PALEONTOLOGY SERIES, VOLUME 1
David D. Gillette, Series Editor

LOWER CARBONIFEROUS ECHINODERMS FROM NORTHERN UTAH AND WESTERN WYOMING

by
Gary D. Webster

Blothrocrinus guntherorum n. sp., holotype, from the Brush Canyon Member, Henderson Canyon Formation, Wellsville Mountain, Utah.

Histocrinus? loganensis n. sp. A ray view of splayed crown with partly disarticulated cup.

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DEPARTMENT OF NATURAL RESOURCES

Webster
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FOREWORD

The science of paleontology has been vital to Utah and surrounding areas since the middle of the nineteenth century. Museums, universities, and government agencies around the world have amassed important collections of Utah fossils. Many of those collections have been pivotal to the overall geologic history of our planet, and more particularly Utah and the western states. More directly, these fossils have played important roles in our understanding of past life on land and in the sea. Scientific interest in Utah's fossils spans the realm of disciplines of natural history: stratigraphy, sedimentology, paleogeography, geochronology, evolution, historical geology, geochemistry, structural geology, taphonomy, biogeochemistry, taxonomy, paleoecology, anatomy, functional anatomy, biomechanics, animal behavior, genetics and more.

Public interest in paleontology in the past two decades has soared with the rise in popularity of dinosaurs, vast improvements in technology, blockbuster museum displays, and spectacular media productions. Nevertheless, the hard work of paleontology, conducted by paleontologists, continues with ever-increasing intensity. Our need to disseminate technical information about Utah's fossil heritage continues to grow. The newly established Utah Geological Survey Paleontology Series will serve to partially satisfy that need.

This publication, written by one of the leading experts in the subject, is the first technical publication in the Paleontology Series. During the early part of the Mississippian Period, the region now called northern Utah and western Wyoming was under marine waters, in a shallow sea where invertebrates thrived. Marine sediments accumulated in a back arc fold, a geological setting that has only recently been recognized for this area. This publication describes echinoderms (crinoids and echinoids) that lived in that back arc fold setting and addresses important aspects of their paleobiological significance, such as paleogeographic distribution and relationship to other faunas of similar age, and faunas both older and younger.

As the first description of an Early Mississippian echinoderm fauna from Utah, this study extends the recognized paleogeographic distribution of many of the taxa and includes descriptions and illustrations of new genera and species. Overall, it provides significant new information about the geologic history of Utah and its fossils, important to both the public and professional geologists for personal, general, and academic interests. This publication will be the primary reference for (1) future studies of Early Mississippian echinoderms throughout Utah and adjacent states, and (2) research on echinoderms and invertebrate paleontology of Early Mississippian with regional, national, and global perspectives.

Gary D. Webster, the author of this publication, was born in Hutchinson, Kansas and has been on the faculty of the Department of Geology at Washington State University since 1968, currently at the rank of Full Professor. His education includes Bachelor of Science Degree from the University of Oklahoma (1956), Master of Science Degree from the University of Kansas (1959), and Ph.D. from University of California Los Angeles (1966). He began studying late Paleozoic crinoids of Utah, Nevada, and Arizona in 1961. Gary is the only Paleozoic crinoid specialist living and teaching in the western United States. He has published more than 70 professional papers in international journals, geological surveys, and guidebooks. Gary has published one monographic paper on the Middle Mississippian crinoids (1987), two on the Permian crinoids of southern Nevada (1966, 1967), and a major paper describing Late Mississippian and Pennsylvanian crinoids of Utah, Arizona, and Nevada, all jointly with N. Gary Lane (Emeritus Professor, University of Indiana). He has also published three major papers on Permian crinoids of Australia (1987, 1990, 1992) and nearly thirty shorter papers on crinoids. Gary continues to compile the Bibliography and Index of Paleozoic Crinoids, a project started in 1968 that resulted in five important publications by the Geological Society of America.

With 35 years of experience, Gary is the recognized expert on late Paleozoic crinoid faunas of western North America; Permian crinoid faunas of the world; and Mississippian and Pennsylvanian conodonts, microscopic fossil relatives of the vertebrates. A dedicated field paleontologist, Gary has made extensive collections of crinoids in the American West. He considers the months spent collecting crinoids in Utah, Nevada, and Montana to be some of the most productive and pleasant field experiences of his career.

David D. Gillette, Paleontology Series Editor and State Paleontologist, December 4, 1996

Editor's Note: In keeping with scientific practice, all measurements in this bulletin are metric. To convert metric dimensions to English units, use the following equivalents:

1 mm (millimeter)	=	1/1000 cm	=	0.04 inches
1 cm (centimeter)	=	1000 mm	=	0.4 inches
1 m (meter)	=	1000 cm	=	39 3/8 inches, or 3.28 feet
1 km (kilometer)	=	1000 m	=	0.621 mile

1 inch	= 25.4 mm, or 2.54 cm
1 foot	= 305 mm, or 30.5 cm
1 yard	= 915 mm, or 91.5 cm
1 mile	= 1.61 km

Or, use the following conversion factors:

To convert millimeters to inches: multiply by 0.039
To convert centimeters to inches: multiply by 0.394
To convert meters to feet: multiply by 3.281
To convert meters to yards: multiply by 1.094
To convert kilometers to miles: multiply by 0.621

TABLE OF CONTENTS

ILLUSTRATIONS

TABLES

LOWER CARBONIFEROUS ECHINODERMS FROM NORTHERN UTAH AND WESTERN WYOMING

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ABSTRACT

Lower Carboniferous echinoderm faunas are described from the Henderson Canyon Formation of northern Utah and western Wyoming. Faunas are reported from six intervals, two from each of the three members of the Henderson Canyon Formation. The faunas range in age from the *Sipohonodella isosticha* - Lower *Siphonodella crenulata* into the *Polygnathus communis carina* Conodont Biozones. They lived on a back arc fold to the west of a trough and carbonate ramp in Wyoming. The most abundant and diverse faunas are from the peloidal bank of the Brush Canyon Member and lived in a shallow water setting above normal wave base. This is the first recognition of Paleozoic crinoid faunas from a back arc fold setting. Time correlative faunas with several common taxa occur in the carbonate ramp setting of the Lodgepole and Banff Formations of Montana and Alberta.

The described faunas include 45 taxa: 17 camerates, 22 inadunates, three flexibles, one blastoid, and two echinoids. New crinoid taxa introduced are the camerates: *Cribanocrinus honeyvillensis* n. sp., *Paradichocrinus wellsvillensis* n. sp., *Platycrinites beirdneauensis* n. sp., and *Platycrinites portiotortuosus* n. sp.; and the inadunates: *Zygiosocrinus typicus* n. gen, n. sp., *Scytalocrinus occiduus* n. sp., *Bridgerocrinus jamisoni* n. sp., *Histocrinus? loganensis* n. sp., *Blothrocrinus guntherorum* n. sp., *Aphelecrinus? utahensis* n. sp., *Paracosmetocrinus utriculus* n. sp., *Paracosmetocrinus rotundus* n. sp., *Paracosmetocrinus peterseni* n. sp., *Apokryphocrinus wellsvillensis* n. gen., n. sp., and *Adiakritocrinus oviatti* n. gen., n. sp. The new echinoid is *Aarchaeocidaris strawberryensis* n. gen., n. sp. Nineteen taxa are left in open nomenclature although four are judged to represent new genera and most represent new species.

INTRODUCTION

An abundance of crinoid ossicles was noted in the early reports of Lower Carboniferous strata of northern Utah and southeastern Idaho (King, 1876; Mansfield, 1927; among others). Articulated crinoid cups and crowns, however, were not reported. Collections of the past 50 years and especially the past 15 years have found significant numbers of well-preserved crinoid cups and crowns along with a few echinoids, blastoids, and asterozoans in the Gardison Limestone of the Wasatch Range, Henderson Canyon Formation of the Bear River Range, Wellsville Mountain, and northern parts of the Wasatch Range of northern Utah, as well as in the Lodgepole Limestone of western Wyoming (figure 1).

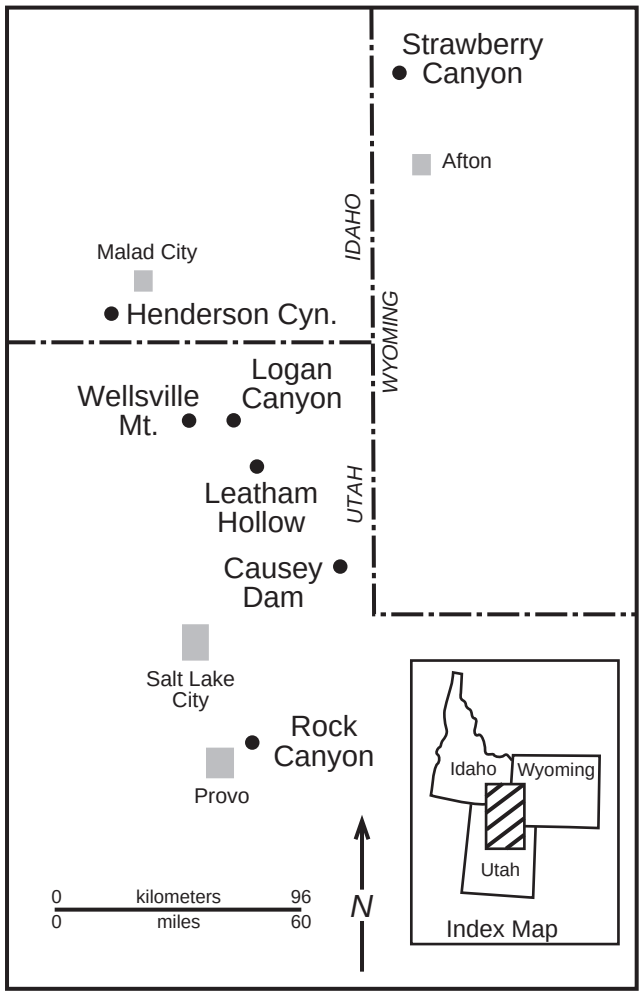

Figure 1. *Locality map, showing general specimen locations. For detailed locality information see appendix.*

The purposes of this paper are to describe the crinoids, blastoid, and echinoids from northern Utah and western Wyoming, discuss their relationship to previously described faunas from North America and Europe, and relate their stratigraphic occurrences to conodont zonations and their geographic occurrence to recent interpretations of the regional carbonate facies and tectonic setting.

STRATIGRAPHY

Lower Carboniferous strata of the northern Wasatch region were previously referred to the Madison Formation (Holland, 1952) and its lower member the Lodgepole Limestone (Strickland, 1956, 1960). Stratigraphic studies (Wickwire and others, 1985, among others) during the past two decades, however, have resulted in the recognition of carbonate strata of sufficiently distinct facies in the northern Utah and southern Idaho region that they were designated the Henderson Canyon Formation by Webster and others (1987). The Henderson Canyon Formation is the lateral time equivalent of the Lodgepole Limestone and basal part of the Mission Canyon Formation as recognized in western Wyoming and central Montana (figure 2). It is a shallowing-upward, offshore peloidal bank (Chen and Webster, 1994) containing numerous debris flows of tempestite origin in the lower and middle parts and coarse grainstone in the upper part. The Henderson Canyon Formation (Webster and others, 1987) weathers as a lower cherty cliff (Chinese Wall Member), overlain by a poorly to moderately exposed, alternating ledge- and slope-forming unit (Brush Canyon Member), and a less cherty upper cliff (Devil Creek Member). These three members represent four major shallowing-upward cycles (Chen and Webster, 1994)

All members of the Henderson Canyon Formation contain some articulated crinoid pluricolumnals, thecae, and crowns, but they are most abundant in thin grainstones. In the Logan Canyon area the Chinese Wall Member locally contains an abundance of pluricolumnals up to 15 cm in length. In some of the beds columnals and pluricolumnals form grainstones in a carbonate mud matrix. Most of the well-preserved thecae and crowns are found along bedding planes at the top of grainstones in the middle to upper part of the Brush Canyon Member with fewer thecae and crowns in grainstones of either the Chinese Wall or Devil Creek Members.

In the Wasatch Mountains near Provo, Utah, strata equivalent to the Henderson Canyon Formation are the Fitchville Formation and the basal part of the overlying Gardison Limestone (Sandberg and Gutschick, 1979, among others). In general, these units are coarse grainstones with fewer debris flows and fewer articulated echinoderm specimens. A conodont zonation (figure 2) for the Henderson Canyon Formation and the Gardison Limestone, extending from the *Siphonodella isosticha* - Lower *Siphonodella crenulata* Biozone into the *Polygnathus communis carina* Biozone, was established in studies by Sandberg and Gutschick (1979), Newman (1980), Wickwire and others (1985), and Webster and others (1987). Conodont recoveries within the Brush Canyon Member are low based on sampling intervals at the meter level. More closely spaced sampling may ultimately provide a more precise location of the uppermost occurrence of the top of the *Siphonodella isosticha*-Upper *Siphonodella crenulata* Biozone, but it will probably correspond to, or be within a meter or two of, the currently recognized uppermost occurrences reported by Chen and others (1994). Newman (1980) reported a barren conodont interval in the upper part

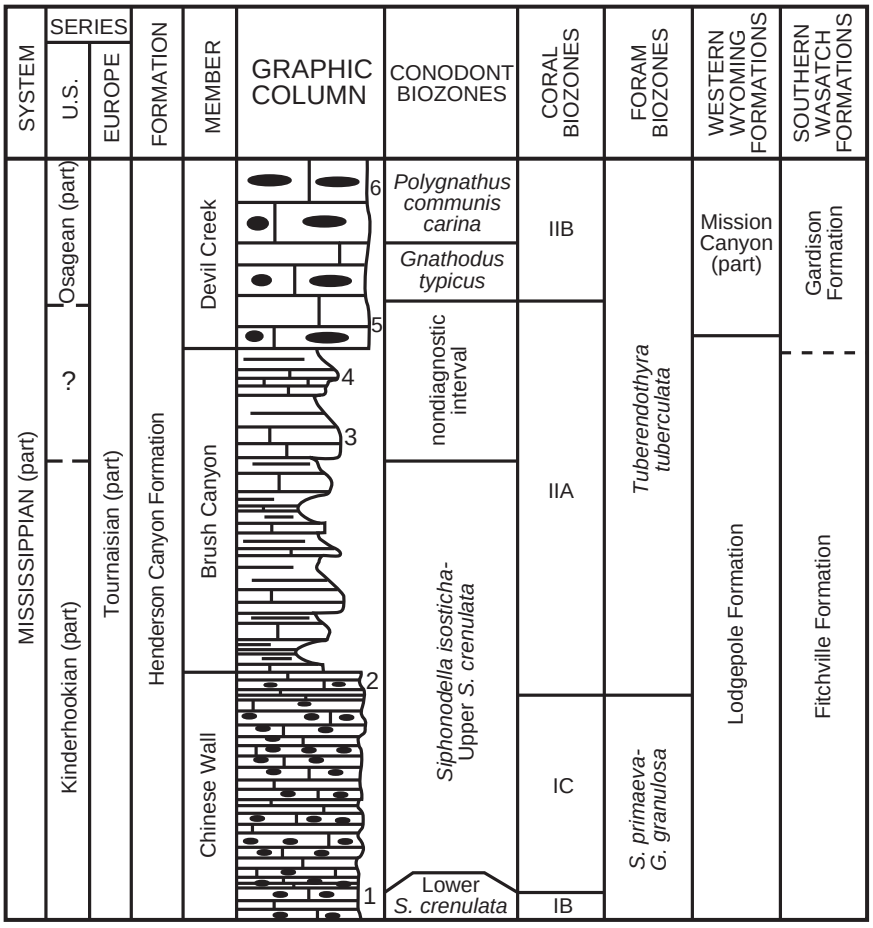

Figure 2. *Generalized graphic column of the Henderson Canyon Formation with invertebrate biozones and adjacent correlative lithostratigraphic units. Thickness of graphic column not to scale. Thickness range of each member of the Henderson Canyon Formation as reported by Webster and others (1987) is: Chinese Wall Member, 16.86 - 83.4 m; Brush Canyon Member, 43.7 - 89.6 m; Devil Creek Member, 30 - 58.2 m. Crinoid intervals are indicated by numbers 1 through 6 and black ovals represent chert nodules on graphic column. Conodont biozones after Chen and others (1994). Coral biozones after Sando and Bamber (1985). Foram biozones after Derewetzky (1995); S. =* ***Septaglomospiranella****, G. =* ***Granuliferella****.*

of the Fitchville Formation at Rock Canyon, near Provo, that is correlated here to the non-diagnostic conodont interval in the upper part of the Brush Canyon Member reported by Webster and others (1987) at Causey Reservoir and Logan Canyon in the northern Wasatch and at Gardner Canyon in the Samaria Mountains of southern Idaho.

At Strawberry Canyon, along the western edge of the thrust belt of western Wyoming, the Lodgepole Limestone consists of 169 m of debris flows with a few coarser grainstones in the upper third. Relatively few megafossils were found in the deeper water debris flows in the section reported by Chen and others (1994). Conodonts, however, were abundant, except in the uppermost 17 m of the coarser grainstones. The lower 152 m of the Lodgepole Limestone contained conodonts of the *Siphonodella isosticha*-Upper *Siphonodella crenulata* Biozone. The upper 17 m yielded few conodonts and was considered part of the non-diagnostic interval by Chen and others (1994). At Haystack Peak, on the north side of Strawberry Canyon, Sando and others (1981) placed the Kinderhookian-Osagean boundary in the lower part of the Woodhurst Member of the Lodgepole Limestone, well below where it would be placed on the conodonts as reported by Chen and others (1994).

In central Montana, Laudon and Severson (1953) considered the Lodgepole Limestone and most of the overlying Mission Canyon Formation to be Kinderhookian based on their identification of crinoids and brachiopods. Klapper (1966) reported that the basal 5 m of the Lodgepole Limestone at several localities in central Montana contained conodonts of the *Siphonodella isosticha*-Lower *Siphonodella crenulata* Biozone. Sando and others (1969) placed the Kinderhookian-Osagean boundary in the basal part of the Woodhurst Member of the Lodgepole Limestone. Conodont recovery in association with crinoid crowns (Webster, unpublished data) from several localities in the Big Snowy Mountains, Belt Mountains, Bridger Range, and Gravelly Range of central Montana agrees with Klapper's (1966) view that the basal few meters of the Lodgepole Limestone belongs to the Lower *Siphonodella crenulata* Biozone. Most of the overlying part of the Lodgepole Limestone yielded species of the Upper *Siphonodella crenulata* Biozone with only the uppermost 15 to 25 m yielding few conodont specimens and considered part of the non-diagnostic interval of Chen and others (1994). A detailed conodont study, with a meter or less sampling interval, is needed for the Lodgepole Limestone at several localities in central Montana to determine a more precise position of the biozone boundaries throughout the region. Based, however, on the preliminary coarse sampling intervals in central Montana and the detailed section at Strawberry Canyon, the Lodgepole Limestone is here considered to be mostly of Tournaisian 2 (Tn2) age, with only the upper few meters of Tn3 age. This means that the Lodgepole Limestone is essentially restricted to the Kinderhookian.

Foraminiferal biozones within the Henderson Canyon Formation at Gardner Canyon and Lodgepole Formation at Strawberry Canyon include the *Granuliferella granulosa-Septaglomospiranella primaeva* Biozone overlain by the *Tuberendothyra tuberculata* Biozone (Derewetzky, 1995). The contact between these two biozones is within the upper part of the Upper *Siphonodella crenulata* Biozone and corresponds to the Chinese Wall-Brush Canyon contact at Gardner Canyon, Samaria Mountains, Idaho.

European series names (figure 2) are applied to the Henderson Canyon Formation because the Kinderhookian-Osagean boundary, which occurs within the upper parts of the formation, has been defined in the standard midcontinent sections on an unconformity separating the two series. Recent studies of this boundary problem in the western U. S. (Chen and others, 1994), concluded that deposition was continuous in the Henderson Canyon Formation across the time interval equivalent to the unconformity as recognized in the midcontinent, however, a boundary must be defined on a paleontological basis before its position can be determined in other areas. On the basis of foraminifera and conodont occurrences the Henderson Canyon Formation spans the interval from middle Tn2 into early Tn3 or middle Kinderhookian (*Siphonodella isosticha*-Lower *Siphonodella crenulata* Biozone) into early Osagean (*Polygnathus communis carina* Biozone). As noted by Chen and others (1994) the Kinderhookian-Osagean boundary has been proposed for any of several fossil levels from the last occurrence of *Siphonodella* to the base of the *P. communis carina* Biozone. I currently consider the Kinderhookian-Osagean boundary to be the base of the *Gnathodus communis carina* Biozone. Until agreement on a defined Kinderhookian-Osagean boundary is attained, the European series terms should be followed for clarity.

CRINOID FAUNAS AND CORRELATION

Major North American Kinderhookian crinoid faunas have been reported from the Cuyahoga Formation of Ohio (Hall, 1863, 1864; Hall and Whitfield, 1875; Roeser, 1986), Hampton and Gilmore City Formations of Iowa (Laudon, 1933; Laudon and Beane, 1937), Lodgepole Limestone of Montana (Laudon and Severson, 1953), and Banff Formation of Canada (Laudon and others, 1952). Major Osagean faunas are more abundant and have been reported from several formations in Iowa, Illinois, Indiana, Tennessee, Kentucky, and Missouri (Wachsmuth and Springer, 1897; Kammer and Ausich, 1994, among many others), the Lake Valley Formation in New Mexico (Miller, 1881; Laudon and Bowsher, 1941), the Redwall Limestone in Arizona (Brower, 1970) and the Anchor Limestone in southern Nevada (Webster and Lane, 1987). Webster and Lane reported a possible late Kinderhookian age for the basal part of the Anchor Limestone, but Webster (unpublished data) has since found conodonts including *Polygnathus communis carina* at two localities in the basal-most part of the Anchor Limestone in the Arrow Canyon Range, Nevada, indicating an Osagean age for the oldest crinoid taxa of the Anchor Limestone. Webster (1991) reported undescribed Osagean crinoid faunas from western Montana, Utah, and Nevada. Correlative faunas with many of the same genera are also known from middle and late Tournaisian strata of Ireland and Scotland (Wright, 1951-

1956; Ausich and Sevastopulo, 1993), and a few late Tournaisian faunas are known from Russia (Yakovlev and Ivanov, 1956). Nearly all of these faunas show an association of abundant dichocrinids, platycrinitids, actinocrinitids, and primitive poteriocrinitids, with rare flexibles. In addition, rhodocrinitids and mastigocrinids are moderately to poorly represented in these faunas. In North America, batocrinids and synbathocrinids are common in the younger faunas. Microcrinoids are also known from many, but have not been looked for, or reported, from some of these faunas. Although species of camerates dominate most of these faunas numerically, the inadunates are the most diverse on some association slabs (see discussion below). Associated echinoderms are blastoids, echinoids, and rarely asterozoans. Only the blastoids have been described (Macurda, 1970; Sprinkle and Gutschick, 1990, among others) in significant numbers, but generally are much less abundant than the crinoids.

The echinoderms reported from the Henderson Canyon Formation are described or discussed in the Systematics Section. They are:

Crinoids
- Camerates
  - *Rhodocrinites* sp., cf. *R. macrotumidus* Laudon and Severson, 1953
  - Rhodocrinitid? indet.
  - *Cribanocrinus honeyvillensis* n. sp.
  - *Cusacrinus kuenzii* sp. (Laudon, Parks, and Spreng, 1952)
  - *Cusacrinus* sp. 1
  - *Cusacrinus* sp. 2
  - *Cusacrinus* sp. 3
  - *Cactocrinus* sp., cf. *C. magnidactylus* (Laudon and Severson, 1953)
  - *Dichocrinus laudoni* Broadhead, 1981
  - *Dichocrinus quadriceptatu*s Laudon and Severson, 1953
  - *Dichocrinus delicatu*s Wachsmuth and Springer, 1897
  - *Dichocrinus* sp.
  - *Paradichocrinus wellsvillensis* n. sp.
  - *Platycrinites bozemanensis* (Miller and Gurley, 1897)
  - *Platycrinites canadensis* Laudon and Severson, 1953
  - *Platycrinites* sp., cf. *P. canadensis* Laudon and Severson, 1953
  - *Platycrinites beirdneauensis* n. sp.
  - *Platycrinites portiotortuosus* n. sp.
- Inadunates
  - *Cyathocrinites* sp.
  - *Zygiosocrinus typicus* n. gen., n. sp.
  - Rhenocrinidae?, genus and species unnamed
  - *Scytalocrinus occiduus* n. sp.
  - *Bridgerocrinus fairyensis* Laudon and Severson, 1953
  - *Bridgerocrinus jamisoni* n. sp.
  - *Histocrinus? loganensis* n. sp.
  - Scytalocrinidae n. gen., n. sp. undesignated
  - Scytalocrinidae indet.
  - *Blothrocrinus guntherorum* n. sp.
  - *Blothrocrinus* n. sp. undesignated
  - *Aphelecrinus? utahensis* n. sp.
  - Aphelecrinidae? n. gen., n. sp. undesignated
  - *Paracosmetocrinus madisonensis* (Laudon and Severson, 1953)
  - *Paracosmetocrinus utriculus* n. sp.
  - *Paracosmetocrinus rotundus* n. sp.
  - *Paracosmetocrinus peterseni* n. sp.
  - *Apokryphocrinus wellsvillensis* n. gen., n. sp.
  - *Pelecocrinu*s n. sp. undesignated
  - *Adiakritocrinus oviatti* n. gen., n. sp.
  - Poteriocrinid indet.
  - Primitive poteriocrine *insertae sedis* n. gen., n. sp.
- Flexibles
  - Taxocrinid indet. #1
  - Taxocrinid? indet. #2
  - *Ainacrinus* sp.

Blastoids
- *Cryptoblastus?* sp.

Echinoids
- *Archaeocidaris?* sp.
- *Aarchaeocidaris strawberryensis* n. gen., n. sp.

The stratigraphic distribution of the crinoids described herein is provided in table 1 (appendix). It is emphasized that no single locality yielded all the specimens reported for the specific stratigraphic level indicated except for those from the Gardison Limestone and Devil Creek Member of the Henderson Canyon Formation.

Six crinoid intervals are recognized within the Henderson Canyon Formation. These are referred to as intervals because many of the crinoids are recognized as coming from two, three, or a few closely spaced beds. Some or all of these beds yielded crinoids. The time duration of individual beds in each crinoid interval is uncertain, but could represent tens to a few tens of thousands of years (Flessa and Kowalewski, 1994). The bedding surface between adjacent tempestites in crinoid intervals one through four could represent the time between major storm events.

Nearly a third of the specimens are from float blocks, and, although an approximate stratigraphic position can be determined for many of these blocks, the repeated lithologies in the tempestites and marginal exposures at several localities preclude recognition of the exact stratigraphic level for each specimen. Echinoderm associations found on the same bedding plane are listed in table 2 (appendix). Unfortunately, at this time it is impossible to determine all associations within some of the levels, especially where some of the specimens are from float blocks. In addition, specimens are reported from the Gardison Limestone, near Provo, Utah and the Lodgepole Limestone, north of Afton, western Wyoming.

The lowest crinoid interval, from three to four meters above the base of the Chinese Wall Member of the Henderson Canyon Formation, is of Tn2 age, basal-most part of the *Siphonodella isosticha* -Upper *Siphonodella crenulata* Conodont Biozone and *Granuliferella granulosa-Septaglomospiranella primaeva* Foraminifera Biozone. Crinoid debris is common in the basal part of the Chinese Wall Member, but articulated cups and crowns are not common or are masked

by complete silicification of beds. The occurrence of *Rhodocrinites* cf. *R. macrotumidus* in this interval suggests correlation with the Lodgepole Limestone from where *R. macrotumidus* was described (Laudon and Severson, 1953). No stratigraphic horizon was designated for *R. macrotumidus* by Laudon and Severson, but I have found the species in the middle and upper part of the Lodgepole Limestone at Swimming Woman Canyon in the Big Snowy Mountains and in the middle part of the Lodgepole Limestone in the Bridger Range of Montana (Webster, unpublished data). Apparently widespread, *Rhodocrinites macrotumidus,* ranges at least through the middle and upper parts of the Lodgepole Limestone.

Crinoid interval two, of slightly younger Tn2 age, occurs in the upper two to three meters of the Chinese Wall Member and is within the middle part of the Upper *Siphonodella crenulata* Biozone (Chen and others, 1994) and uppermost part of the *Granuliferella granulosa-Septaglomospiranella primaeva* Biozone (Derewetzky, 1995). Crinoid taxa within this interval supporting correlation with the Lodgepole faunas are *Cactocrinus* sp., cf. C. *magnidactylus*, *Cusacrinus* sp. 2, *Platycrinites beirdneauensis* n. sp., and *Paracosmetocrinus peterseni* n. sp. At the generic level these taxa also support correlation with Kinderhookian faunas of Iowa (Gilmore City and Hampton faunas) and Alberta, Canada (Banff faunas). *Cactocrinus magnidactylus* was reported by Laudon and Severson (1953, p. 508) from the "upper crinoid zone, Fairy Lake area" in the top of cycle three of the Lodgepole Formation (lower middle part of the formation), which probably approximates the second crinoid interval in the Chinese Wall Member based on stratigraphic position, crinoid fauna, and conodont biozones. The occurrence of *Ainacrinus* sp. in the Chinese Wall Member is surprising as the genus has previously been reported only from Visean strata of Scotland.

The third crinoid interval, late Tn2 age, is the largest and most diverse fauna recognized within the Henderson Canyon Formation. If all of the crinoids listed in table 1 (appendix) as from an unknown level (probably upper middle part of the Brush Canyon Member) are actually from interval three, the number of taxa from interval three would be more than doubled. Most of the taxa reported from an unknown level or levels are most likely from the lower ledge of the Brush Canyon Member, but a few may be from the upper ledge. Crinoid interval three is in the upper part of the Upper *Siphonodella crenulata* Biozone, extending into the basal part of the non-diagnostic interval, and upper lower part of the *Tuberendothyra tuberculata* Biozone. This fauna is most closely related to, but definitely younger than, the "upper crinoid zone, Fairy Lake area" in the top of cycle three of the Lodgepole Limestone reported by Laudon and Severson (1953, p. 508) from the Bridger Range, Montana. Similar faunas to the upper crinoid zone of the Fairy Lake area occur in the Lodgepole Limestone at approximately the same level in the Big Snowy Mountains (Laudon and Severson, 1953), Little Belt Mountains and Tobacco Root Range of Montana (Webster, unpublished data). Also, the faunas reported by Laudon and others (1952) from the Banff Formation of Alberta contain a number of the same taxa, but their stratigraphic position may be younger than the upper crinoid zone of the Fairy Lake area, as they are in the upper crinoid interval some 1400 feet above the base of the Banff Formation at Sunwapta Pass (Laudon and others, 1952) here considered slightly older than or nearly equivalent to crinoid interval three of the Henderson Canyon Formation. Taxa in common with the Lodgepole faunas are *Platycrinites canadensis, Dichocrinus laudoni, D. quadriceptatus, Bridgerocrinus fairyensis,* and *Paracosmetocrinus madisonensis* at the species level and *Rhodocrinites, Cribanocrinus,* and *Pelecocrinus* at the genus level. Taxa in common with the Banff Formation are *Cusacrinus kuenzii* and *Dichocrinus quadriceptatus* at the species level and *Rhodocrinites, Cribanocrinus, Platycrinites, Pelecocrinus,* and *Paracosmetocrinus* at the generic level. If some of the inadunate taxa currently referred to as Scytalocrinidae and Aphelecrinidae could be confidently identified to the generic level it is possible that additional correspondence between crinoid interval three and the Lodgepole and Banff faunas would be recognized. The abundance and diversity of the inadunates in each of these faunas provides added support for their correlation. Differences in the faunas are judged to reflect environmental differences in the carbonate microfacies within each of the areas.

