EVOLUTION OF THE LATE PENNSYLVANIAN CRINOID APOGRAPHIOCRINUS MOORE AND PLUMMER FROM THE NORTH AMERICAN MID-CONTINENT

by

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Apographiocrinus is a common fossil crinoid of the late Middle and Upper Pennsylvanian cyclic deposits of North America's mid-continent region. Samples from sixteen localities in Nebraska, Kansas, Oklahoma and Texas have been examined using both quantitative and qualitative means to decribe the evolutionary changes within the genus during the Late Pennsylvanian. The samples range in age from Late Desmoinesian through Middle Virgilian time.

Apographiocrinus samples of Desmoinesian age are associated with regressive, relatively higher energy and more restricted depositional environments. The genus contains a high degree of morphological variability and is characterized by cups which are larger, more bulbous and more ornate than later Pennsylvanian forms. Missourian and Virgilian samples are associated with transgressive or deeper water regressive deposits of a more open marine environment. There is low intrageneric morphologic variability and these forms are smaller and less ornate than the earlier forms.

Statistical analyses show little in the nature of trends. The decrease in size through time is for the most part not statistically significant, the ratio of cup height to width remaining relatively constant. During Missourian time there is a definite trend for the anal X plate to be expelled from the cup.

Qualitatively, the most obvious morphologic change through the genus history is the decrease in both size and variability of the radial

forefacetal area common to older Apographiocrinus forms. Cup plates tend to become thinner and less ornate. There is no evident change in arm morphology with time.

Speciation events are documented for Apographiocrinus typicalis and A. virgilicus. These events appear to occur among relatively small, geographically isolated populations. Speciation may take place by punctuated equilibrium rather than phyletic gradualism.

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INTRODUCTION

Apographiocrinus is a common cladid inadunate crinoid in the Late Desmoinesian, the Missourian and Early Virgilian strata of the North American mid-continent. The samples of Apographiocrinus used in this study are from sixteen localities in Texas, Oklahoma, Kansas and Nebraska (Fig. 1). All collecting horizons are from Middle Pennsylvanian (Desmoinesian) and Upper Pennsylvanian (Missourian and Virgilian) cyclic deposits of the mid-continent (Fig. 2).

Diagnosis. Apographiocrinus was described by Moore and Plummer (1940) and is characterized by a crown which is relatively tall, slender and sub-cylindrical. The dorsal cup (Plate 1, figs. 1-4, 11) is small compared to other crinoids and relatively low and bowl shaped with, in almost all cases, a well-defined basal concavity. The cup plates are slighty bulbous and are arranged in three circlets of five plates each (Fig. 3). The radials are pentagonal, length about two-thirds of the width. Radial facets are less than the greatest width of the radials with extened 'prongs' along the interradial sutures (see Fig. 4) which is the most diagnostic feature of the genus. The basals are about equal in size save the posterior basal which is obviously larger and truncated distally for contact with a single anal plate. The infrabasals are small, pentagonal and concave to sub-horizontal. The stem impression is round and nearly covers the infrabasals.

The single anal plate (anal X) is located between the posterior radials, resting on the posterior basal (in almost all cases) and generally rises one-half its height above the summit of the dorsal cup.

The arms branch once off each of the first primibrachs (Plate 3, figs. 7, 8) and are ten in number. The B and E primibrachs are slightly shorter than

Fig. 1. Index map showing localities from which samples of Apographiocrinus were taken. Localities numbered in sequence from oldest to youngest. Closed squares indicate sites where measured samples approach a normal distribution. Open squares indicate sites where samples were too small for the use of population statistics. Double dashes indicate localities from which a single individual was taken solely for inclusion in the photographic plates. See Appendix A for register of localities.

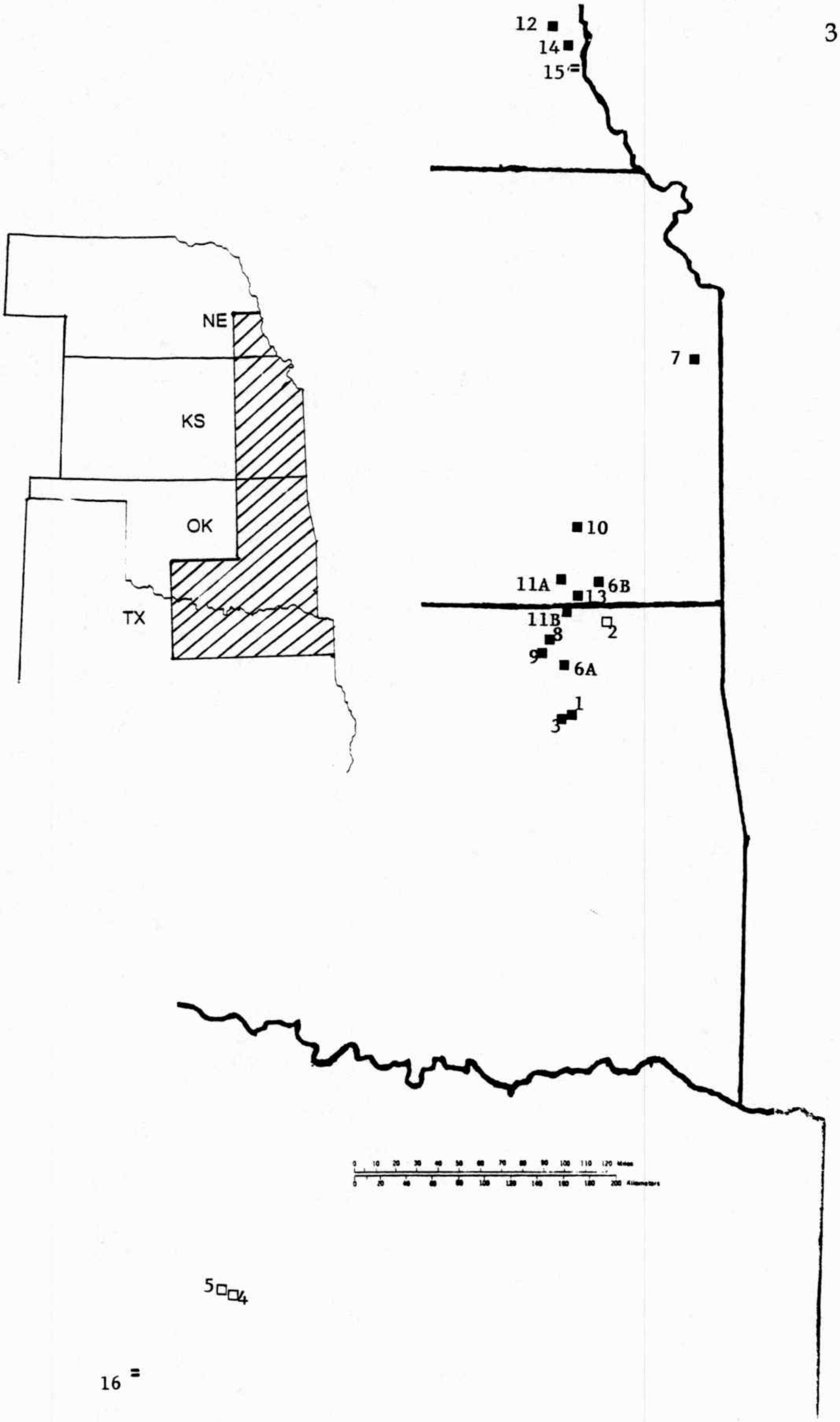

12
14
15
7
NE
KS
OK
TX
10
11A
6B
13
11B
2
8
9
6A
1
3
0 10 20 30 40 50 60 70 80 90 100 110 120 Miles
0 20 40 60 80 100 120 140 160 180 200 Kilometers
5
4
16

Fig. 2. Stratigraphic distribution of localities used in this study. Locality numbers same as in Fig. 1 and Appendix A. Thicknesses not to scale. Upper crinoid horizon of Wann Formation (#9) approximately equivilent to that of Hickory Creek Shale (Plattsburg Formation, #10) (Pabian and Strimple, 1979).

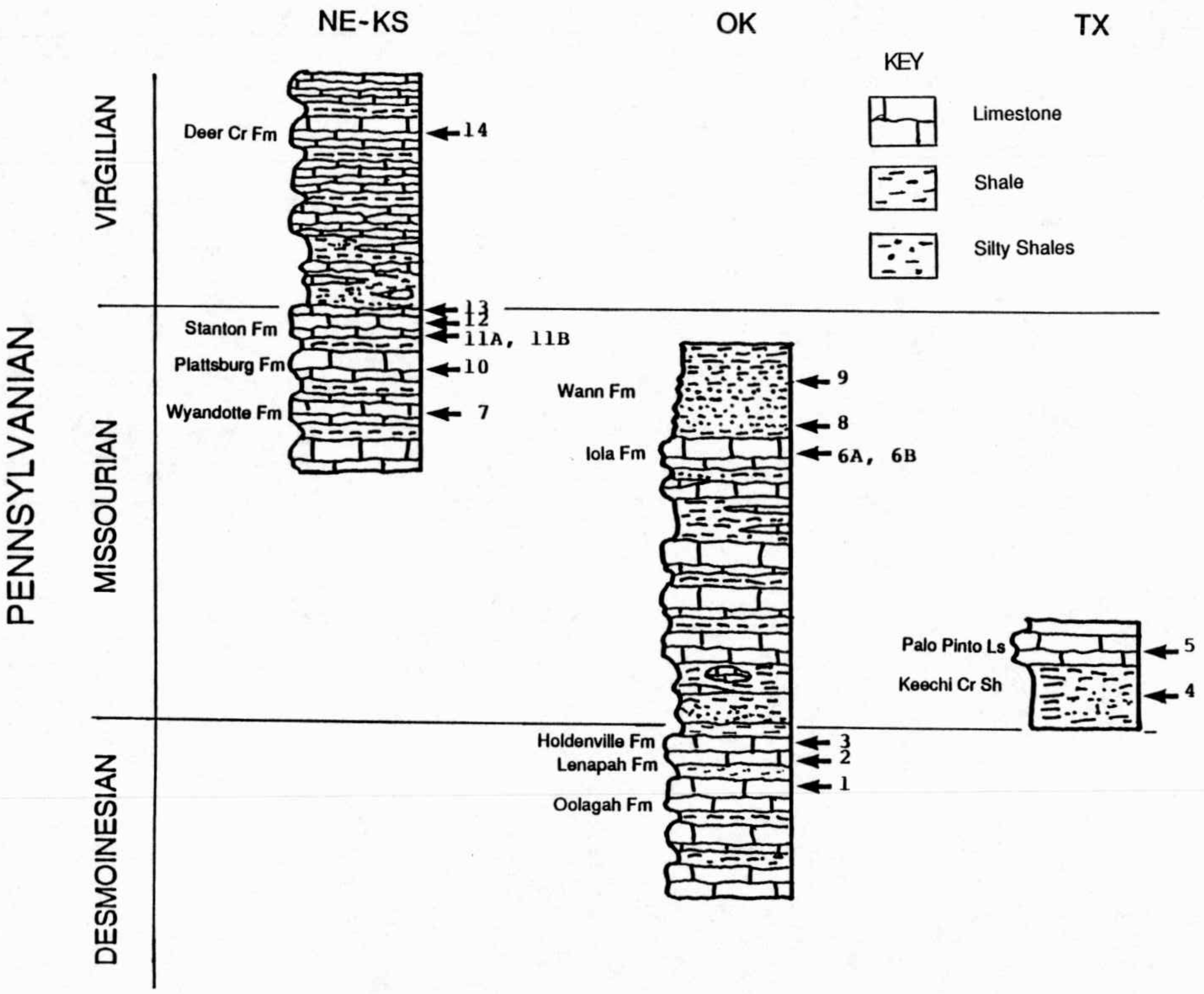

NE-KS
OK
TX
KEY
Limestone
Shale
Silty Shales
PENNSYLVANIAN
VIRGILIAN
MISSOURIAN
DESMOINESIAN
Deer Cr Fm
Stanton Fm
Plattsburg Fm
Wyandotte Fm
14
13
12
11A, 11B
10
7
Wann Fm
Iola Fm
Holdenville Fm
Lenapah Fm
Oolagah Fm
9
8
6A, 6B
3
2
1
Palo Pinto Ls
Keechi Cr Sh
5
4

Fig. 3. Plate diagram of Apographiocrinus. Black plates are radials and the stippled plate marked 'X' is the anal X. Letters represent the appropriate ray. Note how the arms branch once off the first primibrachs (dashed plates). Taken from the Treatise on Invertebrate Paleontology (Moore et al., 1978).

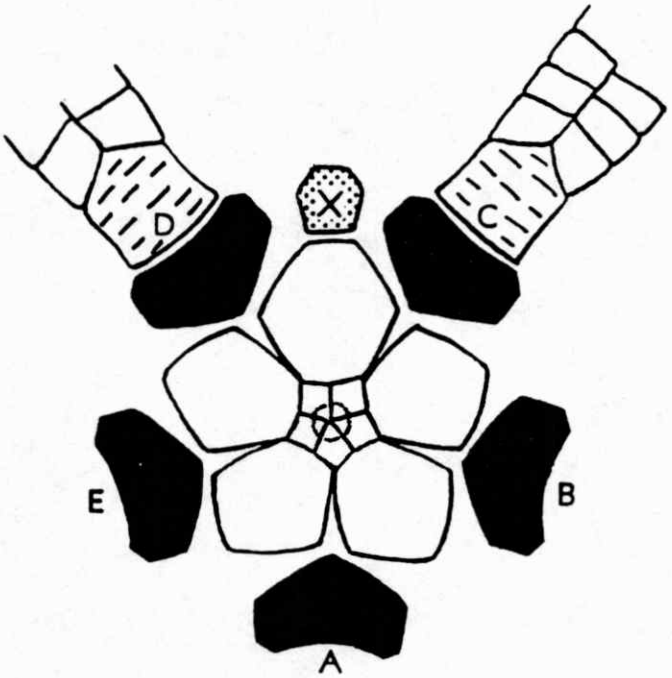
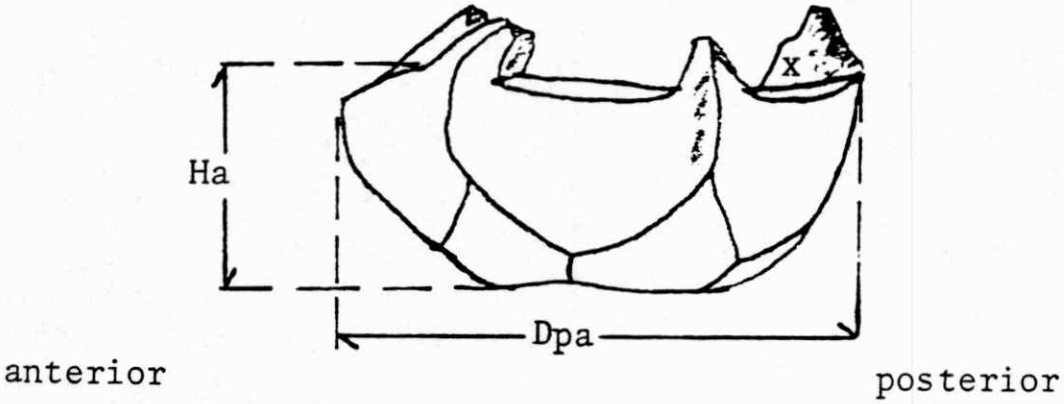
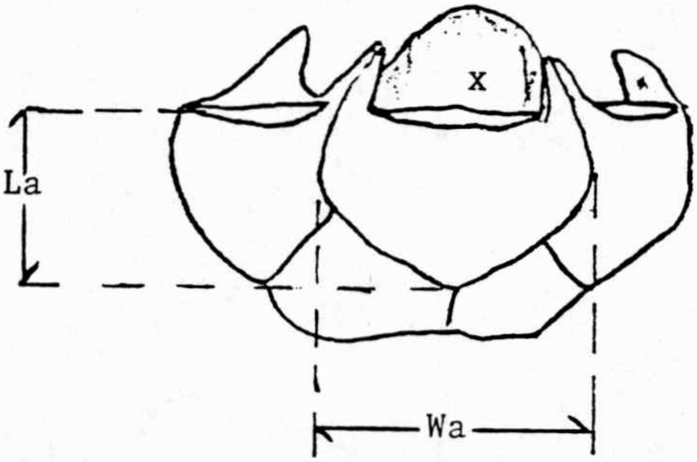

X
D
C
E
B
A

Fig. 4. Outline drawings showing dimensions mearsured on dorsal cups of <u>Apographiocrinus</u>. Dpa, antero-posterior width of cup; Ha, anterior height of cup; La, length of 'A' radial; Wa, width of 'A' radial; 'X' indicates anal X plate. Adapted from Pabian and Strimple (1985).





anterior view

the rest. The arms are uniserial but not strongly pinulate. The anal sac, though not commonly present, is small.

The type species for the genus is Apographiocrinus typicalis Moore and Plummer. Several other species have been described in the genus. The important features used to separate these species are given below in Table 1.

