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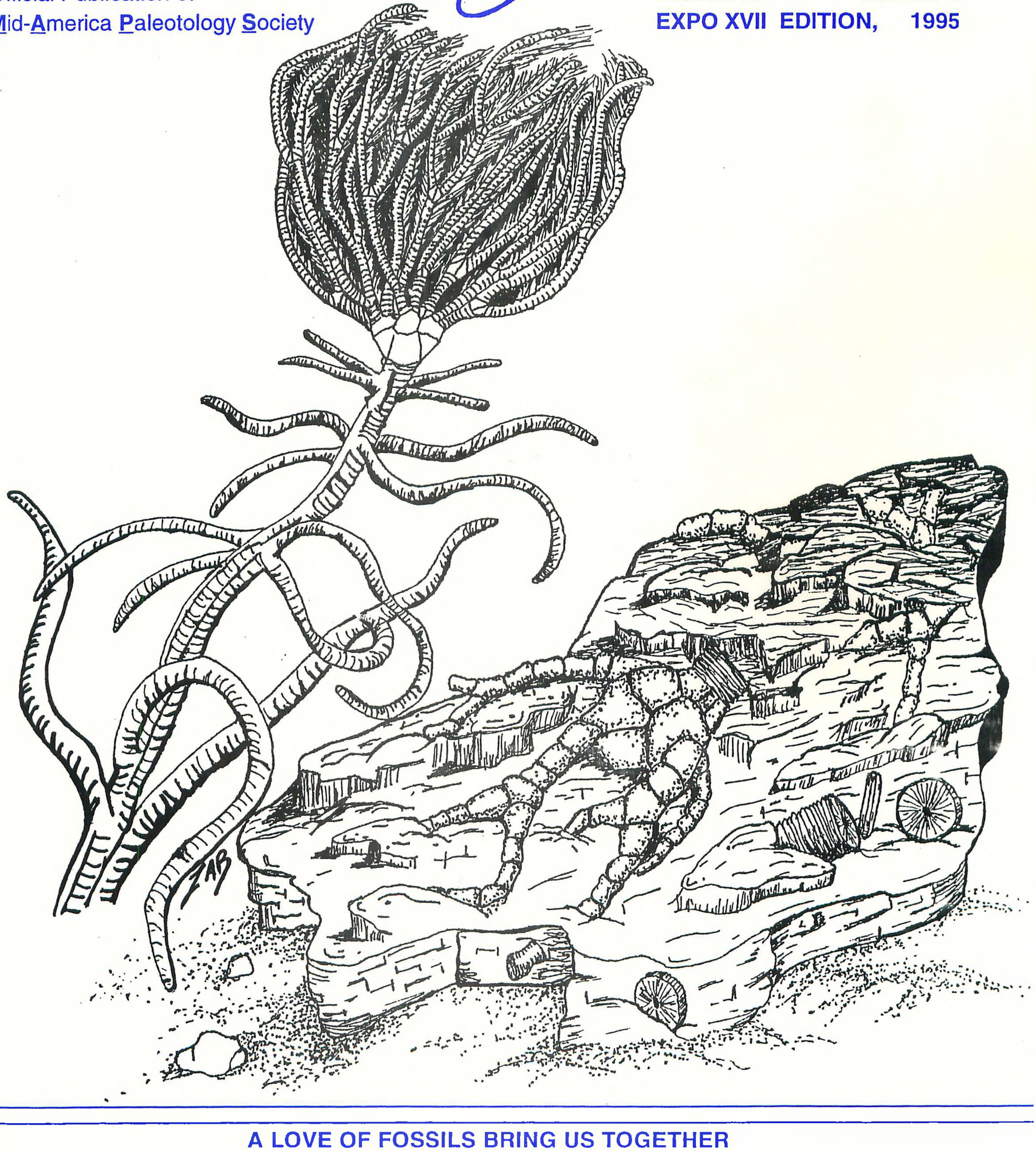

A LOVE OF FOSSILS BRING US TOGETHER

CRINOIDS

MAPS DIGEST

EXPO XVII EDITION

MID-AMERICA PALEONTOLOGY SOCIETY

A LOVE OF FOSSILS BRINGS US TOGETHER

Western Illinois University
Union Ballroom
Macomb, Illinois 61465
April - 1995

ACKNOWLEDGEMENT

Crinoids are among the most beautiful fossils in the world; from the crowns down to and including the columns, with their plant-like appearances. The name **CRINOID,** taken from the Greek word **KRINOEIDES**, meaning **KRINON LILY**. They are the only living representatives of the **PELMATOZOANS**, a division of the subphylum, attached stem - bearing animals.

The largest group of **echinoderms,** they are so beautiful, and have always been known as "sea-lilies". They have carried that name so long that people who are not fossil - wise think they are plants. They are so surprised when told crinoids are animals. When there is a group of crinoids together they resemble a flower garden.

Crinoids are my favorite fossil, that is the reason I chose to submit an article for this issue. I don't know a lot about The scientific significances of the subject, but I do know I love fossils and I also love to collect and read about them. Isn't that what its all about, especially for we amateurs?

Special **THANKS** go out to the **ARTISTS** and **AUTHORS** for sharing their talents and their expertise with the rest of us. The artists also designed the layout for the cover. It is a pleasure to recognize these "first time" contributors: Janise Blong, Ithiel Matteson, Forest Gahn, Dr. Thomas Guensburg, Paul Kirkland, Patrick Norton, Jean-Guy Pellerin and Theresa Seguin, and our **treasured** stand-bys: Alan Goldstein, Robert Howell, Frank Holmes, Joanne Kluessendorf, Dr. N. Gary Lane, Mark McKinzie and Charles Oldham.

The Mid - America Paleontology Society was formed to promote popular interest in the subject of paleontology, to encourage the proper collecting, study, preparation and display of fossil material; and to assist other individuals, groups and institutions interested in the various aspects of paleontology. It is a non-profit society incorporated under the laws of the State of Iowa.

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The Year of the Crinoid

Of all the world's fossils, crinoids are perhaps the most loved. Their structural complexity and exquisite beauty rival that of any of Nature's varied and unique life forms. Crinoids are among the best known and most recognized fossils, exciting the amateur and professional alike.

Living in Iowa, I am well aware of the abundant display of crinoid remains. Many streams expose outcrops of thick layers, exhibiting mass fragments. Fossil crinoids are nearly synonymous with mid-western limestones, as well as sedimentary stone around the world. Crinoids have been leaving their stone remains since the early Ordovician.

Each of the main orders are found in these layers with the exception of the articulates, which is the order that the modern day crinoids belong. These lovely sea lilies are of the phylum Echinodermata along with starfish, sea urchins and sea cucumbers.

Crinoid classification is accomplished by observing the plate arrangement on the cup shaped structure below the movable arms called the calyx. If only other structures are found like an arm or stem, identification is extremely difficult. Several forms of crinoids became so specialized that they may be used as index fossils to recognize a specific layer.

During the Silurian, crinoids made colossal changes, increasing in population and variety. A few during this time became extremely specialized. There are 293 species recorded in the U.S. alone. Considering the ratio of fossilization and the vast amount deposited in some rock layers, many millions of generations must have lived and died in these ancient seas.

Crinoids of our time are not temperature sensitive. They live in a wide range from tropical to frigid waters surrounding the Arctic and Antarctic. Fossil records suggest that they prefer a warm, shallow environment. Many places in the Midwest have sedimentary deposits of 100 feet or more containing largely crinoids parts.

Their incredible ability to continue to evolve has created a remarkable tale in the saga of life. They tell a tale that permeates the depths of antiquity and continues to unfold with new wonders in the present day.

Regarding the cover art; the front page illustrates a modern *Isocrinus* and an artistic rendition of a crinoid of the early Ordovician. Depicting over 500 million years of extraordinary adaption and survival. The back cover is a drawing of a *Cyathocrinite,* logo of the M.A.P.S. club. May these incredible creatures continue to inspire interest and love in the life of a marvelous planet.

Blong, Matteson, Trinka. 1995.

A Love of Fossils Brings Us Together!

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PRELIMINARY INVESTIGATION
OF AN EPIZOIC
CRINOID FAUNA
ASSOCIATED WITH UPPER ORDOVICIAN BRYOZOAN BIOHERMS

by

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BACKGROUND

In recent years I have changed my collecting techniques from selectively choosing particularly well preserved fossils from outcrops - to bulk collecting. Certain soft Ordovician shales and limestones tend to weather very rapidly in the winter months and release a multitude of fossils. This type of bulk collecting envolves clearing the larger slabs of rock to one side and raking the smaller material into a pile. Larger rock fragments that are barren of fossils are discarded and the rest is bagged for transport. At home I have a series of screens that are positioned beneath the drip edge of the barn. Screen sizes are selected depending upon the size of the smallest recoverable fossils. The bulk material is left on the screens until the rain has washed and broken down the remaining rock in a satisfactory manner. At my leisure, the material is examined and sorted. The finer portions are examined by hand lens or microscope.

COMMENTS

Too many times collectors create false perceptions of the faunal content of a given rock unit or locality. They do this by collecting only perfect examples and ignore the imperfect, broken or common fossil remains. And when fossils are abundant, perhaps profuse, many tend to step to one side, looking for the unique. Sometimes one needs to get down and crawl around; to see the fossils that normally you would not see for the fossils you do see!

STRATIGRAPHY

In a disclosed area in north central Kentucky, just south and west of Cincinnati, Ohio - I discovered a unique echinoderm fauna. The fossils occur in the Kope formation (Eden Shale). The Kope is an upper Ordovician formation consisting of alternating limestone and shale beds. Some of the thicker limestone beds are crystalline, all are fossilferous and most are very argillaceous. The total thickness of the formation exceeds 200 feet. The Kope formation contain large amounts of echinoderm debris - mostly very small crinoid columnal disks and short columnal sections. Occasionally scattered cystoids plates (Glyptocystites fultonensis) are encountered. Very infrequently crinoid calyxes are found, generally these are _Iocrinus_ sp. Most of the limestone hard surfaces show evidence of a high energy environment. There are a number of limestone beds that have high relief wave marks, some exceed nine feet from apex to apex in width and more than one foot in relief. There are numerous smaller examples and some of the more resistant shale beds show near shore or shallow water indications - ripple thin limestone beds are determined and the result is an outcrop littered with flagstones.

In the upper portions of the Kope formation are several distinct bryozoan zones. These zones occur in the Southgate and McMicken Members. Occassionally an outcrop will be located in which the bryozoans are so numerous that they mask the occurence of all other fossils. Upon casual inspection these outcrops are a jumble of bryozoan fronds - Batostoma jamesi, Parvohallopora oneallis , Dekayia ulrichi, and Aspidopora newberryi to name a few.

DISCOVERY

In just an outcrop I made a discovery of an unusual relationship. Deciding to make a representative collection of the various species of bryozoan, I cleared an area of the larger limestone slabs. In doing so I noticed that the shale immediately above the area I was collecting in, thickened noticeably. Later when I was sorting the bryozoan fronds I became aware of an epifauna attached to some bryozoan fronds. It is quite common to find other types of bryozoan attaching themselves to each other, or an occasional inarticulate brachiopod (Petrocrania sp.). However in addition to these more common forms I found a curious group of echinoderms - various crinoid bases (c.f. Lichenocrinus), a tiny Iocrinus calyx with attached arms, and what may be cyclocystoids and edrioasteroids.

Occassionally a grapple will be found wound around a bryozoan frond. Many of the bryozoan fronds had scars or impressions where crinoids columnals had been in contact. The crinoid holdfasts may be divided into five general groups:

A. Globular, consisting of gray calcite, showing little or no structure.

B. Somewhat distinguishable plates composed of gray calcite which appear to be fused.

C. Distinct plates, some of which appear to be Lichenocrinus c.f. tuberculatus, composed of light gray calcite.

D. Grapples.

E. Crater - like Podolithus

As always there are some individuals that have characteristics of two or more of these general subdivisions. And some of these may be related to the cyclocystoids and edrioasteroids.

PALEOECOLOGY

The argillaceous nature of the limestones of the Kope formation and the rapid alternation from limestones to shales probably caused echinoderms to seek out colonies of bryozoan for attachment. There is evidence of smothered bottoms in some of the sequences. The substrate or ocean floor was composed of limey muds with little or no hard surfaces. The bryozoan bioherms provided the echinoderms a means to rise above the muddy floor and feed in clear water.

Judging from some of the longer bryozoan fronds and the apparent height of the "mound", these attached echinoderms were about six to ten feet above the ocean floor.

Occassional bryozoan frond "tops" ends demonstrate old but reduced growth, typical of coral colonies that are above water at low tide.

MICRO FAUNA

Some of the bryozoan fronds are pitted by a boring parasite that may be a sponge. There are approximately fifteen different species of bryozoan. The most common ones have been mentioned earlier in this paper. The brachiopod fauna consists of mostly smaller species such as; Petrocrania scabiosa, Orbiculoidea tenuisrtriata, Pholidops cincinnatiensis (inarticulates) and Onniella emicerata, O. multisecta, Sowerbyella rugosa, Rafinesquina sp. (articulates). The pelecypod fauna is somewhat extensive but due to the fact that most are internal molds and few have external ornament the generic and specific details have been lost. One exception is Ambonychia sp. The gastropods are many and varied, some examples are: Loxoplocus sp., Sinuites sp., Clathrospira sp. There are a few monoplacophorans present; the Crytolites sp. is the most common. One specimen of a cricoconarida was found caught in the fork of a bryozoan frond. It did not appear to be there intentionally, but rather the test had settled there and was engulfed by the bryozoan. It resembles Tentaculites. The cephalopods are represented by the form genus Orthonybyoceras and were probably the largest predator. A few medium sized orthocones have been found in association with the bioherm. However, at other localities they appear to be more frequent and larger. The largest incomplete orthocone from the bioherm is about five inches and appeared to have been about a foot long when the cone was complete. Orthocones exceeding ten feet have been reported by other authors in the upper Ordovician in the general area. Quite a number of "worm tubes" have been found attached to bryozoan fronds. Generally found in groups of three to six; these tubes do not have a specific orientional preference. These "worm tubes" belong to the genus Cornulites.

A number of trilobites have been found, however most are incomplete - tails, heads and hypostomas. The largest trilobite was Isotelus sp. Free cheeks and hypostoma is not uncommon. Based on the size of the free cheeks the largest would have been about four inches wide. Which is comparable to the size of the hypostoma. At another locality many miles to the southwest, a complete head measured about six inches across. This head belongs to an Isotelus maximus which can attain two feet or more in length. Isotelus was a bottom feeder which probably burrowed. Other trilobites include; Flexicalymene granulosa, Cryptolithus tesselatus "lace - collar trilobite", Triarthus eatoni, and Proetus spurlocki. Two form genus of trace fossils should also be mentioned here. Rusophycus pudicum - these are convex "objects" found on the under side of limestone slabs and are reputed to be burrows made by trilobites. And Diplichnites multipartitum are sets of small parallel ridges that swing to and fro and are found on the upper side of limestone slabs, these are reputed to be "trilobite tracks". One species of graptolite, Climacograptus typicalis is found, certain layers are covered with fragments of rhabdosomes.

CONCLUSION

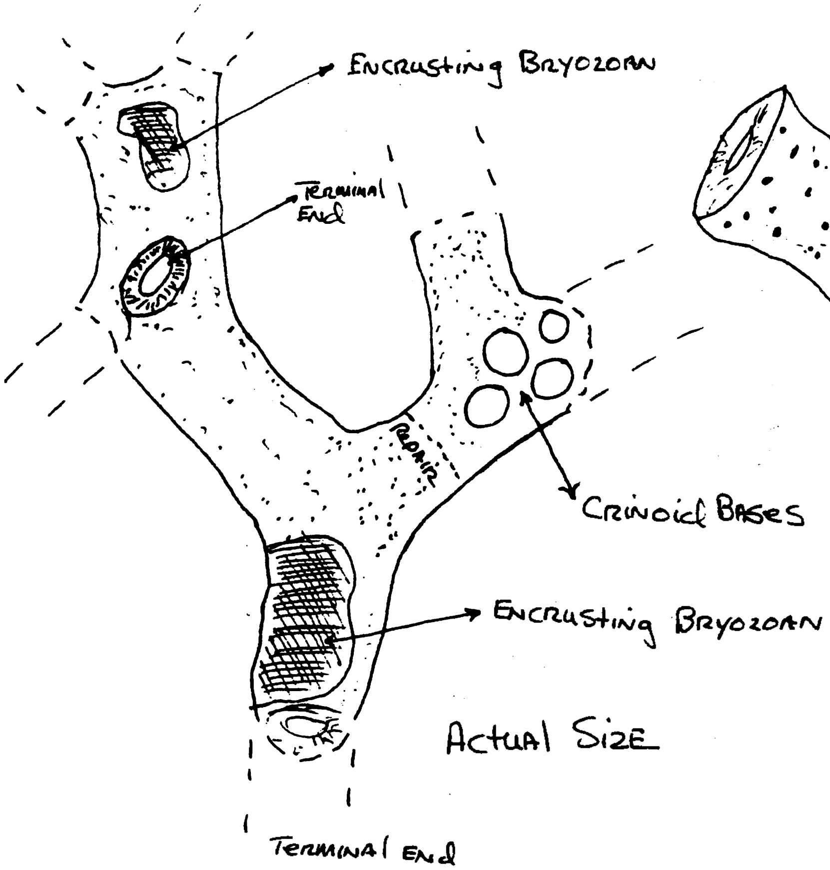
This locality has promise of producing additional research material. Perhaps this fauna will include some fossils that are new to science. The exact locality is being withheld for this reason. However, this same type of association has been found in several locations in the outcrop belt of the Kope formation. Crinoid mounds in the Mississippian age and other occurences generally consist of an outer ring of bryozoans and a few crinoids intermixed, and a core or central area composed almost entirely of crinoids. However these types of crinoids were free standing and not an epifauna. The delicate nature of these Ordovician crinoid columnals; (0 - approx. diameter) made them perfect candidates for living next to or on an object for support.

Perhaps there is a locality in your neighborhood that has a profusion of common and uninteresting fossils. Try collecting a bucketfull and taking the time to examine them up close - who knows you may find some new fossils, never seen before; or was it the fossil you could not see, because of the fossil it was on!

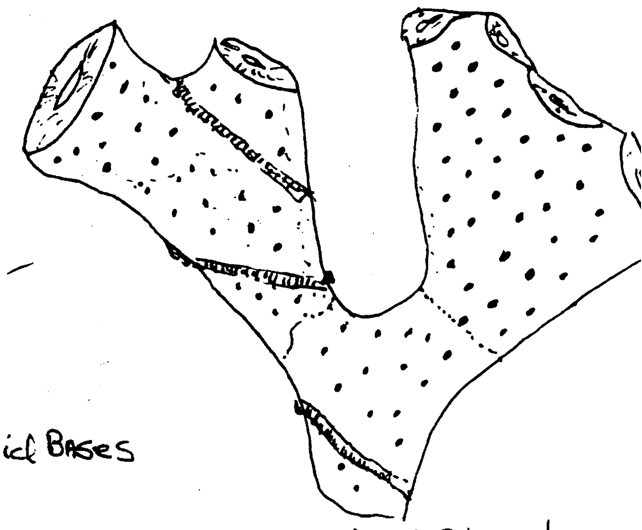
Stratigraphic Names in use in Kentucky Ohio and Indiana for the Upper Ordovician

U.S. Series	U.S. Stages	F.M. Fossils & Lithology	F.m Lithology	Members
CINCINNATIAN	RICHMONDIAN	WHITEWATER	Bull Fork	Saluda
				Lower Whitewater
		*		*Liberty
		WAYNESVILLE		Blanchester
				Clarksville
				Fort Ancient
		ARNHEIM		Oregonia
				Sunset
	MAYSVILLIAN	GRANT LAKE	McMillan	Mount Auburn
				Corryville
				Bellevue
		FAIRVIEW	FAIRVIEW	Fairmount
				Mount Hope
	EDENIAN	LATONIA	KOPE	▨ McMicken
				▨ Southgate
				Economy

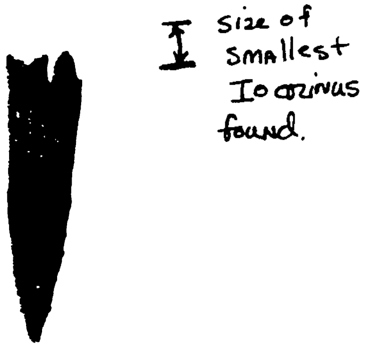
▨ Area of Report



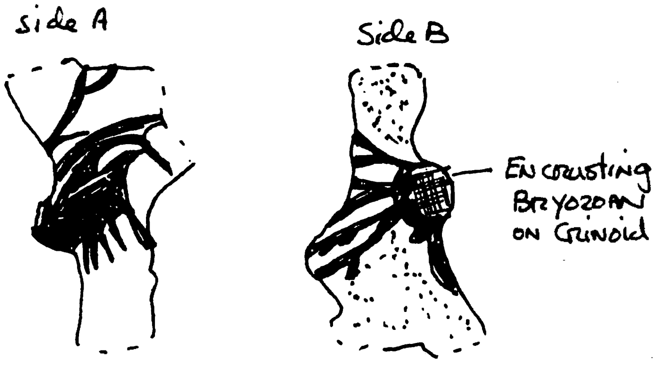
Actual Size



Crinoid Columnal
Wrapped Around Bryozoan



Iocrinus Calyx

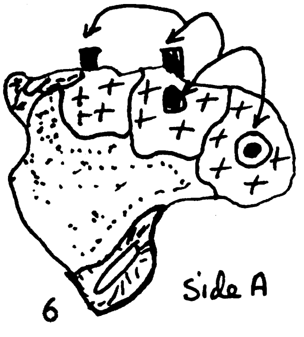


Crinoid Grapple on Bryozoan
Actual Size

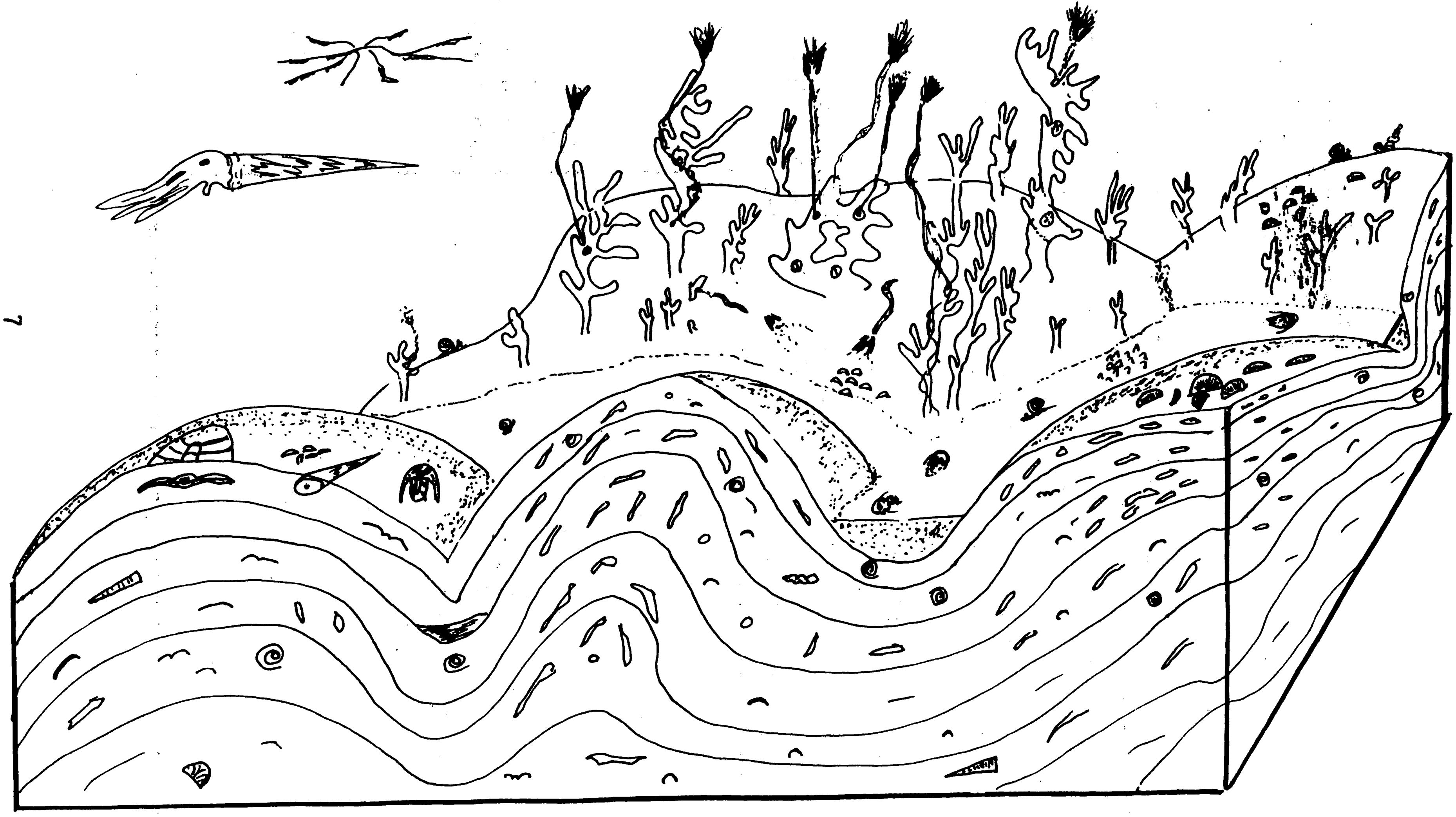
3 crinoid Bases

Side B

4 crinoid Bases



Side A



A DISCOVERY LIKE NO OTHER

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INTRODUCTION:

Any new fossil find enriches your collection, but most of all gives to the collector, great pleasure. However, some discovery out of the ordinary, remains engraved on my memory. One of the many special finds happened to me in August 1983 when I discovered a crinoid, **Archaeocrinus** genus, associated with a gastropod **Cyclonema** genus.

I found this uncommon specimen during a field trip in the Loliette area (Quebec). This outing was planned by two amateur paleontologists, Mr. Richard Carbonneau and Mr. Daniel Garon.

SITE LOCALIZATION:

Located North of St. Thomas (Quebec) in rang II of the Chaloupe concession (Fig.1) the Turnbull Construction Company, quarry is one of twelve companies of varied size that are either, not functioning or are worked sporadically.

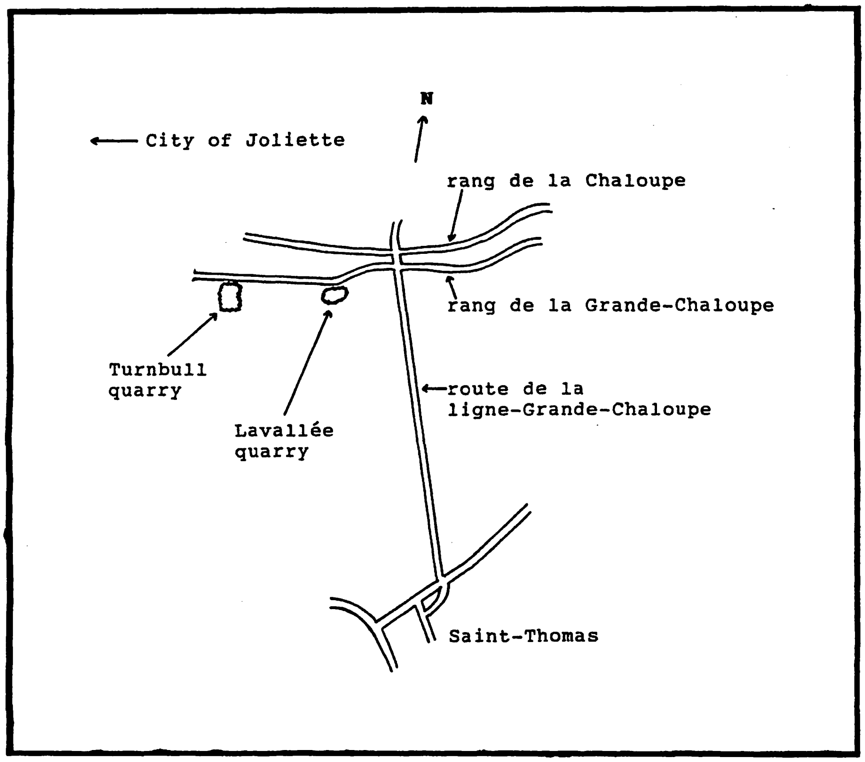


Figure 1
Map of the St. Thomas area showing Turnbull quarry and Lavellee quarry.

STRATIGRAPHY:

This medium sized quarry is not always operational. Most of th rock found there belong to theBlack River group (table 1) This group is divided in three formations: Pamelia, Lowville and Leray (though in the Turnbull quarry only Leray and Lowville formations are well exposed). Just over the Black River group,lays the Ouareau formation, which indicates the strata of the Trenton group. The demarcation between the Turnbull quarry (Ouareau fm. Trenton group) and Leray fm. Black River group) are differentiated with difficulty. However, most of the scientific athorities in this matter, disagree about the stratigraphic localisation of Ouareau fm. This section is completed with Deschambault fm. (lower Trenton gr.).

Deschambault	TRENTON	Middle Ordovician
Ouareau		
Leray	BLACK RIVER	
Lowville		

Table 1

Formations in the Turnbull quarry.

This calyx was found in the shaly interbed of the Deschambault fm. This type of sediment is typical of a quiet environment, and a good site to prevent decay of different organisms after their death. This explains the exceptional state of preservation of this specimen.

Deschambault formation consist of coarse-grained limestone, associated to a high energy environment. These strata are the remains of several marine transgression that happened about 450 Million years ago.

SYMBIOTIC ASSOCIATION:

This Gastropod-Crinoid association has to do with **Archaeocrinus desideratus** and **Cyclonema hageri** W. R. Billings. The round headed calyx is 35 mm in diameter and 22 mm in height. One side of the crinoid head has been greatly damaged by weathering. It gives us the chance to observe directly an area between the arms of the crinoid (Fig.2). Right there , is a Gastropod cast (coarse- grained). Like specified earlier it is **Cyclonema** cf. **hageri** Billings. The shell has been dissolved, we cannot be certain of the species.

Numerous propositions are strongly in favor of symbiotic association hypothesis, among them. Up until now, most of the authors that expressed their opinions, mentioned that neither organisms were living at the detriment of the other. In fact, this gastropoda was thought to be a harmless coprophageous creature, that fed on the refuse matter discharge from the crinoid.

1. The pinnules shape so well the fossilized gastropoda that the possible association of these two specimens by compression is problematic.

2. The gastropoda is located in the center of the crown, just over the anal cone (anal tube).

3. The gastropoda is placed in such a way, that the mouth is face down. This indicates that the animal's head is close by the anal vent (external termination of the digestive system).

4. Another specimen found by Richard Carbonneau, shows a similar association, and is from the same locality. Although its preservation is not very good it is nevertheless an evidence.

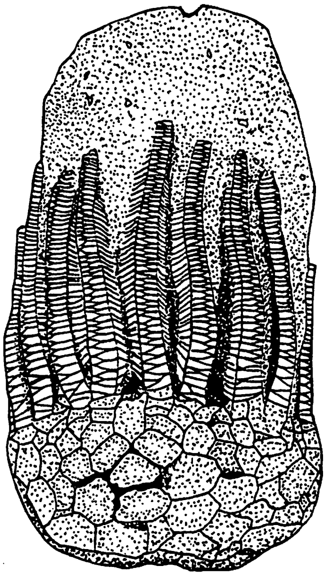
5. **Cyclonema** genus belongs to the Platyceratidae. Many of its relatives are well known for this kind of association during Devonian and Carboniferous.

Recent publications of Rollins and Brezinski (1988) questioned this theory, and suggest that it was more harmful than we thought. According to some authors the position of the head caused a growth deficiency to the crinoid, and as a result, an early death of the animal.

If this new hypoyhesis is well founded, the gastropoda was not a coprophageous animal. It was feeding from the nutrients the crinoid should have feed on, creating a food deficiency for the crinoid.

This behavior is "antagonist" because one of the organism exploits the other. (Babin 1991).

According to the literature, this type of association is not known before Upper Ordovician (about 445 m.y.) and lasted up to Upper Permian (about 230 m.y.). This finding moves back at least of 5 million years the relation gastropoda-crinoid, that is to say 450 Million years ago.



1

2

Fig. 1
Archaeocrinus desideratus
W. R. Billings, anterior view

Fig. 2
Same specimen, posterior view with **Cyclonema** cf.**hageri** Billings. The position of the gastropoda a top the crinoid suggest that the body of **Cyclonema** must have been in contact with the tegmen (area formed with small plates of the crinoid). Maximal length 6.5 cm.

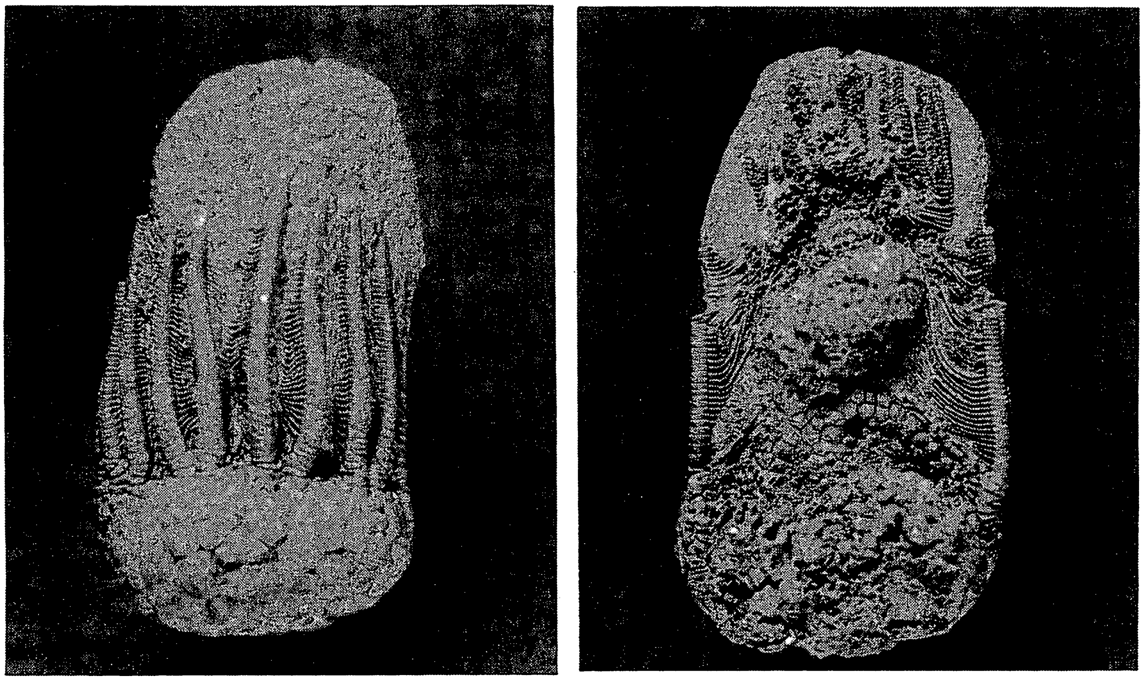


Fig. 3. Anterior view and posterior view of crinoid with associated gastropod.

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SELECTION OF CRINOID HOSTS BY PLATYCERATID GASTROPODS

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Introduction

Fossils of certain Paleozoic crinoids and, more rarely, cystoids and blastoids, are occasionally found with a platyceratid gastropod attached to the calyx (see Bowsher, 1955 for a review of this association). The platyceratids are thought to have settled on a echinoderm host as larvae and remained there for life. That their association was not just a chance occurrence is suggested by several factors: 1) each associated crinoid and gastropod appear to be size coordinated; 2) irregularities in the gastropod's apertural margin correspond closely to irregularities on the crinoid's calyx, and the extent of intergrowth in some cases is so great that the gastropod would have been unable to dislodge itself; 3) the gastropod may leave attachment scars on the crinoid; and 4) the gastropod is not haphazardly located on the crinoid but its thick, cap-shaped shell is situated with its aperture over the crinoid's anal opening.

The platyceratid-crinoid association was first noted in the literature by Austin and Austin (1843-1849), who believed that the crinoids were carnivores that fed upon the gastropods. In contrast, Billings (1870) believed that gastropods were the carnivores and crinoids the prey. Meek and Worthen (1866) may have been the first to suggest that the gastropods were coprophagous; in other words, they lived attached to the crinoid tegmen positioned over the anus where they fed upon its excrement. It is thought that Paleozoic crinoids, like modern forms, discharged small fecal pellets that had nutritional value because they contain undigested food particles (Bowsher, 1955). The gastropod may not have fed only on fecal material, however, but may have inserted its snout into the anus to collect food particles from the crinoid's food grooves located just below the tegmen (Baumiller, 1990). Many later crinoids have long anal tubes that are thought to have evolved in response to platyceratid behavior. In some cases, however, the gastropod bored into the crinoid at the base of the anal tube where it may have been able to access the food grooves (Baumiller, 1990) or feces.

This relationship is generally thought to have been commensal, that is, beneficial to the gastropod and of no harm to the host echinoderm. This is in contrast to a symbiotic relationship where both organisms benefit or a parasitic association where one benefits while the other suffers. Lane (1984) proposed, however, that platyceratids were parasites which fed on the gametes of camerate crinoids, and Rollins and Brezinski (1987) suggested that the host crinoids may have suffered harm in some cases. Apparently, however, this was a successful association that endured from the Ordovician, when platyceratid gastropods first evolved, through the Permian, when both these gastropods and their host echinoderms became extinct (Fig. 1).

Bowsher (1955) suggested that selection of a host crinoid by the gastropod was controlled only by the presence of a smooth place for attachment adjacent to the anus. Examination of Silurian occurrences of this relationship (Kluessendorf, 1983), however, has suggested that certain other features of crinoid morphology and behavior may affect the host selection, as discussed below .

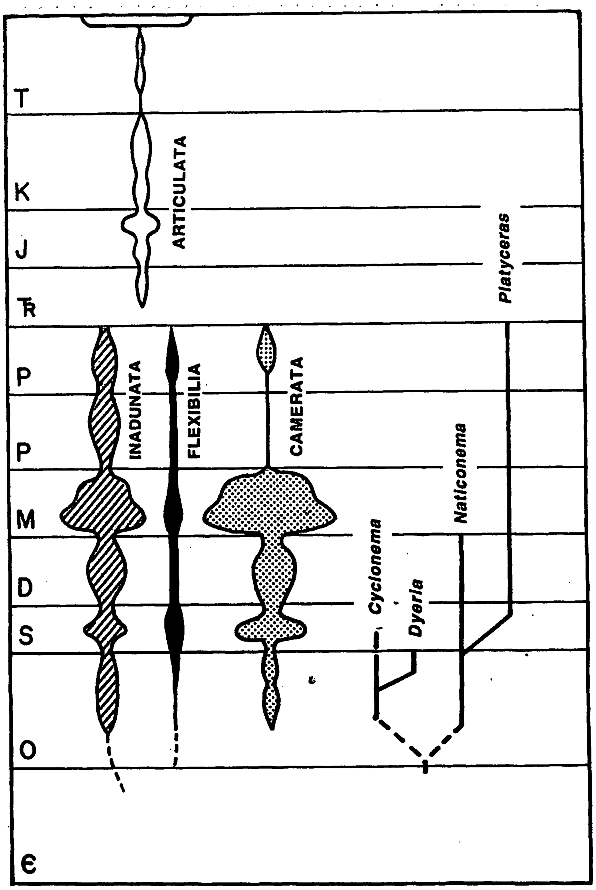

Figure 1. Chart showing range and distribution of crinoid subclasses compared with the range and phylogeny of the four genera of platyceratid gastropods. (after Bowsher, 1955)

Silurian Occurrences

James Hall, the eminent mid-nineteenth century American geologist/paleontologist, figured the first Silurian example of this gastropod-echinoderm relationship in 1852, which he correctly interpreted as a life association and not just an accident of preservation. This specimen showed a platyceratid firmly attached, not to a crinoid, but to the cystoid *Caryocrinites ornatus* from the Rochester Shale at Lockport, New York (Fig. 2a). In 1854, Sir Roderick Impey Murchison, the British geologist who named the Silurian System, published the earliest reference to a Silurian crinoid host, *Marsupiocrinus caelatus*. Murchison, however, assumed that the crinoid was preying upon the gastropod. The oldest occurrence of this relationship in Silurian rocks was found in the Llandovery age Power Glen Shale in New York and Ontario, where Brett (1978a) reported the platyceratid *Naticonema niagarense* attached to many of more than 100 crowns of the crinoid *Ptychocrinus medinensis*. This gastropod species was also reported attached to the crinoid *Macrostylocrinus ornatus* from the younger Wenlock age Rochester Shale in New York and Ontario (Bowsher, 1955; Brett, 1978b). Other echinoderms in this unit found with attached platyceratids include the cystoid *Caryocrinites ornatus* (Hall, 1852) and the crinoids *Lyriocrinus, Saccocrinus,* and *Dimerocrinites* (Kluessendorf, 1983). *Dimerocrinites* has also been found with attached platyceratids in the Wenlock Högklint beds at Häftingsklint, Gotland, Sweden (Kluessendorf, 1983). In England, *Platyceras haliotis* is found in association with the crinoid *Marsupiocrinus caelatus* in the Wenlock Limestone at Dudley (Murchison, 1854; Springer, 1926). Kluessendorf (1983) first reported this commensal behavior in the small crinoid *Clematocrinus* from Dudley (Fig. 2b) and in the crinoid *Periechocrinus christyi* from the Wenlock age Waldron Shale at Waldron, Indiana (Fig. 2c). Lierl (1982) noted this relationship between the crinoid *Scyphocrinites elegans* and the gastropods *Platyceras (Orthonychia) elegans* and *Ptychospirina* sp. at the Silurian-Devonian boundary in Morocco.