At the generic level crinoid interval three also shows similarity to the Hampton and Gilmore City faunas of Iowa (Laudon, 1933; Laudon and Beane, 1937) and the Waverly Sandstone fauna of Ohio (Hall, 1863, 1864; Hall and Whitfield, 1875; Roeser, 1986). Woodson and others (1989) reported the coral *Stelechophyllum* and the last occurrence of *Siphonodella* from the lower part of the Gilmore City Formation. These occurrences are tentatively correlated with the uppermost part of the Brush Canyon Member of the Henderson Canyon Formation and the base of the upper 17 meters of the Lodgepole Formation where the highest *Siphonodella* and abundant *Stelechophyllum* were reported by Webster and others (1987) and Chen and others (1994). Facies control and lack of other biozonal indicators preclude a more definitive correlation at this time. *Dichocrinus quadriceptatus* in the interval three fauna is similar to *D. rotaii* and *D. tomiensis* reported by Yakovlev and Ivanov (1956) from Tn2 strata of the Kuznetz Basin of Russia.

Crinoid interval four is from the ledge-forming upper part of the Brush Canyon Member, within the non-diagnostic conodont interval (Chen and others, 1994), and within the middle part of the *Tuberendothrya tuberculata* Biozone (Derewetzky, 1995). It is the second largest crinoid fauna in diversity and numbers and occurs within 10 to 15 m above interval three fauna to which it is closely allied. The highest stratigraphic occurrence of *Stelechophyllum* in the Henderson Canyon Formation occurs within the base of interval four. At the generic level three taxa, *Cusacrinus, Rhodocrinites,* and *Platycrinites* are common to intervals three and four and the Lodgepole Limestone of Montana. The occurrence of *Aarchaeocidaris* n. gen. in interval four at Beirdneau Hollow in Logan Canyon is younger than the occurrence in the Upper *Siphonodella crenulata* Biozone of the Lodgepole Limestone at Strawberry Canyon. Some generic level taxonomic corre-

spondence of interval four with the Kinderhookian (Hampton, Gilmore City, and Cuyahoga faunas) and Osagean (Burlington and Keokuk faunas and equivalents) of the Illinois Basin and adjacent shelf is also recognized. The correlations with the Kinderhookian faunas are stronger as interval four lacks crinoid taxa such as advanced actinocrinitids (for example, *Physetocrinus*), eretmocrinids, agaricocrinids, and batocrinids that are common in the Osagean faunas of the Midcontinent and southwestern U. S. (Wachsmuth and Springer, 1897; Brower, 1970; Webster and Lane, 1987). This suggests an age for interval four of late Kinderhookian, late Tn2.

The fifth crinoid interval is from the basal part of the Devil Creek Member and is of latest Tn2 or earliest Tn3 age, within the non-diagnostic conodont interval (Chen and others, 1994) or *Gnathodus typicus* Biozone (Sando and others, 1981) and upper part of the *Tuberendothyra tuberculata* Biozone (Derewetzky, 1995). Occurrence of *Platycrinites bozemanensis* at this level is an extension of its previously recognized range within the Lodgepole Limestone of Montana.

Crinoid interval six, in the upper half of the Devil Creek Member, is within the *Polygnathus communis carina* Conodont Biozone (Chen and others, 1994), the upper part of the *Tuberendothyra tuberculata* Biozone (Derewetzky, 1995), and is of Tn3 age. It has yielded a single specimen of an indeterminate taxocrinid providing no firm basis for crinoid correlation of the unit. With future collection, intervals five and six will probably provide a few additional specimens of articulated crinoids which will hopefully provide a better understanding and correlation of their faunas.

The Henderson Canyon faunas show generic affinity in *Platycrinites* and *Cusacrinus* with the Osagean faunas of the Redwall Limestone of Arizona, Anchor Limestone of southern Nevada, and Lake Valley Formation of central New Mexico. Both of these genera, however, range higher in the Osagean, normally occurring with batocrinids, agaricocrinids, cyathocrinitids, and advanced actinocrinitids, that are not present in the Henderson Canyon faunas and imply an older age for the Henderson Canyon faunas, intervals 1-4. Conodonts from the Anchor and Redwall Limestones confirm the crinoid interpretation as the crinoidal-rich parts of these formations yield conodonts of the *Polygnathus communis carina* Biozone or *Pseudopolygnathus multistriatus* Biozone and younger biozones (Pierce and Langenheim, 1974; Racey, 1981; Webster, unpublished data).

PALEOENVIRONMENTAL SETTING

It was initially assumed that the echinoderm-bearing deposits of northern Utah were distal deposits on a carbonate ramp deepening westward from central Wyoming as described by Elrick and Read (1991). More recent carbonate studies of the western Wyoming, eastern Idaho, and northern Utah region have shown that a back arc fold occurs in the vicinity of Samaria Mountain in eastern Idaho and the northern Wasatch Range in northern Utah and that it is separated from the ramp to the east by a trough in western Wyoming (Chen and Webster, 1994). The gentle back arc fold formed as a response to tectonic loading to the west (Chen and Webster, 1994). The shallowing upward Chinese Wall Member formed in deeper water on the back arc fold and was followed by slightly shallower deposits of a shallowing upward peloidal bank (Brush Canyon Member). Both of these deposits were formed *in situ* in water depths that were subjected periodically to tropical storms resulting in repeated tempestite deposits in both members. Ultimately, coarser grained shallow water carbonates, onlapping to the west from central Wyoming to northern Utah, capped the shallowing upward ramp, trough and back arc fold deposits. These coarser grained carbonates are referred to as the Devil Creek Member above the offshore bank in northern Utah and southeastern Idaho and to the Mission Canyon Formation above the trough and on the ramp deposits to the east.

Based on the tectonic and sedimentologic interpretation of the Henderson Canyon Formation by Chen and Webster (1994), the following interpretation of the paleoenvironmental setting of the echinoderm faunas is proposed. The Henderson Canyon echinoderms lived in a carbonate environment along a back arc fold. Faunas of intervals 1-4 were separated from faunas of the ramp or shelf (Lodgepole Formation) to the east by a trough that is situated today along the western edge of the thrust belt of western Wyoming. The earliest faunas, crinoid intervals 1 and 2 (Chinese Wall Member), were in a shallowing upward deeper water setting, below major storm wave base. Faunas of intervals 3 and 4 lived in a shallowing upward sequence on an offshore peloidal bank (Brush Canyon Member), developed on the back arc fold, in water depths above major storm wave base. Faunas in intervals 5 and 6 lived in a shallow water, coarse grainstone environment (Devil Creek Member) as carbonate banks prograded from the east, across the ramp, filling the trough in western Wyoming, and finally covering the peloidal bank.

In all faunal intervals the larger specimens are the camerates, especially the platycrinitids and cactocrinids. The diameter and lengths of preserved portions of pluricolumnals and proximal parts of the attached stems suggest that some species of *Platycrinites*, that is, *P. bozemanensis*, *P. portiotortuosus*, and *P. beirdneauensis* were the highest tier element in these faunas, whereas other camerates (cusacrinids and rhodocrinitids), some of the primitive poteriocrines, and some of the taxocrinids are the intermediate-level elements. The smaller primitive poteriocrines and flexibles are the lowest tier elements with the echinoids occurring along the sediment-water interface, perhaps some infaunal. Asteroids would also have lived along and adjacent to the sediment-water interface.

Today, the peloidal bank and trough are closer to the carbonate ramp and platform edge and some parts within each of these carbonate settings are closer together than they would have been at the time of deposition, as a result of crustal shortening from thrusting (Chen and Webster, 1994). The amount of crustal shortening is uncertain, but tens of kilometers have been proposed as summarized by Chen and Webster (1994). Some distances may have been modified by extension in the Basin and Range Province, perhaps moving the

peloidal bank back to the west after earlier eastward thrusting. Until the true structural relationships of the region have been established, all proposed distances are considered conjectural.

Clearly, taxa exchange between the back arc fold faunas and ramp faunas is indicated by generic and a few specific taxa common to both areas. The abundance and diversity of primitive poteriocrinid species of *Paracosmetocrinus, Bridgerocrinus*, and some scytalocrinids in interval 3 and 4 faunas are interpreted to represent a slightly greater rate of diversification within some of these genera on the peloidal bank, than on the ramp in Wyoming and Montana. Likewise, the greater diversity of species of *Platycrinites*, *Cactocrinus*, and *Rhodocrinites* suggests a greater rate of diversification within those genera on the ramp than on the bank. Some genera are exclusive to the ramp wheras other genera are exclusive to the peloidal bank. The farther offshore position of the bank provided some isolation for the faunas living there, resulting in evolution of some endemic forms such as *Adiakritocrinus oviatti*, n. gen., n. sp., and *Apokyphocrinus wellsvillensis*, n. gen., n. sp., among others described in this paper.

TAPHONOMY

Taphonomic studies of crinoids were recently summarized by Ausich and Sevastopulo (1994) as part of a taphonomic investigation of Early Carboniferous crinoids of the Hook Head Formation of Ireland. The Hook Head crinoid faunas are partly correlative in age to crinoid interval 6 of the Devil Creek Member of the Henderson Canyon Formation (*Polygnathus communis carina* Biozone) but show more similarities in their preservation and taphonomy to the older faunas of intervals 3 and 4 from the Brush Canyon Member.

In order to quantify a taphonomic analysis of particular faunas and their enclosing sediments, two comparison scales have been proposed by Meyer and others (1990) in a study of middle Osagean faunas of the Fort Payne Formation. The first is a clade-specific ranking of generalized resistance to disarticulation (monobathrid camerates - disparids - cladids - flexibles) with monobathrid camerates the most resistant. Ausich and Sevastopulo (1994), lacking disparids in their faunas, modified this scale for the Hook Head faunas as follows: monobathrid camerates - cladids - flexibles, placing the monobathrid camerates *Platycrinites* and *Dichocrinus* with the cladids and *Rhodocrinites* intermediate between cladids and flexibles. This scale reflects the relative resistance to disarticulation of the structure of different types of extinct crinoids when enduring similar taphonomic processes. For universal utility the clade-specific scale will require adjustments to reflect the composition of faunas of different ages and environmental facies. It could be expanded to include echinoids and starfish, both of which would be less resistant than the flexibles.

The number of specimens of each species of the Henderson Canyon faunas given in the systematics and lists of species from the different intervals at each of the localities given in the appendix, table A1, fits the modified clade-specific scale of Ausich and Sevastopulo (1994), that is, monobathrid camerates - cladids - flexibles. This may be used to support correspondence of some environmental facies in these two geographically widely separated stratigraphic units.

The second scale of Meyer and others (1990), a preservational scale, lacks a grade for complete crowns with or without parts of the column but some disarticulation of the thecal plates, as well as no grade for pluricolumnals of various lengths (figure 3).

I.	Complete calyx with arms and column attached.
II.	Complete calyx with arms but no column attached.
III.	Complete calyx with column but no arms attached.
IV.	Complete calyx without arms or column.
V.	Complete calyx, plates articulated.
VI.	Partial calyx, plates articulated.
VII.	Partial calyx, plates disarticulated.
VIII.	Isolated calyx plates.
IX.	Holdfasts.

Figure 3. *Preservational scale of Meyers and others (1990, p. 537).*

Most of the Brush Canyon specimens are articulated crowns with all or parts of the arms and the proximal part of the column still attached. Some of the specimens have minor disarticulation of the cup or calyx plates as a result of compaction, and a number of the specimens that were originally complete or nearly complete lack parts of the arms or the stem as a result of weathering processes. All of these specimens would belong to grade I preservation of Meyer and others (1990). A few specimens are complete crowns lacking the column, and it is not known if the loss of the stem is a natural loss at or shortly after the disruption and death of the specimen, preceding burial, or a result of weathering processes. These are considered to be grade II preservation of Meyer and others (1990). They sometimes occur with more complete specimens and are the second most common type of preservation of specimens in the Brush Canyon Member. Specimens of grade III through VII preservation are very rare in the Brush Canyon Member. Except for a blastoid from the Brush Canyon Member and two *Rhodocrinites* thecae from the Chinese Wall Member, specimens lacking arms and the stem, grade VI preservation of Meyer and others (1990), were not found.

Isolated calyx plates, grade VIII preservation, are recognized in the basal circlets and radials of *Platycrinites*. These are rarely found on slabs with articulated crowns, but moderately common on slabs lacking articulated crowns. This indicates stronger current conditions or less rapid burial for the latter surfaces which are interbedded with the former. Other isolated calyx plates are smaller than those of *Platycrinites* and often present but overlooked unless searched for specifically.

Holdfasts, grade IX preservation, are not common in the Brush Canyon Member and were never found associated with crowns on the same bedding surface. Pluricolumnals of variable lengths, up to 20 cm, occur as solitary specimens and on

bedding surfaces in association with crowns from which they obviously have been disarticulated or are of a completely different type than the proximal parts of the stems still attached to the crowns. Most of these pluricolumnals are of a different type than the proximal attached stems, and are judged not to be the distal stem parts because they lack abundant cirri or other morphologic features common to the distal parts of the stem. They are considered proximal or medial parts of stems of different taxa.

Articulated echinoderm specimens from the Henderson Canyon Formation are interpreted as storm kills that were buried nearly *in situ*, transported relatively short distances before burial. Evidence supporting this interpretation is the occurrence of numerous crinoid specimens with the arms and tegmen intact, as well as many specimens still retaining proximal parts of the stem, and a few specimens with significant lengths of the stem still attached, all grade I preservation. Additional evidence is the preservation of growth stages of some species on one slab and the presence of starfish on a few slabs. The absence of holdfasts on these same surfaces provides evidence for at least some transport before burial. Most disarticulation is minor and judged to represent compaction or chance biological process, rather than scavenging or current disarticulation.

In the Gardison Limestone, echinoids with crushed coronas and spines radiating in all directions indicate *in situ* preservation. The uncrushed coronas of *Aarchaeocidaris* (n. gen.) in the Lodgepole Formation at Strawberry Creek are *in situ* preservation, possibly reflecting an infaunal habitat, whereas the two partial coronas from the Brush Canyon Member show disarticulation and compaction, representing excavation and transportation before burial.

Most of the echinoderms are associated with other sessile invertebrates, most commonly spiriferid and strophomenid brachiopods, less commonly with productid brachiopods. A few are associated with large colonies of *Stelechophyllum* and small auloporid corals, that are *in situ* and have been interpreted by Sando and Bamber (1985) as living in the deeper parts of their shallow-water lithofacies. The crinoids lack distal parts of the stems, and holdfasts are not present on these surfaces, indicating some transport before association with *Stelechophyllum* and burial. The *in situ* presence of *Stelechophyllum* in the peloidal bank of the Brush Canyon Member indicates that they were living above tropical storm wave base, in depths shallower than those suggested by Sando and Bamber (1985).

ASSOCIATIONS

Several slabs were found with two or more taxa of associated echinoderms on a single bedding surface as listed in the appendix, table 2. Except for the association of *Cusacrinus* sp. 2 with a pluricolumnal of *Platycrinites? portiotortuosus* in the upper part of the Chinese Wall Member and *Archaeocidaris*? sp. and *Blothrocrinus* n. sp., with an indeterminate rhodocrinitid from the Gardison Formation, all association slabs were found either *in situ*, or most likely, in crinoid interval three in the Brush Canyon Member.

Where camerates and poteriocrines are associated on the same slab, only one slab from the lower crinoid interval in the Brush Canyon Member contains a fauna with the diversity of the camerates (three species) greater than that of the poteriocrines (two species). The slab bearing the holotype and nine paratypes of *Platycrinites portiotortuosus* contains three different species of small, poorly preserved, unidentified primitive poteriocrines. These poteriocrines are not obvious because of their small size compared to the much larger platycrinitids; however, this slab is an example of how a single species of camerate can dominate the numerical ranking of crinoids in a fauna, yet may not represent the greatest diversity of clades within these Early Mississippian faunas.

Several crinoids are present on the same slabs with *Dichocrinus laudoni* as follows. Specimen USNM 487168 is associated with *Cribanocrinus honeyvillensis,* an indeterminate camerate, immature inadunate (probably *Bridgerocrinus fairyensis*), and two asteroids. Specimens USNM 487166 and 487167 are associated with *Bridgerocrinus fairyensis* and *Paracosmetocrinus utriculus*. Specimens USNM 487169 - 487171 are associated with *Bridgerocrinus fairyensis*, *Paracosmetocrinus madisonensis, Cribanocrinus honeyvillensis*, *Apokryphocrinus wellsvillensis,* and two specimens of an asteroid. These three float slabs are judged to be from the same bedding surface as they have the same matrix lithology and preservation and all were found within two meters of each other. Based on the preserved specimens, this fauna was apparently dominated by *D. laudoni* and *B. fairyensis* along with the asteroids. It lacked the larger upper tier *Platycrinites*. In this fauna the camerate *D. laudoni* and the poteriocrine *B. fairyensis* are the most abundant, and again the fauna has a greater diversity of poteriocrines than camerates.

SYSTEMATIC PALEONTOLOGY

All specimens bear numbers preceded by prefixes for the institution holding the specimens. Specimens are reposited in the collections of Brigham Young University (BYU), U.S. National Museum (USNM), or the Utah Museum of Natural History, University of Utah (UMNH). Specimens were collected by the author unless otherwise credited. Specimens were coated with ammonium chloride before photographing. All measurements are linear, in millimeters. Morphologic terminology follows the *Treatise of Invertebrate Paleontology, Echinodermata 2*, Moore and Teichert (1978) as modified by Webster and Lane (1987) for the crinoids; Echi*nodermata 1*, Moore (1967) for the blastoid; and *Echinodermata 3*, Moore (1966) for the echinoids. The crown and cup longitudinal growth measurements are given as length instead of height. This is to unify the longitudinal dimensional term for all parts of the whole animal and not imply the orientation of the animal, which is normally subvertical, but may be lateral or suspended in an inverted position. Columnal noditaxis patterns are after Webster (1974).

Class CRINOIDEA Miller, 1821
Subclass CAMERATA Wachsmuth and Springer, 1885
Order DIPLOBATHRIDA Moore and Laudon, 1943
Family RHODOCRINITIDAE Roemer, 1855
Genus RHODOCRINITES Miller, 1821

Remarks. *Rhodocrinites* and its junior synonym *Rhodocrinus* have had 70 species assigned to them according to listings by Bassler and Moodey (1943), and Webster (1973, 1977, 1986, 1988). Four of these species are based on columnals, five are of Devonian age and probably belong to genera in the lineage from *Dimerocrinites* to *Rhodocrinites*, and 22 have been transferred to related genera. Of the 39 Carboniferous species currently assigned to *Rhodocrinites*, 26 are from North America and the others from northwestern Europe (10), Russia (2), and Africa (1). The acme for the genus was late Kinderhookian into middle Osagean, across northwestern Europe and North America with the greatest diversity in North America.

Laudon and Severson (1953) summarized the evolutionary characters of *Rhodocrinites* noting that the advanced morphologic features are: a deeply invaginated globose theca; a low relief to nearly flat tegmen that is almost as wide as to slightly overhanging the cup and formed by a few large strongly nodose plates; and six to eight biserial arms per ray, with all branchings outside the theca low on the arms. A literature review of the rhodocrinitids found species of *Rhodocrinites* with advanced and primitive morphologic features coexisting throughout the Carboniferous range of the genus. Thus species with all advanced morphologic features are not necessarily the youngest forms in the *Rhodocrinites* lineage.

Strimple and Boyt (1965), without evolutionary lineage studies, recognized four groups within *Rhodocrinites* species from the Hampton Formation of Iowa. Although they did not specify the distinguishing characters, differences in the groups were recognized on color and morphology of the cup and tegmen. Species of Group A (Strimple and Boyt, 1965) had previously been transferred to the closely allied genus *Cribanocrinus* by Kirk (1944a). Strimple and Boyt (1965) did not comment on Kirk's studies and it is not certain if they recognized *Cribanocrinus* at that time. A modern review, including cladistics, of the species of *Rhodocrinites* would probably reduce the recognized species to approximately two-thirds the current number, greatly enhance their biostratigraphic use and knowledge of their paleogeographic distribution, and provide a clearer understanding of the evolutionary lineages within the genus.

RHODOCRINITES sp., cf. R. MACROTUMIDUS
Laudon and Severson, 1953
Plate 1, Figures 4-6, 14A

Description. Calyx globose, small to moderate size, deep basal invagination, constricted immediately below free arms; ray ridges moderately well developed; strong stellate ornament on all cup plates; tegmen flat-topped, slightly smaller than diameter of ambulacral ring, formed by large coarsely nodose plates. Arms branch on IBr_2 and probably on $IIBr_2$, more distal branching unknown; four arms per ray, biserial within two or three plates after last branching point; brachials strongly rounded transversely, slightly tumid, deep.

Columnals short, circular in transverse section, simple heteromorphic N1 pattern. Nodals bear vertical latus, extend well beyond internodals, nearly enclosing internodals. Internodals approximately half length of nodals, latus rounded to angular.

Remarks. Four specimens referred to *Rhodocrinites* cf. *macrotumidus* have the prominent stellate ornamentation on the large cup plates. Two of the specimens show the deep basal invagination and coarsely noded large plates on the low, nearly flat tegmen. The nodes are not as large or as prominent as on the holotype and one paratype illustrated by Laudon and Severson (1953, plate 2, figures 9, 10). Only one of the two Utah specimens has the proximal part of the biserial arms preserved. There are judged to be four arms per ray with all branchings low on the arm because the brachials are biserial close to the theca.

Material. One specimen (UMNH IP 2248) from the lower part of the Chinese Wall Member, Henderson Canyon Formation, and three (USNM 487158 - 487160) in float blocks from the middle and upper part of the Brush Canyon Member, also Henderson Canyon Formation, south-facing slope on Wellsville Mountain.

RHODOCRINITID? indet.
Plate 8, Figure 7B

Remarks. A partial flared crown (22.6 m long, 28.3 mm wide) lacking the dorsal cup and part of the proximal thecal plates represents a species of *Rhodocrinites* or *Cribanocrinus* different from those described herein. The specimen has six pinnulate arms on each of the two exposed rays and ray ridges appear to have continued onto the arms from the cup. The tegmen is not exposed. The arms are free above the second or third secundibrachial. Branching is isotomous, first within the fixed brachials and secondly on the eighth or ninth secundibrachial, with one additional exotomous branching on the third tertibrachial. Brachials are proximally uniserial, becoming biserial immediately above the last branching. The high second branching and distal development of the biserial brachials is a primitive condition.

Preservation of this specimen is poor as weathering has leached the plates, some extensively. It is questionably assigned to the rhodocrinitids based on the primitive arm structure and possibly represents a new species. It is distinguished from *Rhodocrinites* cf. *R. macrotumidus* by the distal branchings of the arms.

Material. One specimen, BYU 3157, from the Gardison Formation at Rock Canyon, collected by Mark McCutcheon.

Genus CRIBANOCRINUS Kirk, 1944

Remarks. *Cribanocrinus* is closely related to *Rhodocrinites* as both genera have the same basic calyx and arm plate

structure. *Cribanocrinus* was established by Kirk (1944a) for forms with a globose cup shape. Most of the species assigned to the genus lack the stellate ridge ornamentation. The arms of *Cribanocrinus* have a similar evolutionary development as *Rhodocrinites*, in that branching is above the calyx after the first bifurcation and the brachials are cuneate uniserial close to the cup becoming biserial distally. In advanced forms distal branchings are closer to the cup and the biserial condition is developed low in the arms, closer to the calyx.

The stratigraphic range of both *Cribanocrinus* and *Rhodocrinites* is Early Carboniferous, with *Cribanocrinus* extending into the Meramecian, whereas *Rhodocrinites* is not known after the Osagean. *Cribanocrinus* is restricted to North America and Australia, whereas *Rhodocrinites* is reported from Europe, Africa, Russia and North America (Bassler and Moodey, 1943). In North America *Cribanocrinus* is often associated with *Rhodocrinites* but is generally less abundant.

It is possible that species assigned to *Cribanocrinus* are polyphyletically derived from *Rhodocrinites* and that *Cribanocrinus* should not be recognized. Until a morphometric study of the types and known specimens of these two genera is made, both taxa are provisionally retained.

CRIBANOCRINUS HONEYVILLENSIS n. sp.
Plate 1, Figure 10

Etymology. The species name is derived from the village of Honeyville located 2 miles southwest of the collecting locality.

Diagnosis. A *Cribanocrinus* with a globose calyx, tumid calyx plates, 6 arms per ray, basal plates larger than radial plates, weakly developed ray ridges, and cuneate brachials becoming biserial in distal parts.

Description. Crown small, 15 mm length, 12. 8 mm wide, arms splayed distally. Calyx globose bowl-shaped, 5.1 mm wide, 1.8 mm long to base free arms; moderate basal invagination. All plates weakly tumid, ray ridges faint, no stellate ornament. IBB small, confined to basal concavity. BB 5, wider (1.8 mm) than long (1.4 mm), largest calyx plates strongly convex longitudinally, gently convex transversely; proximal tips in basal cavity, distal half gently outflared, forming part of calyx wall. RR 5, equidimensional, 1.1 mm, gently convex transversely and longitudinally. IBr fixed in calyx, 2 per ray, second axillary. IIBr free above $IIBr_1$, slightly tumid. $IIBr_{11}$ axillary. Inner arm never branches again. Outer $IIIBr_4$ or $IIIBr_5$ axillary, no further branching. All brachials above last branching cuneate, short, become more strongly cuneate to weakly biserial in distal parts of arm. Six arms per ray. Pinnules slender, one per brachial, alternate sides of arm. Anitaxis series 1:2:3:?. Primanal in line with radials, slightly smaller. Interprimibrachial series 1:2:2:?. Tegmen not exposed. Proximal columnals simple heteromorphic, short, circular in transverse section; nodals longer and wider than internodals.

Remarks. The holotype is well preserved except for recrystallization that slightly masks the proximal part of the anitaxis and adjacent plates on the calyx. Recognition of the plate structure was made by wetting the specimen under magnification. The presence of six arms is an advanced feature, however, the dominantly uniserial arms, distal branching, and presence of weakly developed ray ridges are primitive features.

Cribanocrinus honeyvillensis differs from other species of the genus by a combination of characters, not one single feature. It lacks the granular ornament and has six arms per ray, whereas *C. bridgerensis* (Miller and Gurley, 1897), reported from the Lodgepole Formation of Montana, has granular ornament and four arms per ray. The basals form a significant part of the cup wall and there are no spines on the proximal brachials of *C. honeyvillensis*, whereas *C. wilsoni* Laudon, Parks, and Spreng, 1952 reported from the Banff Formation, has spines on the proximal brachials and only the distal tips of the basals are in the cup wall. *C. whitei* (Hall, 1861), reported from the Chouteau Limestone, has more tuberculate cup plates and a deeper basal invagination than *C. honeyvillensis.* All of these species are of Kinderhookian age, similar distinctions may be made with the Osagean and Meramecian species of *Cribanocrinus*.

A second specimen is questionably referred to *Cribanocrinus honeyvillensis* because the cup plates of the exposed side of the globose cup are lost by weathering and the brachials never become biserial distally. The crown is 11 mm long and retains 32 mm of the stem. Columnals are circular in cross section and occur in N212 noditaxis proximally and N1 distally.

Material. The holotype (USNM 487161) and second specimen (USNM 487830) are both from float slabs from the middle part of the Brush Canyon Member (probably lower crinoid interval) of the Henderson Canyon Formation, southwest-facing slope of Wellsville Mountain.

Order MONOBATHRIDA Moore and Laudon, 1943
Family ACTINOCRINITIDAE Bassler, 1938
Genus CUSACRINUS Wachsmuth and Springer, 1897

Remarks. The genera *Cactocrinus* and *Cusacrinus* are closely related, with the interprimibrachials of *Cactocrinus* restricted to the calyx below the ambulacral openings, therefore not in contact with the tegmen plates, and the interprimibrachials of *Cusacrinus* in contact with the tegmen plates, extending between the brachials forming the ambulacral ring on the calyx. Lane and Sevastopulo (1987, figure 1) showed the range of *Cusacrinus* to be late Kinderhookian into earliest Osagean and that of *Cactocrinus* as middle to late Osagean. In the text (ibid., p. 201), however, they stated that *Cusacrinus* ranges into the upper part of the Burlington, which makes its upper range limit late middle Osagean. A literature review of the species of both *Cactocrinus* and *Cusacrinus* indicates that both genera have the same range, that is, late Kinderhookian into late middle Osagean. The oldest species for both genera are reported from the Lodgepole Formation of Montana and the youngest from the upper part of the Burlington Limestone of Iowa.

Several variable morphologic features in both *Cactocrinus* and *Cusacrinus* include: the development of the

stellate ridge ornament, both simple and multiple ridge forms; the lack or presence of prominent ray ridges; centrally nodose plate ornament with and without stellate ridges; presence or absence of flanges around the base of the calyx; smooth versus noded to bluntly spinose tegmen plates; short versus extended anal tubes and the plate structure therein; number of arms per ray; and development of transverse serrate ridges, nodes or spines on the brachials. At this time it is not known whether the occurrence of similar variables and the parallel age ranges in both *Cactocrinus* and *Cusacrinus* represent parallel evolution, sexual dimorphism, or are only variations within one clade. It is quite possible that the extension of the interprimibrachials through the ambulacral ring of the calyx may be another morphological variable, not of generic distinction.

Several problems restrict a clear interpretation of *Cactocrinus* and *Cusacrinus.* A few of the types of some of the species assigned to these genera have never been illustrated and from some of the early descriptions and illustrations it is impossible to tell if the interbrachials were confined to the cup or in contact with the tegmen. Several types lack the tegmen and many of the types lack the free arms. Several of the types do not have the anal tube exposed. Numerous species of both genera are based on as few as one to three or four specimens.

Until a systematic review of the types can be made, both *Cactocrinus* and *Cusacrinus* are provisionally retained, but it is also considered that they may be a single clade. Although some 18 to 20 species of each genus are currently recognized, it is here estimated that approximately one-third of the species should be placed in synonymy with the other two-thirds and some species previously placed in synonymy should be recognized or placed in synonymy with species other than those to which they have been referred. For example, *Cusacrinus arnoldi* and *Cusacrinus ornatissimus,* both of which have multistellate ornament, are perhaps synonymous but not synonyms (Macurda, 1974) of *Cusacrinus nodobrachiatus,* which has simple stellate ornament. *Cactocrinus sexarmatus* and *Cactocrinus kuenzii* belong to *Cusacrinus,* and *Cusacrinus bischoffi* and *Cusacrinus ectypus* belong to *Cactocrinus* based on the condition of the interprimibrachials extending across the ambulacral ring or being restricted to the cup respectively.