Range. Early Pennsylvanian (Morrowan)?; Middle Pennsylvanian (Desmoinesian); Early Permian (Wolfcampian). USA, Texas, Oklahoma, Kansas, Missouri, Nebraska, Iowa, Illinois, Michigan. Island of Timor. The known time ranges for species of Apographiocrinus from the Middle and Late Pennsylvanian rocks in the mid-continent are shown Fig. 5. These include both recorded occurrences in the literature and examined samples.

Origin. The timing of origination for the genus Apographiocrinus is uncertain. The oldest described apographiocrinid is A. raderi Strimple from the Morrowan of Texas (Strimple, 1975). With the exception of having a single, large anal X plate, however, this species could be aligned with the genus Phanocrinus. If such is the case, it is believed that Apographiocrinus originated at some time in the Lower Desmoinesian.

From what crinoid stock the genus originated is also difficult to determine. At the family level, there seem to be two reasonable possibilities. The fact that the Morrowan apographiocrinid is of uncertain affinity between Apographiocrinus and Phanocrinus may indicate the Phanocrinidae as a possible ancestral line. With the exception of multiple anal plates and radial articular facets as wide as the radials (plenary), this group shares most of the characteristics of Apographiocrinus.

Another possible origin lies with a splitting from the Decadocrinidae. This family possesses the same arm arrangement as that of Apographiocrinus, contains some forms with only one anal and produces later forms

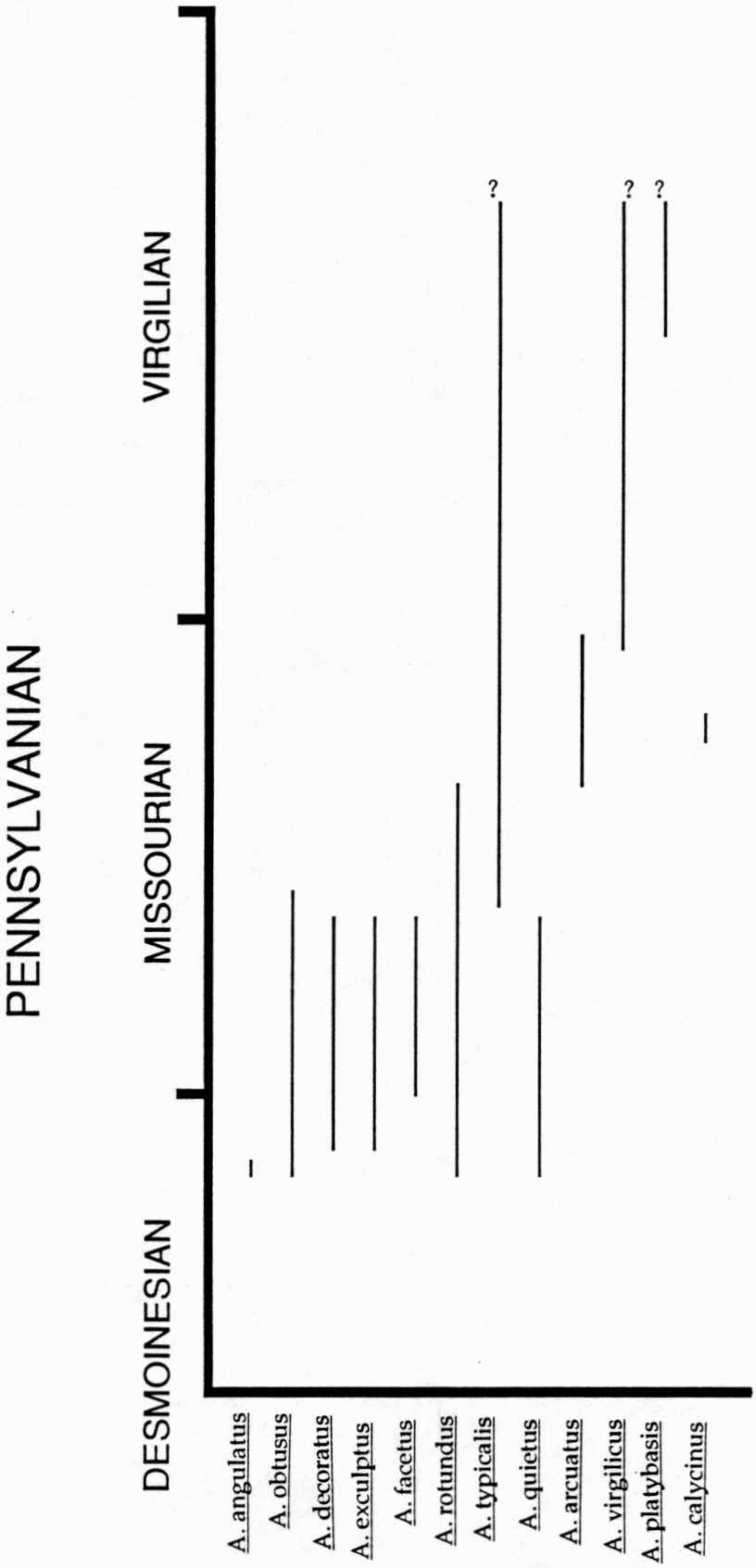
Table 1. Distinguishing characteristics of Apographiocrinus Moore and Plummer species

Species	Cup Shape	Cup Base	IBB Circlet	Slope of Radial Facets	Sutures	Ornamentation	Forefacet	Others
Apographiocrinus typicalis Moore & Plummer, 1940 Pl. 1, figs. 1-4, 11 Pl. 3, figs. 7,8 Pl. 4, figs. 8-13	circular	strongly concave	downflared			none	none	faintly bulbous plates
A. angulatus Strimple, 1948 Pl. 1, figs. 12-14	prominent scallop	concave, broad and shallow		slightly inward		minute, round granules over entire surface	smaller than in other forms	sharply depressed areas at apices of basals and radials
A. obtusus Strimple, 1948 Pl. 1, figs. 8-10	broad, shallow	concave, shallow	slightly downflared	slightly inward	mildly impressed	small, rounded granules	large, vertical occupy most of radial	lack of tumidity to plates
A. rotundus Strimple, 1948 Pl. 2, figs. 1-3	full, deep	concave, shallow	sub-horizontal		slightly depressed	fine, elongate ridges with granules on IBB and basals	flattened, scarlike	
A. quietus Strimple, 1948 Pl. 1, figs. 5-7	scalloped and moderately deep	concave, shallow	sub-horizontal	slightly inward		minute, round granules over entire surface	small, arcuate	
A. decoratus Moore & Plummer, 1940 Pl. 2, figs. 4-6		concave				lower radial - fine granules; upper radial - coarse granules	subvertical over full width of radial	

Table 1. (Continued)

Species	Cup Shape	Cup Base	IBB Circlet	Slope of Radial Facets	Sutures	Ornamentation	Forefacet	Others
A. exculptus Moore & Plummer, 1940 Pl. 2, figs. 7-9	scalloped	concave, deep				granulation on upper radials	wide	bulbous plates; sharp, wavy line demarcating forefacet from rest of radial
A. facetus Moore & Plummer, 1940 Pl. 2, figs. 10-12		concave				coarse granules on upper radials	present	
A. arcuatus Strimple, 1949 Pl. 3, figs. 1-3	shallow, broad	concave, shallow	downflared			node-like projections along lower perimeter of forefacet		
A. virgilicus Pabian & Strimple 1974 Pl. 3, figs. 4,5	bowl-shaped			inward		granules near outer marginal ridge of radials		
A. platybasis Pabian & Strimple 1980 Pl. 3, figs. 9-11		nearly flat	flat			rugose IBB		
A. wolfcampensis Moore & Plummer 1940 Pl. 3, figs. 12-14	bowl-shaped, deep, scalloped	concave, deep	downflared, 5-pointed star	horizontal	not impressed			moderate tumid plates

Fig. 5. Stratigraphic time ranges (first and last appearances) of Middle and Late Pennsylvanian species of Apographiocrinus. Taken from collected samples and recorded ranges in the literature. Vertical axis approximately to scale. Base of graph is base of Marmaton Group; top is top of Wabaunsee Group.


PENNSYLVANIAN
DESMOINESIAN
MISSOURIAN
VIRGILIAN
A. angulatus
A. obtusus
A. decoratus
A. exculptus
A. facetus
A. rotundus
A. typicalis
A. quietus
A. arcuatus
A. virgilicus
A. platybasis
A. calycinus
?
?
?

with radial facets less wide than the radials themselves (peneplanary) (Moore et al., 1978).

Purpose. The purpose of this study was to examine changes within the genus through time using both quantitative and qualitative tools to document any trends in its evolution. Samples were taken and examined from available museum collections. Field sampling was also carried out to augment the museum collections and to observe the depositional environments in which the specimens lived.

Statistical analyses were carried out to document growth patterns within the genus and to determine if any significant trends developed through its history. However, an in depth statistical analysis of the genus was beyond the scope of this project. Qualitative analyses documented gross changes in the morphology of the genus. This information was then to be used in conjunction with paleoenvironmental data to analyse speciation in the genus. It was thought that a comparison might be made between the evolutionary models of phyletic gradualism and punctuated equilibrium.

Repositories. Specimens included in this study are reposited in the invertebrate paleontological collections of the University of Nebraska State Museum (UNSM) and the Department of Geology, University of Iowa (SUI).

Geology and Depositional Environment

The oldest Apographiocrinus specimens treated in this study occur in rocks of the upper Marmaton Group of northeastern Oklahoma. These limestones and shales represent shallow water platform deposits which thin abruptly in about the same area in which these older apographiocrinids were collected (Krumme, 1981). It is significant to note that these collecting horizons are located in regressive portions of the deposits. For instance, that section of the Watkins Shale (Loc. 3) from which that sample was taken is interpreted by Bennison (1984) to be a near shore environment. The Lower Missourian Keechi Creek Shale locality (Loc.4), containing Desmoinesian-type apographiocrinids also appears to be a shallow water regressive unit (Boardman et al., 1989). The apographiocrinid specimens from these deposits are all large, ornate and thick-plated, another indication of a warm, shallow water environment (Pabian and Strimple, 1970 and 1985).

All of the Missourian and Virgilian strata from which the samples of Apographiocrinus used in this study represent deeper, cooler water environments than those Desmoinesian deposits from which samples of the genus were collected. Samples from these Upper Pennsylvanian rocks are located in the transgressive or deeper water regressive portions of the cyclic strata (Heckel and Baesemann, 1975 and Heckel, 1977) common to the Upper Pennsylvanian of the mid-continent. There is at least one sample from each of the four major facies belts decribed by Heckel (1968) in this area. Samples from such units as the Hickory Creek Shale (Loc. 10), the Kiewitz Shale bed of the Stoner Limestone (Loc. 12) and the Haynies Limestone bed of the Ervine Creek Limestone (Loc. 14) are situated at or just above the core shale representative of maximum marine transgression (Heckel et al., 1979). The apographiocrinids of these strata are invariably smaller, have thinner plates and are less ornate than Desmoinesian forms.

STATISTICS

From the above sixteen samples of Apographiocrinus, smaller subsets were taken for statistical analysis in the hope of documenting any quantitative changes in the genus through time. Wherever possible, subsets of at least thirty individuals were taken randomly in order to approach a normal distribution for the population.

Four measurements (Fig. 4) were taken for each individual. The measurements represent common parameters used by previous workers and are easily measured. They are thought to be the best parameters in showing the relation between basal plates and radial circlets as well as growth of the dorsal cup. The measurements and summary statistics for the specimens are recorded in Appendix B (all measurements in mm).

Univariate statistics. The means and standard deviations for each measurement of the Apographiocrinus samples are summarized in Table 2. The standard deviation, s, for each sample, was calculated as

$$s = \sqrt{\frac{\sum(x_i - \overline{x})^2}{n-1}}$$

where n is the number of observations, x_i is the ith observation and $\overline{x}$ is the observed mean.

Bivariate analysis. The paired measurements of cup height vs. cup width and radial length vs. radial width were plotted as scatter diagrams that document isometric growth in the genus. The diagrams are shown in Figs. 6-13 with a reduced major axis regression equation given for each graph. The information from the radial measurements indicate no gross changes in the

Table 2. Summary of means (top, mm) and standard deviations (bottom) for four selected measurements on samples of Apographiocrinus Moore and Plummer. Symbols same as in Fig. 4.

Unit (Locality #)	n	Dpa	Ha	La	Wa
Ervine Creek Ls. (14)	40	6.68	2.41	2.19	3.30
(Haynies Sh. bed)		1.359	0.505	0.467	0.674
South Bend Ls. (13)	40	6.55	2.65	2.30	3.35
		1.667	0.646	0.605	0.914
Stoner Ls. (12)	40	6.44	2.77	2.48	3.49
(Kiewitz Sh. bed)		1.241	0.624	0.538	0.714
Captain Creek Ls. (11A)	40	5.09	2.25	1.83	2.41
(Patterson's Hogfarm)		1.257	0.418	0.435	0.546
Captain Creek Ls. (11B)	30	6.69	2.74	2.29	3.04
(Copan, Ok)		1.413	0.602	0.554	0.656
Hickory Creek Sh. (10)	40	7.25	2.96	2.50	3.70
		1.648	0.758	0.649	0.925
Wann Fm.: Upper horizon (9)	40	7.84	3.06	2.75	4.03
		1.668	0.602	0.551	0.708
Wann Fm.: Lower horizon (8)	32	7.09	2.88	2.57	3.55
		1.379	0.579	0.498	0.717
Quindaro Sh. (7)	30	7.56	2.90	2.53	3.65
		1.098	0.458	0.415	0.653
Avant Ls. (6A)	33	7.82	3.08	2.77	4.01
		0.753	0.371	0.321	0.530
Iola Fm. (6B)	36	6.49	2.53	2.19	3.29
		1.310	0.488	0.417	0.673
Palo Pinto Ls. (5)	12	8.69	3.54	3.11	4.02
		1.091	0.387	0.329	0.557
Keechi Creek Sh. (4)	9	9.00	3.84	3.33	4.36
		1.788	0.718	0.673	0.932
Watkins Sh. (3)	39	10.86	4.89	4.11	4.91
(Glenpool Ls. bed)		1.518	0.897	0.762	0.764
Perry Farm Sh. (2)	8	9.74	4.00	3.46	4.98
		1.744	0.741	0.678	0.982
Altamont Ls. (1)	40	8.12	3.32	2.70	3.63
		1.188	0.596	0.505	0.644

growth of the radials through geologic time although there are significant changes in the morphology of the radials between Desmoinesian and Missourian times.

Population statistics. An initial inspection of the samples used in this study indicated a general decrease in specimen size through geologic time in the genus. To see if this generalization could be statistically tested, simple student t-tests were carried out on the mean cup width (Dpa) for all samples. Mean cup width was chosen because it was thought to be the most representative parameter of overall size.

All tests were performed after Agterberg (1974, p. 187-188) at a 95% significance level. All samples were tested against each other where equality of the variances (s^2) could be shown. Where the sample variances were unequal, no test of the corresponding means were performed. When comparing samples of different sizes, a pooled estimate of s^2 was used.

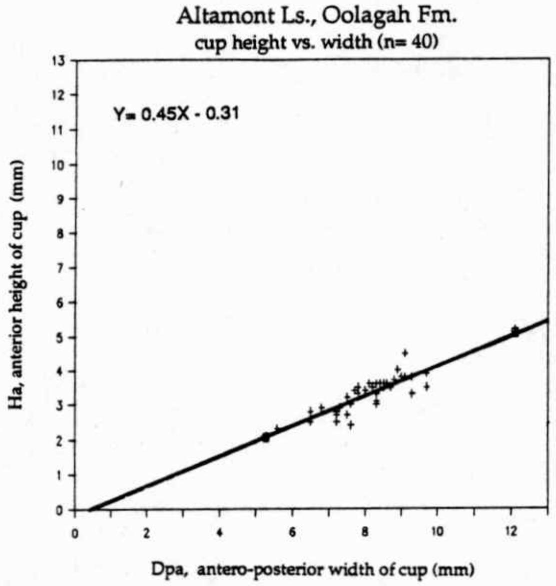
Only very general statements regarding the results can be made. First, there appears to be comparable means between the samples from the Altamont Limestone through the Palo Pinto Limestone. Although there were exceptions, in most of the tests the means for these crinoid samples were found to be equal. Of the stratigraphically higher samples, only the sample from the upper horizon of the Wann Formation had a comparable mean to one of the lower samples (from the Palo Pinto Limestone). Secondly, there was a significant difference between the sample mean from the Captain Creek Limestone at Patterson's Hog Farm (Loc. 11A) and every other sample mean it was tested against.

The significant differences in the means between the Desmoinesian - Early Missourian samples and the stratigraphically higher samples may be the the result of preservational bias between shallower, warmer water

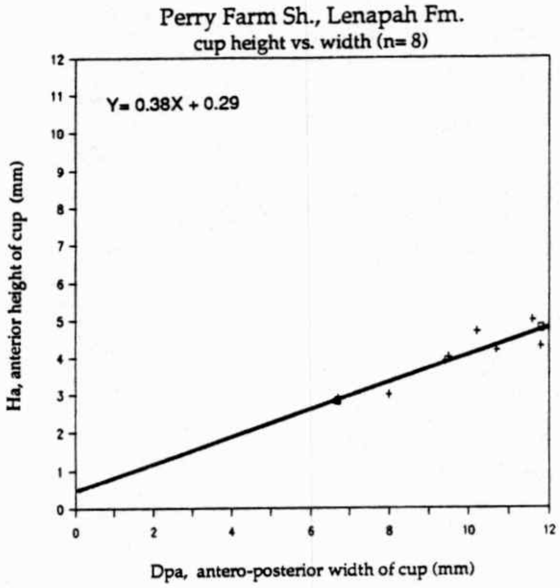
Desmoinesian deposits and deeper, colder water Missourian deposits, as well as a reflection of the small sample sizes from the Perry Farm Shale, Keechi Creek Shale and Palo Pinto Limestone.

