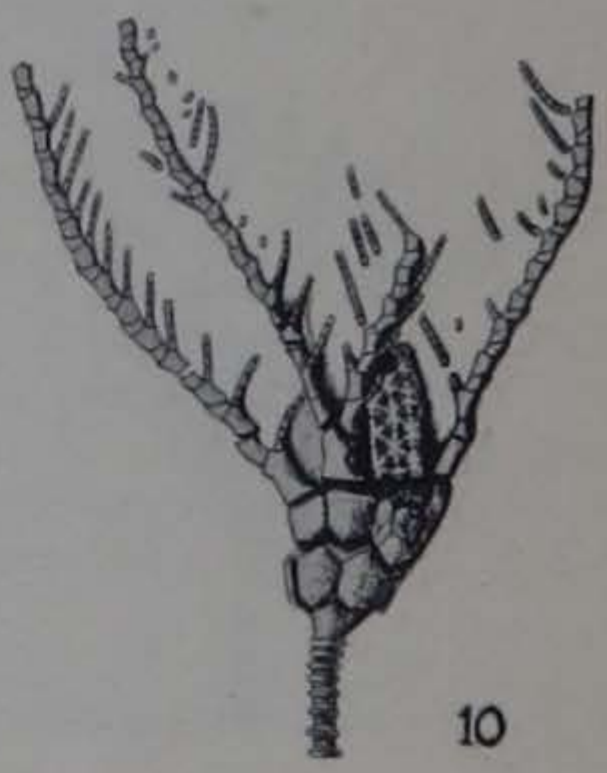
10

C. T. Kohn, del.

specimens average 12 mm. from the base to the tips of the arms. A few complete specimens are now in the collection which measure less than 8 mm. from the base to the arm tips. The calyx occupies one-fourth of the length from the base to the arm tips. The width of the calyx varies with the size of the specimen from one and one-half mm. to 5 mm. The stem is slender, delicate, and reaches a length of 50 mm.

Dorsal cup. Basal cup shallow, expanding very rapidly, interbasal suture not sharply defined. Radials low, slightly convex, only slightly longer than wide. The arm facets occupy about one-third of the upper surface of the radials. The anal is slightly broader at the base than at the top.

Tegmen. The ventral disk has not been observed.

Arms. Arms biserial, three times as long as calyx, and characterized in general by their exceptionally coarse pinnules which are heavy and short. The brachials are large and coarse.

Column. The stem is sinuous, suggesting the possibility of coiling. It consists of regular columnals without marked differentiation into expanded nodals. At regular intervals long slender cirri

EXPLANATION OF PLATE VI

Order INADUNATA Wachsmuth and Springer
Suborder FISTULATA Wachsmuth and Springer
Family CYATHOCRINIDAE (Roemer)
Genus *Lasiocrinus* Kirk
Lasiocrinus expressus n. sp.

Plate VI, Fig. 7-8

This species is known only from a single very delicate specimen. The genus *Lasiocrinus* is not typically a Mississippian genus and although the characters of this form can not be fully determined it seems that it can be referred to no other genus. The length of the holotype is only 28 mm. including the stem. The calyx and arms are only 15 mm. in length.

Dorsal cup. The plates of the dorsal cup can not be fully studied without approaching the specimen from the under side, since it is preserved on a slab of the limestone. There is apparently no change in the structure of the anterior ray since three almost identical rays are in view and the anal interradius is not exposed. The calyx is short, expanding very rapidly, slightly over 1 mm. in height, and a little over 2.5 mm. in width. The infrabasals are small. The basals are smaller than the radials and are widest at their upper ends. The radials are considerably wider than high. The sutures between plates are depressed.

Ventral sac. The anal sac is not exposed but is apparently quite short.

Arms. The structure of the arms suggests that this form should be referred to the genus *Lasiocrinus*. The arm structure is very similar to that of *L. Scoparius* (Hall) from the Devonian. Arms delicate uniserial, branching for the first time on the fourth or fifth brachial. They have a bilaterally heterotomous structure after the first branching. The branch in each case is smaller than the main trunk of the arm. They branch at more frequent intervals near their distal ends than at the proximal end. The pinnules, if present, have not been observed.