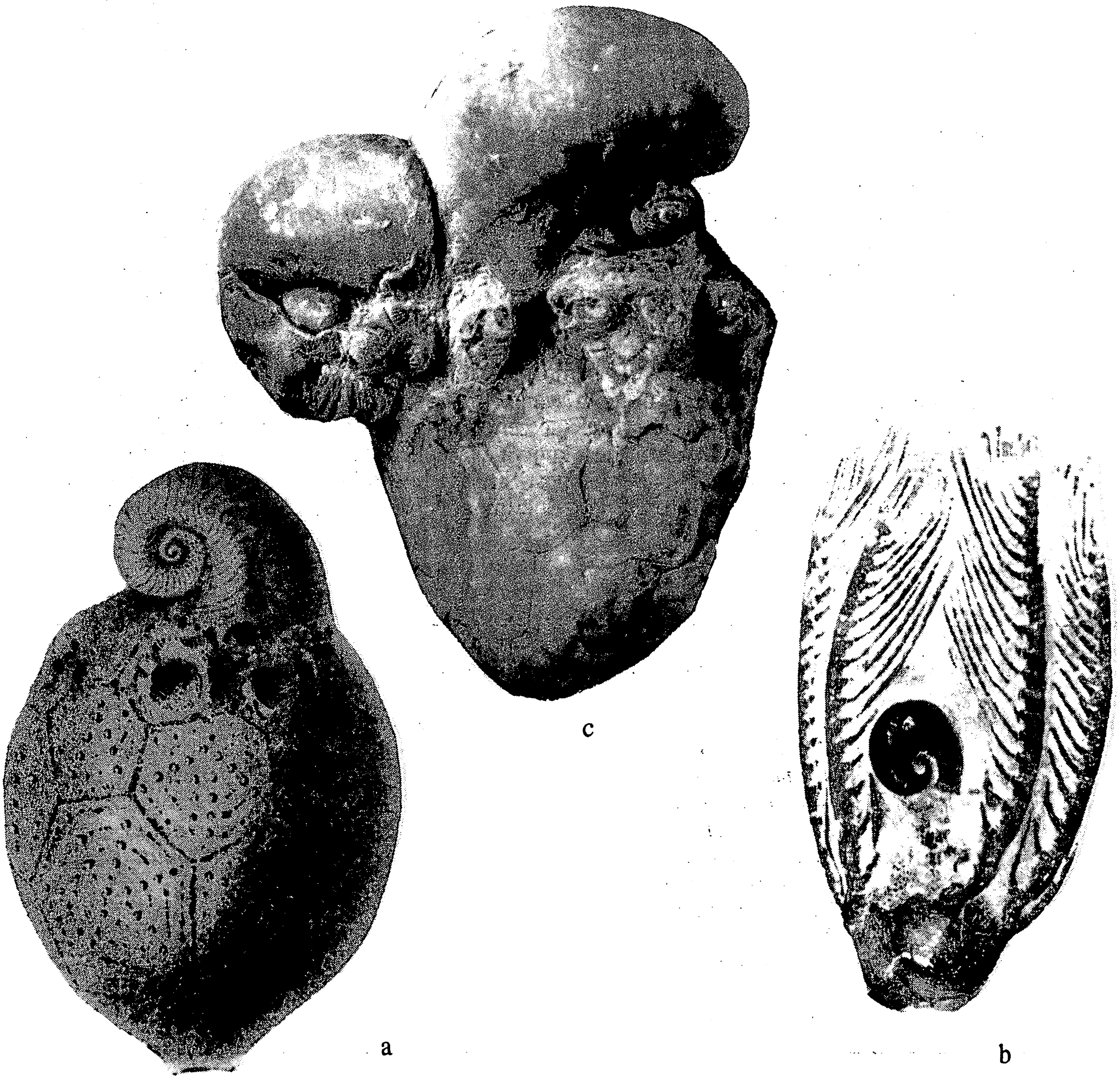

Figure 2. Silurian examples of the platyceratid gastropod-echinoderm relationship. a) (x3) platyceratid on theca of the cystoid *Caryocrinites ornatus,* Rochester Shale, Lockport, New York (from Hall, 1852, Pl. 49, fig. 1d); b) (x6) platyceratid attached to crown of the crinoid *Clematocrinus retiarus* (A12743, Fletcher Collection, Cambridge University), Wenlock Limestone, Dudley, England; c) (x1.2) two platyceratids associated with cup of the crinoid *Periechocrinus christyi,* Waldron Shale, Waldron, Indiana; gastropod on right seems to be attached to the crinoid; the other may be only a fortuitous association.

Interestingly, this commensal behavior has never been reported from the abundant and diverse echinoderm faunas in Silurian reefs of North America. Yet, platyceratids with irregular apertural margins and the cystoid *Caryocrinites* and crinoids *Dimerocrinites, Lyriocrinus, Macrostylocrinus, Marsupiocrinus* and *Periechocrinus,* which serve as gastropod hosts elsewhere, are present in the reefs. Kluessendorf (1983) suggested that the absence of this association is a result of the low sedimentation rate and high energy in the reef environment where echinoderms would likely disarticulate and gastropods become dislodged before burial could take place.

Morphology and Behavior of Crinoid Hosts

The presence of a large, smooth, flat tegmen has been proposed as the chief factor influencing selection of an echinoderm host by the platyceratid (Bowsher, 1955; Lane, 1978). The Silurian crinoid hosts, however, display a wide range of tegmen morphologies and anus types. Regardless of the tegmen or anus morphology, the platyceratid is always associated with the anus opening. Consequently, factors other than tegmen structure are important in controlling host selection.

The Silurian crinoids involved in this commensal relationship all belong to the subclass Camerata. Nine genera from 7 families of the 57 genera and 21 families of Silurian camerate crinoids serve as platyceratid hosts (Table 1) (Kluessendorf, 1983). A camerate crinoid, *Glyptocrinus,* also acted as a host in the earliest known example of this association from the Ordovician (Bowsher, 1955). Of the numerous post-Silurian host crinoid taxa, all are camerates except for six genera belonging to Suborder Poteriocrinina in Subclass Inadunata and one genus (*Taxocrinus*) from Subclass Flexibilia.

Table 1. Classification of Silurian camerate crinoids acting as platyceratid gastropod hosts.

- Order Monobathrida
  - Family Hapalocrinidae
    - *Clematocrinus*
  - Family Marsupiocrinidae
    - *Marsupiocrinus*
  - Family Patellocrinidae
    - *Macrostylocrinus*
  - Family Scyphocrinitidae
    - *Scyphocrinites*
  - Family Periechocrinidae
    - *Periechocrinus*
    - *Saccocrinus*
- Order Diplobathrida
  - Family Rhodocrinitidae
    - *Lyriocrinus*
  - Family Dimerocrinitidae
    - *Dimerocrinites*
    - *Ptychocrinus*

These three host-crinoid groups share similar morphologic and behavioral adaptations. The majority of the camerates and some flexible crinoids, especially taxocrinids, are thought to have been filtration-fan feeders that used currents to their advantage in feeding (Breimer, 1978). This feeding behavior is referred to as rheophilic, or current-loving. The pinnulate arms of these crinoids, which were feather-like with many small branches, formed a filtration net that was oriented perpendicular to the horizontal current in order to collect food particles (Macurda and Meyer, 1974) (Fig. 3a). To maintain this feeding posture the crinoid must have had some means of balance control to avoid being knocked over by the current and to support its heavy crown. Therefore, the stalk had to be flexible enough to bend with the current but rigid enough to keep the crinoid elevated above the sea floor and, in many cases, to provide anchorage. The stalks of most camerate crinoids were capable of significant flexure in the middle, whereas both the distal and proximal ends provided rigidity for maximum leverage. The distally-coiling stalks of dimerocrinitid (e.g., *Dimerocrinites*) and rhodocrinitid (e.g., *Lyriocrinus*) camerates, both of which are platyceratid hosts, may have been very useful in balance control (Breimer, 1978). The pinnulate arms of the more advanced inadunate crinoids were capable of muscular control and could be used to orient the crown in a rheophilic posture (Breimer, 1978). The poteriocrinine inadunates, which were the only inadunate platyceratid hosts, had evolved pinnulate arms capable of the rheophilic feeding posture (Lane and Breimer, 1974; Breimer and Webster, 1975).

Crinoids not adapted to the rheophilic feeding posture were rheophobic (Fig. 3b). These crinoids rested directly on the sea floor or were supported by a short, rigid stalk. They formed a collecting bowl with their nonpinnulated arms to passively catch detritus that settled gravitationally through the water column (Breimer, 1978). These crinoids are thought to have lived where currents were minimal to absent. They had no means of or need for balance control. Some camerates, most flexibles, and many inadunate crinoids were rheophobic. No rheophobic crinoid is known to have been a platyceratid host (Kluessendorf, 1983).

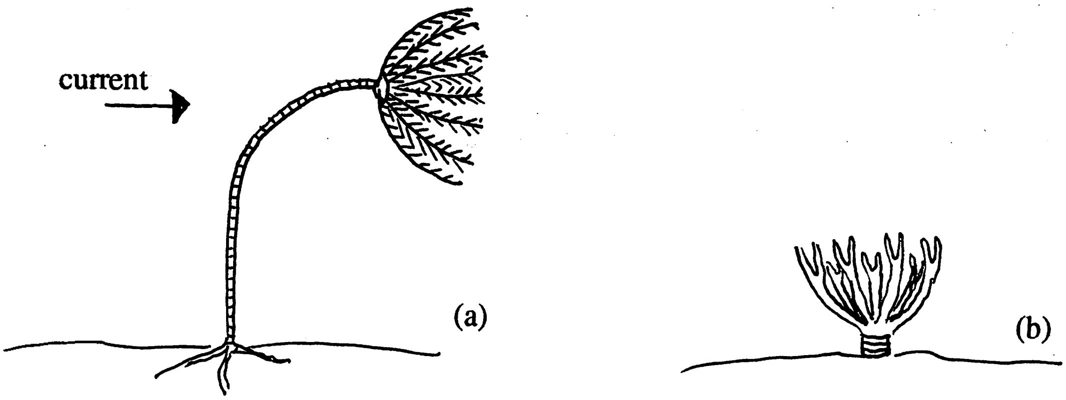

Figure 3. Diagram showing rheophilic (a) and rheophobic (b) crinoid feeding postures.

Interestingly, *Caryocrinites,* the only Silurian cystoid to serve as a platyceratid host, is an atypical cystoid that mimicked the morphology of camerate crinoids (Kluessendorf, 1983). It had a long flexible stalk, pinnulated arms and a tegmen similar to camerate crinoids. This contrasts sharply with the vast majority of cystoids which lie directly on the sea floor or have a short rigid stem and unbranched and unpinnulated arms. Sprinkle (1975) considered *Caryocrinites* a rheophilic filter-feeder in higher levels of the water column.

Platyceratid gastropods selected as their hosts only crinoids that used a rheophilic feeding posture. These crinoids may have been selected because they were capable of some balance control and could have supported the weight of a commensal gastropod while maintaining that feeding posture (Kluessendorf, 1983). Camerates with distally-coiling, prehensile stalks may have been the most efficient rheophiles, and several of the Silurian host-crinoids are of this type. The rheophobic crinoids, which depended strictly on gravitation for food gathering, may have prevented other organisms from settling on their feeding surfaces through some chemical or mechanical means (Kluessendorf, 1983), or they may have been unattractive hosts because they were too close to the sea floor and outside of active current flow. It is also possible that rheophobic and rheophilic crinoids, which fed at different levels in the water column, had different food sources that may have been reflected in the fecal or food groove contents that the platyceratids may have exploited (Kluessendorf, 1983). Furthermore, because they were probably less efficient food-gatherers, rheophobic crinoids may have had a lower rate of feces production or food particle collection than rheophilic taxa (Kluessendorf, 1983). Rollins and Brezinski (1987) proposed that platyceratids were not coprophagous at all, but exploited the aerosol filtration and elevation above the sea floor that the crinoid provided. This lends support to Kluessendorf's (1983) proposal that rheophilic behavior was important to the platyceratid in selecting a host crinoid.

Summary

All Ordovician and Silurian as well as the majority of post-Silurian crinoids that host platyceratid gastropods belong to the subclass Camerata. Non-camerate hosts comprise only six genera of poteriocrinine inadunates and one flexible, all of which resemble camerates morphologically. All three of these crinoid groups were probably rheophilic filter-feeders. *Caryocrinites,* the only Silurian host-cystoid also resembles camerate crinoids. Rheophobic crinoids, which fed by gravitational settling of food particles, lacked flexible stalks and pinnulated arms, and sat close to the sea floor out of current activity, are not known as platyceratid hosts. Therefore, platyceratids selected as hosts echinoderms that possessed the morphological and/or behavioral traits of camerate crinoids. The range of tegmen and anus types on host-echinoderms suggests that factors other than simple morphology were involved in host selection. Adaptations (e.g., balance control and support capabilities) for a rheophilic feeding posture or its results (e.g., filtration, feeding efficiency, fecal production rate) may have been more important (Kluessendorf, 1983).

Post script

I am still investigating the platyceratid-echinoderm association, and I would be interested in hearing of any specimens that turn up in strata of any age.

Acknowledgements

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SIGNIFICANCE OF AN EARLY

ORDOVICIAN CRINOID DISCOVERY

IN RELATION TO OTHER RECENT OCCURENCES FROM EL PASO, TEXAS

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INTRODUCTION

Four distinct crinoid zones have been discovered within the upper portion of the early Ordovician Arbuckle group in the Arbuckle mountains of southern Oklahoma. These occurences, along with recently described echinoderms from the time equivalent beds of the El Paso group in the Franklin mountains of far west Texas indicate that the Paleozoic Evolutionary Fauna was well established along the great carbonate bank of ancient North America by the end of the early Ordovician. This increases the known number of early Ordovician echinoderm occurences from 6 to 7 from North America, and helps to increase our knowledge of echinoderm expansion and evolution.

REGIONAL GEOLOGY & STRATIGRAPHY

The most complete section of lower Ordovician rocks in the southwest is located at the Franklin mountains of extreme west Texas and south-central New Mexico. The Ordovician section here is divided into the lower El Paso group, and upper Montoya group. The El Paso group is correlatable with the Ellenberger group of central Texas, and the Arbuckle group of Oklahoma.

The El Paso group is divided into the following formations in ascending order from oldest to youngest; Bliss ss., Sierrite, Cooks, Victorio Hills, Jose, McKelligon canyon, Scenic Drives, and the Florida Mountains formation (see Figure 1.).

The Florida Mountains formation of the El Paso group is approximately 36 feet thick at the southern end of the Franklin mountains along Scenic Drive. It is composed of a series of alternating limestones with thin shale partings, and gets progressively dolomitic towards the top. The limestones are primarily biomicrudities, biomicrites, and micrites that are inequigranular. Numerous bedding surfaces contain abundant fossil debris; usually thumbnail size or smaller, and incomplete fragments. The limestone is mottled dark gray with yellow to buff sandy layers.

The Arbuckle group of southern Oklahoma is divided into the following formations in ascending order; the basal Fort Sill ls., Royer dolomite, and Signal Mountain limestone of late Cambrian age. This is followed by the Butterly dolomite, McKinzie Hill, Cool Creek, Kinblade, and West Springs Creek formations of early Ordovician age.

The formation (s) containing the crinoid zones are uppermost early Ordovician; Canadian series (which is now called the Ibexian), Cassinian and upper Jeffersonian stages. It is approximately 485 - 500 million years old in absolute age.

The West Spring Creek and Kinblade formation of the Arbuckle group are exposed in the Arbuckle mountains of south-central Oklahoma, and are part of a thick carbonate sequence reaching a maxium thickness of 6700 feet in the Arbuckle anticline, both formations are cyclic deposits of carbonate mudstones, intraclast calcarenites, oolitic calcarenites, and laminated dolomitic limestones. These are all nearshore deposits representing environments ranging from shallow subtidal intertidal and peritidal. The cycles are shallowing upward sequences representing regional abrupt marine transgressions on a local scale.

EARLY ORDOVICIAN PALEOGEOGRAPHY

In early Ordovician, the North American continent was actually south of the equator, and the epieric sea bordering the southern margin of the craton was within the tropical latitudes. The water was very warm, and conductive to both organic and inorganic calcium carbonate precipitation. Many low-lying areas along the coastline were occasionally emergent and supplied fine sand and silt for offshore depostion. Even greater areas were tidal flats that were inhospitable to a normal marine fauna due to periods subarieal expossure and high salt content. It is believed that for miles offshore from the coastline that the water depth was less than a man's height.

The early Ordovician was the time period of maxium marine transgression (flooding) of the continents worldwide since the beginning of the Phanerozoic. With such a vast, extensive, and stable habitat available (it lasted for ten of millions of years!), it was enevitable that marine invertebrates would migrate in and exploit this "Great American Ramp".

Cloud and Barnes recognized in 1948 that the El Paso/Ellenberger/Arbuckle carbonates are analogous to the Bahama Banks of today that you have a humid, tropical - climate carbonate shelf extending for hundreds of miles. However the Bahama Banks are dwarfted in comparison with the early Ordovician carbonate ramp that bordered the southern edge of North American carton. This ramp was as wide as 450 miles in the vicinity of the Arbuckle mountains (see Figure 2.).

OCCURENCES OF CRINOIDS IN THE ARBUCKLE GROUP

The three crinoid zones from the West Spring Creek (WSC) formation, and the zone from the top of the underlying Kinblade formation were all deposited in nearshore environments at the time the crinoids were buried. The limestones of the WSC are gray to blue-gray on a fresh surface with the siltier layer being mottled yellow -tan in color. The beds are dolomitic and thin to medium-bedded.

The crinoid zones occur at the top of a given bed and there are multiple echinoderms on a given bedding surface. None of the crinoids were recovered with their holdfasts or the distal portions of the stems attached. This indicates deposition by a portable storm event in which the crinoids were ripped from their living sites and transported nearer to the shoreline. This is a mass kill event. there is no indication of bioturbation after the crinoids were buried to disarticulate the calcite skeleton.

The bedding plane I recovered the two crowns from the upper Kinblade formation is a special case. They were deposited at the top of a "flat pebble conglomerate" bed (FBC). A FBC is a fine - grained matrix limestone containing large, tabular, lime intraclasts of various shapes and sizes deposited in a chaotic mess with little or no sorting. The stem of one of the crinoids is draped over one very large intraclast while the crown itself is wedged between two adjacent limestone pebbles. This is a very high energy deposit.

The FBC is formed by a gradual withdrawal of the sea along a limey mud tidal flat. As the water recedes, the surface layer of lime mud is exposed to the elements (wind and sun), and dries out faster than the layers underneath. This is analogous to a rain filled ditch that dries up after a heavy thunderstorm. The upper layer dries up first forming mud cracks. Eventually the mud cracks curl up and flake off as they continue dehydrating. The mud chips are now semi - lithified, and could be deposited as a FBC if running water were to re-enter the ditch and transport the mud chips away.

Back to the Ordovician shoreline. At a later time a storm surge floods the now semi - lithified surface. The limestone intraclasts are ripped up and transported shoreward along with whatever organic debris that has already been picked up from farther offshore. They are dumped as a beach berm deposit when the energy of the storm surge recedes to the point it can not carry the load any farther shoreward. The rapid burial and the lack of any potential predators or scavengers onshore assure the preservstion of the crinoid carcasses.

BRIEF DESCRIPTION OF THE ARBUCKLE CRINOIDS

I will give a very brief account of the Arbuckle crinoids here. The formal and detailed description of these echinoderms will be by Dr. James Sprinkle at the University of Texas at Austin at a future date.

The crinoids are small, monocyclic, disparid inadunates (see Figure 3.). The cup is very small and resembles more of a bulge at the end of the stem than a true cup. The column itself is long and slender with each columnal being pentamerate. The distal portion of the stem and the holdfast are unknown. The holdfast is probably "lichenoid" which is one of the oldest types of crinoidal holdfasts known.

The arms are long, uniserial, isotomous, and branch at least three times from the junction with the cup. A very long and slender anal tube rises above the arms. It is at least one and a half times as long as the maximum arm length. The anal tube has distinct ray plates running up one side of it. Otherwise it is composed of tens to hundreds of small, polygonal plates.

ASSOCIATED FAUNA OF THE EL PASO & ARBUCKLE GROUPS

The crinoids were part of a fairly non-diverse benthic assemblage characterized by stalked pelmatazoans, benthictrilobites, orthid brachiopods, gastropods, and stromatolites (see Figure 4.). This suite of fossils is common to early Ordovician carbonates from North America though the specific genera differs from site to site.

Stromatoporids were the only organisms capable of building organic bioherms of any vertical relief. They would be replaced by bryozoans, and later corals in this area as the dominant "bioherm builder" by the middle Ordovician.

The gastropod Ceratopea is commonly found associated with stromatolites and is presumed to have grazed on them (see Figure 5.) . The trilobites were bottom-dwelling deposit feeders. The orthid brachiopods were low-level filter feeders, while the crinoids were higher level filter feeders. The crinoid arms lacked pinnules and probably fed on medium to large macro-plankton. Filter feeding has already advanced to the point here where the organisms utilizing it were arranged into verticle tiers to exploit the food sources available. It is unclear at this time whether the orthocone nautiloids were bottom dwellers or active swimmers yet.

The relative lack of diversity in this fossil community is in part related to preservational bias and in part to the original makeup of the benthos. Though the remains are probably close to their original resting place, the general broken and concentrated nature of fossils in some beds indicates some transportation before burial. However, the occasional complete specimen indicates some of the organisms died very close to where they were found. The exception to this are the molluscs; specifically the gastropods and cephalopods. Their aragonitic shells would have dissolved before burial in the well - oxygenated waters when they died on the seafloor. They appear in lower concentrations than they actually were.

All these fossils represent "normal" marine forms that lived within normal ranges of salinity, temperature, and oxygen levels. The water level was very shallow here over great distances and generally calm. It was however, subject to occasional strong surges caused by storms and typhoons offshore.

THE IMPORTANCE OF THE ARBUCKLE CRINOID ZONES

The importance of collecting any echinoderm from the early Ordovician is that they represent the potential turnover forms from the "Cambrian Evolutionary Fauna" to the "Late Paleozoic Evolutionary Fauna" that was well established by the mid Ordovician. A fundamental shift in shelf sedimentation styles occured near the Cambro- Ordovician boundry. The siliciclastic (sands and shales) nearshore deposits were replaced by extensive bioclastic-dominated shelfal carbonates. This happened along the entire length of the southern margin of the North American craton. These lithified carbonates substrates provided optimal attachment sites for stalked echinoderms such as crinoids and eocrinoids.

Coincident with this great change in sedimentation patterns with a major extinction event at the Cambro-Ordovician boundry. However, the extinctions were not caused by a lithologic change alone. Along the highway 77 roadcut section in the Arbuckle mountains, the faunal turnover occured within a six-inch interval of the Signal Mountain formation. And yet the lithology is a limestone above and below this sampled area with no indication of an obvious paleoenvironmental change to account for the extinction event.

One proposed cause for the mass extinctions is an upwelling of cold, anoxic basinal waters onto the tropical shelves. The warm water adapted fauna, dominated by trilobites as seen in Utah and Nevada, were eliminated. The trilobites were replaced by outer- shelf, cold-water genera. New niches were available to stalked echinoderms that could colonize the carbonate hardgrounds and firmgrounds. The eocrinoids and the disparid inadunate crinoids were the first echinoderms to effectively do so. The mechanisms that could have caused the upwelling of cold basinal waters has yet to be resolved.

The seven known early Ordovician echinoderm localites from the United States are:

1) Nine Mile sh. - Nevada
2) Fillmore fm. - Utah
3) lwr. Garden City fm.- Utah/Idaho
4) Manitou ls. - Colorado
5) Al Rose fm. - California
6) upr. El Paso group - west Texas
7) upr. Arbuckle group - Oklahoma

Interesting enough, there is a definate decrease in the number of classes of ecninoderms as you move from west to east. From the Nine Mile shale and the Fillmore formation of Utah and Nevada there are 8 classes present (Crinoidea, Eocrinoidea, Paracrinoidea, Cystoidea, Parablastoidea, Asteroidea, Edrioasteroidea, and Stylophoran carpoids). From the El Paso group of Texas there are three (crinoids, cystiods, and eocrinoids). From the Arbuckle group of Oklahoma only the crinoids are present in the early Ordovician. This could imply a eastward migration and expansion of echinoderms across the southern carbonate shelf following the extinction event at the end of the Cambrian.

Further focused collecting is required to confirm this trend if one exist. Also, renewed attention needs to be applied to the early Ordovician Knox group of the Appalachian region as all seven of these echinoderm localities are from west of the Mississippi River. Is this a true representation of echinoderm distribution in the early Ordovician of North America or merely an artifact of collecting bias? Only time will tell.

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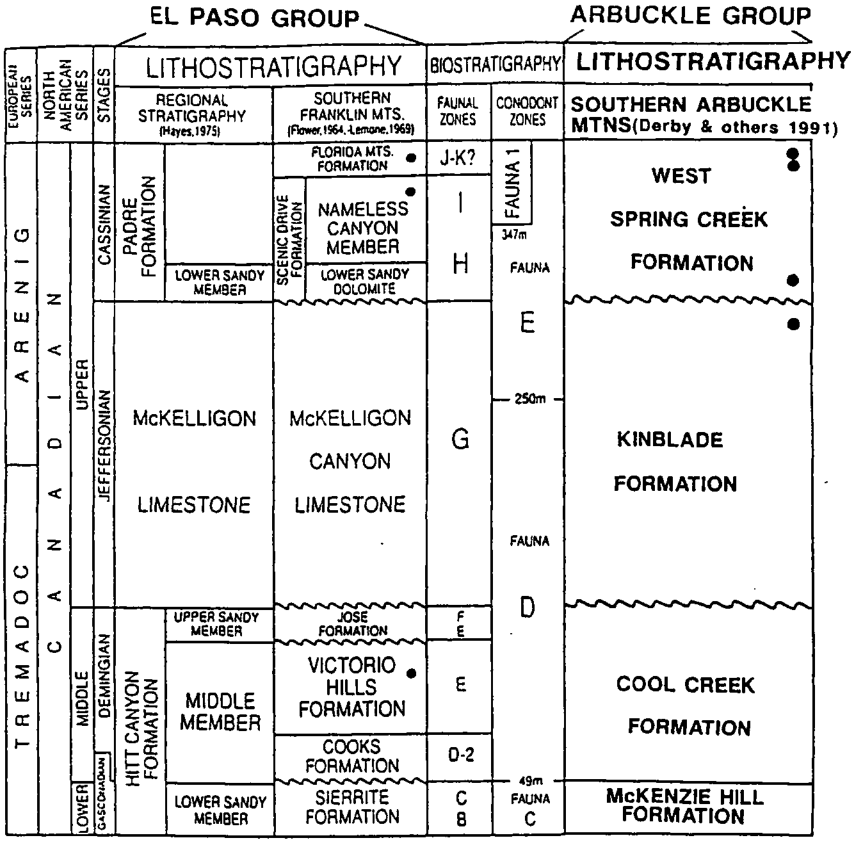
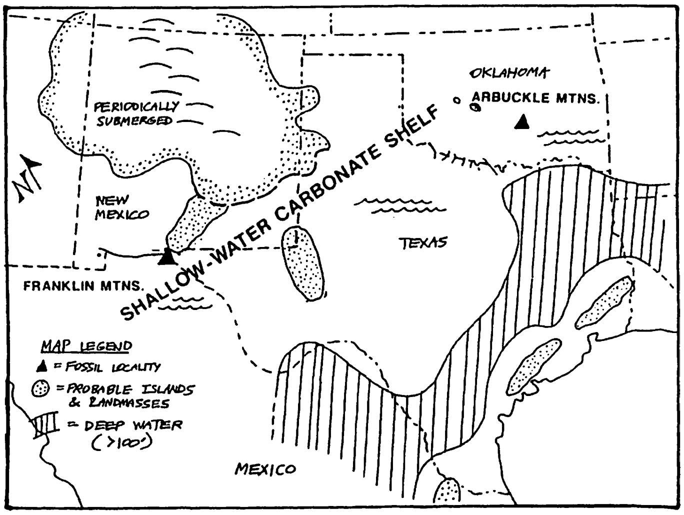


Figure 1.—Stratigraphy of the El Paso Group. The biostratigraphic faunal zones indicate Flower's (1964) and LeMone's (1969–1988) correlations to the Western United States Standard Section trilobite zones of Hintze (1951, 1952) and Ross (1951). The conodont zones are from Repetski (1982) and the measurements given are from his measured section of the El Paso Group along Scenic Drive in the southern Franklin Mountains. Dots indicate where the complete echinoderm taxa described here were collected in this section.

Stratigraphy of the Arbuckle Group. The biostratigraphic faunal zones same as El Paso Group. No measurements given. Dots indicate where complete crinoids were collected.

FIGURE 2

LOWER ORDOVICIAN (IBEXIAN) PALEOGEOGRAPHY SHOWING DISTRIBUTION OF ARBUCKLE - EL PASO CARBONATE PLATFORM:



(MODIFIED AFTER BARNES ET AL,1959)

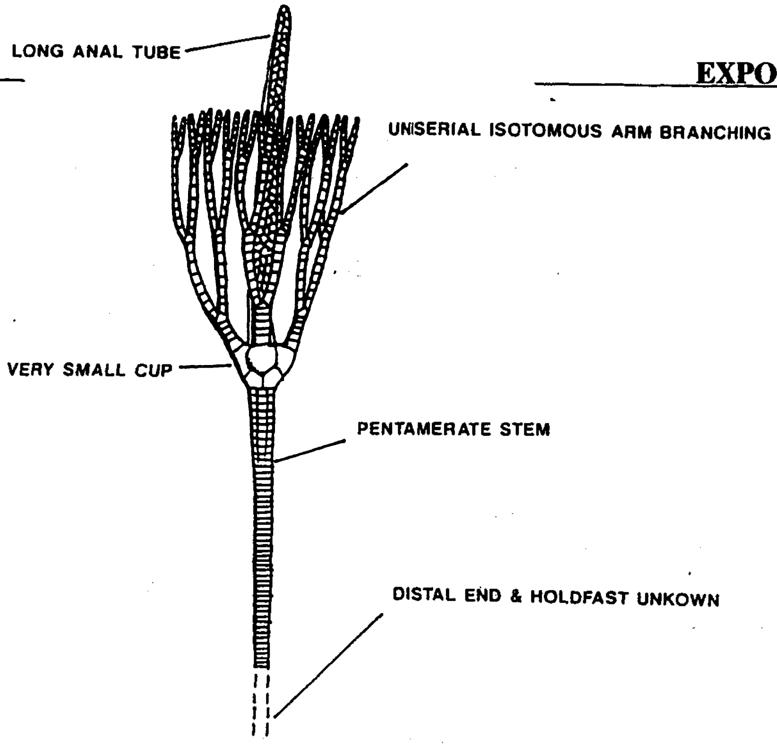


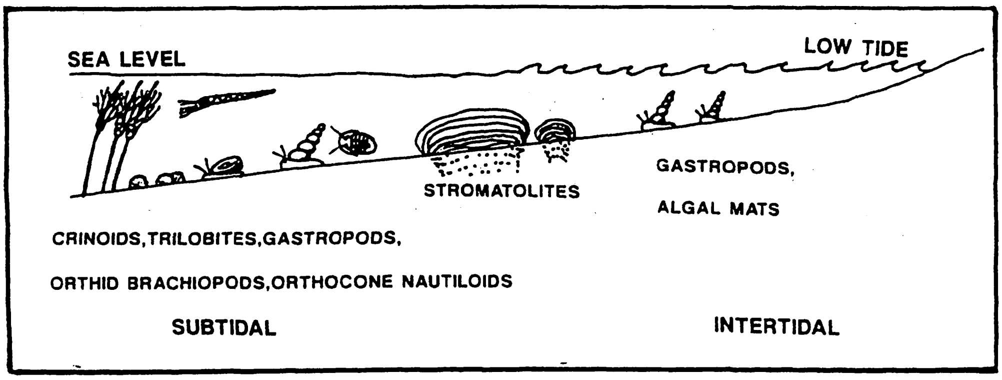
FIGURE 3. REPRESENTATIVE DISPARID INADUNATE CRINOID

FROM EARLY ORDOVICIAN ARBUCKLE GROUP OF SOUTHERN OKLAHOMA

FIGURE 4. - FAUNAL LISTINGS FROM EARLY ORD. TIME-EQUIVALENT UNITS:

	EL PASO GROUP PADRE FORMATION	ARBUCKLE GROUP WEST SPRING CREEK FORMATION
BRACHS	*Archeorthis sp. (orthid)* *Hesperonomia (Taffis) sp.* *Syntrophopsis magma* *Tritoechia typica*	*Anomalorthis sp.? (orthid)* *Desmorthis nevadensis* *Diparelasma typicum* *Polytoechia subrotunda*
GASTROS	*Liospira sp.* unidentified molds	*Ceratopea buttsi, C.hami* *Ceratopea knighti, C.unquis* *Holopea sp.* *Lophospira sp.*
CEPHS	none to date	orthocone nautiloids
TRILS	*Asaphus curiosus* *Bathyurus sp.* *Cybeloides primus* *Isoteloides whitfieldi?*	*Aponileus latus* *Bathyurellus sp.?* *Isoteloides flexus* *Isoteloides polaris*
STROMATOLITES	yes	yes
ECHINOS		
CRINOIDS	*Elpasocrinus radiatus*	undescribed inadunate
CYSTOIDS	*Cuniculocystis floweri*	none to date
EOCRINDS	undescribed Macrocystellid eocrinoid	none to date

Figure 5.



PALEOECOLOGY
OF A
CRINOID - SPONGE COMMUNITY
FROM LAKE BRIDGEPORT, WISE COUNTY TEXAS

Mark G. McKinzie
Nov.1994

INTRODUCTION

The completion of road construction along FM 1658 between the town of Bridgeport and the Lake Bridgeport spillway has enhanced the collecting at a famous crinoid locality in north - central Texas. this location is again producing complete crinoid crowns plus a host of other fossil invertebrates. I will briefly summerize the geology and paleontology of the site.

CRINOID LOCALITY

The locality is situated a few miles northwest of Bridgeport in Wise County, Texas. It is approximately an hour from the Fort Worth area. The exposure is 1/10 of a mile north of the intersection of FM 1658 & 2952 on the east side of FM 2952 across from the water tower (see Figure 1). The roadcut consists of a low hill exposure and adjacent flat drainage area parallel to the county road. Fossils occur thruout the exposure and are especially abundant along weathered surfaces.

The flat area adjacent to the road had been used as a road metal dump and heavy equipment parking lot during road construction on FM 1658. Bulldozing, grading, and the ruts left behind by the heavy machinery had torn up the locality. Many a collector feared the site was going to be lost forever if the state highway department planned on sodding the area afterwards. Luckily they did not. The heavy equipment and road gravel piles are gone now. Heavy fall rains and the envitable erosion they produce has exposed fresh surfaces containing crinoid crowns and cups. The site is probably in better shape now than it has been in years.

GEOLOGY

The formation exposed here is the Jasper Creek shale member of the Graford formation of the Canyon group. It is located near the top of the Missourian stage in the upper Pennsylvanian. The formation is correlatable with the Wann fm./upper Kansas City gr./of the Washington County area in northeast Oklahoma.

The shale was originally considered the "Lake Bridgeport" shale = Wolf Mountain shale of later usage. However, recent stratigraphic work placed it in the younger age Jasper Creek shale. It is slightly younger than the Wolf Mountain shale exposed at the Run-away Bay locality on Lake Bridgeport which is famous for its ammonoid (goniatite) fauna.

CRINOIDS

Strimple (1951) was the first to report on the well peserved and abundant crinoid fauna from this locality. He felt there was a strong resemblence of this community to the crinoid - sponge bearing horizon in the Captain Creek limestone mbr./Stanton limestone fm. of southeast Kansas.

The next detailed anlysis of the crinoids from Lake Bridgeport was by Pabian, Boardman II, and Holterhoff (1989). They were attempting to distinquish crinoid assemblages by arm structure/ feeding strategies versus water depth for the late Pennsylvanian of north - central Texas. Meyer (1979) demonstrated that crinoids with open - mesh, non - pinnulate arms fed in lower energy, multidirectional currents. Flexible crinoids utilized this type of feeding strategy based on their arms. On the other hand, crinoids with closed mesh, pinnulated arms (filtration fans) fed in reef environments and carbonate banks in high energy, undirectional currents. Camerates, and to a lesser extent, cladid inadunates employ this type of feeding strategy.

The authors were able to subdivide the crinoid faunas of north - central Texas into five assemblages from nearshore. They considered the crinoids from this Lake Bridgeport locality to most closely resebmle the"pirasocrinid - Delocrinus - Erisocrinus - Graffhamicrinus" assemblage. This is one of the more nearshore assemblages. It does however, have elements of a more offshore community; Apographiocrinus and the flexible crinoids. Table 1 is a complete listing of the crinoids from this locality.

The mud matrix the fossils are encased in indicates predominately quiet water conditions but with enough current activity to supply the nutrients to support a thriving crinoid - sponge community. For this to have been a nearshore community it must have been away from any major depocenters (deltas) and protected from major storm events by some natural geographical barrier seaward. The fine grained matrix of a shale indicates a muddy bottom which is attributed to slow sedimentation rates.

As can be seen from Table 1, the crinoid fauna is dominated by cladid inaduates of the suborder Poteriocrinina. These were a very successful group of crinoids in the Pennsylvanian of North America. As stated in the Treatise of Invertebrate Fossils on Crinoids (1978); "as a whole, they exhibit remarkable diversity, exceeding the other suborders in this regard, and in the numbers of recognized taxa at all levels."

Of the 16 genera of cladid inadunates, 4 genera belong to the family Pirasocrinidae. The pirasocrinids can be distinquished by their very low, almost discoid cups; multi - branched uniserial arms; and a tegmen which terminates in a prominent, flat - topped anal sac which extends at least to or beyond the length of the arms. The spines at the top of the mushroom capped anal sac are horizontally spread and of variable length. The anal spines can be common fossils at some localities rich in crinoidal debris.

The other 4 genera of crinoids are Flexible. Flexible crinoid crowns can be distinquished from cladid inadunate crowns by the arms. They are uniserial and non - pinnulate with the distal portion curling in at the tips giving it a "chicken foot" appearence. All totaled, there are at least 20 genera of crinoids present at this locality. Some of the species names may be synonymous with each other as the same species has been given different names thru time when described from different localities by different individuals.

PALEOECOLOGY

The crinoids are but one component of the biota at this locality. The assemblage has been termed a "crinoid - sponge community" because these two groups are the diominant members of the benthos here. Table 2 has a complete listing of the fossils (excluding crinoids) that I have collected from this locality. The sponges are well represented by the calcareous forms Heliospongia, Girtyocoelia, and Girtycoelia (and no, that is not a typo but 2 forms whose names differ by one vowel). They are all upright, more or less cylindrical, and can be branching colonies. Heliospongia can also be an encrusting, massive form found in the sandstone lenses within the shale unit.

The other prominent echinoderm from here is the cidarid echinoid Archeocidaris. Isolated plates, and especially barbed spines are common fossils. Like modern - day sea urchins; if you find one, you are bound to find others nearby. They apparently colonized in "nests" with tens to hundreds of individuals grazing together on the sea floor. This occurs today along the Great Barrier Reef offshore Australia. Archeocidaris is a "form genus", and lots of possibly different Pennsylvanian cidarids have been lumped together under this name. Some of you have probably already seen and/or purchased the beautifully preserved Archeociradids from the Lake Brownwood spillway area of Brown County, Texas. These occur in shale beds of the lower Winchell limestone of the Graford formation which is contemporaneous with the Jasper Creek shale.

Another common element of this sea floor community were the archeogastropods (seeTable 2). Snails today are grazers/scrapers of algae on and off the sea bottom. This might indicate that some sort of seaweed or seagrass was present but not preserved in the fossil record due to their lack of a hard skeleton to fossilize.

An exception to this feeding mode was the archeogastropod Platyceras. since the Silurian, it has been found attached to the tegmen of crinoids, especially camerates, lodged over the anal opening. Presumably it fed on the excretment of its host. I guess this proves once again that "one organism's junk is another organism's treasure". The spines capping the anal sac of some cladid inadunate crinoids may have been a response to the feeding behavior of Platyceras. More likely, predation by chondrichthyan fishes in the Carboniferous led to the evolution of long anal spines by stalked crinoids. A fish choking on the spines of a crinoid calyx it just bit off the column might persuade it to feed on a camerate the next time around. If this strategy worked or not is another story.

Other molluscs included clams, and the occasional goniatite cephalopod passing through on his/her way to greener sea pastures. The goniatites that are so abundant at the Run - Away Bay locality a few miles away are a rare element of this fauna. I have only collected two crushed conchs from here; one a very large Neodiomorphoceras. To me this indicates that this environment was not preferred by the coiled cephalopods or the straight - shelled nautiloids. Other benthic organisms included solitary rugos corals, brachiopods, and fennestrate bryozoans. Figure 2 is a diarama depicting what the sea bottom may have looked like at the time of deposition of the Jasper Creek shale at this locality. Besides those organisms living or attached to the sea bottom; a bradyont shark swims by in search of a meal while a jellyfish floats along in the current. The bradyonts were cartilageous fishes that are primitive ancestors of the modern - day chimeras. I have found a few Petalodus teeth at this locality. The blunt - ending teeth of a Petalodus shark were arranged as crushing plates. They fed on molluscs and other hard - shelled invertebrates, possibly even crinoid calyxes.

Of course, we only find fossils of organisms with hard parts that have the potential of being fossilized except under extraordinary conditions. As I mentioned before, seaweed/seagrasses, other types of algae, jellyfish, sea slugs, sea cucumbers, polycheate worms, crusteans, and others may have dwelled on the sea bottom at this locality. We as collectors are biased in what we recover by what is available to collect.

It takes vision to imagine "what might have been" beyond the obvious at any collecting site. I know that all of us who collect fossils (and are not in it only for the money!) do so because when we pick up a fossil - we see beyond the piece of rock in our hand to a time when it was a living, "breathing" organism. That is the wonder of fossils.

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TABLE 1. - CRINOIDS OF THE JASPER CREEK SHALE MEMBER OF THE GRAFORD FM.