The Captain Creek Limestone at Loc. 11A represents what is probably the deepest water conditions in which of a sample of Apographiocrinus occurs , possibly even below the photic zone (Heckel and Baesemann, 1975; Holterhoff, 1988). These individuals may have been subject to less scavenging than at other deep water localities.

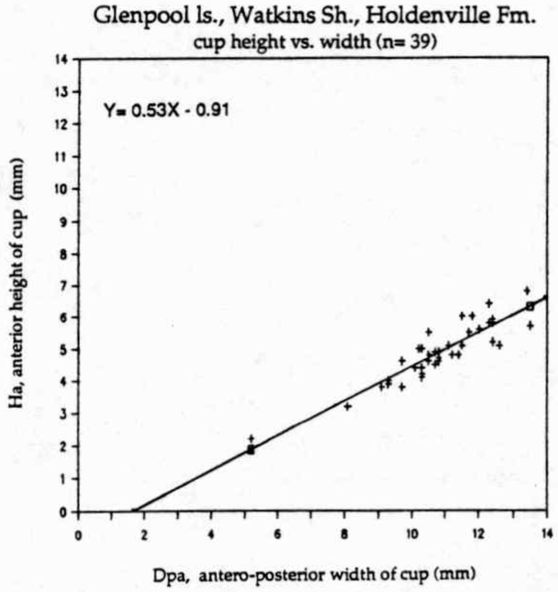
Fig. 6. Scatter diagrams for paired observations of cup height vs. width for Apographiocrinus subsamples from locs. 1, 2, 3 and 4. Regression line represents 'best-fit' line for all pairings in each subsample. Regression equations given in upper left of each diagram.



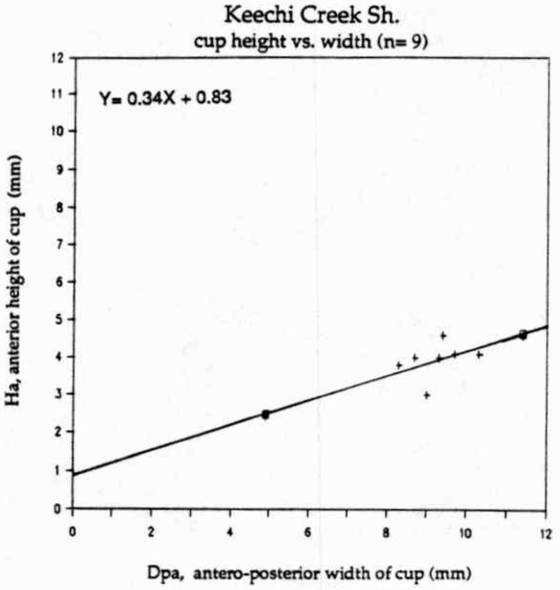
Altamont Ls., Oolagah Fm.
cup height vs. width (n= 40)



Perry Farm Sh., Lenapah Fm.
cup height vs. width (n= 8)



Glenpool ls., Watkins Sh., Holdenville Fm.
cup height vs. width (n= 39)

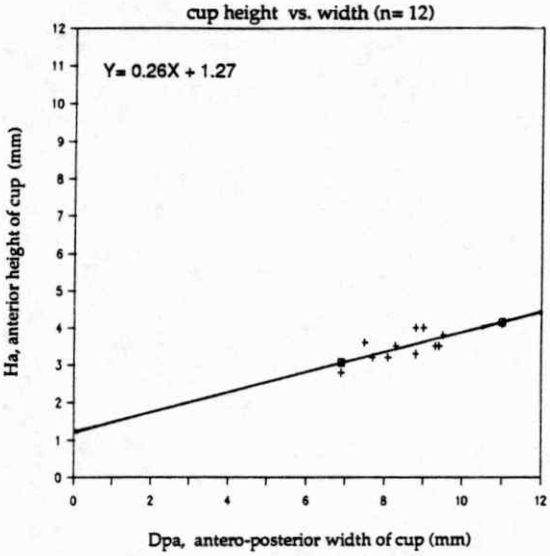


Keechi Creek Sh.
cup height vs. width (n= 9)

Fig. 7. Scatter diagrams for paired observations of cup height vs. width for Apographiocrinus subsamples from locs. 5, 6A, 6B and 7. Regression line represents 'best-fit' line for all pairings in each subsample. Regression equations given in upper left of each diagram.

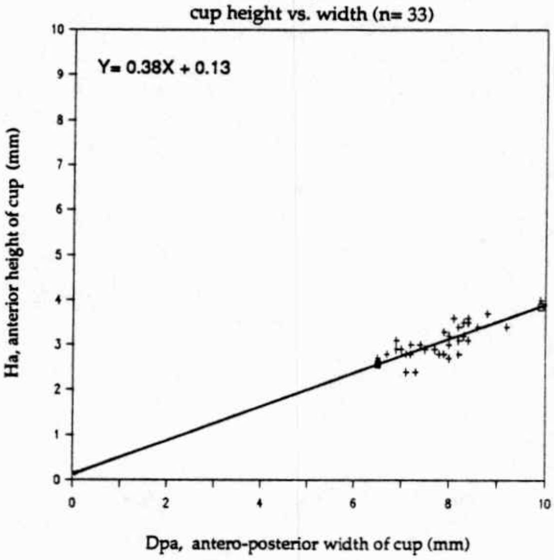
Palo Pinto Ls.

cup height vs. width (n= 12)



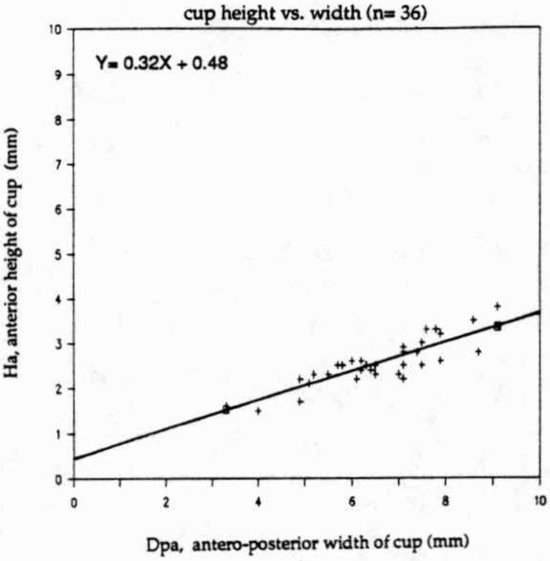
Avant Ls., Iola Fm.

cup height vs. width (n= 33)



Iola Fm.

cup height vs. width (n= 36)



Quindaro Sh., Wyandotte Fm.

cup height vs. width (n= 30)

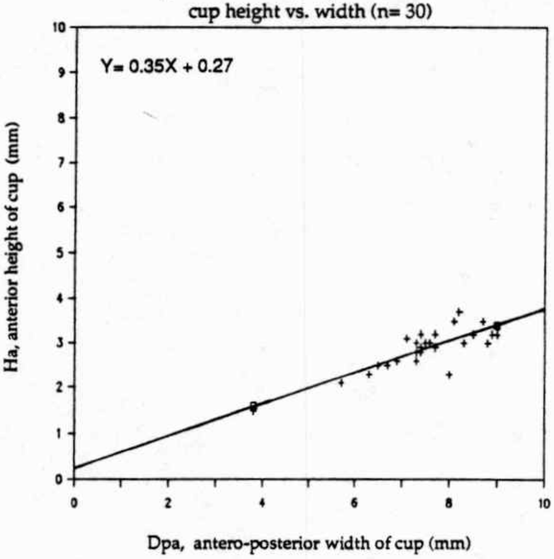
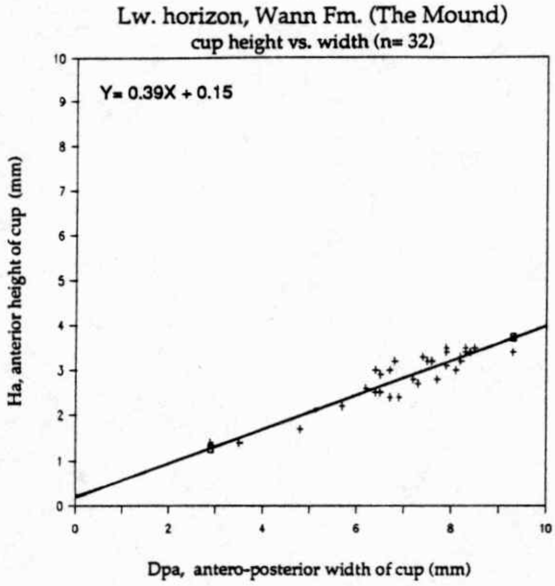
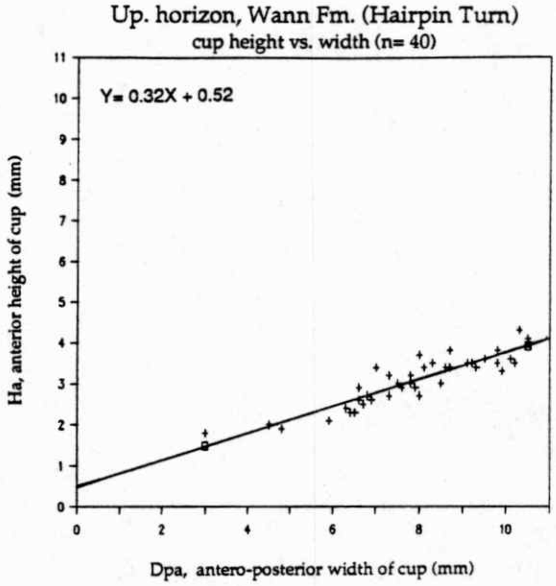


Fig. 8. Scatter diagrams for paired observations of cup height vs. width for Apographiocrinus subsamples for locs. 8, 9, 10 and 11A. Regression line represents 'best-fit' line for all pairings in each subsample. Regression equations given in upper left of each diagram.



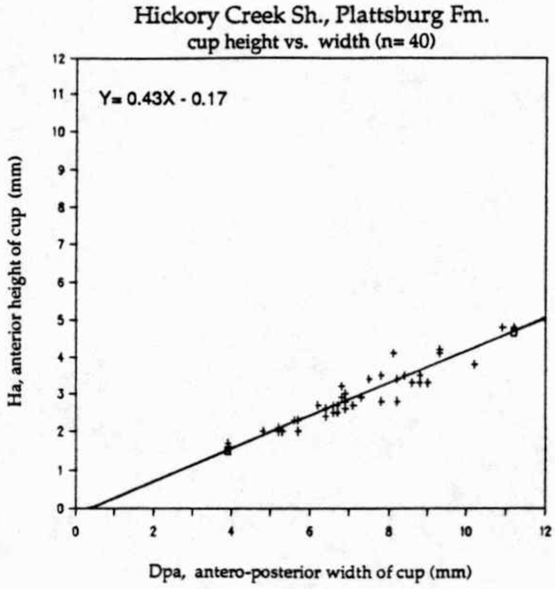
Lw. horizon, Wann Fm. (The Mound)

cup height vs. width (n= 32)



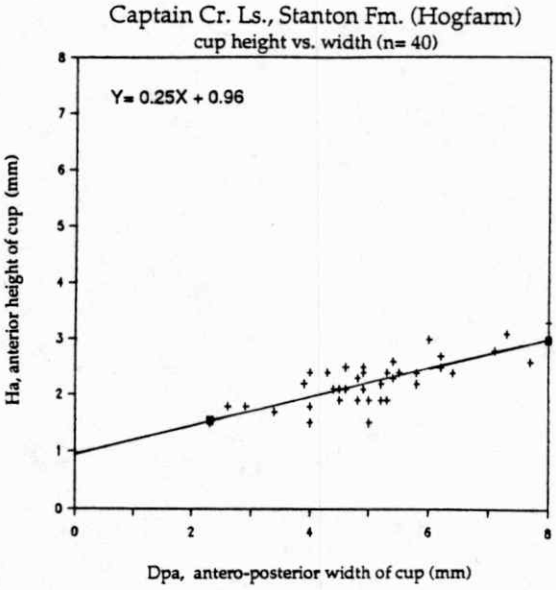
Up. horizon, Wann Fm. (Hairpin Turn)

cup height vs. width (n= 40)



Hickory Creek Sh., Plattsburg Fm.

cup height vs. width (n= 40)



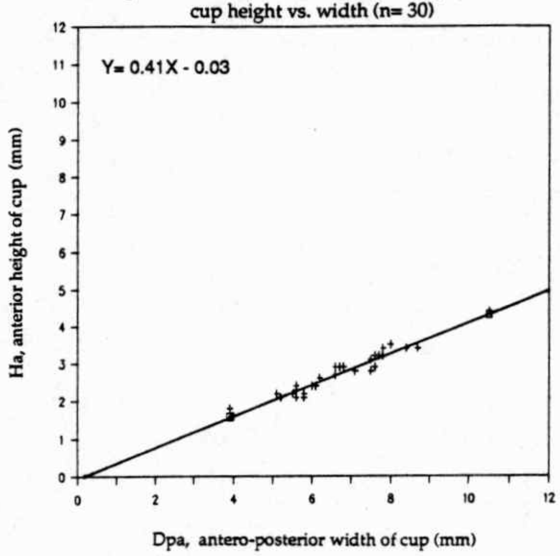
Captain Cr. Ls., Stanton Fm. (Hogfarm)

cup height vs. width (n= 40)

Fig. 9. Scatter diagrams for paired observations of cup height vs. width for Apographiocrinus subsamples from locs. 11B, 12, 13 and 14. Regression line represents 'best-fit' line for all pairings in each subsample. Regression equations given in upper left of each diagram.

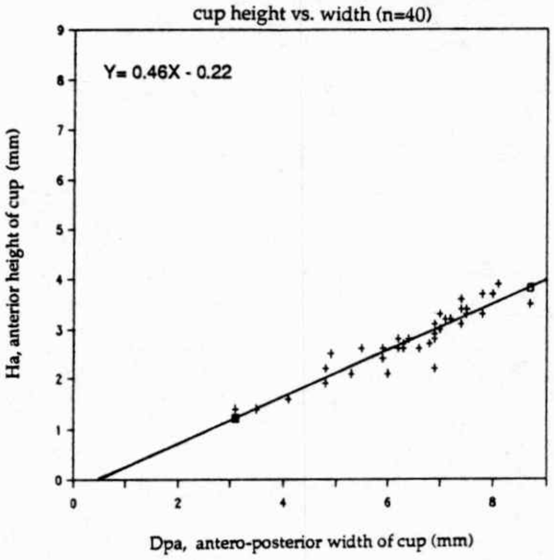
Captain Cr. Ls., Stanton Fm. (Copan, OK)

cup height vs. width (n= 30)



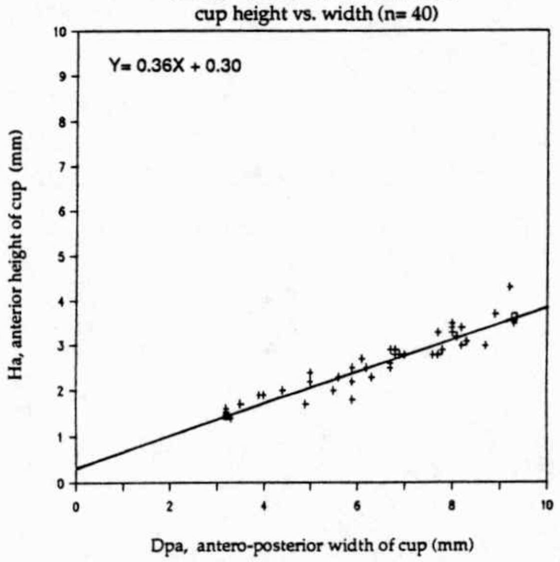
Kiewitz sh., Stoner Ls., Stanton Fm.

cup height vs. width (n=40)



South Bend Ls., Stanton Fm.

cup height vs. width (n= 40)



Haynies sh., Ervine Cr. Ls., Deer Creek Fm.

cup height vs. width (n= 40)