Column. The column is definitely pentagonal throughout its exposed length. Only 14 mm. of the stem is preserved. Each columnal of the stem is expanded into a low node at each of the corners. Long delicate cirri are given off at regular intervals throughout the

length of the stem. The columnals from which the cirri arise are definitely expanded and of larger size. Four whorls of cirri are given off in the 14 mm. of stem that is preserved on the holotype.

Relationships. While *Lasiocrinus* is not a widely distributed genus nor typically Mississippian; the non-pinnulate arms, the pentagonal stem, the bilaterally heterotomous type of arm branching, and the rapidly expanding calyx all suggest that it is to be correctly classified with this genus. It may be differentiated from the New York forms by the cirri on the stem and by its delicate nature. Later work in the area may yield better specimens for study.

Occurrence. Gilmore City formation, Gilmore City, Iowa.

Type. State University of Iowa. Holotype No. 2093.

Family GLOSSOCRINIDAE Goldring

Genus *Goniocrinus* S. A. Miller

Goniocrinus maximus n. sp.

Plate VII, Fig. 8

This species represents the second known occurrence of this genus in North America. It is similar in many respects to the form described from the LeGrand beds at the time the genus was erected. Almost all of the characters of the original form are reflected in this new species.

Since this form is known from only one broken specimen, it is not possible to give complete measurements. It appears that a portion of the central part of this specimen has been lost. The specimen was at least 60 mm. in length from the base of the cup to the arm tips.

Dorsal cup. The lower portion of the dorsal cup of this specimen, including infrabasals and lower portion of the basals, is missing. The radials and the upper portion of the basals are preserved. The calyx appears to be conical in shape and is probably not over 3½ mm. in height. It measures 5 mm. in width at the arm bases. The radials are considerably wider than long and their upper faces are quite concave. The anal plate is small, quadrangular, and is located quite differently than that of any other members of the Glossocrinidae. It was probably because of the position of the

radianal plate that this genus has been referred to the cyathocrinidae. The radianal is in contact with the anal and the right postero-lateral radial above and with two basal plates below. The anal plate is in contact laterally with two radial plates, with the posterior basal and the radianal beneath, and with the middle primary tube plate above.

All plates of the dorsal cup are nodose and roughened.

Ventral sac. The anal sac is long and tapering reaching the entire length of the arms. The posterior side is marked by a median row of heavy pieces that strongly resembles an extra arm. The presence of this median row of plates on the anal side is of important taxonomic significance. The remaining plates of the sac are small and exceptionally irregular. It is very difficult to locate interplate sutures in the tube since the surface is covered with small irregular spines. The median row of plates on the posterior side of the anal articulates directly upon the anal plate and is not offset to the right as is usual in Devonian members of the Glossocrinidae. In many of the Devonian forms the central primary tube plate is in contact with both the radianal and the anal plates thereby separating the anal plate from the right postero-lateral radial. The anal opening has not been observed.

Arms. The arms of this form are very similar to those of the LeGrand form. They branch once on the fourth brachial instead of on the third brachial as in *G. sculptilis.* They give rise to long, strong, ramules from every other brachial. The arrangement of these ramules on every fourth brachial gives the arm the appearance of having a bilaterally heterotomous structure.

Stem. The stem has not been observed. Although the stem of this form has not been seen, it may be inferred that it will be pentagonal. This form closely parallels the LeGrand form in all other ways and will undoubtedly also have a pentagonal stem. This stem was covered with exceptionally long whorls of cirri probably throughout its entire length. These cirri are undoubtedly longer and stronger than those of the typical LeGrand form. Although the stem is missing, a group of six of these cirri have been preserved with the specimen and measure at least 17 mm. in length. The entire length of them was undoubtedly much greater.