CUSACRINUS KUENZII
(Laudon, Parks, and Spreng, 1952) new combination
Plate 1, Figures 1-3, 9

Synonymy. *Cactocrinus kuenzii* Laudon, Parks, and Spreng, 1952, p. 572, Plate 68, figures 7-10; Plate 69, figure 22. Webster, 1973, p. 71 (catalog listing)

Remarks. Two crowns are assigned to *Cusacrinus kuenzii* on the basis of cup shape and ornamentation. The smaller crown (25.5 mm long, incomplete; 18.4 mm wide slightly above the base of the free arms) is in the enclosed position, lacking the basal circlet and distal tips of the arms. The larger crown (46.0 mm long, 35.8 mm wide) has the arms slightly splayed and retains the proximal 14.5 mm of the column. Both specimens are weathered and have a partly silicified rind on some of the plates. The silicification has obliterated part of the ornament.

The cups are moderate bowl-shaped, with a small basal flange and impressed sutures. Calyx ornament consists of single stellate ridges connecting all basals, radials, primibrachials, first interprimibrachials and first anals. Ray ridges are well developed on radials continuing onto the tertibrachials. Large blunt nodes are present on the third and fourth ranges of interprimibrachials and on the interbrachials. Blunt nodes may have been present on some of the proximal biserial brachials, but these may be silicification-produced irregularities. Hooks or spines are present on the pinnules and laterally directed spines are present on some of the distal anal tube plates. The interprimibrachials are in a narrow interval between brachials of the ambulacral ring on the smaller crown and in a wider and more visible interval on the larger crown, in direct contact with the tegmen plates.

Arms of the smaller crown are six each in the A and E rays, five each in the C and D rays, and four in the B ray, for a total of 26. On the larger crown the C ray has five arms and a minimum of four in the D ray and two in the partly exposed B ray, with all others not exposed. The proximal column of the larger crown is formed of thin heteromorphic columnals with a pluricolumnal pattern (Webster, 1974) type II, formula N212, becoming type III, formula N3231323, distally.

The three specimens of *Cusacrinus kuenzii* from the Banff Formation of Alberta, Canada, illustrated by Laudon and others (1952, Plate 5, figures 7-10) each have six arms per ray. It is not known if the variable number of arms per ray on the smaller crown and the five in the C ray of the larger crown of this study represent growth stages or variation. Laudon and others (1952, p. 572) reported the interprimibrachials to be in contact with the tegmen. Therefore the species is transferred to *Cusacrinus.*

Material. Two crowns, both on float blocks from the Brush Canyon Member of the Henderson Canyon Formation. The smaller crown (USNM 487162), found by Paul Jamison, is from the lower ledge of the Brush Canyon Member, Logan Canyon, Utah and the larger crown (BYU 3155), found by Lloyd Gunther, is from an unknown horizon in the Brush Canyon Member, Wellsville Mountain.

CUSACRINUS sp. 1
Plate 1, Figure 8

Description. Partial crown (length 28 mm) small, with parts of C and D rays preserved. Cup relatively high bowl, steep walls; multiple stellate ray ridge ornament on basals and radials, single stellate otherwise; basals slightly bulged but not flanged. Radials largest cup plates. Anitaxis 1:2:3:?, projecting into tegmen. B-C interprimibrachial series 1:2:2:2:?, appears to project into tegmen. Anals and interprimibrachials weakly nodose. Minimum of five arms in C ray and two in D Ray. Brachials biserial within two or three brachials of last branch; branching low.

Remarks. With only a part of the crown preserved it is difficult to identify this specimen. The high non-flanged cup is most similar to some of the multiple stellate cusacrinids, as

the single stellate forms tend to be more bowl shaped. The small size may indicate immaturity.
Material. One partial crown, USNM 487163, float, from the middle or upper part of the Lodgepole Limestone, north side Strawberry Canyon, western Wyoming.

CUSACRINUS sp. 2.
Plate 4, Figure 2A

Description. Crown small (length 26 mm, incomplete), arms splayed. Cup medium bowl, basals and radials large, radials largest cup plates. First interprimibrachial large. Ray ridge ornament weakly developed, not obvious. Anitaxis 1:3:2:?, continuing into tegmen. D-E interprimibrachial series 1:2:1, in contact with tegmen. Five arms in D ray, four arms in E Ray; branching low; brachials biserial close to last branching.
Remarks. The cup is weathered, chipped on the base, and impacts on the talus slope have shattered some cup plates making sutures difficult to recognize. With preparation the ornamentation on unexposed parts of the cup was found to be very weakly developed.

The small crown is close to *Cusacrinus* sp. 1 in size, but shows marked differences in the very weakly developed ray ridge ornament, relatively smaller size of cup plates, and arrangement of interprimibrachials. Of described species, *Cusacrinus* sp. 2 is most similar to *Cusacrinus penicillus* Meek and Worthen, from the lower part of the Burlington Limestone in Iowa. Both have similar ornament and shape, but *Cusacrinus penicillus* has a greater number of arms, seven or eight per ray.
Material. The crown, USNM 487164, is on a float block from the uppermost part of the Chinese Wall Member, Henderson Canyon Formation, Blacksmith Fork Canyon.

CUSACRINUS sp. 3
Plate 1, Figure 11

Description. Crown moderately large, 30 mm length, 26.8 mm wide, crushed from compaction. Theca low bowl shape, 5.5 mm length to base free arms, 11.6 mm wide, plates tumid, single stellate ornamentation. Basals extended beyond proximal columnal. Radial largest cup plate, approximately equidimensional. Anitaxis 1:3:3:1, with 3rd order anal adjacent to C ray elongate, extending beyond 4th order anal. D-E interprimibrachials 1:2:?, extending between brachials to tegmen. Brachials short, wide, bear transverse ridge proximally and distally. Branching isotomous, on IBr_1, $IIBr_{6\text{ or }7}$, and $IIIBr_3$ on inner half of ray; biserial on 3rd or 4th brachial after last branch, six arms per ray. Stem circular in transverse section, heteromorphic; nodal series N1.
Remarks. Compaction of the crown pushed the primibrachials back over the radials in part, masking some cup features and distorting the cup shape slightly. Weathering has rounded the cup plates removing any fine morphologic features. The single stellate ridge pattern is discernible on the tumid plates and no ray ridges are believed to have been present. The anal interray and D and E rays are exposed but partially dislocated.

The specimen lacks the higher cup with very large radials of *Cusacrinus nodobrachiatus* and is much larger with a lower cup than either *Cusacrinus* sp. 1 or *Cusacrinus* sp. 2. It lacks nodes and spines on the brachials and has no basal flange. It probably represents a new species, but the preservation is insufficient for the specimen to serve as a holotype.
Material. One crown, USNM 487165, from the upper ledge of the Brush Canyon Member of the Henderson Canyon Formation, Beirdneau Hollow, Logan Canyon; collected by Paul Jamison.

Genus CACTOCRINUS Wachsmuth and Springer, 1897
CACTOCRINUS sp., cf. C. MAGNIDACTYLUS
(Laudon and Severson, 1953)
Plate 1, Figures 12, 13

Description. Calyx elongate, conical, base truncated, dominated by large basals and radials, all plates bear interconnected multiple stellate ridge ornament with or without central nodes. BB, 3, subequal, 8.3 mm long, 12.5 mm wide, base subhorizontal, distal two-thirds upflared, visible in lateral view, gently convex transversely. RR, 5, slightly wider (12.0 mm) than long (10.9 mm), gently convex transversely, nearly straight longitudinally, gently outflared. Primanal large, longer (11.6 mm) than wide (8.7 mm), in line with radials. Anitaxis 1:2:?. IBr_1 hexagonal, wider (7.8 mm) than long (6.6 mm), gently convex transversely and longitudinally. IBr_2 septagonal, axillary, slightly wider (7.0 mm est.) than long (6.3 mm). Interbrachial series 1:2:3:?, decreasing plate size distally; hexagonal IBr_1 largest, 8.0 mm long, 9.0 mm wide. Stem attachment, arms and tegmen unknown.
Remarks. The calyx is flattened along a plane through the B and D rays. Most of the proximal brachials and interprimibrachial plates as well as all tegmen plates are missing. The ornament is more complex than that known on any of the Lodgepole Formation species described by Laudon and Severson (1953) or the Banff Formation species described by Laudon and others (1952) but is most similar to *Cactocrinus magnidactylus* from the Lodgepole. The stellate ridges continue across the tegmen plates on the Utah specimen whereas the center of the plates is a smooth node on *Cactocrinus magnidactylus.* The smooth nodes might represent the gerontic morphotype, since the specimen is quite large as noted by Laudon and Severson (1953), and the Brush Canyon specimen could represent the neanic morphotype with the ridges still extended across the center of the plates. Additional specimens of various growth stages are needed to resolve this question.

Laudon and Severson (1953) considered the more complex stellate ridge patterns to be an advanced feature of the genus; however, many of the species from the Burlington Limestone (Osagean) have less complex patterns than those from the Kinderhookian Lodgepole, Hampton, and Gilmore City Formations. The multiple stellate ridge ornament suggests evolved forms of *Cactocrinus* such as *C. opusculus* (Hall) and may represent the early development of the multiple stellate lineage within the clade. It is also possible that the

multiple stellate ornamentation may have evolved repeatedly from the single stellate ridge pattern.

Material. One partially silicified calyx (BYU 3156), found by Richard Moyle, in a small float block from an unknown interval in the Henderson Canyon Formation, west of the Boy Scout Camp north of Causey Reservoir, Utah. The silicification and matrix suggest that this specimen came from the uppermost part of the Chinese Wall Member.

Family DICHOCRINIDAE Miller, 1889
Subfamily DICHOCRININAE Miller, 1889
Genus DICHOCRINUS Münster, 1839
DICHOCRINUS LAUDONI Broadhead, 1981
Plate 2, Figures 5-7, 10

Remarks. *Dichocrinus laudoni* Broadhead, 1981 is based on two crowns from the Lodgepole Formation of Montana originally assigned by Laudon and Severson, 1953, to *D. bozemanensis* Miller and Gurley, 1897. Three of the seven specimens from the Brush Canyon Member preserve proximal plates of the tegmen. On specimen USNM 487166 the second anal plate is large and slopes upward and inward at a fairly high angle indicating a moderately high tegmen. A similar condition is suggested for the smaller interambulacral plates on two other specimens, USNM 487169 and USNM 487167. The high conical cups of most specimens are crushed or distorted from compaction reflecting the thinness of the basal and radial plates. Most of the associated thicker plated inadunates and camerates are not as crushed or distorted but may be slightly disarticulated.

Material. Seven specimens of *Dichocrinus laudoni*, USNM 478166-478172, from the middle to upper part of the Brush Canyon Member, Henderson Canyon Formation, Wellsville Mountain locality, including one specimen found *in situ* and the other six on three float blocks, most judged to be within a short distance of origin, and all probably from the same bedding surface.

DICHOCRINUS QUADRICEPTATUS Laudon and Severson, 1953
Plate 4, Figure 6

Remarks. One calyx with associated, but disarticulated proximal parts of the arms, shows the moderately expanded conical cup with protruded arm bases typical of the types of *Dichocrinus quadriceptatus* illustrated by Laudon and Severson (1953). The impressed upper lateral parts of mutually adjacent radials gives a distinct scalloped shape to this species. Broadhead (1981) included *D. rotaii* and *D. tomiensis*, both described by Yakovlev (*in* Yakovlev and Ivanov, 1956), in the synonymy of *D. quadriceptatus.* Although *D. tomiensis* and *D. rotaii* are probably synonymous, these forms lack the impressions along the mutual lateral edges of the radials and should not be included in the synonymy of *D. quadriceptatus.*

Material. The specimen (USNM 487173) is from a float block from the lower ledge, upper middle part of the Brush Canyon Member, Henderson Canyon Formation, ridge on east side of Beirdneau Hollow, Logan Canyon, Utah; found by Paul Jamison.

DICHOCRINUS DELICATUS Wachsmuth and Springer, 1897
Plate 2, Figure 8

Remarks. One small (0.8 cm length) crown of *Dichocrinus delicatus* shows the wedge-shaped anal tapering rapidly distally. The basal circlet is a widely-flared conical shape and the radials are subvertical to slightly inwardly sloped, a condition which could be the result of distortion from compaction. The arms are uniserial, two in the D ray. A 1.35 mm section of the proximal stem contains heteromorphic columnals with an angular latus in a simple alternating nodal-internodal pattern from the proximal 0.45 mm of the stem then grading into longer homeomorphic straight latus columnals. An associated 3.0 mm of a homeomorphic pluricolumnal bearing a few small cirri probably represents the middle or distal part of the stem for this specimen. There is no size difference between the nodals and internodals in this section of the stem.

This is the first report of *Dichocrinus delicatus* from the western U. S., extending the range from the midcontinent.

Material. The specimen, USNM 487174, is from a float block from the upper middle part of the Brush Canyon Member (probably lower ledge), Henderson Canyon Formation, south-facing slope of Wellsville Mountain.

DICHOCRINUS sp.
Plate 2, Figure 11

Remarks. A crushed crown of *Dichocrinus* sp. occurring on a slab with *Holcocrinus* represents a fourth species of the genus in the Brush Canyon Member. The crushed cup has a shape similar to *Cribanocrinus*. Under magnification, however, the radial facet shows the narrow, high, slightly protruded oval shape typical of *Dichocrinus.* The fractured smooth radials and basals would have had a conical form with a more expanded base, probably similar to *D. multiplex*, but there are four arms in the central ray exposed and at least two arms in each of the adjacent rays. Unfortunately, the specimen is from a float slab that was damaged by weathering processes and the proximal brachials were destroyed so that the number of branchings and exact branching patterns are uncertain. The arms consist of short cuneate uniserial brachials that become biserial in the distal one-third of the arm, perhaps indicating an immature specimen.

The specimen probably represents a new species but is unsuitable to serve as a holotype. It is reported for stratigraphic and association information.

Material. This specimen (USNM 487175) is on a float slab from the upper ledge, upper part of the Brush Canyon Member, Henderson Canyon Formation, Woodcamp Hollow, Logan Canyon, Utah; found by Paul Jamison.

Genus PARADICHOCRINUS Springer, 1926

PARADICHOCRINUS WELLSVILLENSIS n. sp.

Plate 2, Figures 4, 9

Etymology. The species name refers to Wellsville Mountain, on which the specimen was found.

Diagnosis. Cup conical, weakly developed basal flange, six arms per ray, one exotomous branching, all brachials biserial within two to five brachials of branching, cup ornamentation probably striae radiating from base of arms onto basals.

Description. Crown slender, 36.5 mm long, 23.9 mm wide, incurved distally. Cup conical, slightly wider (12.8 mm) than long (9.9 mm). BB circlet low (2.4 mm long, 7.1 mm wide), gently upflared, visible in lateral view, impressed with circular stem facet, slight basal flange. RR 5, longer (7.1 mm) than wide (6.3 mm), widest at distal end, gently convex transversely and longitudinally. IBr_1 low, wider (3.7 mm) than long (1.4 mm). IBr_2 axillary, wider (3.9 mm) than long (1.7 mm). IIBrr slightly wider than long; $IIBrr_2$ axillary. Outer IIIBrr never branch again, become biserial on fourth or fifth brachial. Inner $IIIBr_2$ axillary. IVBrr become biserial with second or third brachial. All biserial brachials small, wider than long, tumid. Pinnules one per brachial, elongate, slender, formed of more than six plates tapering distally. Visible first interambulacral large, tumid. Proximal two columnals round, heteromorphic. Tegmen unknown.

Remarks. The steep outward slope of the first interambulacral plates suggests that *Paradichocrinus wellsvillensis* has a relatively high, somewhat inflated tegmen. A silicification rind occurs on all plates and has destroyed details of any fine ornamentation on the cup or brachial plates. An elevated triangular area radiating from the base of the arms towards the basals is masked with liesegang silicification. This suggests that the ornamentation on the cup was striae radiating from the base of the arms onto the basals as on *Dichocrinus douglassi.* If this is an artifact of the silicification then the unornamented *D. quadriceptatus* would be a likely progenitor of *P. wellsvillensis.*

Paradichocrinus wellsvillensis may be the oldest known species of the genus and the first species reported outside the midcontinent region of the United States. The small conical cup with subvertical walls distally and small brachials are typical of *Dichocrinus*, whereas the exotomous branching is typical of *Paradichocrinus.*

Broadhead (1988) suggested that *Paradichocrinus* evolved from *Dichocrinus douglassi*, a form reported from the Lodgepole Limestone of Montana, Banff Formation of Alberta, Canada, and the Gilmore City Formation of Iowa. With development of the exotomous branching, *P. wellsvillensis* represents an intermediate stage between *D. douglassi* or *D. quadriceptatus* and *P. liratus*. The former two species have 20 arms, without exotomous branching; the latter has aligned nodes on the cup, spinose plates on the high inflated tegmen, and one exotomous branching giving six arms per ray. The six arms per ray of *P. wellsvillensis* is similar to that of *P. polydactylus* and *P. liratus*, but the cup lacks the coarse nodose ornament typical of those genera. The third species of the genus, *P. planus*, has 10 arms per ray, lacks a basal flange and ornamentation on the cup; it is easily distinguished from *P. wellsvillensis.*

Material. The holotype BYU 3152 found by K. Fridal on Wellsville Mountain, east of Deweyville, Utah. The exact stratigraphic horizon for the float block containing the specimen is unknown, but the lithology and preservation suggests that it is from the Brush Canyon Member, Henderson Canyon Formation. Paratype USNM 487176 is a crushed crown from the upper ledge in Brush Canyon, one mile east of Beirdneau Hollow, Logan Canyon, Utah.

Family PLATYCRINITIDAE Austin and Austin, 1842

Remarks. Platycrinitids have been assigned to several genera based upon differences in the tegmen or arm structure as discussed by Brower (1970). The cup is commonly preserved without the tegmen and arms, making generic identification of such specimens provisional at best. The phylogenetic origin of the tegmen structure has not been demonstrated. It is possible that the tegmen differences are polyphyletic, with similar forms arising repeatedly during the Carboniferous and Permian. Thus, the acceptance of *Pleurocrinus* Austin and Austin, 1843 and *Exsulacrinus* Bowsher and Strimple, 1986 is followed with reservations at this time.

Genus PLATYCRINITES Miller, 1821

Remarks. The genus *Platycrinites* was one of the genera defined by J. S. Miller (1821) and, along with its junior synonym *Platycrinus*, has had nearly 300 species assigned to it (Bassler and Moodey, 1943; Webster, 1973, 1977, 1986, 1988, 1993). Nearly half of the species assigned to the genus have been transferred to other genera or placed in synonymy of other recognized species. Many species are based on single specimens of basal circlets, partial cups, and calyces; their validity and relationship to species based on multiple specimens and crowns is often questionable. Currently, approximately 180 species are assigned to the genus, although an uncertain number are undoubted synonyms and a few belong to other genera. The taxonomic morass of *Platycrinites* has been discussed or commented on, but not resolved by, Wachsmuth and Springer (1897), Wright (1955, 1956), Brower (1970), and Webster and Lane (1987). Additional discussion of parts of this problem are given in the remarks section under *P. beirdneauensis* and *P. portiotortuosus*. Until a modern systematic revision of the platycrinitids is completed, the phylogenitic relationships within the clade will not be resolved, and their stratigraphic utilization will remain minimal.

PLATYCRINITES BOZEMANENSIS

(Miller and Gurley, 1897)

Plate 3, Figure 6A

Remarks. *Platycrinites bozemanensis* is the most common crinoid in the Lodgepole Formation of Montana. The species occurs at various horizons in both the ramp and basin envi-

ronments of the Lodgepole Formation at numerous localities in the Bridger Range, Big Snowy Mountains, Little Belt Mountains, Gravelly Range, Madison Range, Ruby Range, Milligan Canyon, Old Baldy Mountain, and Tobacco Root Mountains as recorded by Laudon and Severson (1953), Laudon (1967), and Webster (unpublished data), among others. The species was reported from Wellsville Mountain (Oviatt, 1985) and also occurs in the Snake River Range and Samaria Mountains of southeastern Idaho and the Salt River Range of western Wyoming (Webster, unpublished data).

Although crowns of *P. bozemanensis* are not abundant in the present material, the species is present at several localities in northern Utah. Pluricolumnals and isolated columnals of *P. bozemanensis* as well as other species of the genus are common elements in the Brush Canyon Member, but less abundant in the Chinese Wall and Devil Creek Members. *Platycrinites bozemanensis* has the continuous "twist" stem and coexisted, at least during part of its range, with *P. portiotortuosus* n. sp. that has the "segmented twist" columnal.

Material. Eight immature or intermediate growth stage crowns (USNM 487177-487184) on one float slab and one mature crown (USNM 487185) in association with *P. beirdneauensis* on a float slab from an unknown interval in the middle or upper part of the Brush Canyon Member, Henderson Canyon Formation, Beirdneau Hollow area, Logan Canyon; found by P. Jamison. One crown (USNM 487186) on a float block from the upper crinoid interval of the Brush Canyon Member, one mile east of Beirdneau Hollow, Logan Canyon. One partial crown (UMNH IP 2244) from the basal part of the Devil Creek Member, Henderson Canyon Formation, Wellsville Mountain, found by Jack Oviatt.

PLATYCRINITES CANADENSIS
Laudon and Severson, 1953
Plate 3, Figure 3

Description. Crown elongate, 34.7 mm length, 16.4 mm wide at base tertibrachials. Cup bowl-shaped, 10 mm long, 14.4 mm wide at top radials. Basal circlet upflared, 4.9 mm long, 9.0 mm wide. Radials wider (7.8 mm) than long (7.4 mm), gently convex longitudinally and transversely. Radial facets at distal end of radials, small, elliptical, longest transversely. Arms four per ray, axillary brachials IBr_1, $IIBr_{2\ or\ 4}$. Brachials deep, strongly convex transversely, become biserial within four to six brachials after last branch, not ornamented. Pinnules slender, elongate, one per brachial. Ornamentation of aligned nodes or coalesced noded ridges parallel to distal edges of plates and basal flange. Proximal stem heterotomous, alternating nodals and internodals; columnals elliptical transversely; latus rounded.

Remarks. The cup of this specimen is crushed and calcification along the fractures has distorted some plates making all dimensions approximate. Weathering has destroyed part of the ornamentation. Isotomous branching on the second secundibrachial in one half of the ray and in the fourth secundibrachial in the other half of the ray suggests there could be five or six arms in some rays if branching were on the second secundibrachial and on the second tertibrachial in two of the quarter rays thereafter, a normal branching pattern in six-armed rays in many platycrinitids.

The ornamentation of *P. canadensis* was described as delicate nodes in a random arrangement on the basals and radials (Laudon and Severson, 1953). Also, *P. canadensis* has four arms per ray. The brachials are biserial shortly above the last branching and the specimen is judged to be mature. The two illustrations in Laudon and Severson (1953) of the same specimen do not show the same ornamentation, however. On the first (ibid., plate 54, figure 8) the discrete nodes are in vague but definitely aligned rows that parallel the sides of the plates or are subparallel to the radial facet. On the second (ibid., plate 55, figure 25) the nodes are both discrete and coalesced into irregular ridges with a definite alignment parallel to the plate margins or radial facet on the radials and the basal circlet bears irregular nodose ridges that are parallel to the distal plate facets. A weakly developed basal flange is present. The original specimen has ornamentation as here described for the illustration on plate 55, figure 25. There is no statement by Laudon and Severson (1953) about the difference in the illustrations, however, Laudon and others (1952) reported the use of restored photographs and unretouched photos of the same specimen for the Banff crinoid fauna. The illustrations in the Laudon and others (1952) and Laudon and Severson (1953) papers are of the same format: early plates are made of retouched photos and the last plate is made of original photos. Using the information provided in Laudon and others (1952), it is here judged that the Laudon and Severson (1953) illustration on plate 54, figure 8 is a restored figure and plate 55, figure 25 is an original photograph.

The Brush Canyon specimen is assigned to *P. canadensis* because it has only four arms in the one well-preserved ray and ornamentation consisting of more discrete nodes rather than coalesced nodes and irregular ridges as on *P. beirdneauensis*. It is an adult specimen, larger than any of the five associated specimens of *P. beirdneauensis*. The association suggests close affinity of these two species, with *P. beirdneauensis* derived from *P. canadensis* by increased coalescence of nodes, resulting in irregular ridges parallel to the plate boundaries, and increasing number of arms.

Laudon and Severson (1953) consider *P. canadensis* to be the most primitive form of the noded cup lineage, however, they do not specify the level within the Lodgepole Formation where *P. canadensis* was found. They considered the younger early Burlington forms with a variable number of arms, four to six, and five-armed forms to be next in the lineage with six-armed forms the more advanced. If *P. canadensis* is from the lower or middle part of the Lodgepole (middle to early late Kinderhookian), their conclusions are supported by the occurrence of a transitional form of *P. canadensis* with six-armed forms in the upper part of the Brush Canyon Member, of latest Tn2 age, older than the Burlington Limestone.

Material. One crown (USNM 487187), *in situ*, from the base of the lower ledge, upper middle part of the Brush Canyon Member, Henderson Canyon Formation, approximately one mile east of Beirdneau Canyon, north side of Logan Canyon.

PLATYCRINITES sp., cf. P. CANADENSIS
Laudon and Severson, 1953

Remarks. This specimen is crushed and weathered. It is referred to *P. canadensis* because the ornamentation consists of discrete nodes and coalesced ridges. The number of arms per ray is uncertain. It is associated with a colony of *Stelechophyllum* sp.

Material. Loose slab from an unknown level (probably middle part) of the Brush Canyon Member, Henderson Canyon Formation, Wellsville Mountains, approximately 200 meters north of C Section 26, T. 11 N., R. 2 W. Specimen USNM 487188 is associated with a large colony of *Stelechophyllum* sp.; found by Aram Derewetzky.

PLATYCRINITES BEIRDNEAUENSIS n. sp.
Plate 3, Figures 1, 2B, 4, 6B, 7; Table 1

Etymology. Most specimens were discovered east of Beirdneau Hollow on the southern slopes of Beirdneau Peak, from which the species name is derived.

Diagnosis. A *Platycrinites* recognized by the combination of a basal flange, irregular ridge ornament parallel to the radial and basal margins, and more than four arms per ray.

Description. Crown elongate, slender, vase shaped, slight arm girdle at one-third arm length, six arms per ray, single arms on outer sides of second branching, 36 total. Cup medium bowl, wider than high, with basal flange; ornament of coarsely noded irregular ridges parallel to plate margins. Basal circlet three plates, upflared, shallow bowl; flange surrounds impressed column facet, three to four nodose ridges between flange and distal facets. RR 5, longer than wide, widest at distal apices, gently convex transversely and longitudinally; maximum of six ornament ridges between radial facet and basal facet, three ornament ridges along central sides of radial. Radial facet small, slightly elevated, slopes outward, fills central third of distal quarter of radial. IBr and IIBrr, wider than long, strongly convex transversely, slightly tumid longitudinally. Proximal IIIBrr and IVBrr uniserial, becoming biserial within three to five plates of last branch. Pinnules slender, six to eight plates, longitudinal ridge to distal tip on outer side. First interambulacral plate bears fine granules and coarse nodes with multiple fine spines or irregular vermiform ornament. Other tegmen plates not exposed.

Stem continuous twist type. Proximal 15 columnals heteromorphic, alternating nodals and internodals with circular transverse section on proximal-most columnals, becoming increasingly elliptical in transverse section distally. Nodals with rounded latus extending well beyond straight to slightly rounded latus internodals. More distal columnals homeomorphic, elliptical in transverse section; latus strongly rounded.

Remarks. Wachsmuth and Springer (1897) recognized 60 species of North American *Platycrinites* which they subdivided into 12 groups based on cup shape, ornamentation, thickness of cup plates, and arm structure among other morphologic features. Of the 12 groups, nine have species with ornamentation. Of these nine, the *P. sculptus* group have the bowl-shaped cup and nodose or coalesced nodose ridge ornament of *P. beirdneauensis.*

Table 1.
Dimensions of the holotype and paratype of *Platycrinites beirdneauensis* n. sp.

Measurements	Holotype (USNM 487191) (mm)	Paratype (USNM 487193) (mm)
Crown length	34.7	18.7
Crown width	23.3 (arms splayed)	9.1
Cup, height (top radials)	7.8	5.5
Cup, width (base radial facet)	13.2	7.9
Basal circlet, length	2.0	1.0
Basal circlet, diameter	7.8	4.4
Radial, length	6.2	3.8
Radial, width	5.8	2.7
Radial facet, width	2.3	1.3
IBr, length	1.5	1.2
IBr, width	2.5	1.6
Proximal columnal, diameter	4.1	1.4
Proximal stem preserved	17.6	11.2

Hall (1858) defined *Platycrinites sculptus* on a basal circlet, that has nodose ridge ornament paralleling the outer plate margins and secondary noded ridges radiating from the edge of the depression surrounding the stem facet to the apices with the radials; there is no basal flange. Wachsmuth and Springer (1897) deplored the designation of a species on partial material such as a basal circlet, yet recognized the *sculptus* group containing eight species with nodose ridge ornament paralleling the plate margins of the basals and radials. They illustrated one cup and two partial crowns that they assigned to *P. sculptus* on the basis of the ornament and they also considered *P. rotundus* Miller, 1891 (based on a cup), a junior synonym of *P. sculptus*. All of these specimens are of Osagean age, from the Burlington Limestone of Iowa and Missouri, including *P. sculptus* which has also been reported from the Chouteau Limestone of Kinderhookian age (Bassler and Moodey, 1943). It is here judged that the three specimens illustrated by Wachsmuth and Springer (1897) represent two distinct species, but neither is *P. sculptus. P. rotundus*, however, is considered a junior synonym of *P. sculptus.* The arms of *P. sculptus* are unknown which does not allow comparison of cup shape or of arm structure of crowns with some type of the coalesced nodose ornament with the holotype of *P. sculptus.* Thus, the utility of *P. sculptus* is quite restricted.

Variation in the size and degree of discreteness or coalescence of nodes, size of ridges, and alignment of nodes in ornamented species of *Platycrinites* in the Osagean is perhaps developed to an extreme. This is evident when comparing the illustrations of types and identified specimens from the nu-

merous publications of the Burlington crinoids in the literature (Hall, 1858; Meek and Worthen, 1868; Wachsmuth and Springer, 1897; among others) or identifying new material. It is estimated here that at least one-third of the 60 species that Wachsmuth and Springer (1897) recognized in their 12 groups are synonymous.

Of some geographic distinction is the lack of a basal flange on the Burlington Limestone species of *Platycrinites* and the presence of a basal flange on several species from the Lodgepole Limestone (Laudon and Severson, 1953), Banff Formation (Laudon and others, 1952), and Henderson Canyon Formation. The Henderson Canyon specimens have a basal flange that is not present on *P. sculptus* or on other members of the *P. sculptus* group; also, Henderson Canyon specimens lack the secondary ornamentation of aligned nodes extending from the rim of the stem facet depression to the apices of the basal/radial sutures and from the apices of the basal-radial sutures toward the radial facet on the radials that is present on most members of the *P. sculptus* group.