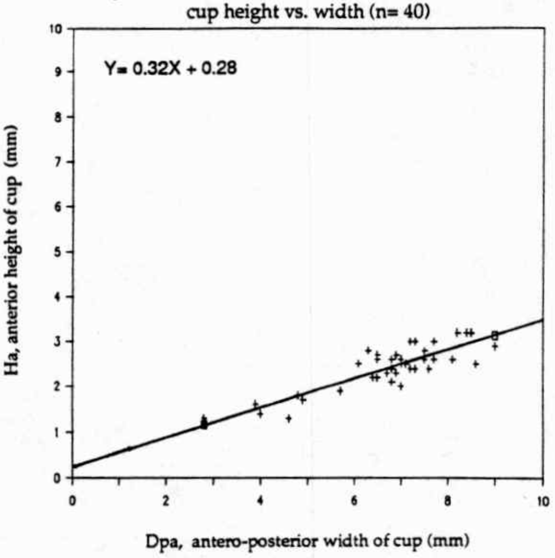
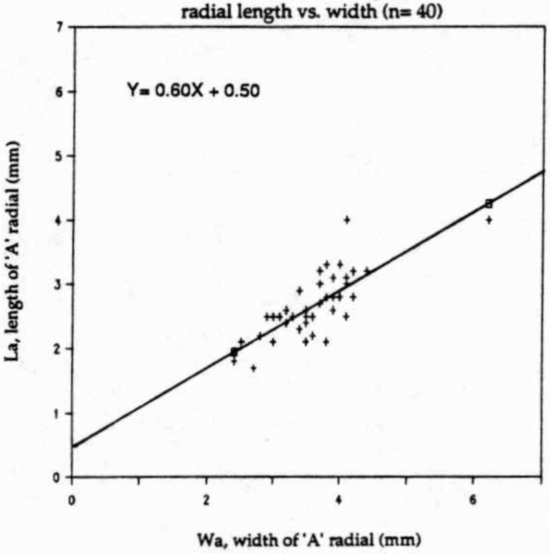
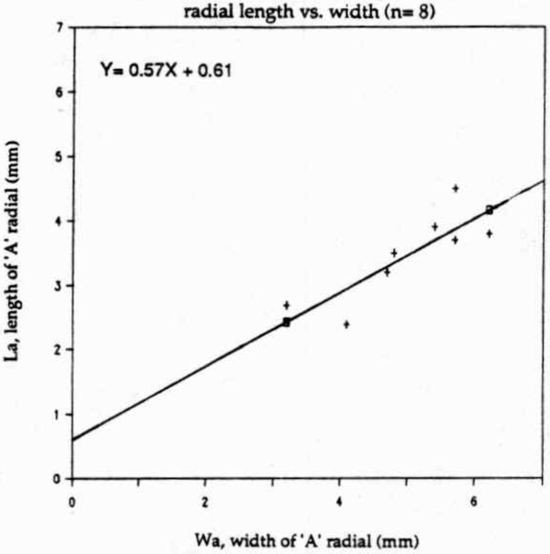


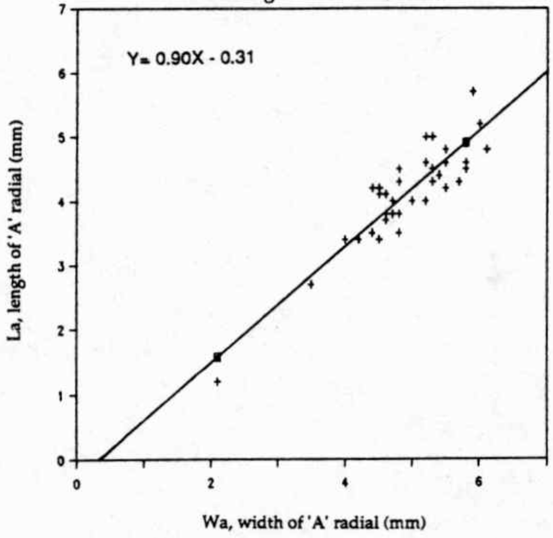
Fig. 10. Scatter diagrams for paired observations of radial length vs. width for Apographiocrinus subsamples from locs. 1, 2, 3 and 4. Regression line represents 'best-fit' line for all pairings in each subsample. Regression equations given in upper left of each diagram.



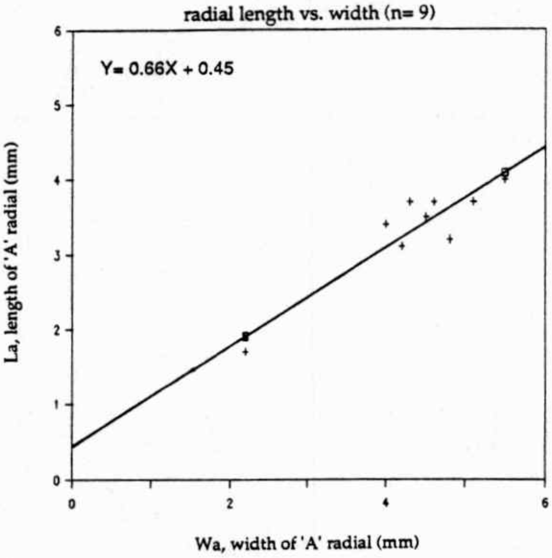
Altamont Ls., Oolagah Fm.
radial length vs. width (n= 40)



Perry Farm Sh., Lenapah Fm.
radial length vs. width (n= 8)

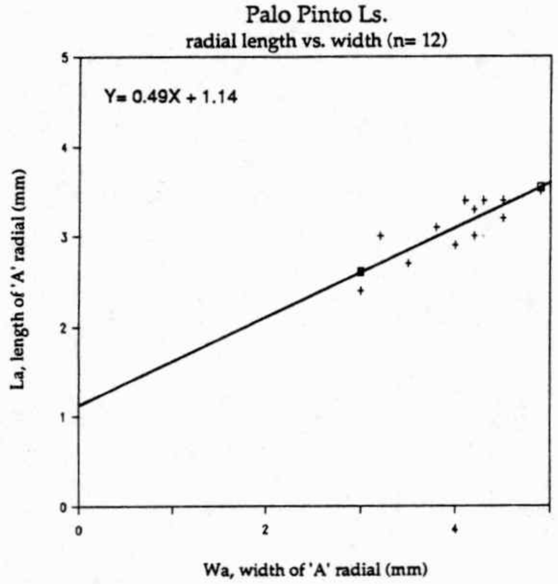


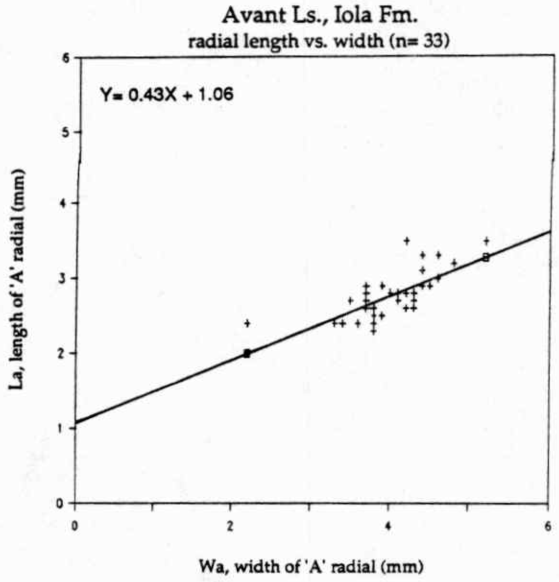
Glenpool ls., Watkins Sh., Holdenville Fm.
radial length vs. width (n= 39)

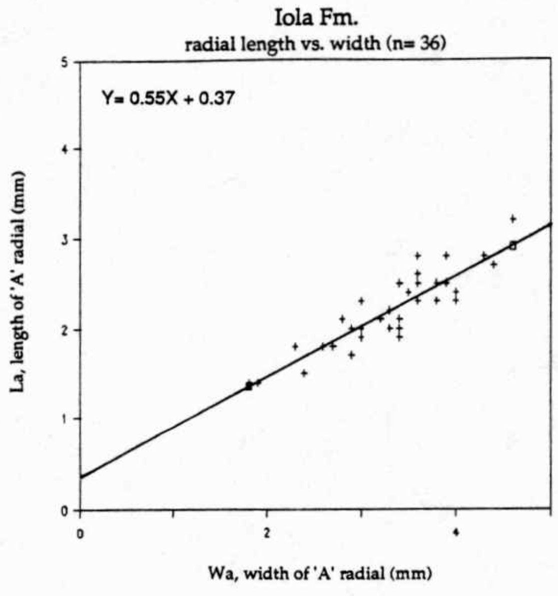


Keechi Creek Sh.
radial length vs. width (n= 9)

Fig. 11. Scatter diagrams for paired observations of radial length vs. width for Apographiocrinus subsamples from locs. 5, 6A, 6B and 7. Regression line represents 'best-fit' line for all pairings in each subsample. Regression equations given in upper left of each diagram.


Palo Pinto Ls.
radial length vs. width (n= 12)


Avant Ls., Iola Fm.
radial length vs. width (n= 33)


Iola Fm.
radial length vs. width (n= 36)

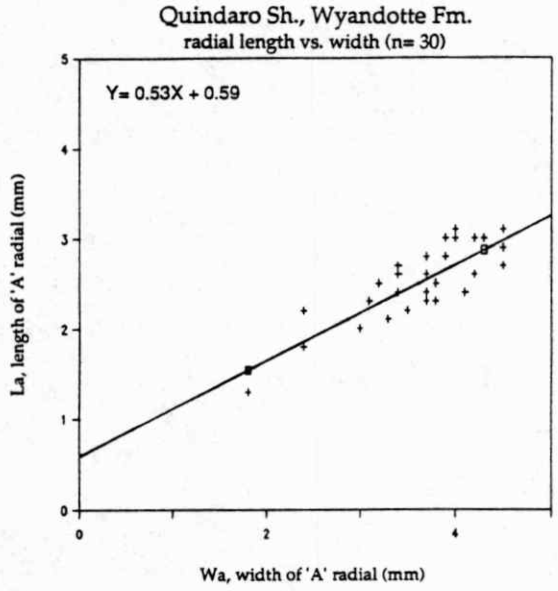
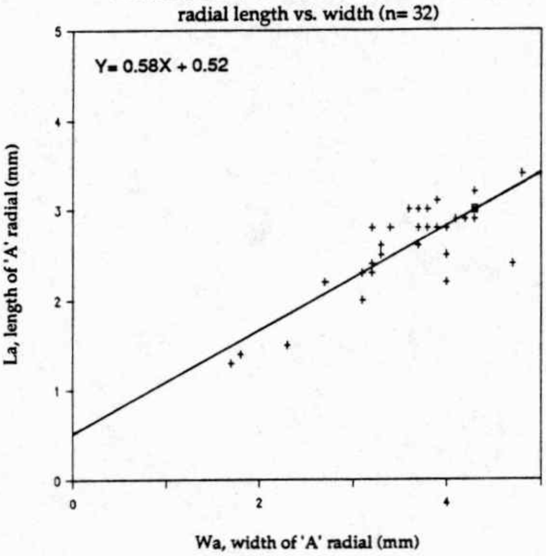
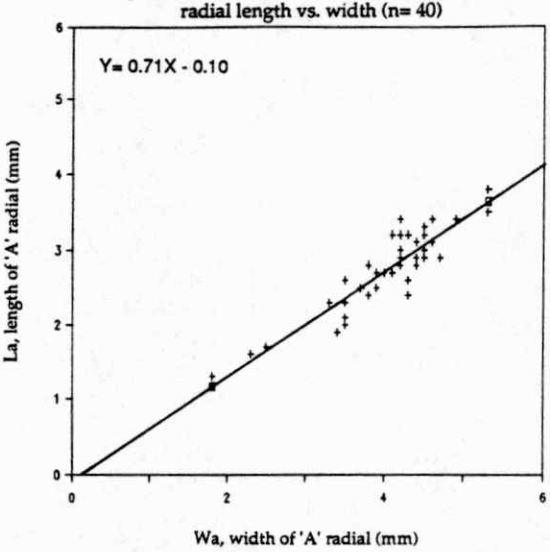
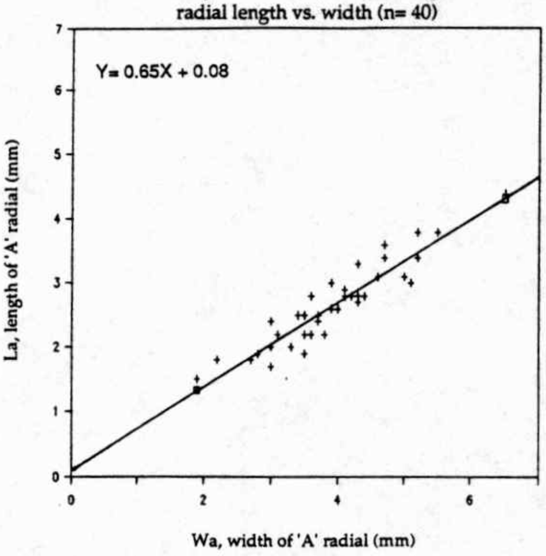

Quindaro Sh., Wyandotte Fm.
radial length vs. width (n= 30)

Fig. 12. Scatter diagrams for paired observations of radial length vs. width for Apographiocrinus subsamples from loc. 8, 9, 10 and 11A. Regression line represents 'best-fit' line for all pairings in each subsample. Regression equations given in upper left of each diagram.


Lw. horizon, Wann Fm. (The Mound)
radial length vs. width (n= 32)


Up. horizon, Wann Fm. (Hairpin Turn)
radial length vs. width (n= 40)


Hickory Creek Sh., Plattsburg Fm.
radial length vs. width (n= 40)

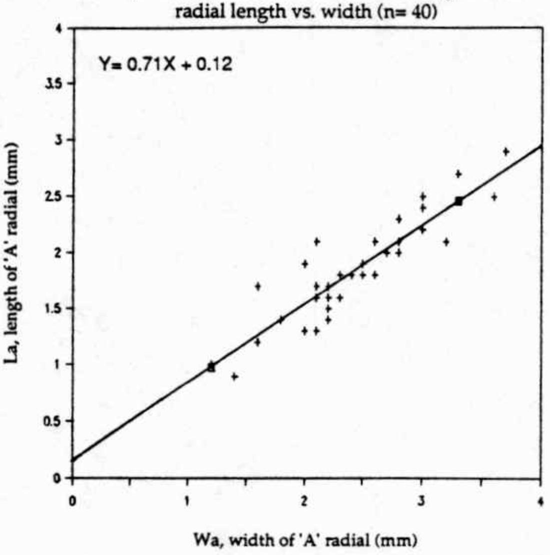
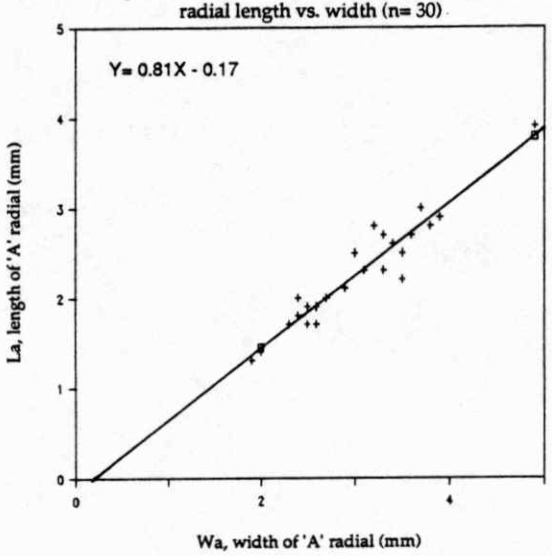
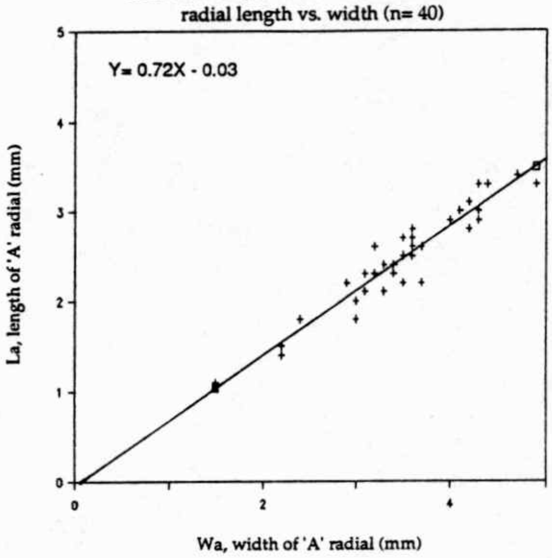

Captain Cr. Ls., Stanton Fm. (Hogfarm)
radial length vs. width (n= 40)

Fig. 13. Scatter diagrams for paired observations of radial length vs. width for Apographiocrinus subsamples from locs. 11B, 12, 13 and 14. Regression line represents 'best-fit' line for all pairings in each subsample. Regression equations given in upper left of each diagram.