Relationships. This form has been classified with the Cyatho-

crinidae because of the position of the anal and radianal plates and because of the structure of the arms. The genus is considered as belonging to the family Glossocrinidae by the writer because of the following reasons. The type and structure of the anal tube in Inadunate crinoids is always highly diagnostic. The long tube with the median row of plates is sufficiently different from other groups of Inadunate crinoids to place the form in the Glossocrinidae. The only modification which has been necessary to produce the *Goniocrinus* calyx structure from that of the typical *Glossocrinus* structure is a shifting of the radial plate over against the anal plate thereby enclosing the radianal within the calyx. The position of this radianal plate would suggest immediately that the form belonged to the Cyathocrinidae. However, when all of the characteristics of the form are considered, such as the long primitive tube with the median row of plates, the slender arms with elongated brachials which give rise to long ramules it would appear that this form had definitely been derived through a differentiation of some form of the family Glossocrinidae.

Occurrence. Gilmore City formation, Gilmore City, Iowa.

Types. State University of Iowa. Holotype No. 2094.

Family POTERIOCRINIDAE Springer

Genus *Pachylocrinus* Wachsmuth and Springer

Pachylocrinus cirrifer n. sp.

Plate VI, Figs. 3-4

A small rather delicate form averaging between 15 and 18 mm. in length from the base of the calyx to the tips of the arms. The calyx averages between 3 and 5 mm. in length and is as wide as it is high. The stem is characterized by an abundance of cirri which are given off throughout its length.

Dorsal Cup. Cone shaped, expanding quite rapidly, having a typical *Pachylocrinus* structure. Infrabasals short, wider than long. Basals comparatively large averaging 2 mm. in length. Radials short, width about twice length. Radianal pentagonal almost as large as the anal. No plate decorations.

Ventral sac. Not observed but definitely not as long as the arms.

Arms. Imperfect unilateral heterotomy, branching once on the

first brachial except in the anterior ray where the first branching occurs on the fourth brachial. Branching three times all together. Brachials of the second order varying from 6 to 8 and brachials of the third order from 8 to 13. Axillary brachials considerably larger than others. Slightly cuneform pieces developed only in the upper portions of the arms. Pinnules rather short and stout.

Column. Nodals and internodals alternately spaced in upper portion of stem. Columnals much longer in lower portion of stem and nodals appear on every fourth columnal. The outstanding feature of the stem is found in the long cirri which are given off throughout the length of the column. Many of these cirri are over 22 mm. in length.

Relationships. The two forms of the *Pachylocrinus* in this fauna exhibit to a marked extent the variations in the arm structure within this genus. As usually defined the arm structure must be dichotomous, although many of the forms have a marked tendency for unilateral heterotomy. The arms of this form are rounded and definitely not abutting but their method of branching is imperfect unilateral heterotomy.

This is not an abundantly occurring form in the fauna. About 10 specimens are all that have been obtained as yet. It apparently is found much more extensively near the very base of the *Rhodocrinus* zone than in any other part of the formation.

Occurrence. Gilmore City formation, Gilmore City, Iowa.

Types. State University of Iowa. Holotype, 2082; paratype, 2081.

Pachylocrinus fimbria n. sp.

Plate V, Figs. 2-3

A large robust form of *Pachylocrinus* with stout arms, a rapidly expanding calyx, and a stem covered with cirri, throughout its length. The height of a specimen showing calyx and arms is 27 mm. The calyx averages 10 mm. in width at its junction with the arms.

Dorsal cup. Cup as in other forms of *Pachylocrinus.* Infrabasals comparatively large, forming a considerable portion of the dorsal cup. Basals large averaging 4 mm. in width, and 3 mm. in

height. Radials considerably wider than high. Radianal nearly as large as anal.

Ventral sac. Only two specimens of this form have been collected and the tube is not exposed in either specimen.

Arms. Arms rounded, not abutting, branching once on the first brachial, exhibiting perfect unilateral heterotomy in their manner of branching. The second branch occurs on the 8th brachial, the third on the 15th brachial, the fourth on the 25th brachial, and the fifth on the 37th brachial on the left side of the anterior ray. The branching is somewhat less often in the other rays. The brachials are not markedly cuneform. The pinnules are stout and rather short.