Variation in the ornamentation of *P. beirdneauensis* ranges from nearly discrete aligned nodes to coalesced noded ridges. Alignment of the nodes and ridges is parallel to the basal-radial or radial-radial sutures or the edges of the radial facet. Specimens of *P. beirdneauensis* are not common in the Lodgepole Formation in Montana but do occur at a number of localities in the Big Snowy Mountains, Bridger Range, and Gravelly Range (Webster, unpublished data).

The two largest specimens (USNM 48719, table 1; and 487195) of *P. beirdneauensis* are judged to be mature individuals with biserial brachials shortly above the last branching. The smallest specimen (USNM 487193, table 1) is judged to be immature as the brachials are cuneate, becoming biserial only in the distal parts of the arms. *P. beirdneauensis* was evolved from *P. canadensis* by an increasing incidence of coalescence of nodes into irregular ridges and an increased number of arms.

Laudon and Severson (1953) noted that the ornamented species of *Platycrinites* were uncommon in the Kinderhookian, but became very abundant in the Osagean. They considered *P. canadensis* a primitive species of the ornamented forms of *Platycrinites* because it has discrete nodes and only four arms. The occurrence of *P. beirdneauensis* in the middle part of the Brush Canyon Member is within the *Siphonodella isosticha*-Upper *Siphonodella crenulata* Biozone (Webster and others, 1987) and is of Tn2 age, equivalent to or possibly slightly younger than *P. canadensis.*

Material. One basal circlet (UMNH IP 2247) from the uppermost part of the Chinese Wall Member, Henderson Canyon Formation, and one basal circlet (USNM 487190) from a float slab in the upper middle part of the Brush Canyon Member, Henderson Canyon Formation, at Wellsville Mountain. Five crowns on one small slab (USNM 487191, holotype; and 487192-487195, paratypes), *in situ*, from the lower ledge, middle part of the Brush Canyon Member, 1 mile east of Beirdneau Hollow. Paratype (USNM 487197) a crown on a float slab, associated with *P. bozemanensis* from an unknown level in the middle or upper part of the Brush Canyon Member at Beirdneau Hollow; collected by Paul Jamison. Crown (USNM 487196) with four arms regenerated at mid-length on a float block from an unknown level in the middle or upper part of the Brush Canyon Member at Leatham Hollow.

PLATYCRINITES PORTIOTORTUOSUS n. sp.
Plate 1, Figure 14B; Plate 4, Figures 2B, 5, 7; Table 2

Etymology. The species name is derived from the Latin *portio*, meaning part, and *tortuosus*, meaning twist. The combination of the two terms refers to the "segmented twist" of the stem.

Diagnosis. A *Platycrinites* with flanged high bowl cup and segmented twist stem.

Description. Crown slender, elongate, flaring slightly distally. Cup high bowl, nearly twice as long as wide, walls subvertical to gently convex, basal flange thin, distinct; plates smooth, no surface ornament. Basal circlet fused, bowl shaped, shorter than wide, widely flared, flange approximately half circlet width. Radials five, longer than wide, moderately convex transversely; proximal two-thirds straight to slightly concave longitudinally; distal third incurves, moderately convex. Radial facet small, two-thirds radial width, wider than long, slope outward. Tegmen elevated moderately; orals bear nodes or short blunt spines. Anal series highly inflated, slope inward slightly, lack nodes or spines, form short anal tube projecting eccentrically above tegmen. Arms six per ray, biserial, slender, gently convex transversely, taper only on distal ends, length two to three times length of cup. Endotomous branching on IBr_1, $IIBr_1$, and inner $IIIBr_2$. Pinnules slender elongate, one per brachial. Stem elongate, non-cirral bearing in proximal 10 to 12 cm, formed by segmented twist pluricolumnals. Proximal-most columnal circular on proximal facet, elliptical on distal facet. Columnals heteromorphic; noditaxis (one twist segment) formula N212 most typical, N11 less common. Nodals rectangular with rounded corners, latus rounded angular, with medial ridge or small nodes, fulcral ridges at 60^o. Internodals elliptical; IN_1 larger, noded or rounded medial ridge latus, becoming less noded distally; IN_2 latus rounded or medial ridge.

Table 2. Dimensions of the holotype and two paratypes of *Playcrinites portiotortuosus* n. sp.

Measurements	Holotype (USNM 487198) (mm)	Paratype 1 (USNM 487199) (mm)	Paratype 2 (USNM 487200) (mm)
Crown length	45.5*	38.2	22.8
Calyx length	22.5	9.0*	10.0
Calyx width	12.5	9.6	8.1
Basal circlet length	6.0	2.7	1.3
Basal circlet, width	12.3	7.5	4.2
Diameter basal flange	5.3	4.5*	3.7
Radial length	11.8	6.2	4.6
Radial width	9.5+	6.5	—
Width radial facet	4.1	3.1	—
* incomplete		+ estimated	

Remarks. Early and Middle Mississippian *Platycrinites* are generally considered to have elliptical columnals which show a *continuous twist* throughout the length of the stem, except the distal most part or distal part of the holdfast section. The twist is the result of the slight offset of the fulcral ridges on opposite sides of each elliptical columnal and it develops with the first or on the first two or three proximal columnals. Stems with elliptical internodals forming straight sections (the fulcral ridges on opposite sides of each columnal are parallel) connected by a rounded quadrangular-shaped twist nodal (the fulcral ridges on opposite sides of the columnal are offset up to 60°) have been described from Osagean strata of Kentucky (Moore and Jeffords, 1968), Moscovian strata of Russia (Arendt and Hecker, 1964), Middle Pennsylvanian strata of Texas (Moore and Jeffords, 1968) and New Mexico (Bowsher and Strimple, 1986), and Early Permian strata of Nevada (Webster and Lane, 1967) and Western Australia (Webster and Jell, 1992). They are here referred to as *segmented twist* stems. The segmented twist columnal may have developed as a result of segmentation of the through-going ligaments as discussed by Baumiller and Ausich (1992). The intercolumnal ligament at the twist columnal (a nodal) connects the through-going ligament of the straight segments (internodals).

Moore and Jeffords (1968) assigned the segmented twist pluricolumnals to the genus *Platyplateium*; their material lacked the crowns. Webster and Jell (1992) assigned the Western Australia specimens to *Platycrinites/Neoplatycrinus*. Except for disarticulated cup plates that are associated with columnals and posses an elliptical columnal facet on the basal circlet (Webster and Lane, 1967; Bowsher and Strimple, 1986; Webster and Jell, 1992), no cups or crowns articulated with the segmented twist stem have previously been described. *Platyplateium* is a junior synonym of *Platycrinites* unless the genera are to be recognized on the basis of the different types of stem, continuous twist for *Platycrinites* and segmented twist for *Platyplateium*. It is possible that other genera of the Platycrinidae in addition to *Platycrinites*, known only from the cup or crown, have a twist stem. Recognition of the type of stem, continuous twist or segmented twist, has not been demonstrated for many species assigned to the various genera of the platycrinitids. Wachsmuth and Springer (1897), among others, have illustrated a number of specimens of crowns with articulated stems of the continuous twist type, some of which were complete through the distal holdfast.

Considering only *Platycrinites*, the recognition of two genera, *Platycrinites* and *Platyplateium*, would leave all species known from the cup or crown, lacking the stem, as well as those known only from the column, in definable assignments. *Platycrinites* would contain all species known from the cup or crown with or without the parts of the stem. *Platyplateium* retained as an informal repository for specimens only known from the columnals and pluricolumnals provides a convenient method of recognizing the forms based on columnals and their separate study for biostratigraphic purposes. This avoids considerable taxonomic confusion in the Platycrinitidae, allowing the transfer of species based on columnals to *Platycrinites* when those columnals are found attached to or in direct contact with the cup or crown. It also allows the biostratigraphic use of species of *Platyplateium* in areas where the cups or crowns are not known.

Segmented twist columnals are not very common until the early Late Mississippian (Ste. Genevieve Limestone), when they become dominant over the continuous twist columnal. The continuous twist columnal is rarely found after the Mississippian. This suggests that with the development of the segmented twist columnal either two lineages of *Platycrinites* continued through the Mississippian or there was polyphyletic evolution of the segmented twist stem, and the segmented twist lineage gradually became the dominant form of the Late Mississippian continuing into the Permian. Cups or crowns of platycrinitids are not common after the Mississippian except in the Permian deposits of Timor as discussed by Bowsher and Strimple (1986).

Growth stages of *Platycrinites portiotortuosus* show a change in the cup from a low to medium bowl in immature forms to a high bowl in gerontic forms. The basal circlet is nearly flat in immature forms, becoming a medium bowl in gerontic forms. Radials are nearly as wide as long in immature forms but lengthen at a much greater rate with growth. The combination of the growth in the basal circlet and radials produces the high bowl of the gerontic forms. Brachials are biserial low in the arms of immature forms and branch with an early development of six arms per ray. No cirri are present in the 10 to 12 cm of proximal stems of the holotype and one paratype.

Without the stem, immature crowns of *P. portiotortuosus* are distinguished from *P. bozemanensis* by the greater development of the basal flange. In the mature forms the much more elongate cup of *P. portiotortuosus* is narrower at the base of the radial facets than at the top of the basal circlet and the basal flange is larger than that of *P. bozemanensis*. Evolution of *P. portiotortuosus* may have been through *P. bozemanensis* by development of these distinguishing cup features and the segmented twist stem.

A noditaxis of *Platycrinites portiotortuosus* is formed by two or three straight internodals and one twist nodal. Noditaxes of younger platycrinitids with segmented twist stems (Moscovian of Russia) have been described with as many as 11 internodals (Trautschold, 1879; Yakovlev and Ivanov, 1956). It is not known if an increasing number of internodals is a normal evolutionary trend or if the number of internodals increases or decreases distally along the stem. The variation in number of internodals within one stem or within stem sections is unknown, but pluricolumnals with incomplete(?) noditaxes of three (Webster and Lane, 1967) to seven (Yakovlev and Ivanov, 1956) internodals have been illustrated.

Webster and Lane (1987) suggested that the continuous twist stem acted as a wind vane channeling currents up around the cup and the arms whether in the feeding filter fan position or resting position. During periods of low current velocity this may have been an aid, channeling food particles to the filtration fan. Also, it may have generated current eddies that aided in catching food particles. During periods of very high current velocity it might have added excess stress to the crown in the open filter fan position and caused eddies that may have disrupted or hindered the normal filter fan food-gathering

processes. The channeling of currents up the stem could have given a small amount of lift to the crown for positioning and possibly elevation, although Baumiller (1992) concluded that the crinoid crown was normally not able to use the lift for elevation purposes. Flume studies by Riddle (1989) demonstrated that the current made one turn around the continuous twist stem and particles were dispersed into a wide and deep band in the lee of the stem. This may have allowed the crinoid to take advantage of potentially slower moving currents for entrapping nutritional resources.

The segmented twist stem should provide greater disruption of the passing currents than the continuous twist stem. If so this could provide even greater dispersion of food particles in slower current eddies that the animal could use to its advantage in obtaining nutritional resources. Flume studies are needed to compare the difference in hydrodynamic effects on the continuous and segmented twist stems. The relatively large size of the columnals in some of the Pennsylvanian and Permian species may have aided in the elevation of the crown off the substrate by providing a less flexible and more rigid column, rather than a flexible stem.

The lack of cirri or cirral facets along the 12 cm preserved on *Platycrinites portiotortuosus* indicates that this proximal portion of the stem was free, not part of the holdfast system. The relatively small size was moderately flexible as reflected in the curvature of sections as preserved.

A pluricolumnal (USNM 478208) with a noditaxis pattern of N3231323 and cirri on some of the primary and secondary internodals (plate 4, figure 3) is tentatively considered to be a distal segment of the stem of *Platycrinites portiotortuosus*, although it could belong to another species. The cirri are circular in transverse section, but details of the articular facets bearing a crenularium are not exposed or lost by weathering.

Material. One slab bearing 10 crowns, the holotype (USNM 487198) and nine paratypes (USNM 487199-487207), from upper crinoid interval of the Brush Canyon Member, Henderson Canyon Formation, 0.5 mile west of Wind Cave, Logan Canyon. Measurement of the holotype and two paratypes are presented in table 2. The loose slab is judged to have moved less than one meter from the point of origin. Pluricolumnal (USNM 487208) is on a float block from the top part of the Chinese Wall Member, Henderson Canyon Formation, above the toilet west of Boy Scout Camp Kiesel, north of Causey Reservoir. Pluricolumnal specimen (USNM 487210) is from the uppermost part of the Chinese Wall Member, Blacksmith Fork Canyon. Pluricolumnal (USNM 487209) and pluricolumnal (USNM 487211) occurring with part of a disarticulated crown are both on float blocks from the middle part of the Brush Canyon Member, Wellsville Mountain.

Subclass INADUNATA Wachsmuth and Springer, 1885
Order CLADIDA Moore and Laudon, 1943
Suborder CYATHOCRININA Bather, 1899
Superfamily CYATHOCRINITACEA Bassler, 1938
Family CYATHOCRINITIDAE Bassler, 1938
Genus CYATHOCRINITES Miller, 1821
CYATHOCRINITES sp.
Plate 5, Figure 7

Description. Crown crushed, incomplete, cylindrical, 31.4 mm long. Cup bowl-shaped, 9.1 mm long, 13.8 mm wide. Infrabasal circlet convex, very gently upflared; IBB distal tips visible in lateral view. BB large, wider (6.4 mm) than long (4.8 mm), gently convex transversely and longitudinally, strongly upflared. RR large, wider than long, moderately convex transversely and longitudinally, subvertical to slightly incurved distally. Radial facet angustary, deep, slope outwards. Single large anal in radial circlet, adjoining posterior basal. Brachials rectilinear, transversely deep U-shaped proximally, becoming more V-shaped distally. Ambulacral groove deep, covered by numerous small plates. Arms branch on IBr_3; distal branchings occur, position indeterminate. Tegmen crushed, bearing hexagonal plates, length indeterminate. Stem round transversely, 2.9 mm diameter, heteromorphic, N212 pattern, non-cirriferous in proximal 45 mm. Columnal latus strongly convex.

Remarks. This specimen is weathered and was chipped by tumbling float blocks. It resembles specimens illustrated by Laudon and others (1952, plate 65, figures 3-7) from the Banff Formation and Laudon and Severson, (1953, plate 51, figures 13-14) from the Lodgepole Limestone. It differs from those specimens in that the infrabasal circlet is relatively larger and upflared with the distal tips visible in lateral view and the first arm branching is on the third primibrachial instead of the second (Banff specimens) or fourth (Lodgepole specimens). The specimen is not suitable to serve as a type but is briefly described for faunal completeness and comparisons with other faunas.

Material. One crown (USNM 487212) on a float slab from the middle part of the Brush Canyon Member, Henderson Canyon Formation, probably from the lower ledge, from Wellsville Mountain.

Suborder DENDROCRININA Bather, 1899
Superfamily MASTIGOCRINACEA Jaekel, 1918
Family MASTIGOCRINIDAE Jaekel, 1918
Genus ZYGIOSOCRINUS TYPICUS n. gen., n. sp.
Plate 5, Figure 6

Etymology. The generic name is from the Greek, *zygios*, meaning of a yoke, and refers to the morphologic features on this taxon found in two separate families. The species name refers to being the first named species assigned to the genus.

Diagnosis. A mastigocrinid with truncated cone-shaped cup, isotomous arm branching on second primibrachial, ramules on alternating brachials, and pentagonal stem.

Description. Crown cylindrical, small, incomplete length 13.7 mm, width 19.2 mm with arms splayed. Cup medium truncated cone, length 2.3 mm, width 3.6 mm; walls straight, outflared, fine shagreen ornamentation. IBB circlet diameter 1.7 mm, subhorizontal, distal tips upflared 0.4 mm above basal plane, visible in lateral view. BB hexagonal, length 1.0 mm, width 1.1 mm, gently convex transversely, straight longitudinally. RR largest cup plates, length 1.2 mm, width 2.0 mm, gently convex transversely, straight proximally becoming slightly convex distally. Radial facet plenary, subhori-

zontal to slightly inward slope. Anals not observed, probably three. All brachials strongly convex transversely. IBr two, moderately constricted medially, hourglass shaped; suture between very faint. IBr_1 rectilinear, widest proximally, length 1.2 mm, width 1.9 mm. $AxIBr_2$ pentagonal, slightly longer (1.2 mm) than wide (1.0 mm). IIBr elongate, rectilinear (non-ramule bearing) or pentagonal (ramule bearing) with large ramule facet. Ramules coarse, elongate, extending to distal tips of arms, one on every other brachial on alternating sides of arm. Arms stout, isotomous branching on $AxIBr_2$, no further branching. Transverse stem outline pentagonal at base of cup, 0.9 mm diameter. Columnals heteromorphic, N1 pattern.

Remarks. The cup of *Zygiosocrinus typicus* is slightly crushed parallel to the BC-D ray plane and oriented with the A ray centered and arms splayed. The anals are not exposed, but the very wide area of the CD interray suggests there are three anals present.

Zygiosocrinus typicus has features of both disparids and poteriocrines. Without the arms the truncated cone-shaped cup would be classified in the slightly advanced poteriocrines, probably in the Scytalocrinidae. The cup is not a high cone with impressed sutures or ray ridges as is common to the Mastigocrinidae. Branching of the arms on the second primibrachial and lacking more distal branchings is an advanced condition, common to many poteriocrines and atypical of the mastigocrinids. The suture between the two primibrachials is very faint, as though they were near a fused state, also suggesting an advanced condition, perhaps approaching branching on the single primibrachial, as is common to advanced poteriocrines. The coarse elongate ramules, however, are smaller in width but as long as the remainder of the arm from where they originate. Brachials bearing ramules alternating with non-ramule bearing brachials precludes inclusion of this taxon with the Scytalocrinids as classified in the *Treatise of Invertebrate Paleontology* (Moore and Teichert, 1978). Therefore, *Z. typicus* is tentatively assigned to the Mastigocrinidae.

Material. One crown (USNM 487213) from the upper part of the Brush Canyon Member, Henderson Canyon Formation, Beirdneau Canyon, Logan Canyon; found by Paul Jamison.

Suborder POTERIOCRININA Jaekel, 1918

Remarks. Representatives of the Suborder Poteriocrinina of the Subclass Inadunata are the most diverse and common crinoids from the Late Mississippian throughout the remainder of the Paleozoic. They rivaled the camerates for greatest diversity, but generally were less abundant, during the Early Mississippian. Classification of most of the superfamilies and families as given in Part T of the *Treatise* (Moore and Teichert, 1978) is judged to be artificial and parts or all of the classification have been questioned for some time (Kelly, 1982; Webster and Lane, 1987; Webster and Jell, 1992; Kammer and Ausich, 1994; among others). Recently, Simms and Sevastopulo (1993) considered the Inadunata a paraphyletic taxon, recommended that it be discarded, proposed a classification subdividing the former Inadunata into two Subclasses and one Incertae Sedis taxon, and included the Flexibilia and Articulata as infraclasses of the Subclass Cladida. They commented only briefly on the merits and justification of their classification. Although in partial agreement with their proposed classification, I believe that the phylogenetic relationships of the taxa remain to be fully demonstrated and the Incertae Sedis taxon, requiring considerable investigation, will probably be divided into two or more subclasses. Thus, the classification suggested by Simms and Sevastopulo is not followed at this time.

The *Treatise* classification (Moore and Teichert, 1978) is based primarily on cup shape, cup plate arrangement, number of anals, radial facets, arm branching patterns, and total number of arms. Dissimilarity or similarity of morphologic features within this classification are considered to have developed from a combination of polyphyletic origins and mosaic evolution during the middle to late Paleozoic.

Kammer and Ausich (1992, 1993, 1994) reviewed the poteriocrine crinoids from the Middle Mississippian of the east-central U. S. and based a subdivision of the genera on the basis of the shape of the cup. Their primitive-grade cups (ibid., 1992) have a medium to high cone- or bowl-shape with the infrabasals clearly visible in lateral view, intermediate-grade cups (ibid., 1993) have a truncated cone- or intermediate bowl-shape with the infrabasals confined to the base or basal cavity, and advanced-grade cups (ibid., 1994) have a low bowl- or disc-shape with the radials the dominant cup plates. These three cup grades or distinctions have been considered to reflect an evolutionary trend within the cladids for many years (Moore and Plummer, 1940; among many others); however, the evolution of cup shape alone is not a pure phylogenetic lineage. Indeed, although assigned to different genera of families, all three cup shapes occur together in Devonian through Permian faunas.

Brachial plate structure has been given little consideration for classification and evolutionary trends in the early diversification of the Poteriocrinina. The *Treatise* classification (Moore and Teichert, 1978) includes genera with slender arms composed of externally strongly rounded cuneate brachials in the same family with genera in which the arms are made of narrow to wide, externally flat to rounded rectilinear brachials. Virtually no evaluation was made of the evolutionary development of these two quite dissimilar brachial forms. In some families genera are grouped together on the basis of cup shape and number of anals with only one or two "oddball" genera bearing cuneate brachials and all others rectilinear, specifically, *Holcocrinus* in the Graphiocrinidae. Commonly, there are additional differences (sometimes minor) in the cup shape and other features of the arms that suggest a different phylogenetic origin of the "oddball" form in the family.

The cuneate brachial evolved polyphyletically as it is found in the camerates (for example, *Alisocrinus*, Late Ordovician - Early Silurian; *Clematocrinus*, Middle Silurian) and articulates (for example, *Dunnicrinus*, Late Cretaceous; *Cenometra*, Recent) as well as the inadunates. Although not as closely spaced as in the biserial arm structure, the cuneate brachials provide another method of closer spacing of the

pinnules. This results in an increased density of the opened feeding posture of the filter fan.

I suggest that an evolutionary clade consisting of *Culmicrinus* and *Blothrocrinus* of the Blothrocrinidae, all of the Aphelecrinidae, *Corythocrinus* (Corythocrinidae), *Chlidonocrinus, Proampelocrinus, Ampelocrinus*, and *Armenocrinus* (Ampelocrinidae), *Holcocrinus* (Graphiocrinidae), *Ascetocrinus* (Cercidocrinidae), along with several genera of the Scytalocrinidae and Decadocrinidae may be recognized. A few other genera currently assigned to other poteriocrine families may also belong in this clade or may represent later polyphyletic evolution of the cuneate brachial. The proposed clade (recognized by the narrow, transversely strongly rounded cuneate brachials) basically retained a conservative conical cup containing three anals in a slightly advanced position throughout most of its history. Where known, most of the clade taxa have sizable tegmens, some of which are recurved or ballooned distally. Mosaic evolution during clade history shows trends similar to those previously recognized in the inadunates. That is, a tendency for first arm branchings to become lower and development of different arm branching patterns. Modification of the cup shape toward a bowl or impressed base is minimal. Only in a few genera are the infrabasals not a part of the cup wall (*Abrotocrinus*) or are less than three anals in the cup (*Holcocrinus, Agnostocrinus*).

Recognition of the cuneate brachial clade will result in major changes in the *Treatise* classification of the Poteriocrinina. Justification of the clade and classification within it requires additional investigation. The possibility of polyphyletic origin of taxa currently considered to belong to this clade must be evaluated as well as the possible evolutionary descendants currently assigned to various families within the poteriocrines. The cuneate brachial clade is discussed here because other crinoid workers need to be aware of problems within the currently used classification and criteria that require evaluation when revisions are made. Complete revision of the classification is beyond the scope of this study but must be made before the full stratigraphic and paleoecologic utilization of the Poteriocrinina will be known.

Family RHENOCRINIDAE Jaekel, 1918

RHENOCRINIDAE?, n. gen., n. sp. undesignated

Plate 3, Figure 5

Description. Crown small, cylindrical, length 15.4 mm (incomplete), width 6.5 mm (distorted slightly). Cup truncated medium cone; faint interplate stellate ridge ornamentation and pits at apices of basal and radial sutures. IBB small, distal tips extend beyond proximal columnal, upflared, visible in lateral view of cup. BB hexagonal, slightly wider (1.6 mm) than long (1.4 mm), gently convex transversely and longitudinally, strongly upflared, form large part of cup wall. RR pentagonal, wider (2.1 mm) than long (1.6 mm), gently convex transversely and longitudinally. RR facet peneplenary, crescent shaped, on elevated platform, sloping down and out; transverse ridge nearly full width of facet; outer ligament area deep; ligament pit external of outer ligament ridge and furrow; muscle areas and central pit not visible. Anals three (?) in cup, large, elongate extending nearly vertically upwards to tube plates. IBr_1 wider (1.6 mm) than long (1.2 mm), constricted medially, widest at base. IBr_2 wider (1.4 mm) than long (1.3 mm), axillary, constricted medially, widest at distal ends of bifurcation facets. Brachials increasingly cuneate distally after isotomous branching, constricted medially, strongly convex transversely. Pinnules elongate, slender, one per brachial on opposite sides of arm. Stem heteromorphic; noditaxis pattern N212 proximally, N1 distally, 18.7 mm preserved, 1.2 mm diameter uniform. Columnals circular in transverse section, thicken distally.

Remarks. The specimen is crushed from compaction; cup plates are slightly dislocated and the arms slightly splayed. As a result of the dislocation of some plates, the distorted cup shape appears to be a medium bowl rather than a medium cone. Orientation of the crown is such that the anal interarea and the D and E rays are visible.

Apical pits and stellate ridge ornamentation, as developed on this specimen, are common features on cups of the poteriocrinids and rhenocrinids. The arms, however, branch on or above the third primibrachial and commonly branch again, three or four times in genera in the Poteriocrinitidae and Rhenocrinidae. The morphology of the radial facet, with the exception of the ligament pit being external of the ligament ridge, is most like that of the rhenocrinids, which is more like the facets of most late Paleozoic Poteriocrinina. The cuneate brachials are not typical of the Rhenocrinidae but are typical of the clade mentioned in the discussion of the Poteriocrinina above. The specimen is questionably assigned to the Rhenocrinidae because of the cup and radial facet characters. It is not given a genus or species name because the cup is distorted and some plate relationships are not clearly known.

Material. UNMH IP 2246, One crown from the base of the Chinese Wall Member, Henderson Canyon Formation, south-facing slope on Wellsville Mountain, Utah. Found by Jack Oviatt.

Family SCYTALOCRINIDAE Moore and Laudon, 1943

Genus SCYTALOCRINUS Wachsmuth and Springer, 1880

Remarks. Laudon (1941) pointed out the problems of generic assignment of Early Carboniferous poteriocrines with ten arms in which the branching is on or before the second brachial. This group of poteriocrines underwent a major radiation during the Lower Carboniferous and mosaic evolution in the cup and arms was common within the lineages. Laudon (1941) noted the characteristics and some problems with genera such as *Decadocrinus, Phanocrinus*, and *Melbacrinus* and suggested that species then assigned to *Scytalocrinus* could perhaps be grouped under at least three additional genera based on shape of the cup, characters of the infrabasals, and type of brachials. After 1941 and prior to 1992 four new genera were proposed and a few of the species reassigned to other genera, however, the increased number of new species assigned to *Scytalocrinus* and the degree of variation among them and those previously recognized had not resolved the problems. Kammer and Ausich (1992, 1993)

considered four species of late Osagean-early Meramecian to be true *Scytalocrinus* (*S. robustus, S. cantonensis, S. decadactylus*, and *S. disparilis*) and reassigned two other species (*S. validus* and *S. hamiltonensis*) to *Parascytalocrinus*, a fifth genus.

Scytalocrinus remains an agglomeration of species, here considered of polyphyletic origin. The 24 species currently assigned to the genus include at least eight species [*S. deminutivus* Strimple, 1939; *S. kalmiusi* Yakovlev and Ivanov, 1956; *S. larvalis* Strimple, 1939; *S. pentacolumnus* Strimple, 1940; *S. reconditus* Webster and Lane, 1970; *S. talboti* (Worthen, 1882); *S. tenuis* (Miller, 1821); and *S. urna* (Trautschold, 1879)] that are here judged to be incorrect generic assignments and two species [*S. elongatus* (Sladen, 1878) and *S. loreus* (Sladen, 1878)] that have never been illustrated and are considered to be doubtful assignments, perhaps *nomen dubia*. The remaining 14 species may be divided into three groups based primarily on the brachial shape and secondarily on the cup morphology.

1. *Scytalocrinus robustus* (Hall, 1861), group: typical of the genus and characterized by an expanded bowl- or truncated cone-shaped cup, with infrabasals confined to the subhorizontal base, only the distal tips of the infrabasals visible in lateral view of the cup, and the brachials slightly but not strongly cuneate. This group also includes the species *S. abnormis* Worthen, 1875; *S. aftonensis* Strimple, 1951; *S. dunlapi* Laudon, 1941; *S. garfieldi* Laudon, 1941; *S. cantonensis* (Miller and Gurley, 1890); and *S. seafieldensis* Wright, 1948. It is restricted to the Lower Carboniferous of northern Europe and the Osagean-Chesterian parts of the Mississippian of the United States.

2. *Scytalocrinus disparilis* (Miller and Gurley, 1890), group: has a bowl-shaped cup, infrabasals confined to the base or the distal tips are upflared, visible in lateral view of cup, and the brachials moderately to strongly cuneate. It includes *S. braggsi* Laudon, 1941, and *S. occiduus* n. sp. This group is known from Kinderhookian and Chesterian strata of North America.

The *Scytalocrinus disparilis* group is morphologically similar to the *Scytalocrinus robustus* group but distinguished by having more strongly cuneate brachials. These groups are probably derived from a common or different lineages from forms such as *Culmicrinus* or *Blothrocrinus* by lowering of the first branching in some rays to the first primibrachial and confinement of the infrabasals to the basal plane or barely above. It is possible that these two groups form an intricately related clade that should be recognized as one genus with the more strongly cuneate brachials evolved from the less cuneate forms.

3. *Scytalocrinus decadactylus* (Meek and Worthen, 1860), group: also with a wide bowl- or truncated cone-shaped cup; the infrabasals confined to the subhorizontal base; the distal tips of the infrabasals upturned and visible in lateral view; the brachials very short, moderately rounded transversely, and rectilinear instead of cuneate. The arms, which are widest in the central part resulting in a club-like appearance, are the distinguishing character of this group, which also contains *S. crassibrachiatus* Moore and Strimple, 1973, *S. fremontensis* Pabian and Strimple, 1974, and *S. validus* Wachsmuth and Springer, 1897. Kammer and Ausich (1993) designated *S. validus* the type species of *Parascytalocrinus*. They considered the atomous A ray one of the key characters of the genus. The arm structure may provide a phylogenetic link and better classification of the scytalocrinids when fully understood. Thus, I currently considered *Scytalocrinus validus to* belong to the *Scytalocrinus decadactylus*, a group not considered to be *Scytalocrinus* sensu stricto. The *S. decadactylus* group is known from Osagean into Morrowan strata from North America and possibly originated from *Bollandocrinus*, retaining the arm structure, with lowering of the cup and the arms branching on the first primibrachial.

SCYTALOCRINUS OCCIDUUS n. sp.
Plate 5, Figure 2

Etymology. The specific name *occiduus* is Latin meaning western and refers to the western U. S.

Diagnosis. A *Scytalocrinus* recognized by the hourglass shape of the primibrachials.