- SUBCLASS INADUNATA
- ORDER CLADIDA
  - *Allagecrinus bassleri nodosus, A.status*
  - *Lecythiocrinus sp.*
  - SUBORDER POTERIOCRININA
    - *Apographiocrinus arcuatus, A. typicalis*
    - *Athlocrinus sp.*
    - *Delocrinus pictus, D.subhemisphericus, D.sp.*
    - *Elibatocrinus sp.*
    - *Endelocrinus grafordensis, E.tumidus*
    - *Erisocrinus sp.*
    - *Graphiocrinus bridgeportensis*
    - *Laudonocrinus subsinuatus*
    - *Stellarocrinus angulatus, S.texani, S.virgilensis, S. sp.*
    - *Ulocrinus convexus, U.sp.*
    - FAMILY PIRASOCRINIDAE
      - *Pirasocrinus invaginatus*
      - *Perimestocrinus moseleyi*
      - *Plaxocrinus laxus, P.oeconomicus*
      - *Utharocrinus cf. granulosus*
- SUBCLASS FLEXIBILIA
- ORDER SAGENOCRINIDA
  - *Aexitrophocrinus sp.*
  - *Amphicrinus sp.*
  - *Cibolocrinus erectus*
  - *Euonychocrinus subservire* (taxocrinid)

TABLE 2. - INVERTEBRATE FOSSILS (EXCLUDING CRINOIDS) OF THE JASPER CREEK SH.

GASTROPODS
Bellerphon graphicus?
Euphemites vittatus
Meekospira choctawensis
Platyceras parvum
Strobeus paludinaeformis

BRACHIOPODS
Hustedia mormoni
Neospirifer cameratus

RUGOSE CORALS
Lophophyllidium plummeri

ECHINOIDS
Archeocidaris sp.

PELECYPODS
Astartella concentrica
Myalina subquadrata

CEPHALOPODS
Neodiomorphoceras sp.

BRYOZOANS
Fenestrellina sp.

SPONGES
Heliospongia ramosa
Girtycoelia sp.
Girtyocoelia beedei

FIGURE 1.-CRINOID LOCALITY NW. OF BRIDGEPORT

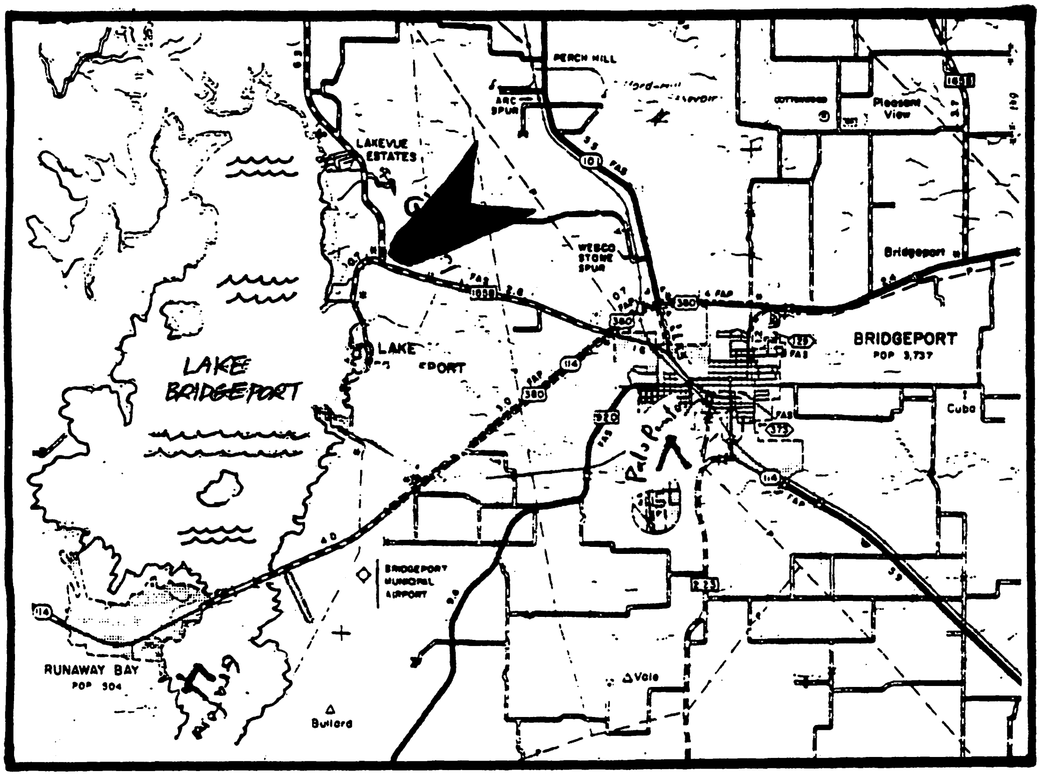
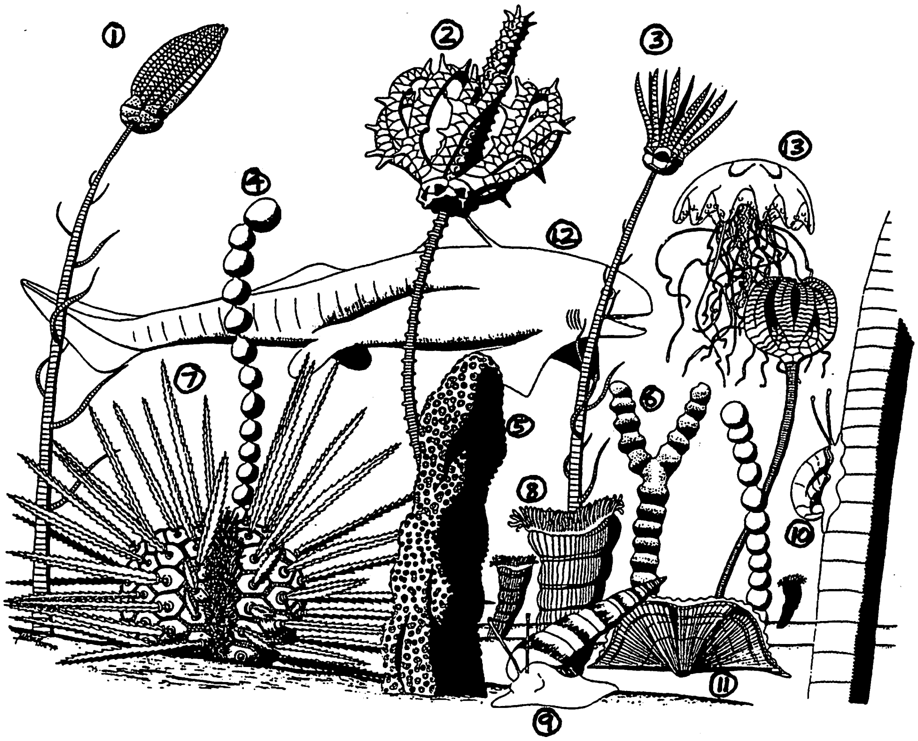


FIGURE 2.-CRINOID-SPONGE COMMUNITY FROM LAKE BRIDGEPORT.



IDENTIFICATION KEY TO THE FOSSILS REPRESENTED IN FIGURE 2.

(1) INADUNATE CRINOID: Delocrinus graphicus
(2) INADUNATE CRINOID: Stellarocrinus virgilensis
(3) FLEXIBLE CRINOID: Amphicrinus sp.
(4) CALCAREOUS SPONGE: Girtyocoelia beedei
(5) CALCAREOUS SPONGE: Heliospongia ramosa
(6) CALCAREOUS SPONGE: Girtycoelia sp.
(7) ECHINOID: Archeocidaris sp.
(8) RUGOSE CORAL: Lophophyllidium plummeri
(9) ARCHEOGASTROPOD: Meekospira choctawensis
(10) ARCHEOGASTROPOD: Platyceras parvum
(12) BRADYDONT SHARK: Helodus -type
(13) SCYPHOZOAN COELENTERATE: medusoid jellyfish

FIGURE 2.-CRINOID-SPONGE COMMUNITY FROM LAKE BRIDGEPORT.

A Middle Mississippian Crinoid Fauna from Kentucky and a Comparison with Indiana Species and Depositional Environments

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Discovery

In the summer of 1989 Ron Yates and the author were looking for mineral-bearing rock strata of Middle Mississippian age. One site we visited was found to contain abundant complete crinoids in rocks of the Muldraugh Formation (Osagean). During the hour we had to investigate the site, I collected five complete or nearly complete calices of various species (the best being a three inch (eight cm) *Scytalocrinus robustus* (Hall). The second visit to the locality a week later was productive. I collected an additional 30 partial or complete crowns, including a *Taxocrinus colletti* (White) immediately below the door where I parked my pick-up truck! There have been no unproductive collecting days since the discovery.

After the second visit, I contacted Professor Gary Lane at Indiana University. He came down the following week and agreed that Ron Yates and I had found a "Crawfordsville South." Dr. Lane put me in touch with two former graduate students -- Dr. William I. Ausich at the Ohio State University and Dr. Thomas W. Kammer at West Virginia University, both renown for their work in Osagean crinoids. Thus began "the crinoid project." This site, which may be Kentucky's most prolific Mississippian crinoid locality, has been kept secret to fully explore the unique and diverse crinoid fauna that will be described in this paper. Two studies are planned, the first describing the stratigraphic and regional environmental setting, with descriptions of species. The second describing the juvenile crinoids should be published professionally from the research on this site. Additional studies could be made from the abundant shark teeth and the relationships of the fauna to the sedimentary structures.

Stratigraphy and Sedimentary Structures

Site stratigraphy was studied and measured by Ron Yates and myself. The lowest exposure is a siltstone facies of the Muldraugh Formation. Although the Edwardsville Formation has not been reported in Kentucky, the siltstone facies exposed at the site appears to be time equivalent. Less than five feet (1.5 m) is exposed. It contains abundant crinoids (some complete from holdfast to crown), hexallinid sponges (some with enormous spicules), bryozoa, gastropods, conularids and brachiopods.

The dominate facies of the Muldraugh Formation at this locality is crinioidal limestone, some 30 feet (10 m) thick. Like the Edwardsville Formation, the Ramp Creek Formation is not reported from Kentucky. However, the crinoidal limestone exposed at our site has many features in common with the Ramp Creek in Indiana. There are a wide assortment of textures, lithologies and structures in the upper part of the Muldraugh at our site. Strata are separated with shale partings. Crinoids (including complete crowns) may be found throughout the entire interval. The blastoid *Metablastus* is found in this facies. The upper Muldraugh Formation has glauconitic grains, pyrite and contains abundant fish remains. Some concentrated bone beds on hard ground surfaces contain 50 or more whole and partial teeth in an area 12 inches (15 cm) square.

A three foot (1 m) thick layer of the Harrodsburg Limestone is above the Muldraugh formation. This marks the Osagean / Meramecian boundary within the Mississippian. This formation is cross-bedded and has a uniform lithology. It forms a distinct boundary with the underlying Muldraugh Formation. The Harrodsburg has not been fully explored, due to its thickness and relative inaccessibility. No distinctive crinoid material has been observed in this formation. A three inch (eight cm) goniatite was observed.

The Salem Limestone caps the exposure, with the Somerset Shale Member and Limestone Member. The Somerset Shale is about ten feet (3 m) thick. Both contain abundant blastoid *Pentremites conoideus* (Hall) and the crinoids basal cups of *Platycrinites bonoensis* (White) and *Dichocrinus simplex* Shumard. Other crinoid species can be found as basal cups, fragments or individual plates. Horn coral, brachiopods, bryozoans are the most abundant fauna of the Somerset / Salem. Some spectacular carbonized plants have been found in a silty facies of what appears to be the Salem Limestone. Work to determine if they are new species will need to be done.

The various formations from the prodelta or bottomset beds to the topmost delta platform beds form the Borden Group. The Muldraugh Formation represents the delta platform, at the top of the Borden delta. The change from siltstone to limestone was probably the result of the delta shifting laterally, with a corresponding decrease in terrigenous silt (Carbonate Petrology Seminar, 1987). The silt was replaced by carbonate-skeletal sediment. Storm-produced features, such as ripple marks are widespread across the locality. One set that was so large, they were not discovered while walking across them, but rather from a vantage point on an adjacent rock pile. Those regularly placed ripples measured over 12 inches (30 cm) from crest to trough and slightly less than 10 feet (3 m) from crest to crest. Crinoid columns up to seven feet (2.1 m) long were observed. Most were less than 40 inches (one meter) in length, including one *Actinocrinites* from the holdfast to the disarticulated calyx. *Platyceras* snails were observed to be consistently inverted (aperture upwards). This discovery enabled us to orient loose rocks containing *Platyceras*. A few hexallinid sponge holdfasts were preserved in situ. Asymmetrical ripples tend to have well-preserved crinoids, often in close proximity.

Geodes containing gypsum occur throughout the Muldraugh Formation. Some are up to 20 inches (50 cm) in diameter. Some are geodized crinoid calices, with the calcified plates still preserved. The only *Forbesiocrinus* collected is a geode. Many large crinoid columns have been found becoming geodes. Bedding plane gypsum in the form "satin spar" is common. One occurrence of crinoidal "limestone" contained the gypsum rather than calcium carbonate as the cementing agent.

Crinoids Collected

Table 1 lists the rank order abundance of crinoid genera collected at the site. The genera recognized by one specimen are listed alphabetically. "Type" indicates camerate (C), flexible (F), and inadunate (I). A number of specimens have not been "keyed out" yet at the time of writing, so some variation with the final count is anticipated. When compared to a list of crinoids from Crawfordsville, Montgomery County Indiana, there are a couple of important differences. Only a single *Agaricocrinus* has been found at our site. This genus is both common and widespread in comparable age faunas in the central United States. The camerate *Macrocrinus* is completely absent, yet ranks as one of the most common genera in Montgomery Co., Indiana. *Adinocrinus* is relatively common at this site and is unknown from the Crawfordsville vicinity and very rare everywhere else. The first reported complete crowns have been found. *Holcocrinus* is represented by a single calyx, but it is the fifth one documented and the most complete.

Table 1

Genus	Type	Genus	Type		
1. *Dizygocrinus*	C	15. *Pachylocrinus*	I	29. *Forbesiocrinus*	F
2. *Scytalocrinus*	I	16. *Camptocrinus*	C	30. *Holcocrinus*	I
3. *Synbathocrinus*	I	17. *Hypselocrinus*	I	31. *Hylodecrinus*	I
4. *Barycrinus*	I	18. *Aulocrinus*	I	32. *Hypselocrinus*	I
5. *Taxocrinus*	F	19. *Culmicrinus*	I	33. *Lanecrinus*	I
6. *Adinocrinus*	I	20. *Dichocrinus*	C	34. *Lekocrinus*	I
7. *Gilbertsocrinus*	C	21. *Eratocrinus*?	C	35. Myelodactylid?	C
8. *Halysiocrinus*	I	22. *Paradichocrinus*	C	36. *Onychocrinus*	F
9. *Ulrichicrinus*	I	23. *Wachsmuthicrinus*	F	37. *Ophiuricrinus*?	I
10. *Actinocrinites*	C	24. *Agaricocrinus*	C	38. *Parascytalocrinus*	I
11. *Cyathocrinites*	I	25. *Alloprosallocrinus*	C	39. *Poteriocrinites*	I
12. *Abrotocrinus*	I	26. *Cosmetocrinus*	I	40. *Sarocrinus*	I
13. *Platycrinites*	C	27. *Eucatillocrinus*	I	41. *Springericrinus?*	I
14. *Histocrinus*	I	28. *Eucladocrinus*	C		

Multiple crinoid associations usually represent a mixture of genera. One interesting slab contains some 45 calices (in pure limestone). Most of these are represented by the inadunate *Ulrichicrinus*. Another contains what may be a new species of *Sarocrinus* associated with *Halysiocrinus* and a well-formed five millimeter diameter *Taxocrinus*.

Crinoids and Depositional Environment

Ausich (1980, 1983) studied the components of fossil communities consisting of three depositional environments. They occur in the Borden delta in south-central Indiana near Lake Monroe. Relevance to the Kentucky crinoid site is that they are of similar age, although slightly older. The Lake Monroe sites are from the Edwardsville Formation. This may equal the lower part of the Muldraugh Formation at the Kentucky site. Inferences could be made with regards to sediment type, turbidity (how muddy the water was) and the prevalent energy conditions of the environment. The three environments noted: sandstone channel deposits (high energy conditions with ripple marks and channeling in a fine-grain sandstone); carbonate bank (moderate energy conditions with graded bedding and rare cross bedding in limestone containing varying amounts of silt); interchannel mudstone (low energy, without structural features). Some 77 different types of crinoids were studied (Ausich 1983). All other fossils were interpreted, including foraminifera, sponges, bryozoa, brachiopods, mollusks, arthropods, other echinoderms, etc. Their presence (or absence) in the three environments were noted.

This writer can make some generalizations about our crinoid site based on Ausich's studies at Lake Monroe. A more accurate account will be available with additional research. The siltstone facies bearing abundant well-preserved crinoids is within a very small area. Whether this constitutes Ausich's sandstone channel or interchannel mudstone facies is not yet known. Wide spread ripple marks were observed in limestone (carbonate banks?). Some shale partings contain crinoids, but most crinoids occur on limestone that was covered by shale. This likely represents a localized influx of sediment on a fairly large scale. Individual strata are separated by shale partings of one inch (2.5 cm) or less. They tend to be distinct across the width of the site which runs about 1/2 mile (<0.6 km) in a northerly direction. The strata running about 1/2 mile in to the west show a general dip in the strata, possibly due to the position above the Borden delta sediments. The Harrodsburg Limestone does not reflect this structural dip.

Table 2, column 1, lists species (when known). Identifications by William I. Ausich and Thomas W. Kammer, except Myelodactylid?, *Onychocrinus* and *Sarocrinus* new species by Robert Howell. Column 2 ranks them, the method is somewhat arbitrary: 10 or more = Abundant (A), 5 - 9 = Common (C), 3 - 4 = Uncommon (U), 2 = Rare (R), 1 = Very Rare (V). Column 3 is the facies (rock type) crinoids are found: Ls = Limestone, ALs = Argillaceous limestone, BSh = Bedding plane shale between limestone layers, St = Siltstone, Ch = Chert. Column 4 indicates depositional environment of species (if listed in Ausich, 1983) from the east shore of Lake Monroe, Indiana. SC = Sandstone channels, CB = Carbonate bank, IM = Interchannel mudstone facies. Column 5 lists other known occurrences by state. Where Kentucky is listed, it is other locations within the state.

Table 2

Name	**Rank**	**Facies**	**Ausich**	**Other localities reported**
Abrotocrinus new species	R	Ls		
Abrotocrinus sp.	U	Ls		IA, IL, IN, MO
Abrotocrinus unicus (Hall)	V	BSh	SC, CB	IA, IN
Actinocrinites jugosus (Hall)	R	BSh		IA, IL, KY, TN
Actinocrinites spp.	A	BSh	CB, IM	IA, IL, IN, KY, MO, TN
Adinocrinus nodosus (Wachsmuth & Springer)	A	St, BSh	CB	IN, KY, TN
Agaricocrinus sp.	V	Ls	CB, IM	IA, IL, IN, KY, MO, TN
Alloprosallocrinus conicus Lyon & Casseday	V	ALs	CB	IN, KY, TN
Aulocrinus bellus (Miller & Gurley)	R	BSh		IN
Barycrinus bullatus	R	St		
Barycrinus hoveyi (Hall)	R	St, ALs	CB, IM	IN, KY?
Barycrinus stellatus (Hall)	R	St, ALs		IA, IN
Barycrinus spp.	A	Ls, St	SC, CB, IM	IA, IL, IN, KY, TN
Camptocrinus crawfordsvillensis Springer	U	St	SC (dif. sp.)	IN
Cosmetocrinus gracilis (Kirk)	V	ALs		IN
Culmicrinus obscurus	R	BSh		
Cyathocrinites farleyi (Meek & Worthen)	V			

Cyathocrinites parvibrachiatus (Hall)	C	St, BSh	SC, CB, IM	IN
Cyathocrinites spp.	C	St, BSh	SC, CB, IM	IA, IL, IN, KY, MO, TN
Dichocrinus sp.	U	St	SC, CB, IM	IA, IL, IN, KY, MO, TN
Dizygocrinus biturbinatus (Hall)	U			IN, IL, IN, MO
Dizygocrinus spp.	A	St, ALs, Ls, BSh		IA, IL, IN, KY, MO, TN
Dizygocrinus new species?	V			
Eratocrinus? sp.	R		SC (*E. salemensis*)	IA, IL, IN, MO
Eucatillocrinus? sp.	V	St		IN
Eucladocrinus millebrachiatus (Wachsmuth & Springer)	R	Ls		IA, IL, IN, KY, MO
Forbesiocrinus sp.	V	ALs		IN, KY, MO, TN
Gilbertsocrinus tuberosus (Lyon & Casseday)	A	St, Ls	SC, CB, IM	IN, KY
Halysiocrinus tunicatus (Hall)	A	St, Ls, Ch	CB, IM	IN, KY
Histocrinus coreyi (Worthen)	U	BSh	SC, IM	IN
Histocrinus sp.	V			IN, MO
Holcocrinus nodobrachiatus (Hall)	V	St	SC	IN
Hylodecrinus bonoensis (Miller & Gurley)	V	ALs		IN, MO
Hypselocrinus indianensis (Meek & Worthen)	V		CB	IN
Hypselocrinus? sp.	V		CB, IM	IN
Lanecrinus depressus (Meek & Worthen)	V	St	SC	IA, IN
Lekocrinus planobrachiatus (Meek & Worthen)	V			IA, IL
Myelodactylid?	V	St		
Ophiuricrinus? sp.	V	BSh		IA
Pachylocrinus aequalis (Hall)	R	BSh		
Pachylocrinus validus	R	St		
Paradichocrinus planus Springer	V		SC, IM	IN, KY
Paradichocrinus sp.	V			IN, KY
Parascytalocrinus hamiltonensis (Worthen)	V			IA, IL
Platycrinites georgi (Hall)	V	BSh		IA, IL, KY, MO
Platycrinites hemisphericus (Meek & Worthen)	V	St	SC, CB, IM	IN
Platycrinites saffordi (Hall)	V	St	CB, IM	IA, IL, MO
Platycrinites spp.	U	St		IA, IL, IN, KY, MO, TN
Poteriocrinites sp.	V	St	Primarily IM	IN
Sarocrinus new species?	V	St	SC (*S. nitidus* Kirk)	
Scytalocrinus robustus (Hall)	A	St, Ls, BSh	SC	IN
Scytalocrinus sp.	A			IA, IL, IN, MO
Springericrinus? sp.	V	ALs	CB, IM	IN, KY
Synbathocrinus bradleyi	V	Ch		
Synbathocrinus swallovi (Hall)	A	St	CB, IM	IA, IL, IN, KY, MO
Taxocrinus colletti (White)	C	St	IM	IN
Taxocrinus sp.	A	St	SC (*T. ungula*? M&G)	
Ulrichicrinus brittsi	C	Ls		
Ulrichicrinus sp.	V	BSh, Ls		IL, IN
Wachsmuthocrinus sp.	R	St		IN, KY, MO

There are many crinoids that have not been identified at the genus or species level at the time of writing. This will affect the outcome of table 2, by nudging some species upward in abundance and perhaps adding additional species or genera to the list. There are 36 named species and possibly 3 new species. Twenty-two genera out of 42 have species awaiting closer scrutiny. The poor preservation of some will make accurate identification very difficult or impossible.

Adinocrinus nodosus (W & S) occurs in the siltstone at the Kentucky site, but in the carbonate bank (limestone) at Lake Monroe. *Holcocrinus nodobrachiatus* (Hall) occurs in the sandstone channel at Lake Monroe, but in the same siltstone as *Adinocrinus* here. *Scytalocrinus robustus* (Hall) occurs in the sandstone channel deposits at Lake Monroe, but in virtually all deposits at our Kentucky site. *Platycrinites hemisphericus* (Meek & Worthen) occurs in all facies at Lake Monroe, but has only been found in the siltstone here. Many other differences may be noted. Further work remains to compare the relationship between the depositional environments and crinoid species across the Borden delta.

Acknowledgments

The writer would like to acknowledge Ron Yates for his hard work at this site, assisting in collecting and stratigraphic studies. Gary Lane has been an invaluable resource. Bill Ausich and Tom Kammer have provided copies of their research, assisted in identifying crinoids and will be responsible for seeing that this site is the research is published in a professional manner. Bob Howell helped identify some crinoid specimens and prepared some for additional study.

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SILURIAN CRINOIDS

WALDRON SHALE - NIAGARAN SERIES

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Introduction

The Silurian strata in the United States was first studied in New York, the section for that state became a standard of comparison for all American Silurian strata. The Silurian is generally subdivided into three major portions or series, these in turn being subdivided into various stages. The principal division or series of the Silurian system are Cayugan (Upper), Niagaran (Middle), Medinan (Lower). Silurian Seas were shallow, and during the Middle Silurian it was the greatest.

The Waldron Shale Formation, Niagaran series is located in the southcentral part of Indiana, and extends from two miles south of the town of Waldron, with outcrops in Shelby, Bartholomew, Jennings, and Jefferson counties. The formation is covered throughout Shelby and Bartholomew counties by glacier drifts, and can be seen only in the quarries of these counties where the drift has been removed to get to the stone, and in Conn's Creek south of Waldron, west of the quarry, in Shelby County. In Clifty Creek and its tributaries in Bartholomew County between Hartsville and Newbern. The tributary which is the most profilic is Fall Fork at Anderson Falls.

Waldron Fauna

The fauna in the Waldron Shale was discovered by Professor David Christy of Cincinnati Ohio in 1860. He conveyed the information he had collected to Professor James Hall, State Geologist of New York. Christy and Hall did most of their collecting at the Waldron Quarry and Conns Creek which runs along the back side of the quarry. Many fine specimens were collected by the two, and were identified for the most part by Hall. Some species were named for Christy, along with Dr. Elrod, Waldron, Indiana, Niagara, Silurian and Nova Scotia.

Other geologists to follow were: S. A. Miller, C. B. Dyer and U. P. James.

The Waldron Shale is also accessible in Tennessee, New York and may be in other localities yet to be discovered. It is an amazing formation, you can be collecting in a spot which will be really profilic, almost solid fossils; then there will be several feet of shale where there will not be anything not even a fragment of a fossil. I don't understand why, but that's the way it is.

It is still possible to collect on the spoil banks at the Waldron Quarry. The site has been purchased by the Blue Springs Corporation, a scuba diving group. The pit is filled with water, and that is where they train divers. They charge a fee to collect.

Hartsville

Hartsville is located on a rolling elevation, ranging from 40 to 50 feet above the valleys. It is bounded on the west by the deep beds of Clifty Creek, and on the south by the gorges through which flows Boners Branch. The upland gravel west of Anderson Falls in Clifty Township is an extensive bed of gravel that seem to be in someway connected with the drainage of Bartholomew County at the close of the Glacier drift period.

Dr. Moses Elrod, M.D. Of Hartsville did the geological survey of Bartholomew County. He presented the survey to Dr. John Collett, Indiana State Geologist, September 4, 1881. He collected many fine specimens at Fall Fork and the Hartsville quarry, no longer there.

Anderson Falls

The Anderson Falls is located on Fall Fork of Clifty Creek. The Falls are remarkable as being in a small way the geological equivalent of the Niagara Falls shale and limestone. Here as well as at the great Niagara Falls may be seen the same processes in action. At the Falls the creek is about 40 feet wide with sharp mural fronts over which the water pours at flood stage with a great roar, falling 15 feet into the pool below, presenting a great spectacle. All the elements are present for a first class picturesque resort which is probably the reason the site was chosen for a Bartholomew County Recreational Park in the early 80's.

In my many (well...not that many) years of collecting I've encountered interesting, strange and wonderful experiences. Once in 1978 while near the Falls with some friends, Bill and Mary Luedeman and their grandson Pat, a strange and very dangerous event happened. First, I should explain you needed a rope to get down to the creek to collect, you anchored the rope to a tree on top of the bank which went straight down 10 or 12 feet, there was one small tree growing out of the bank and hung out over the shale. The tree roots were used as a step and there were usually snakes laying on the trunk and limbs of it, and you had to scare them away so they would not drop down on as you collected. Bill, Pat and I were down on the shale bank having a wonderful time hunting. The sun was shining bright; suddenly we heard a loud roar, and I said, "wonder what that is?" Bill at first said, he didn't know. The roar seem to get closer, suddenly Bill looked up and yelled, lets get out of here! The roar was the water rushing over the Falls- -yellow mud! about 5 feet high. Bill and Pat got up the bank with the rope, but I didn;t have time, I only got up against the bank as the rushing waters spread out across the creek and lowlands, it came within two feet of me as it rushed past. after the surge was over we still had about a 5 feet wide area to collect along the creek, and as the sun was still shining there, we decided it would be safe to go ahead and collect. To be on the safe side we threw most of our gear up on top, and started hunting again. It lasted only about 10 minutes, then we heard the roar again, only louder. Looking at the Falls, the muddy water this time was much higher. don't know for sure how, but we both got to the top. As the rushing waters reached us it was to the top of the bank. We later learned there was a "flash flood" a few miles up stream, we thanked our "lucky stars" we were safe.

Fall Fork of Clifty Creek

In the late 60's and early 70's, in summer when Fall Fork would dwindle to a lazy rivulet, and in a very dry season vanish into thin air. That was the time I was in "seventh heaven." It was such a time June 3, 1979, when a friend, Clara Weasner and I went there to collect fossils. The creek had all but disappeared, and I could dig out in the creek under the flag stone rocks, about 300 yards down stream from Anderson Falls. I was prying up the shale and at first glance I thought I had found a complete Arctinurus and a Trimerus under one large slab of shale. After a closer look I came back down to earth, because neither one of them had heads. I was disappionted so I decided I would sit down and rest for a short (very short) time, because when I'm collecting I rarely ever stop to rest, not even for lunch, which usually consists of an apple or a peanut butter sandwich, something I can hold, eat, walk and look at the same time (I never like to waste time when I'm collecting) anyway for the minute I sat I never stopped looking.

Suddenly I saw some bright blue/gray shale, so I decided that's where I would dig. There was a small thin ledge from where I had broken off some shale earlier that day and had gotten some nice trilobites. So I placed my large flat chisel under it and began to pound; I could see the shale move to the back about a foot. I decided I needed to put another chisel under it (a crow bar in fact) and raise the whole slab up, what a wonderful supprise! There lay a complete *LYRIOCRINUS MELISSA,* the crown with long arms and the complete column. I got so excited I was almost afraid to touch it. Afraid I would spoil it getting it out and making it secure. I'm usually prepared, so I carefully got it packed and was placing some of the loose shale around it for protection when I noticed a nodule of shale with what looked like a small crinoid column curved over something, showing up through the shale.

I decided I better investigate and find out for sure what it was. I took out my trusty tooth brush and knife then started picking and brushing. The farther I went the more excited I became, (anyone who has collected with me knows I get excited!) Then by the time I discovered what I had I was almost at the point of hysteria. I had found an *ALISOCRINUS CARLEYI* complete down to all the holdfast! Of course at the time I had no idea what it was, but knew I had something great. I packed up and made it home that day only by accident, because I was on a high for weeks after that. To find not just one, but two such crinoids almost together was about all I could take. Dr. N. Gary Lane of Indiana University later indentified it for me. He said he had never seen one so complete.

I had another such episode, but maybe not quite as bad just recently. April 2, 1994, when I found a *Caryocrinites* in the Waldron Shale at Tunnel Mill. (a place I will tell about later) I knew they were found in the Waldron Shale in New York and Tennessee, but had never seen or heard of one being found here. Professor James

Hall said there was not any found In the Waldron Shale in Indiana.

TUNNEL MILL

The Waldron Shale exposure in Jennings County (that's where I live) is in an old abandoned tunnel called Tunnel Mill. The mill was built in 1824 and was considered to be an extraordinary engineering feat for that time. A tunnel was excavated through solid rock from the north to the south side of the hill. A dam was constructed to channel the Muscatatuck River waters through the 10 feet wide tunnel to power the large turbine wheel. Muscatatuck River was given that name by the Potawatomi Indians, they called it MUSCUKUTUCK , which means winding waters (that's another story).

For many years the mill prospered and its products were well known throughout southern Indiana. Eventually Tunnel Mill was abandoned, the elements as well as progress took their toll on Tunnel Mill. You see the tunnel which was excavated through the hill in the rock was directly beneath the 4 feet thick layer of Waldron Shale. The shale began to deteriorate and fall in to choke up the tunnel. The mill was destroyed in the flood of 1897 when the waters of Muscatatuck came through with such force the shale was hollowed out as the waters came through. Turning the spot into a "Mother Load" of fossils. The tunnel is now about 30 feet wide and 8 to 10 feet high, the fossils are in the walls of shale. This outcrop of the Waldron Shale is quite different from other localities because here you are looking at the edges of the layered shale, so its difficult to extract slabs, because you can only chip away at the edges a small amount at a time. When the Tunnel was made the Waldron Shale had not been titled as such. All that's left of the old Mill is the smoke stack and 1 corner of the stone wall.

One of my most memorable experiences at Tunnel Mill was May 30. 1973 when I discovered my first *EUCALYPTOCRINITES CRASSUS* with a column attached. It was a small juvenile and was so perfect, I got so excited! The shale was wet, and when that spot of Waldron Shale is wet, its gray mud! The soft chunk had a gastropod, a Favosites and three brachiopods with it. I knew if I tried to free it I would lose the column. I wrapped it in a day's worth of newspaper along with a dry slab of shale, and got it home. I let it set until the next day before I had nerve to unwrap it. I had marked on the wrappings where the top was, so I layed it on the table and cut the newspaper away with scissors. When I got to the specimen I knew I couldn't pick it up or work with it. Luckily I had plaster of Paris. I hurriedly mixed some really thin, then poured it into a round cardboard box lid. Then placed a wide putty knife covered with a strong scrap of cloth under the paper beneath the specimen and sank it into the soupy plaster of Paris, by holding the edges of the cloth, then set it aside to dry. It was three weeks before I could clean it. With that shale the longer it dries the harder it gets. So of course I had to leave it in the plaster, and its still there.

The date was October 10, 1975 when I found the large *EUCALYPTOCRINITES CRASSUS*. This time the shale was completely dry and hard; and I was in the tunnel chipping away, Two friends, Charlie and Lila Murray from Michigan were with me. We had so far, a good day of collecting, found several Cups (Base of crinoid crowns) lots of gastropods and two or three good trilobites; and a lot of chunks we didn't know what was inside. When during the chipping I saw this column lying horizontal in the shale layers. I always follow one of those, but I should say I chipped away some of the column before I noticed it, so that was lost. I saw part of the crown showing, so I moved several inches away from the specimen and went around it allowing plenty of room so as not to cause damage if it turned out to be anything. I suppose it took me an hour or longer with the help of my friends watching to see when or if it moved so the crinoid wouldn't break up. The sun went behind a cloud and that added to the problem, because then I couldn't see very good. Charlie held the flashlight while Lila put gloves and papers around it to hold it is place as I dug it loose. It was still in intact when it broke loose. I wrapped in all the newspapers I had left and even took off my extra shirt and wrapped it. I didn't unwrap it for almost two months . I was afraid it wouldn't all be there still together because of the arms and interbrachials plates which were in place. I cleaned on it for several months, a little at a time. I never work on anything until I get tired, too much danger of doing damage to a specimen. One slip and you have nothing when you are cleaning by hand, and that's how I do it. Every part of it is still together.

Did you wonder how I so readily come up with these dates? Its because when I find a specimen I always put down the date, and record in my mind exactly the spot where I found it.

It was March 29, 1987 when I found the first *AMPHERISTOCRINUS TYPUS* at the tunnel. It was in a spot where I rarely dug, because there was never much if anything there. The shale was sifting down real good with my pick when I saw pyrite shining (usually where there is pyrite there is a fossil of some kind) so I took out my chisel and began to work at it. At first I thought it was the more common Saccocrinus but when I got it out I was thrilled! Because I had never seen anything like that in the Waldron Shale. The one that's shown in the Waldron book is so small and only the base of the crown showing that I couldn't tell what it was suppose to look like. When I arrived home I Immediately looked it up and when I showed it to Dr. Lane he said I was right. I didn't go back to the tunnel for two weeks. April 14, I decided I would dig in that same spot. I guess they run in pairs because there was another one almost in the same spot only not quite as large as the first. I couldn't believe it, I have collected at the tunnel since 1963 and I had never seen even a piece of an Ampheristocrinus.

I make several trips to the tunnel each year even in the winter. I only go there on week-ends when I go collecting alone, because it is a tourist attraction and there are always people coming and going. During the week I never go there alone. It is such a desolate place. I always feel safe when there are a lot of people around. Tom Walsh and Tim came down once and We went collecting at night. It doesn't matter as long as you have a light, and I usually take one. There are many fossils of all kind there but the crinoids excite me most.

Silurian crinoids are short stemmed, probably because the Silurian Seas were so shallow.

Through the years of collecting at my favorite site, I have had some rather bizarre experiences. There was one time I was about middle ways back in the tunnel when I pried out a chunk of shale and a pair of bats flew out, one hit me in the face it came out so fast. Another time I lifted up a piece of shale and a large snake was coiled underneath; that day I just quit and went home, snakes scare me almost to death.

In 1963, my first trip to the tunnel I found a beautiful Dalmanites tail, a gastropod and a bunch of brachiopods. I was just looking, I didn't have any tools along, and of course I didn't know what any of them were. It was at the tunnel where I found my first complete trilobite, (1965). The days when you could just go along and pick up specimens are long gone, now there are so many people who visit there they keep everything loose picked up.

The site is now owned by the State of Indiana, and is part of the Crosley Fish and Game area.

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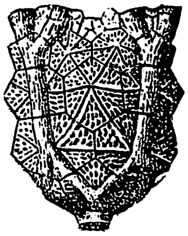
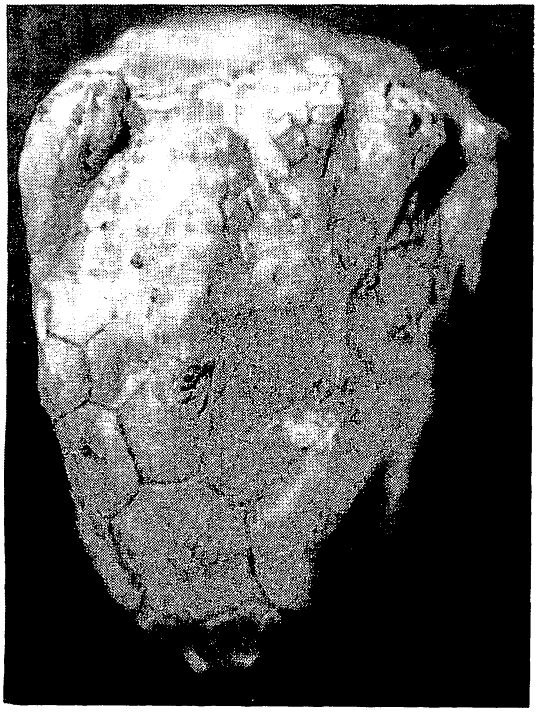
Glyptaster occidentalis

Specimen, body broadly subturbinate distinctly developed, view showing the interradialarea and surface markings



Saccocrinus christyi

The body below the arms elongate subovate very spreading at the arms. The basal plates proportionally small, more abruptly spreading than the succeeding plates, their lower margins somewhat produced near their junction with the column. The column enlarging just before reaching the base of the cup. Arms bifurcated composed of very thin discs, which are coarsely granulose on their margins.



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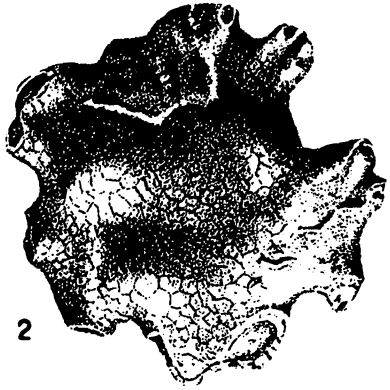
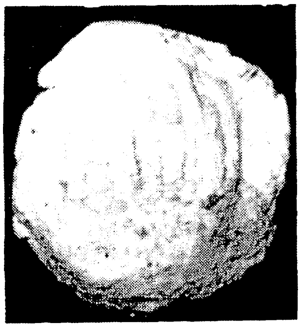


2

1. Lateral view of a large specimen.
2. The summit of the same specimen. (Jennings County, 1988)

Eucalyptocrinites elrodi

Body ovoid, base broadly truncate and concave for attachment of the column. Basal plates consealed in the cavity and covered by the summit of the column. composed by strong thick plates, with margins projecting and rounded. Surface ornamentation always conspicous and with variations.