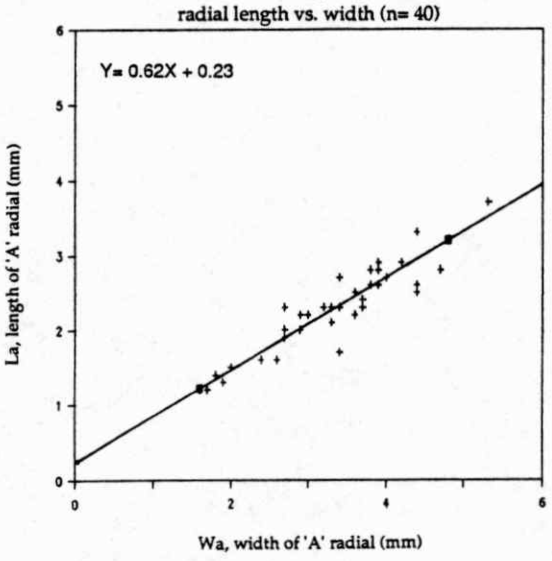
Captain Cr. Ls., Stanton Fm. (Copan, OK)

radial length vs. width (n= 30)



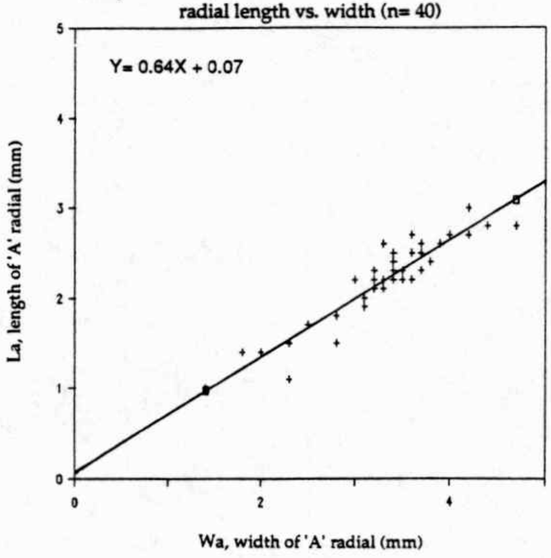
Kiewitz sh., Stoner Ls., Stanton Fm.

radial length vs. width (n= 40)



South Bend Ls., Stanton Fm.

radial length vs. width (n= 40)



Haynies sh., Ervine Cr. Ls., Deer Creek Fm.

radial length vs. width (n= 40)

Radials

In all Desmoinesian and earliest Missourian apographiocrinids there is some form of radial forefacetal area dividing the radial into two parts. (See plates 1 & 2 and Fig. 14 B-D). There are two kinds of forefacetal areas: (1) a relatively narrow, sub-horizontal area (Fig. 14B) giving the radial an outline more nearly that of A. typicalis (Fig. 14A) and (2) a wide area (Fig. 14C,D) differentiated from more proximal areas of the radial by a sharp angulation. The nature of this difference is more readily seen in comparing photographs of A. rotundus (possessing the sub-horizontal forefacet, Plate 2, figs. 1-3) to those of other Desmoinesian forms (A. quietus, Plate 1, figs. 5-7; A. obtusus, Plate 1, figs. 8-10; A. angulatus, Plate 1, figs. 12-14; A. decoratus, Plate 2, figs. 4-6; A. exculptus, Plate 2, figs.7-9; A. facetus, Plate 2, figs. 10-12.).

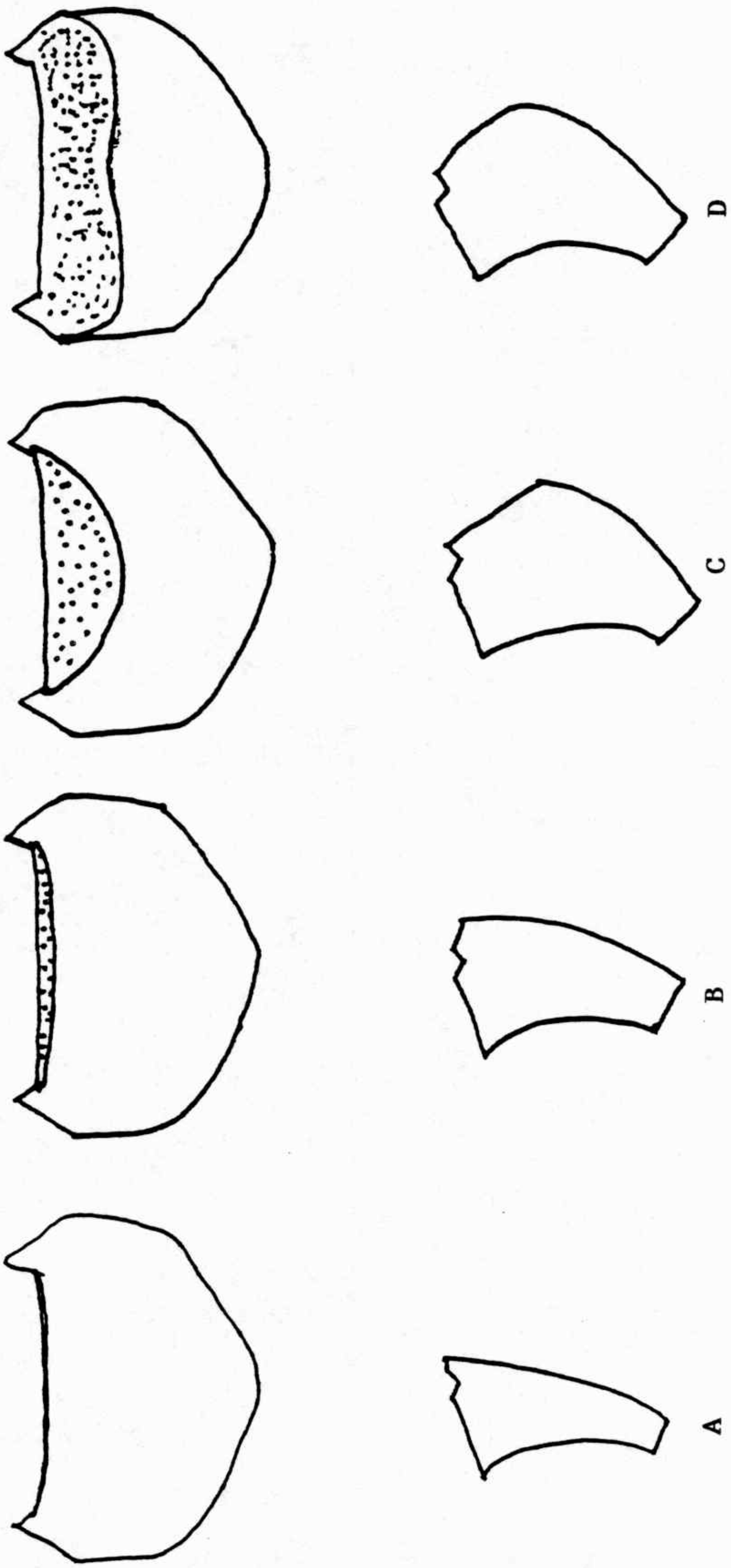
The wider forefacetal(Fig. 14C,D) areas can themselves be broken into two kinds. The forefacetal area in apographiocrinids from the Altamont Limestone and later A. arcuatus is more crescent shaped or arcuate in nature, thus occupying less of the width of the radial (peneplenary) (Fig. 14C). Those Missourian forms from Texas described by Moore and Plummer (1940) tend to have a greater area of the radial occupied by the forefacetal region (plenary) (Fig.14D) than those forms described by Strimple (1948, 1949) because they occupy a greater width of the radial. The forefacetal area in apographiocrinids from the Altamont Limestone and later A. arcuatus is more crescent shaped or arcuate in nature, thus occupying less of the width of the radial. (Fig. 14B,C)

Discussion. It has been assumed that these forefacetal areas served some function in feeding when the arms were open (Strimple, 1949). While it is possible that this area was associated with some functional aspect of the arms, the radial forefacet may be interpreted in other ways.

Raup (1972) has discussed a framework for interpreting morphology based on the work of Seilacher (1970) where the basic thesis is that any morphologic structure is a result of a combination of forces or influences. There are 5 major factors: (1) historical-phylogenetic factors are those aspects of morphology that are not subject to significant genetic variability; (2) functional factors are those aspects of morphology directly resulting from adaptations via natural selection; (3) structural factors are "non-adaptational elements of low taxonomic significance"; (4) ecophenotypic factors are those where environmental conditions influence the phenotypic expression of a given genotype; and (5) a random chance factor.

It would appear that for Desmoinesian and early Missourian apographiocrinids, the overriding factor involved in the generation of a radial forefacet would be a functional factor. These early forms are common to shallow water, regressive sequences in a probable high energy environment. In such an environment, a thicker endoskeleton might be preferable. A cross section through a typical Desmoinesian apographiocrinid radial (Fig. 14C, D) shows that a forefacetal area would tend to increase plate thickness whereas deep, cold water forms live in lower energy environments where a thinner endoskeleton may suffice. The presence and type of forefacet are of great taxonomic importance in the genus. As such, this structure would not be considered a structural factor (as the ornamentation on an individual might be). Ecophenotypic factors might also be suspected; however, the co-existence of A. arcuatus (with forefacet) with A. typicalis (no

Fig. 14. Drawings showing variation in radial forefacetal areas in Desmoinesian and Early Missourian forms of Apographiocrinus. Top drawings are front views of radials; bottom drawings are cross sections through the radials. (A) A. typicalis Moore & Plummer, (B) A. rotundus Strimple, (C) A. quietus Strimple, (D) A. exculptus Moore & Plummer.


A
B
C
D

forefacet) at locations 6A, 7, 8, 9, and 11A, B would be more difficult to explain.

My samples show that the radial forefacetal area showed greatest variation in the Late Desmoinesian and Early Missourian. This feature stabilized toward the Middle and Late Missourian when forefacets became narrow.

Anals

One general trend long noted (e.g., Moore and Laudon, 1943) for inadunate crinoids through Paleozoic time has been the reduction in number and/or size and the expulsion and/or resorption of plates in the anal series. Strimple (1960) described three significant trends for Carboniferous inadunate crinoids of Oklahoma, all of which ended in reduced number of anal plates and decreased size of the remaining anals. Apographiocrinus would fall within Strimple's Developmental Trend A (Fig. 15) where the anal X plate, the sole remaining anal left, is ultimately expelled from the cup.

Study of the available samples of Apographiocrinus shows a general trend for the anal X to be expelled (Table 3) in about 3-7% of the specimens, especially among Late Desmoinesian and Missourian samples. Examples of expelled anal X plates are shown in Plate 1, fig. 11 and Plate 3, fig, 6. It should be noted that expelled anal X plates do not appear to be species specific. The adaptive significance, if any, for this trend is unknown, and it does not appear to lead to additional speciation. Thus, the variations in the anal plates, once considered to be very important, may be less important than variation in the forefacetal areas.

Fig. 15. Strimple's Developmental Trend A showing overall loss in the number of anal plates and the expulsion of the anal X plate from the dorsal cup. Stippling indicates anal X; horizontal lines, RX; diagonal lines, RA. Arrows indicate probable trends. The trend for Apographiocrinus appears to be from 15e to 15f. Taken from Strimple (1960).

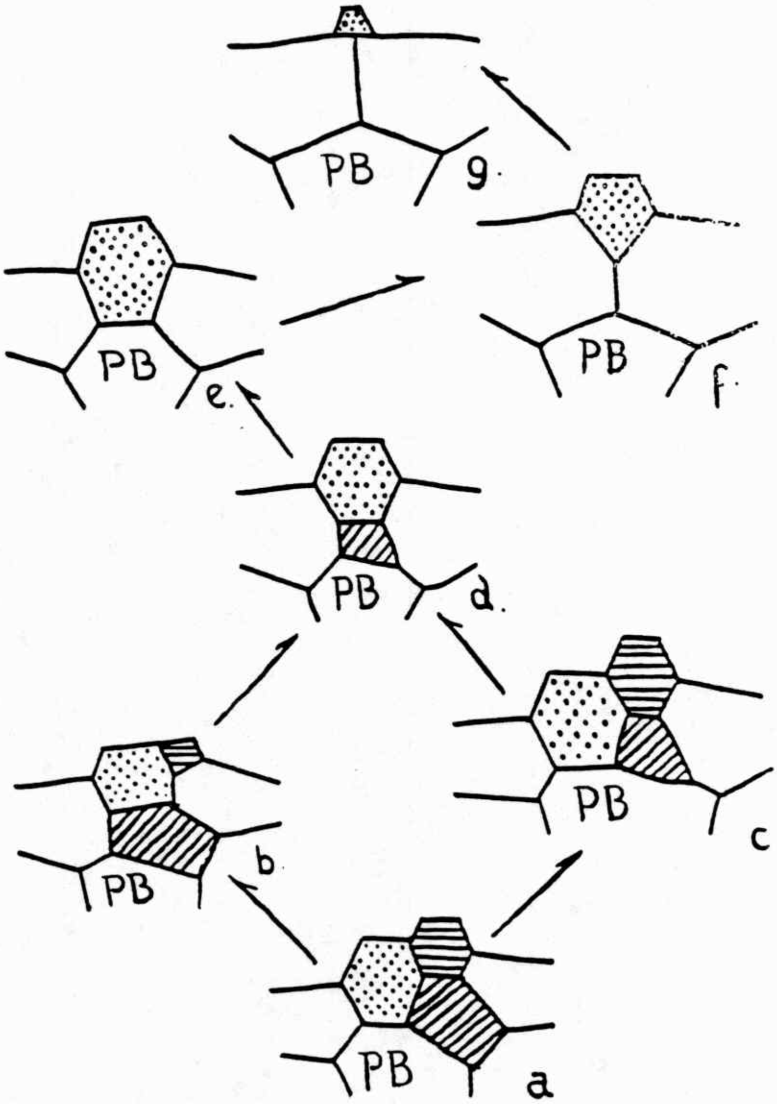

PB
g.
PB
e.
PB
f.
PB
d.
PB
b.
PB
c.
PB
a

Table 3. Percentage of expelled anal X plates

	Unit (Loc. #)	n	Normal	Expelled	% Expelled
VIRGILIAN	Ervine Cr Ls. (14)	393	378	15	3.83

****

MISSOURIAN	South Bend Ls. (13)	109	101	8	7.34
	Stoner Ls. (12) (Kiewitz sh.)	256	238	18	7.03
	Capt. Cr. Ls. (11 A&B)	364	348	16	4.40
	Hickory Cr. Sh. (10) (= Up. Wann)	46	42	4	8.70
	Upper Wann Fm. (9) (Hairpin Turn)	285	275	10	3.51
	Lower Wann Fm. (8) (The Mound)	89	88	1	1.12
	Quindaro Sh. (7)	26	24	2	7.69
	Avant Ls. (6A) (Upper horz.)	53	52	1	1.89
	Iola Fm. (6B)	45	43	2	4.44
	Palo Pinto Ls. (5)	16	16	0	0.00
	Keechi Cr. Sh. (4)	8	7	1	12.50

****

DESMOINESIAN	Watkins Sh. (3) (Glenpool ls.)	51	47	4	7.84
	Perry Farm Sh. (2)	6	5	1	16.67
	Altamont Ls. (1)	85	82	3	3.53

Arms

As noted above, Apographiocrinus has ten arms that branch once off the first primibrachs (Fig. 3). In well preserved crowns the cuneiform arms bear pinnules off alternate brachials (Fig. 16). Examination of whole and partial Apographiocrinus crowns show some change in arm development during ontogeny (Plate 3, figs. 7-8 and Plate 4, figs. 1-13). Most important is that the first primibrach plates are relatively longer on very small individuals than on more mature individuals (for example, compare crowns for A. typicalis from the Ervine Creek Limestone, loc.14, Plate 4, figs. 10-13). Although not enough Apographiocrinus crowns were collected for statistical analysis, it appears from the present collections that there is little evolutionary change in arm development through Missourian and Virgilian time.

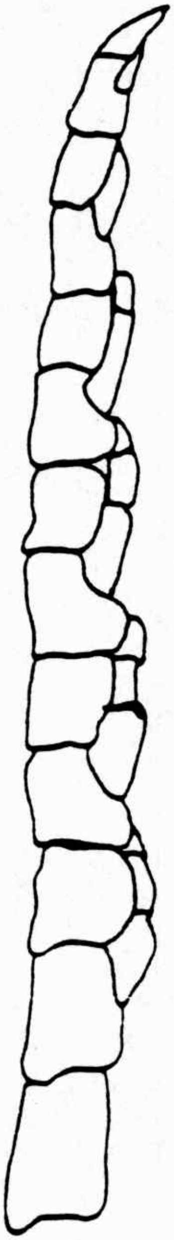
Discussion. It should be noted that all crowns available for study are Missourian and Virgilian in age and, with the exception of one specimen from the Keechi Creek Shale, all are from deep water deposits. Of the Desmoinesian material, only four or five specimens have one or two primibrachs. Strimple (1948, 1962) has not described any complete crowns of the genus from the Altamont Limestone.

Kammer and Ausich (1987) have shown that arm morphology can be related to environmental conditions and current velocities for Late Osagean crinoids from the East Central United States. Non-pinnulate crinoids (with open-mesh filtration fans) were invariably associated with low current velocities and feeding schemes of motile particle capture and gravitational deposition.

Although pinnulate, Apographiocrinus crowns would be considered to have an open-mesh filtration fan (Holterhoff, 1988). Holterhoff showed that for deposits of the Stanton Formation (Missourian), Apographiocrinus was invariably associated with other open-mesh filtration fan, deep water crinoid assemblages.

Desmoinesian apographiocrinids are shallow water forms, from regressive sequences. No complete crowns to my knowledge have been described from these units. It is predicted that the nature of the arms, as has been described for the radial plates, will change significantly due to paleoecologic changes in environment. It is believed that any apographiocrinid crowns from these regressive units will possess more of a closed-mesh filtration fan when compared to stratigraphically younger forms of the genus.