Column. Only the upper portion of the stem has been observed. It consists of alternately expanded nodals and gives rise to whorls of cirri at intervals starting almost immediately below the calyx. These cirri extend upwards beyond the dorsal cup in some cases.

Relationships. This form with its unilaterally heterotomous arms can not be correctly classified as *Pachylocrinus* under the present definition of that genus. All of the characteristics of the genus *Pachylocrinus* are answered by this form except the manner of branching of the arms. Springer[14] includes forms having one or two unequal arms which branch on the inside of the ray in this genus. "Although having typically dichotomous arms, it will include some forms in which there are one or two arms branching unequally on the inner side of the ray, provided these arms are rounded and not abutting as in *Zeacrinus.*"

It would appear then that the genus *Pachylocrinus* might better be defined as having both dichotomous and heterotomous arm structure. The arms should branch on or before the second brachial, should branch more than once, and should be rounded and not abutting. *Pachylocrinus arboreus* of the Chester from Huntsville, Alabama, has exactly the same type of arm structure that is exhibited in this form.

The form does not occur abundantly and has been found only in the very basal beds of the *Rhodocrinus* zone. Both specimens were

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[14] Springer, F., Unusual Fossil Crinoids, Proc. United States Nat. Mus., vol. 67, Art. 9, p. 70, 1926.

isolated and had no relation to the "nests" of crinoids in the region.

Occurrence. Gilmore City formation, Gilmore City, Iowa.

Types. State University of Iowa. Holotype No. 2083; paratype No. 2084.

Genus *Zeacrinus* Hall

Zeacrinus compactus n. sp.

Plate V, Figs. 4-5

This form exhibits all of the common characters of the genus *Zeacrinus* and is a very early occurrence of this genus. It is characterized by rugged decorated plate structure and spinose nodose projections on the axillary pieces in the arms. The holotype is 37 mm. in height from the base to the arm tips. The arms flare considerably in their upper portion and are incurved at their tips.

Dorsal cup. Base flattened. Infrabasals hidden at bottom of a wide basal concavity. Basals inflated into nodes which project laterally. Radials very low and angular, width 5 mm. height 2 mm. The upper face being somewhat concave. The radianal plate is as large as the radial and is in a normal position in contact with two basals beneath, with the right radial and anal laterally, and the right primary tube plate above. In no place does it come in contact with the right costal. The anal is in contact with the left postero-lateral costal and left radial with the radianal and right primary tube plate, with the central and left primary tube plates above, and with the posterior basal beneath. Plates of the anal interradius are very rough and nodose.

Ventral sac. The sac is not visible in specimens which have been collected so far.

Arms. The arms exhibit perfect unilateral heterotomy throughout. The first costal is axillary and is much larger than either the basal or radial plates; being 5 mm. in width and 3 mm. in height and sharply nodose. The arms branch 7 times at a maximum with the exception of the anterior ray. In the left postero-lateral ray the branching takes place on the following brachials 1, 7, 13, 21, 31, 38; on the right postero-lateral ray 1, 7, 13, 20, 28, 38; on the left antero-lateral ray 1, 7, 13, 20, 28, 36, 47; on the anterior ray 3, 9, 17, 25, 37, 56, and on the right anterior-lateral ray 1, 8, 14, 20, 28,

and 37. The brachials tend to be more cuneiform in the upper portions of the arms than is usually characteristic of the genus *Zeacrinus*. The pinnules are short and closely set together.

Column. The stem is round consists of alternate sharply expanded brachials. It tapers quite rapidly and apparently is not a long stem. Only the upper portion has been observed.

Relationships. This form is structurally very much like other forms of the genus that occur in the lower portion of the Mississippian. It differs from all others however in its exceptionally rough nodose plate markings. The anal area has not been greatly modified as yet from that of the usual number of the Poteriocrinidae.

The form does not occur abundantly in the fauna. Three specimens have been collected to date. All three were found during the last field season in the region, in "nest" No. one of the Pennsylvania Dixie Quarry.