Description. Crown slender, elongate, 35 mm length (enclosed, estimated), width 8.0 mm (enclosed, estimated). Splayed length 23.2 mm, width 40.8 mm. Cup medium bowl, flattened along A-CD symmetry plane, length 5.1 mm, width 7.7 mm. IBB five, small, distal tips project upward beyond proximal columnal, visible in lateral view. BB 5, large, outflared, gently convex transversely; CD basal largest, 2.5 mm length and width, truncated distally for anal X. RR 5, largest cup plate, 2.3 mm long, 2.7 mm wide. Radial facets plenary. Anal interradius wide. Anals three below radial summit, intermediate condition, RA large, 1.8 mm length, 1.6 mm width, offset to lower left side of C radial and above distally truncated CD basal; adjoined distally by anal X and right tube plates. Anal X adjoined by three tube plates; proximal half of anal X and right tube plate below radial summit. Brachials moderately large, cuneate, strongly rounded transversely. IBr_1 hourglass shaped, sides constricted medially, widest on proximal end; axillary in D (3.1 mm length, 3.4 mm width) and E (2.0 mm length, 3.4 mm wide) rays. No further branching observable.

Anal tube elongate, slender, formed of four rows, vertically stacked, large, thick hexagonal plates; plates strongly rounded to bulbous; rows offset, plates interlock laterally.

Column circular in transverse section, diameter 2.4 mm proximally, 1.3 mm distally, 18.5 mm preserved. Columnals with rounded latus, heteromorphic N121 pattern. Cirri long, developed close to cup.

Remarks. The crown of *Scytalocrinus occiduus* is moderately flattened and weathered. Shape of the cup is based on the weakly upflared infrabasals that would only have the distal tips visible in lateral view. The incomplete tegmen, with a narrow cylindrical shape, resembles that of *Holcocrinus longicirrifer*, a form that has much thinner, alternating short and long, vertically stacked plates, and lacks the uniform interlocking pattern of *Scytalocrinus occiduus*. Also *H. longicirrifer* has distal branchings in each ray, lacking or uncertain in *Scytalocrinus occiduus*, and only one anal below the radial summit.

Scytalocrinus occiduus belongs to the *S. disparalis* group of *Scytalocrinus* and differs from species in that group by having a higher cup and a greater hourglass shape to the primibrachials. It differs from *Scytalocrinus braggsi* by having a greater taper to the walls of the cup, rather than strongly rounded, and the primibrachs and first secundibrachs are considerably smaller.

Material. One crown (USNM 487214) on a float slab from an unknown level in the upper half of the Brush Canyon Member, Henderson Canyon Formation, Beirdneau Hollow area, Logan Canyon; found by Paul Jamison.

Genus BRIDGEROCRINUS Laudon and Severson, 1953

Remarks. *Bridgerocrinus* was named for specimens from the Lodgepole Formation of Montana by Laudon and Severson (1953) with the type species *B. fairyensis.* In a rather lengthy discussion of the origin of the scytalocrinids and *Bridgerocrinus*, Laudon and Severson (1953) reported a range of Late Devonian through Osagean for the genus, however the only species they recognized was *B. fairyensis*. Furthermore, they report the second primibrachial to be axillary, when the third primibrachial is axillary in one ray on the paratype illustrated by them on plate 51, figure 8.

I consider *Poteriocrinus (Decadocrinus) zethus* Williams, 1882, reported from the Ithaca Formation (Frasnian) of New York, to be a *Bridgerocrinus.* It is possible that Laudon and Severson were considering inclusion of this taxon in *Bridgerocrinus* when they recognized a Late Devonian through Osagean range for the genus.

Bridgerocrinus was reported by Waisfeld (1989) from Devonian strata of Argentina. The radial facets, however, of the Argentinian specimen are angustary, instead of plenary, and the proximal brachials are quite short with first branching on the third primibrachial of the known partial C ray. The Argentinian specimen is here judged to belong to the Rhenocrinidae, probably *Maragnicrinus*, to which it is questionably assigned. The range of *Bridgerocrinus* is here recognized to be Late Devonian, Frasnian, to Mississippian, possibly earliest Osagean, and the genus is considered to have the second, or less commonly third, primibrachial axillary.

BRIDGEROCRINUS FAIRYENSIS Laudon and Severson, 1953

Plate 5, Figures 1, 3, 4, 9

Remarks. New morphologic information is provided by three specimens of *Bridgerocrinus fairyensis* from the Brush Canyon Member. All known specimens of *B. fairyensis* are small, typically the cup is less than 4 mm in length, and crowns are less than 25 mm length as reported by Laudon and Severson (1953). The four specimens reported herein are judged to be immature, ranging in cup length from 1.0 to 1.4 mm with the two crowns 9.9 and 10. 6 mm long. All arms visible are axillary on the second primibrachial. The strongly transversely rounded first and second primibrachials are laterally constricted medially, producing a faint hourglass shape. With a casual glance the arms could be erroneously interpreted as branching repeatedly on the most distal two or three brachials as the proximal pinnulars on these most distal parts of the arm are nearly as large as the brachials to which they are articulated. The brachials are recognized by their slight cuneate shape, transversely rounded exterior, and shoulder bearing the pinnule facet. The pinnulars bear a longitudinal ridge, are narrower, and are rectangular, not cuneate. A slender high tegmen is composed of hexagonal plates in staggered interlocking rows as shown on specimen USNM 487216.

The stem, based on a single columnal, was reported as round by Laudon and Severson (1953). Two of the crowns reported herein have 2.6 and 5.0 mm of the proximal part of the stem attached. Columnals are round in transverse section with a gently rounded latus and hetermorphic proximally (N1 pattern) becoming homeomorphic at 1 mm distance from the cup.

Dimensions of four specimens are: (1) USNM 487215 larger crown: cup length 1.4 mm; crown length 2.6 mm through IBR_1; total crown length 6.6 mm; length crown plus stem 10.6 mm; (2) USNM 487216: crown length 7.2 mm; cup length 1.2 mm; length crown plus stem 9.9 mm; (3) USNM 487218 small crown, weathered, poorly preserved; cup length 1.0 mm; crown length 3.0 mm through $1BR_1$; no stem preserved; (4) USNM 487219: cup length 1.1 mm; crown length 7.0 mm, with stem 9.6 mm.

Bridgerocrinus fairyensis was previously known only from the Lodgepole Formation of Montana (Laudon and Severson, 1953). With the elongate brachials these small forms could be interpreted as immature. Many specimens, however, of *B. fairyensis* are known from Montana and all, including those reported here from the Brush Canyon Member, are also quite small.

Material. Two crowns (USNM 487215 and 487216) on separate float blocks from unknown levels within the upper parts of the Brush Canyon Member, Henderson Canyon Formation, Wellsville Mountain. Five crowns (USNM 487218-487222) on a single float slab from the lower ledge, middle part of the Brush Canyon Member, Wellsville Mountain.

BRIDGEROCRINUS JAMISONI n. sp.

Plate 5, Figure 8

Etymology. The species name is for Paul Jamison, Logan, Utah, who found the specimen.

Diagnosis. A *Bridgerocrinus* distinguished by exceptionally long parallel-walled primibrachials and proximal most secundibrachials.

Remarks. Crown elongate, slender, 36 mm long, 18 mm wide (distal end). Cup truncate cone, 2.8 mm long, 4.3 mm wide, sutures impressed, apical pits shallow. IBB mostly confined to base of cup, distal tips barely visible in lateral view. BB moderately large, straight longitudinally, moderately convex transversely, 1.4 mm long, 1.5 mm wide. RR large, form upper half of cup, outflared, straight longitudinally, moderately convex transversely, 1.6 mm long, 1.5 mm wide. Radial facets plenary; moderate gape between RR and IBrr along mutual facet. IBr_1 elongate, sides parallel, 3.5 mm

long, 1.7 mm wide, axillary in three rays, in fourth ray non-axillary IBr_1 and axillary IBr_2 equal AxIBr length in other rays. IIBr elongate proximally, subequant distally; $IIBr_1$ 2.5 mm length, $IIBr_2$ 1.9 mm length, $IIBr_3$ 1.1 mm length. Brachials slightly cuneate above $IIBr_2$, strongly rounded transversely, stout shoulder bearing pinnule facet, slight zig-zag appearance. Pinnules slender, elongate, stout, with longitudinal angular ridge; wide, large V-shaped ambulacral groove. Branchings isotomous on IBr_1 or IBr_2 and on $IIBr_{16}$ or higher in some rays. Arms incurl at distal tips. Anals and tegmen unknown. Stem round in transverse section, 1.8 mm diameter proximally, 7.7 mm preserved. Heteromorphic, N212 and N1 patterns in proximal 24 mm, homeomorphic distally with gradual increase in length of columnals. Columnals with rounded latus.

Remarks. The long proximal brachials, branchings on the first or second primibrachial, one isotomous distal branching, and a conical cup are the characteristics of *Bridgerocrinus* to which *B. jamisoni* is assigned. Unfortunately the anals are not exposed on *B. jamisoni* precluding a comparison of the anal series. The wide space in the unexposed part of the crown, however, suggests that the anal series is probably formed by a series of three anal plates within the cup. It is possible that the elongate axillary primibrachials of *B. jamisoni* are each formed by the fusion of two primibrachials, which are not fused in the one ray with the second primibrachial axillary. This is judged to be an advanced evolutionary condition.

The crown of *B. jamisoni* is not considered an adult *B. fairyensis* because the relative length of the brachials above those of the proximal three are approximately all subequant. Even more distal brachials above the proximal three are elongate on *B. fairyensis* and all the elongate brachials of *B. fairyensis* have slight constrictions in the central part of each brachial, rather than the parallel sides of brachials of *B. jamisoni*.

Four genera of the cladid inadunates, *Bridgerocrinus, Phacelocrinus, Hydriocrinus,* and *Melbacrinus,* as well as some species assigned to *Scytalocrinus,* have elongate proximal brachials. Although those of *Hydriocrinus* are the shortest, they are relatively elongate compared to more distal brachials on the same specimen and compared to the proximal brachials of most other cladids that do not bear spines or large nodes on the axillary single primibrachial. On *Phacelocrinus* and *Hydriocrinus* only the primibrachials are very elongate, whereas the primibrachials and proximal secundibrachials are elongate on *Bridgerocrinus.* The nature of the length of the secundibrachials is not known on *Melbacrinus*. Although these four taxa occur sequentially in the Mississippian and Pennsylvanian, separated by time gaps, the relative lengths and shapes of the brachials suggest that they are not an evolutionary lineage. It is possible that they are derived from a common ancestor. The brachials of these four taxa, although similar among themselves, are sufficiently different from those of other genera in the Scytalocrinidae that they could be grouped into a subfamily or a separate family. Such a subdivision is not here formally proposed pending further study of the family and related cladids.

Material. One crown (USNM 487224) on a float slab from an unknown level in the upper half of the Brush Canyon Member, Henderson Canyon Formation, Beirdneau Hollow, Logan Canyon; found by Paul Jamison.

HISTOCRINUS Kirk, 1940

Remarks. *Histocrinus* Kirk, 1940 was defined, with the type species *H. coreyi* (Worthen and Meek, 1875), as the first radials "....truncated their whole width for the reception of a second radial piece," (Worthen and Meek, 1875, p. 516). There are, however, radial notches on the illustrations of the two specimens illustrated by Worthen (ibid., Plate 29, figures 2-3). Also, the types have an atomous A ray, nine arms total. As noted by Kammer and Ausich (1992), other species assigned to *Histocrinus* have 10 arms, with the A ray branching on the second primibrachial. The genus is here interpreted to have nine or ten arms, with or without small radial notches.

HISTOCRINUS? LOGANENSIS n. sp.
Plate 6, Figure 4

Etymology. The name refers to Logan Canyon, Utah where the specimen was found.

Diagnosis. A scytalocrinid with pentagonal shaped stem, radial notches, arm branchings on the first primibrachial, and cuneate brachials.

Description. Crown slender, cylindrical, incomplete length 35.8 mm, width 24.8 mm arms splayed. Cup medium cone-shape, 5.5 mm length, 7.5 mm estimated width. IBB 5, small, dart-shaped, 1.5 mm length, 1.3 mm width, distal tips upturned, visible in lateral view, bear pentagonal stem facet (1.9 mm diameter). BB 5, hexagonal, gently convex transversely and longitudinally, form two-fifths cup wall, 2.3 mm length, 2.5 mm width. RR 5, large, wider (4.0 mm) than long (2.5 mm), widest at proximal end of small to medium radial notch, gently convex transversely and longitudinally. Radial facets peneplenary. One anal, large, longer than wide, sitting on truncated end of posterior basal. IBr_1 axillary in three rays exposed, strongly convex transversely, constricted medially, hourglass shaped, slightly wider (3.5 mm) than long (3.2 mm), widest on proximal end. Brachials strongly cuneate, strongly convex transversely, bear one pinnule on alternate sides of arm. Pinnules stout, slender, bear medial longitudinal ridge, slightly constricted transversely. Branching isotomous. Stem pentagonal, heteromorphic proximally. Anals and tegmen not exposed.

Remarks. On the single known specimen, the cup, primibrachials and short section of the stem are partly silicified and the cup is slightly disarticulated. Distal parts of the arms are not silicified. Silicification and weathering have destroyed most details of the small stem segment adjacent to the facet. The crown is oriented with the B, A and E rays exposed. The cup has the proximal end slightly upturned and preparatory removal of matrix displayed the slight dislocation of the C and D radials.

Generic assignment of this specimen is tentative. The pentagonal stem and presence of radial notches suggest affinity with the Rhenocrinidae from which this specimen may have been derived. The single branching of the arms, however, on the single primibrachial is atypical of the rhenocrinids, which tend to branch numerous times with the first branch most commonly higher than the second primibrachial. Cuneate brachials are also atypical of the rhenocrinids. With casual observation the specimen appears similar to *Scytalocrinus occiduus*, but differs by the presence of radial notches, more strongly cuneate brachials, a pentagonal stem and more conical shaped cup. The presence of radial notches are atypical of the Scytalocrinidae, however, they are developed in *Histocrinus*, which has arms branching on the second, not the first primibrachial.

In the Scytalocrinidae two genera, *Phacelocrinus* and *Hydriocrinus*, have pentagonal stems. I consider the pentagonal stem to be of significance in the classification of the inadunates but, at present, not well understood. *Phacelocrinus* and *Hydriocrinus* have very high conical cups and are recognized on minor differences in the arrangement of the anals, which may not be a significant generic difference. Both genera have had species assigned to them with cuneate and rectilinear brachials and need revision.

The questionable assignment of this specimen to *Histocrinus* is based on the cup shape, radial notches, brachial type, and arm branching pattern. It is possible that *H.? loganensis* represents a new genus belonging to a clade with a pentagonal stem that evolved concurrently with the Scytalocrinidae.

Material. One crown (USNM 487225) on a float slab from an unknown level in the upper half of the Brush Canyon Member, Henderson Canyon Formation, Beirdneau Hollow Logan Canyon; found by Paul Jamison.

SCYTALOCRINIDAE n. gen., n. sp. undesignated

Plate 6, Figures 1, 2, 7; Table 3

Description. Crown slender elongate, may flare distally. Cup high cone-shaped, widest at radial summit, sutures slightly impressed, becoming moderately impressed distally along mutual RR sutures; plates not ornamented. IBB 5, subhorizontal proximally bearing stem facet, upflared sharply at edge of stem facet, distal half visible in lateral view forming base of cup. BB 5, gently convex transversely, gently concavo-convex to straight longitudinally, widest at distal ends of lateral sutures. CD basal largest, truncated distally for anal X. RR 5, moderately convex transversely, increasing transverse convexity distally, gently convex longitudinally, widest at distal tips. Radial facet plenary, slopes outward, downward. Gape between radial and primibrachial. Anal interradius wide; anals three in primitive condition, RA offset on lower left of C radial. RA pentagonal, large. Anal X large, hexagonal, in contact with three tube plates distally, proximal half below radial summit. Right tube plate large, proximal third below radial summit.

Brachials stout, strongly rounded transversely, cuneate distally. IBr_2 axillary in rays exposed, no distal branching. Pinnules very elongate, slender, one per brachial on alternate sides of arm.

Stem circular in transverse section, heteromorphic: N212 to N3231323 pattern. Columnals thin proximally, thicken distally, and pattern not well developed; latus rounded. Syzygial articulation of columnals.

Table 3. Dimensions of two specimens of Scytalocrinidae n. gen., n. sp. undesignated.

Measurements	UMNH IP 2249 (mm)	USNM 487226 (mm)
Crown length		35.8 (incomplete)
Crown width		27.8
Cup width		4.7 (est., slightly disarticulated)
Cup length		4.0
IBB width	1.4	0.8
IBB length	1.4	0.8
BB width	1.8	1.4
BB length	2.7	1.9
RR width	2.0	1.8
RR length	1.6	2.0
RA width	1.7	
RA length	1.4	
Anal X width	1.4	
Anal X length	1.7	
Columnal diameter (proximally)		1.6
Columnal diameter (distally)		1.4

Remarks. Preservation of UMNH IP 2249 is a crown with the cup collapsed along the A-CD plane of symmetry with dislocation of brachial plates distally in some rays. The D, E, and B rays have the second primibrachial axillary and the C and A rays may also be axillary on the second brachial, but dislocation of plates makes this uncertain. On USNM 487226 the arms are splayed and the cup is moderately crushed with dislocation of part of the basals and radials along the right side. The second primibrachial is axillary in each of the three rays (E, A, B, or A, B, C) exposed.

These crowns belong to the cuneate brachial clade. The high conical cup, three anals, infrabasals visible in lateral view, plenary radial facets, and branching on the second primibrachial suggest relationship with the Scytalocrinidae. No genus of the scytalocrinids fits the morphologic characteristics of these crowns. Neither crown is worthy of being a holotype, thus the specimens are left in open nomenclature.

Material. One crown (UMNH IP 2249), *in situ*, 60 m above base of the Brush Canyon Member, Henderson Canyon Formation, south-facing slope of Wellsville Mountain, Oviatt (1986) measured section; found by Jack Oviatt. One crown

(USNM 487226) on a float block, unknown level in the upper half of the Brush Canyon Member, Beirdneau Hollow, Logan Canyon; found by Paul Jamison. Dimensions are presented in table 3.

SCYTALOCRINIDAE indet.

Plate 6, Figure 5

Description. Crown slender, elongate. Cup truncated cone, 12 mm length, 7.5 mm width estimated at radial summit, walls straight, expanding slightly distally. IBB horizontal proximally for articulation with stem, upturned distally forming basal part of cup wall, visible in lateral view. BB large, hexagonal, straight longitudinally, convex transversely, highly upflared. RR large, pentagonal, straight longitudinally, convex transversely, highly upflared. Radial facets plenary. IBr axillary on three preserved, elongate, 5.4 mm long, 2.9 mm wide at base. Brachials cuneate, elongate, constricted centrally, deep, externally rounded, hourglass shape. Stem round in transverse section, heteromorphic, N212 pattern, 3.5 mm diameter proximally. Columnals with straight latus, large pentalobate lumen, one-third stem diameter.
Remarks. Unfortunately, the specimen is crushed and primibrachials are dislocated occupying the position of the basals and radials, in part. This form is judged to represent a new species of *Bridgerocrinus* or other scytalocrinid with axillary primibrachials and a high conical cup. The specimen is not suitable to serve as a type; it is mentioned for faunal completion and left in open nomenclature. It is associated with *Aarchaeocidaris strawberryensis.*
Material. A crown (USNM 487227) on a float slab, upper part of Brush Canyon Member, Henderson Canyon Formation, east wall of Beirdneau Hollow, Logan Canyon.

Family BLOTHROCRINIDAE Moore and Laudon, 1943

Remarks. The Blothrocrinidae are subdivided into two groups in the *Treatise* (Moore and Teichert, 1978) on the basis of number of infrabasals. Only *Elibatocrinus* has three infrabasals and forms a monotypic group. Genera with five infrabasals are divided into three subgroups on the basis of the number of primibrachials. This subdivision does not take into account the types of brachials, which represent two major morphotypes. Phylogenetically, brachial type is of earlier importance than the number of primibrachials.

The oldest of the two brachial morphotypes is the slender, strongly transversely rounded, cuneate form and includes the genera *Blothrocrinus, Carcinocrinus, Culmicrinus, Elibatocrinus,* and *Ulrichicrinus*. This morphotype also has a prominent anal tube that may or may not extend above the distal tips of the arms and is recurved with the opening near the base of the arms to above half length of the arms. It is judged to represent an evolutionary lineage or clade. If the cuneate brachials develop from rectilinear brachials as proposed by Grabau (1903) this cuneate brachial clade could not be derived from the younger rectilinear or weakly cuneate clade. The most primitive member of this clade is *Culmicrinus* (Kinderhookian into Chesterian), which is judged to have given rise to *Blothrocrinus* (late Kinderhookian-Osagean), *Carcinocrinus* (Chesterian), and *Ulrichicrinus* (Osagean into Chesterian) by lowering the first branching on the primibrachials. No member of this clade is currently recognized from the Morrowan and Atokan. *Elibatocrinus*, ranging from Middle Pennsylvanian into Early Permian, was the last member of the clade, probably derived from *Carcinocrinus* or an unknown intermediary. *Scammatocrinus* was assigned to the Blothrocrinidae by Burdick and Strimple (1983), but is herein considered to be derived from a different lineage of the rhenocrinids. It should not be included in the Blothrocrinidae. Burdick and Strimple (1983) recognized the relationship of *Scammatocrinus* and *Exoriocrinus*, the latter of which is here considered to be derived from *Scammatocrinus* by development of an advanced anal series, with only one anal below the radial summit.

The second morphotype within the Blothrocrinidae has wide, gently to moderately transversely rounded, rectilinear brachials and the anal tube is not as prominent a feature, where preserved. This morphotype may be of polyphyletic origin and is considered to be derived from the rhenocrinids or other related inadunates. The oldest form (Visean) in this second morphotype is *Fifeocrinus*, which has faintly cuneate brachials, with the first primibrachial axillary. *Fifeocrinus* has been assigned forms transitional between the two morphotypes. Chesterian specimens of *F. popensis* (Worthen, 1882), *F.* cf. *F. tielensis* (Wright, 1936), and *F.* cf. *F. propinquus* (Worthen, 1882), assigned to *Fifeocrinus* by Burdick and Strimple (1983), are not considered herein to belong to the genus. In those specimens the cup is lower and more bowl-shaped with the infrabasals barely visible in lateral view. These forms have cuneate brachials, are probably descended from one of the true blothrocrinid morphotypes, and are believed to represent a new genus. *Stinocrinus*, late Osagean, first occurred later than *Fifeocrinus* but has the first branching on the second primibrachial with rectilinear brachials. The first branching on the second primibrachial is a more primitive feature than branching on the first primibrachial. *Stinocrinus* was probably derived from a rhenocrinid such as *Cydrocrinus* by reduction in number of branchings, development of plenary radial facets, and loss of the apical pits in the cup. *Woodocrinus* (Namurian) is possibly derived from *Fifeocrinus*, but it more likely evolved through an unknown ancestor, as it has wide, rectilinear brachials. There are no known members of the rectilinear brachial morphotype from the Meramecian and late Morrowan into Desmoinesian. *Moscovicrinus* (Moscovian into Wolfcampian) and *Nebraskacrinus* (Wolfcampian) are the youngest members of the rectilinear brachial morphotype and were possibly derived from *Woodocrinus.*

Genus BLOTHROCRINUS Kirk, 1940

Remarks. Not all species assigned to *Blothrocrinus* are herein considered to belong to the genus. The type species, *B. jesupi* (Whitfield, 1881) has cuneate brachials as do *B. cultidactylus* (Hall, 1859), *B. impressus* (Phillips, 1836), *B. longidactylus* (Austin and Austin, 1847), *B. spartarius* (Miller and Gurley, 1890), and *B. thorntonensis* (Wright, 1952). Species with very slightly cuneate to rectilinear brachials include *B. brevidactylus* (Austin and Austin, 1843), *B. litvi-*

novitschae (Yakovlev, 1954), *B. rugosus* (Grenfell, 1876), and *B. swallovi* (Meek and Worthen, 1860). These taxa are transitional to, and perhaps derived from, the rectilinear brachial genera referred to under the discussion of the Blothrocrinidae above. They are considered to be a modified *Blothrocrinus* and could be placed in a separate genus. The Westphalian taxon, *Blothrocrinus balconi* Termier and Termier, 1950, has the first primibrachial axillary precluding its assignment to *Blothrocrinus*. The specimen of *B. balconi* lacks the distal parts of the arms and is here judged to be a scytalocrinid, such as *Haeretocrinus* or *Morrowcrinus*.

BLOTHROCRINUS GUNTHERORUM n. sp.
Plate 6, Figure 9

Etymology. The species is named for Mr. and Mrs. Lloyd Gunther, of Brigham City, Utah, who found the specimen.
Diagnosis. A *Blothrocrinus* recognized by the elongate cuneate brachials, zigzag appearance to the arms and spinose plates on the tegmen at the point of recurvature.
Description. Crown slender, elongate, length 39.4 mm incomplete, width 14.0 mm with slightly splayed arms. Cup truncated cone, wider (7.8 mm) than long (5.8 mm). IBB 5?, form basal part of cup, horizontal proximally for stem attachment, distal 1.6 mm upflared, visible in lateral view. BB 5, large, gently convex transversely, straight longitudinally; posterior basal 3.0 mm long, 2.4 mm wide, truncated distally for anal X. RR 5, moderately convex transversely, slightly convex longitudinally, wider (2.9 mm) than long (2.2 mm). Radial facets plenary, gently rounded outer margin. Anals three, in intermediate position. RA slightly longer (2.0 mm) than wide (1.9 mm), offset between BC basal and C radial, adjoined by C radial, BC basal, CD basal, anal X, and right tube plate. Anal X large, elongate, 2.6 mm long, 1.8 mm wide, distal two-fifths above radial summit, adjoined distally by one tube plate. Rt large, elongate, 2.3 mm long, 1.7 mm wide, distal half above radial summit, adjoined distally by one tube plate. Brachials cuneate, strongly rounded transversely. IBr_2 and $IIBr_{8\text{-}12}$ axillary, four arms per ray, 20 total if same branching in all rays. All branching isotomous. Brachials slightly zigzag, large pinnule facets. Pinnules stout, slender, elongate. Pinnulars elongate, cuneate, bear longitudinal medial ridge. Anal tube elongate, recurved, formed of several rows of stacked polygonal plates; short blunt spines on summit, at point of recurvature. Anal opening slightly above first arm branching. Column round, 25.8 mm preserved; 2.9 mm diameter proximally, tapers distally to 2.2 mm. Columnals trans-versely round; latus gently rounded; syzygy articulation; homeomorphic proximally, heteromorphic N434243414342434 noditaxis pattern distally.
Remarks. The crown of *Blothrocrinus guntherorum* is well preserved, exposed on the anal side, with the posterior basal plate mostly lost. Other species of *Blothrocrinus* with strongly cuneate brachials have shorter brachials and less of a zigzag appearance within the arms.
Material. One crown, BYU 3153, from an unknown level in the Brush Canyon Member, Henderson Canyon Formation, Wellsville Mountain, Utah.

BLOTHROCRINUS n. sp. undesignated
Plate 8, Figure 7A

Description. Crown slender, elongate, length 30.6 mm, width 7.9 mm (incomplete), distal tips of arms incurled. Cup truncated cone, length 5.5 mm, width 8 mm, walls straight, outflared. IBB circlet moderately large, diameter 3.1 mm, height 1.7 mm, horizontal proximally for articulation with proximal columnal, distal tips upflared, visible in lateral view; forms lower one-fourth of cup wall. BB 40% of cup wall, length 2.7 mm, width 2.3 mm, gently convex transversely, straight longitudinally. Posterior B truncated for reception of anal X. RR slightly larger than BB, length 2.8 mm, width 3 mm, moderately convex transversely, slightly convex longitudinally. Radial facet plenary, on distal end of RR, moderate radial-primibrachial gape. Anals three?, radianal not exposed; anal X large, length 2.5 mm, width 1.9 mm, distal one-fifth above radial summit; RT small, proximal half below radial summit. Tegmen plates mostly covered, parts of two rows of hexagonal laterally interlocking plates exposed, suggest tegmen slender, elongate. IBr_1 wider (2.5 mm) than long (2.0 mm), gently convex transversely, rectilinear. IBr_2 axillary; isotomous branching. Distal brachials rectilinear, strongly rounded transversely, pinnulate on alternating sides of arms. Pinnules large, slender, elongate, rectilinear, strongly rounded transversely; seven or eight pinnulars per pinnule. Stem facet probably circular.
Remarks. A specific name is not proposed for this form because the plate surfaces are solution weathered, destroying or modifying any surface ornamentation present. There is some suggestion of coarse granules on the cup plates, but this may be the result of weathering. This specimen is similar to the specimen identified as *Blothrocrinus* sp. by Laudon and others (1952, p. 553, plate 65, figure 27) from the upper crinoid zone of the Banff Formation, Alberta, Canada. It differs in that the brachials are longer.
Material. One partial crown, BYU 3158, from the Gardison Limestone, Rock Canyon, Wasatch Range, Utah; found by Mark McCutcheon.

Family APHELECRINIDAE Strimple, 1967

Remarks: Presence of several specimens of aphelecrinids in the Henderson Canyon faunas tentatively identified as *Aphelecrinus sacculatus* and *Paracosmetocrinus madisonensis* prompted a literature review of the species assigned to both genera as well as a review of the family. The conclusions from that review are summarized below.

The Family Aphelecrinidae, as defined by Strimple, (1967), included three genera, *Aphelecrinus* Kirk, 1944, *Cosmetocrinus* Kirk, 1941, and *Paracosmetocrinus* Strimple, 1967. These genera all have cuneate brachials. A key for the Aphelecrinidae in the *Treatise* (Moore and Teichert, 1978, p. T653) distinguished *Paracosmetocrinus* on the basis of the first branching in the A ray occurring above the first primibrachial. *Aphelecrinus* was described as having a crown which flared upward and brachials that are rectangular externally, whereas *Cosmetocrinus* has a slender cylindrical crown with brachials that are externally cuneate. The differences in

the crown shapes possibly reflect a straight tegmen in *Cosmetocrinus* and a recurved tegmen in *Aphelecrinus*. The difference in shape of the brachials is incorrect as they are externally cuneate in the illustrations of the types of all species of both genera. Unfortunately the tegmen is unknown in most species of both genera, which leaves the generic distinctions very subjective. I consider it quite possible that the three Early Mississippian species of *Cosmetocrinus* represent evolution from different species of *Aphelecrinus* by straightening of the anal tube, perhaps representing a polyphyletic clade. If this is correct, then the two genera could be judged synonyms and *Cosmetocrinus* would have priority. Until more detailed study of the types is completed, I conditionally recognize both *Aphelecrinus* and *Cosmetocrinus*.