Fig. 16. Single arm of Apographiocrinus vigilicus showing pinnulation on alternate brachials. Taken from Pabian and Strimple, 1985.



TAXONOMY

As noted in the introduction and detailed in Table 1, a number of species have been described for Apographiocrinus. These are species for which there are referable specimens in the invertebrate paleontology collections of the University of Nebraska State Museum (UNSM) and the University of Iowa (SUI). Several other species have also been described from other geographic areas.

Meek and Worthen (1861) described an apographiocrinid species (Apographiocrinus carbonarius) based on two dorsal cups from the Carboniferous of Illinois. Examination of their illustrations of the specimens (Meek and Worthen, 1873, pl.24, fig. 2) suggests that these two cups come from different age rocks. The larger specimen is probably referable to A. arcuatus while the other is probably referable to one of the Desmoinesian forms. Strimple (1975) described the species A. raderi from a single cup from the Morrowan of Texas, but an examination of that specimen leaves some doubt as to its actual generic affinities. Wanner (1916) described two other apographiocrinids (A. quinquelobus and A. verbeeki var. pumila), but they are from the Upper Permian of Timor and are not included in this study.

Discussion. In my opinion, the large number of species of Desmoinesian and Early Missourian age is probably unwarranted. Species descriptions, particularly those of Moore and Plummer (1940) and Strimple (1948, 1949, 1962), are often based on but a single dorsal cup. A great deal of emphasis seems to be placed on the degree and kind of ornamentation over the cup surface, as well as the degree of bulbousness of the cup plates. These parameters work fairly well in general descriptions of single specimens, but an examination of a large collection of Desmoinesian apographiocrinids from the same locality and horizon will show a clear gradation of morphology and ornamentation. Strimple (1948) noted this variability in morphology , but still described four discrete species from the Altamont Limestone.

Although studies in interspecific variation have not been done with Late Paleozoic inadunate crinoids, work done with recent invertebrates may help shed some light on the subject. For example, Gould and Woodruff (1978) have indicated that the Bahaman land snail Cerion shows a tremendous diversity of form but does not parcel its populations into true species. That is, few species of Cerion are considered biolgically valid as distinct non-interbreeding populations. In all but one case, any two distinct Cerion morphs in geographic proximity are capable of interbreeding and producing hybrids at their point of geographic contact.

For these reasons, the species diversity represented in Table 1 and Figs. 5 and 17 is not an accurate representation for Desmoinesian and earliest Missourian samples. Those 'species' I think to be actually conspecific have been left as discrete entities in Figs. 5 and 17 to show the degree of morphologic variation present in these early apographiocrinids and because a detailed taxonomic analysis is beyond the scope of this report.

SPECIATION IN APOGRAPHIOCRINUS

Eldredge (1976) has stated that evolution, no matter how defined, is "quintessentially a matter of speciation". During the past fifteen or so years, much evidence has been gathered from the fossil record in support of either of two theories of speciation. By far the older concept, the phyletic gradualism theory holds that new species arise from the slow, even *transformation* of an ancestral population into its modified descendants. Such a transformation involves a large number of individuals (essentially the entire ancestral population) occurring over all or a large portion of the ancestral geographic range. The theory of punctuated equilibrium via allopatric speciation (Eldredge and Gould, 1972 and Gould and Eldredge, 1977) states that new species arise by the rapid *splitting of lineages*, involving a small subpopulation of the ancestral form in a very small part of the ancestral geographic range.

As Fortey (1985) has pointed out, the data needed to test each theory are not the same. Punctuated equilibrium can use few numbers of specimens in a qualitative character analysis to demonstrate punctuation and stasis, whereas gradualism demands large numbers of individuals for quantitative treatment. To compete on an equal level, Fortey suggests using the "principle of parsimony"; that is, preferring the simpler or more logical explanation.

Little can be said of the speciation events surrounding the origination of the Desmoinesian and earliest Missourian apographiocrinid morphs as these are the oldest apographiocrinids under study. Therefore, speciation within Apographiocrinus is best examined by looking at events during Missourian time.

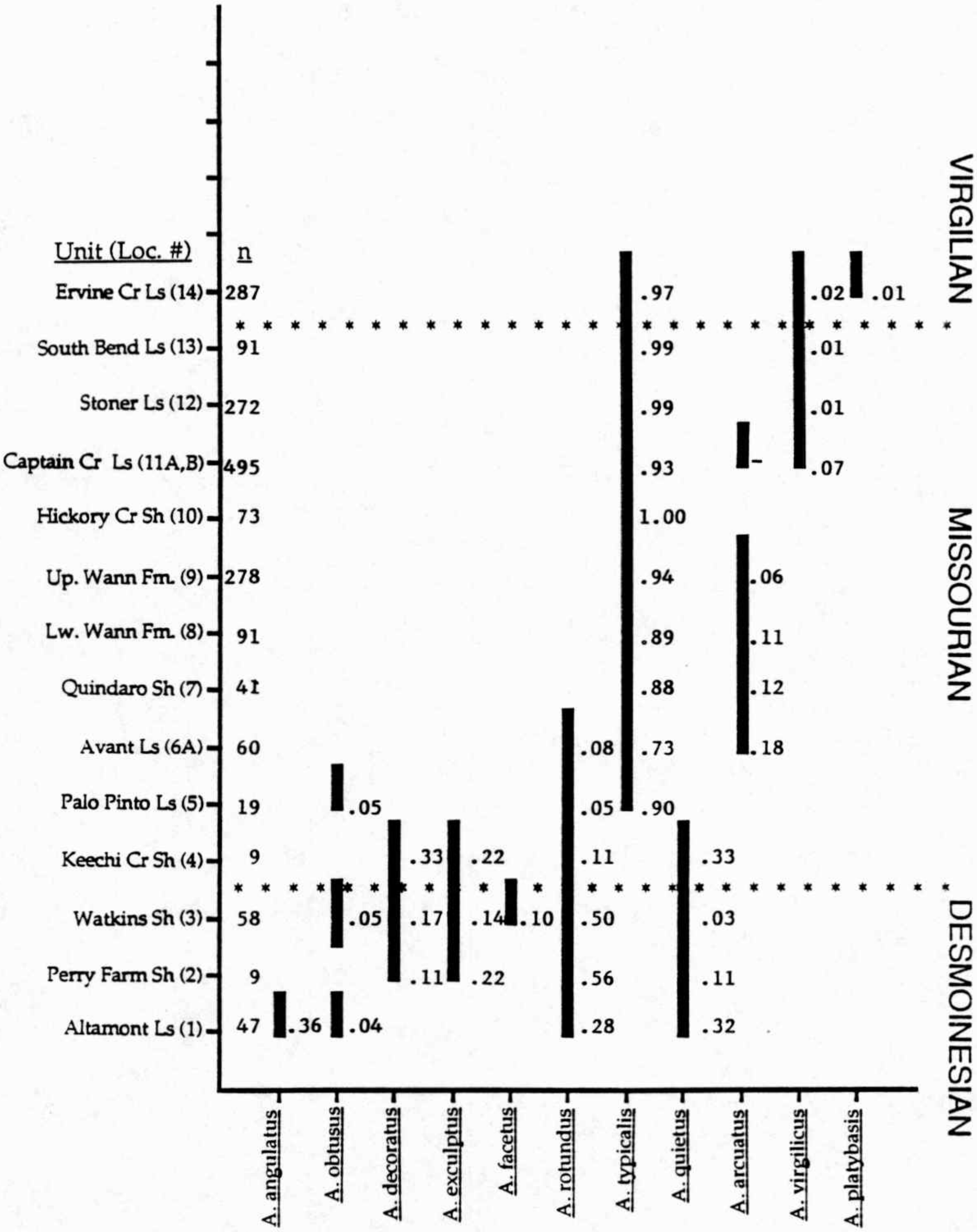
Figure 17 shows the relative abundance of Apographiocrinus morphospecies as well as the stratigraphic distribution through time for all samples in the study area. The species diversity shown for the four oldest units is possibly more representative of high phenotypic variance than true species diversity. Nonetheless, the diversity shown by forefacets in Apographiocrinus is bottom heavy, (cf. Gould et al., 1987).

Desmoinesian morphs are relatively evenly distributed in numbers within a shallow water environment (Krumme, 1981) during periods of marine regression (Bennison, 1984). These marine units thin abrubtly into more terrestrial dominated clastic units near the Desmoinesian collecting localities (Krumme, 1981).

It is unlikely that these Desmoinesian morphs represent true peripheral isolates as described by Eldredge and Gould (1972) since true isolates would comprise an extremely small number of individuals in geographic isolation. It is possible, however, that such environmental conditions could eventually lead to the geographic isolation of a peripheral group of individuals in such an area. Under such restricted conditions, it is difficult to see how an entire population could be transformed over a large area into a new descendent species as postulated by the phyletic gradualism model.

Although the samples of Apographiocrinus from Texas are small in number, Fig. 17 indicates a sharp turnover in apographiocrinid morphs between the Keechi Creek Shale and Palo Pinto Limestone. The origin of A. typicalis, perhaps from A. rotundus which possesses a similar radial slope, may occur as a rapid event, not as a slow transformation. This may, however, be a product of poor sampling from the lowest Missourian units in this region. The earliest recorded occurrence of A. typicalis (Moore and

Fig. 17. Stratigraphic distribution and relative abundance of _Apographiocrinus_ morphospecies from the sixteen sample localities. "n" is the number of specimens assigned to species level for that sample. Number to the right of the bar gives the relative frequency of each corresponding species. Dash (-) indicates a frequency of less than 0.01. Vertical axis not to scale.


Unit (Loc. #)
n
Ervine Cr Ls (14) 287 .97 .02 .01
South Bend Ls (13) 91 .99 .01
Stoner Ls (12) 272 .99 .01
Captain Cr Ls (11A,B) 495 .93 - .07
Hickory Cr Sh (10) 73 1.00
Up. Wann Fm. (9) 278 .94 .06
Lw. Wann Fm. (8) 91 .89 .11
Quindaro Sh (7) 41 .88 .12
Avant Ls (6A) 60 .08 .73 .18
Palo Pinto Ls (5) 19 .05 .05 .90
Keechi Cr Sh (4) 9 .33 .22 .11 .33
Watkins Sh (3) 58 .05 .17 .14 .10 .50 .03
Perry Farm Sh (2) 9 .11 .22 .56 .11
Altamont Ls (1) 47 .36 .04 .28 .32
A. angulatus
A. obtusus
A. decoratus
A. exculptus
A. facetus
A. rotundus
A. typicalis
A. quietus
A. arcuatus
A. virgilicus
A. platybasis
VIRGILIAN
MISSOURIAN
DESMOINESIAN

Plummer, 1940) as well as the oldest specimens examined during this study are from the Palo Pinto Limestone of north central Texas. This unit is correlated with the Dennis Limestone of the northern mid-continent (Boardman and Heckel, 1989). The oldest occurrence of A. typicalis from the northern mid-continent is from the statigraphically younger Drum Formation (Pabian and Strimple, 1980b). While this is obviously not strong evidence in itself for allopatric speciation, it is consistent with the implication of origin in one area and later migration into another. Using Fortey's principle of parsimony, the punctuated equilibrium concept seems a better explanation for the origin of A. typicalis.

The appearence of A. typicalis in the Palo Pinto Limestone marks a change in relative species diversity for the genus. Fig. 17 shows that A. typicalis establishes itself from its first recorded appearence as the dominant species of the genus through Missourian and Virgilian time. From this point, all samples of Apographiocrinus are known from deeper, colder water, presumably lower energy environments of transgressive or deep water regressive sequences. It is probable that these observations are a natural consequence of relatively thinner plates and possibly more open-mesh filtration fans being more advantageous in a low energy environment than the thicker plated, possibly more closed-mesh filtration fans of ancestral forms. With a change in environment, ecophenotypic factors might be used to explain the sudden morphologic changes within the genus, but the later introduction of A. arcuatus (Plate 3, figs. 1-3) would argue against this.

With the lack of good samples of Apographiocrinus from the Lower Missourian rocks of the mid-continent, the timing and mode of speciation in A. arcuatus is undeterminable. The arcuate nature of the wide radial forefacet, however, indicates possible descent from the Desmoinesian apographiocrinids described by Strimple (1948).

The loss of *A. arcuatus* and the introduction of *A. virgilicus* (Plate 3, figs. 4, 5) during the latter part of the Missourian presents a difficult problem in determining mode of speciation in a case where stratigraphic control over the samples is fairly good. The two species overlap in terms of time and geographic ranges, but, by the information at hand, not extensively. There does not appear to be any transitional forms betwwen the two in the overlap region. Of the 495 specimens of *Apographiocrinus* from the Captain Creek Limestone identified to species level in Fig. 17, only three were identified as *A. arcuatus*.

The history of *A. arcuatus* is one of stasis; one specimen is much the same as another through its time range. The same may be said of *A. vigilicus*. Moreover, the presence of a very narrow arcuate area before the radial facet in *A. virgilicus* would indicate an ancestral-descendant relationship with *A. arcuatus*, not the far more populous *A. typicalis*. Both form a minute portion of the entire local apographiocrinid population and (at least for *A. virgilicus*) seem to enter the record suddenly (Figs. 4, 17). Figure 17 does not give the appearence of the transformation of one species into another, a postulate of gradualism. This, along with with the small overlap of geographic range and small populations, may indicate a puntcuated event for the speciation of *A. virgilicus.*

CONCLUSIONS

The general history of the Late Pennsylvanian inadunate crinoid Apographiocrinus Moore and Plummer is one of high morphologic variability in a shallow water, regressive environment followed by rapid (puncuated) speciation and migration into deeper water , transgressive environments. These latter morphs of the genus tend to show stasis through out their history.

Desmoinesian and early Missourian apographiocrinids are all characterized by thicker, more bulbous plates which are thought to add strength to the endoskeleton in a higher energy environment. Later Missourian forms are thinner plated with arms characterized as open-mesh filters in a much lower energy environment.

Species diversities are thought to be generally less than earlier supposed for the genus. High phenotypic variance is thought to explain these high diversities, not the presence of many species.

Speciation appears in all species to occur in small sub-groups of the overall population. These sub-groups are probably isolated from the larger population to a greater or lesser extent. Speciation within the genus has the appearence of puncuated events, not a gradualistic change.

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APPENDIX A

Register of Localities

Locality No.	Unit and Legal Description
1	Altamont Limestone, Oolagah Formation, in and near Tulsa, OK: a) Garnett Quarry, S 1/2 , sec. 28, T. 20 N., R. 14 E. b) on Oklahoma route 33, NW 1/4, sec. 4, T. 19 N., R. 14 E. c) 51st St. in Tulsa, SE 1/4 , SE 1/4 , sec. 27, T. 19 N., R. 14 E. d) west of Mayo Rd., NE 1/4 , sec. 21, T. 19 N., R. 14 E. e) Skelly Dr., east of Tulsa, SE 1/4 , SW 1/4 , sec. 18, T. 20 N., R. 14 E.
2	Perry Farm Shale, Lenapah Formation, SE 1/4, sec. 30, T. 27 N., R. 16 E., Nowata Co., OK
3	Glenpool Limestone bed, Watkins Shale, Holdenville Formation, 10 miles south of Tulsa, OK on Hwy. 75, NW 1/4, NW 1/4, sec. 23, T. 17 N., R. 12 E.
4	Keechi Creek Shale, Mineral Wells Formation, 5.5 miles nw of Mineral Wells, roadcut on west side of Tex-337, Palo Pinto Co., TX
5	Palo Pinto Limestone, Perrin, TX
6A	Upper horizon, Avant Limestone, E 1/2, sec. 25, T. 25 N., R. 12 E., 3 miles west of Ramona, Osage Co., OK
6B	Iola Formation, various localities: a) NW 1/4 , NW 1/4 , NE 1/4 , sec. 19, T. 29 N., R. 14 E., Washington Co., OK b) SE 1/4 , SE 1/4 , sec. 23., T. 29 N., R.13 E., Washington Co., OK c) lease in OK, south of Tyro, KS d) brick pit, Tyro, KS e) Iola, KS
7	Quindaro Shale, Wyandotte Formation, road cut on US-69, Louisburg, KS