Occurrence. Gilmore City formation, Gilmore City, Iowa.

Types. State University of Iowa. Holotype No. 2085.

Genus *Culmicrinus* Jaekel
Culmicrinus thomasi n. sp.

Plate VI, Figs. 5-6

This form averages somewhat smaller than the commonly occurring forms of *Culmicrinus* from the St. Louis formation. The length of the calyx and arms of typical specimens is about 32 mm. The calyx is cone shaped, 5 mm. wide at arm bases and 5 mm. high. The arms and pinnules are delicate.

Dorsal cup. The structure of the dorsal cup is very definitely that of the common member of the Poteriocrinidae. Infrabasals comparatively large. Basals a little higher than wide. Radials are slightly smaller than basals and about as high as wide. Radianal nearly as large as anal and its upper face is about at the mid-point on the side of the radial.

Ventral sac. The sac is long reaching nearly the full length of the arms. The plates are mainly hexagonal with sharp radiating decorations running from the center of each plate to the center of each side of the plate. The anal opening is low, directly behind the anterior ray. The upper end of the tube is spinose.

Arms. The arms are uniserial, dichotomous, and branch only twice, once on the fifth brachial and once on the twelfth brachial. The brachials are markedly cuneform and give rise to comparatively slender long pinnules. The length of the arms on the holotype is about 28 mm. The anterior ray varies slightly in that it branches first on the 8th brachial instead of the fifth and apparently branches only once.

Column. The stem is round and consists of alternately expanded columnals. It is comparatively slender for the size of the calyx. The cirri are small, delicate, and not numerous.

Relationships. This form is apparently one of the rather primitive forms of this genus. The forms described by Goldring[15] as *Liparocrinus* are not to be referred to this genus nor are they closely related to this form. In the report by Springer[16] *Liparocrinus* is considered as a synonym for *Culmicrinus.* The genus *Culmicrinus* has apparently had its origin directly from one of the larger forms of *Pachylocrinus.* The structure of the tube and of the anal interradius is much more closely related to the *Pachylocrinus* than it is to any of the Glossocrinidae. This form may be distinguished from the described forms of *Culmicrinus* by the fact that the arms branch on the fifth brachial rather than on later ones and by the general delicate nature of the species in comparison to others.

This form occurs very abundantly in the fauna and has been found in all three of the "nests" in the Pennsylvania Dixie Quarry at Gilmore City.

Occurrence. Gilmore City formation, Gilmore City, Iowa.

Types. State University of Iowa. Holotype No. 2086; paratype No. 2053.

Genus *Decadocrinus* Wachsmuth and Springer
Decadocrinus douglassi (Miller and Gurley)

Plate V, Fig. 6, Plate VII, Fig. 7.

1896. *Poteriocrinus douglassi* Miller and Gurley, Illinois State Museum of Nat. Hist., Bull. 10, p. 83, pl. V.

This form is one of the smaller crinoids of the fauna. Several

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[15] Goldring, Winifred, Devonian Crinoids of New York: New York State Mus. Mem., No. 16, p. 397, 1923.

[16] Springer, Frank, Unusual Fossil Crinoids: Proc. United States Nat. Mus., vol. 67, Art. 9, p. 1-137, pl. 1-26, 1926.

specimens have been obtained which show almost the complete form including the exceptionally long delicate stem. The maximum length of the calyx and arms is about 15 mm. On smaller forms the calyx and arms are less than 8 mm. in length. One form in which the calyx and arms are 15 mm. in length has a stem which measures 55 mm. in length.

Dorsal cup. The dorsal cup expands rapidly making a shallow conical cup. The infrabasals are small and make up only a small portion of the cup. The basals are smaller than the radials and definitely much wider on the top than on the bottom. The radials tend to be considerably wider than long. The posterior basal is considerably larger than the others and supports comparatively small radianal and anal plates. The structure of the anal interradius is similar to all members of the Poteriocrinidae.