Aphelecrinus is a semi-advanced form belonging to the cuneate brachial clade of the poteriocrines. It retains the primitive conical or campanulate cup with three anals in intermediate position, the infrabasals are upflared forming a significant part of the basal half of the cup wall, radial facets are plenary, arms branch isotomously on the single primibrachial in all rays and normally have one or more additional branchings distally, the slender tegmen formed of stout equant plicate plates interlocking laterally may be recurved, and columnals are round in transverse section. Since Kirk (1944b) first described *Aphelecrinus*, 29 species have been assigned to it and three forms have been referred to one of the species or to the genus. Subsequently, Strimple (1967) transferred *A. madisonensis* to *Paracosmetocrinus* (a genus with the first branching in the A ray on the third or higher primibrachial) and three species (*Aphelecrinus limatus, A. mundus* and *A. oweni*) were placed in synonymy with *A. randolphensis* by Chestnut and Ettensohn (1988). Although I agree that *A. limatus* and *A. oweni* are synonyms, they differ from *A. randolphensis* by the presence of obvious peneplenary radial facets and a lower cup with the infrabasals confined to the basal plane. Therefore *A. limatus* and *A. oweni* should not be included in *Aphelecrinus*. *A. mundus* has a pentagonal stem with medially constricted primibrachials and should not be included in *Aphelecrinus*.

Of the other species currently assigned to *Aphelecrinus*, I consider *A. dilatatus* Wright, 1945, *A. parvus* Wright, 1945, *A. roscobiensis* Wright, 1945, and *A.* sp. Wright, 1951 to represent variants of a single species with peneplenary radial facets and obvious radial notches. The arms are unknown on this Visean form from Scotland and it probably belongs to an unnamed new genus.

A. exoticus Strimple, 1951, and *A. planus* Strimple, 1951, have truncated conical or medium bowl shaped cups with infrabasals covered by the stem or with the distal tips of infrabasals barely extending beyond the stem and basically confined to the basal plane. These two cuneate brachial forms from the Fayetteville Shale (Chesterian) also have peneplenary radial facets with obvious radial notches and are considered synonymous, representing a new genus. The Chester species *A. randolphensis*, from the Illinois Basin, belongs to this same genus but differs from *A. exoticus* by having narrower notches and greater numbers of arm branchings. It is possible that these two species were derived from the Scotland forms described by Wright (1945, 1951) by lowering of the cup with the restriction of the infrabasals to the basal plane. As noted above, however, the arms are unknown on the Scotland forms, thus the relationships are questionable at this time. *A. columbiensis* (Worthen, 1882) from Meramecian and Chesterian strata of the Mississippi Valley may also belong to this lineage. It has a slightly higher conical cup with the infrabasals visible in lateral view and obvious radial notches with peneplenary radial facets. *A. columbiensis* has only 10 arms representing a simplification of the arms.

The Osagean form, *A. delicatus* (Meek and Worthen, 1869), has angustary radial facets, a pentagonal columnal facet, and rectilinear brachials. It probably represents a new genus and is rejected from *Aphelecrinus*. *A. meeki* (Kirk, 1941) has a truncated conical or medium bowl-shaped cup, the distal part of the infrabasals are barely upturned distally to form the basal part of the wall of the cup, and the stem facet is pentagonal. This form is also judged to represent a new genus and is rejected from *Aphelecrinus*.

Two Visean forms, *A. dunlopi* and *A. greenhillensis*, are from Scotland, have brachials that are only slightly cuneiform, and have high conical cups lacking the outflaring at the base of the radials. These forms probably originated from a different lineage than that of the older American Kinderhookian forms and do not belong to *Aphelecrinus*.

With the removal of the above forms from *Aphelecrinus* there remain 13 species currently recognized in the genus. These range from Kinderhookian to Chesterian in age. Four species from the U. S. are Kinderhookian. *A. sacculatus*, from the middle to late Kinderhookian Lodgepole Limestone of Montana, has brachials that are only moderately cuneate and the A ray is not exposed. It is tentatively reassigned to *Paracosmetocrinus* because of similarities to *P. utriculus* n. sp. (see discussion below). Three late Kinderhookian species, *A. elegans* (LeGrand beds, Iowa), *A. crineus*, and *A. richfieldensis* (both from the Cuyahoga Formation, Ohio), have strongly cuneate brachials. The former has a bowl-shaped cup with a distally expanded crown shape in the enclosed position. The latter two have high conical cups lacking the outflaring at the base of the radials and may be synonyms. These Kinderhookian forms are considered to show the initial diversification in the genus.

The Meramecian-Chesterian species *A. scoparius* has a medium high bowl-shaped cup with the distal-most brachials rectilinear. Eight species are known from Chesterian strata of the United States Mississippi Valley and adjacent areas and represent the greatest diversification of the genus before its apparent termination during the late Chesterian. These forms all have cuneate brachials, but the cup may be conical with an outflaring at the base of the radials or a medium high bowl-shape. In *A. crassus* the distal brachials are biserial and *A. bayensis* has only 10 arms. All other species branch at least once above the initial dichotomy on the primibrachial.

Genus APHELECRINUS Kirk, 1944

APHELECRINUS? UTAHENSIS n. sp.

Plate 5, Figure 5

Etymology. Named for the state of Utah, wherein the specimen was found.

Diagnosis. An *Aphelecrinus*? distinguished by the relatively short, weakly cuneate brachials and slightly lower cup than other species recognized in the genus.

Description. Crown slender elongate, length 12.5 mm, width 15.7 mm arms splayed. Cup medium truncated cone, length 2.2 mm, width 3.4 mm. IBB small, horizontal proximally for stem attachment, distally tips upflared barely visible in lateral view. BB large, wider (1.4 mm) than long (1.0 mm), outflaring, moderately convex transversely, form lower half of cup wall. RR wider (1.5 mm) than long (1.0 mm), outflaring, moderately convex transversely. Radial facets plenary, slope outward weakly. Anals three in primitive position, followed by upwardly projected hexagonal, laterally interlocking anal tube plates. IBr_1 axillary in three rays exposed, longer than wide, strongly rounded transversely, constricted medially, widest proximally, variable length in different rays. IIBrr faintly cuneate, strongly convex transversely, slightly longer than wide proximally, become progressively shorter distally with width equal to length. $IIBr_6$ axillary. IIIBrr cuneate, strongly rounded transversely, much longer than wide proximally, becoming progressively shorter distally. Pinnules slender, elongate, one per brachial on alternate sides of arm. Pinnule facet on IIIBr nearly as large as brachial facet. All arm branching isotomous. Stem round, 0.8 mm diameter proximally. Columnals heteromorphic, N1 or N121 pattern; latus convex.

Remarks. This small, delicate crown has partly recrystallized ossicles in the cup and lower parts of the arms masking some sutures, even when the specimen is viewed wet under magnification. It is oriented with the C ray centered. The tegmen projects well above the cup with the distal extent covered by the arms and matrix. The arms are four in the C ray with similar branching on each of the parts of the B and D rays exposed, suggesting 20 arms if all rays branch the same. It is uncertain if this specimen branched on the first primibrachial or higher in the A ray. Thus it is questionably assigned to *Aphelecrinus.*

Material. One crown (USNM 487237), float block, middle part of Brush Canyon Member, Henderson Canyon Formation, Wellsville Mountain, Utah.

APHELECRINIDAE? n. gen., n. sp. undesignated
Plate 6, Figure 8

Description. Crown elongate, slender, incomplete length 28 mm, splayed width 12.4 mm. Cup medium bowl shape, length 3.6 mm, width 7.0 mm; weakly developed pits at basal and radial apices. IBB subhorizontal, distal tips form base of cup, barely visible in lateral view. BB, hexagonal, gently convex transversely and longitudinally, length 1.7 mm, width 1.7 mm, base in basal plane of cup. RR slightly bulbous, strongly convex longitudinally, moderately convex transversely. Radial facet plenary, slopes out and down; moderate gape between radial and primibrachial. Brachials weakly cuneate, strongly rounded transversely, wider than long except IBr_1, $IIBr_1$, and $IIIBr_1$. First isotomous branching on IBr_1 in two rays, on IBr_6 in third ray. Additional branching on $IIBr_8$ or $IIBr_9$ in rays branching on IBr_1 and in one half of one ray of $IIIBr_6$. Stem round in transverse section, 1.4 mm diameter 6.8 mm from cup.

Remarks. The specimen is oriented with what are judged to be the E, A and B rays exposed. The central ray is unbranched until the IBr_6. It is flanked by rays with branching on the first primibrachial and there is one additional branching in the E ray and two additional branchings in the B ray. The arms and branching pattern are similar to those developed in *Aphelecrinus*. An unbranched A ray or the first branching higher than in other rays is a primitive character in the poteriocrines common to some genera in the Blothrocrinidae, Rhenocrinidae, Scytalocrinidae, and Aphelecrinidae. Most of these families have conical cups except a few genera of the Scytalocrinidae that have bowl-shaped cups with the distal end of the infrabasals concealed or exposed. The apical pits suggest relationship to *Sostronocrinus* or *Scytalocrinus*, but the former has the first branching on the second or third primibrachial in all except the A ray and the latter never branch above the primibrachial. Only some species, but not the type species, assigned to *Scytalocrinus* have apical pits and the pits on *Sostronocrinus* are much deeper. The number of anals is unknown, but the wide cup and exposed three rays suggest a wide anal interarea that probably has three anals in the cup. This form could represent mosaic evolution from *Paracosmetocrinus* by flattening of the infrabasals. The specimen is questionably assigned to the Aphelecrinidae and is judged to represent a new genus. It is left in open nomenclature because the specimen is not suitable to serve as a type.

Material. One crown (USNM 487228) on a float slab from an unknown level in the upper half of the Brush Canyon Member, Henderson Canyon Formation, Beirdneau Hollow, Logan Canyon, Utah. Found by Paul Jamison.

Genus PARACOSMETOCRINUS Strimple, 1967
PARACOSMETOCRINUS MADISONENSIS
(Laudon and Severson, 1953)
Plate 7, Figure 9

Synonymy.

Ampelecrinus madisonensis Laudon and Severson, 1953, p. 521, plate 51, figures 20, 21; plate 55, figures 10, 11. Strimple, 1967, p. 81. Webster, 1973, p. 190 (catalog listing).

Aphelecrinus madisonensis (Laudon and Severson, 1953). Strimple, 1967, p. 81. Webster, 1973, p. 190 (catalog listing).

Paracosmetocrinus madisonensis (Laudon and Severson, 1953). Strimple, 1967, p. 81. Webster, 1973, p. 190 (catalog listing).

Diagnosis. A *Paracosmetocrinus* with truncated cone-shaped cup, three anals in cup, slightly cuneate brachials gently rounded transversely, and first branching in A ray on primibrachial 7.

Description. Crown cylindrical, flaring distally, 12.4 mm long, 9.2 mm wide. Cup truncated cone, flaring widely, 1.7 mm high, 3.4 mm wide, walls straight, slightly incurved on distal ends, no ornamentation. IBB 5, distal tips of plates not

upflared, restricted to basal plane of cup, not visible in lateral view; proximal part horizontal, bearing stem facet. BB 5, gently convex transversely, length 1.6 mm (estimated), width 1.4 mm. RR 5, convex transversely, length 1.3 mm, width 1.5 mm. Radial facet plenary, bearing articular ridge, external ligament pits. Brachials slightly cuneate, gently rounded transversely, straight to slightly convex longitudinally. Pinnular facet shoulder large, internal, not recognizable in lateral view except on distal most brachials. Pinnules slender, elongate, bear longitudinal angular ridge externally, large deep V-shaped ambulacral groove. IBr_1 of A (length 1.8 mm) and D (length 1.6 mm) rays longer than IBr_1 of B (length 1.2 mm) and E (length 1.5 mm) rays. IBr_1 axillary in all except A ray; IBr_3 axillary in A ray. $IIBr_5$ or $IIBr_6$ axillary in rays with single AxIBr, one additional branching on $IIIBr_8$ in some rays. All branching isotomous, 20 to 28 arms total, four to six arms per ray, four arms only in A ray. Tegmen not exposed. Stem slender, heteromorphic, N1212 pattern proximally. Columnals circular in transverse section, diameter 0.8 mm.

Remarks. The weathered specimen of *Paracosmetocrinus madisonensis* has considerable resemblance to *P. sacculatus* from which it may be derived. Laudon and Severson (1953) considered *P. sacculatus* to be shorter and stouter than other species of *Ampelecrinus* to which they assigned the species. The A ray of the holotype of *P. sacculatus* is not exposed so that it is uncertain if the first branching is on the first primibrachial or higher. *Paracosmetocrinus* is the only aphelecrinid with the first branching of the A ray significantly above that of all other rays. Laudon and Severson (1953, p. 521) stated "Brr simple, exhibiting no tendency to become cuneiform." On the retouched photographs of plate 51, figures 20, 21, the brachials are rectilinear; however, on their unretouched photographs of plate 55, figures 10, 11, with magnification, the brachials are weakly cuneate. Branching on the A ray of the Montana specimens is on the fifth primibrachial. The second branching on the Utah specimens is on the fifth, sixth, or eighth secundibrachial. These differences may reflect genetic drift or intraspecific variation, since the Utah material is slightly younger than the Montana specimens.

Material. One crown (USNM 487230) on a float slab from an unknown level in the upper half of the Brush Canyon Member, Henderson Canyon Formation, Beirdneau Hollow, Logan Canyon; found by Paul Jamison.

PARACOSMETOCRINUS UTRICULUS n. sp.
Plate 7, Figures 1, 2, 7; Table 4

Etymology. The species name *utriculus* is Latin, meaning leather bag or bottle, and refers to the recurved tegmen.

Diagnosis. A *Paracosmetocrinus* recognized by the small nodes to blunt spines on the summit of the recurved part of the tegmen.

Description. Crown small, slender cylindrical to slightly flared distally in enclosed position. Cup medium cone to bowl-shaped, walls gently convex, maximum width at radial summit. IBB circlet small, upflared; IBB distal tips extend beyond stem, barely to obviously visible in lateral view. BB 5, large, widely outflared, strongly convex transversely and longitudinally, forming central part of cup wall. CD basal largest, truncated distally for anal X. RR 5, gently convex transversely and longitudinally, wider than long. Radial facets plenary, slope steeply outward. Anal series wide, three plates below radial summit, in slightly advanced position. RA large, pentagonal, positioned to left below C radial and to right above BC basal. Anal X hexagonal, largest, distal third above radial summit, adjoins two tube plates distally above radial summit and right tube plate below radial summit. Rt longer than wide, hexagonal, proximal one-fourth below radial summit.

Brachials stout, strongly convex transversely, slightly cuneate. IBr_1 and $IIBr_{6\text{ or }7}$ axillary in B, C, D, and E rays. A ray IBr unbranched, first branching probably IBr_3; 18 arms total, four per ray except two in A ray. $IIIBr_1$ longer than following IIIBrr and distal IIBrr. Pinnules stout, slender, elongate, seven-nine plates in each, bear rounded angular medial longitudinal ridge. One pinnule per brachial on alternate sides of arm. Cover plates on pinnule ambulacrum small, eight-ten per pinnular, four or five each side of groove.

Anal tube stout, slender, recurved, maximum width 1 mm below summit. Formed of laterally interlocking plicate hexagonal plates. Initial trunk nearly circular in transverse section; formed of six, possibly seven, rows of plates, bearing medial longitudinal ridge along recurved section. Recurved section opening at base, formed of five rows of plates; three central rows with medial longitudinal ridges, lateral row of bulbous plates on each side abuts trunk section and lacks longitudinal ridge. Anal opening elongate, covering plates or integment not preserved. Tegmen summit plates with coarse nodes to short blunt spines on lateral rows of plates, medial row slightly bulbous.

Stem round in transverse section, heteromorphic proximally. Columnals with rounded latus.

Table 4.
Dimensions of the holotype and both paratypes of *Paracosmetocrinus utriculus* n. sp.

Measurements (mm)	Holotype USNM 487231	Paratype USNM 487232	Paratype USNM 487233
Crown length, enclosed, est.	30.0	28.0	16.0
width, enclosed, est	7.0	8.0	5.5
Crown length splayed	29.9	16.0	12.7
width splayed	29.3	28.1	24.7
Cup length	3.0	3.6	1.4
width	5.5	4.9	3.6 (crushed)
IBB circlet diameter	2.8	2.8	—
BB length	1.5	1.6	—
width	1.5	2.1	—
RR length	1.6	1.7	—
width	1.6	2.5	—
IBr_1 length	2.4	2.4	—
width	2.5	2.8	—
Anal tube length above RR	16.2	8.0	10.7
width, maximum	4.5	3.2	2.7
Stem diameter, proximal	1.6	1.6	—

Remarks. Morphological information for the description was based on all three crowns. The holotype (USNM

487231) overall has the most complete preservation of the crown, with the cup weathered, parts of all arms well preserved, and the tegmen slightly weathered. Paratype one (USNM 487232) has the best preservation of the cup with parts of the A, B, and E arms splayed, and the tegmen summit partly weathered. Paratype two (USNM 487233) has the best preservation of the tegmen, the cup is weathered and parts of the C and E arms are splayed. The series of specimens show that the infrabasal circlet forms the base of the cup wall with growth. In the immature condition, paratype two (USNM 487233), the infrabasal circlet is so small that the distal tips of the plates extend only slightly beyond the proximal columnal but form the base of the cup wall. The larger specimens have a larger part of the infrabasals forming an upflared part of the cup wall.

The unbranched primibrachial in the A ray, with branching on IBr_1 in all other rays, along with the medium cone-shaped cup, second isotomous branching of the B and E rays, and recurved stout tegmen are generic characters of *Paracosmetocrinus*. Some variation in the length of the radial facet is present on paratype one (USNM 487232), wherein the C, D, and E radial facets are slightly peneplenary, whereas the A and B facets are plenary. The ambulacral cover plates are preserved only on paratype one (USNM 487232).

The tegmen of *P. utriculus* is so distinct, compared to those of other cladids in the fauna, it provides easy identification of the species. The form is closely allied to *Paracosmetocrinus sacculatus* (Laudon and Severson, 1953), n. comb. from which it is probably derived by modification of the single large spine on the summit of the recurved tegmen to several smaller nodes or blunt spines.

Material. Three crowns (USNM 487231-487233), from lower and upper ledges, the upper middle and upper part of the Brush Canyon Member, Henderson Canyon Formation, Beirdneau Hollow, Logan Canyon, found by Paul Jamison. Dimensions are presented in Table 4. A fourth specimen, paratype (USNM 487831), from the Brush Canyon Member, Wellsville Mountain, was chipped as a talus slab and is partly silicified. It has a slightly higher conical cup but retains the noded tegmen.

PARACOSMETOCRINUS ROTUNDUS n. sp.

Plate 7, Figures 3, 4, 10, 11, Table 5

Etymology. The species name *rotundus* is Latin, meaning round or circular, and refers to the transversely rounded brachials.

Diagnosis. A *Paracosmetocrinus* recognized by the strongly rounded nature of the brachials.

Description. Crown elongate, slender, arms incurve slightly distally. Cup low bowl-shaped, walls outflared, no ornamentation. IBB 5, small, distal tips project upward beyond stem, barely visible in lateral view. BB 5, gently convex transversely and longitudinally. BC basal bears facet for RA on upper left. RR 5, gently convex transversely and longitudinally, wider than long; C radial bears facet on lower left for RA. Radial facets nearly plenary, bear transverse ridge, outer ligament pit and furrow, and internal muscle areas. Anals three, dislocated, not exposed.

Brachials robust, strongly rounded transversely, rectangular to weakly cuneate, wider than long after IBr_1 except distal most two or three may be longer than wide. IBr_1 axillary in B, C, and E Rays; IBr_4 axillary in A ray on holotype; first axillary unknown in D ray. $IIBr_8$ axillary in E ray on holotype. Second branching on D ray in paratype. Pinnulars robust, slender, elongate, transversely rounded; five or six per pinnule. Anal tube slender, elongate extending unknown distance above base of arms, formed of vertical rows of hexagonal plates; plates alternating laterally to interlock.

Stem circular in transverse section. Columnals with rounded latus, heteromorphic, irregular to N121 pattern.

Table 5.
Dimensions of the holotype and one paratype of *Paracosmetocrinus rotundus* n. sp.

Measurements (mm)	Holotype (USNM 487234)	Paratype (USNM 487235)
Crown length	34.2	26.1
width	11.5*	11.3
Cup length	4.2	2.4
width	8.0#	6.7#
BB length	2.4	1.8
width	2.4	2.2
RR length	2.2	1.6
width	3.0	2.9
IBr_1 length	2.8	2.2#
width	2.3	2.9
Anal tube length	—	6.0*
width	—	3.5#
Stem diameter, proximal	1.9	1.8
* incomplete	# estimated	

Remarks. Recrystallization of most of the cup plates and proximal primibrachials on the holotype has resulted in a coarse nodose surface, but only where recrystallized. The paratype and parts of some plates of the holotype are not recrystallized and show that the original surface is unornamented. Both specimens are positioned so that the A ray is centered and the anal interray not exposed. The holotype is crushed slightly along the BC-DE interray plane. Paratype cup plates are slightly dislocated. Preparation of the holotype exposed the anal side of the C ray showing the facets for the radianal on the BC basal and C radial. The radianal would have been mostly positioned to the left of the C ray and elevated to have only the proximal part below the summit of the basals. Thus, it is judged that the specimen had three anals with anal X and right tube plate mostly or partly below the radial summit.

The total number of arms in *P. rotundus* is uncertain. On the holotype the E ray branches again distally as the D ray does on both paratypes, making a minimum of 12 arms on each specimen. Unfortunately the D ray is not exposed on the holotype and the E ray is lost by weathering above $IIBr_6$ on paratype USNM 487235. On paratype USNM 487229 there are four arms on the B and E rays and a minimum of two on the A and D rays. It is likely that there are 18 arms total, with

four in each ray except the A ray, although the A ray may branch again distally making a total of 20 arms. Distal branchings may reflect intraspecific variation providing a wider range of total number of arms.

The wide anal series of paratype USNM 487229 probably extended upward into a narrow cylindrical anal tube of which only the base is exposed. Preparation also exposed the base of the D ray showing the axillary single primibrachial.

Paracosmetocrinus madisonensis was based on two specimens, which have seven primibrachials in the A ray, the arms may branch much more distally, and the brachials are less rounded transversely than on *P. rotundus*. As noted below *P. peterseni* n. sp. has flat rather than transversely rounded brachials. Thus *P. rotundus* represents the most rounded brachials.

Material. Holotype (USNM 487234) on a float slab from an unknown level in the upper half of the Brush Canyon Member, Henderson Canyon Formation, Beirdneau Hollow, Logan Canyon, Utah, found by Paul Jamison. Paratype (USNM 487235) on a float slab from the upper part of the Brush Canyon Member, approximately one-half mile west of Wind Cave, Logan Canyon. Paratype (USNM 487229) on a float slab from the lower ledge, upper middle part of the Brush Canyon Member, Wellsville Mountain, Utah.

PARACOSMETOCRINUS PETERSENI n. sp.

Plate 7, Figures 5, 6; Table 6

Etymology. The species is named for Sidney M. Petersen who found the specimen.

Diagnosis. A *Paracosmetocrinus* distinguished by nearly transversely flat brachials.

Description. Calyx elongate, arms gently outflaring with distal tips incurving, all plates lacking ornamentation, sutures flush. Cup cone-shaped, base flat with impressed stem impression. IBB 5, small, proximal ends horizontal for columnal facet, distal ends upflared, form basal part of cup wall. BB 5, moderately large, gently convex transversely, straight longitudinally; AB, DE, and EA hexagonal, slightly longer than wide, gently outflaring; BC and CD basals heptagonal adjoining anal series. RR 5, pentagonal, slightly wider than long, gently outflaring, widest at summit. Radial facets plenary, probably subhorizontal or gently sloping inward. Gape between radials and primibrachials slight. RA large, pentagonal, as wide as high, nearly reaching radial summit, adjoins two basals, anal X, first tube plate and C radial. Anal X large, hexagonal, extends above radial summit, adjoins CD basal, D radial, second tube plate, first tube plate, and RA in clockwise direction. Base of first tube plate slightly below radial summit in contact with RA.

Arms slender, brachials nearly flat, slight convexity transversely, straight longitudinally, slightly cuneate. IBr_1 axillary in B, C, and E rays; IBr_4 axillary in A ray; D ray not exposed. $IIBr_6$ axillary in B and C rays, $IIBr_{11}$ axillary in A ray, $IIBr_{17}$ axillary in E ray. Probably 20 arms total. Pinnules slender, elongate, moderately convex transversely. Proximal columnal round; lumen destroyed by silicification.

Table 6.
Dimensions of the holotype of *Paracosmetocrinus peterseni* n. sp.

Measurements (mm)	BYU 3154
crown length	25.7
cup length	4.3
width	7.0
IBB length	2.0
width	1.7
basal length	2.4
width	2.2
radial length	2.6
width	2.6
IBr_1 length	2.7
width	3.0
RA length	2.5
width	2.5
anal X length	1.8
width	1.8

Remarks. *Paracosmetocrinus peterseni* is most similar to *P. strakai* Strimple, 1967, in that it has four primibrachials in the A ray. It differs in that the cup is more conical and the brachials are nearly flat externally. The nearly flat exterior surface of the brachials distinguishes *P. peterseni* from all other species assigned to the genus.

The slightly cuneate brachials and axillary IBr_4 in the A ray of *P. peterseni* are judged to be primitive features. *P. peterseni* probably evolved from *P. madisonensis* (Laudon and Severson, 1953) by reduction in the number of primibrachials in the A ray. Primibrachial seven is axillary in *P. madisonensis*, a species from the basal part of the Lodgepole Formation near Virginia City, Montana.

Conodonts etched from the block containing *P. peterseni* are *Siphonodella isosticha*, *Polygnathus communis*, and *Spathognathodus stabilis* indicating a late Kinderhookian (Upper *Siphonodella isosticha-Siphonodella crenulata* Biozone) age.

Material. Holotype, one crown (BYU 3154) in float block from the uppermost part of the Chinese Wall Member, Henderson Canyon Formation, along the road leading to Camp Kiesel, adjacent to reservoir behind Causey Dam, Utah.

Genus APOKRYPHOCRINUS n. gen.

Etymology. Derived from the Greek *apokrypho* meaning concealed or obscure and refers to the somewhat obscure or problematic family relationships of the form.

Diagnosis. An aphelecrinid with a cylindrical crown, truncated cone cup, single anal in the cup, brachials weakly cuneate, slightly zigzag appearance to brachials, IBr_1 axillary in all rays, second branching in some rays.

Type species. *A. wellsvillensis* n. sp.

Description. See description of *A. wellsvillensis* below.

Remarks. Familial assignment of *Apokryphocrinus* is tentative, based primarily on the truncated intermediate conical cup shape and similarity of the arm morphology to that of the

Aphelecrinidae. That is, the first branching is on the solitary primibrachial in all rays, a second isotomous branching occurs in at least one ray, there are stout elongate pinnules, and the brachials appear to be slightly zigzag. In addition, some species of *Paracosmetocrinus*, an aphelecrinid, have abundant cirri in the proximal part of the stem as does *Apokryphocrinus*. The single anal in *A. wellsvillensis* is an advanced condition and occurs stratigraphically concurrently or before many other species of the Aphelecrinidae, all of which have three anals. Thus, *A. wellsvillensis* is tentatively assigned to the Aphelecrinidae.

The truncated intermediate cone shape of the cup of *Apokryphocrinus* is marginally comparable to genera within several poteriocrinid families, such as Scytalocrinidae, Blothrocrinidae, and Corythocrinidae. Genera within these families normally have three anals in primitive to advanced arrangement and a higher conical cup.

Without the second branching *Apokryphocrinus* could have been questionably assigned to *Holcocrinus*, a genus with strongly cuneate brachials. The abundance of cirri, most of which were removed in preparation of the specimen, and the single anal in the cup are characters common to *Armenocrinus*, an ampelocrinid, and *Holcocrinus*, a taxon assigned to the Graphiocrinidae in the *Treatise on Invertebrate Paleontology* (Moore and Teichert, 1978). *Armenocrinus* has a higher conical cup, rectilinear brachials, and the first branching of the arms is on the second to fourth primibrachial. *Holcocrinus* belongs to the cuneate brachial clade as discussed under the Suborder Poteriocrinina. Neither the Ampelocrinidae nor the Graphocrinidae are judged by me to be an evolutionary clade. Both families are considered to contain representatives of at least two lineages that are not closely related.

APOKRYPHOCRINUS WELLSVILLENSIS n. sp.
Plate 8, Figures 2, 8

Etymology. Named for Wellsville Mountain, Utah where the specimen was found.

Diagnosis. As for the genus.

Description. Crown small, cylindrical, slightly flared distally, 13.3 mm length incomplete, unornamented. Cup intermediate truncated cone, 3.6 mm long, 6.2 mm wide. IBB 5, horizontal? proximally, covered by proximal columnal; upflared distally, visible in lateral view; 1.6 mm wide, length unknown. BB 5, hexagonal (posterior basal septagonal) upflared, gently convex transversely, straight longitudinally; AE basal slightly longer (1.9 mm) than wide (1.7 mm). RR 5, pentagonal, gently convex transversely, straight longitudinally; A radial wider (3 mm) than long (1.8 mm). Radial facets plenary, ligament pit and outer ligament furrows visible in gape between radial and primibrachial. Single anal large, rectangular, 1.7 mm long, 2.4 mm wide, projects above radial summit 0.8 mm, adjoined distally by incurving single large plate.

Brachials strongly rounded transversely, slightly cuneate, faintly zigzag, relatively large pinnule facets. IBr axillary in all rays, constricted medially, hourglass shape, widest at proximal end, variable in length: A ray 2.2 mm, C ray 3.2 mm, E ray 2.8 mm. E ray $IIBr_3$ axillary; all branchings isotomous. Distal branching unknown. Pinnules slender, elongate. Tegmen slender elongate, formed of six rows of thin polygonal plates. Stem circular in transverse section, heteromorphic, cirriferous, poorly preserved.

Remarks. The holotype of *Apokryphocrinus wellsvillensis* is slightly crushed and weathered on the anterior side. Distal parts of the tegmen and arms are lost. Numerous cirri fragments were removed from the posterior side when cleaning the specimen. Other cirri fragments are visible to the upper left in the anterior view of the specimen (plate 8, figure 8).

Material. Two crowns (USNM 487233 and 487236) on separate float blocks from the lower crinoid interval of the Brush Canyon Member, Henderson Canyon Formation, Wellsville Mountain, Utah. The crown (USNM 487233) has cup plates that are partly disarticulated and the arms are splayed.

Family PELECOCRINIDAE Kirk, 1941
Genus PELECOCRINUS Kirk, 1941
PELECOCRINUS n. sp. undesignated
Plate 6, Figure 6

Description. Crown large, elongate, length 23.7 mm incomplete, width 13.0 mm minimum, arms slightly splayed. Cup globular, 14.0 mm wide crushed, 10.0 mm length incomplete. IBB not exposed. BB 5, large, 4.9 mm wide, 5.0 mm long. RR 5, wider (6.1 mm) than long (3.6 mm). Radial facet angustary, protrude laterally. Radial facets slope strongly outward. Anals three, large, primitive position. RA 4.0 mm long, 3.6 mm wide. Anal X strongly convex. Brachials cuneate, large, strongly convex transversely. IBr_1, $IIBr_6$ or $IIBr_8$, $IIIBr_9$ axillary, enlarged, protrude with rounded exterior. All branching isotomous. Stem and anal sac not exposed.