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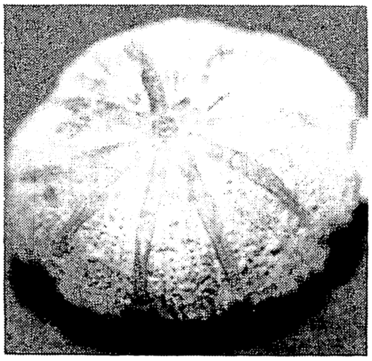
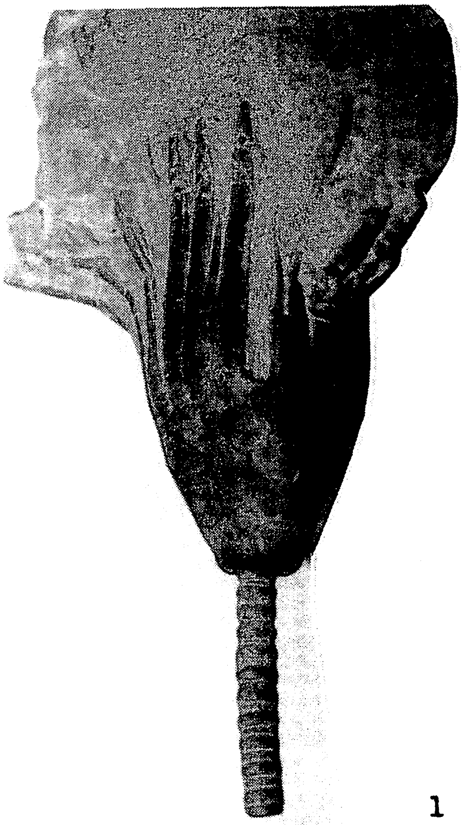


2

1. A lateral view of a specimen showing the calyx and the solid interbrachial plates. (Shelby County, 1992).
2. The summit of a specimen interbrachial plates and the accessory plates. (Jennings County, 1991)

Eucalyptocrinites crassus



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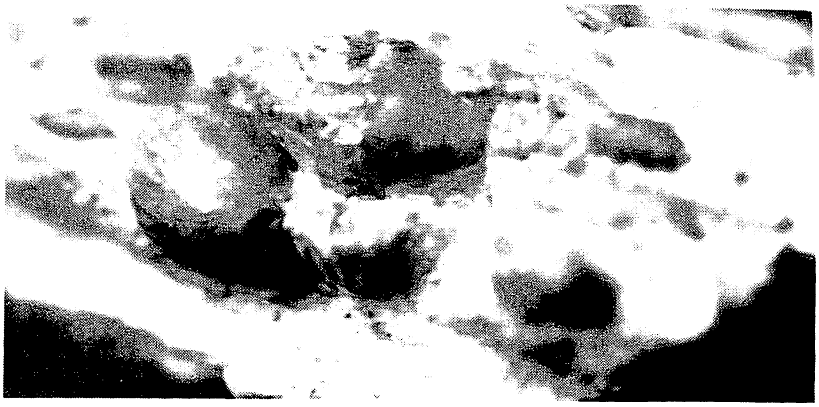
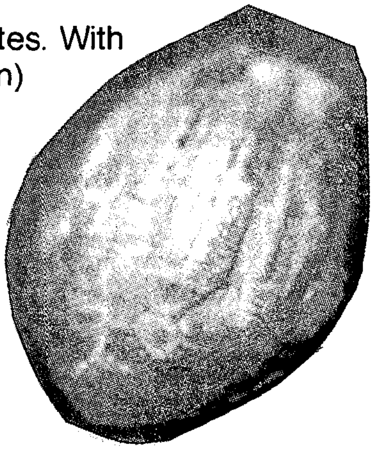


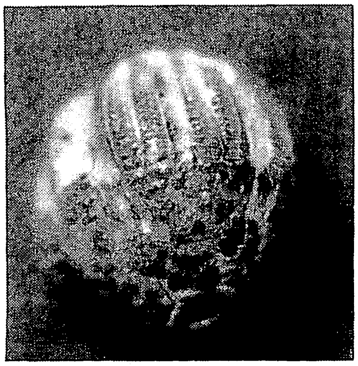
3

Body massive turbinate from the base to the arms, with the interbrachial plates and arms attached it has a general subovate form with truncate base. First radial plates much larger than the succeeding ones, height and width sub-equal.

1. A lateral view of a more spreading form retaining the arms and interbrachial plates in place. With a 1 1/2 Column attached. (Jennings County, 1975)
2. A juvenile specimen retaining the arms. void of the interbrachial plates. With a 3 inch column attached. (the 3 inches was probably all the column) (Jennings County, 1973)
3. Other forms of the same species.



Eucalyptocrinites ovalis



1

2

Body oval-ovoid outline curved from base to summit; calyx deeply cup-shaped, having a height equal to 2/3 the height from base of arms to summit.

1. view of an almost perfect juvenile specimen, without the column. 2. Summit of the same specimen (Shelby co.1993)

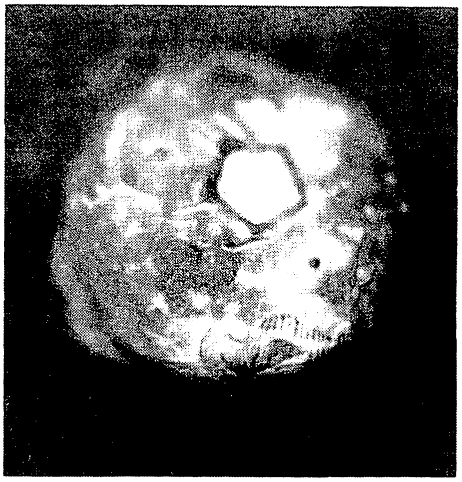
Alisocrinus carleyi

Body pentangularly turbinate having the angles coincident with the rays and marked by a rounded ridge, the intermediate spaces concave, a view of an entire specimen showing the features of the species including crown,column and holdfast. (Bartholomew Co. 1979)

Lyriocrinus melissa

1

2



3

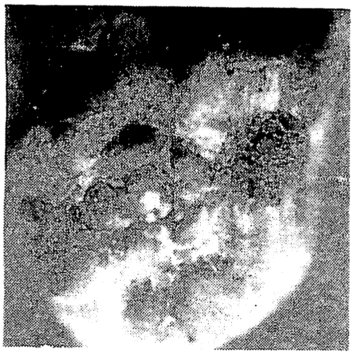
Body depressed subspherical, or nearly hemisperic; base nearly flat or very depressed convex; central column cavity abruptly and deeply depressed; sides inflated in the lower part and contracted just below the arm-bases, where it is again a little expanded. Basal plates small consealed within the cavity and covered by the column. subradial plates elongate hextagonal, their greatest width about 1/3 above their lower margin, radial plates large.

1. Specimen retaining the arms, columnal and one branch of the holdfast. The color of this specimen is a rich reddish brown. (Bartholomew County, 1979)
2. Basal view of a specimen showing a thickened derpessed pentagonal ring where the column is attached; also developed nodes on the first and second radial plates. (Jennings Co.1980)
3. A specimen showing a trilobite attached. (Jennings Co. 1987)

Ampheristocrinus typus

1

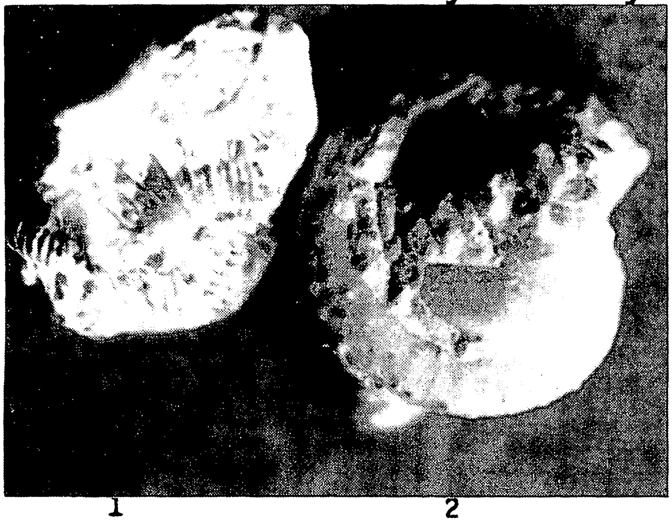
Body somewhat angularly turbinate, base a little protuberant for the column attachment, narrow and distinctly pentangular above the middle of the subradial plates. The basal plates are distinctly flattened or sometimes slightly concaved; and in like manner the areas formed by the lateral portions of adjacent radial plates and the upper part of the subradials are flattened. Radials fully 1/3 wider than high.
(Jennings County, 1987)



2

1. Lateral view of a specimen, specked with pyrite. 2. Basal view of the same specimen.

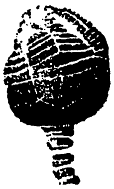
Myelodactylus convolutus

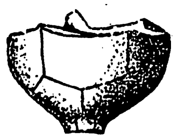


1. Small specimen, crown slinder; column coiled, abundant long cirri concealing the crown. (Jennings County, 1970)

2. A larger specimen attached to a Eucalyptocrinites elrodi. (Jennings County, 1982)

Lecanocrinus pusillus





Calyx small, forming a broad, shallow cup inflated on the anal side; basal plates very small.
Anterior and posterior view of a calyx.
(Shelby County, 1969)

Macrostylocrinus faciatus

Body rotund, calyx symmetrically cup-shaped; basal plates three, closely anchylosed, and supporting five hexagonal first radial plates. Surface granulose striate, the striae sometimes in strong fascicles, to the most entire exclusion of granulae.

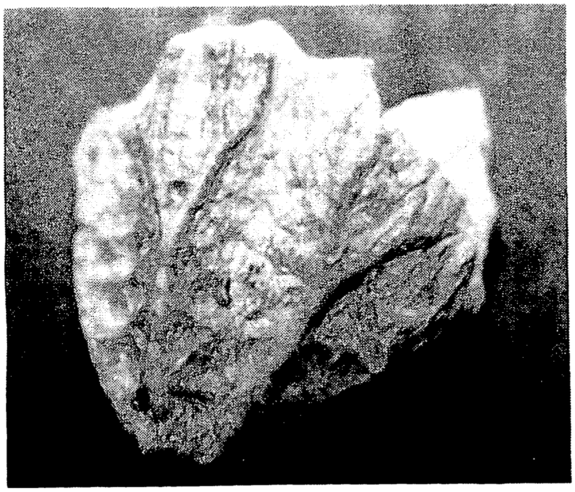
Lateral and basal view of a specimen, Shelby County (1975)

Cyathocrinus polyxo

Body broadly turbinate, base large and somewhat protuberant, sides angular from the prominence of the centers of the subradial and radial plates. Basal plates wider than high. Lateral view of a specimen, (Jennings County, 1994)

BASE

Glyptocrinus carleyi



Body pentangular turbinate. Radial series strongly marked by a longitudinal rounded ridge, which bifurcates with the first and second division of the ray giving the form four to eight arms to each ray as it leaves the body, Besides the longitudial ridge, the plates of the radial, interadial and superadial series are marked by sharp radiating ridiges, with the intermediate spaces finely granulose. Rays bifurcating on the third or fourth plate and again on the second or third above and on the sixth or seventh of the superadial series.

Laterial view of A specimen without a column. (Jennings County, 1994)

Other Crinoids in my collection, which I have collected *Poteriocrinus corleyi, Platycrinus siluricus, Melocrinus obconicus, Stephanocrinus gemmiformis*. Some others which have not been identified.

CRINOIDS OF OREGON

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In the summer of 1972, I embarked on a six week camping trip encompassing the entire western half of the United States. In doing so, one of the many places we found ourselves was the very small community of Mist, Oregon.

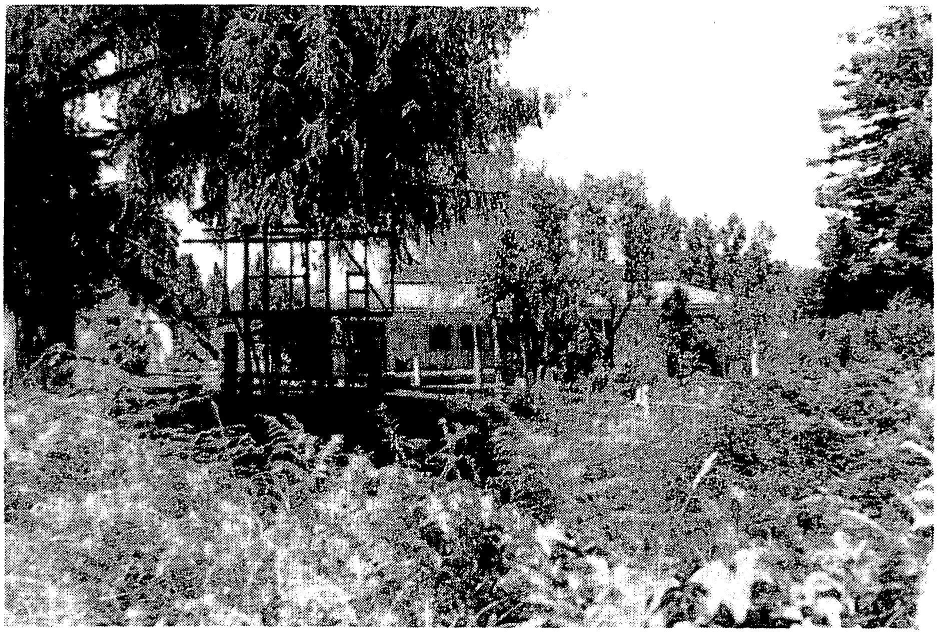
I had heard of the famous Oligocene specimens of crinoids Isocrinus, that occurs here, and so decided to spend the day looking for fossils near the river along the bluff which contains the wonderful fossils. At that time we found only "bits and pieces" of badly weathered crinoids and other fossils, but this was a fine indication of the potential this locality possessed for these extremely rare fossils of the Keasy Formation.

Almost two years passed, and for reasons having nothing to do with fossils, we decided to pack up our household and move to Oregon, settling in Salem, the capitol of Oregan. First order of business upon arriving was to unpack and find employment. We had a 4X4 pickup truck and a large cargo trailer for the move. These helped us find employment cleaning up construction sites.

It was winter. However, in California, winters are warm and sunny, while in Oregon it is cold and wet. Mud... YUCK!

Months passed, winter turned to summer and we finally got a break from work. Coincidentally, the small town of Mist, Oregon was only about two hours away. With the "bits and pieces" in mind, a one day trip was planned.

Upon arriving at Mist, we noticed the 100 year old farmhouse on the adjacent property was for sale. (For the first time since 1936). This house is just a short walking distance from the locality. (Approximately one-half mile).



Farmhouse at Mist, Oregon

Having only one day to collect we walked the bluffs along the Nehalem River picking up whatever scraps of fossils we could find. We came across a large boulder, approximately 400 pounds, that had fallen from higher - up on the bluff, much too high to climb.

This block had a natural split along the fossiliferous bedding plane. I carefully split the boulder along the fracture, and to my surprise, it was covered with hundreds of specimens of the sea urchin, Salina, with their spines, resembling hundreds of starbursts. The block was roughly two and a half feet square, and had both positive and negative sides. I left this specimen at the site, too heavy to carry to the car, thinking again, this was another indication of the great promise this locality possessed. Regretably. I didn't keep even a small chunk of this fantastic specimen, thinking I would return later to collect it in tact. However, I was not familiar with river collecting, and in the short time it took me to return, about a month, the river had risen, and there was not a trace of this unique piece.

Even though I have found many mass Salina plates since, nothing has come close to rival this block.

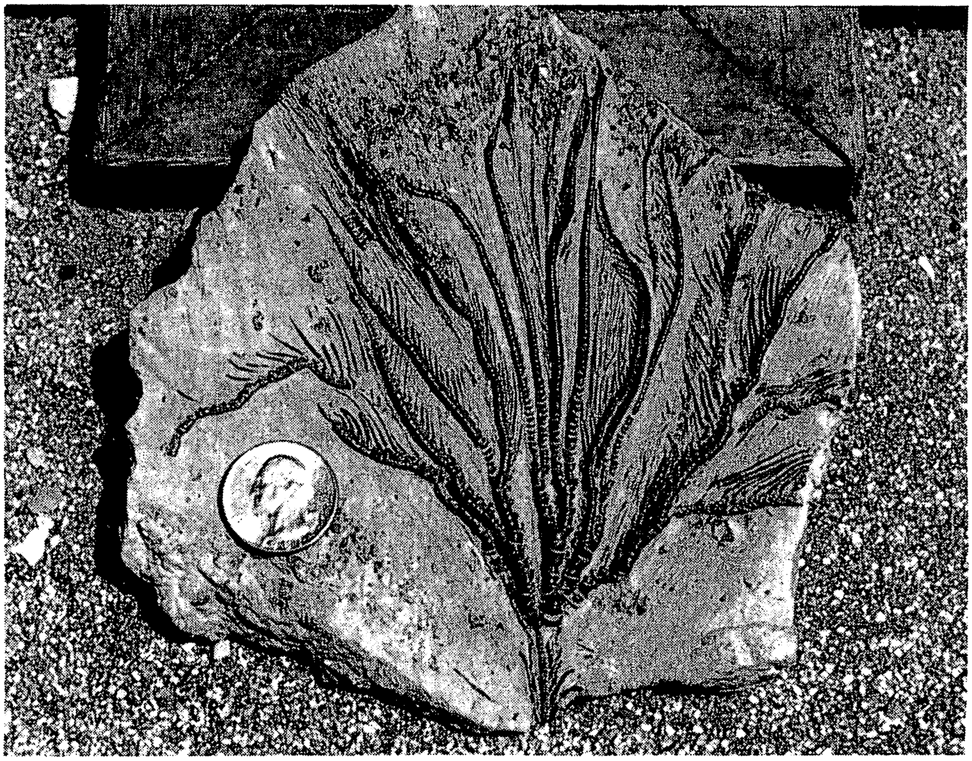
We returned to Salem, and upon reviewing the material we had collected, noticed many of the plates of gray, shale/mudstone, contained cross sections of large black crinoids, several of which even fit to one another. Two broken pieces specifically come to mind. One piece was approximately 4 X 5 inches, the other 2 X 6 inches. these pieces fit together forming a thick "L" shape. After preparation this specimen turned out to be two of three parts of three parts of a very large complete crinoid crown, together with two sea urchins with spines.

One who is familiar with unprepared crinoids, knows they can be very difficult to see in the rough. Much of the material cannot be seen unprepared, unless broken. There were many pieces broken, I was astonished. After evaluating the material obtained at the locality, I came to the conclusion that some very inexperienced collector had recently, unknowingly, hacked through the rare crinoid producing lens.

After due deliberation, and the usual seemingly endless hassels of purchasing new property, we decided Mist is where we wanted to settle in Oregon. Six and a half acres, in the middle of 500 uninhabited woodland acres, a world class fossil site within walking distance of a two story, five bedroom farmhouse. We moved in, in late August of 1975. That winter we did some exploring to find the exact area along the huge bluff that was producing the beautiful, unweathered three-dimentional crinoids, (not an easy task). In the summer of 1976, we began collecting in earnest.

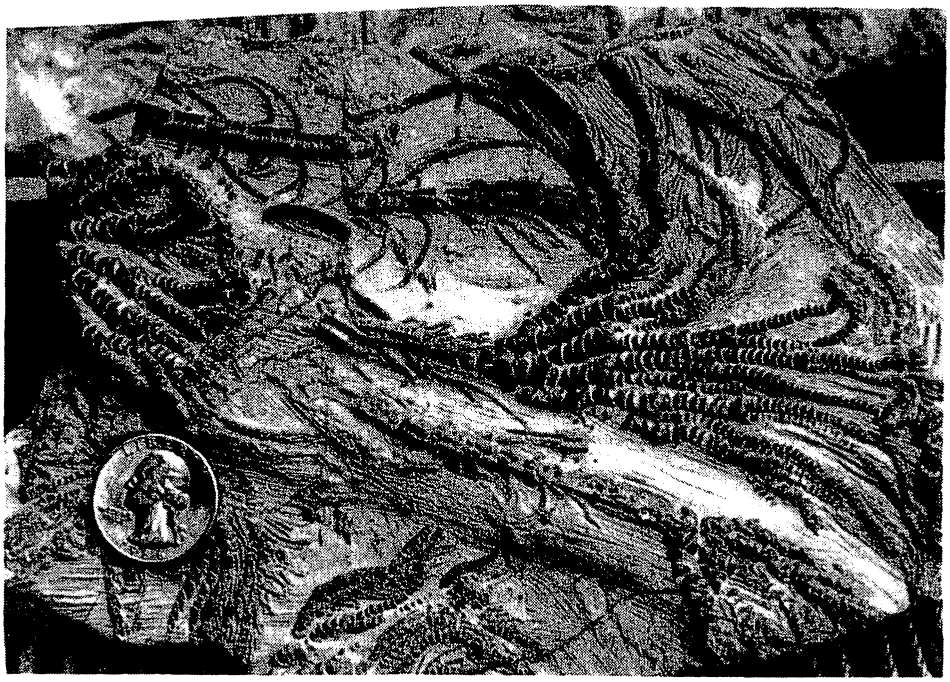
The area selected had a very tough, indurated over burden of approximately three feet, sloping up to six feet, ending abruptly in a cliff-wall approximately 20 vertical feet. To make removing specimens even more difficult, the productive unit was inundated by the usual fracturing against the bedding plane, making large pieces almost impossible to collect. A thin exfoliation pattern at 90 degrees to the bedding plane, also made it difficult to obtain much more than narrow strips of the crinoid bed. this was a constant annoying problem throughout the years of collecting. Moreover, many of the fossils in this Oligocene unit of the Keasy Formation are quite large.

Mass mortality plate from 1976 quarry Isocrinus oregonensis - Now property, L.A. County Museum, Invertebrate Paleontology, Los Angeles, California.



Isocrinus oregonensis Note: Regenerative growth on tip of arm, just above the quarter

The first major scientific work done on the crinoid producing unit near Mist, Oregon was done by Raymond Moore and Harold Volks in 1953. Isocrinus oregonensis, rare, but more common crinoids in the Keasy Formation, are quite large. (with a 5 to 10 inch crown). The less common crinoid I. nehalemensis, is small (3 to 4 Inch crown), with very minor differences that even the experts have trouble distinguishing. Each have approximately 40 long slinder arms. However, the main difference is the size.



Isocrinus nehalemsis ? Note the "slip-joint" fault, along lower 1/4 offsetting lower stem segments

The genus Isocrinus belongs to the order Pentacrinus. Therefore, Isocrinus possesses a "star- shaped" stem cross section. Isocrinus also has small "armlets" or cirri protuding from the stem. Each cirrus was itself segmented. There are five cirri on one segment plate every six to seven segments.

I have never collected or even seen an Isocrinus with a grasping root system, at the base. The stem always seems to terminate abruptly. It is not uncommon to find a stem, attached to a crown, lying along the bedding plane with no root system.

When Isocrinus was in the juvenile stage, it had a semi root system. This root system was a mass of cirri which anchored the young crinoid to a solid base. As the crinoid matured, the "anchor system" would break off and the crinoid, with a partial stem, would drift along the ocean bottom to a suitable resting place. The stem would lay along the bottom and the cirri would embed themselves in the surrounding area, acting as an anchor. I've even found stems at a slight angle, through several horizontal bedding planes. The longest stem section I've found to date is over 22cm.

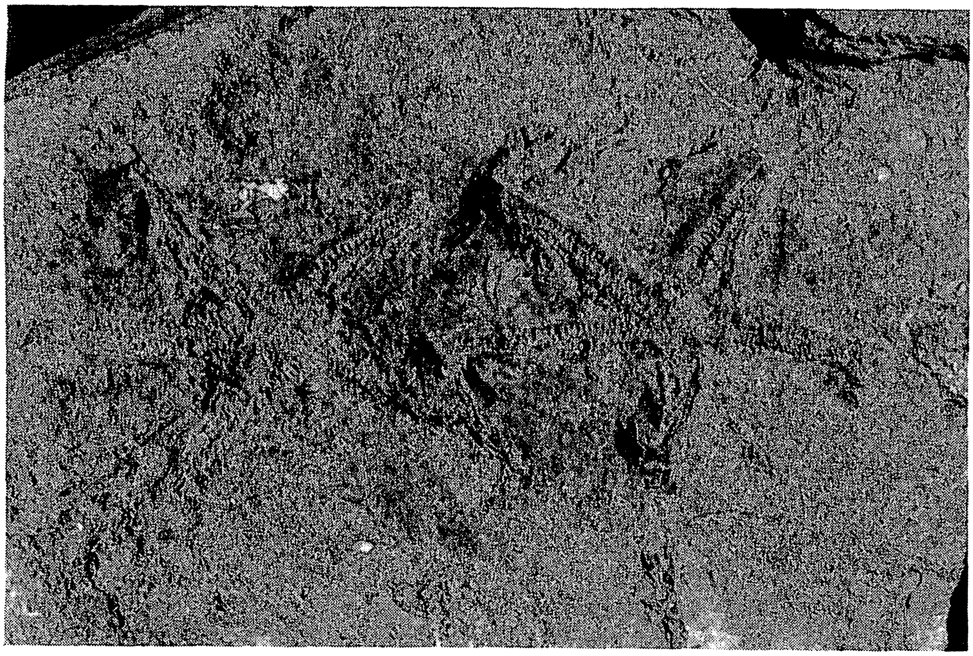
Some background on crinoids of the Tertiary, indicates crinoids from the Tertiary are almost nonexistent. Oregon is the only locality in the world that produces articulated Tertiary crinoids. All other localities produce only fragmentary material, generally stem fragments. There are some small fragments found in Haiti. This is the nearest Tertiary crinoid locatity to Oregon. There are also some fragmentary remains of Tertiary crinoids found in northern Italy and adjacent areas. Other localities are New Zealand and Australia. These are the only known Tertiary crinoid producing zones in the world, none of which produces the same species as Oregon.

The paleoecology of the Keasy Formation near Mist is interpreted from associated flora and fauna. The fact that well preserved terrestrial leaves, cold and deep water mollusks and deep water shark teeth occur in this same unit, makes interpretation of the paleoecology more difficult than most formations. This material indicates the area of deposition was probably a deep sub-marine trench, relatively near land (within a few miles). The non-eroded, articulated condition of the crinoids, along with the sea urchins *Salina*, with spines, also indicate quiet, deep water (approximately 500 to 1000 fathoms).

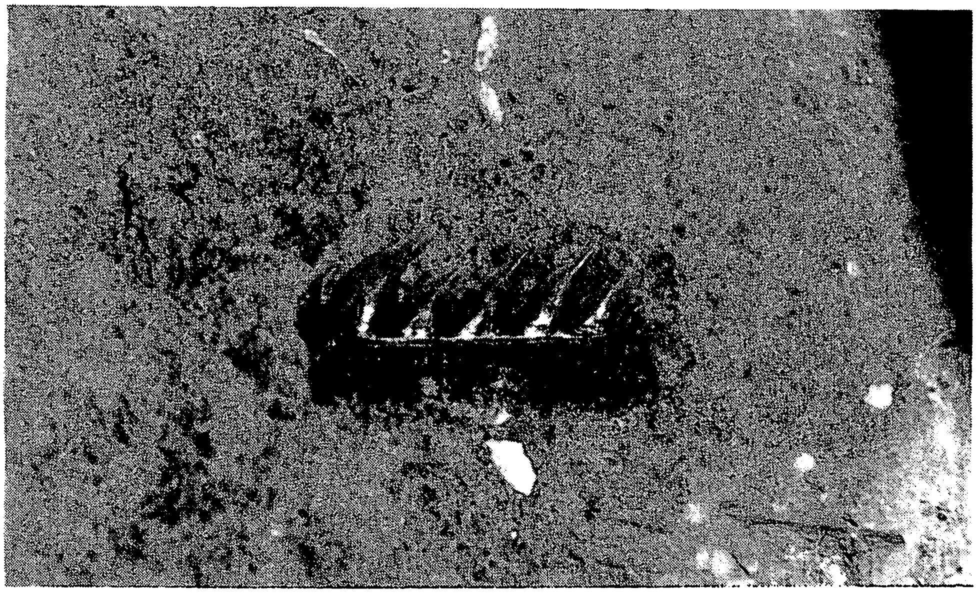
Over 40% of the fossil material I've found at the Mist locality is of the group Echinodermata. A simple list of the fossil material I have collected at this locality over the years reads:

- * starfish
- * crinoids
- * sand dollars
- * terrestrial plant leaves
- * pelecypods
- * gastropods
- * foraminifera
- * diatoms
- * crabs
- * sea algae
- * coral
- * shark teeth
- * fish
- sea urchin
- sponge
- terredo wood
- tissoa burrows
- marine mammal (bones)

* indicates multiple species



Starfish *Astropecten* each specimen 5 inches across



A rare deep water shark tooth Heptranchias

The amount of material collected from the first quarry was overwhelming, leading me to believe the suppply of crinoid specimens was endless, which reflects the misconception about the endless supply of oil, trees and salmon.

Last quarry dug
at Mist 1981

This was not the case, as I was to shortly discover. so, in the summer of 1981, with great enthusiasm, I started a new extension of the earlier quarry, confident that I would soon be basking in a new supply of these wonderful crinoid fossils. After struggling with ten cubic yards of very resistant rock and eight long days of hard digging, just to remove the overburden, I was rewarded with only one disappointing specimen. It turned out that the quarry of 1981 proved that the previous abundance of material was from the broad section of a wedge - shaped lens. I was unaware at the time that I was quarrying the thick portion of a small lens, digging toward the pinched end. It seems the fossil zone had come to an end. I learned a good, hard lesson about collecting Oregon fossil localities. I don't do as much digging now. I concentrate on surface collecting. Since the Mist locality has played out, I've turned my attention to other fine northwest fossils.

COMATULIDS: THE FORGOTTEN FOSSILS

Frank Holmes, 15 Kenbry Road, Heathmont, Victoria, 3135, Australia.

The following article gives a brief outline of the historical study of comatulids, their overall classification, general morphology and fossil record. Illustrations are provided as a general quide to the recognition of comatulid specimens in the field and in existing collections. Historical information is based on A. H. Clark's "Monograph of the existing crinoids" and the "Treatise on Invertebrate Paleontology".

Introduction

Comatulids, or feather stars as they are commonly known, are in their adult stage, small free swimming crinoids with feathery arms springing from a central flat topped plate known as a centrodorsal. The central stem or stalk of the sessile crinoids (sea-lilies) degenerated during evolution to the comatulids and only the centrodorsal, which represents 3 or 4 fused columnal plates, remains. At the same time the cirri or rootlets on this greatly reduced stem developed into strong grasping structures often with hooked tips (Fig. 1). While comatulids are recorded as fossils from many parts of the world, what we understand of their overall anatomy and life style is based principally on our knowledge of extant forms which live in the oceans today, primarily in Indo-Pacific waters. They are generally unable to tolerate a wide variation in pressure and live predominently on the continental shelves from the intertidal zone to a depth of around 200 metres, although a minority of forms are found on the continental slopes. While their maximum diversity is in shallow tropical zones, they are known in large numbers, but few species, from temperate and polar regions.

Comatulids are suspension feeders using podia (tube feet) located along the pinnules and arms to trap planktonic organisms or detritus; this is passed down the ambulacral groove and across the disc to the mouth.

Swimming and crawling are performed by use of the arms & cirri; swimming by raising and lowering one set of arms alternately with certain others; and crawling by lifting the body from the substrate and moving about on the cirri.

Historical Outline

In his Monograph of the existing crinoids (volume 1, part 1, 1915), A. H. Clark wrote:

> "The common comatulids of the coasts of Europe (Antedon petasus, A. bifida, A. mediterranea, and A. adriatica) were undoubtedly known, at least to fishermen, long before any record of them appears in literature; so also it is probable that numerous specimens of the large species from the Orient had reached Europe and found their way into the cabinets of collectors soon after the establishment of regular trade between Europe and the East, though they had not aroused sufficient interest to lead to a definite announcement of the fact."

The first conclusive reference to a comatulid was made by Fabius Columna in 1592 who described at some length the common Mediterranean species *Antedon mediterranea*. Apparently the remarks of Columna aroused considerable interest as they were incorporated in many of the succeeding works on zoology.

Although fossil crinoids were widely known, especially the detached columnals, it was not until 1699 and again in 1703 that Edward Llhuyd pointed out the connection between fossil crinoids and the recent sea stars, suggesting that *Decampeda cornubiensium* Llhuyd (now referred to as *Antedon bifida*) was the type of sea star to which they were most closely related.

In 1733, Henry Linck published in a single volume all the facts which had been discovered about the sea stars at that time. He differentiated the comatulids from the asteroids (star fish) and ophiuroids (brittle stars) placing them in a separate genus in the class "Stellae Crinitae".

However, in 1758 Linne placed the comatulids, starfish and brittle stars in a single genus *Asterias*, throwing the study of the group into utter chaos.

Referring purely to the Linnean system of nomenclature, it was de Freminville (1811) who took the first step in recognising the comatulids as a group distinct from other sea stars by erecting the genus *Antedon* for the common west European species, *A. bifida*.

A year later (1812), Lamarck suggested the vernacular name "Comatule" for the comatulids but did not latinise or formerly describe the genus (*Comatula*) until 1816. However, he failed to recognise the affinities of the comatulids also placing them with the starfish as other post-Linnean authors had done.

During the remainder of the nineteenth century a vast amount of literature was produced on the crinoids including numerous attempts at the classification of this diverse and complex group.

One of these classifications, Austin and Austin, 1842, separated the crinoids into two orders, one named Cionacineti for those with a jointed, flexible column and the other Liberidae for crinoids that lacked a stem or were capable of free motion. This latter group included *Marsupites* and *Comatula* thus placing the living stalkless crinoids with fossil relatives.

The major nineteenth and early twentieth century contributions to the knowledge

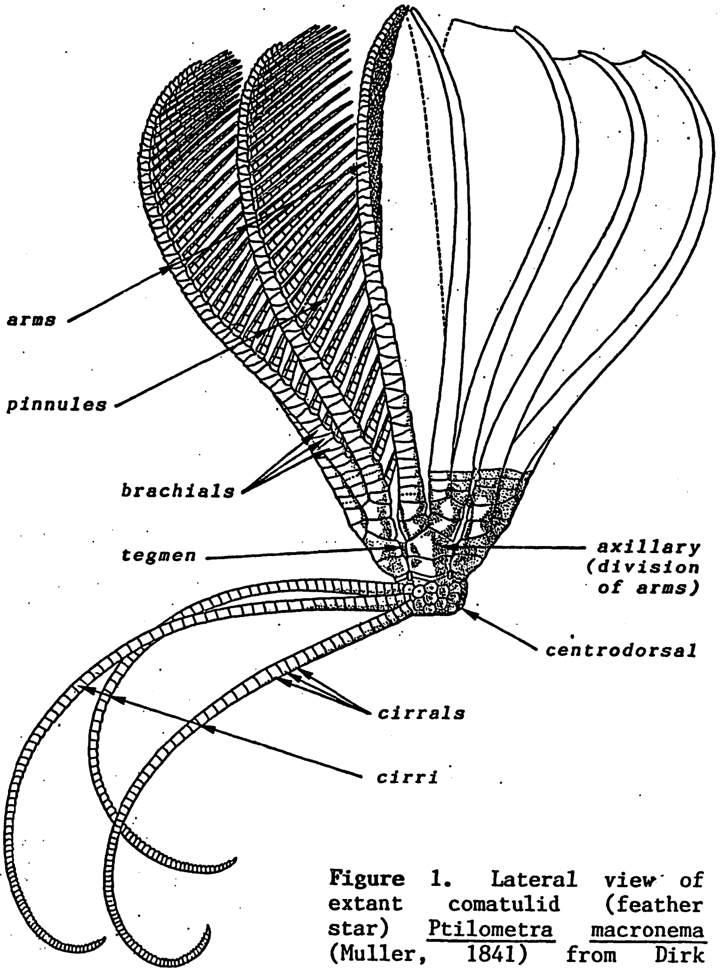


Figure 1. Lateral view of extant comatulid (feather star) *Ptilometra macronema* (Muller, 1841) from Dirk Hartog Island, Western Australia [after Clark, 1915].

of the comatulids were made by Lamarck (1816) in Histoire naturelle des animaux sans vertebres; J. Muller (1849) in Uber die Gattung Comatula; P. H. Carpenter (1888) in his report on the Comatulae collected during the voyage during the voyage of HMS Challenger; and A. H. Clark (1915-1967) in his monumental work "A Monograph of the Existing Crinoids - The Comatulids". However, as the title states, this latter work deals purely with extant species, although it is essential to the understanding of the anatomy of these creatures and consequently the interpretation of fossil remains.

Only the Treatise on Invertebrate Paleontology, Part T, Echinodermata 2 (3), published in 1978, provides any comprehensive listing of fossil comatulids. As we shall see, genera known to occur in the fossil record amount to a mere 21% of the total recorded up to the 1970s.

Classification

The phylum Echinodermata embraces an extremely diverse group of marine invertebrates, the majority of which had become extinct by the end of the Permian some 250 million years ago.

Of the nineteen classes in the phylum, as listed in the Treatise on Invertebrate Paleontology, only four contain extant genera: Crinoidea (sea lilies and feather stars); Stelleroida (starfish and brittle stars); Echinoidea (sea urchins, heart urchins and sand dollars); and Holothuroidea (sea cucumbers).

The class Crinoidea is divided into five subclasses, with only the Articulata, which includes the order Comatulida, represented by extant forms.

The following classification, to the level of order, indicates the extent of the fossil record of the comatulids:

Phylum	**Echinodermata**
Subphylum	**Crinozoa** Matsumoto, 1929 [Early Cambrian to Recent]
Class	**Crinoidea** Miller, 1821 [Middle Cambrian to Recent]
Subclass	**Articulata** Zittel, 1879 [Early Triassic to Recent]
Order	**Comatulida** A. H. Clark, 1908 [Early Jurassic to Recent]

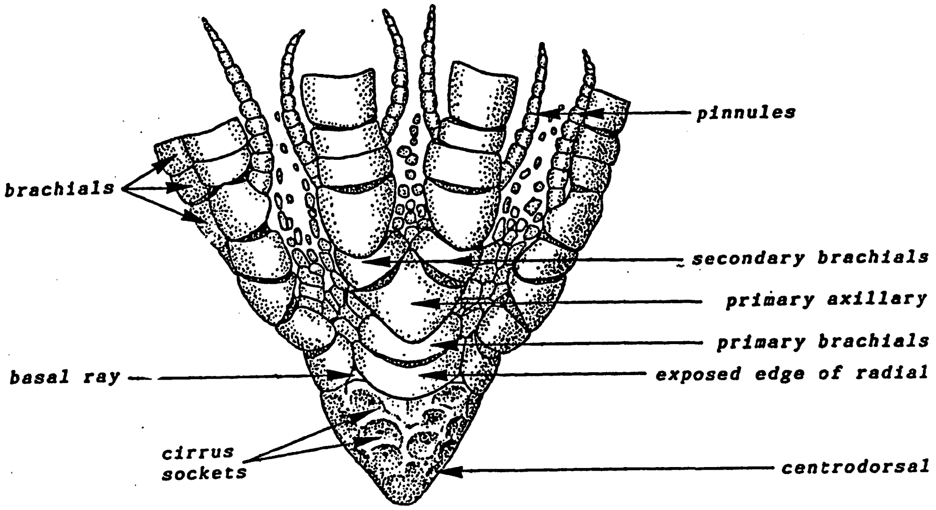


Figure 2. Lateral view of crown and centrodorsal of Notocrinus virilis Mortensen, a Recent comatulid from the Antarctic region, x 4. Note the conical centrodorsal and the cirrus sockets in columns (normally 10). Drawing after Mortensen, 1918.

When the Treatise was published in 1978, the order Comatulida contained 169 genera (from 23 families) out of a total of 256 listed in the subclass Articulata. Only 36 of these comatulid genera had a known fossil record.

General Fossil Record

Among the oldest fossil comatulids recorded in the Treatise are specimens of a centrodorsal, Antedon morierei, and a radial circlet, A. caraboeufi from the Early Jurassic (Pliensbachian) of France. Both described by de Loriol in the late nineteenth century, they have since been tentatively assigned to the genus Palaeocomaster (see Treatise T877). Recently a new species Palaeocomaster styriacus Kristan-Tollmann, 1988, has been described from three centrodorsals (less than 2mm in diameter) and isolated fragments of theca and brachials. These latter specimens are from the lowermost alpine Liassic (? Hettangian) of Austria, and stated to be the oldest comatulids so far recorded. Other specimens from this genus are known from the Middle and Late Jurassic of England and France.

While Mesozoic comatulids are well documented from throughout Europe, from Portugal in the west to Poland in the east, as well as from Sweden and the former Yugoslavia; outside Europe the record of described material is extremely poor, reference in the Treatise being made only to Algeria, Colombia, Lebanon and the USA (Texas).

The Tertiary record is little better, with Europe again contributing the major source of described species, mainly from the Early Paleocene and the Miocene, with Eocene and Oligocene material recorded only from Italy and Germany respectively.

Non European species are noted as occurring in the Paleocene (Tunisia); Eocene (USA - N. & S. Carolina and Louisiana); Miocene (Algeria, Argentina and Indonesia); and Pliocene (Indonesia).

Based purely on the recorded stratigraphic and geological distribution, one could be forgiven in believing that the apparent abundance of fossil comatulids found in Europe and the paucity of material from the remainder of the world, has some evolutionary or even palaeoenvironmental significance.

However, as with so many other groups of fossil invertebrates that appear to have significant gaps in the non European record, it is not because they did not exist, or that there is a scarcity of material to be found, merely a lack of systematic collecting in the past and an apparent lack of interest or even general awareness of this particular group of crinoids.

It is interesting to note that A. H. Clark (1915) considered the small

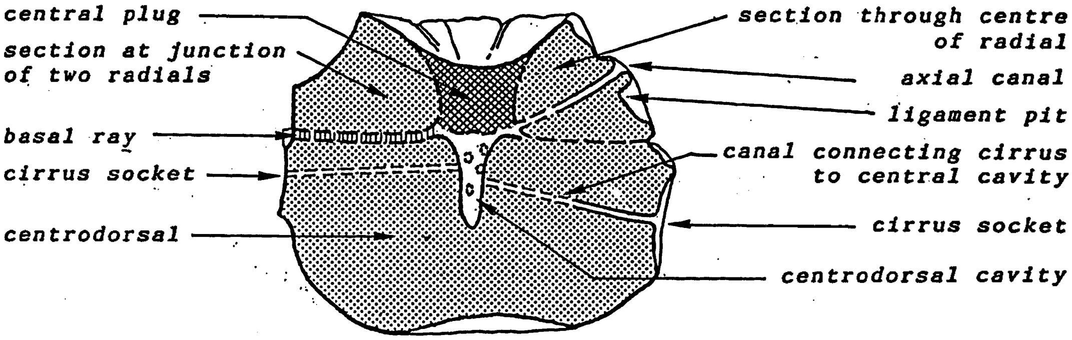


Figure 3. Section through centrodorsal and radial pentagon showing centrodorsal cavity, central plug and axial canal etc., x 3.5 [based on actual specimen].

importance previously given to the crinoids as recent animals in comparison with other echinoderms, arose from three causes: firstly, the extraordinary completeness of the palaeontological record; secondly, the small number of species then known; and lastly, the paucity or absence of accessible species along the shores of countries where the greatest interest in zoology was taken.

Today the position is somewhat reversed. Thanks to Clark and his monumental 4,336 page monograph, we now know an enormous amount about recent forms, yet our knowledge of fossil comatulids has advanced little since the early part of this century.