Ventral sac. The ventral sac is not well preserved in any of the specimens. It is considerably shorter than the arms and consists of alternately placed hexagonal plates. The anal opening has not been observed. The summit of the sac is ornamented with two small sharp spines.

Arms. The species carries 10 arms, the branching of which takes place on the first brachial. This first brachial occupies only a portion of the upper face of the radial and is usually nearly 2 mm. in length in larger forms. It is constricted at its mid-length and flares most at its junction with the radial. The brachials are long and all somewhat constricted at their mid-lengths. The sutures between the brachials are such that the arms have the appearance of being sinuous. Each brachial gives rise to a long strong ramule from alternate sides of the arm. The number of brachials in large specimens is not over twelve.

Column. The stem is slender and long, although the distal end is quite minute. It tapers slowly. Columnals are close together immediately below the calyx but are nearly as long as wide in the lower portion of the stem. Every fourth or fifth columnal is greatly expanded in the lower portion of the stem. Cirri have not been observed.

Relationships. The genus *Decadocrinus* is an old long ranging genus. This form differs from most Devonian forms in that the arms branch for the first time on the first brachial rather than on

the second. This form is identical, with the form described from the Madison limestone, in structure and general appearance. The Madison form appears in general to be considerably larger. This form was undoubtedly in the line of ancestry to the large number of forms of this general type that appear later in the Mississippian. *D. ulrichi* of the Keokuk is very similar in structure to this species.

This form has been found only in the thin bedded limestones that make up the upper portion of the *Rhynchopora* zone in the south end of the Pennsylvania Dixie Quarry. It may have a larger range but as yet specimens have all been confined to this horizon.

Occurrence. Gilmore City formation, Gilmore City, Iowa.

Figured specimen. State University of Iowa. No. 2095.

Gilmocrinus n. gen.

Genotype: *Gilmocrinus iowensis* n. sp.

The genus *Gilmocrinus* is erected to care for crinoids belonging to the Poteriocrinidae; which carry either five or six arms to the specimen. All other genera in this family bear at least 10 arms. The five armed form is more common in the Gilmore City fauna.

These forms have all of the typical calyx and anal structure of the Poteriocrinidae. The radianal is in contact laterally on one side with the radial and basal, on the other with the anal and posterior basal, and above with the left primary tube plate. The basals are hexagonal, except for the posterior and the right posterolateral, which are heptagonal. The anus opens low on the anterior side much as in *Culmicrinus*. The plates of the ventral sac are ornamented with raised radiating ridges. The summit of the sac carries several spinose plates.

Arms exceptionally long in adult specimens and comparatively short in immature specimens. Immature specimens characterized by an exceptionally long first brachial. Arms uniserial, brachials exceptionally cuneiform. Stout pinnules are given off from each brachial. The arms are usually single but occasional specimens have a single arm branching once on the first brachial. There is apparently no regularity as to which arm branches.

A specimen belonging to this genus was described by Miller and Gurley[17] from the Madison limestone of Montana as *Poteriocrinus*

[17] Miller and Gurley, Illinois State Mus. of Nat. Hist., Bull. 10, p. 82, 1896.

bozemanensis. The type specimen has been restudied by the writer and its seems certain that it belongs to this genus.

Gilmocrinus iowensis n. sp.

Plate V, Figs. 7-9, Plate VI, Figs. 9-10, Plate VII, Figs. 3-6

Since this is one of the abundantly occurring species in the Gilmore City formation, specimens have been obtained ranging from large adult forms to very immature forms. The length of the calyx in the larger forms averages 10 mm. and the width is usually around 9 mm. The arms are exceptionally long in the adult specimens and comparatively short in the young forms. The length of the arms in the holotype is 74 mm. and their upper portions are broken off. One exceptionally large specimen shows an arm length of over 90 mm.