8	Lower crinoid horizon, Wann Formation, 'The Mound', SW 1/4, SE 1/4, SW 1/4, sec. 3, T. 26 N., R. 12 E., Bartlesville, OK
9	Upper crinoid hoizon, Wann Formation, 'Hairpin Turn', S 1/2 , sec. 15, T. 25 N., R. 12 E., Osage Co., OK
10	Hickory Creek Shale, Plattsburg Formation,: a) 3.4 miles north of Altoona, KS on Hwy. 75 b) c, S 1/2 , SE 1/4 , SE 1/4 , sec. 17, T. 27 S., R. 15 E., Wilson Co., KS
11A	Captain Creek Limestone, Stanton Formation, 'Patterson's Hog Farm', SW 1/4 , NW 1/4 , NW/4 , sec. 36, T. 33 S., R. 14 E., Montgomery Co., KS
11B	Captain Creek Limestone, Stanton Formation, 2 miles west of reservoir near Copan, C-W. Line, sec. 18, T. 28 N., R. 13 E., Washington Co., OK
12	Kiewitz Shale bed, Stoner Limestone, Stanton Formation: a) NE 1/4 , NE 1/4 , sec. 14, T.12 N., R. 11 E., Cass Co., NE b) SE 1/4 , NE 1/4 , sec. 13, T. 12 N., R. 11 E., Cass Co., NE c) E 1/2 , NE 1/4 , SE 1/4 , NE 1/4 , sec. 16, T. 12 N., R. 11 E., Sarpy Co., NE
13	South Bend Limestone, Stanton Formation, Montgomery Co., KS: a) SW 1/4 , NW 1/4 , sec. 4, T. 34 S., R. 14 E. b) SE 1/4 , NW 1/4 , sec. 4, T. 34 S., R. 14 E. c) NE 1/4 , SW 1/4 , sec. 17, T. 32 S., R. 14 E.
14	Haynies Shale bed, Ervine Creek Limestone, Deer Creek Formation, SW 1/4 , NE 1/4 , sec. 3, T. 10 N., R. 11 E., Sarpy Co., NE
15	Beil Limestone, Lecompton Formation, quarry, SE 1/4 , sec.17, T.10 N., R. 14 E., Cass Co.,NE
16	Camp Creek Shale, Pueblo Formation, near Grosvenor, Brown Co., TX

APPENDIX B

Univariate statistics: Apographiocrinus (Oolagah Limestone)

	Dpa	Ha	La	W a
	5.3	2.1	1.8	2.4
	5.6	2.3	1.7	2.7
	6.5	2.5	2.1	2.5
	6.5	2.8	2.1	3.0
5	6.8	2.9	2.4	3.2
	7.2	2.5	2.2	2.8
	7.2	2.8	2.5	3.1
	7.2	2.7	2.3	3.4
	7.3	2.9	2.1	3.5
10	7.5	3.2	2.6	3.2
	7.5	2.7	2.2	3.6
	7.6	3.0	2.5	2.9
	7.6	2.4	2.1	3.8
	7.7	3.4	2.5	3.0
15	7.8	3.3	2.4	3.5
	7.8	3.5	2.6	3.5
	7.8	3.3	2.5	3.6
	8.0	3.4	2.8	4.0
	8.1	3.6	2.8	3.8
20	8.2	3.5	2.5	3.3
	8.3	3.3	2.5	3.5
	8.3	3.0	2.7	3.7
	8.3	3.1	2.6	3.9
	8.3	3.6	2.5	4.1
25	8.4	3.6	2.8	3.9
	8.5	3.5	2.9	3.4
	8.5	3.6	2.9	3.4
	8.6	3.6	3.0	3.7
	8.6	3.6	3.1	3.9
30	8.7	3.5	3.0	4.1
	8.8	3.7	3.0	4.1
	8.9	4.0	3.1	4.1
	9.0	3.8	3.2	3.7
	9.1	3.8	3.3	4.0
35	9.1	4.5	4.0	4.1
	9.3	3.8	3.3	3.8
	9.3	3.3	2.8	4.2
	9.7	3.5	3.2	4.2
	9.7	3.9	3.2	4.4
40	12.1	5.2	4.0	6.2
AVG	8.12	3.32	2.70	3.63
STD	1.188	0.596	0.505	0.644
VAR	1.410	0.355	0.255	0.415

Univariate statistics: Apographiocrinus (Perry Farm Shale)

	Dpa	Ha	La	W a
	6.7	2.9	2.7	3.2
	8.0	3.0	2.4	4.1
	9.4	3.9	3.2	4.7
	9.5	4.0	3.5	4.8
	10.2	4.7	3.9	5.4
	10.7	4.2	3.7	5.7
	11.6	5.0	4.5	5.7
	11.8	4.3	3.8	6.2
AVG	9.74	4.00	3.46	4.98
STD	1.744	0.741	0.678	0.982
VAR	3.040	0.549	0.460	0.965

Univariate statistics: *Apographiocrinus* (Watkins Shale)

	Dpa	Ha	La	W a
	5.2	2.2	1.2	2.1
	8.1	3.2	2.7	3.5
	9.1	3.8	3.4	4.0
	9.3	4.0	3.4	4.0
5	9.3	3.9	3.4	4.2
	9.7	3.8	3.5	4.4
	9.7	4.6	3.5	4.8
	10.1	4.4	3.8	4.6
	10.2	5.0	4.0	5.0
10	10.3	4.2	3.4	4.5
	10.3	4.4	3.8	4.6
	10.3	4.1	3.7	4.6
	10.3	4.4	4.0	4.7
	10.3	5.0	4.0	5.0
15	10.5	4.8	4.2	4.4
	10.5	5.5	4.3	4.8
	10.5	4.6	3.8	4.8
	10.7	4.9	4.1	4.5
	10.7	4.5	4.1	4.6
20	10.8	4.7	3.8	4.7
	10.8	4.6	4.0	5.2
	10.8	4.9	4.3	5.3
	11.1	5.1	4.5	4.8
	11.2	4.8	4.2	4.5
25	11.4	4.8	4.2	5.5
	11.5	6.0	4.6	5.2
	11.5	5.1	4.4	5.4
	11.7	5.5	4.5	5.3
	11.8	6.0	5.0	5.2
30	12.0	5.6	4.8	5.5
	12.3	5.8	4.3	5.7
	12.3	6.4	5.2	6.0
	12.4	5.8	5.0	5.3
	12.4	5.8	4.6	5.5
35	12.4	5.2	4.6	5.8
	12.4	5.9	4.8	6.1
	12.6	5.1	4.5	5.8
	13.4	6.8	5.7	5.9
	13.5	5.7	4.9	5.9
AVG	10.86	4.89	4.11	4.91
STD	1.518	0.897	0.762	0.764
VAR	2.305	0.805	0.581	0.584

Univariate statistics: Apographiocrinus (Keechi Creek Shale)

	Dpa	Ha	La	W a
	4.9	2.4	1.7	2.2
	8.3	3.8	3.4	4.0
	8.7	4.0	3.7	4.3
	9.0	3.0	3.1	4.2
	9.3	4.0	3.5	4.5
	9.4	4.6	3.2	4.8
	9.7	4.1	3.7	4.6
	10.3	4.1	3.7	5.1
	11.4	4.6	4.0	5.5
AVG	9.00	3.84	3.33	4.36
STD	1.788	0.718	0.673	0.932
VAR	3.198	0.515	0.453	0.868

Univariate statistics Apographiocrinus (Palo Pinto Limestone)

	Dpa	Ha	La	W a
	6.9	2.8	2.4	3.0
	7.5	3.6	3.0	3.2
	7.7	3.2	2.7	3.5
	8.1	3.2	2.9	4.0
5	8.3	3.5	3.0	4.2
	8.8	3.3	3.1	3.8
	8.8	4.0	3.4	4.1
	9.0	4.0	3.4	4.3
	9.3	3.5	3.3	4.2
10	9.4	3.5	3.2	4.5
	9.5	3.8	3.4	4.5
	11.0	4.1	3.5	4.9
AVG	8.69	3.54	3.11	4.02
STD	1.091	0.387	0.329	0.557
VAR	1.190	0.150	0.108	0.311

Univariate statistics: <u>Apographiocrinus</u> (Iola Formation)

	Dpa	Ha	La	W a
	3.3	1.6	1.4	1.8
	4.0	1.5	1.4	1.9
	4.9	2.2	1.8	2.3
	4.9	1.7	1.5	2.4
5	5.1	2.1	1.7	2.9
	5.2	2.3	1.8	2.6
	5.2	2.3	1.8	2.7
	5.5	2.3	2.0	3.0
	5.5	2.3	1.8	2.3
10	5.5	2.3	2.1	2.8
	5.7	2.5	1.9	3.4
	5.8	2.5	2.0	2.9
	6.0	2.6	2.3	3.0
	6.1	2.2	1.9	3.0
15	6.2	2.6	2.0	3.0
	6.2	2.4	2.1	3.2
	6.3	2.5	2.1	3.4
	6.4	2.4	2.2	3.3
	6.5	2.5	2.0	3.3
20	6.5	2.3	2.0	3.4
	7.0	2.3	2.3	3.6
	7.1	2.2	2.3	3.8
	7.1	2.5	2.5	3.4
	7.1	2.9	2.4	4.0
25	7.1	2.8	2.6	3.6
	7.4	2.8	2.4	4.0
	7.5	2.5	2.5	3.8
	7.5	3.0	2.5	3.6
	7.5	2.5	2.4	3.5
30	7.6	3.3	2.8	3.6
	7.8	3.3	2.5	3.9
	7.9	2.6	2.3	4.0
	7.9	3.2	2.8	3.9
	8.6	3.5	2.8	4.3
35	8.7	2.8	2.7	4.4
	9.1	3.8	3.2	4.6
AVG	6.49	2.53	2.19	3.29
STD	1.310	0.488	0.417	0.673
VAR	1.716	0.238	0.174	0.453

Univariate statistics: Apographiocrinus (Avant Limestone, Upper horizon)

	Dpa	Ha	La	W a
	6.5	2.7	2.4	2.2
	6.7	2.8	2.4	3.3
	6.9	2.9	2.5	3.9
	6.9	3.1	2.7	3.7
5	7.0	2.9	2.4	3.4
	7.1	2.8	2.6	3.7
	7.1	2.4	2.4	3.6
	7.1	2.8	2.8	4.0
	7.2	2.8	2.4	3.8
10	7.2	3.0	2.8	3.7
	7.3	2.4	2.6	3.8
	7.4	3.0	2.9	3.9
	7.5	2.9	2.7	4.3
	7.7	2.9	2.6	4.3
15	7.8	2.8	2.8	4.1
	7.9	3.3	2.8	4.3
	7.9	2.8	2.3	3.8
	8.0	2.7	2.5	3.9
	8.0	3.0	2.7	4.1
20	8.0	3.2	2.9	4.5
	8.1	3.6	3.5	4.2
	8.2	3.1	2.6	4.2
	8.2	2.8	2.5	3.8
	8.2	3.4	2.8	4.2
25	8.3	3.2	2.9	4.4
	8.3	3.5	3.1	4.4
	8.4	3.6	3.2	4.8
	8.4	3.1	2.7	3.5
	8.4	3.5	2.9	3.7
30	8.6	3.4	3.0	4.6
	8.8	3.7	3.3	4.4
	9.2	3.4	3.3	4.6
	9.9	4.0	3.5	5.2
AVG	7.82	3.08	2.77	4.01
STD	0.753	0.371	0.321	0.530
VAR	0.567	0.138	0.103	0.281

Univariate statistics: *Apographiocrinus* (Quindaro Shale)

	Dpa	Ha	La	W a
	3.8	1.5	1.3	1.8
	5.7	2.1	1.8	2.4
	6.3	2.3	2.0	3.0
	6.5	2.5	2.2	2.4
5	6.7	2.5	2.1	3.3
	6.9	2.6	2.3	3.1
	7.1	3.1	2.5	3.2
	7.3	2.6	2.3	3.7
	7.3	2.8	2.6	3.7
10	7.3	3.0	2.4	3.4
	7.3	2.8	2.4	3.7
	7.4	3.2	2.8	3.9
	7.4	2.8	2.4	3.7
	7.4	2.9	2.2	3.5
15	7.5	3.0	2.7	3.4
	7.5	3.0	2.5	3.8
	7.6	3.0	2.6	3.4
	7.7	3.2	2.8	3.7
	7.7	2.9	2.4	4.1
20	8.0	2.3	2.3	3.8
	8.1	3.5	3.0	4.2
	8.2	3.7	3.1	4.0
	8.3	3.0	3.0	4.0
	8.5	3.2	2.7	4.5
25	8.7	3.5	3.0	3.9
	8.8	3.0	2.6	4.2
	8.9	3.2	3.1	4.5
	8.9	3.2	2.9	4.5
	9.0	3.4	2.9	4.5
30	9.0	3.2	3.0	4.3
AVG	7.56	2.90	2.53	3.65
STD	1.098	0.458	0.415	0.653
VAR	1.207	0.210	0.172	0.426

Univariate statistics: Apographiocrinus (Wann Formation, The Mound)

	Dpa	Ha	La	W a
	2.9	1.4	1.4	1.8
	3.5	1.4	1.3	1.7
	4.8	1.7	1.5	2.3
	5.7	2.2	2.0	3.1
5	6.2	2.6	2.2	2.7
	6.4	2.5	2.3	3.1
	6.4	3.0	2.6	3.3
	6.5	2.9	2.5	3.3
	6.5	2.5	2.3	3.1
10	6.7	2.4	2.3	3.2
	6.7	3.0	2.2	4.0
	6.8	3.2	2.9	4.1
	6.9	2.4	2.4	3.2
	7.2	2.8	2.5	4.0
15	7.3	2.7	2.6	3.7
	7.4	3.3	2.8	3.9
	7.5	3.2	3.0	3.6
	7.6	3.2	2.8	3.2
	7.6	3.2	3.0	3.8
20	7.6	3.2	2.8	3.7
	7.7	2.8	2.8	4.0
	7.9	3.4	2.9	4.2
	7.9	3.5	3.4	4.8
	7.9	3.1	3.0	3.7
25	8.1	3.0	2.8	3.9
	8.2	3.2	2.8	3.9
	8.2	3.3	2.8	3.8
	8.3	3.5	3.2	4.3
	8.3	3.4	2.8	3.4
30	8.4	3.4	3.1	3.9
	8.5	3.5	2.4	4.7
	9.3	3.4	2.9	4.3
AVG	7.09	2.88	2.57	3.55
STD	1.379	0.579	0.498	0.717
VAR	1.901	0.336	0.248	0.514

Univariate statistics: Apographiocrinus (Wann Formation, Hairpin Turn)

	Dpa	Ha	La	W a
	3.0	1.8	1.3	1.8
	4.5	2.0	1.6	2.3
	4.8	1.9	1.7	2.5
	5.9	2.1	1.9	3.4
5	6.3	2.4	2.3	3.5
	6.4	2.3	2.3	3.3
	6.5	2.3	2.4	3.8
	6.6	2.9	2.5	3.7
	6.6	2.6	2.1	3.5
10	6.7	2.5	2.0	3.5
	6.8	2.7	2.5	3.7
	6.9	2.6	2.6	3.5
	7.0	3.4	2.7	3.9
	7.3	3.2	2.8	4.2
15	7.3	2.7	2.5	3.9
	7.5	3.0	2.9	4.7
	7.6	2.9	2.8	3.8
	7.8	3.0	2.6	4.3
	7.8	3.2	2.7	4.0
20	7.9	2.9	2.4	4.3
	7.9	2.9	2.7	4.1
	8.0	3.7	3.2	4.5
	8.0	2.7	3.1	4.6
	8.1	3.4	2.9	4.5
25	8.3	3.5	2.9	4.2
	8.5	3.0	2.8	4.4
	8.6	3.4	3.0	4.2
	8.7	3.8	3.2	4.2
	8.7	3.4	3.4	4.2
30	9.1	3.5	3.3	4.5
	9.2	3.5	3.2	4.3
	9.3	3.4	2.9	4.4
	9.5	3.6	3.2	4.3
	9.8	3.5	3.2	4.1
35	9.8	3.8	3.0	4.5
	9.9	3.3	3.1	4.4
	10.1	3.6	3.4	4.6
	10.2	3.5	3.4	4.9
	10.3	4.3	3.5	5.3
40	10.5	4.1	3.8	5.3
AVG	7.84	3.06	2.75	4.03
STD	1.668	0.602	0.551	0.708
VAR	2.783	0.363	0.304	0.501

Univariate statistics: Apographiocrinus (Hickory Creek Shale)

	Dpa	Ha	La	W a
	3.9	1.7	1.5	1.9
	4.8	2.0	1.9	2.8
	5.2	2.0	1.8	2.2
	5.2	2.1	1.9	2.8
5	5.3	2.0	2.0	3.0
	5.3	2.0	1.8	2.7
	5.6	2.3	2.2	3.5
	5.7	2.3	2.0	3.3
	5.7	2.0	1.7	3.0
10	6.2	2.7	2.5	3.7
	6.4	2.6	2.2	3.6
	6.4	2.4	1.9	3.5
	6.6	2.5	2.2	3.1
	6.6	2.7	2.8	4.2
15	6.7	2.5	2.2	3.5
	6.7	2.7	2.4	3.0
	6.8	3.2	2.8	3.6
	6.8	2.9	2.6	3.9
	6.9	2.8	2.5	3.4
20	6.9	3.0	2.5	3.5
	6.9	2.6	2.2	3.8
	6.9	3.0	2.4	3.7
	7.1	2.7	2.6	4.0
	7.3	2.9	2.4	3.7
25	7.5	3.4	3.0	3.9
	7.8	2.8	2.7	4.3
	7.8	3.5	3.1	4.6
	8.1	4.1	2.9	4.1
	8.2	3.4	3.3	4.3
30	8.2	2.8	2.8	4.4
	8.4	3.5	2.8	4.1
	8.6	3.3	2.8	4.3
	8.8	3.3	3.4	5.2
	8.8	3.5	3.0	5.1
35	9.0	3.3	3.1	5.0
	9.3	4.1	3.4	4.7
	9.3	4.2	3.6	4.7
	10.2	3.8	3.8	5.2
	10.9	4.8	3.8	5.5
40	11.2	4.8	4.4	6.5
AVG	7.25	2.96	2.62	3.88
STD	1.648	0.758	0.649	0.925
VAR	2.716	0.575	0.421	0.856