The Australian Fossil Record

Currently the only fossil comatulid described from Australia is Antedon protomacronema Chapman, 1913, based on an isolated centrodorsal found in a bore sample from the Mallee region of Victoria at a depth of about 130m. The specimen measures a mere 1.15mm high and 1.7mm wide (smaller than a match head). Another centrodorsal, several brachials and a cirral from a larger species were also recorded from Mallee bores but not figured. Chapman also notes brachials occurring in "the Janjukian series, having a Mount Gambier facies" and at Batesford near Geelong, Victoria, as well as a comparatively large form, with few cirrus sockets and a low centrodorsal, from Torquay, Victoria and Mount Gambier, South Australia, however, they were never described. Later in 1926, Chapman lists Antedon sp. as occurring at Neumerella, near Orbost, Victoria.

H. L. Clark (1946) considered A. protomacronema Chapman to be more likely related to the family Ptilometridae than to the Antedonidae. [Note: the generic name Antedon is now restricted to extant species]

References in Australian paleontological and geological papers to the occurrence of comatulids, or indeed any other fossils not referred to by specific names, are almost impossible to check, as such items are rarely if ever, indexed.

Probably the only significant reference to the presence of fossil comatulids in Australia is contained in Geological Survey of South Australia Bulletin 36, Stratigraphy of the Murray Basin in South Australia by N. H. Ludbrook (1961). In this Bulletin, Ludbrook notes that the smooth surface of a granite inlier in Section 156, Hundred of Younghusband, is thinly covered with a few feet of coarse rubbly crinoidal calcareous sandstone. Considered an island at the beginning of the transgression, the granite was submerged to shallow depth at the end of the deposition of the Mannum Formation (Early Miocene), thus probably providing optimum conditions for the establishment of a crinoid colony. Associated with the comatulids are echinoids, brachiopods and bivalves as well as a large range of foraminifera.

The comatulids at this location are known from one articulated specimen, various forms of centrodorsals, some with radial pentagons attached, and a diverse range of brachials, pinnulars and cirrals representing several species.

Comatulids are now known to occur in the following Australian locations:

South Australia
: Mannum Formation (Early Miocene); Murray River cliffs, Murray Bridge to Bow Hill.
: Gambier Limestone (Late Oligocene/Early Miocene); Mt Gambier district.

: Port Willunga Formation (Oligocene/Early Miocene); Wool Bay, Yorke Peninsula.
: Kingscote Limestone (Late Eocene); Kingscote, Kangaroo Island.

Victoria
: Gippsland Limestone (Early/Middle Miocene); Merriman Creek, near Rosedale; Mississippi Creek, near Lakes Entrance; Neumerella, near Orbost.
: Batesford Limestone (Early Miocene); Batesford, near Geelong.
: Puebla Formation ? (Early Miocene); Torquay.
: formation uncertain (? Early Miocene): Mallee Bores, near Murrayville.
: Jan Juc Formation, Point Addis Limestone Member (Late Oligocene); Point Addis.

Western Australia
: unnamed sediments (Quaternary); Jandakot.
: Pirie Calcarenite (Late Palaeocene); Giralia Station, north west W.A.
: Miria Marl (Late Cretaceous); Giralia Station, north west W.A.

No doubt our knowledge of the distribution of comatulids through Late Cretaceous and Tertiary strata in Australia will expand quite considerably as more people become aware of their existence.

As with virtually all fossils, taxonomy must by necessity be based on the animals' hard parts. In the case of the comatulids it is the centrodorsal and the radials on which genera and species are determined,

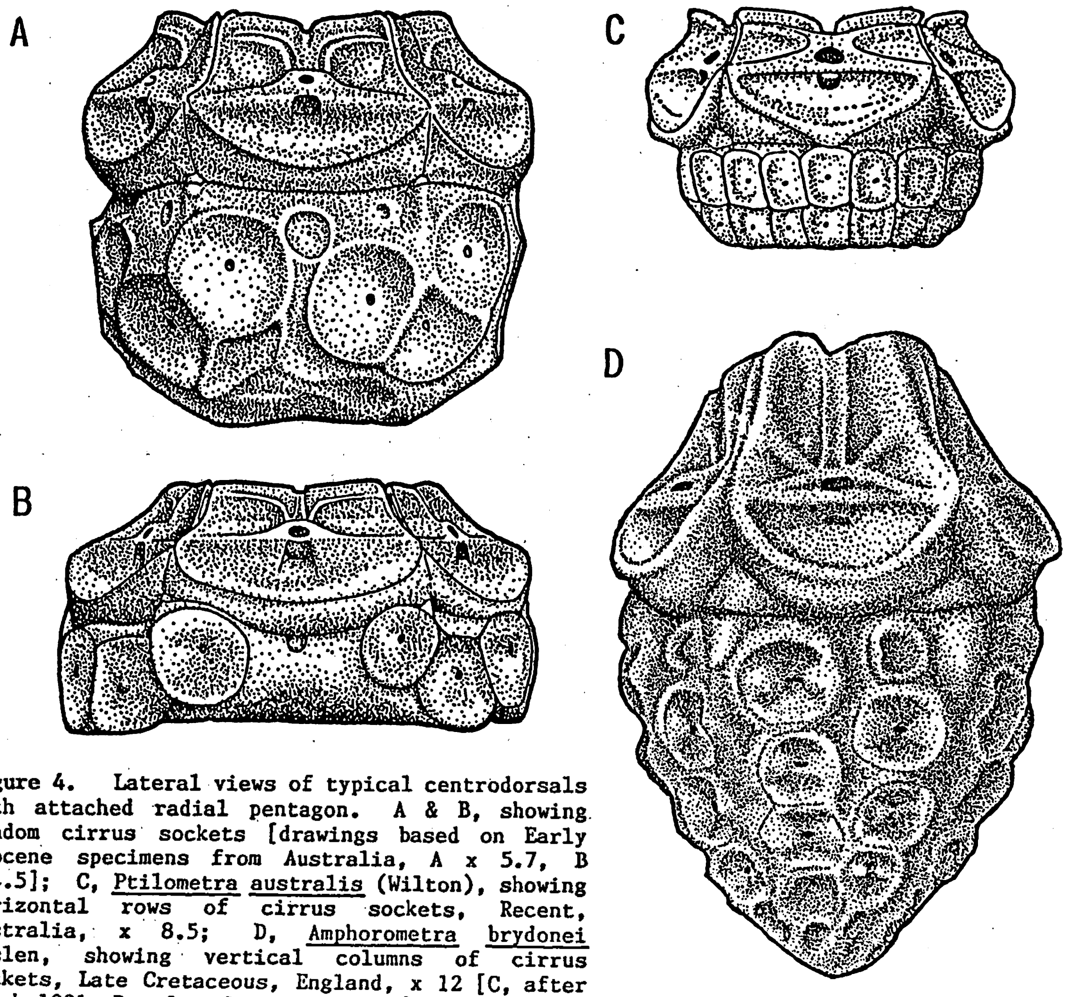


Figure 4. Lateral views of typical centrodorsals with attached radial pentagon. A & B, showing random cirrus sockets [drawings based on Early Miocene specimens from Australia, A x 5.7, B x 4.5]; C, Ptilometra australis (Wilton), showing horizontal rows of cirrus sockets, Recent, Australia, x 8.5; D, Amphorometra brydonei Gislen, showing vertical columns of cirrus sockets, Late Cretaceous, England, x 12 [C, after Clark 1921; D, after Rasmussen 1961].

as these creatures are rarely found preserved with their arms and cirri attached. In fact the only articulated specimens figured in the Treatise are either Mesozoic (mainly Jurassic) or Recent.

Unfortunately, two important diagnostic features used to differentiate species of Recent comatulids, the division of the arms and the structure of the soft parts, in particular the tegmen, are rarely, if ever found in the fossil record. Consequently taxonomic links between recent and fossil forms are difficult to establish below the level of family.

It is not the purpose of this article to attempt any classification or description of Australian fossil comatulids; simply to illustrate typical specimens, so that the remains of these free swimming crinoids can be recognised in the field and in existing collections.

Acknowledgement

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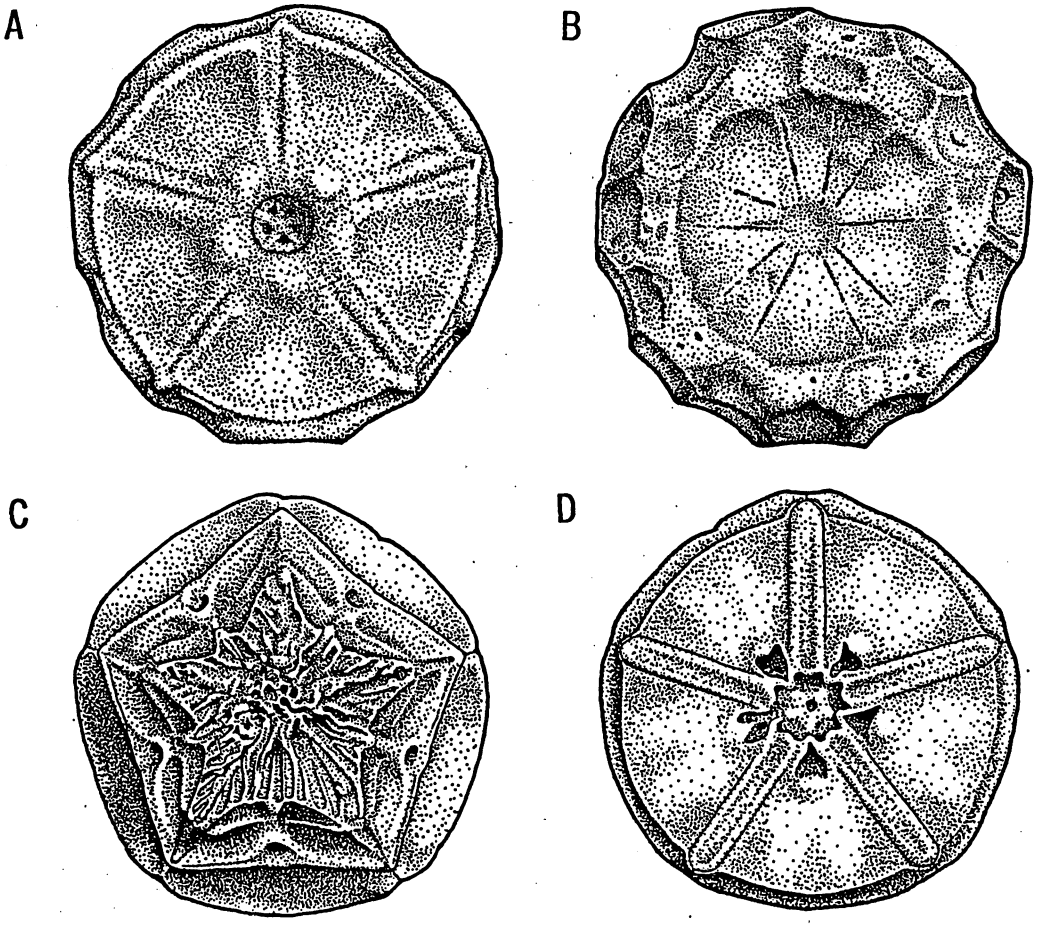

Figure 5. A, ventral (adoral) surface of a centrodorsal showing five radial depressions, centrodorsal cavity and interradial furrows, x 5; B, dorsal (aboral) surface showing a central concave depression. C, ventral (adoral) surface of a radial pentagon with calcified central plug; D, dorsal (aboral) surface showing interradial basal rays. Drawings based on Early Miocene specimens from Australia, x 5.

Glossary

The following glossary of morphological terms is restricted to the primary elements of the comatulid skeleton likely to be found in Late Cretaceous and Tertiary marine sediments and to general terms used in this article.

aboral - directed away from mouth.

adoral - directed towards mouth.

ambulacra - shallow grooves running along ventral (adoral) surface of the pinnules and arms and traversing the disc to converge at the mouth; serve to convey food to mouth.

ambulacral grooves - see ambulacra.

arms - series of brachials (ossicles) extending upwards or outwards from the radials irrespective of the number of divisions. Term restricted in use by some authors (Clark) to undivided distal branches.

axial canal - longitudinal passageway for axial cord which penetrates cirrals, thecal plates (centrodorsal and radials), brachials and pinnules. Usually but not always located centrally.

axillary - brachial supporting two arm branches (Fig.1).

basal ray - any of five calcareous rodlike structures of secondary origin developed in the basal grooves between the radial pentagon and centrodorsal in an interradial position and usually connected with the rosette (Fig.6B).

basals - any plate or circlet next proximal to radials, each basal typically in interradial position.

brachial - calcareous segments or ossicles of which the arms are composed. May be axillary or non axillary.

central canal - see axial canal

central cavity - see centrodorsal cavity

central plug - a more or less spongy calcareous deposit on adoral surface of radial pentagon.

centrodorsal - the stellate, discoidal, button-like, conical, cup-shaped or collumnar central plate, from which all other structures appear to radiate. Its sides generally bear varying numbers of cirrus sockets, which mark the place of attachment of the cirri. These cirrus sockets may be arranged in definite alternating horizontal rows, in vertical columns (Fig.4C) or closely crowded and quite without any precise arrangement (see Fig.4A & B).

centrodorsal cavity - depression on adoral surface of centrodorsal containing chambered organ and accessory structures.

cirral - single cirrus segment.

cirrus (pl. cirri) - slender unbranched jointed appendage of practically uniform thickness arising from the centrodorsal and used for attaching the comatulid to the sea floor etc. (Fig.1).

cirrus socket - a shallow pit or facet each with a small central perforation, situated on the side of the centrodorsal to which a cirrus is attached (Fig.2 & 3).

column - series of segments (ossicles) composing stem of sessile crinoids; excludes cirri and anchorage structures (holdfasts). In comatulids the stem is discarded in early life when the animal becomes free swimming.

disc - the tegminal covering of the ventral surface of the body between the arm bases. It is traversed by the ambulacral grooves which converge on the mouth and in one of the areas bounded by these grooves, rises into an anal tube.

distal - direction or position away from polar or central axis.

dorsal - direction or side away from the mouth normally downward and outward. Mainly used to describe the underside

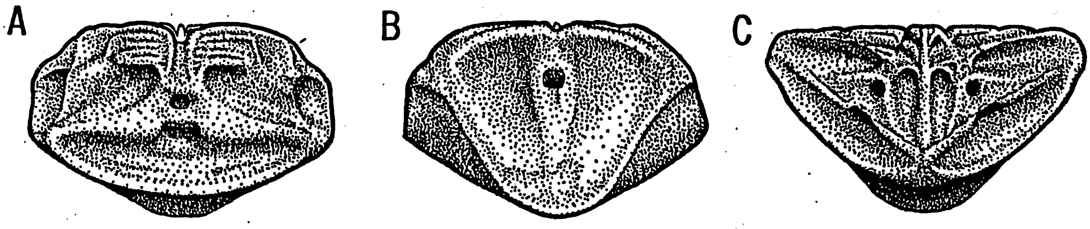

Figure 6. A, proximal surface of a typical first primary brachial (primibrach) showing muscular articulation; B, distal surface. C, distal surface of a typical primary axillary (primaxil) showing dual muscular articulation; proximal surface (not illustrated) similar to distal surface of first primibrach. Drawings based on Early Miocene specimens from Australia, x 6.

of the centrodorsal or radial pentagon. (see also aboral, the preferred term).

dorsal star - stellate hollow around aboral pole of centrodorsal in some comatulids, often fused with depression.

facet - surface in ossicles (cirral, brachial or pinnular) and radials that functions for connection with adjoined skeletal element.

fossa (pl.fossae) - elongate depression or articular face of ossicle for attachment of muscles or ligaments; less localised than pit.

ligament pit - usually a steep sided small depression in aboral ligament fossa adjoining centre of transverse ridge.

ossicle - any single calcareous segment of crinoid skeleton pinnular plate forming part of aboral skeleton of pinnule.

pinnule - slender unbifurcated branchlet of arm.

primary axillary - (primaxillary, primaxil) - proximal (first) axillary of arm.

primary brachial (primibrachial,primibrach) - proximal brachials (ossicles) of arm following the radials up to and including the first axillary (primaxil). Where the arm does not divide, all brachials are regarded as primibrachs.

proximal - direction or position toward polar or central axis.

radial pentagon - subpentagonal ring formed of mutually adherent radials after removal of all other structures (Fig.6A & B).

radial pit - radially disposed depression in ventral (adoral) surface of centrodorsal in some comatulids.

radials - the plates from which the arms arise, normally five in number although two extant genera have ten. They usually appear externally as narrow oblong or more or less crescentric plates protruding beyond the edge of the centrodorsal (Fig.6A & B); although in many genera they barely reach the edge of the centrodorsal, and in others may be entirely concealed by it.

ray - radial plate, together with all structures borne by it.

rosette - a delicate calcareous plate formed of metamorphosed basals, centrally located just below the dorsal surface of the radial pentagon.

stem (stalk) - see column.

tegmen - adoral part of theca (see disk).

theca - crinoidal skeleton exclusive of stem, holdfasts and free arms.

ventral - adoral side of theca and rays. Mainly used to describe the upper surface of the centrodorsal or radial pentagon (see also adoral, the preferred term).

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FOSSILS OF THE MAINE STATE CAPITOL

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ABSTRACT - Black limestone floor tiles in the Maine State Capitol contain the fossilized remains of a variety of marine invertebrates. Fossiliferous limestone was first installed in the Capitol by the architect John C. Spofford during construction of the Capitol's west wing from 1889 to 1890. Additional fossil bearing lomestone was installed by the architect G. Henri Desmond during an extensive remodeling and renovation of the original Capitol building from 1909 to 1911. The composition and fossil content of the stone is consistent with the carbonaceous limestone of the Middle Ordovician Crown Point Formation at Isle La Motte, Vermont. Quarries at Isle La Motte have been providing dimension limestone for architectural purposes for more than 200 years and are the most likely source for the fossiliferous building stones of the State Capitol.

Paleontologists often say that there are two places to find fossils: in the field and in the museum. A casual stroll through the Maine State Capitol in Augusta, however, is enough to remind the observant visitor that buildings made of stone offer us a third place to make fossil discoveries. Building stones in the Maine State Capitol are home to a variety of marine invertebrate fossils that date back some 475 million years to the middle Ordovician period, a tumultuous time in the geologic history of eastern North America. These fossils lend a unique element of natural history to the State Capitol and help answer important questions about its architectural history.

This is the first report of fossils in the Maine State Capitol, but the fact that fossils can be found in the building stones is neither new nor surprising. Stones has been used as a building material for thousands of years and there are many documented instances of fossiliferous building stones. The Egyptian pyramids, for example, were constructed of a limestone that is rich in fossilized Foraminifera, and many old buildings in Europe show the fossilized shells of ammonites and brachiopods (Matthews 1989). Floor stones in a Chicago museum contain occasional fossil cephalopods and the door arches in some of the oldest homes in Lyme Regis, England, are adorned with giant fossil ammonites (MacFall and Wollen 1983). The American Museum of Natural History and the Ohio Department of Natural Resources even offer walking tours of the fossils found in the churches, banks, courthouses and government buildings of New York and Cincinnati (Hannibal and Davis 1992; Steinmann 1978).

I first recognized the fossils in the State Capitol floors stones in 1992. After discussion with Walter Anderson, the State Geologist, he and the staff from the Maine Geological Survey examined the stones and identified them as a carbonaceous limestone from the middle Ordovician Crown Point Formation at Isle La Motte, Vermont. That identification was based upon the composition of the stone and an initial survey revealing the presence of numerous specimens of Macurites, a distinctive Ordovician snail-like mollusk abundant in the Crown Point Limestones of the

Champlain Basin. My subsequent survey of the State Capitol limestones has revealed the presence of at least four phyla of fossil marine invertebrates, all of which are consistent with fossil assemblages documented in the Chazy Group of limestone formations at Isle La Motte (Baldwin 1987; Erwin 1957; Welby 1962). No historical records have been found indicating exactly where the limestones of the State Capitol were quarried, but a review of its architectural history strongly supports the geologic and fossil evidence pointing to Isle La Motte as the orgin of the stones. Richly fossiliferous "Radio Black" and "Champlain Black" limestone has been quarried at Isle La Motte since 1788 (Dale 1912) and has been used in such famous buildings as the RCA building, the Metropolitan Museum of Art in New York, the National Gallery of Art in Washington and the Borg Warner building in Chicago (Steinmann 1978). At the time the stones were being installed in the State Capitol, Isle La Motte was the largest and the nearest source of black architectural limestone and must have been well known to the large Boston architectural firms involved in the expansions and renovations of the Capitol.

Construction of the original State Capitol, designed by the famous architect Charles Bulfinch, was begun in 1829 on Weston Hill, a small knoll overlooking the Kennebec River in Augusta, Maine. Granite for the original structure was quarried in Hollowell and was hauled by oxen to the Westin Hill site. Since its completion in 1831. many of the details about the interior of the original building have been lost. It seems, however, that Bulfinch's original floors were made of wood (Leg. Doc. 1981; Shettleworth 1981). Fossiliferous limestone was installed in the State Capitol floors on two occasions. The first of the fossil bearing stone was installed in 1889 and 1890 by th Boston architect John Spofford during the construction of the Capitol's west wing. In his design, Spofford (1889) specified the new wing be faced with "first quality, fine hammered Hollowell granite... that harmonized with the present structure." Like Bulfinch, Spofford quarried his granite in Hollowell. Unlike Bulfinch, however, Spofford's floors were steel and terra cotta block arches covered with one inch thick white marble floor tiles. Probably for aesthetic reasons, to offset the white marbles, Spofford also chose to incorporate a "black marble" border into his floor design (Leg. Doc. 1891). As we now know, those border stones are not marble at all, but black limestones from Isle La Motte (Fig. 2).

For twenty years following the completion of Spofford's addition, the floors of the State Capitol apparently remained a mixture of wood in the old part and marble in the newer west wing. Then, from 1909 and 1911 more fossiliferous limestone was installed by another Boston architect, G. Henri Desmond, during an extensive renovation and remodeling of the original Capitol. Desmond's work included the enlargement of the

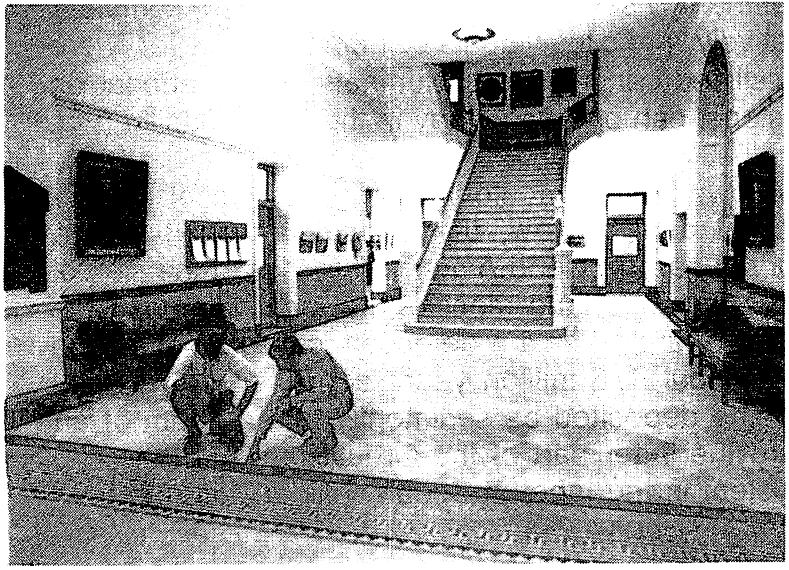


Figure 2. Patrick Norton (right) and John Kelley examine fossils in the black limestone flooring of the Maine State Capitol. Photo by John Kelley.

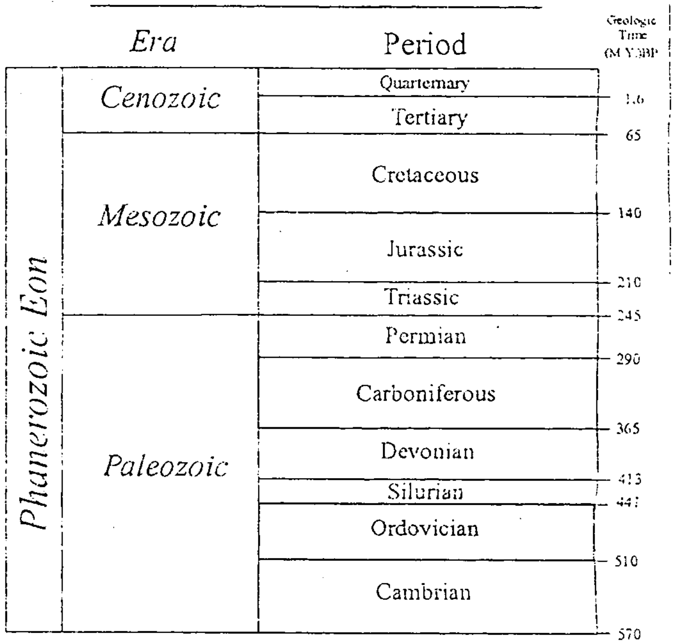
north and south wings to provide new chambers for the Senate and the House of Representatives, the replacement of the old central columns and the addition of a new, larger dome. Except for Spofford's west wing, which was generally not distrubed, most of the Capitol's exterior granite and all interior staircases, partitions and roofs, including the dome were removed. The old wooden floors, which were "a menace to life and a fire trap", were also removed (Desmond 1909; Leg.Doc. 1911). To unify the floors within the Capitol, Desmond required that "all the corridor floors above the lower one are of white marble with a colored marble base and border...to match the old work in every particular" (Desmond 1909).

Based on the fossil content of Desmond's stones, he matched the "old work" by returning to the same quarry that Spofford had relied upon nearly 20 years earlier. Those quarries had been active between 1890 and 1909, however, and a survey of the fossils in the stones installed by the two architects reveals that Desmond ended up with stone either from a different layer of the same quarry or from a Crown Point exposure in another nearby quarry. Differences in the fossil content of the stones follow the exact line separating the work of the two architects and offer confirmation that the two sections of the floor were installed at different times. The stones in Spofford's west wing contain a rich variety of invertebrate fossils, but fossils in the stone installed by Desmond consist exclusively of the fragmented stalks of crinoids, animals similar to todays sea lilies.

The Class Crinoidea is one of five surviving classes of the Phylum Echinodermata, a large group with a long and complex fossil record dating back to the early Cambrian Period. The five-sided symmetry shared by all living and many extinct classes of echinoderms is clearly seen in the starfish (class Asteroidea) and sea urchins (class Echinoidea) common today along the coast of Maine. Although almost all living echinoderms are mobile, fossil crinoids such as those found in the State Capitol spent their adult lives fixed to the ocean bottom by long stalks. That primitive stalked condition, predominant among crinoids during the Ordovician is seen today only in the sea lilies, a small and relatively rare group of deep water crinoid species. Like the sea lilies, the stalks of these fossil crinoids were composed of hard plates, called columnals, which support a flower-like crown consisting of a body cavity and branching arms that assisted in feeding. Because of their delicate form and a tendency for the individual stalk columnals to separate after the animal died, complete specimens of fossil crinoids are relatively rare. Individuals columnals, however, were often preserved. Thousands of fossilized crinoid stalk columnals, which appear as small, "life-saver" like circles in the stone, can be seen today in the State Capitol (Fig. 3).

Although evidence from the Crown Point limestones suggest a local marine environment that was relatively quiet and shallow, the Ordovician itself was a tumultuous time in the geologic history of eastern North America (Fig. 4). At the start of the period, roughly 500 million years ago, the land masses that now comprise the eastern margin of North America were separated by a wide ocean, called Iapetus, and were located south of the equator. About 475 million years ago, the Crown Point limestones of Isle La Motte were being deposited as sediment at the bottom of an ocean that teemed with life. Toward the latter part of the Ordovician, perhaps 450 million years ago, a major island system in the Iapetus Ocean collided with the then eastern margin of North America, closing a portion of that ocean. The sediments of that portion of the ocean bottom were compressed, folded and thrust upward into what eventually became the Taconic Highlands, one of several northeastern mountain ranges formed during the Paleozoic era. Where the heat and pressure were the greatest, the ocean sediments were "cooked" into marbles, destroying any fossils that may have been present. Elsewhere, where the pressures were not so great, the sediments were compressed into limestone and the fossils were preserved. Gradually, over millions of years, the Taconic Highlands eroded and eventually exposed the old Ordovician marbles and limestones (Raymo and Raymo 1989). Those limestones were used by Spofford and Desmond in the floors of the State Capitol.

Figure 3. Crinoid stalk columnals (diameter of largest specimen in photograph is 8 mm). Photo by John Kelley.



The State Capitol fossils date from the Ordovician Period, shown here as the shaded area.

Prepared by Patrick Norton

Figure 4. Geologic time scale.

Unlike the stones installed by Desmond, which seemed to contain only crinoidal remains, the stones installed by Spofford in the west wing contain a rich variety of fossils, many are fragments and have yet to be identified. Others such as those described here, are more complete and are identifiable at various levels of classification. Unfortunately most of them are seen only in cross- section with none of the 3-demensional relief often necessary for identification at the species level. The floor stones have also been scratched, chipped and cracked from a century of heavy use and some of the fossils have been clouded by years of waxing and polishing. Despite those hazards, and the passage of 475 million years, remarkably beautiful detrails can still be observed in many of the fossils.

The coiled shell of the gastropod *Maclurites* can be seen throughout the west wing of the State Capitol. Gastropods members of the Phylum Mollusca, were extremely abundant during the Ordovician and even today are second only to the insects in the number of living species. The shore periwinkle (*Littorina littorea, L..*) is probably the most recognizable gastropod found in Maine, but snails and their relatives are found almost everywhere in the world. *Maclurites* was a relatively large gastropod, with a shell diameter up to 17 centimeters and a flat bottom that allowed it to remain stable on the ocean floor. One interesting specimen in the State Capitol is closely associated in the stone with an operculum, a calcareous "lid" that, in life, would have been attached to the animal's foot and would have neatly sealed the shell opening when the foot was retracted.

The Phylum Coelenterata, a group that includes corals, sea anemones and jellyfish, are represented by two forms in the State Capitol. A single beautifully preserved specimen of the rugose coral *Lambeophyllum,* relatively rare in the Crown Point formation, can be seen on the second floor of the west wing. Other stones in the west wing have captured pieces of the colonial coelenterate *Stromatocerium.* Colonies of *Stromatocerium*, which often appear as large cabbage-shaped masses in the rocks, frequently grew to be more than a meter thick. The size of the floor stones, however, only allow us to see isolated sections of those impressive former colonies.

Crinoid stalk columnals can be seen in the west wing; one stone contains a longitudinal section of a crinoid stalk fragment that remained intact after the animal died (Fig. 8). That specimen shows large and small columnals arranged along the stalk in a pattern of nodals and internodals common in many fossil crinoids. The small wedgeshaped projections from the stalk are branchlets, called cirri, which grew from each nodal. The canal that supplied nutrients to the living animal can also be seen running centrally down the length of the stalk fragment.

I classify two other specimens found in the west wing as belonging to the Phylum Bryozoa, or "moss animals." This classification is somewhat tentative since these specimens are each seen only once in the State Capitol and bryozoans from the Crown Point are generally not described as well as other phyla from that formation. The Crown Point, however, is one of a group of closely associated limestone formations in the Champlain Basin, and bryozoans from another of these formations have been described in more detail (Welby 1962). The small circular form seen on the third floor of the State Capitol is very similar to the branching bryozoan *Eridotrypa.* A large form, also on the third floor shows the same general size, shape and internal organization as the biscuit- shaped bryozoan, *Pasopora.* Bryozoans are reported as abundant in the Crown Point, but useful descriptions of both*Eridotrypa* and *Prasopora.* are found in surveys of a slightly more recent limestone formation of the Champlain Basin (Welby 1962).

The creatures fossilized in the State Capitol limestones shared the ancient Iapetus Ocean with many others that may or may not have been captured by the stone cutters working for Spofford and Desmond. Ammomites and many species of trilobites lived during that time, and have been preserved as fossils in the Crown Point limestones, but have not yet been found in the State Capitol. A more thorough survey is needed and a closer examination of the beautifully detailed fragmental remains would undoubtedly reveal the presence of additional phyla. Many other types of creatures are almost certainly hiding somewhere in the limestones of the State Capitol. Perhaps one is under an old bench, or over in a dusty corner, waiting for the next curious visitor to make another fossil discovery.

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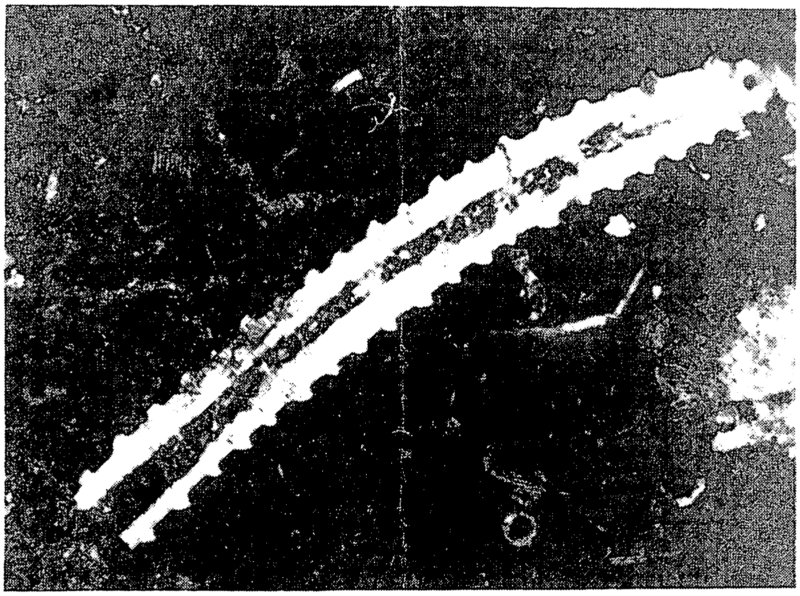

Figure 8. Longitudinal section of crinoid stalk fragment. 60 mm in length.
Photo by John Kelley.

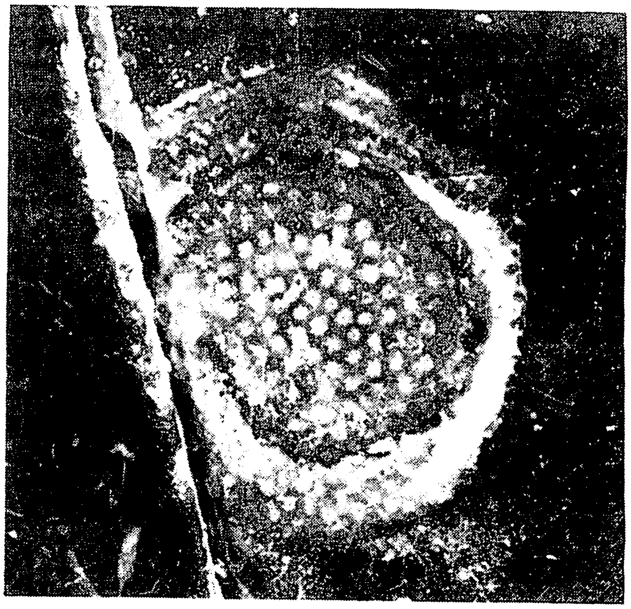

Figure 9. bryozoan Eridotrypa? 28mm across
Photo by John Kelley.

LIVES AND TIMES OF CRINOIDS

by

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INTRODUCTION

Virtually all of us who have collected fossils in Paleozoic aged rocks are familiar with crinoids or fossil "sea lilies". Examples of these fossils form prized portions of the collections of many amateurs and museums. Crinoids were far and away the most abundant and diverse class of Paleozoic echinoderms (sea stars and sea urchins are other echinoderms) comprising one of the most important groups of marine invertebrates. In some cases crinoid remains literally form large portions of the rocks in which they occur. Much can be deduced about the evolutionary history and lifestyles of crinoids because of this abundance and the fact that they had highly complex skeletons that show much about their basic anatomy and ways of life. However, the record of early crinoids is poor and our understanding of their origin and oldest history is very incomplete. The field work that James Sprinkle from the University of Texas and I have conducted for the past five years has made it possible to narrow this gap in knowledge. Although our study of the individual fossil species is only partly completed, we have observed big changes in the lifestyles of crinoids that resulted in their rise to dominance. A thumbnail sketch of the changes in crinoid lifestyles with some of our conclusions is presented below. The basic construction and classification of crinoids is briefly reviewed for needed background. Evolution occurs in concert with physical changes in the environment and the rise of crinoids corresponds with the appearance of the widespread shallow seas that also left the Paleozoic rock record here in the Midwest.

CONSTRUCTION AND CLASSIFICATION

Typical crinoids have a characteristic construction that is probably well-known to most amateur paleontologists so I will be brief in my description. I refer the reader to the excellent work of Georges Ubaghs in *The Treatise on Invertebrate Paleontology (T) Echinodermata 2(1)* for details. Crinoids superficially resemble plants, hence the common name "sea lily" (FIGURE 1). The "business end" of the animal is referred to as the crown that consists of a more or less globular or conical calyx with projecting free arms. The calyx houses the body cavity with most essential organs such as the digestive tract and reproductive systems.

The lower part of the calyx (below the free arms) is the cup consisting of a system of skeletal pieces or plates arranged in a more or less regular pattern. The number, size, and shape of cup plates is the most commonly used feature in classifying crinoid species. Cup plates are aligned in rows or circlets in a five-fold symmetry pattern. The single interruption of this plating pattern is referred to as the anal series and is considered to be posterior. Anal series plates have great significance in the determination of relationships among the various crinoid species. The lowest plates in the cup that are aligned with the arms have traditionally been designated the radials. These are traditionally used as landmarks for designating other cup plates. Beneath and offset from the radial circlet are basals. When basals form the base of the cup, these crinoids are said to be monocyclic. Some crinoids have a plate circlet below the basals and in line with the radials; these are infrabasals and species having them are called dicyclic. Many crinoids have no cup plates above the radials. Plates above and aligned with the radials are fixed brachials while those that lie between fixed brachials are interbrachials. Roofing the calyx is the tegmen and it consists of oral plates and sometimes many other smaller plates. There can be a distinctive anal tube rising from the tegmen. Free arms extend from the top of the cup giving the crown its flower-like appearance. Free-arms together with radials and fixed brachials, if present, comprise rays. The shape and arrangement of arm plates varies considerably and is again a useful identifying feature. In nearly all cases crinoid arms fork or branch. Thin hair-like skeletal extensions called pinnules project from the brachials of most crinoids producing the delicate "feathery" appearance of the arms.

Extending below the crown is the column or stem; it is usually made up of individual skeletal pieces stacked like poker chips called columnals, although in some early crinoids the column is made of circlets of plates called pentameres. Below the column there is often a root-like or button-like holdfast (FIGURES 2,3,4). In some cases, the holdfast is lost in the adult crinoid and instead there is a looping or coiling of the column or by specialized projections from the column called cirri (FIGURES 5,6). In most modern crinoids the stem is reduced to a single button-like plate below the cup called the centrodorsal and cirri attach to it (FIGURE 7).

Aside from a few early species, most crinoids readily fall into one of four major groups: inadunates, camerates, flexibles, and comatulids. The first three groups are entirely Paleozoic, the comatulids are post-Paleozoic. Inadunate crinoids have relatively simple cup plating without interbrachials; radials usually form the top of the cup. Monocyclic inadunates are called disparids and dicyclic inadunates are cladids. Camerate crinoids have large calyces usually with extra plating including fixed brachials and interbrachials; arms are pinnulate. Flexible crinoids were derived from dicyclic inadunates; they had globular crowns, incurved, non-pinnulate arms, and three (instead of five) infrabasal plates. Comatulid crinoids were derived from a cladid inadunate ancestor. They have a reduced calyx, pinnulate arms and in most species the stem is reduced to a centrodorsal plate.

HISTORY AND LIFESTYLES

The earliest crinoid is apparently *Echmatocrinus*, known by a handful of specimens from the famous Burgess Shale fauna of Middle Cambrian age in western Canada (FIGURE 8). It is a peculiar fossil that has few characteristics in common with typical

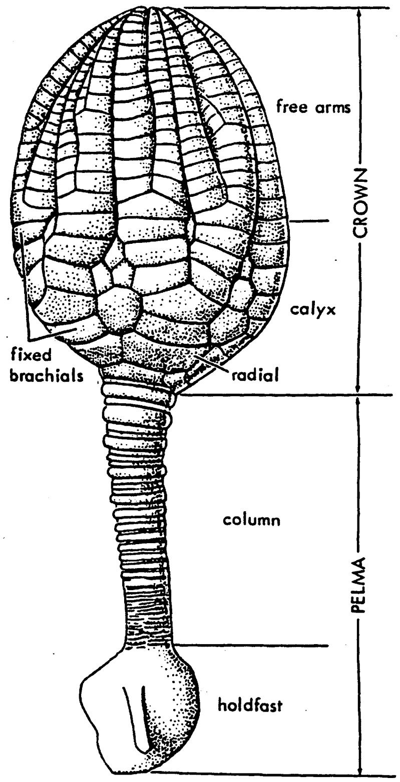


FIGURE 1 - A complete specimen of the Silurian flexible crinoid *Calpiocrinus* with various features labeled (from Springer, 1920).

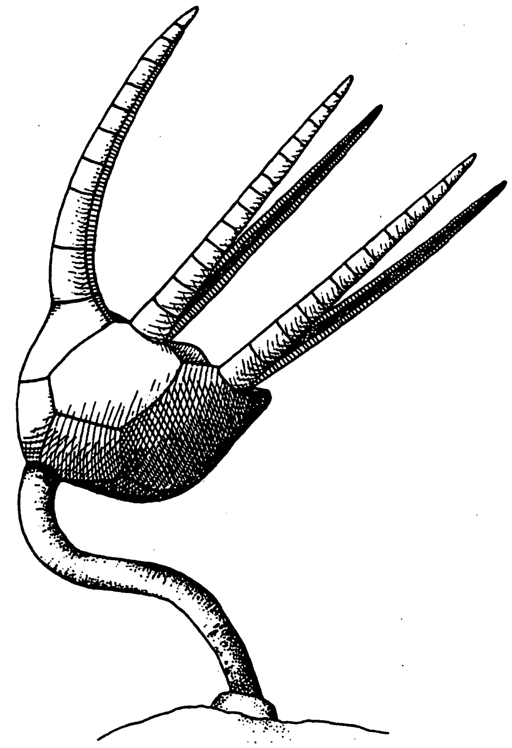


FIGURE 2 - Reconstruction of the Ordovician inadunate crinoid Hybocrinus. There is a short stem and small button-like holdfast. Arms are unusual in being unbranched (from Guensburg, 1992).