Dorsal cup. Cone shaped. Infrabasals comparatively large, making a considerable portion of the dorsal cup. Basals slightly wider at top, 4 mm. in width and 4 mm. in height, hexagonal except the posterior and the right postero-lateral which are heptagonal. Radials much wider than high, 4 mm. in width and 2 mm. in height. Posterior basal slightly larger than others. Radianal plate pentagonal, smaller than anal; in contact on the right with the right postero-lateral basal and radial, on the left with the posterior basal and anal plate, and above with the right primary tube plate. The anal plate projects slightly above the line of contact of the radial with the first brachial of the arm.

Ventral sac. Very long, reaching nearly to the full length of the arms in adult specimens. Considerably shorter than arms in immature forms. Consisting of rows of hexagonal plates marked with radiating raised ridges which radiate from the center of each plate to each of the sides. The upper end of the sac is ornamented by two or three sharp spines. The anal opening is very low and directly behind the anterior ray very much as in *Culmicrinus*.

Arms. The arms of this form are very distinctive. The proximal brachial is longer than any of the others and the brachials become progressively shorter towards the distal end of the arm. In immature specimens the first brachial is exceptionally long apparently reaching its full length almost immediately. The brachials throughout the arms are exceptionally cuneiform but at no place in the arm are they crowded closely together. Stout pinnules are given off

from alternate brachials beginning with the first brachial. On some specimens the arms are single throughout the entire five rays. On others, one may branch making a six armed specimen. The six armed specimens are less common than the five armed forms. There is apparently no regularity as to which of the arms shall branch. On one form the right postero-lateral ray bears two arms. Another specimen shows the left antero-lateral ray bearing two arms. The arms branch on the first brachial whenever they branch showing their relation to *Decadocrinus*.

Column. The stem is round, with very little differentiation in the way of alternately expanded columnals. One of the smaller specimens appears to carry long cirri near its lower portion.

Relationships. Crinoids bearing only five arms have been described from the Devonian under the genus *Catactocrinus*. A close examination of the forms from the Gilmore City formation shows that these two genera are not at all closely related. The genus *Gilmocrinus* has undoubtedly had its origin in the modification of one of the varieties of *Decadocrinus*. The anal structure of *Catactocrinus* is entirely unlike that of *Gilmocrinus*. The only other known occurrence of these forms is in the Madison limestone of Montana.

Occurrence. Gilmore City formation, Gilmore City, Iowa.

Types. State University of Iowa. Holotype No. 2089; paratypes Nos. 2087, 2088, 2090, 2091, and 2092.

EXPLANATION OF PLATE VII

Page

Figs. 1,2. *Dichocrinus campto* n. sp. 56
1. Lateral view of the holotype. x 1. A small specimen of *Decadocrinus* is preserved on the same slab.
2. The same specimen enlarged x 2.

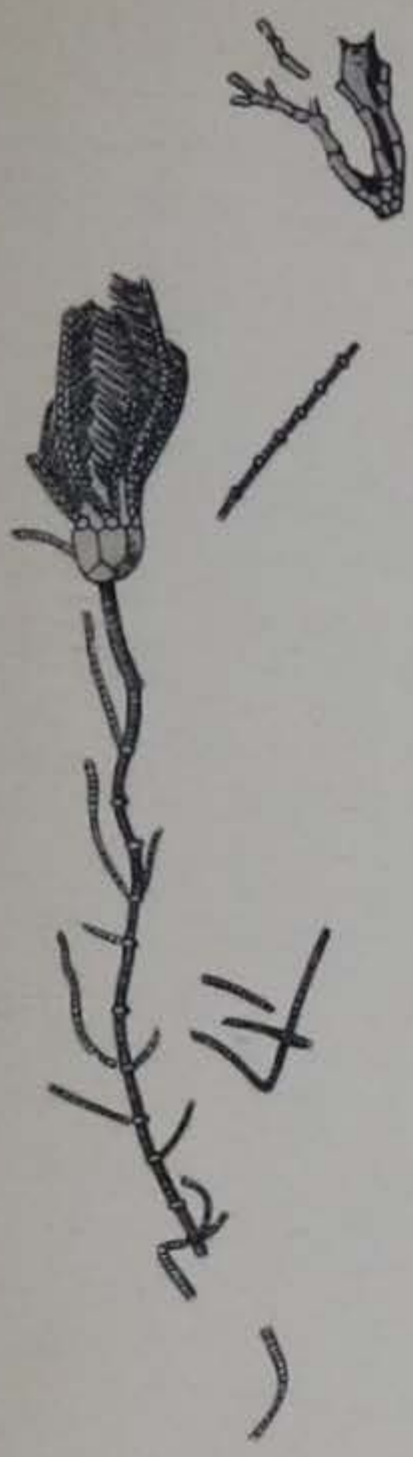
Figs. 3-6. *Gilmocrinus iowensis* n. sp. 71
3. Anterior view of a specimen showing the position of the anal opening. x 1.
4. The same specimen enlarged x 2.
5. Posterior view of a small immature specimen. x 1.
6. The same specimen enlarged x 2.