Remarks. The crown is crushed and a calcite-filled fracture runs lengthwise between the B and C rays. The brachial structure and branching pattern are typical of the genus. A crown, *Pelecocrinus* sp., from the Lodgepole Limestone of Montana, (Laudon and Severson, 1953, plate 51, figure 15) is the most closely allied form to this specimen. The Montana specimen differs in having more primibrachials before the first branching, the axillary brachials are not as protruded, and the cup is more conical shaped. Although judged to be a new species, no species name is designated because the preservation of the specimen is insufficient for it to serve as a type.

Material. One partial crown (USNM 487238), *in situ*, from the lower ledge of the Brush Canyon Member, Henderson Canyon Formation, Wellsville Mountain, Utah.

POTERIOCRINE, FAMILY UNCERTAIN
ADIAKRITOCRINUS n. gen.

Etymology. The generic term is from the Greek, *adiakritos*, meaning mixed or indistinguishable, referring to the evolutionary state of the various major morphologic features of the taxon.

Diagnosis. Poteriocrine with truncate cone-shaped cup, sin-

gle anal, 10 uniserial arms, isotomous branching on single primibrachial; brachials longer than wide, bearing medial ridge; pinnules large; stem round, heteromorphic.
Type species. *A. oviatti* n. sp.
Description. See description of *A. oviatti* below.
Remarks. The wide brachials with the rounded medial ridge are the distinctive feature of *Adiakritocrinus.* The medial ridge, combined with the elongate and wide shape of the brachials, is somewhat similar to that of *Spaniocrinus* and *Cupressocrinus*, however, the arms do not taper as rapidly and the brachials do not have lateral morphologic features resembling the brachials of these two genera. Several genera of the poteriocrines have rounded to sharp medial ridges along the primibrachial, such as *Aulocrinus* and *Ramulocrinus*, but all distal brachials are shorter, somewhat zigzag, cuneate, or otherwise significantly different from those of *Adiakritocrinus.*

The stout pinnules could be considered ramules because of the large size, but there is one per brachial, on alternate sides of the arm, as is typical of pinnules. These large pinnules are judged to be a primitive feature, probably derived from ramules. The two isotomous arms originating from branching on the single primibrachial and the presence of a single anal in the cup is common to many of the advanced poteriocrines, such as the graphiocrinids. The truncated cone-shaped cup is an intermediate evolutionary feature in several genera assigned to various families of the primitive and slightly advanced poteriocrines. If the infrabasals were restricted to the basal plane or restricted to a basal impression *Adiakritocrinus* would be classified with the Graphiocrinidae. The major morphologic features of *Adiakritocrinus* are judged to be the result of mosaic evolution and make it difficult to classify at the family level within the *Treatise* classification. It is here considered an intermediate form somewhat between the scytalocrinids and graphiocrinids with unique brachials. Until the reclassification of the poteriocrines is completed, *Adiakritocrinus* is placed in an *incertae sedis* status.

ADIAKRITOCRINUS OVIATTI n. gen., n. sp.
Plate 3, Figure 2A; Plate 8, Figure 3

Etymology. The type species is named for Jack Oviatt, who found the specimen.
Diagnosis. As for the genus.
Description. Crown small, slender, cylindrical, incomplete length 14.5 mm, arms splayed, incomplete width 11.8 mm. Cup truncated cone, wider (4.3 mm) than long (2.2 mm), widest at radial summit. IBB 5, small, mostly confined to basal plane, distal tips upturned, barely visible in lateral view. BB 5, hexagonal, wider (1.7 mm) than long (1.5 mm), gently convex transversely and longitudinally. RR 5, much wider (2.4 mm) than long (1.5 mm), gently convex transversely and longitudinally. Radial facets plenary. Single anal, longer than wide, distal third projecting above radial summit, proximal end on truncated distal end of CD basal. Brachials wide, rectilinear, rectangular to pentagonal, proximal and distal ends parallel; non-pinnulate side straight; pinnular facet side wide, wedge-shape with pinnular facet equal to non-facet length; concave longitudinally, concavo-convexo-concavo transversely, bear medial longitudinal rounded ridge. IBr_1 length 1.8 mm, width 2.4 mm; $IIBr_2$ length 2.1 mm, width 1.3 mm. Pinnules very stout, elongate, rectilinear, wide. Stem length 15.6 mm preserved, heteromorphic, N212 pattern, diameter proximal columnal 1.4 mm, round in transverse section. Nodal latus strongly rounded; internodal latus moderately rounded.
Remarks. The holotype of *Adiakritocrinus oviatti* is an adult, with loss of part of the arms by weathering. It is associated with *Platycrinites bozemanensis*. The paratype is an immature specimen, the cup is crushed, and part of the arms have been lost by weathering. It is associated with *Platycrinites beirdneauensis.*
Material. One crown, holotype, UMNH IP 2245, in the lowermost part of the Devil Creek Member of the Henderson Canyon Formation, found by Jack Oviatt, Wellsville Mountain, east of Deweyville. Paratype (USNM 487239), one partial crown, slightly disarticulated, showing the ridged brachials, is from the base of the lower ledge (*in situ)* of the Brush Canyon Member, approximately one mile east of Beirdneau Hollow, Logan Canyon, Utah.

POTERIOCRINID indet.
Plate 6, Figure 3

Description. Crown partly silicified, cup and arms partly disarticulated. Cup medium bowl shape, base truncated for articulation with proximal columnal, distal part incurved. IBB circlet horizontal proximally, distally upturned forming basal part of cup wall. BB large, hexagonal, except posterior basal septagonal, truncated distally for anal X. RR wide, strongly convex longitudinally, incurved distally. Radial facets angustary, horseshoe shaped, deep, bearing prominent transverse ridge, moderately deep, narrow ambulacral notch. Notches between facets wide. Anal, probably single, large. Brachials cuneate, strongly rounded transversely, hourglass-shaped. Single IBr axillary in A, B, C, and D rays, not preserved in E ray, probably axillary. $IIBr_8$ axillary. Branching isotomous, arms flared laterally. Stem round transversely; large lumen, probably pentagonal or pentalobate. Columnals heteromorphic proximally, N1 pattern, becoming homomorphic distally, syzygy articulation.
Remarks. This specimen has morphological characters, in part, similar to *Cyathocrinus*, *Pelecocrinus,* and stellarocrinids. The cup shape and facets are similar to some of the cyathocrinids such as *Anarchocrinus* except the IBB are slightly longer and more prominent. The cup and general shape of the brachials are similar to *Pelecocrinus*, but only one anal is thought to have been present. There was no radianal and the facet on the truncated basal is for a large single anal which is not preserved. The number and position of the distal anal plates is unknown. The A ray does not branch until IBr_{10} and the brachials of *Pelecocrinus* tend to be more cuneate than on this specimen. The arm branching and single anal suggest relationship with the stellarocrinids with the multiple isotomous branchings and widely laterally flaring arms.

The specimen is judged to represent a new genus and species of the poteriocrinids, but is not suitable for serving as a type. Thus it is left in open nomenclature, adding to the known Early Mississippian faunas.

Material. One partial crown (USNM 487240) from talus slope in the upper part of the Chinese Wall Member, Henderson Canyon Formation, above the toilet along the road, west of Boy Scout Camp Kiesel, north of Causey Reservoir.

PRIMITIVE POTERIOCRINE insertae sedis
n. gen., n. sp. undesignated
Plate 8, Figure 1

Description. Crown elongate, length 29.8 mm, slender enclosed, width 29.0 mm arms splayed. Cup high conical, width 7.0 mm. IBB not exposed. BB 5, moderately large, gently convex transversely and longitudinally, form major part of cup wall. RR 5, large, 3.2 mm long, 3.5 mm wide, moderately convex transversely, nearly straight longitudinally. Radial facet peneplenary, moderately rounded, protruded; distinct shoulders on either side of radial between radial facet and interradial sutures. IBr_1 or IBr_2 axillary in three rays exposed; axillary IBr_1 shorter than non-axillary IBr_1. Axillary IBr_1 very short, triangular. Brachials strongly rounded transversely, distal brachials strongly cuneate; slightly constricted medially on wide side; project outwardly on narrow side beyond base of overlying brachial, making shingled appearance. Distal isotomous branching two or three times per ray, somewhat irregular, may be endotomous; $IIBr_{6, 8}$ or $_{10}$, $IIIBr_{7, 8, 9}$ or $_{12}$, $IVBr_{12}$ axillary in visible arms. Anals not exposed. Tegmen bearing coarse, blunt spines distally, well below distal ends of arms. Stem round transversely, heterotomous. Complex noditaxis patterns not symmetrical, variable, at 15 mm N433434414342332434N. Very cirriferous close to cup, 28.5 mm preserved.

Remarks. This specimen shows characters common to genera assigned to several families. The high conical cup with peneplenary facets with moderately rounded exteriors suggests affinity with the Rhenocrinidae, members of which have arms that branch on the second or higher primibrachial and have different tegmens. The conical cup and arm branching on the first or second primibrachial suggests affinity with the Scytalocrinidae or any of several other families, genera of which normally have plenary radial facets, fewer arms, and a different type tegmen. Coarse, blunt spines on the distal end of the tegmen and endotomous arms suggest affinity with the Zeacrinitidae, members of which have low, flat, or impressed cups and rectilinear or faintly cuneate brachials. The cirriferous nature of the specimen suggests affinity with genera in the Ampelocrinidae and Graphiocrinidae, but cup and arm differences preclude assignment to either of these families. Because each of the families to which this specimen shows some affinities also have recognized classification problems within them (discussions above), it is not assigned to a family at this time.

The cup of this specimen is slightly crushed; the infrabasals are not visible, if preserved; and two of the basals are dislocated, moved upward, partly under the radials. The radial on the right side of the cup is cracked and outwardly dislocated. Although believed to represent a new genus and species, the specimen is not suitable to serve as a holotype. It is illustrated because it adds to the known diversity of the Henderson Canyon fauna and Early Mississippian poteri-ocrines. It is associated with *Dichocrinus* sp.

Material. One crown (USNM 487241) on a float slab from the lower ledge of the Brush Canyon Member, Henderson Canyon Formation, ridge east of Beirdneau Hollow, Logan Canyon, Utah. Found by Paul Jamison.

Subclass FLEXIBILIA Zittel, 1895
Order TAXOCRINIDA, Springer, 1913
Superfamily TAXOCRINACEA Angelin, 1878
Family TAXOCRINIDAE Angelin, 1878
TAXOCRINID indet. #1
Plate 2, Figure 2

Description. Crown small, wider (14.7 mm) than long (12.8 mm). Cup medium bowl-shaped, wider (6.5 mm) than long (3.6 mm). IBB circlet subhorizontal, barely visible in lateral view. BB and RR moderately upflared. Anal series 1:1:1, not in contact with posterior basal. IBr two in D ray, three in B, C, and E rays. All branching isotomous, one or more, probably two distal branchings. Brachials much wider than long proximally, becoming more equidimensional distally. Arms strongly incurled distally. One large interbrachial in DE interray. Stem larger proximally, tapering distally; stem diameter 1.8 mm at base cup. Columnals very thin proximally, thicken distally in proximal 2.5 mm; noditaxial series N212 distally. Cup, primibrachial and secundibrachial plates very thick; more distal brachials relatively thinner.

Remarks. The crown is slightly flattened along the B-E rays and has been deeply solution etched along plate edges by weathering processes. The specimen probably represents a new genus of taxocrinid with an advanced arrangement of the anal plates, the anals not in contact with the posterior basal. The irregular number of primibrachials is unusual in the taxocrinids and suggests relationships to *Eutaxocrinus* and *Taxocrinus*. Preservation of the specimen is sufficient to show the major morphologic characters but insufficient to serve as a holotype. Because flexibles are uncommon in the Henderson Canyon Formation, the specimen is illustrated for faunal completeness.

Material. One crown (USNM 487242) on a float slab from an unknown level within the upper part of the Brush Canyon Member, Henderson Canyon Formation, Beirdneau Hollow, Logan Canyon; found by Paul Jamison.

TAXOCRINID? indet. #2
Plate 2, Figure 1

Description. Cup medium bowl shape. IBB fused, pentagonal, large, 4.6 mm diameter. BB 5, pentagonal, posterior may be hexagonal, irregular sizes, posterior largest (3.1 mm long, 5.0 mm wide). RR 5, wider (7.4 mm) than long (4.2mm), strongly convex transversely, straight to faintly concave lon-

gitudinally. Radial facets angustary. Anal series, arms, and stem unknown.

Remarks. Flexibles with a fused infrabasal circlet are uncommon except in the Permian of Timor (Moore and Teichert, 1978). All known genera with a fused infrabasal circlet have plenary or angustary radial facets which typically are inset with the lateral sides extended distally as unequal prongs. Thus, a specimen with angustary radial facets on radials of a typical taxocrinid is of special interest, but difficult to classify. Curvature of the cup plates suggests that the proximal columnal did not extend beyond the infrabasal circlet, however silicification has destroyed the columnal facet scar. The lateral sides of the radials likely attached to interbrachial plates as is common to many taxocrinids and other flexibles. The specimen is questionably assigned to the taxocrinids.

An associated pluricolumnal which may or may not belong to the cup has a round transverse section and a noditaxis of minimally N3231323 pattern. Columnals have a rounded latus and syzygy articulation. The specimen is illustrated for faunal completeness.

Material. One partly silicified cup (USNM 487243) with cup plates slightly disarticulated on an *in situ* slab from the upper half of the Devil Creek Member, Henderson Canyon Formation, south face, Wellsville Mountain.

Order SAGENOCRINIDA Springer, 1913
Family EURYOCRINIDAE Moore and Strimple, 1973
Genus AINACRINUS Wright, 1939
AINACRINUS sp.
Plate 2, Figure 3

Description. Crown small, ovoid, length 25 mm, incomplete width 18.5 mm. Cup low, shallow bowl-shaped. Cup plates firmly united with proximal brachials to form base of crown. IBB 3, small. BB 5, pentagonal with very short basal-basal sutures; posterior basal largest, truncated distally for reception of anal X. BC and DE basals next largest, AB and EA basals smallest. RR large, much wider (5.2 mm) than long (2.0 mm). Two primibrachials, three secundibrachials, minimum six tertibrachials. All brachials wider than long. Branching isotomous. Interprimibrachials series 1:1:1:1. Anal series unknown. Stem uncertain.

Remarks. The flattened crown is preserved in a ribbon chert and the external surface of the plates is lost by weathering. Plate surfaces are silicified and outlines generally well defined, however, outlines of the IBB and BB are faint and discernible only under a microscope. The stem probably covered the IBB and proximal parts of the BB circlet, if the fragmentary pluricolumnal at the base of the crown actually attached to the crown. That pluricolumnal is formed of very thin columnals which thicken distally, assuming it originally attached to the specimen. Two other associated pluricolumnals in the same block may or may not belong to the crown. Truncation of the posterior basal is nearly masked by the chert and position of the crown.

The specimen is assigned to *Ainacrinus* because it fits the general morphologic characters of the genus and the monotypic species *A. smithi* (Wright, 1939). No species is designated because the anal series and exterior surface of the crown are unknown.

Material. One partial crown (USNM 487244) in float block from the top of the Chinese Wall Member, Henderson Canyon Formation, Leatham Hollow, Utah. Found by John Watkinson.

Class BLASTOIDEA Say, 1825
Order SPIRACULATA Jaekel, 1918
Family GRANATOCRINIDAE Fay, 1961
Genus CRYPTOBLASTUS Etheridge and Carpenter, 1886
CRYPTOBLASTUS? sp.
Plate 1, Figure 7

Remarks. Blastoids are moderately common in the Lodgepole Formation of western Montana as described by Sprinkle and Gutschick (1990). Only one specimen has been found in the Henderson Canyon Formation. The specimen is embedded in well-lithified grainstone, exposing part of three radials and the oral surface. Unfortunately the silicification has destroyed much of the details of the plates, that is, even the deltoid-radial sutures and some of the spiracles are not discernible with certainty on the exposed parts of the thecae. Thus, the identification, based on shape and recognizable relationships of the ambulacra, must be questioned.

Material. One theca (USNM 487245), float block from the middle part of the Brush Canyon Member, Henderson Canyon Formation, approximately one mile east of Beirdneau Hollow, Logan Canyon.

Class ECHINOIDEA Leske, 1778
Subclass PERISCHOECHINOIDEA M'Coy, 1849
Order CIDAROIDA Claus, 1880
Family ARCHAEOCIDARIDAE M'Coy, 1844
Genus ARCHAEOCIDARIS M'Coy, 1844
ARCHAEOCIDARIS? sp.
Plate 7, Figure 8; Plate 8, Figure 7C

Remarks. Loose interambulacral plates bearing a large central boss and tubercle are present on several of the crinoid-bearing blocks from the Henderson Canyon Formation as are large spines greater than 10 cm in length, some of which are hollow. Crushed tests are rarely found.

One slab from the Gardison Limestone contains splayed spines and crushed tests of nine specimens that are questionably referred to *Archaeocidaris* because the number of rows of interambulacral plates is not determinable and the ambulacral rows are not exposed. The thin, delicate spines attain lengths of 23.5 mm and widths of 2 mm. Tests are small, 10 mm diameter crushed, perhaps representing immature forms. It is not known if these tests and spines are from the same species as the loose ossicles and spines, but it is likely that more than one species is present. Thus a minimum of two echinoid taxa are present in the Henderson Canyon and coeval rocks in the northern Utah - southern Idaho area.

Material. One slab bearing nine tests with radiating spines (BYU 3159) from the Gardison Limestone, found by Mark

McCutcheon. Slab contains the echinoid tests, one partial crown of an indeterminate rhodocrinitid, and *Blothrocrinus* n. sp. undesignated. The Gardison Limestone is considered to be of earliest Osagean (Tn3) age by Poole and Sandberg (1991). A single crushed test with spines (USNM 487246) on a float slab from the Brush Canyon Member, Wellsville Mountain.

AARCHAEOCIDARIS n. gen.

Etymology. The generic name is the negative *A* added to *Archaeocidaris* to refer to the form as not an *Archaeocidaris*.
Type species. *Aarchaeocidaris strawberryensis*, n. sp.
Diagnosis. An archaeocidarid with a semirigid test, four rows of interambulacral plates, two rows of ambulacral plates, ambulacral plates slightly overlap adjacent interambulacral plates along radial suture, pore pairs uniserial, and lacking a large central boss on the interambulacral plates.
Description. See description of type species below.
Remarks. Two late Paleozoic echinoid orders, Echinocystitoida and Palaechinoida, have imbricating plates and most lack a large primary tubercle on the interambulacral plates. The Echinocystitoida have a flexible test. The ambulacral plates bevel over the interambulacral plates in the Palaechinoida. These features preclude assignment of *Aarchaeocidaris* to either of these two orders.

All other late Paleozoic echinoids are currently assigned to the order Cidaroida and have a large central boss on the interambulacral plates. Paleozoic families of the cidarids are the Miocidaridae and the Archaeocidaridae. The Miocidaridae have two rows of interambulacral plates, precluding assignment of *Aarchaeocidaris* to that family. The Archaeocidaridae, to which *Aarchaeocidaris* is assigned, have four or more rows of interambulacral plates. The plate structure of *Aarchaeocidaris* is basically the same as *Archaeocidaris*, however, the absence of the large boss on the interambulacral plates makes for ease of distinction. All other genera of the Archaeocidaridae differ from *Aarchaeocidaris* by having large spines and, if the test is known, with a large boss on the interambulacral plates.

AARCHAEOCIDARIS STRAWBERRYENSIS n. gen., n. sp.

Plate 4, Figures 1, 4; Plate 8, Figures 4-6, 9

Etymology. The specific name refers to the Strawberry Canyon, Wyoming where the holotype was found.
Diagnosis. As for the genus.
Description. Test subspherical, 19.5 mm height, 23.2 mm diameter, semirigid, radially symmetrical originally, slightly distorted along aboral-adoral axis, formed of 30 rows of plates, peristomial area slightly depressed. Ambulacral plates in two rows, widening slightly to midlength, slightly overlap adjacent interambulacral plates; plates slightly sinuous, do not develop diads or triads, nonconjugate pore pair on adradial end, two or three nodes (probably small tubercle bases) on abradial end; maximum size 1.2 mm width, 0.3 height. Interambulacral plates in four rows, lacking bosses, surface with numerous small tubercle bases. Plates of middle two rows hexagonal; right row plates wider than high, maximum size 3.5 mm width, 3.3 mm length; left row plates higher than wide, maximum size 3.5 mm length, 2.9 mm width. Plates of outer two rows pentagonal, adjoined by four to six ambulacral plates per interambulacral plate. No large primary spines. Numerous small spines, maximum 0.9 mm length.

Oculogenital ring dicyclic. Exsert oculars small, dart shaped, longer than wide, bear single pore toward adoral end. Genitals large, septagonal, bear three pores each; central pore toward adoral end, lateral pores slightly aboral of central pore. Madreporite larger, bears five pores. Periproct not preserved. Lantern and teeth unknown.
Remarks. The description and measurements are based mostly on the holotype USNM 487247, an uncrushed but slightly distorted silicified test. Paratype USNM 487248 is also silicified, but has numerous unsilicified small spines in the matrix around the apical area. Silicification has destroyed most of the surface morphologic features on both of these specimens. Paratype USNM 487249 is a partial crushed unsilicified test that shows small nodes representing what is left of the weathered small tubercles on the interambulacrals and ambulacral plates. Weathering has destroyed the small nodes on some corona plates. This specimen also has numerous small spines in the matrix around the test but oral and apical areas are not preserved.

The lack of large spines, uncrushed preservation of the holotype, partial crushing of one paratype, and fine-grained matrix preserving the specimens suggest these forms may have had a shallow infaunal habitat.
Material. Holotype (USNM 487247), a test, found by Aram Derewetzky in the upper part of the Lodgepole Formation (148 m above the base) and paratype (USNM 487248), one partial test, from the Lodgepole Formation (float, 15 m above marker bed in middle of unit), both south wall of Strawberry Creek, Wyoming. Paratype (USNM 487249) partial corona on loose block nearly in place, from the lower ledge of the Brush Canyon Member, Henderson Canyon Formation, Beirdneau Hollow, Logan Canyon; specimen associated with Scytalocrinidae indet. A crushed distorted test (USNM 487250) associated with *Histocrinus? loganensis*, from an unknown level in the upper half of the Brush Canyon Member, Beirdneau Hollow, Logan Canyon, Utah; found by Paul Jamison.

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APPENDIX

Table A1.
Taxa identified from crinoid intervals at various localities of the Henderson Canyon Formation.

Wellsville Mountain
- Devil Creek Member
  - Upper half
    - Taxocrinid? indet. #2
  - Basal part
    - *Platycrinites bozemanensis*
    - *Adiakritocrinus oviatti*

- Brush Canyon Member
  - Upper ledge (uppermost part of Brush Canyon Member)
    - *Rhodocrinites* cf. *R. macrotumidus*
    - *Aarchaeocidaris strawberryensis*
  - Lower ledge (upper middle part of Brush Canyon Member)
    - *Rhodocrinites* cf. *R. macrotumidus*
    - *Dichocrinus laudoni*
    - *Bridgerocrinus fairyensis*
    - Scytalocrinidae n. gen., n. sp. undesignated
    - *Aphelecrinus? utahensis*
    - *Paracosmetocrinus rotundus*
    - *Apokryphocrinus wellsvillensis*
    - *Pelecocrinus sp.*
    - *Archeocidaris? sp.*
  - Unknown level (probably lower ledge of Brush Canyon Member)
    - *Cribanocrinus honeyvillensis*
    - *Cusacrinus kuenzii*
    - *Dichocrinus delicatus*
    - *Paradichocrinus wellsvillensis*
    - *Platycrinites bozemanensis*
    - *Platycrinites cf. canadensis*
    - *Platycrinites beirdneauensis*
    - *Platycrinites portiotortuosus* (col)
    - *Platycrinites portiotortuosus*
    - *Cyathocrinites sp.*
    - *Bridgerocrinus fairyensis*
    - *Blothrocrinus guntherorum*
    - *Paracosmetocrinus utriculus*
    - *Archaeocidaris sp.*

- Chinese Wall Member
  - Float blocks, uppermost 2-3 m of unit
    - *Platycrinites beirdneauensis*
  - Basal 3-4 m
    - *Rhodocrinites* cf. *R. macrotumidus*
    - Rhenocrinidae?, n. gen., n sp. undesignated

Beirdneau Hollow Area
- Brush Canyon Member
  - Upper ledge
    - *Cusacrinus* sp. 3
    - Scytalocrinidae indet.
    - *Paracosmetocrinus utriculus*
  - Lower ledge
    - *Cusacrinus kuenzii*

Dichocrinus quadriceptatus
Paracosmetocrinus utriculus
Archeocidaris? sp.
Aarchaeocidaris strawberryensis
Unknown level (most are probably from the lower ledge; all from lower or upper ledge)
Platycrinites bozemanensis
Platycrinites beirdneauensis
Taxocrinid indet. #1
Zygiosocrinus typicus
Scytalocrinus occiduus
Bridgerocrinus jamisoni
Histocrinus? loganensis
Scytalocrinidae n. gen., n. sp. undesignated
Aphelecrinidae? n. gen., n. sp. undesignated
Paracosmetocrinus madisonensis
Paracosmetocrinus rotundus
Primitive poteriocrine *insertae sedis* n. gen., n. sp.
Aarchaeocidaris strawberryensis

Woodcamp Hollow, Logan Canyon
Brush Canyon Member
Upper ledge
Dichocrinus sp.
Primitive poteriocrine *insertae sedis* n. gen., n. sp.

Logan Canyon, north side, 1 mile east of Beirdneau Hollow
Brush Canyon Member
Upper ledge
Paradichocrinus wellsvillensis
Platycrinites bozemanensis
Lower ledge
Platycrinites canadensis
Platycrinites beirdneauensis
Adiakritocrinus oviatti
Uncertain level, float block
Cryptoblastus? sp.

Logan Canyon, north side, ½ mile west of Wind Cave
Brush Canyon Member
Upper ledge
Platycrinites portiotortuosus
Float block, upper part of Brush Canyon Member
Paracosmetocrinus rotundus

Blacksmith Fork - Letham Hollow
Brush Canyon Member
Float block, undesignated level
Platycrinites beirdneauensis

Chinese Wall Member
Float blocks, uppermost part of unit
Cusacrinus sp. 2
Platycrinites portiotortuosus (col)
Ainacrinus sp.

Along road, west of Boy Scout Camp Kiesel, north of Causey Dam
Chinese Wall Member
Uppermost part
Cactocrinus cf. *C. magnidactylus*

Paracosmetocrinus peterseni
Platycrinites? portiotortuosus (col)
Poteriocrinid indet.

Gardner Canyon, Samaria Mountains, Idaho
Brush Canyon Member
Platycrinites bozemanensis

Rock Canyon, northeast of Provo
Gardison Limestone
Rhodocrinitid? indet.
Blothrocrinus n. sp.
Archaeocidaris? sp.

Strawberry Creek, western Wyoming
Float block
Upper half of Lodgepole tempestites
Cusacrinus sp. 1
Aarchaeocidaris strawberryensis

Table A2.
Taxa associations occurring on same bedding surface.

Several slabs contain two or more crinoids or other echinoderms on the same bedding surface. These associations are given with the stratigraphic information and general locality information for biostratigraphic and paleoecologic purposes.

Gardison Formation, Rock Canyon
Archaeocidaris? sp.
Blothrocrinus n. sp.
Rhodocrinitid? indet.

Chinese Wall Member, upper 3-4 m., Blacksmith Fork, Leatham Hollow
Cusacrinus sp. 2
Platycrinites portiotortuosus

Brush Canyon Member, upper crinoid interval, float slab, Logan Canyon, Woodcamp Hollow area
Dichocrinus sp.
Primitive poteriocrine *insertae sedis* n. gen., n. sp.

Brush Canyon Member, upper crinoid interval, *in situ*; Logan Canyon, east of Beirdneau Hollow
Platycrinites beirdneauensis
Platycrinites canadensis
Paradichocrinus wellsvillensis
Adiakritocrinus oviatti
Pelecocrinus n. sp. undesignated

Brush Canyon Member, float slabs, probably lower crinoid interval, Beirdneau Hollow area
Slab 1:
Aarchaeocidaris strawberryensis
Scytalocrinidae indet.

Slab 2:
Histocrinus? loganensis
Aarchaeocidaris strawberryensis

Slab 3:
Platycrinites bozemanensis
Platycrinites beirdneauensis

Brush Canyon Member, float slab, nearly *in situ*, lower crinoid interval, ½ mile west of Wind Cave, Logan Canyon
Platycrinites portiotortuosus
3 indet. inadunates

Brush Canyon Member, probably lower ledge, Wellsville Mountain
Slab 1:
Cyathocrinites sp.
Platycrinites portiotortuosus
Platycrinites cf. *canadensis*

Slab 2:
Platycrinites beirdneauensis
Adiakritocrinus oviatti

Slab 3:
Dichocrinus laudoni
Bridgerocrinus fairyensis
Paracosmetocrinus utriculus

Slab 4:
Cribanocrinus honeyvillensis
Dichocrinus laudoni
Asteroid
Immature inadunate, probably *Bridgerocrinus fairyensis*
Indeterminate camerate

Slab 5:
Cribanocrinus honeyvillensis
Dichocrinus laudoni
Bridgerocrinus fairyensis
Apokryphocrinus wellsvillensis
Asteroid

Devil Creek Member, lower part
Platycrinites bozemanensis
Adiakritocrinus oviatti

Table A3.
Locality Register.

Many specimens were found on float slabs on scree slopes. Therefore, the localities listed indicate a general area from which the slabs were found. Other specimens were found *in situ* in these same areas as listed in appendix, table 2. Listings are for U.S. Geological Survey 7.5-minute topographic maps.

Wellsville Mountain, Utah - C. Sec. 26, T11N, R2W, Honeyville Quadrangle

Wind Cave, Logan Canyon, Utah - NE¼, SE¼ , Sec. 27, T12N, R2E, Mt. Elmer Quadrangle

Beirdneau Hollow, Logan Canyon, Utah - C. NW¼, Sec. 23, T12N, R2E, Mt. Elmer Quadrangle

Woodcamp Hollow, Logan Canyon, Utah - S½, SE¼, Sec. 6, T12N, R2E, Mt. Elmer Quadrangle

Leatham Hollow, Utah - SE¼ , NW ¼ , Sec. 34, T11N, R2E, Logan Quadrangle

Blacksmith Fork Canyon, Utah - S½ , NW¼ , Sec. 3, T10N, R2E, Logan Quadrangle

Boy Scout Camp Keisel, Causey Dam area, Utah - SW¼ , SE¼, Sec. 26, T7N, R3E, Causey Dam Quadrangle

Rock Canyon, Utah - NE¼, SW¼, Sec. 28, T6S, R3E, Bridal Veil Falls Quadrangle

Strawberry Creek, western Wyoming - NW¼, NW¼, SE¼, Sec. 24, T34N, R117W, Man Peak Quadrangle

Gardner Canyon, Samaria Mountains, Idaho - C. SW¼, Sec. 12, T16S, R4W, Samaria Quadrangle

PLATES

Plate 1

Figures 1-3, 9. *Cusacrinus kuenzii* Laudon, Parks and Spreng, 1952. Figures 1-3. Oral, C ray and basal views, USNM 487162, X2. Figure 9. C ray view; BYU 3155, X1.2.