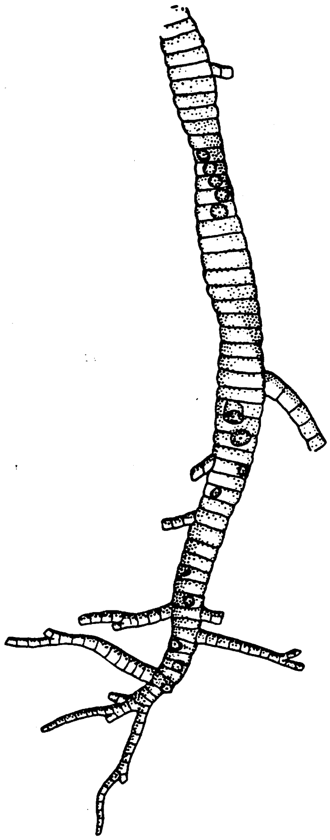


FIGURE 3 - Stem and root-like holdfast of the Mississippian camerate crinoid *Platycrinites (*from Wachsmuth and Springer, 1897).

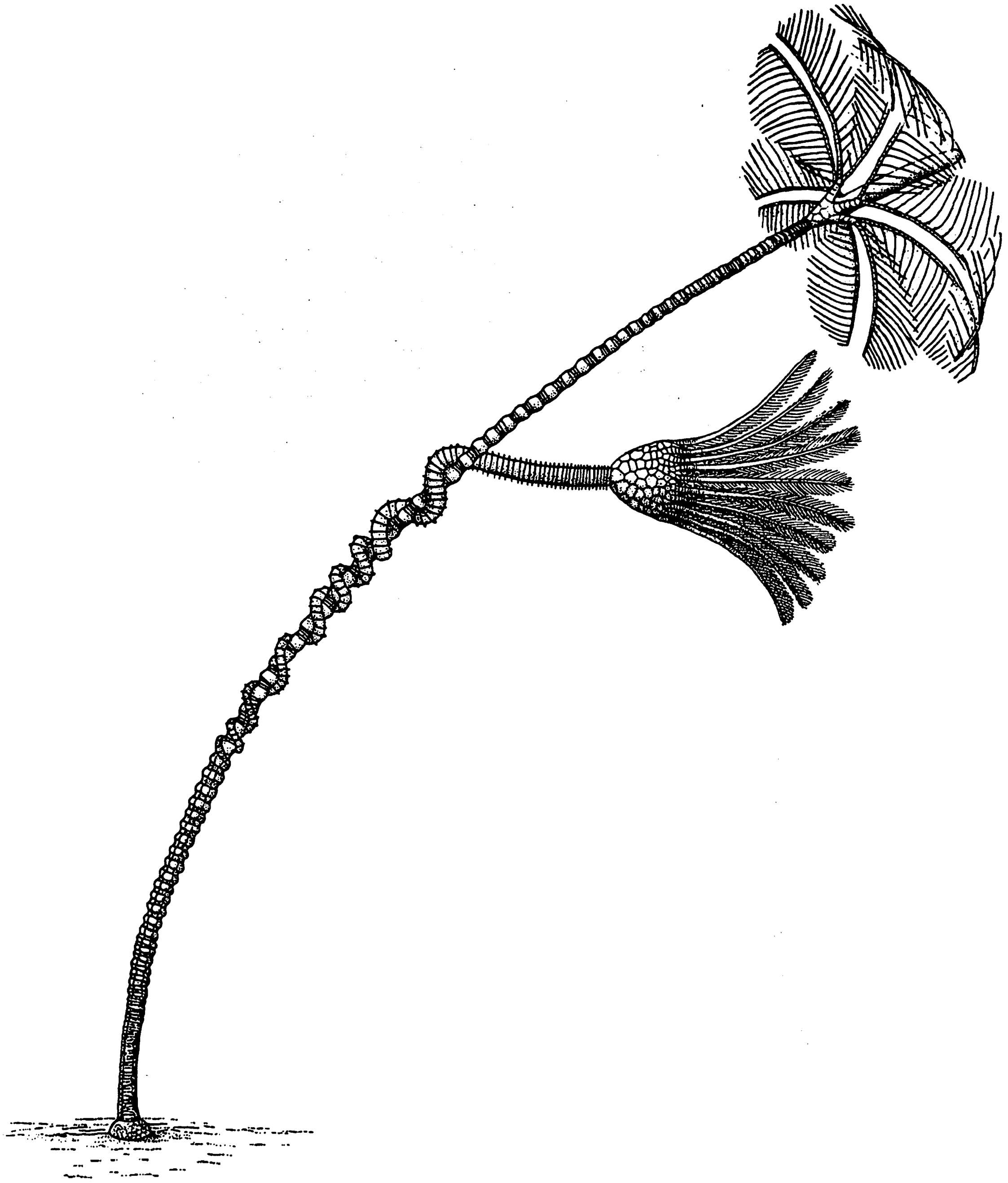


FIGURE 4 - Reconstructions of the Ordovician disparid inadunate crinoid *Tryssocrinus* that attached by a small button-like holdfast and the camerate *Gustabilicrinus* that attached by a coiled column (from Guensburg, 1992).

FIGURE 5 - Reconstruction of the Ordovician crinoid *Archaeocrinus* attached by a coiled stem to a bryozoan; arms are densely pinnulate (from Guensburg, 1992).

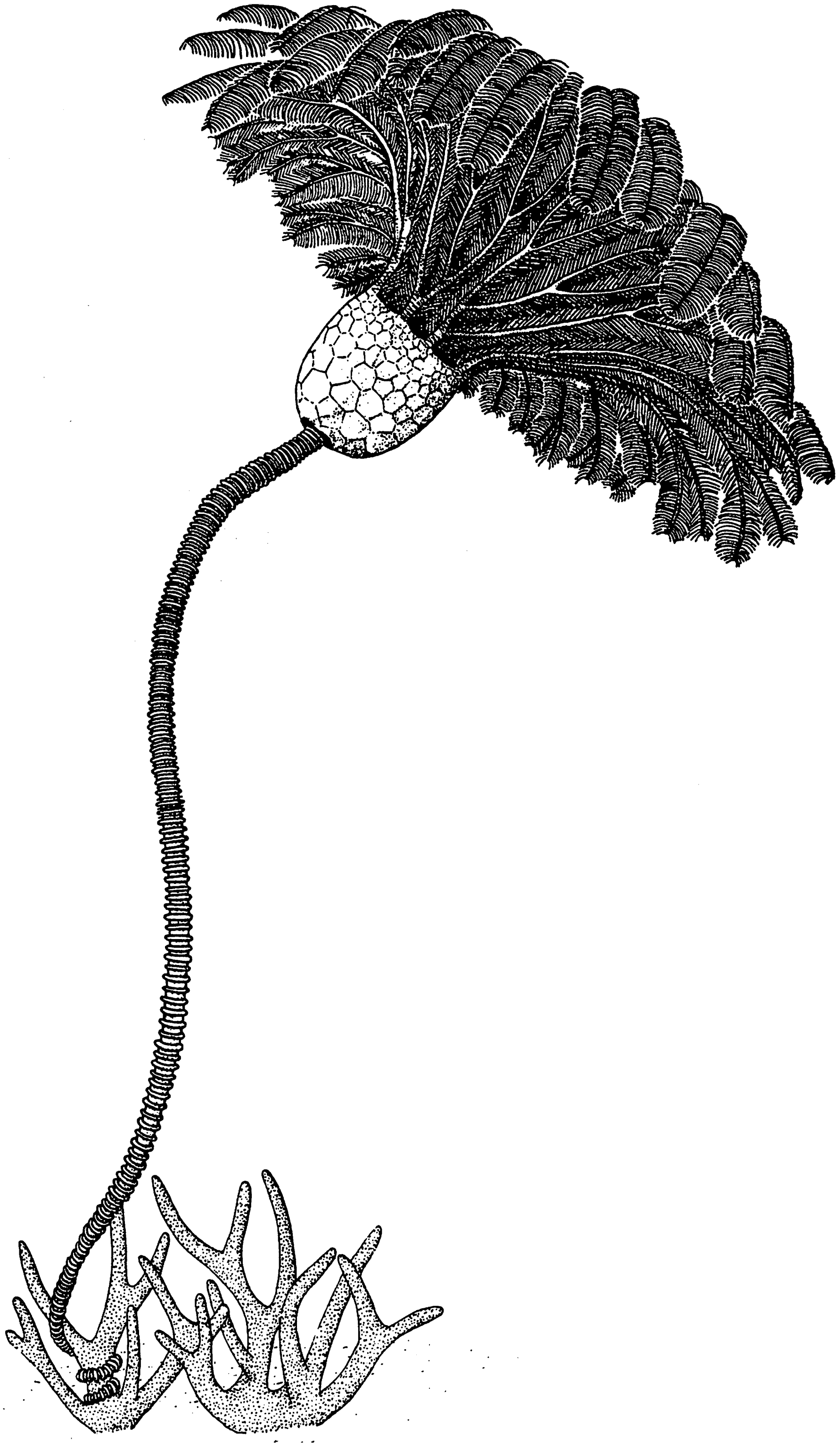
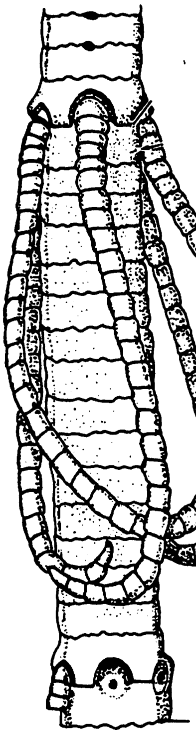


FIGURE 6 - Detail of the column of a modern stalked comatulid crinoid showing cirri (from Breimer, 1978).



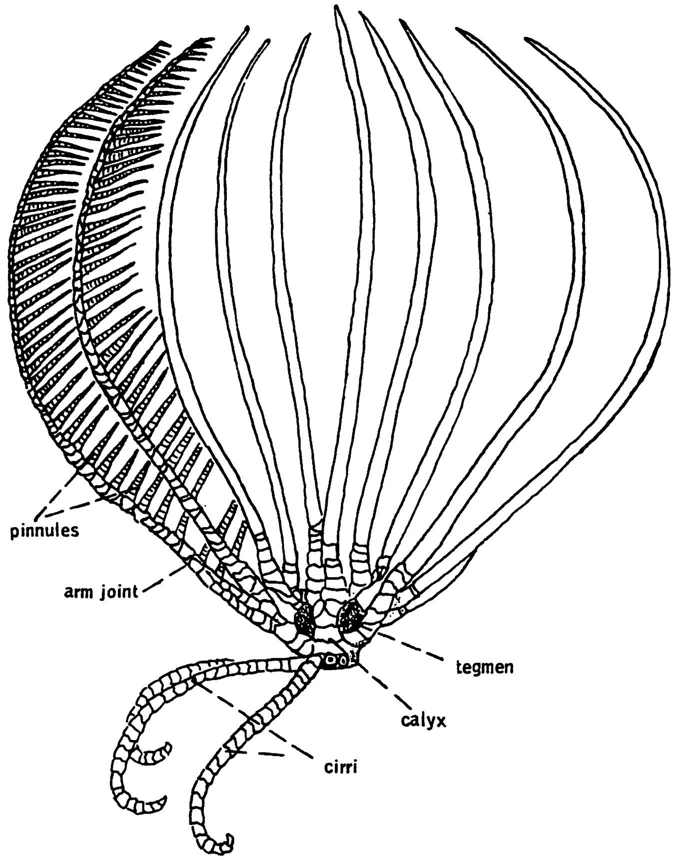


FIGURE 7 - A modern stalkless comatulid crinoid that is able to move freely using cirri (from Clark and Hyman).

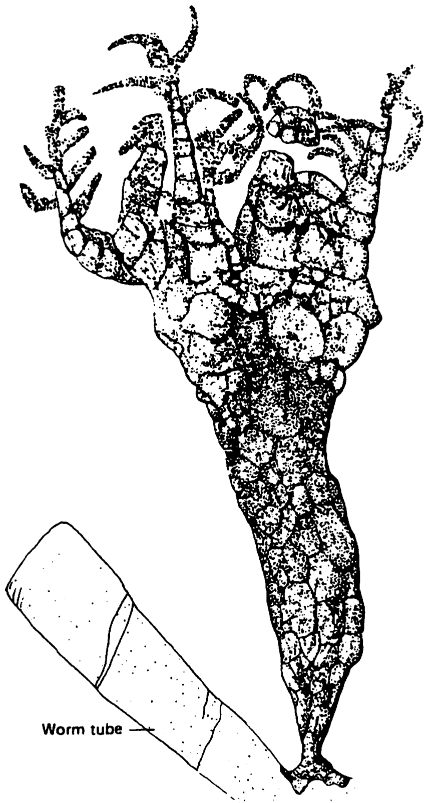


FIGURE 8 - The earliest crinoid *Echmatocrinus* from the Middle Cambrian Burgess Shale; tube feet are preserved projecting from arms (from Paul and Smith, 1983).

crinoids and does not fit into any of the major crinoid subgroupings. Calyx plates are not well organized and there is no stem. The calyx tapers directly to a small encrusting holdfast that is preserved attached to "worm" tubes. The arms are about the only uniquely crinoid feature of this fossil and are short and unbranched with large tube feet (soft-part extensions for capturing food particles). This seems to indicate that *Echmatocrinus* was capable of feeding on relatively larger prey than contemporary and much more common suspension-feeding echinoderms, the eocrinoids. No crinoids are known from the Late Cambrain anywhere in the world but important evolutionary innovations must have taken place because a wide variety of fairly typical species had evolved by the Early Ordovician. Moderate numbers of specimens from this time have recently been found in the western U. S. and in the Baltic region of Russia. These seem to have had generally similar lifestyles. Arms are all non-pinnulate with large food grooves, indicating that, like Echmatocrinus, larger food particles were preferred. Many species already had long columns; holdfasts were typically button-shaped encrusting types and they attached to hard seafloors or shells. Disparid and cladid inadunates and camerates were all recognizable by the Early Ordovician. Other stemmed echinoderms including eocrinoids were apparently able to live in a greater variety of environments then because they had a wider range of attachment structures.

However, crinoids rose to dominance over all other echinoderms in a much wider range of environments by the Middle Ordovician. The expansion took place by evolution of many new types of attachment and feeding features. This allowed exploitation of many more attachment sites and ability to feed on a wider menu of food particles. Root-like holdfasts permitted attachment on muddy or other soft seafloors. Other species autotomized or broke free from their holdfasts as juveniles; many of these species attached to fixed objects projecting above the seafloor with coiled stems as adults. (They were not capable of unwinding and detaching, however). Cirri-bearing crinoids had evolved by the Late Ordovician; they attached by grappling to fixed objects. These basic modes of attachment continued to be used by crinoids throughout the Paleozoic and later, although cirri-bearing and rooted styles were most common by the Middle Paleozoic. Pinnule-bearing crinoids with dense filtration fans and small food-grooves first occurred and became common with Middle Ordovician species. This could have produced direct competition with eocrinoids and their descendants, which became increasingly less common during this time. Crinoids reached their zenith during the Mississippian Period when famous occurrences such as Crawfordsville, Indiana, and Le Grand, Iowa, were deposited.

Crinoids seem to have been increasingly vulnerable to predation by the end of the Paleozoic, particularly by fishes with crushing type teeth, and many formerly important groups disappeared entirely. Extinction also correlates with the disappearance of widespread cratonic seas. Crinoids were very scarce in the Early Mesozoic but were moderately common again during the Middle Mesozoic. Non-stalked modern-type crinoids evolved at that time. These have the important ability to move slowly across the seafloor or even swim if needed. They are locally common on coral reefs today. Column-bearing crinoids became scarce after the Middle Mesozoic and today are limited to deep water environments.

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PALEOZOIC ECHINODERMS FROM CHINA

Gary Lane, Indiana University; Christopher Maples, Kansas Geological Survey; Johnny Waters, West Georgia College; Sara Marcus, Kansas State University

HOW IT ALL STARTED

This story begins in 1987 when Chris Maples and Johnny Waters attended the International Carboniferous Congress in Beijing, PRC. They went on one of the post-conference field trips. One stop was made at a large shale pit for a brick factory on the outskirts of Xinxu, in Guangxi Province. During the 10 minute stop Johnny and Chris discovered a thin, 2 inch, band of fossiliferous marine shale and shaly limestone and proceeded to collect a couple of bags of the rock, much to the amusement of the other participants, who mainly saw the 100's of feet of unfossiliferous shale.

The shale proved exceedingly difficult to break down, having a waxy, oily matrix that failed to respond to most preparation procedures. Finally, they hit upon Liquid Plumber as a reactant and after numerous rounds of processing they released 100's of microfossils including baby cephalopods, snails, brachiopods and hundreds of microcrinoids. Chris Maples and his student, Sara Marcus, began study of the microcrinoids and Howard Feldman, of the Kansas Geological Survey, began work on the microgastropods.

The scene now shifts to Oxford University, England, August, 1988, where Johnny Waters and Gary Lane gave papers at a international symposium on Paleozoic Biogeography. Attending this symposium was Dr. Hou Hong-fei a senior paleontologist with the Chinese Academy of Geological Sciences in Beijing, essentially equivalent to our U. s. Geological Survey. Hou is a specialist on

Devonian brachiopods. He also gave a paper at this symposium and upon meeting us he told Johnny that he had two excellent blastoid specimens from China that he would send to him for study. Johnny heard no more from Hou until November of that year when a tiny parcel arrived in the mail from Paul Sartenaer of the Royal Institute of Natural Sciences in Belgium. He had just returned to Brussels from field work in China with Hou. The parcel was a small Chinese match box that contained a perfect blastoid and a perfect small crinoid crown, both from the type locality of the Honggulelung Formation of very latest Devonian age (Famennian Stage). This locale is in northwestern Xinjiang-Uygur Autonomous Region, a remote area of northwestern China called the Junggar Basin, part of the western Gobi desert and west of Mongolia.

The blastoid turned out to be a new species of a hyperoblastoid and the crinoid a new species of the flexible crinoid Eutaxocrinus. The specimens were from Hou.

With the two new echinoderm occurrences in hand, we applied for a grant in 1990 to do field work in China from the National Geographic Society and were successful in obtaining money for field work to be undertaken in July, 1991. We made arrangements with Hou to visit both the south China locality and the northwest Xinjiang area. It takes several days of travel to get from a home base in the U.S. to a field area in remote parts of China. Needless to say we were very intense on finding more specimens, as two specimens already in hand would hardly be worth the time, energy, and considerable expense of travel to and within China.

CHINESE FIELD WORK

When we pulled up to the Hongguleleng outcrop in a Toyota land cruiser we charged out of the vehicle, up the steep slope of bedded limestones packed full of brachiopods and corals, but initially no sign of crinoids. After an hour or so of futile searching Hou yelled to come over to a low saddle where he had found the initial two specimens. We immediately began to find crinoids and a few blastoids. The rock was a dark mudstone that weathered to a fluffy soft dust. We called this interval the "marly" beds. The echinoderms had weathered free of matrix and could be picked up loose, like apples on the ground. By the end of the first day we had collected close to 50 specimens and we knew that our trip was successful and the expenses justified. On the second day we proceeded up section (actually down section because the outcrops were an overturned syncline shot through with dolerite dikes) to look for echinoderms still higher in the section. Gary wandered off to inspect a low hill in the valley alongside the outcrop and found a 5-foot thick lens of very coarse crinoidal limestone. Careful collecting on this little knob yielded over 100 complete blastoid calyces as well as a few crinoids--it became "blastoid hill". We were commonly interrupted by nomadic Mongol herders, with flocks of goats and sheep, who traveled around the area on horseback or on motor scooters.

After another day's collecting we then proceeded to look at other rock sections in the area. These yielded a very few specimens. The sedimentary rocks were very badly broken up and recrystallized by many faults and local igneous intrusions.

We cannot leave this discussion without mention of the living accommodations. Anyone who thinks doing field work in remote parts of China is easy or enjoyable has never had to stay in a guest house in a village like Hoxtolgay where we were for 5 nights. This guest house was the only accommodations available for foreign visitors within a 50 mile radius. The rooms were filthy. All water (including the toilet that had no seat) was shut off from 8 pm to 7 am. There was no hot water at all. The only water to drink was boiled. The food was ill-prepared and everyone in our group got sick. Gary's pillow had a brocade cover that clearly had not been washed in years, dust seeped in the windows, and a large sow scavenged garbage just outside the windows of our rooms.

We spent some time visiting other localities in the Junggar Basin, mostly Carboniferous in age, but without success--a few crinoid stems, some possible calyx plates, and that was it. We then went to south China and spent some time re-collecting the Xinxu microcrinoid site, measuring the section, and generally following up on the initial collection made in 1987.

After a day or two of recovery and sightseeing in Beijing we returned to the U.S.A., paying a long visit to a McDonalds in Hong Kong on the way.

FIELD WORK IN 1993

Before we had left for field work in 1991 we had submitted a proposal to the National Science Foundation for new funding from 1992 to 1994 to make a second trip to China. We were counting on the first trip sponsored by National Geographic to be a success. Upon return we informed the NSF of our discoveries, although we were told that would make no difference in acceptance or rejection of our proposal. At any rate, we did get funded and set wheels in motion to return in May, 1993. This time Hou was accompanied by Wang Jin-xing, a young paleontologist with the Chinese Academy. She is becoming an expert of Paleozoic echinoderms. Chris, Johnny and Sara visited Xinxu again, as well as other localities in south China and met Gary, who had been still teaching, at Kunming, capital of Yunnan Province, very southwesternmost China. Here we went in the field with Chen Zhong-tai, professor at the Kunming Institute of Technology. We were very surprised to learn that Chen had been collecting and studying Paleozoic echinoderms from Yunnan for many years and had prepared a monograph of Ordovician through Pennsylvanian echinoderms of Yunnan. He and his students had collected thousands of crinoids, cystoids and blastoids over the years. Chen took us on a field trip to some of his Lower Carboniferous localities. We travelled over 200 miles on the original Burma Road of World War II, a highway paved with hand-laid cobblestones.

Chen's monograph has since been published, with many new species and several new genera of crinoids and cystoids. Unfortunately only about a dozen copies of this 100 page book made it out of China, so it is not readily accessible to many scientists.

From Kunming we returned to Xinjiang-Uygur and there met Liao

Zhou-ting, with the Nanjing Institute of Paleontology, the approximate equivalent of our U. S. National Museum. Liao has worked on late Paleozoic and Devonian brachiopods of Xinjiang-Uygur for many years and knew many localities that could contain echinoderms. We returned to our Devonian haunts of 1991 and made important new collections. Liao took us to one new locality, a small fault block of the "marly" beds from which we collected over 100 crinoids in one-half day.

This successful trip was much more enjoyable because our Hoxtolgay guest house had been greatly cleaned up and the food was much better, and we didn't get sick (just queasy). We returned to the capital of Xinjiang-Uygur, Urumqi, a city of 3 million people. From there we went to Turfan (or Turpan), to the east, south of the huge Tien Shan mountains, and the second lowest spot on earth, after the Dead Sea and slightly lower than Death Valley. From Turfan we visited an Upper Carboniferous locale in the southern foothills of the Tien Shan, about 30 kilometers away. Here Liao showed us a great white mound of coarse crinoidal limestone. This was capped by black conglomerates composed of the debris of volcanic rocks, some boulders up to 6 feet across. Imagine our surprise to find abundant crinoidal debris and crinoid cups and broken calyces in this volcanic rubble. Upon leaving Turfan, a grape and melon growing area that is on the old Silk Route, we returned to Urumqi, then Beijing, and then to the U.S.

Since then we applied for a second NSF grant to continue our research and again we were successful with this second application.

So, we plan to return once again in May and June, 1995. We will spend most of the time in Xinjiang-Uygur and Liao rather than Hou will be our host and leader. He promises many new localities with echinoderms, including some in the remote eastern part of the Junggar Basin.

SCIENTIFIC SIGNIFICANCE

At this point, you, the reader, would be well-justified in asking: " So what?". Why are these Chinese echinoderms important? What can they tell us that we didn't know before? Without getting too technical, here are some of the answers to those questions.

In the first place, Paleozoic echinoderms have been virtually unknown from mainland Asia. We estimate that fewer than 20 species represented by about 150 specimens had been described from the entire Asian continent over the past 200 years. This is a huge gap in our knowledge of fossils over a vast area. This despite the fact that large areas of fossiliferous marine Paleozoic rocks crop out in China.

On a worldwide basis our knowledge of very late (Famennian) Devonian echinoderms has been seriously deficient. In many parts of the world rocks of this age consist of widespread black shales (like the New Albany and Chattanooga black shales in the U.S.). These shales yield few fossils and no echinoderms. Similar shales occur in Germany, Canada, and other parts of the world. Thus, finding Famennian crinoids was in itself an important discovery. The fauna is significant for two reasons. First, it is the forerunner of the amazing evolutionary explosion of echinoderms (crinoids and blastoids) in the Mississippian/Lower Carboniferous. We have never understood just how this evolutionary event took place. Finding a rich echinoderm fauna just prior to the expansion will help us unravel the sequence of events.

Secondly, the Late Devonian witnessed one of the four largest extinction events in earth history, generally placed between the Frasnian (below) and Famennian (above) stages. Those crinoids so typical of older Devonian rocks, like <u>Arthrocantha</u>, the megistocrinoids and dolatocrinoids, are now gone. We are looking at the survivors of this major extinction--the "winners", not the "losers".

We believe that the Junggar Basin area was a refugium, or refuge, for echinoderms, during Late Devonian time. The survivors persisted here whereas many other echinoderms became extinct and could not live in the huge areas of dark, fetid mud represented now by widespread black shales. From this refugium, the successful survivors radiated out worldwide in the Mississippian to become some of the most successful marine animals of all time--the Age of Echinoderms.

One of the astonishing things about Chen's work on Lower Carboniferous crinoids of Yunnan Province is the fact that his crinoids are virtually identical to the same age crinoids found in the Clitheroe area of central England. Chen even uses some of the same British species names for his specimens. This congruence provides evidence for what has been called a Paleo-Tethys, a major east-west arm of the sea that extended across central Europe and central Asia at one time. The Tethys proper was a much younger seaway now represented by the Himalayas, and the Caspian, Black, Mediterranean, and Caribbean seas. Only a fairly direct pathway of marine migration could have provided such a remarkable similarity. Even the preservation of the crinoids is similar and Chen has collected hundreds of specimens.

Our Upper Carboniferous crinoids from the volcanic conglomerates near Turfan record a highly unusual environment from which fossil crinoids have never before been recorded. They provide evidence for a tectonic setting consisting of a narrow continental shelf with a steep outer slope along which debris from nearby volcanos flowed downslope, carrying along with the rubble the broken remains of shallow water stalked crinoids. the crinoids have clearly been battered around and large camerate crinoid thecae have been torn into large scraps. Specimens are complete enough to identify to either the generic or familial level but are too incomplete for attribution to species. The most abundant crinoid is Platycrinites, a crinoid that one normally associates with the Lower, not the Upper, Carboniferous. While platycrinoids have been reported from many areas in Upper Carboniferous or Permian rocks, they usually are not the most common crinoid in the fauna. The only similar occurrence of which we are aware is the Upper Carboniferous crinoids from New Mexico described by Art Bowsher.

Finally, the microcrinoids from Xinxu are the first recorded microscopic crinoids from Asia. They are still in the process of being studied, but the genera all seem to be ones that have been recorded previously from the United States or from western Europe.

We are certain that future studies of Asian Paleozoic echinoderms will prove them to be even richer in abundance and diversity than we now imagine. The worldwide distribution of fossil life cannot be clearly understood without study of this largely unexplored Asian continent--unexplored at least as far as Paleozoic echinoderms are concerned.

REFERENCES

We have published numerous abstracts on various technical aspects of our Chinese research, primarily in conjunction with oral and poster presentations at all Geological Society of America national meetings since 1988. These are availabe in the GSA Programs with Abstracts.

In addition we have published a preliminary paper on the Hongguleleng crinoids and blastoids in Stratigraphy and Paleontology of China, vol. 2, 1994, p. 1-16. The two plates of fossils reproduced here are from that paper.

We have submitted a paper on the Turfan volcanic conglomerate fauna to the Journal of Paleontology, but it is not yet published. We also have in hand a large monograph on the Devonian fauna that we hope to have completed in the near future. Plans call for submission of this work to the Memoir series of the Paleontological Society.

ILLUSTRATIONS

Plate 1, figures 1 through 7 are photographs of various inadunate crinoids in the fauna. The first two are of a calceocrinoid. Figures 8 through 14 are of two species of Eutaxocrinus, figure 8 from blastoid hill, the others from the marly beds. All magnifications are X2.

Plate 2, figures 1 and 2 are of a platycrinoid with recumbent arms, fig. 3 is a decadocrinoid, figure 6 a camerate crinoid that stands between the batocrinoids and actinocrinoids. All other figures are blastoids. Figures 4 and 9 are of hyperoblastoids, 7 is a granatocrinoid, 8 is a troosticrinoid, and 10 is an orophocrinoid. Despite these crinoid endings these latter are all blastoids. Magnifications range from X2 to X6.

Plate 3. Field photographs in the Xinjiang-Uygur Autonomous Region. A. Field party in the foothills of the Tien shan mountains northwest of Turfan. From left to right, Johnny Waters, driver, Sara Marcus, Hou hong-fei, Chris Maples, Gary Lane, Wang jin-xing. Black volcanoclastic Upper Carboniferous beds that yielded crinoids can be seen in the central right background. B. View of the "marly" beds, white band across center of picture, that yielded many complete Famennian (Devonian) crinoids at the type locality of the Hongguleleng Formation. C. Field party collecting in the marly beds. Note sparse desert vegetation. The climate is similar to southern Nevada. D. Lower fossiliferous limestones at the Honggulelung type locality, Zhou (a provincial geologist) at crest, Lane to left. E. Wang jin-xing and Chris Maples at Section 3, a structurally complex section of the Honggugelung that yielded sparse crinoids and blastoids. The 1991 field party, with Waters, driver, two Mongol goatherders on either side of Lane, and Maples,

PLATE 1


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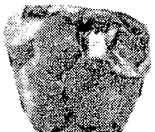
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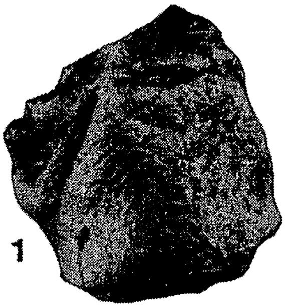
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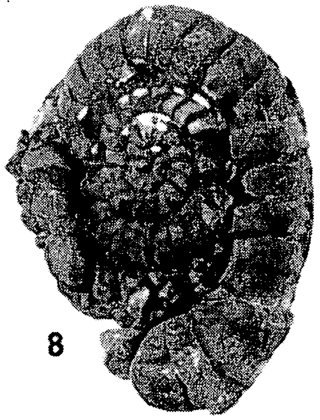
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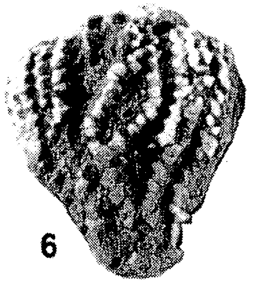
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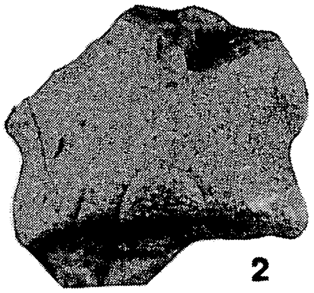
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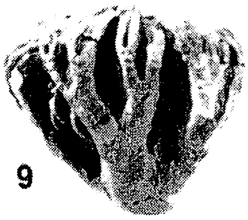
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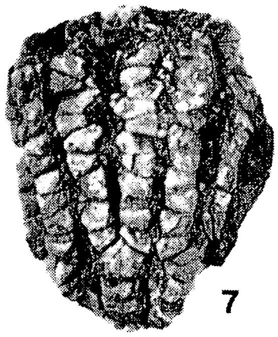
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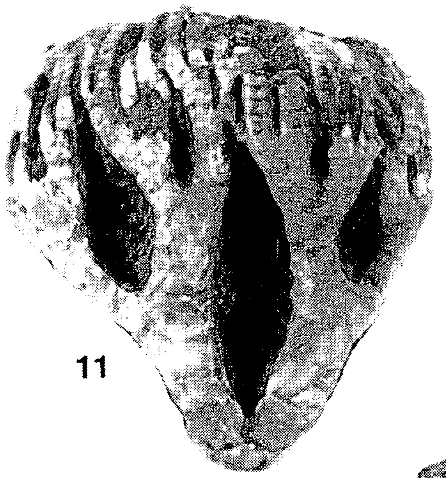
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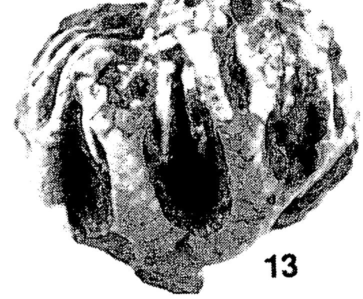
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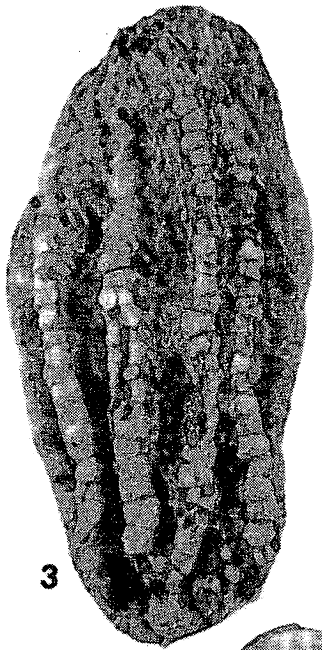
PLATE 2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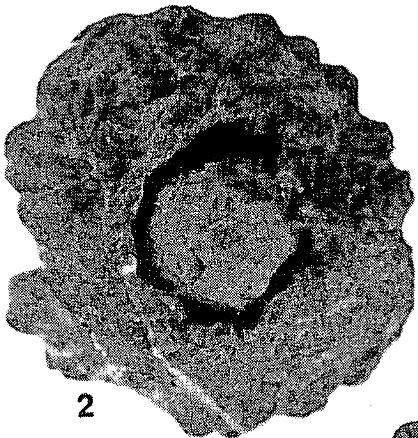
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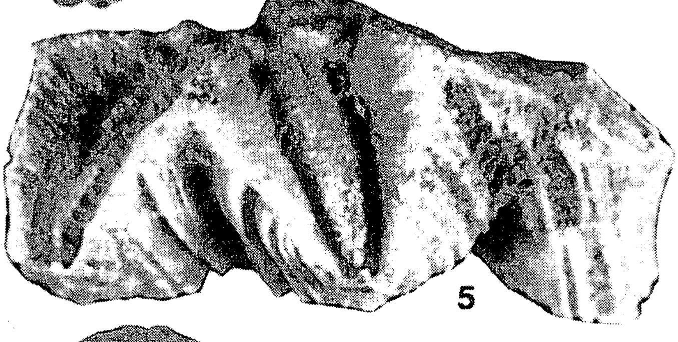
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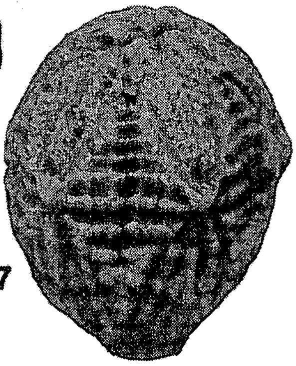
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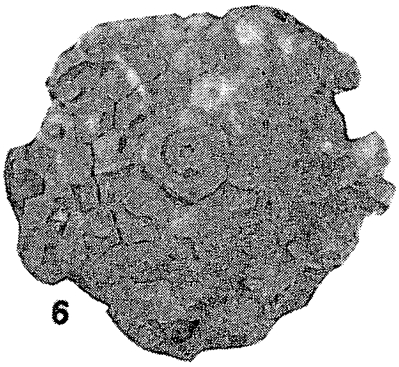
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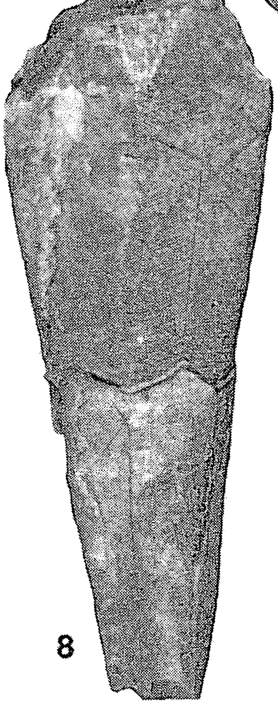
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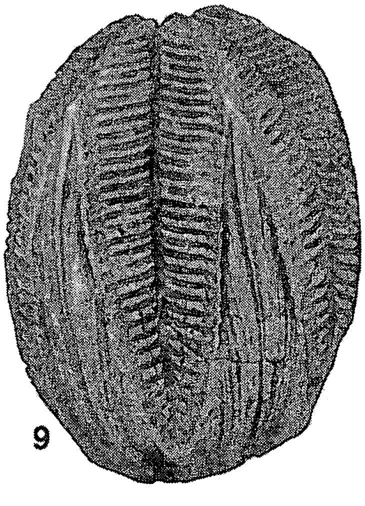
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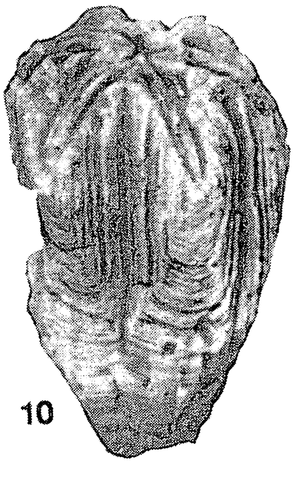
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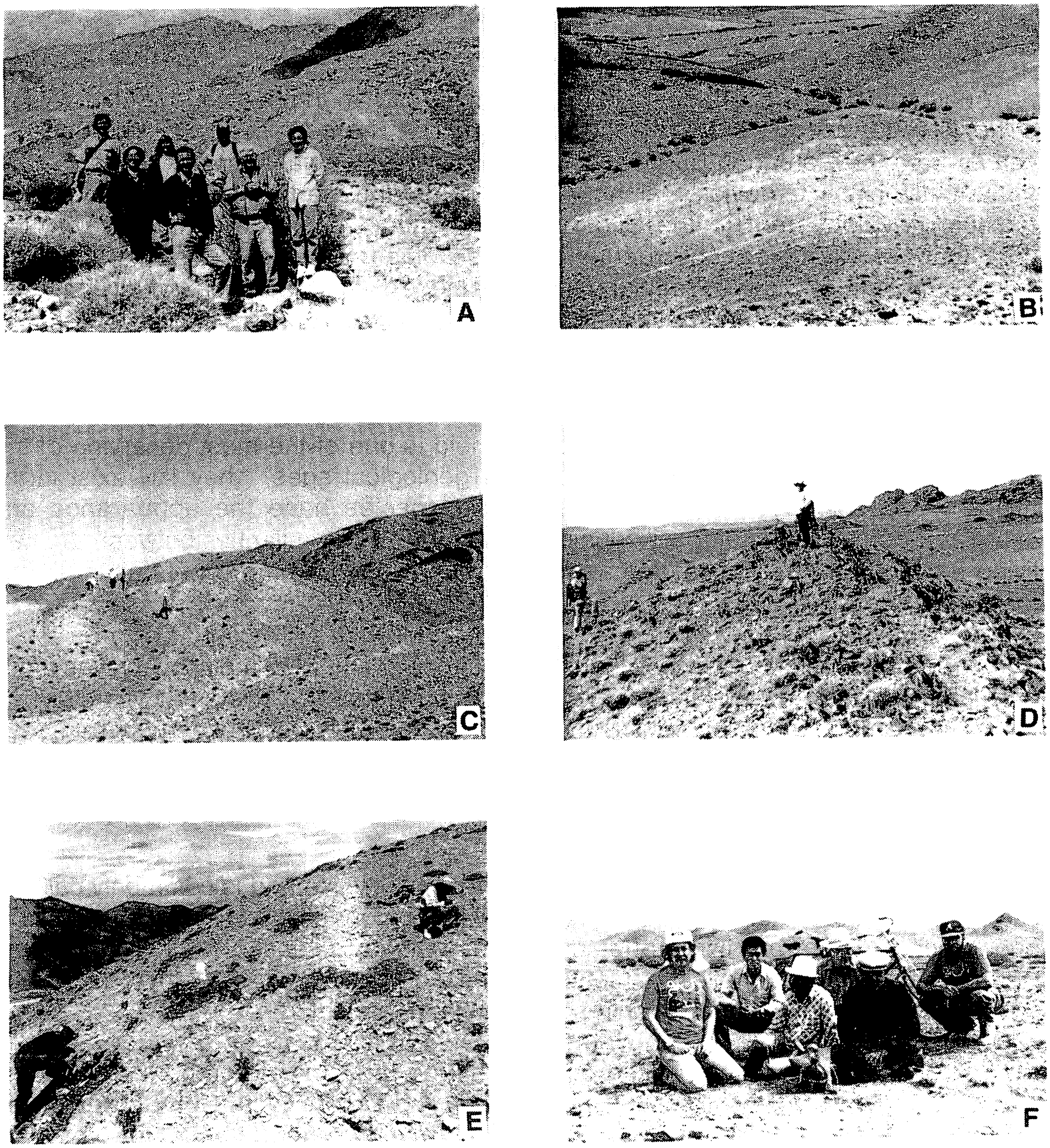
PLATE 3



CLASS CRINOIDEA

AND ITS

SUBCLASSES

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An important group of echinoderms that have had an interesting fossil history and still exist today are the sea lilies and feather stars. The earliest known crinoid genus comes from the Cambrian Burgess Shale of British Columbia. Crinoids first appeared abundantly in the Ordovician along with blastoids and starfish. They attained their maxium developement in the Silurian and became very widely distributed. The crinoids were the major echinoderms of the Devonian but the Mississippian period is called "The Age of Crinoids". During this time they reached their peak of diversity and abundance with over 800 genera. By the end of the Permian, most of the ancient species of crinoids died out. These ancient groups were replaced by a new group of crinoids which evolved from them and can be found living in modern seas. Plate 1

Of all the so called "living fossils" the criinoid is one of the most deserving of this terminology. Found throughout most of the geological ages, they still exist in the modern seas today. Some of these living species have the appearance and characteristic structures of fossil crinoids. Because of the similarities between the two, living crinoids provide knowledge as to the morphology and the living habits of their fossil counterparts. Plate 2, Fig. 4, Fig. 2.