Fig. 7. *Decadocrinus douglassi* (Miller and Gurley) 68
Posterior view of the specimen figured on Plate V, figure 6 enlarged x 2.

Fig. 8. *Goniocrinus maximus* n. sp. 61
Posterior view of the holotype showing the long anal tube with the strong median row of plates. x 1.

GILMORE CITY FORMATION

Plate VII



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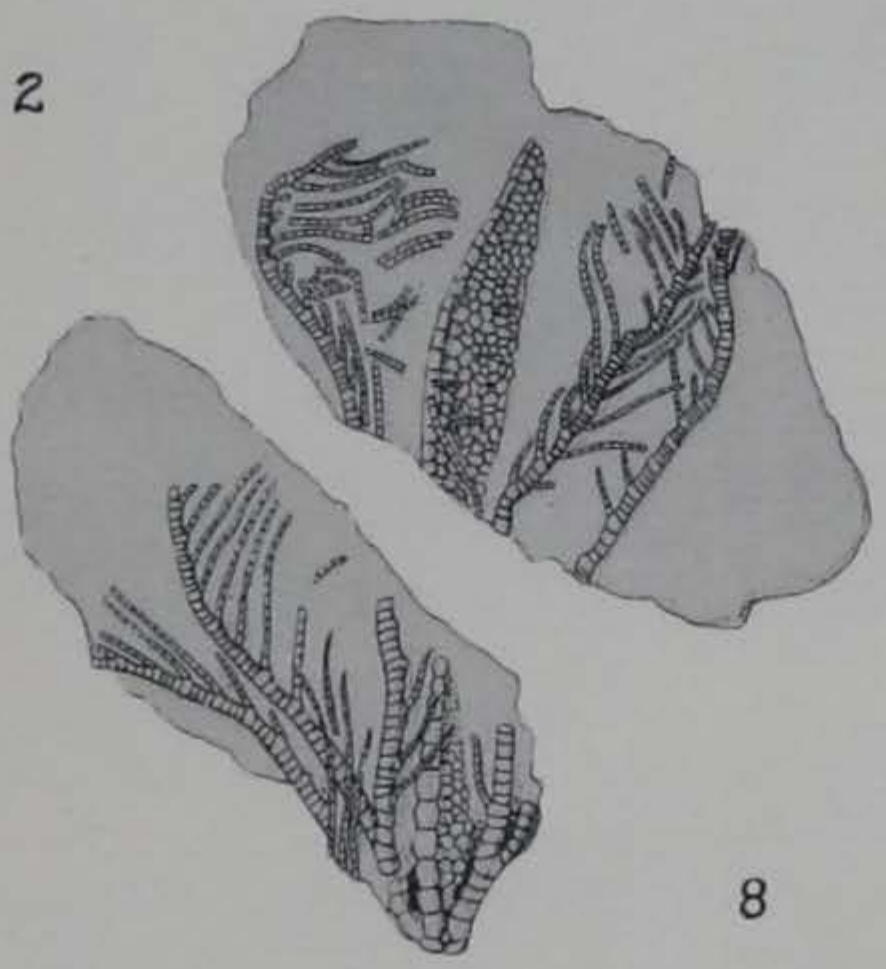

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C. T. Kohn, del.

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