Univariate statistics: Apographiocrinus (Captain Creek Limestone, Copan, OK)

	Dpa	Ha	La	W a
	3.9	1.8	1.4	2.0
	4.0	1.6	1.3	1.9
	5.1	2.2	1.7	2.3
	5.2	2.1	1.7	2.5
5	5.5	2.2	1.7	2.3
	5.6	2.1	1.8	2.4
	5.6	2.3	1.9	2.5
	5.6	2.4	2.0	2.4
	5.8	2.1	1.7	2.6
10	5.8	2.2	1.9	2.6
	6.0	2.4	2.0	2.7
	6.1	2.4	2.0	2.7
	6.2	2.6	2.1	2.9
	6.6	2.7	2.3	3.3
15	6.6	2.9	2.3	3.1
	6.7	2.9	2.5	3.0
	6.8	2.9	2.5	3.0
	7.1	2.8	2.3	3.1
	7.5	2.8	2.2	3.5
20	7.5	3.1	2.6	3.4
	7.5	3.1	2.7	3.6
	7.6	2.9	2.5	3.5
	7.6	3.2	2.8	3.2
	7.7	3.2	2.6	3.4
25	7.8	3.2	2.7	3.3
	7.8	3.4	2.8	3.8
	8.0	3.5	3.0	3.7
	8.4	3.4	2.8	3.8
	8.7	3.4	2.9	3.9
30	10.5	4.4	3.9	4.9
AVG	6.69	2.74	2.29	3.04
STD	1.413	0.602	0.554	0.656
VAR	1.997	0.362	0.307	0.430

Univariate statistics: Apographiocrinus (Captain Creek Limestone, Patterson's Hog Farm)

	Dpa	Ha	La	W a
	2.3	1.5	1.0	1.2
	2.6	1.8	0.9	1.4
	2.9	1.8	1.2	1.6
	3.4	1.7	1.3	2.0
5	3.9	2.2	1.4	2.2
	4.0	1.8	1.3	2.1
	4.0	1.5	1.4	1.8
	4.0	2.4	1.4	2.2
	4.3	2.4	1.8	2.6
10	4.4	2.1	1.6	2.1
	4.5	2.1	1.6	2.2
	4.5	1.9	1.5	2.2
	4.6	2.5	1.6	2.3
	4.6	2.1	1.8	2.4
15	4.8	2.3	1.7	2.2
	4.8	1.9	1.7	2.1
	4.9	2.4	1.8	2.5
	4.9	2.1	1.9	2.0
	4.9	2.5	1.9	2.5
20	4.9	2.4	1.9	2.0
	5.0	1.9	1.9	2.5
	5.0	1.5	1.8	2.3
	5.2	2.2	1.9	2.5
	5.2	1.9	1.7	1.6
25	5.3	2.4	2.3	2.8
	5.3	1.9	1.5	2.2
	5.4	2.6	2.0	2.7
	5.4	2.3	2.1	2.1
	5.5	2.4	2.0	2.7
30	5.8	2.2	1.9	2.5
	5.8	2.4	2.0	2.8
	6.0	3.0	2.1	2.8
	6.2	2.7	2.4	3.0
	6.2	2.5	2.1	2.6
35	6.4	2.4	2.1	3.2
	6.4	2.4	2.2	3.0
	7.1	2.8	2.5	3.0
	7.3	3.1	2.5	3.6
	7.7	2.6	2.9	3.7
40	8.0	3.3	2.7	3.3
AVG	5.09	2.25	1.83	2.41
STD	1.257	0.418	0.435	0.546
VAR	1.580	0.175	0.189	0.298

Univariate statistics: Apographiocrinus (Stoner Limestone, Kiewitz Shale bed)

	Dpa	Ha	La	W a
	3.1	1.4	1.1	1.5
	3.5	1.4	1.4	2.2
	4.1	1.6	1.5	2.2
	4.8	1.9	1.8	2.4
5	4.8	2.2	1.8	2.4
	4.9	2.5	2.0	3.0
	5.3	2.1	1.8	3.0
	5.3	2.1	2.2	2.9
	5.5	2.6	2.1	3.1
10	5.9	2.4	2.1	3.3
	5.9	2.6	2.4	3.3
	6.0	2.1	2.3	3.2
	6.2	2.6	2.4	3.3
	6.2	2.8	2.5	3.6
15	6.2	2.6	2.4	3.4
	6.3	2.7	2.3	3.1
	6.3	2.6	2.3	3.4
	6.4	2.8	2.3	3.2
	6.6	2.6	2.2	3.5
20	6.6	2.6	2.5	3.5
	6.8	2.7	2.7	3.6
	6.9	2.9	2.6	3.2
	6.9	2.2	2.2	3.7
	6.9	2.8	2.6	3.6
25	6.9	3.1	2.7	3.5
	7.0	3.0	2.9	4.3
	7.0	3.3	2.9	4.0
	7.1	3.2	2.6	3.7
	7.2	3.2	2.6	3.7
30	7.4	3.6	3.0	4.3
	7.4	3.4	3.1	4.2
	7.4	3.1	2.8	3.6
	7.4	3.4	3.0	4.1
	7.5	3.4	2.8	4.2
35	7.5	3.3	3.0	4.1
	7.8	3.3	2.9	4.0
	7.8	3.7	3.3	4.3
	8.0	3.7	3.3	4.4
	8.1	3.9	3.4	4.7
40	8.7	3.5	3.3	4.9
AVG	6.44	2.77	2.48	3.49
STD	1.241	0.624	0.538	0.714
VAR	1.541	0.390	0.289	0.510

Univariate statistics: Apographiocrinus (South Bend Limestone, Montgomery Co., KS)

	Dpa	Ha	La	W a
	3.2	1.6	1.2	1.6
	3.3	1.4	1.2	1.7
	3.5	1.7	1.3	1.9
	3.9	1.9	1.4	1.8
5	4.0	1.9	1.3	1.9
	4.4	2.0	1.5	2.0
	4.9	1.7	1.6	2.4
	5.0	2.2	2.0	2.7
	5.0	2.4	2.3	2.7
10	5.5	2.0	1.6	2.6
	5.6	2.3	2.2	2.9
	5.9	1.8	1.7	3.4
	5.9	2.5	2.3	3.2
	5.9	2.2	2.0	2.9
15	6.1	2.7	2.1	3.3
	6.2	2.5	2.2	2.9
	6.2	2.5	2.2	3.0
	6.3	2.3	1.9	2.7
	6.7	2.6	2.3	3.7
20	6.7	2.9	2.7	3.4
	6.7	2.5	2.3	3.4
	6.8	2.8	2.2	3.6
	6.8	2.9	2.6	3.9
	6.9	2.8	2.5	3.6
25	7.0	2.8	2.6	3.8
	7.6	2.8	2.3	3.3
	7.7	3.3	2.9	3.9
	7.7	2.8	2.4	3.7
	7.8	2.9	2.7	4.0
30	8.0	3.4	2.9	3.9
	8.0	3.5	2.9	4.2
	8.0	3.3	2.8	3.8
	8.1	3.2	2.8	3.9
	8.2	3.4	2.9	4.2
35	8.2	3.0	2.5	4.4
	8.3	3.1	2.6	4.4
	8.7	3.0	2.8	4.7
	8.9	3.7	3.3	4.4
	9.2	4.3	3.7	5.3
40	9.3	3.5	3.2	4.8
AVG	6.55	2.65	2.30	3.35
STD	1.667	0.646	0.605	0.914
VAR	2.777	0.417	0.366	0.836

Univariate statistics: Apographiocrinus (Ervine Creek Limestone)

	Dpa	Ha	La	W a
	2.8	1.3	1.0	1.4
	3.9	1.6	1.4	2.0
	4.0	1.4	1.4	1.8
	4.6	1.3	1.1	2.3
5	4.8	1.8	1.5	2.3
	4.8	1.8	1.7	2.5
	4.9	1.7	1.5	2.8
	5.7	1.9	1.8	2.8
	6.1	2.5	1.9	3.1
10	6.3	2.8	2.2	3.4
	6.4	2.2	2.1	3.2
	6.5	2.2	2.2	3.4
	6.5	2.6	2.3	3.2
	6.5	2.7	2.1	3.2
15	6.5	2.6	2.2	3.0
	6.7	2.3	2.2	3.5
	6.8	2.1	2.1	3.3
	6.8	2.4	2.2	3.2
	6.8	2.6	2.2	3.3
20	6.9	2.3	2.4	3.4
	6.9	2.7	2.3	3.4
	7.0	2.5	2.3	3.5
	7.0	2.6	2.4	3.4
	7.0	2.0	2.0	3.1
25	7.1	2.5	2.2	3.6
	7.2	2.4	2.3	3.7
	7.2	3.0	2.5	3.4
	7.3	3.0	2.6	3.3
	7.3	2.4	2.2	3.5
30	7.5	2.6	2.5	3.6
	7.5	2.8	2.5	3.7
	7.6	2.4	2.6	3.7
	7.7	2.6	2.7	3.6
	7.7	3.0	2.8	4.4
35	8.1	2.6	2.4	3.8
	8.2	3.2	2.6	3.9
	8.4	3.2	2.7	4.2
	8.5	3.2	3.0	4.2
	8.6	2.5	2.7	4.0
40	9.0	2.9	2.8	4.7
AVG	6.68	2.41	2.19	3.30
STD	1.359	0.505	0.467	0.674
VAR	1.847	0.255	0.218	0.454

PLATE 1

Figures 1-4. Apographiocrinus typicalis Moore & Plummer (hypotype, UNSM-11935), summit, anterior, posterior and basal views, x6.4, Kiewitz shale bed, Stoner Limestone Member, Stanton Formation, loc. 12a.

5-7. A. quietus Strimple (hypotype, SUI-53782a), anterior and basal views, x6.2, Altamont Limestone Member, Oolagah Formation, loc. 1b. Note the arcuate nature of the radial forefacet.

8-10. A. obtusus Strimple (hypotype, SUI-53783a), summit, anterior and basal views, x5.6, Glenpool limestone bed, Watkins Shale Member, Holdenville Formation, loc. 2. Note the almost vertical nature of the radial forefacets.

11. A. typicalis Moore & Plummer (hypotype, UNSM-24886), posterior view showing expelled anal, x4.9, Hickory Creek Shale Member, Plattsburg Formation, loc. 10a.

12-14. A. angulatus Strimple (hypotype, SUI-53781a), summit, anterior and basal views, x8.4, Altamont Limestone Member, Oolagah Formation, loc. 1a. Note the nature of the forefacets and the pronounced scalloped appearence.


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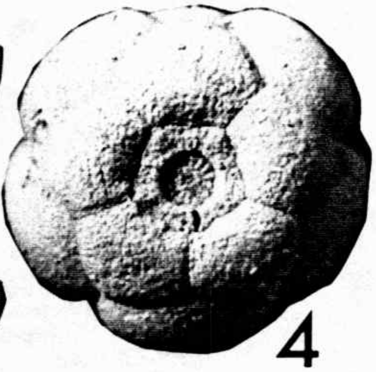
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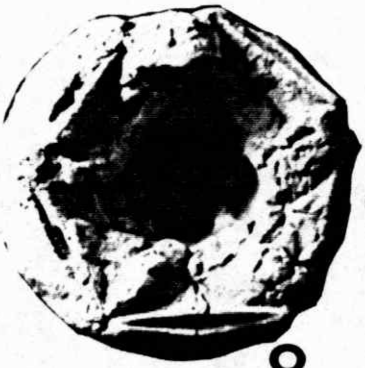
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PLATE 2

Figures 1-3. *Apographiocrinus rotundus* Strimple (hypotype, SUI-53780a), summit, anterior and basal views, x4.6, Glenpool limestone bed, Watkins Shale Member, Holdenville Formation, loc. 3. Note that the radial forefacet is smaller in relative area and more horizontally oriented than in other Desmoinesian forms.

4-6. *A. decoratus* Moore & Plummer (hypotype, UNSM-28392), summit, anterior and basal views, x5.8, Keechi Creek Shale Member, Mineral Wells Formation, loc. 4. Note the vertical and arcuate nature of the forefacets.

7-9. *A. exculptus* Moore & Plummer (hypotype, UNSM-28393), summit, anterior and basal views, x5.4, Keechi Creek Shale Member, Mineral Wells Formation, loc. 4. Note the "wavy" nature of the forefacets.

10-12. *A. facetus* Moore & Plummer (hypotype, SUI-53780b), summit, anterior and basal views, x4.0, Glenpool limestone bed, Watkins Shale Member, Holdenville Formation, loc. 3. Note the arcuate nature of the forefacets.

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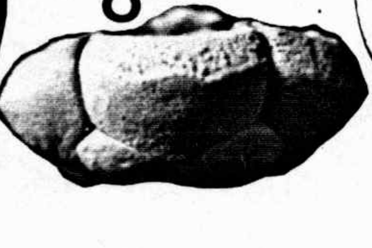

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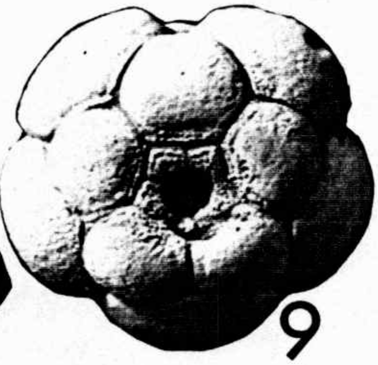

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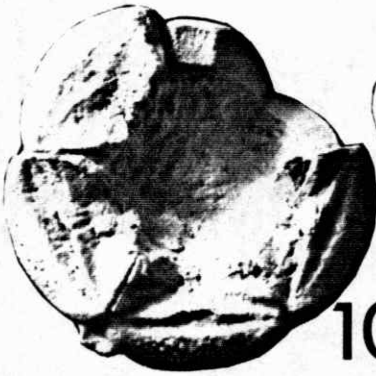

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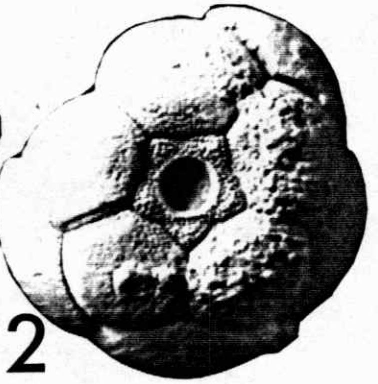

12

PLATE 3

Figures 1-3. Apographiocrinus arcuatus Strimple (hypotype, UNSM-14000),summit, anterior and basal views, x6.2, lower crinoid horizon, Wann Formation, loc. 8. Note that the arcuate forefacets are relatively smaller in area compared to older forms.

4-5. A. virgilicus Pabian & Strimple (hypotype, UNSM-26868), anterior and summit views, x5.9, Captain Creek Limestone Member, Stanton Formation, loc. 11B.

6. A. typicalis Moore & Plummer (hypotype, UNSM-15867), posterior view showing expelled anal, x7.7, Kiewitz shale bed, Stoner Limestone Member, Stanton Formation, loc. 12a.

7-8. A. typicalis Moore & Plummer (hypotypes, UNSM-15655, 17918), view of crowns, x3.2, Kiewitz shale bed, Stoner Limestone Member, Stanton Formation, loc. 12a.

9-11. A. platybasis Pabian & Strimple (holotype, UNSM-16774), summit, anterior and basal views, x4.9, Beil Limestone Member, Lecompton Formation, loc. 15. Note the broad, nearly flat infrabasal disk.

12-14. A. wolfcampensis Moore & Plummer (hypotype, UNSM-19499), summit, anterior and basal views, x4.3, Camp Creek Shale Member, Pueblo Formation, loc. 16.


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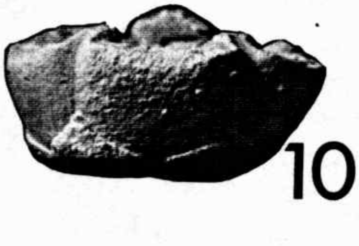
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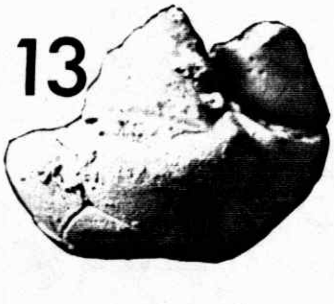
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PLATE 4

Figures 1-3. *Apographiocrinus* sp. (UNSM-15853-15855), crowns, x2.9, Avant Limestone, loc. 6A.

4-7. *Apographiocrinus* sp. (UNSM-18455-18458), crowns, x2.9, upper crinoid horizon, Wann Formation, loc. 9.

8-9. *A. typicalis* Moore & Plummer (UNSM-22699-22700), crowns, x5.4, Captain Creek Limestone Member, Stanton Formation, loc. 11A.

10-13. *A. typicalis* Moore & Plummer (UNSM-21232-21235), crowns, x4.3, Haynies shale bed, Ervine Creek Limestone Member, Deer Creek Formation, loc. 14.


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