For many years crinoids were thought to be extinct. In 1755 a discovery was made of a living crinoid in deep water off Martinique in the Carribean and a few years later in the waters of Barbados. About a hundred years later, one was dredged up from deep water off the coast of Norway. This discovery caused great excitement in the scientific community. It raised as much excitement as the Coelacanths, another "living fossil" would arise seventy years later.

Although the word "crinoid" conveys the meaning lily-like and is commonly called a sea lily, the crinoid is strickly an animal form with no connection to plants except in its appearance. There are two groups of crinoids in today's seas. The stalked or fixed crinoid comprises the smallest percentages of species. Plate 2 Fig. 2, 10 - 15%. The stemless or free moving crinoid makes up the rest. Plate 2, Fig. 1.

In the ancient seas the stalked crinoid was the predominate group. Crinoids are related to sea urchins, starfish, sand dollars and others in the group known as echinoderms. Characteristics which place these marine animals together are calcareous plates or ossicles and a radial body. Plate 3, Fig. 3. Some crinoids are made up of fewer than a dozen plates and other species have possibly more than two million.

The body of most fossil crinoids consist of crown and pelma. Plate 3, Fig. 2. The crown contains the body cavity which houses the vital organs of the crinoid. These being ambulacral, digestive, water vascular, hemal (blood), nerve and reproductive systems. The arm structure is also part of the crown.

Crinoids are filter feeders. They depend upon the current flow to bring planktonic food particles into a basket formed by the arms. Each arm has an ambulacral or food groove. The food particles are trapped by tube feet and transferred into a mucus substance in the food grooves. The particles travel in the mucus down the food grooves onto the mouth and through the digestive system. Plate 3, Fig. 4.

The pelma of the crinoid consist of the stalk, or column and the holdfast. Columns are made up of numbers of calcareous disks stacked on top of each other to form the column. Through the center of each disk is a hole which forms an axial canal in the column. Plate 3, Fig. 2.

In recent crinoids this canal holds coelomic and nervous extensions of the crown. This is most likely also true of the fossil crinoids. Columns of crinoids are of great diversity in shape and size. They range from 1 mm to 10 cm. or more in diameter and from a few mm to greater than 20 meters long. New disks or ossicles are added to the column in one of two ways. Either at the end nearest the crown or at various points along the stalk. In some species cirri are formed along the stalk. There is very little known of the use of these appendages, which vary greatly from specie to specie. The holdfast is on the end of the stalk opposite the crown. It is used in anchoring the crinoid to the sea floor or some other object. The holdfast comes in many shapes and sizes depending on the species. Plate 4, Fig. 2-8. Most fossil crinoid holdfasts look much like roots of a plant while others look like boat anchors.

If one is serious about the study of crinoids, it is fundamental to know termonology that is basic to the study of crinoids. The taxonomy (or systematics) of the class crinoidea (crinoid) Must be understood as well as that of the subclasses.

Once these points are mastered, one can identify a new crinoid to the subclass level. Even tho this is a long way from the generic and specific identification, it will put one in the group of crinoid so one can work his way through family to specific names.

SUBCLASSES

Extinct subclass Echmatocrinea, Sprinkle and Moore, 1973 Middle Cambrian.

This is a primitive subclass with irregularly plate cup, irregularly plated holdfast. This is the oldest crinoid, described from a few poor specimens. These crinoids were found in the famous Burgess Shale of western Canada. Plate 4, Fig 1.

Extinct subclass Inadunates, Wachsmuth And Springer, 1885, Lower Ordovician, to Upper Triassic.

This is a free-armed crinoid, calyx plates sutured (joined) together firmly, tegmen plates arms generally not incorporated into calyx and free above radials. Plate 5, Fig. 5-13.

Extinct subclass Flexibile, Zittle, 1895, Middle Ordovician - Upper Permian, plates not rigidly sutured together, tegmen flexible, arms uniserial, non-pinnulated. Stem round, Plate 5, Fig. 1- 4.

Extinct subclass Camerata, Wachsmuth and Springer, 1885, Lower Ordovician -Upper Permian. Calyx rigid, plates between any two rays, arms are uniserial or biserial and pinnulate, anus commonly raised on a tube. Plate 6, Fig. 1-6.

Present day crinoids also found in fossil form subclass Articulata, Zittle, 1879. Dorsal cup greatly reduced, arms always uniserial, pinnules always present, column circular, elliptical or five sided. Plate 2, all Fig.

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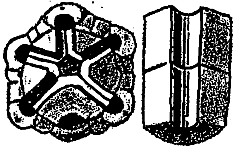
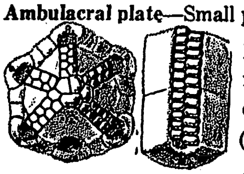
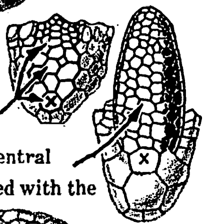
TERMINOLOGY



Ambulacrum—Groove on pinnule, arm, or tegmen that conducts water and food (plural, ambulacra).

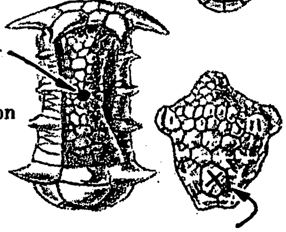


Ambulacral plate—Small plate, covering part of ambulacral groove, designated Amb (pl. AmbAmb).



Anal plates—Plates of the posterior interray area. designated XX.

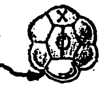
Anal sac or tube—Ventral structure associated with the anal vent.



Anal vent—External termination of the digestive system.

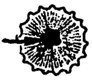
Anal—Lowest plate, designated as X, in anal series, excluding radianal.

Anal series—All anal plates in dorsal cup.

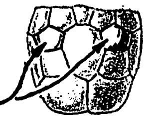


Anterior—Side opposite anal interradius, designated A.

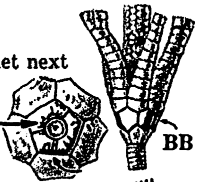
Arm—Main ambulacrum-bearing appendage.



Axial canal—Central nerve and circulatory channel extending through column.



Axillary—Ray plate on which bifurcation takes place, designated Ax (plural AxAx).

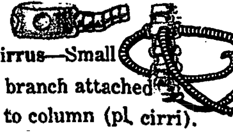


Basal—Plate of circlet next below radials, designated B (plural BB).

Biserial—Interlocking arrangement of arm segments in a double series.

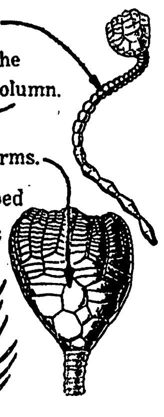
Brachial—Any ray plate above radials (except in pinnules) both in dorsal cup and arms, designated Br (plural BrBr).

Calyx—Dorsal cup and ventral structures exclusive of free arms.



Cirral—Segment of cirrus.

Cirrus—Small branch attached to column (pl. cirri).

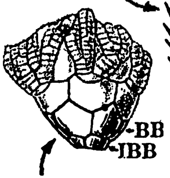


Column—Stem or stalk.

Columnal- Segment of the column.

Crown—The calyx and arms.

Cuneiform—Wedge-shaped arm segments.

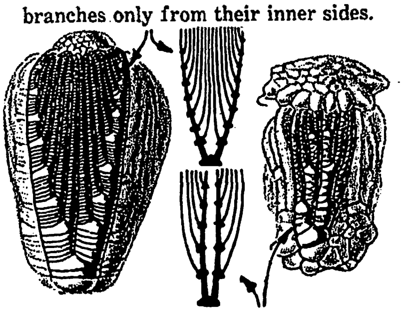


Dicyclic—Crinoids having infrabasals.

Distal—Direction away from center of base of dorsal cup.

Dorsal—Position occupied by dorsal cup.

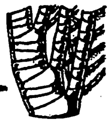
Dorsal cup—Portion of calyx below free arms.



Endotomous—Arm structure in which two main arms give off branches only from their inner sides.

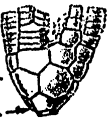
Exotomous—Arm structure in which two main arms give off branches only from their outer sides.

Facet—Articulating surface between last ray plate in dorsal cup and first free arm plate, or between free arm segments.

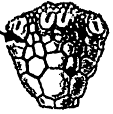


Heterotomous—Arm structure characterized by unequal branches.

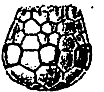
Inferradial—Lower half of a compound radial.



Infrabasal—Plate of lowest circlet in dicyclic crinoids, designated IB (pl. IBB).



Interbrachial—Plate between brachials of different rays, designated IBr (plural, IBrBr).

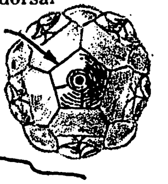


Interradial—Plate (except anal) between two radials, designated IR (plural, IRR).

Isotomous—Arm structure characterized by equal branches.

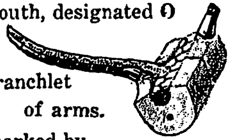
Left Anterior—Side next to anterior on left, designated LA.

Left Posterior—Side next to posterior on left, designated LP.

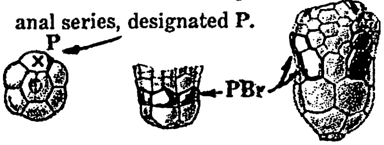


Monocyclic—Structure of dorsal cup in which one circlet occurs between column and radials.

Oral—Plate of circlet that surrounds the mouth, designated O (plural, OO).



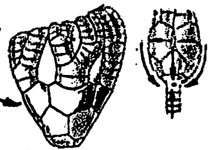
Pinnule—Small branchlet of arms.



Posterior—Side marked by anal series, designated P.

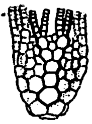
Primibrachial—First brachial plate above radial, designated PBr (plural, PBrBr).

Proximal—toward base of dorsal cup.

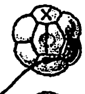


Radial—Lowermost plate of a ray, designated R (plural, RR).

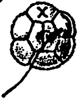
Radianal—A plate of the anal series located directly or obliquely below the right posterior radial, designated RA.



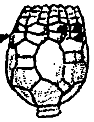
Ray—Series of plates beginning with a radial and including the arm brachials.



Right anterior—The side next to the anterior lying on the right, designated RA (always in combination, as RAB, RAR).

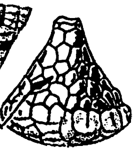


Right posterior—The side next to the posterior lying on the right, designated RP.

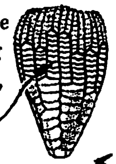


Secundibrachial—Brachial above first axillary up to and including the second axillary, designated SBr (plural, SBrBr).

Superradial—Upper half of a compound radial.



Tegmen—Cover above dorsal cup.

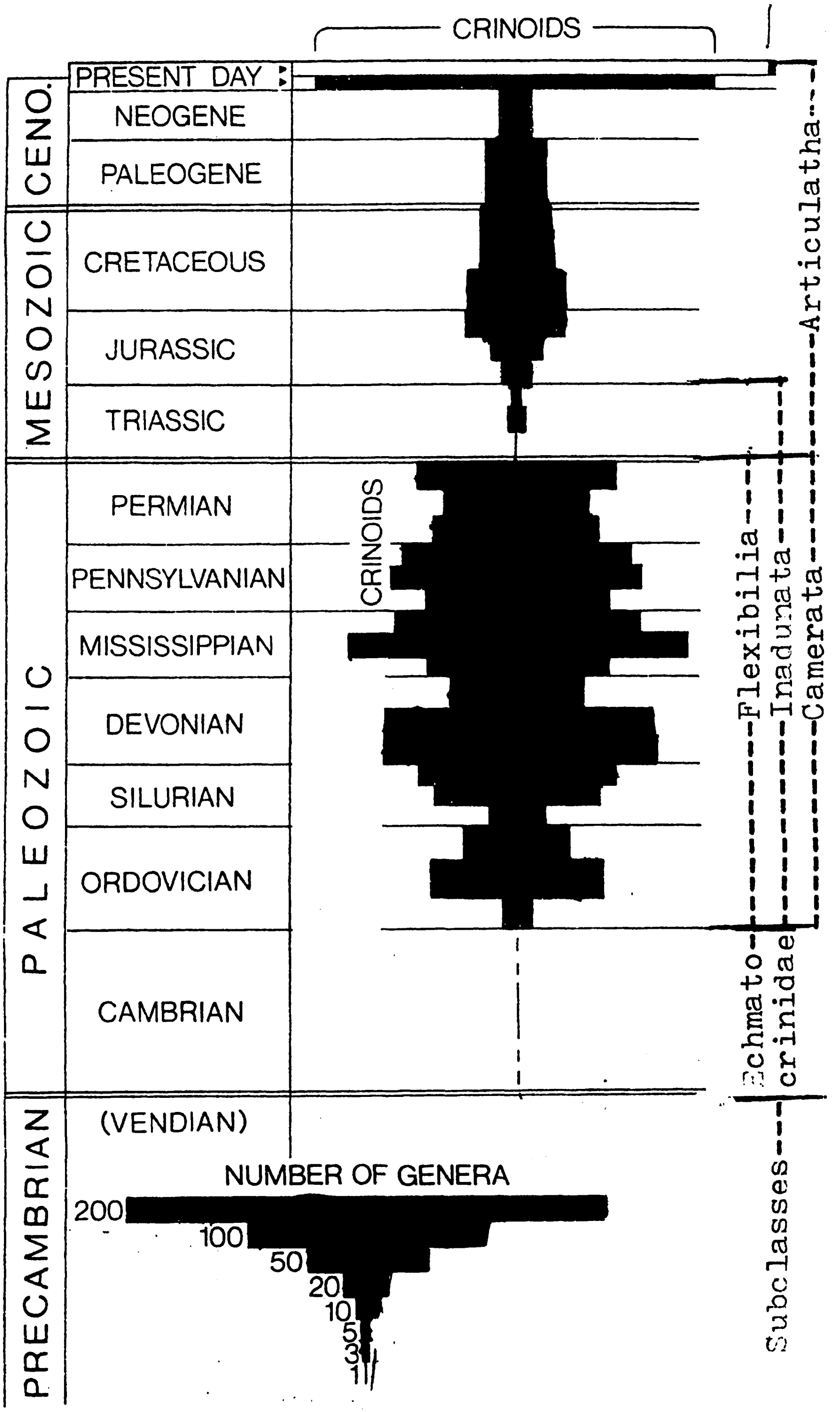


Tertibrachial—Brachial above the second axillary plate up to and including third axillary plate, designated TBr (plural, TBrBr).

Uniserial—Arm structure in which the brachials are in single series.

Index Fossils of North America Shimer & Shrock,1943

PLATE 1



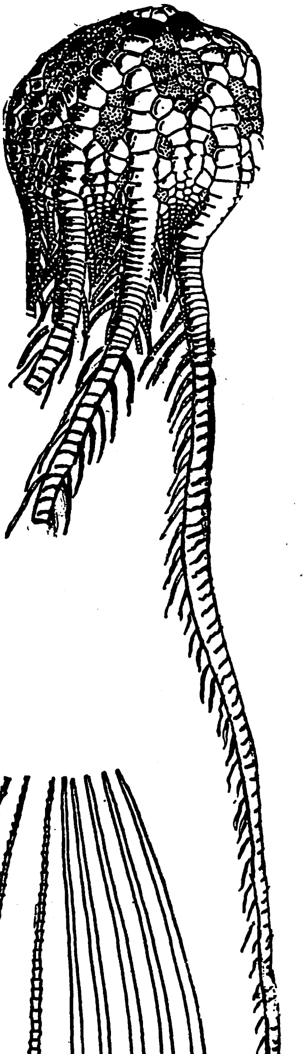
Modified from Sprinkle, 1973A

Evolutionary history of crinoid subclasses based on their known Phanerozoic fossil record. Stratigraphic range indicated by vertical scale; generic diversity indicated by horizontal width of band.

PLATE 2

Fig. 1-5 Subclass Articulata

Fig. 5 Uintacrinus an unusual crinoid from Upper Cretaceous



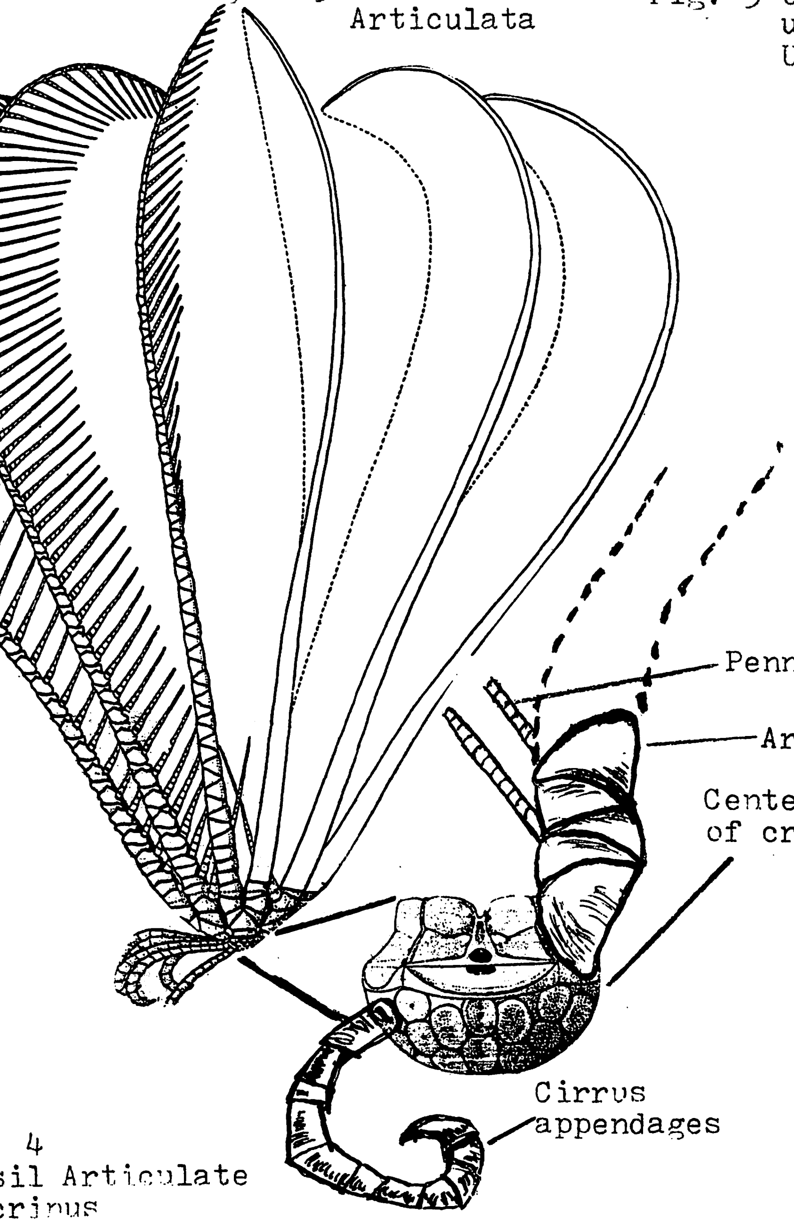


Fig. 4 Fossil Articulate Isocrinus

Fig. 1 Present day Feather star (Comatula)

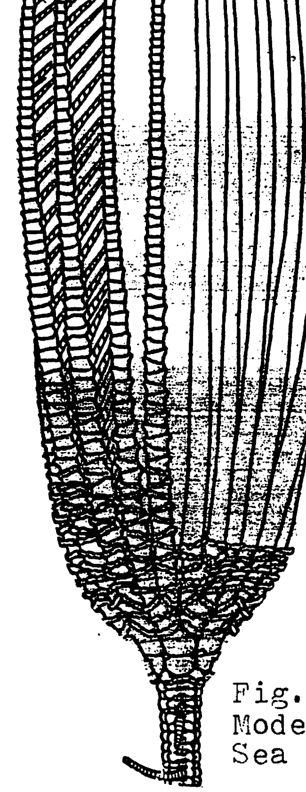


Fig. 2 Modernday Sea lilly

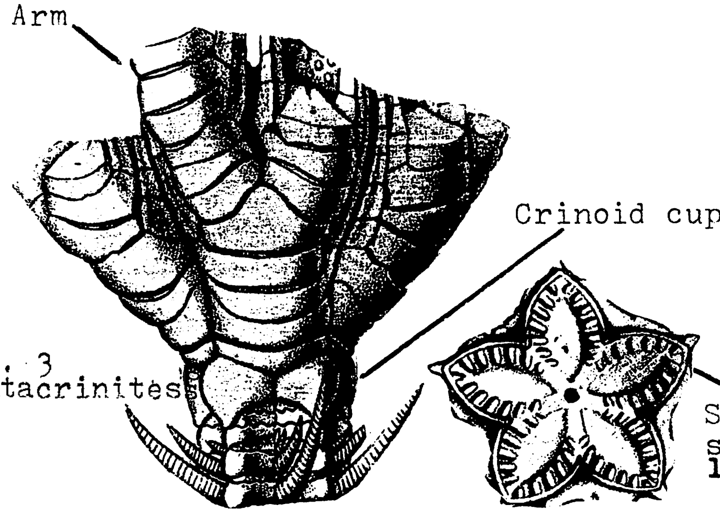


Fig. 3 Pentacrinites

PLATE 3

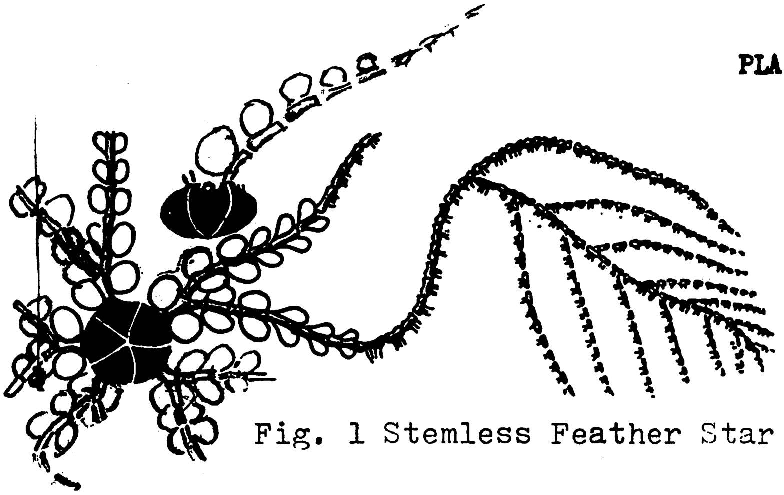


Fig. 1 Stemless Feather Star

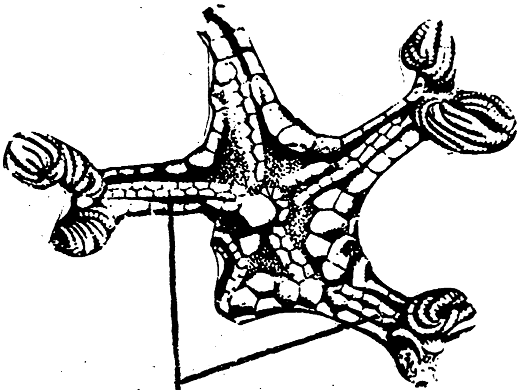


Fig. 4 Flexible crinoid
ventral view
showing food groves
in the arms

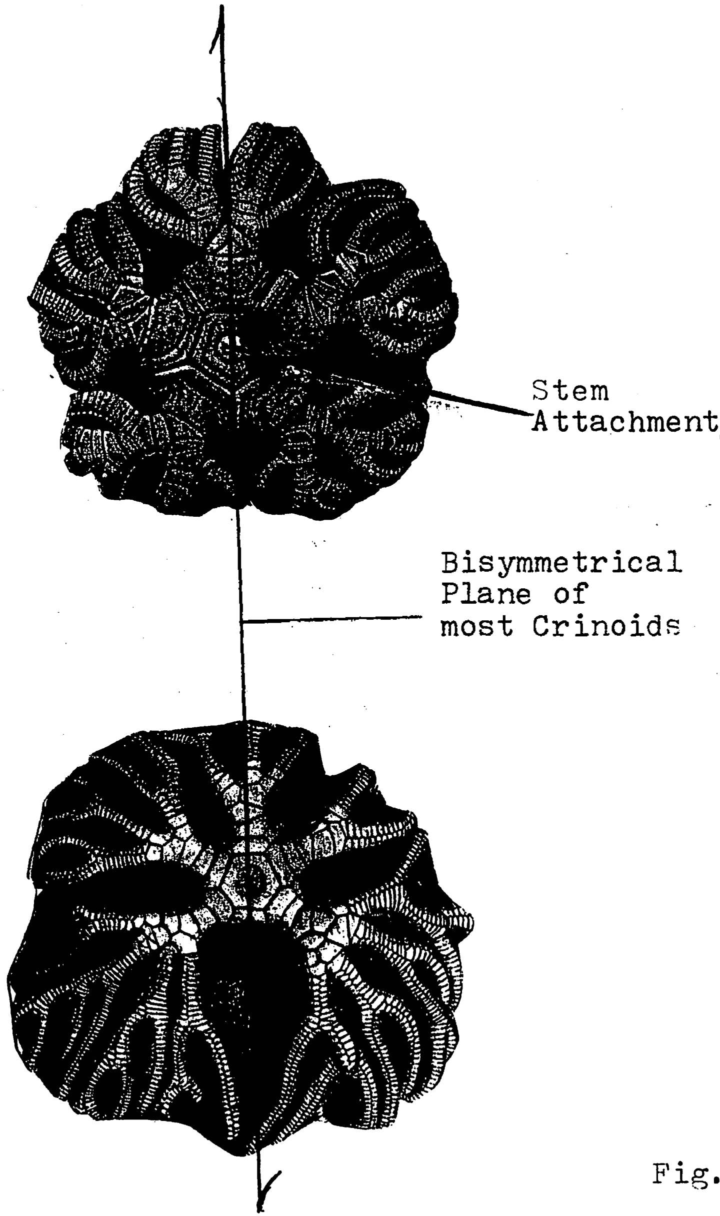


Fig. 3

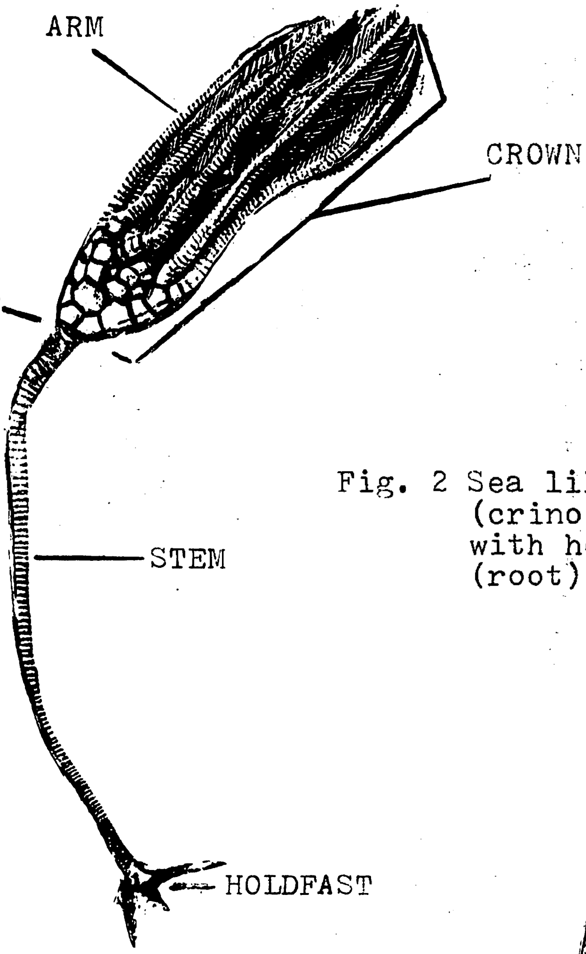


Fig. 2 Sea lilly
(crinoid)
with holdfast
(root)

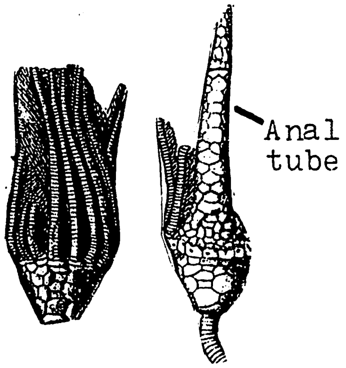
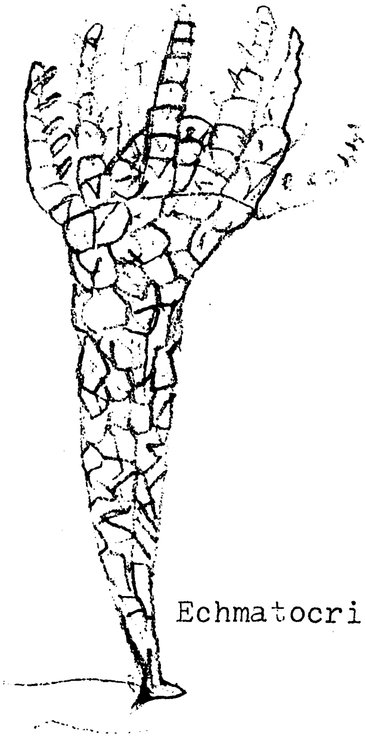


Fig. 5 Camerata crinoid
Macrocrinus
with and without
arms

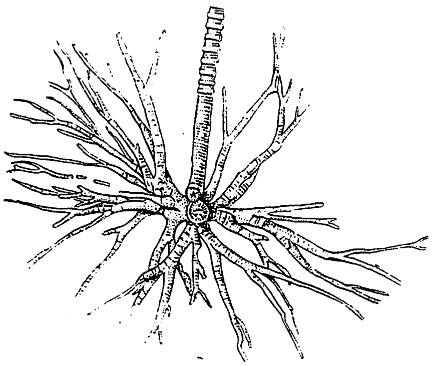
PLATE 4

Subclass Echmatocrinea
Echmatocrinus brachiatus is known from only 5 specimen. The oldest of crinoids it is from the Burgess Shale of Western Canada, middle cambrian. The artist has taken liberties in the reconstruction of this drawing

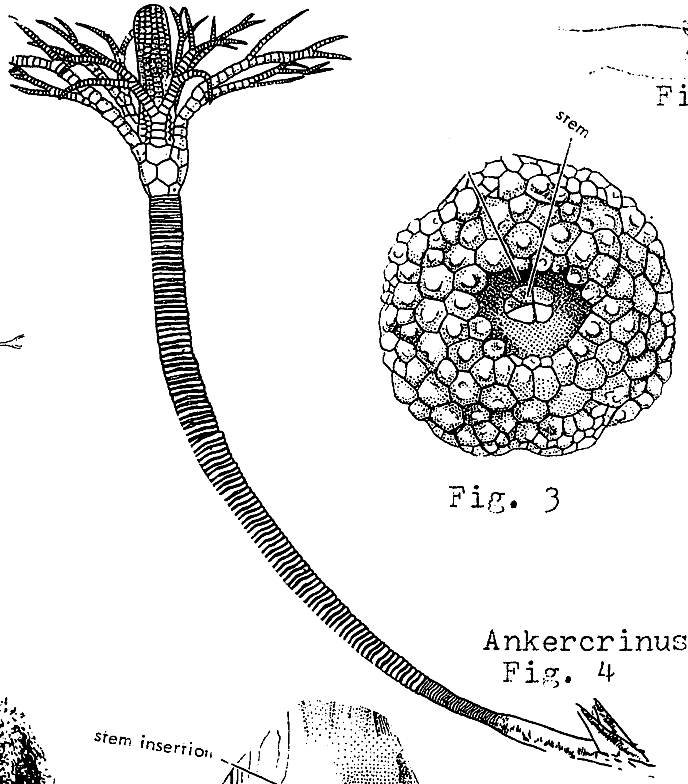


Echmatocrinus

Fig. 1



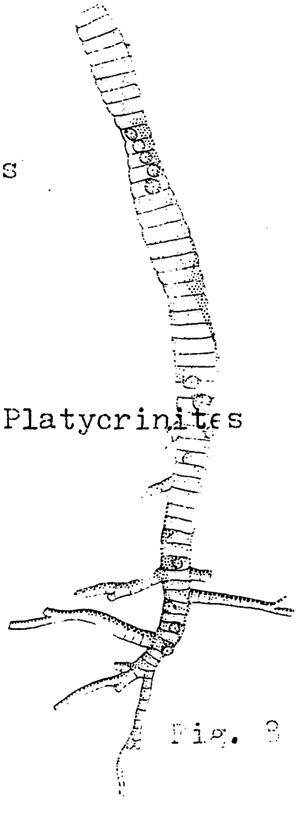
ucalyptocrinites Fig. 2



Ankercrinus
Fig. 4

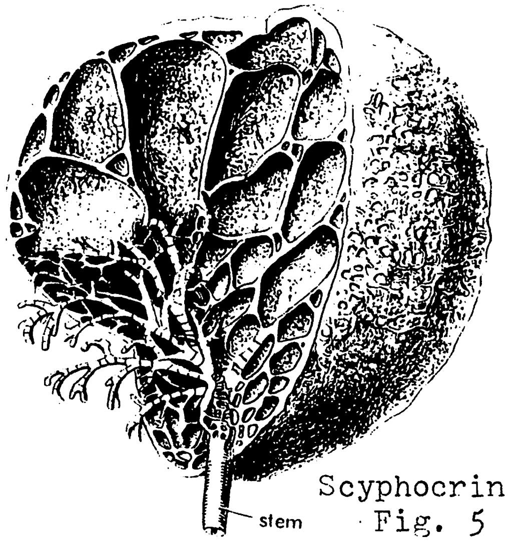
Lichenocrinus

Fig. 3



Platycrinites

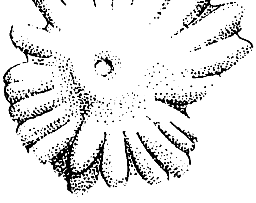
Fig. 8



Scyphocrinites
Fig. 5

Aspidocrinus

Fig. 6



Aspidocrinus
Fig. 7

Fig. 2-8 Various Holdfast

PLATE 5

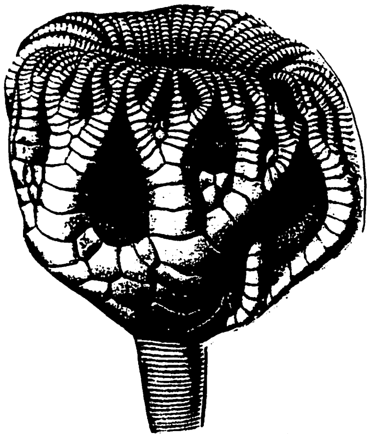


Fig. 1 Taxocrinus

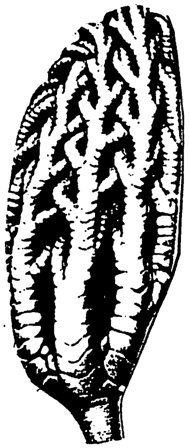


Fig. 2 Onychocrinus

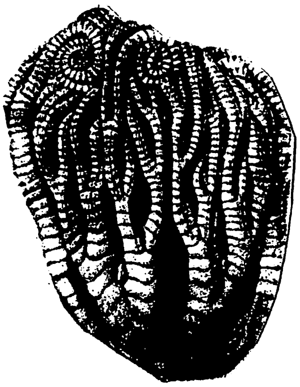


Fig. 3 Taxocrinus

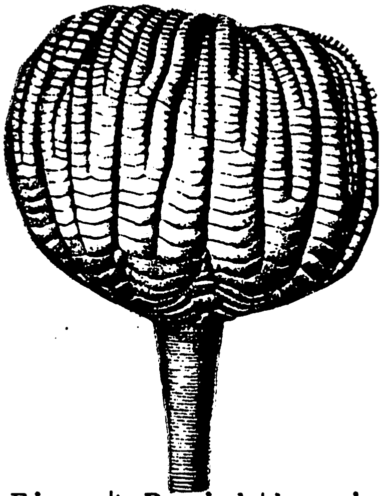


Fig. 4 Parichthycrir

Fig. 1-4 Subclass Flexibilia

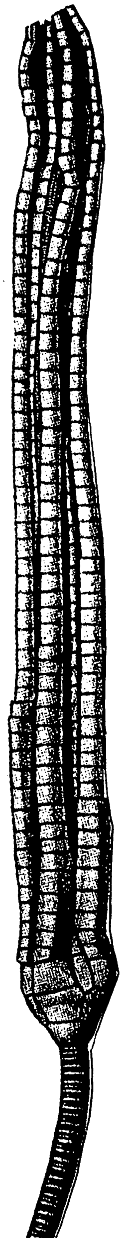


Fig. 5 Synbatocrinus


Fig. 6 Catillocrinus


Fig. 7 Catillocrinus


Fig. 8 Ascetocrinus

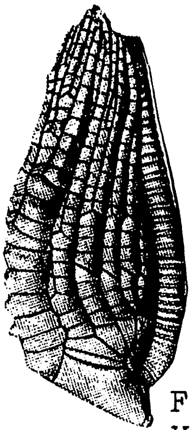


Fig. 9 Halysiocrinus

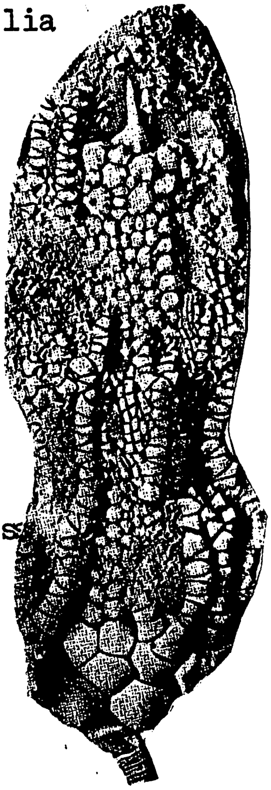


Fig. 10 Pelecocrinus

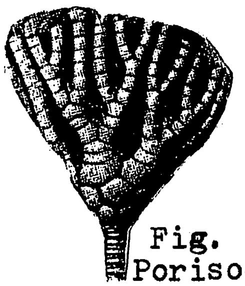


Fig. 11 Porisocrinus


Fig. 12 Gissocrinus

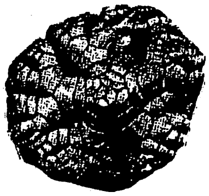



Fig. 13 Coeliocrinus

Fig. 5-13 Subclass Inadunata

PLATE 6

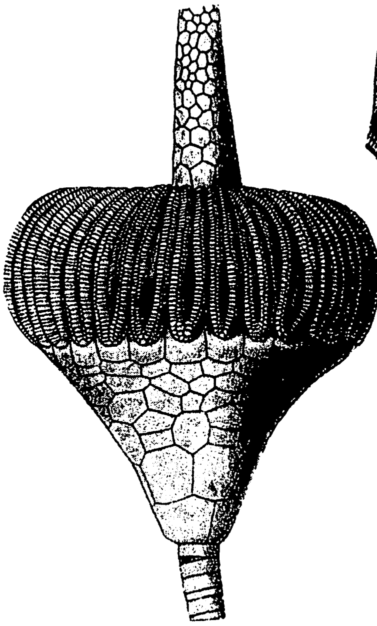


Fig. 1
Eutrochocrinus

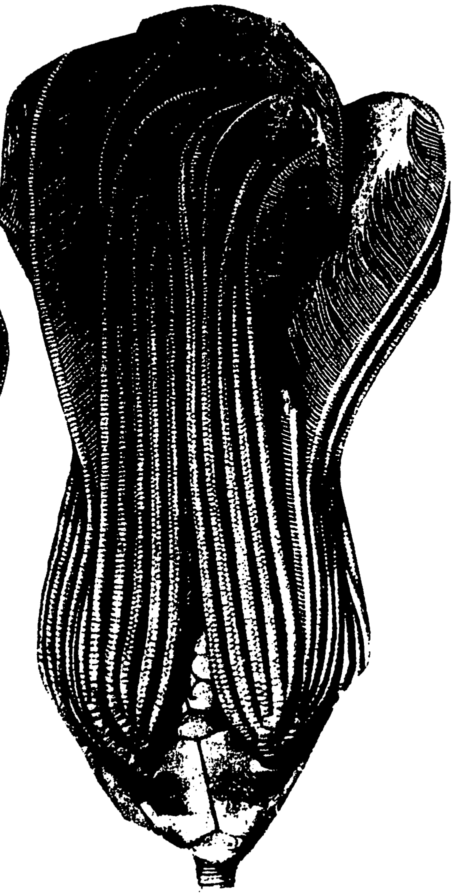


Fig. 2
Paradichocrinus

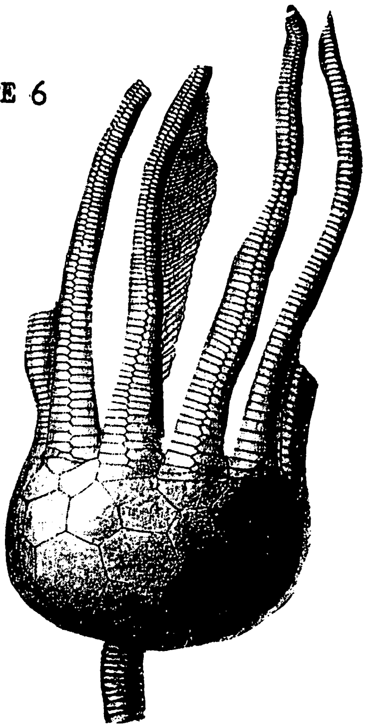


Fig. 3
Lyriocrinus

Fig. 4
Glyptocrinus

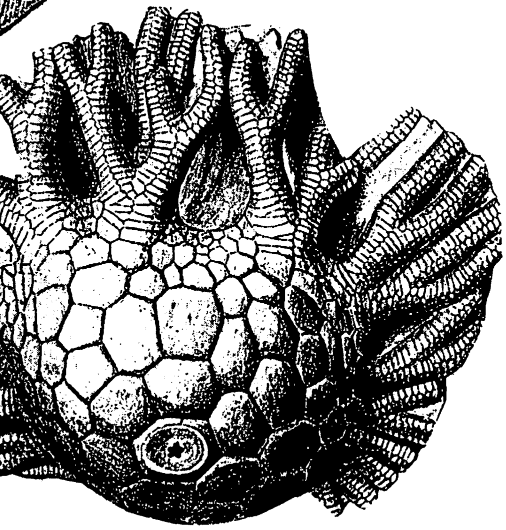


Fig. 5
Megistocrinus

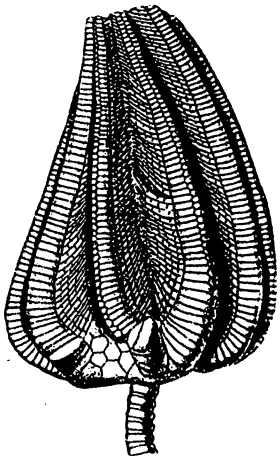


Fig. 7
Agaricocrinus

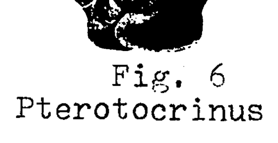


Fig. 6
Pterotocrinus

Fig. 1-6 Subclass Camerata

A MISSISSIPPIAN CRINOID ASSEMBLAGE FROM THE LODGEPOLE FORMATION OF SOUTHEASTERN IDAHO

FOREST J. GAHN
1201 Virginia
Burlington, IA. 52601

INTRODUCTION

Few people are aware of the outstanding crinoid faunas of western North America. Nevertheless, Mississippian crinoids are as equally prolific and diverse in the west as they are in the classical midcontinental localities. Webster (1987) described eight crinoid-bearing formations from Western Canada and the United States. One of the more famous of these is the Lodgepole Formation.

Recently, over fifty partial to complete crinoids have been collected from the Snake River Range of Idaho. The collection was made from a single locality in the Kinderhookian (Lower Mississppian) Lodgepole Limestone. The crinoids represent twelve genera and fourteen species that belong to the families *Rhodocrinitidae, Batocrinidae, Coelocrinidae, Dichocrinidae, Platycrinitidae, Cyathocrinitidae, Scytalocrinidae, Blothrocrinidae, Graphiocrinidae,* and *Staphylocrinidae.*

Since most of the species are very similar to those described by Laudon and Severson (1953), precise morphologic descriptions will not be presented in this paper. However, the significance of the Lodgepole fauna will be discussed in conjunction with current studies that are being made in surrounding crinoid-bearing formations and their midwestern counterparts. Furthermore, modern theories and classificational problems concerning Mississippian crinoids will be addressed.

STRATIGRAPHY AND LOCATION

The Lodgepole Formation was named for the limestone exposed along Lodgepole Canyon in the Little Rocky Mountains of Montana (Staatz and Albee, 1966). It consists of hundreds of feet of blue-gray to dark gray limestone and dolostone that were deposited in western Montana, west-central Wyoming, and southeastern Idaho. The majority of the unit is fine-grained and thin-bedded with intermittent coarse-grained beds consisting of disarticulated fossil fragments. Directly above many of the coarse-grained beds is a thin layer of silty limestone in which articulated crinoids

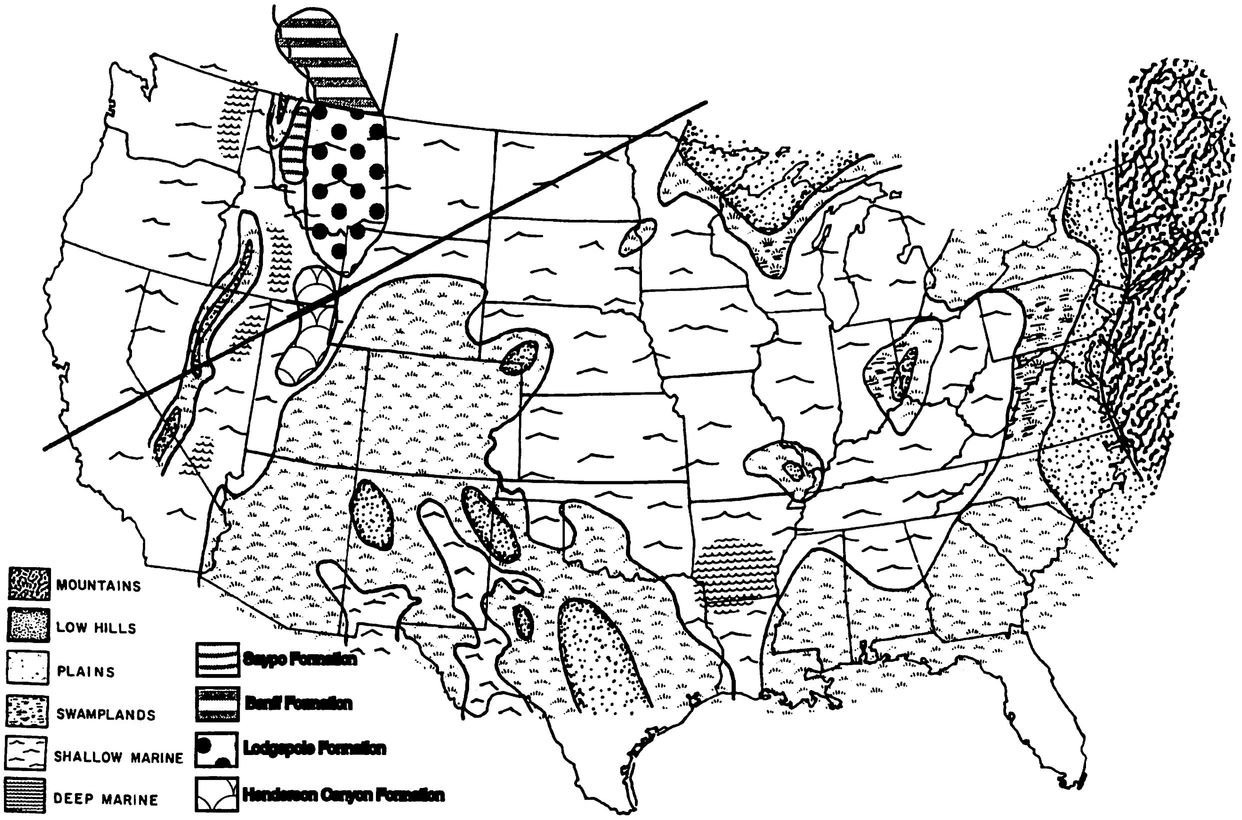


Figure 1- Kinderhookian paleogeography of the United States including the location of the Banff, Saypo, Lodgepole, and Henderson Canyon Formations. (Modified from Frazier and Schwimmer, 1987 and Webster, 1987). The straight heavy line represents the Mississippian paleoequator.

and other fossils are well preserved.

In the Snake River Range, the Lodgepole Formation rests uncomformably on the Devonian Darby Formation and underlies the younger Mission Canyon Formation. The crinoids presented in this paper were collected from two hundred feet of silty fossiliferous limestone southeast of Stouts Mountain, Bonneville County Idaho, in the NE1/4 sec. 6, T. 2N., R. 43 E.. The beds in the area are highly fractured, strike to the northwest, and dip approximately forty-five degrees to the west.

At least three other crinoid-bearing formations geographically border the Lodgepole (Webster, 1987). They include the Banff Formation of Alberta, Canada, the Saypo Formation of northwestern Montana, and the Henderson Canyon Formation of southeastern Idaho and north-central Utah.. Each consists of encrinital limestones that were deposited during the Kinderhookian and Osagean Series (Figure 1).

ENVIRONMENT OF DEPOSITION AND PALEOECOLOGY

The Lodgepole Formation was deposited when North America lay five to ten degrees north of the equator. The sediment accumulated on a broad carbonate platform on the western border of the Williston Basin (Frazier and Schwimmer, 1987). Fossil evidence suggests that numerous marine organisms flourished in the warm tropical sea. Occasional storms disturbed the area which lowered the effective wave base and disrupted the fragile community. Record of such events are present in the thin coarse-grained units of the Lodgepole Formation. As the tempest passed, silt settled to the bottom of the ocean floor and preserved a variety of extinct lifeforms.

Crinoids, brachipods, bryzoans, gastropods, and coelenterates are the most common fossils found in the silty limestones. Blastoids, echinoids, trilobites, and fish plates occur less frequently. Such diverse and abundant fossil evidence suggests a once viable ecosystem.

Webster (personal communication) stated that the fossil assemblages were preserved in a deep shelf or ramp environment. Below wave base, the marine benthos could rely on gentle ocean currents for efficient respiration. The warm waters also supplied the ocean floor with an adequate supply of nutrients. The crinoids, blastoids, and bryzoans, filtered the currents for planktonic life. Brachiopods, coelenterates, and trilobites scoured ocean sediments. Most of the gastropods lived on the ocean floor. However, they are sometimes found attached to a crinoid calyx, suggesting commensalism.

CRINOIDEA

A well-preserved assemblage of fossil crinoids from any part of the world is noteworthy. The conditions and events required to preserve the delicate pinnules, arms, and cirri of such echinoderms rarely present themselves. Professional and amateur paleontologists alike find themselves fortunate to happen upon an articulated crinoid.

Preservation in the Lodgepole Formation ranges from disarticulated plates to complete crinoids displaying even the most distal portions of the stem and cirri. The crinoids presented in this paper mimic several of the forms described by Laudon (1933), Laudon and Beane (1937), Laudon, Parks, and Spreng (1952), and Laudon and Severson (1953), from the Gilmore City, Hampton, Banff, and Lodgepole Formations, respectively.

At least Five Gilmore City species, six Hampton species, four Banff species, and one species from the Burlington Limestone are present in the Lodgepole Formation (Broadhead and Waters, 1980). Webster (personal communication) has collected four crinoid species from the Henderson Canyon Formation that also occur in the Lodgepole fauna. Furthermore, the author has collected three Lodgepole species from the Wassonville Formation of Iowa.

Such similarities are very useful for tracing the evolutionary origins and trends of the Crinoidea. The stratigraphic distribution and migrational patterns of individual species can also be established by relative dating of associated formations. Much work is needed to correlate the distinct lithologies and faunal assemblages in order to better understand the Mississippian System.

The crinoids collected from the Snake River Range consist of eight camerates and six inadunates. Classification is based on the descriptions made by Laudon (1953). Nevertheless, the author is aware of problems and inconsistencies that exist within Laudon's (1933,1937,1952, and 1953) publications concerning specific genera and species. Note that a few of the crinoids presented below may be classified differently in more recent and future studies.

Family RHODOCRINITIDAE (Roemer, 1855)
Figure 2.1-2.2

Two species representing the Rhodocrinitidae are included in the collection from the Snake River Range. They include *Rhodocrinities douglassi* (Miller and Gurley, 1897) and *Cribanocrinus watersianus*

(Wachsmuth and Springer, 1890). They occur second only to *Platycrinities bozemanensis* in abundance. *R. douglassi* also occurs in the Hampton and Gilmore City Formations. *C. watersianus* has also been collected from the Hampton, Gilmore City, and Wassonville Formations.

Both *Rhodocrinities* and *Cribanocrinus* are diplobathrid or dicyclic camerate crinoids. Their infrabasals are typically hidden within the basal concavity of a high globe-shaped calyx. One of the most distinct differences between the two genera is displayed in the ornamentation of the plates. *Rhodocrinities* has very ornate, stellate plates while those of *Cribanocrinus* are smooth.

Laudon and Severson (1953) listed some distinct evolutionary trends within the Rhodocrinitidae. They stated that the single most important character in determining evolutionary stages within the group is the nature of the tegmen. From the most primitive to the most advanced forms there was a reduction of plates that eliminated interradial depressions and produced an overall flattening of the adoral skeleton.

The nature of the arms is also very important to note. From immature to mature, and primitive to advanced forms, the arms range from being uniserial to cuneiform to biserial. Furthermore, a second bifurbication of the arms appeared high on the crown in earlier forms and gradually shifted toward the tegmen producing eight arms in each ray.

Webster (personal communication), noting the extreme similarities between *Rhodocrinities*. and *Cribanocrinus* suggested that the two forms may actually be sexual dimorphs. The equal abundance of both forms and their common occurrence together may support that theory. Another strength lies in the fact that sexual dimorphism has been observed in modern articulate crinoids.

Family BATOCRINIDAE (Wachsmuth and Springer, 1881)
Figure 2.3

Batocrinus gallatinensis (Laudon and Severson, 1953) is the only species representing the Batocrinidae in the collection. Although it occurs only in the Lodgepole Formation, *B. macbridei* (Wachsmuth and Springer, 1890) from the Hampton Formation, is very similar. The only significant difference between the two species is the position and relationship of the interbrachials to the rest of the calyx (Laudon and Severson, 1953).

The interbrachials of *B. gallatinensis* separate some of the rays and are fused by brachial plates in others. This caused the brachials to become partially joined with the tegmen. In *B. macbridei*, all of the interbrachials

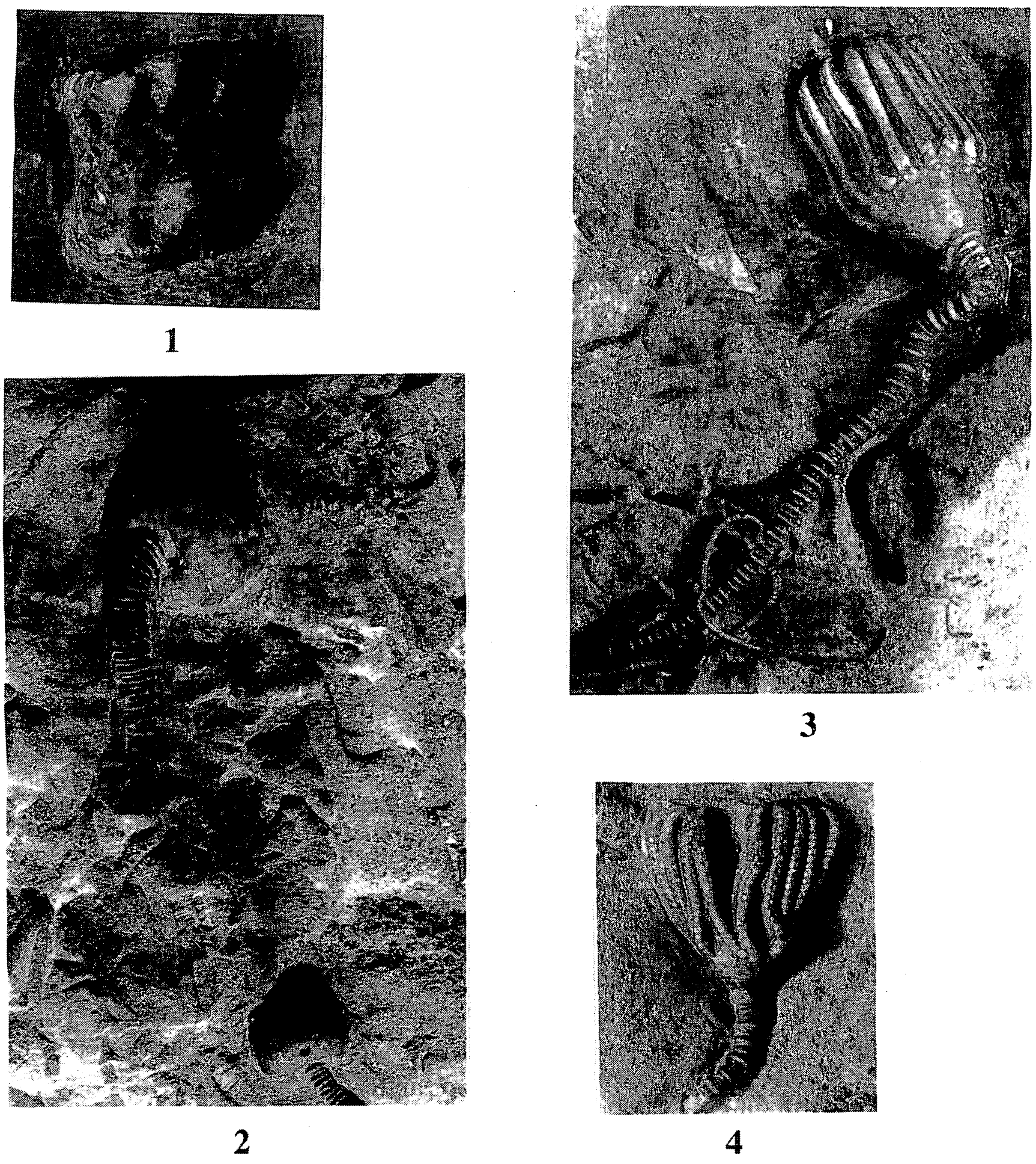


Figure 2 - 1, *Rhodocrinities douglassi* (Miller and Gurley, 1897), anterior view of the caylx, FG41L, x1.5. 2, *Cribanocrinus watersianus* (Wachsmuth and Springer, 1890), lower specimen shows anterior view of the caylx, upper shows posterior view of the aboral cup, FG7L, x3. 3, *Batocrinus gallatinensis* (Laudon and Severson, 1953), posterior view of a complete specimen, note the cirri attatched to the column, FG1L, x1.5 4, *Aorocrinus douglassi* (Laudon and Severson, 1953), C-D ray view of the crown and column, FG37L, x2.

are isolated by brachials, making it a more advanced batocrinid.

The specimen of *B. gallatinensis* from Stouts Mountain is especially remarkable. It appears that it was literally buried *in situ*. The entire stem is visible along with the cirri. The incurving biserial armtips and the rim-forming basal cavity also give this species a very majestic appearance.

Family COELOCRINIDAE (Wachsmuth and Springer, 1897)
Figure 2.4

A single specimen of *Aorocrinus douglassi* (Laudon and Severson, 1953) represents the coelocrinids in the collection. The stellate plates of the dorsal cup and the overall basic shape of this species make it very similar to *A. radiatus* (Wachsmuth and Springer, 1890) from the Hampton Formation.

The only difference between the two forms is in the number of arms. *A. douglassi* has four arms to the ray whereas *A. radiatus* has only two. The greater number of arms in *A. douglassi* represent a more effective feeding filtration fan. Therefore, it may be a more advanced form of the genus.

The Stouts Mountain representative of *A. douglassi* is also significant because of its nature of preservation. It was collected with only the tips of the arms exposed in a soft silty limestone and easily cleaned under the microscope. Perfect detail can be observed in the arms, calyx, and stem.

The stem was undescribed by Laudon and Severson (1953). However, in this specimen it is easy to see that it is very similar to that of *A. radiatus*. It is made up of distinct nodal and internodal columnals that become proportionally smaller as they reach the distal end of the stem. Moreover, a small spine or node is visible on the tegmen above the C ray. It also appears that this species lacks an anal tube.

Family DICHOCRINIDAE (Miller,1889)
Figure 3.1-3.3

Two dichocrinids have been collected from the Lodgepole Formation of southeastern Idaho. They include *Dichocrinus bozemanensis* (Miller and Gurley, 1897) and *Dichocrinus douglassi* (Miller and Gurley, 1897). *D. bozemanensis* represents a more primitive form with small, thin plates and ten delicate arms. *D. douglassi* displays thicker, ornate plates and strongly cuneiform arms which are diagnostic of more advanced forms.

Confusion exists concerning the precise classification of these

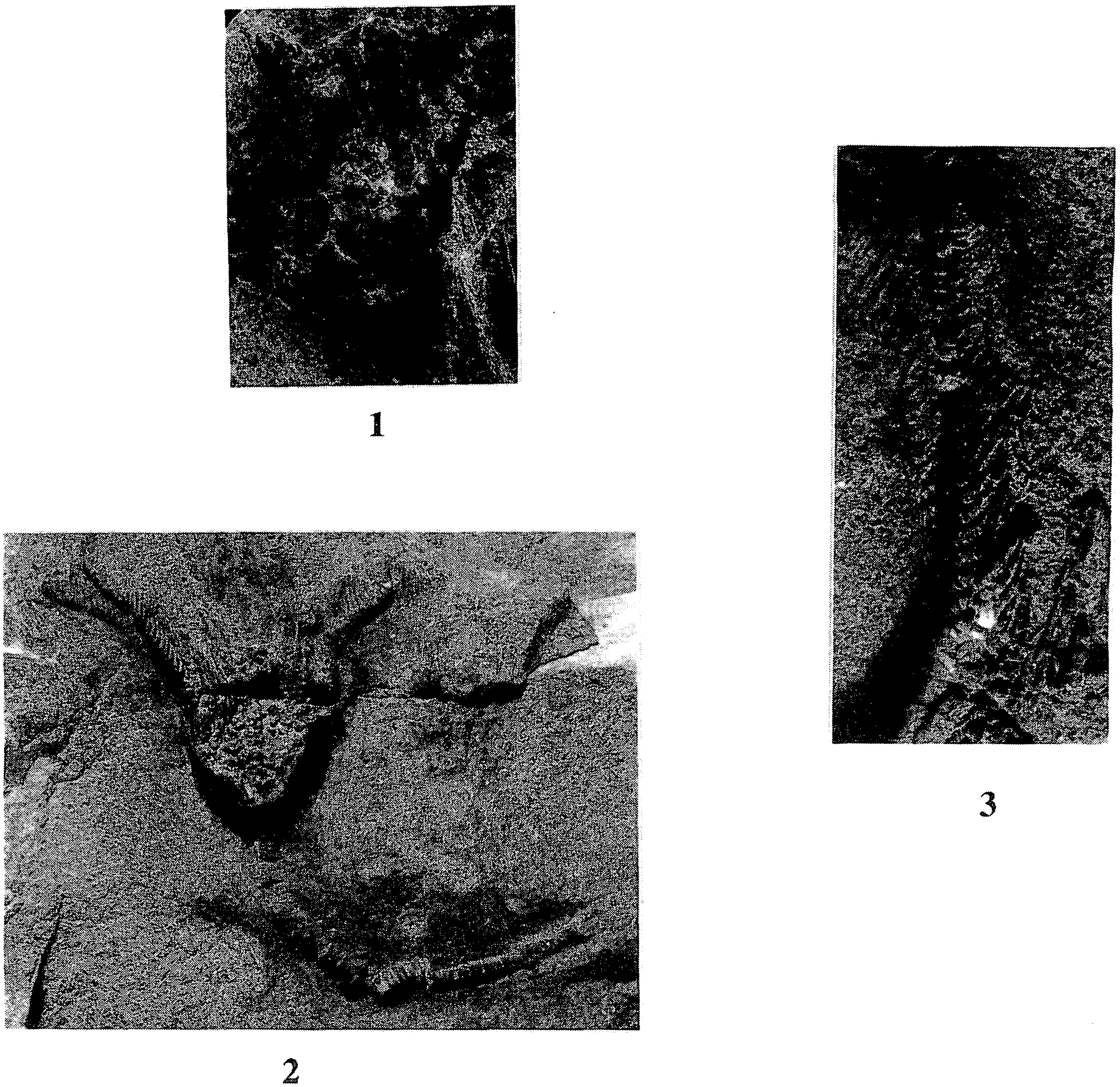


Figure 3 - 1, *Dichocrinus bozemanensis* (Miller and Gurley, 1897), lateral view of the crown, FG38L, x4. 2-3, *Dichocrinus douglassi* (Miller and Gurley, 1897). 2, lateral view of the crown and column, FG39L, x2. 3, view of the regenerated arm, FG39L, x4.25.

crinoids. Although Broadhead has revised the Dichocrinidae, his work was not available for reference. Therefore, correlating these species with those of other formations will not be attempted in this paper.

One crinoid from the collection, described as *D. douglassi* , is worthy of further discussion. The specimen lost its arm tips during life. At the base of the slightly cuneiform arms, the pinnules are long and robust. However, at the distal ends the arm are uniserial and the pinnules are so fine that they are barely visible unless magnified. This abrupt change suggests that the arms have been regenerated.

Laudon and Severson (1953) figured a crinoid of the same species with regenerated arm tips from Montana. This occurrence among crinoids is not uncommon. Meyer (1985), found that 47% of an observed group of recent comatulid crinoids near Lizard Island had at least one missing or regenerated arm.

Predation by fish is the primary cause of damage to crinoid arms. As fish grazed over crinoidal gardens it is very likely that they cropped crinoid arms containing small invertebrate organisms. Other fish, such as the shell-crushing sharks, may have even fed on criniods. For example, the modern shell-crushing triggerfish has been known to harvest crinoids from the Great Barrier Reef (Meyer, 1985). The evolution of thicker plates, long spines, and an increasing number of arms in fossil crinoids may represent an evolutionary means of self-defense.

Family PLATYCRINITIDAE (Austin and Austin, 1842)

Figure 4.1-4.4

Platycrinities bozemanensis (Miller and Gurley, 1897) and *Platycrinities canadensis* (Laudon and Severson, 1953), are the only two species representing the Platycrinitidae in the collection. *P. bozemanensis* is by far the most abundant crinoid. Twenty-seven out of the fifty-six crinoids collected belong to this species. *P. canadensis* is less common, represented by only three specimens.

Paul Jamison (personal communication) has collected several *P. bozemanensis* from the Henderson Canyon Formation of northern Utah. It is rarely found associated with less common fossil invertebrates. Jamison has recovered the species with platycerid gastropods attached to the cup. One of the more exceptional platycrinitids from his collection sits beside a beautifully preserved starfish.

Dominance of *P. bozemanensis* in both the Lodgepole and Henderson Canyon Formations suggests that it was a very resilient species. A

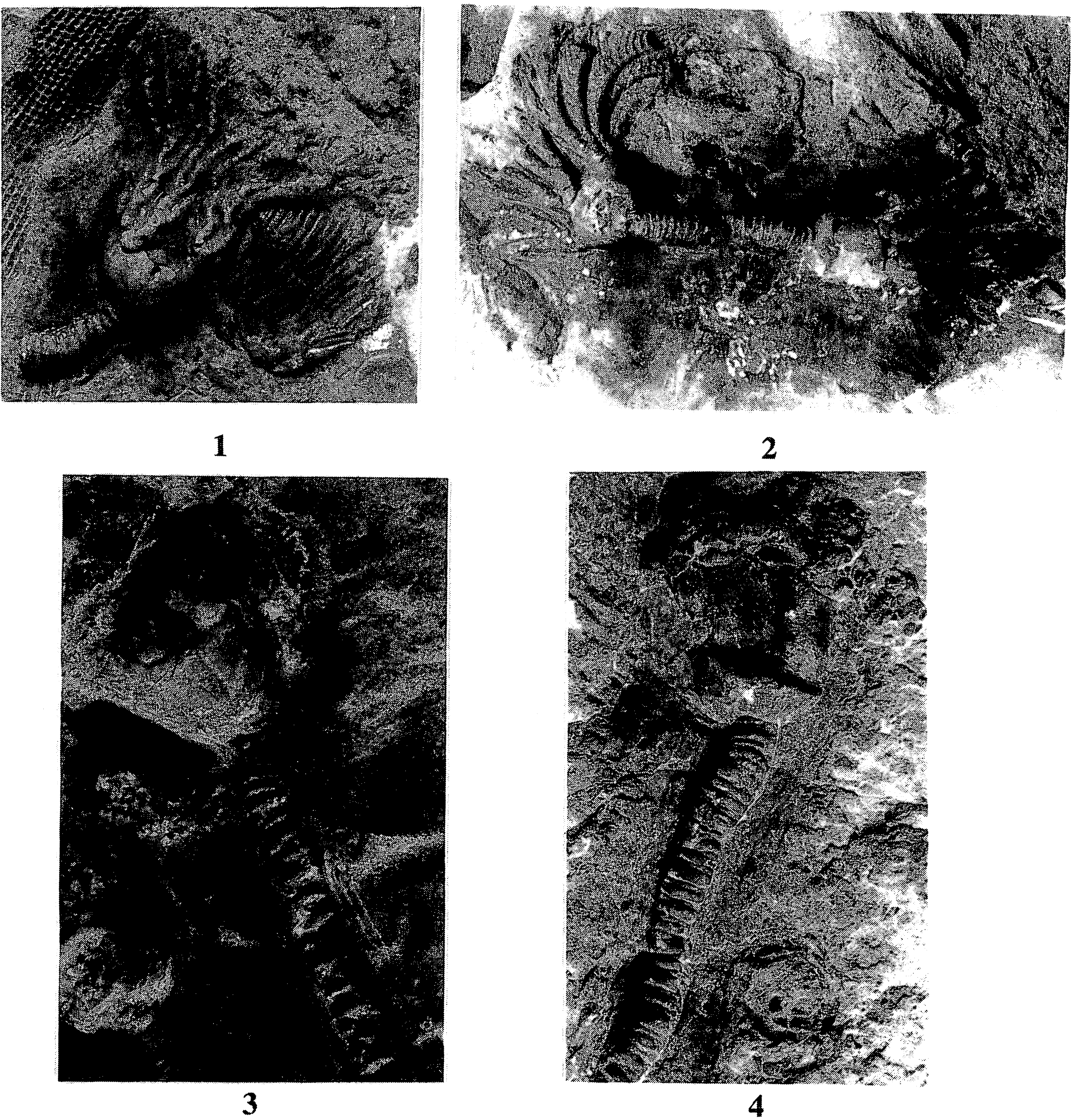


Figure 4 - 1-2, *Platycrinities bozemanensis* (Miller and Gurley, 1897). 1, lateral view of the crown and column, FG3L, x2. 2, lateral view of two crowns and columns, FG22L, x2. 3-4, *Platycrinities canadensis* (Laudon and Severson, 1953). 3, lateral view of the crown and column, juvenile, FG36L, x2. 4, lateral view of the aboral cup and column, FG2L, x2.

complete array of growth stages can be observed within the group. Laudon (1967) studied the development from the most immature forms to adulthood. He found that as the species grew, the arms progressed from an initial uniserial conformation, to cuneiform in adolescents, and fully biserial in the adult form. The brachials seemed to reach a maximum height early on and simply became increasingly robust as *P. bozemanensis* matured.

Laudon and Severson (1953) suggested that the tegmen is the most important character in determining evolutionary stages within the platycrinitids. As the group advanced, the number of plates gradually decreased as their size increased. Considering that fact, *P. bozemanensis* is most closely related to the smooth-plated *P. burlingtonensis* (Hall, 1897), *P. aequalis* (Hall, 1861), and *P. symmetricus* (Wachsmuth and Springer, 1890) from the Burlington and Hampton Formations, respectively.

Two distinct morphologic features distinguish *P. canadensis* from *P. bozemanensis*. First, *P. bozemanensis* has six arms to the ray whereas *P. canadensis* has only four. Secondly, they differ in plate ornamentation. *P. bozemanensis* is a smooth-plated platycrinitid. On the other hand, *P. canadensis* displays very subtle ornamentation.

The plate ornamentation of *P. canadensis* is characterized by slightly excavated grooves that give the calyx a stippled appearance. Laudon and Severson (1953) considered the species to be the most primitive of all the platycrinids with ornate plates. *P. scobina* (Meek and Worthen, 1861) from the Dolbee Creek Member of the Burlington Limestone also has delicately ornate plates. Moreover, the species has only four arms to the ray suggesting that it may be a close relative of *P. canadensis.*

Family CYATHOCRINITIDAE (Bassler, 1938)
Figure 5.1

Three crinoids belonging to the genus *Cyathocrinities* (Miller, 1821) have been collected from the Snake River Range. Although, their state of preservation is poor, they all pertain to the same species. This crinoid will be referred to only by its generic name since a specific one has not been assigned to the cyathocrinitids of the Lodgepole Formation (Laudon and Severson, 1953).

Cyathocrinities sp. from Idaho has a low globe-shaped calyx with a depressed base composed of five pentagonal infrabasals, basals, and radials. The infrabasals are not visible on the calyx wall, but the basals and radials are large, making up nearly the entire aboral cup.

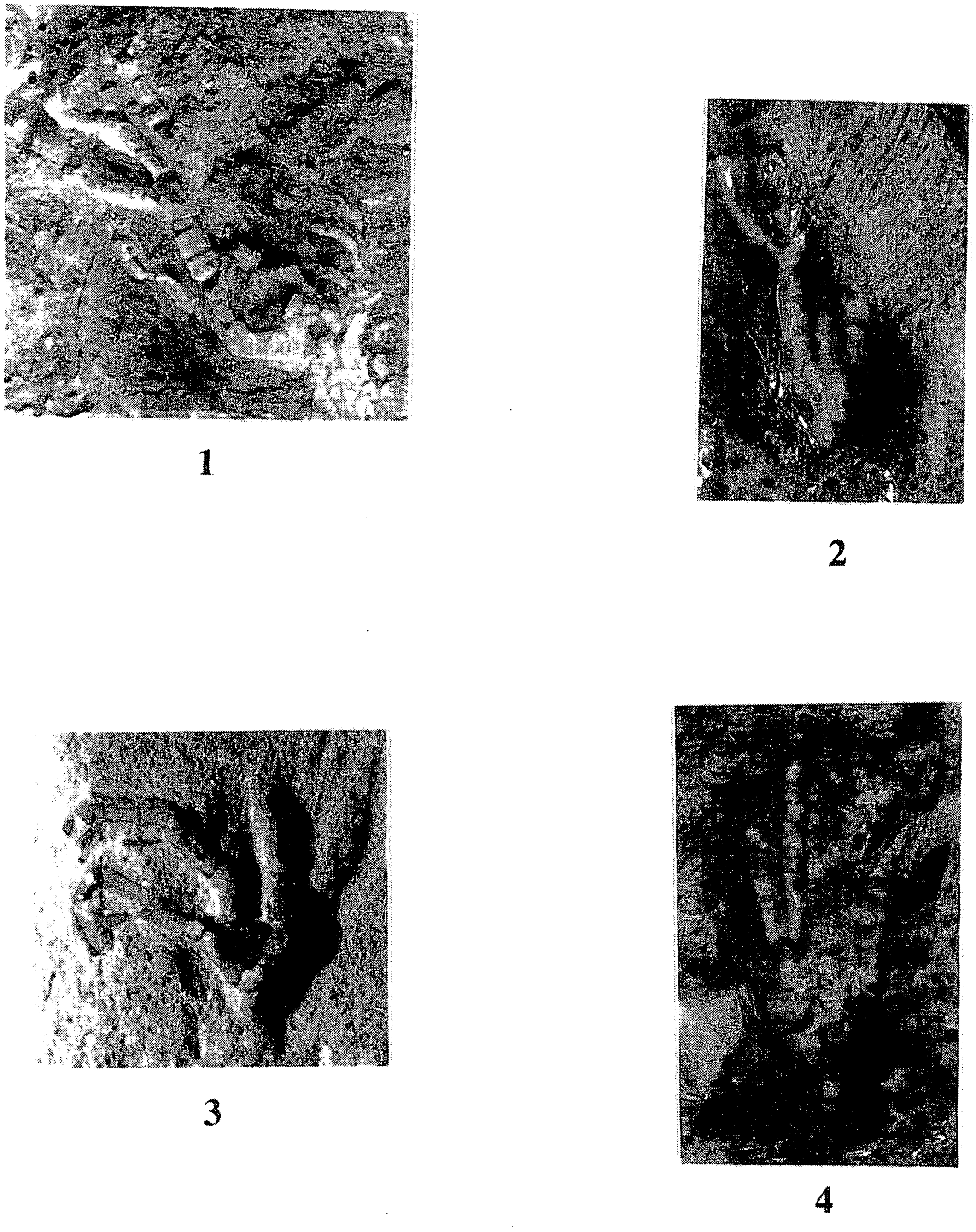


Figure 5 - 1, *Cyathocrinities sp.*, lateral view of the crown, FG40L, x2.5. 2, *Bridgerocrinus fairyensis* (Laudon and Severson, 1953), C-D ray view of the crown, FG5La, x3. 3-4, *Hypselocrinus maccabei* (Miller and Gurley, 1894). 3, Lateral view of the crown and column, FG16L, x4. 4, C-D ray view of the crown, FG5Lb, x4.

Only one of the specimens displays the arm structure. They are uniserial and non-pinnulate. Branching is isotomous, once on the third primibrach and again on the third segundibrach.

Family SCYTALOCRINIDAE (Moore and Laudon, 1943)
Figure 5.2-5.3

Bridgerocrinus fairyensis (Laudon and Severson, 1953) and *Hypselocrinus maccabei* (Miller and Gurley, 1894) are the most common scytalocrinids in the Lodgepole Formation. Webster (personal communication) has also collected *B. fairyensis* from the Henderson Canyon Formation. *H. maccabei* has also been recovered from the Hampton Formation. *H. douglassi* (Miller & Gurley, 1896) from the Gilmore City Formation may be synonymous or at least very closely related to *H. maccabei.*

According to Kammer and Ausich (1992), *B. fairyensis* and *H. maccabei* have primitive-grade calyces or those in which the infrabasals, basals, and radials are visible in the aboral cup. *B. fairyensis* has a high cone-shaped calyx with a convex base. The arms are very long, slender, and pinnulate, branching isotomously only once. The best specimen in the collection displays a slender anal sac consisting of small hexagonal plates.

Laudon and Severson (1953) proposed that *B. fairyensis* is the most primitive form representing the Scytalocrinids. Therefore, *H. maccabei* evolved from the more slender *B. fairyensis. H. maccabei* has a low bowl-shaped calyx with a convex base. The arms are long and pinnulate, branching only once on the first primibrach. The anal sac could not be observed in any of the specimens collected.

Family BLOTHROCRINIDAE (MOORE AND LAUDON, 1943)
Figure 6.1

A solitary blothrocrinid has been recovered from Stouts Mountain. However, the assignation of this specimen to the Blothrocrinidae is somewhat questionable. As of yet, *Blothrocrinus* (Kirk, 1940) has not been described from the Lodgepole Formation.

Laudon, Parks, and, Spreng (1952) figured three new species from the Banff Formation that they placed in the Blothrocrinidae. They were doubtful of the classification of these crinoids, suggesting that they could represent individuals from new genera or immature specimens from one previously described.

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Figure 6 - 1, *Blothrocrinus sp.*, anterior view of the crown and column, FG9L, x4. 2, *Holcocrinus longcirrifer* (Wachsmuth and Springer, 1890), anterior view of the crown, FG42L, x3. *Dinotocrinus logani* (Laudon and Severson, 1953), C ray view (top) of the crown and column, note the prominent infrabasals and the cirri attatched to the column, FG10L, x7.

The specimen that is being referred to as *Blothrocrinus sp.* most closely resembles the last two blothrocrinids described by Laudon, Parks and, Spreng (1952, p. 553). The partially crushed calyx has a high cone-shape and a convex base. The infrabasals are pentagonal, accounting for about one-third the height of the aboral cup. The basals are hexagonal and higher than wide. The radials are pentagonal and slightly wider than high. The radial facets are straight and plenary.

The arms of *Blothrocrinus sp.* are only partially preserved. However, it is obvious that they branch isotomously on the second primibrach. The brachials are rectangular, stout, and very robust. From this specimen it is not determinable whether or not the arms are pinnulate. The column is round and heteromorphic or composed of alternating nodal and internodal columnals.

Family GRAPHIOCRINIDAE (Wachsmuth and Springer, 1886)
Figure 6.2

Holcocrinus longcirrifer (Wachsmuth and Springer, 1890) is the only graphiocrinid that has been collected from Stouts Mountain. As of yet, only one example of this crinoid exists in the collection. *H. longicirrifer* has also been collected from the Hampton and Lodgepole Formations.

Only the basals and radials are distinctly visible in the aboral cup. The infrabasals are at least partially hidden by the columnal attachment area. The calyx has a low cone-shape and a subhorizontal base. Such characteristics are representative of intermediate-grade caylces (Kammer and Ausich, 1993).

The arms of this specimen are only partially preserved. It is obvious that *H. longcirrifer* had ten pinnulate arms, two branching from the first primibrach of each ray. Laudon (1933) described a very long anal sac and a columnal blanketed with cirri, as being diagnostic features of this species.

Family STAPHYLOCRINIDAE (Moore and Strimple, 1973)
Figure 6.3

Dinotocrinus logani was originally described by Laudon and Severson (1953) from the Lodgpole Formation of Montana. One well preserved example of this species has been collected in the Snake River Range of Idaho. Most recently, the author collected *D. logani* from the Wassonville Formation of Iowa. This is the first reported occurrence of the species from the Kinderhookian strata of either state.

The Idaho form of the species differs slightly from the one described by the original authors. The calyx is low cone-shaped with a subhorizontal base consisting of five small pentagonal infrabasals. The infrabasals are completely visible on the aboral cup wall.

Laudon and Severson (1953) described the species with only the very distal tips of the infrabasals protruding from a convex base. As a matter of fact, the most recent description of the genus states that the infrabasals are not visible at all, but instead are hidden by the columnal attachment area (Ausich and Kammer, 1993). This morphologic separation from the generic description may be considered significant enough to place the species within a more primitive staphylocrinid genera.

An evolutionary trend within the inadunates is a decrease in the number of plates constituting the aboral cup and a visible migration of the basals and infrabasals toward the columnal attatchment area. Therefore, the conspicuous infrabasals in the Idaho representative of *D. Logani* suggest that it is more primitive than the Montana form. If the species does indeed represent *D. logani*, then it is the most primitive dinotocrinid described. If it does not, then it is very closely related to the species, possibly representing an evolutionary ancestor of the Dinotocrinidae.

CONCLUSION

Although little is known about the crinoids of the western United States, they are not uncommon. Most Mississippian strata contain an abundance of crinoidal limestones and dolostones, some units yielding hundreds of perfectly preserved specimens. Further stratigraphic and paleontologic data must be acquired for greater understanding of these echinoderms. Knowledge of familiar origins within the class, evolutionary trends, and correlation with other horizons in the Mississippian System would be enhanced by a more thorough regional study.

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