Figures 4-6, 14A. *Rhodocrinites* cf. *R. macrotumidus* Laudon and Severson, 1953. Figures 4-6. Oral, basal and E ray views, USNM 487158, X4. Figure 14A. Posterior - C ray view, showing distal brachials and pinnules above and to the right and lower right of the calyx, USNM 487160, X1.5.

Figure 7. *Cryptoblastus?* sp. Oblique view, orientation uncertain, USNM 487245, X3.

Figure 8. *Cusacrinus* sp. 1. C ray view, USNM 487163, X2.

Figure 10. *Cribanocrinus honeyvillensis* n. sp. Posterior view, holotype, USNM 487161, X3.

Figure 11. *Cusacrinus* sp. 3. D ray view, USNM 487165, X2.

Figure 12-13. *Cactocrinus* cf. *C. magnidactylus* (Laudon and Severson, 1953). C and A-E ray views, BYU 3165, X1.5.

Figure 14B. *Platycrinites portiotortuosus* n. sp. Pluricolumnal, USNM 487209, X1.5.

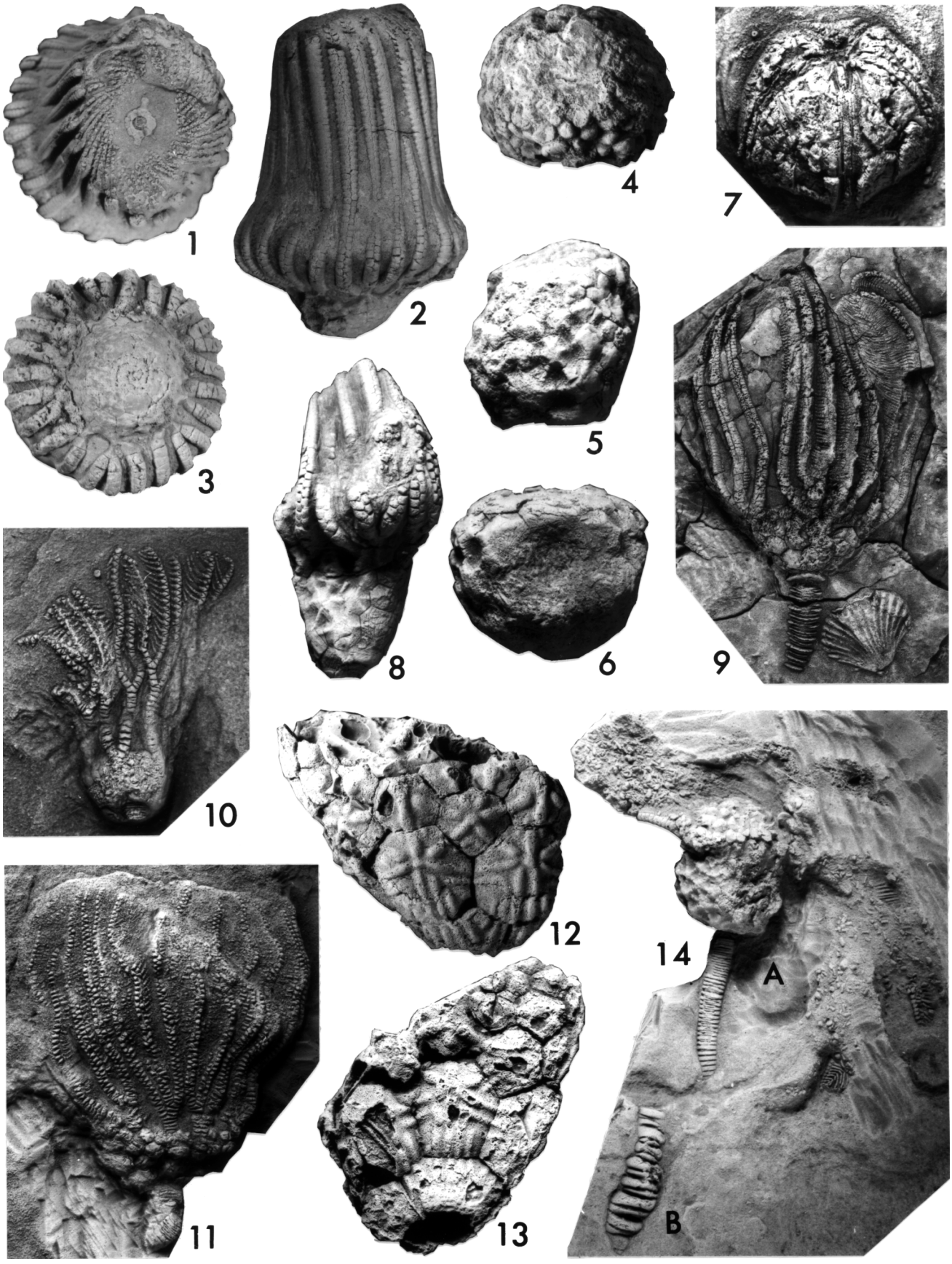
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Plate 2

Figure 1. Taxocrinid? indet. #2. Basal view, A ray at top of slightly disarticulated, partly silicified specimen, USNM 487243, X2.

Figure 2. Taxocrinid indet. #1. Posterior view of solution-weathered specimen, USNM 487242, X2.5.

Figure 3. *Ainacrinus* sp. Posterior view, outer rims of plates silicified and weathering has dissolved the exterior surfaces and calcite stereom interiors, USNM 487244, X2.

Figures 4, 9. *Paradichocrinus wellsvillensis* n. sp. Figure 4. D-E ray view of crushed paratype, USNM 487176, X2. Figure 9. E-A or A-B interray view showing biserial arms extending to base of last branching, holotype BYU 3152, X2.

Figures 5-7, 10. *Dichocrinus laudoni* Broadhead, 1981. Figure 5. Posterior ray view, USNM 487166, X3. Figure 6. Crushed crown showing distal uniserial brachials, USNM 487168, X3. Figure 7. Crushed crown, orientation uncertain, USNM 487169, X3. Figure 10. Posterior view of partly silicified and solution-weathered elongate adult crown, USNM 487166, X3.

Figure 8. *Dichocrinus delicatus* Wachsmuth and Springer, 1897. Posterior view, distally tapering anal right center, D radial on left, USNM 487174, X 4.

Figure 11. *Dichocrinus* sp. Lateral view of crown, orientation uncertain; cup crushed with basals pushed up into radials. Note the elongate, thin, delicate pinnules with expanded bases along the proximally cuneate and distally biserial brachials, USNM 487175, X2.5.

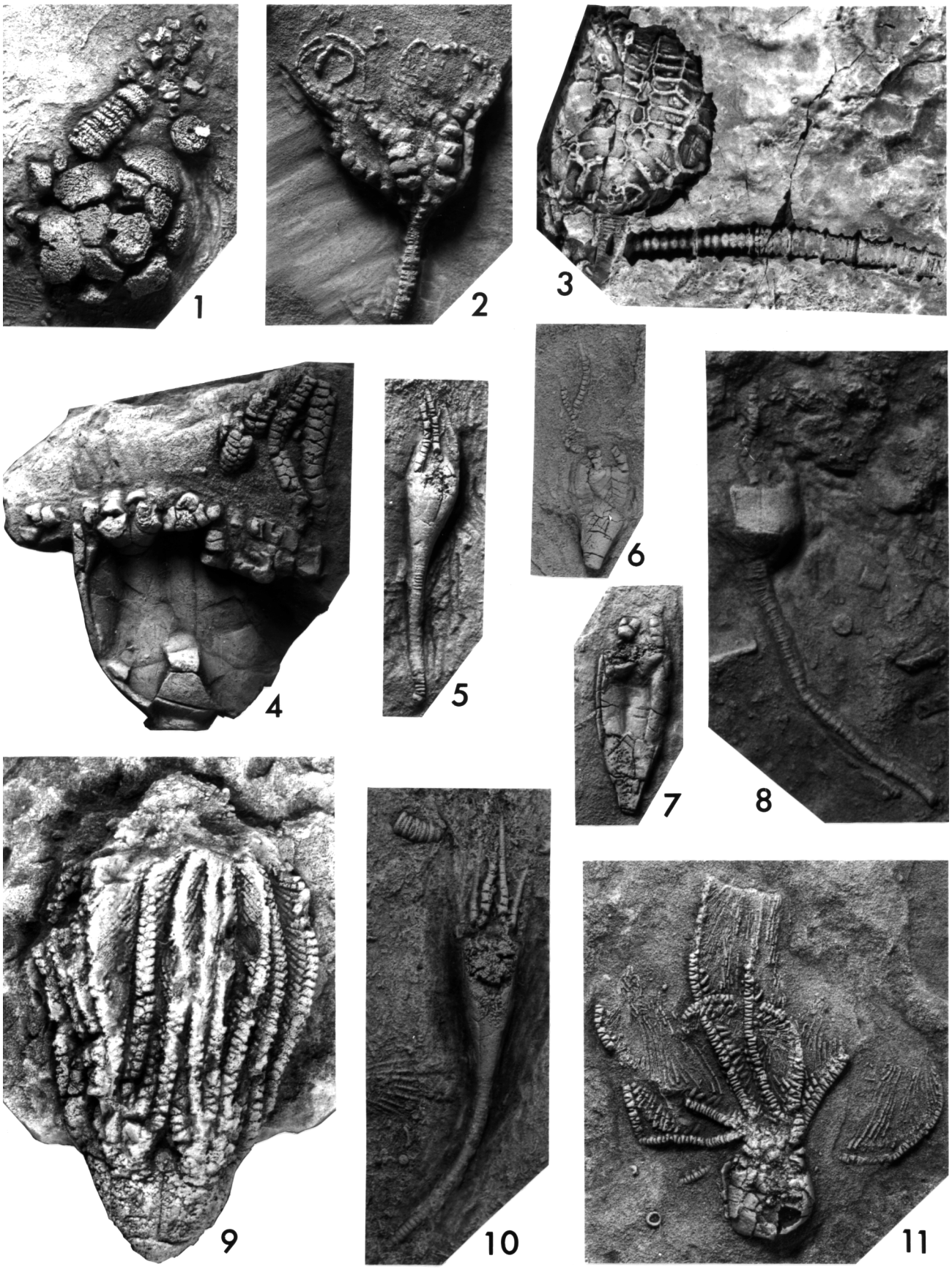
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Plate 3

Figures 1, 2B, 4, 6B, 7. *Platycrinites beirdneauensis* n. sp. Figure 1. Crushed partial crown showing arm branching, orientation uncertain, paratype, USNM 487194, X3. Figure 2B. Mature crown, orientation uncertain, paratype, USNM 487195, X2.1. Figure 6B. Partial crown with stem, orientation uncertain, paratype, USNM 487197, X1.7. Figure 7. Crown displaying well-preserved proximal part of stem, cup ornamentation and biserial arms, orientation uncertain, holotype, USNM 487191, X2.2. Figure 4. Basal view of basal circlet, UNMH IP 2247, X3.

Figure 2A. *Adiakritocrinus oviatti* n. gen., n. sp. D ray view of immature crushed crown, paratype, USNM 487239, X2.1.

Figure 3. *Platycrinites canadensis* Laudon and Severson, 1953 Figure 3. Crushed crown, orientation uncertain, USNM 487187, X2

Figure 5. Rhenocrinidae? n. gen., n. sp. undesignated. D ray view, anals to right are slightly dislocated, UNMH IP 2246, X2.

Figure 6A. *Platycrinites bozemanensis* (Miller and Gurley, 1897). Mature crown showing biserial arms distally, orientation uncertain, USNM 487185, X1.7.

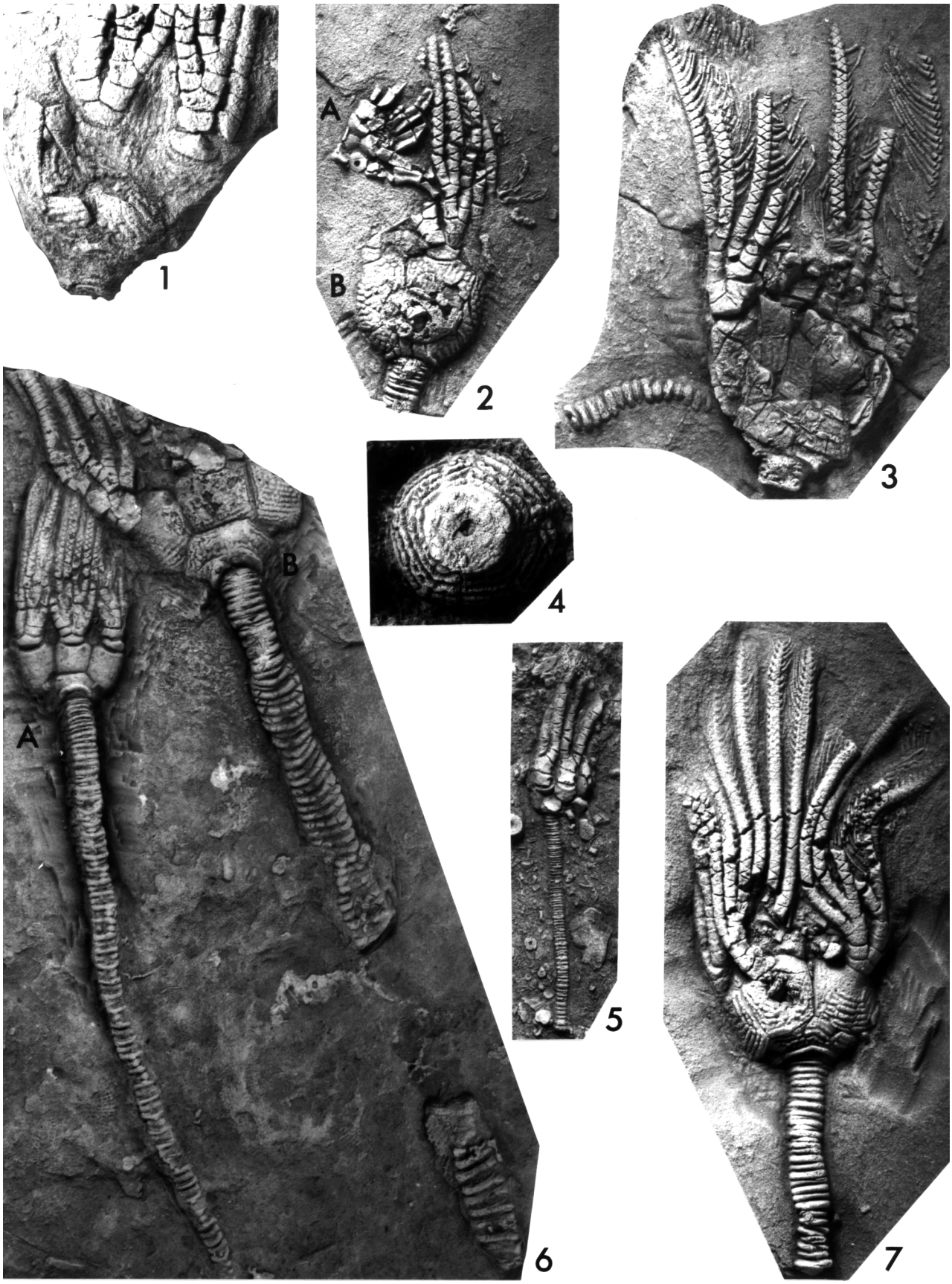
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Plate 4

Figures 1, 4. *Aarchaeocidaris strawberryensis* n. gen., n. sp. Crushed corona, orientation uncertain, paratype, USNM 487248, X2.

Figure 2A. *Cusacrinus* sp. 2 C ray view, USNM 487164, X3.

Figures 2B, 5, 7. *Platycrinites portiotortuosus* n. sp. Figure 2B. Pluricolumnal segment USNM 487210, X3. Figure 5. Posterior view of crown and proximal column showing segmented twist structure, holotype, USNM 487198, X1. Pluricolumnal segment crossing the stem of the holotype is part of the stem, paratype, USNM 487202. A partly exposed unidentified inadunate crown is to the right of the stem in the lower part of the figure. Figure 7. Crown with proximal column, orientation uncertain, paratype, USNM 487199, X2.

Figure 3. *Platycrinites ?portiotortuosus* n. sp. Pluricolumnal showing parts of four twist sections with a cirrus on the left side of the second columnal from the upper end of the lowermost section, USNM 487208, X1.5.

Figure 6. *Dichocrinus quadriceptatus* Laudon and Severson, 1953. Three rays showing protruded arm base, orientation uncertain, USNM 487173, X3.

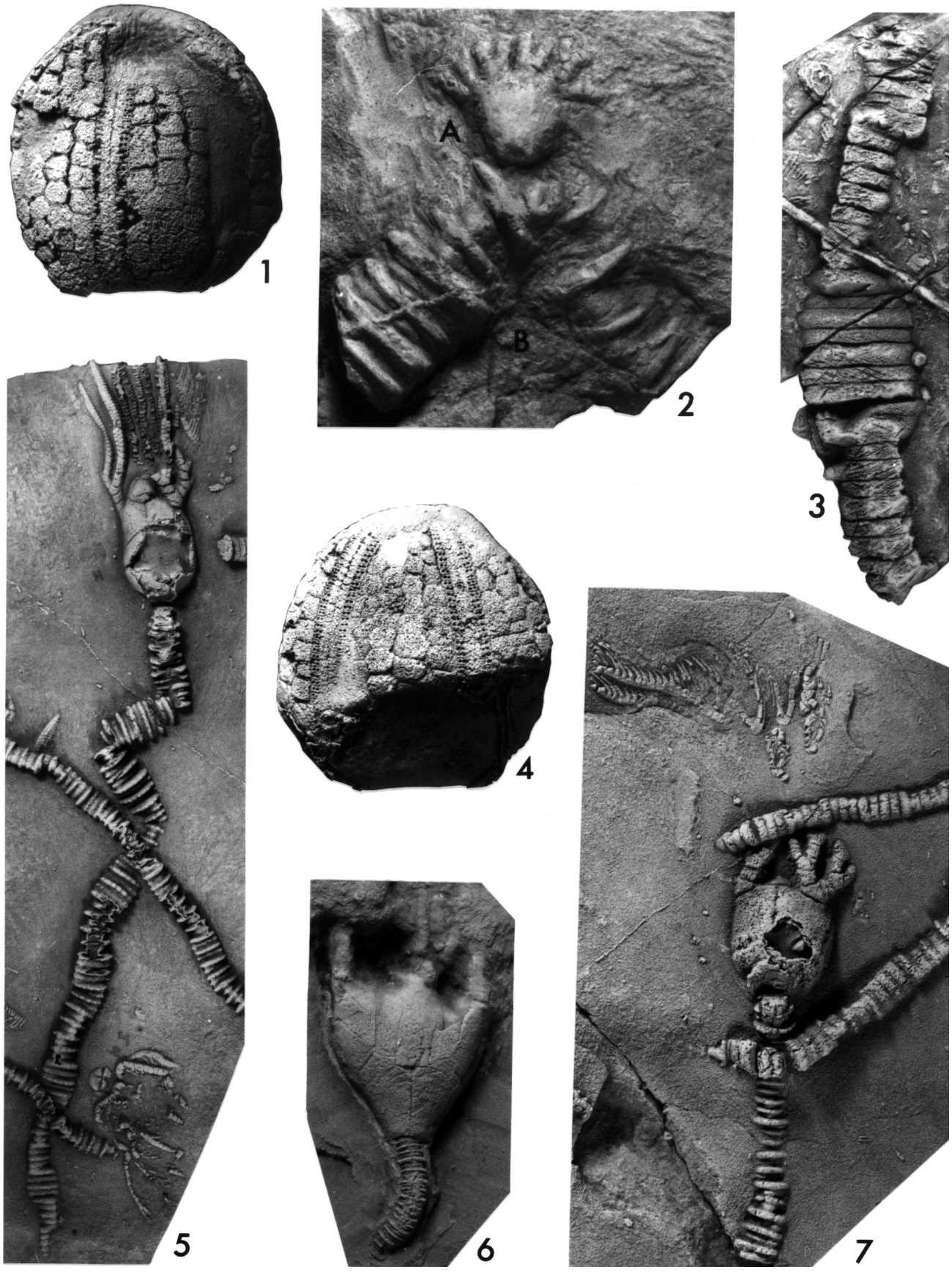
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Plate 5

Figures 1, 3, 4, 9. *Bridgerocrinus fairyensis* Laudon and Severson, 1953. Figure 1. Posterior view, with proximal parts of anal tube extending above the cup; plates etched from solution weathering, USNM 487216, X6. Figure 3. C ray view, USNM 487215, X4. Figure 4. A or B ray view showing two primibrachials in two rays and an associated asteroid, USNM 487219, X5. Figure 9. Immature individual, note narrow elongate primibrachials; cup poorly preserved, orientation uncertain, USNM 487218, X4.

Figure 2. *Scytalocrinus occiduus* n. sp. A ray view showing distal part of anal tube, holotype, USNM 487214, X2.

Figure 5. *Aphelecrinus utahensis* n. sp. C ray view showing the isotomous branching in the middle of the arms, holotype, USNM 487237, X3.

Figure 6. *Zygiosocrinus typicus* n. gen., n sp. A ray view, showing solution-weathered distal parts of the arms and ramules, holotype, USNM 487213X, X3.5.

Figure 7. *Cyathocrinites* sp. Posterior view of crushed crown, USNM 487212, X1.2.

Figure 8. *Bridgerocrinus jamisoni* n. sp. E-A or A-B rays view of crown retaining medial stem. Note the lengthening of the columnals and loss of noditaxis patterns distally, holotype, USNM 487224, X1.5.

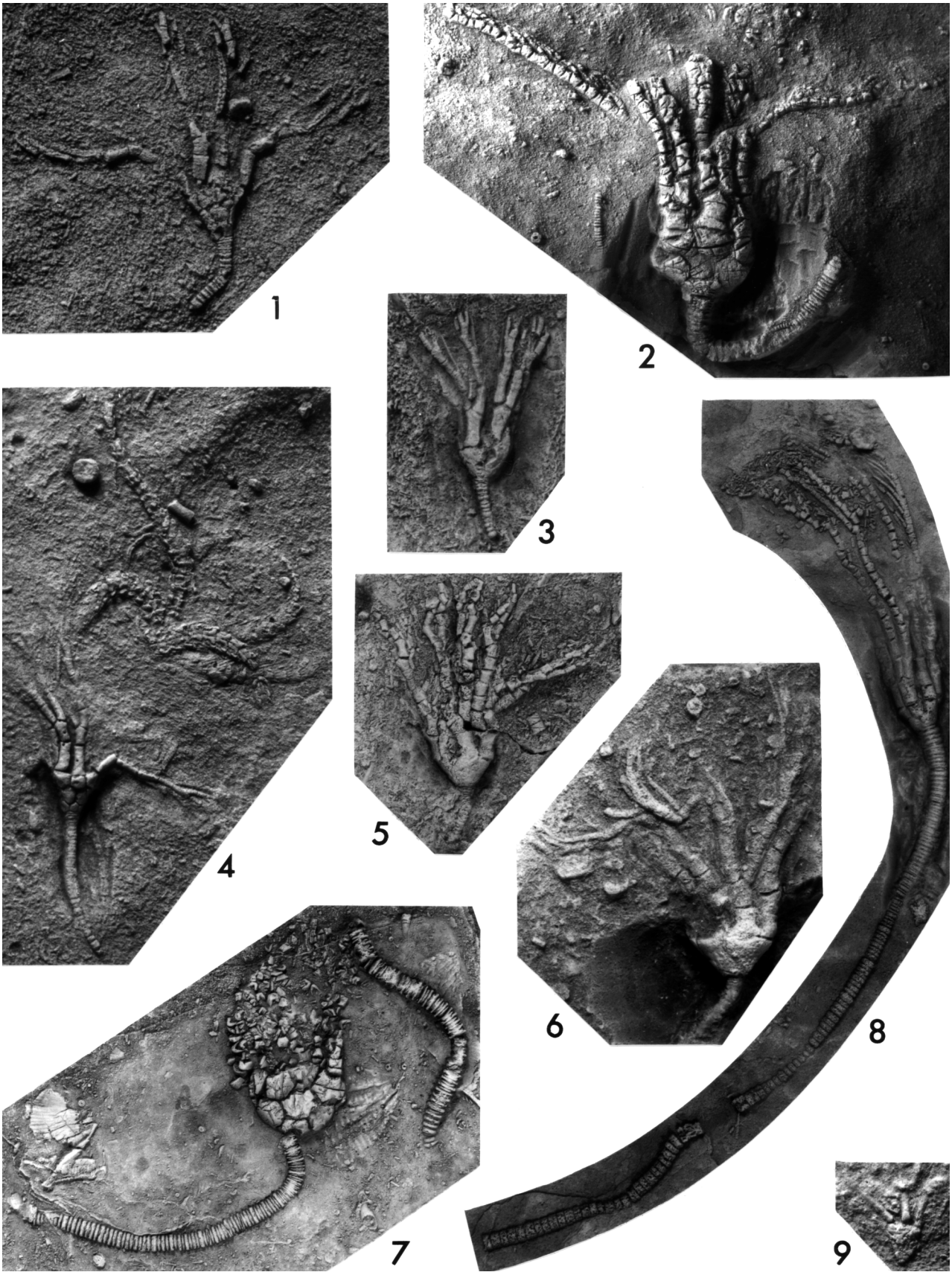
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Plate 6

Figures 1, 2, 7. Scytalocrinidae n. gen., n. sp. undesignated. Figures 1, 2. C and D ray views of crushed crown with proximal parts of infrabasals lost by weathering, UMNH IP 2249, X3. Figure 7. Crown with cup plates on right side partly dislocated, orientation uncertain, USNM 487226, X2.

Figure 3. Poteriocrinid indet. Cup plates and proximal brachials of partly disarticulated crown, USNM 487240X2.

Figure 4. *Histocrinus? loganensis* n. sp. A ray view of splayed crown with partly disarticulated cup, holotype, USNM 487225, X2.

Figure 5. Scytalocrinidae indet. Crushed crown, cup plates partly dislocated, orientation uncertain, USNM 487227, X2.

Figure 6. *Pelecocrinus* n. sp. undesignated. Crushed crown, orientation uncertain, USNM 487238, X2.5.

Figure 8. Aphelecrinidae? n. gen., n. sp. undesignated. A ray view of partly recrystallized crown, USNM 487228, X3.

Figure 9. *Blothrocrinus guntherorum* n. sp. Posterior view, holotype, BYU 3162, X2.

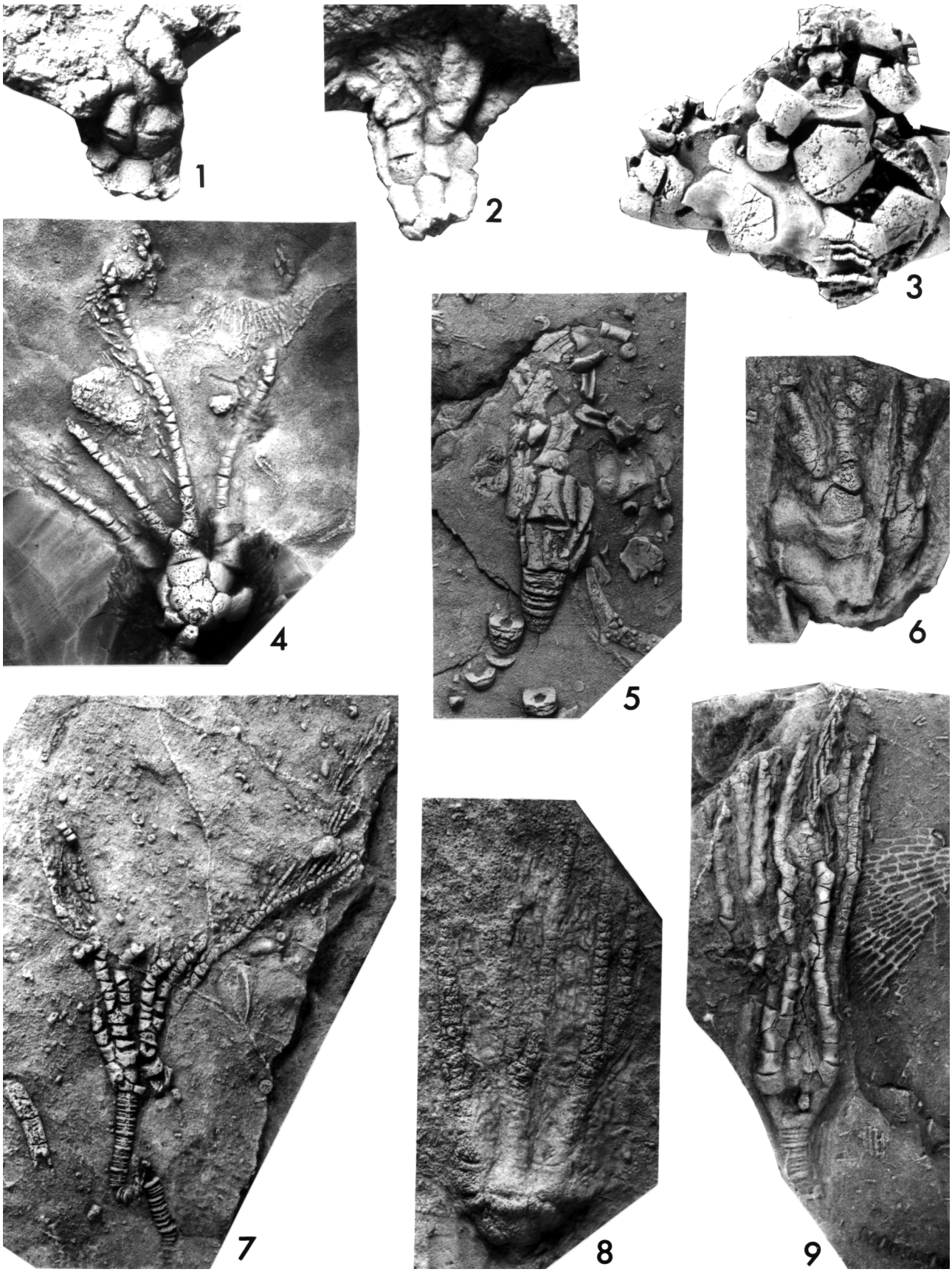
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Plate 7

Figures 1, 2, 7. *Paracosmetocrinus utriculus* n. sp. Figure 1. D ray view of holotype, USNM 487231, X2. Figure 2. Posterior view, paratype, USNM 487232, X3. Figure 7. Posterior view showing nodes on recurved tegmen, paratype, USNM 487233, X2.5.

Figures 3, 4, 10, 11. *Paracosmetocrinus rotundus* n. sp. Figures 3, 4. A ray and B ray views, holotype, USNM 487234, X1.5. Figure 10. Posterior view, paratype, USNM 487235, X2. Figure 11. A ray view of splayed crown, paratype, USNM 487229, X3.

Figures 5, 6. *Paracosmetocrinus peterseni* n. sp. E ray and basal views, holotype, BYU 3154, X2.

Figure 8. *Archaeocidaris?* sp. Partial corona showing four interambulacral rows between the ambulacra, USNM 487249, X2.

Figure 9. *Paracosmetocrinus madisonensis* (Laudon and Severson, 1953). E-A ray view of slightly opened crown showing distal arm branching, USNM 487230, X4.

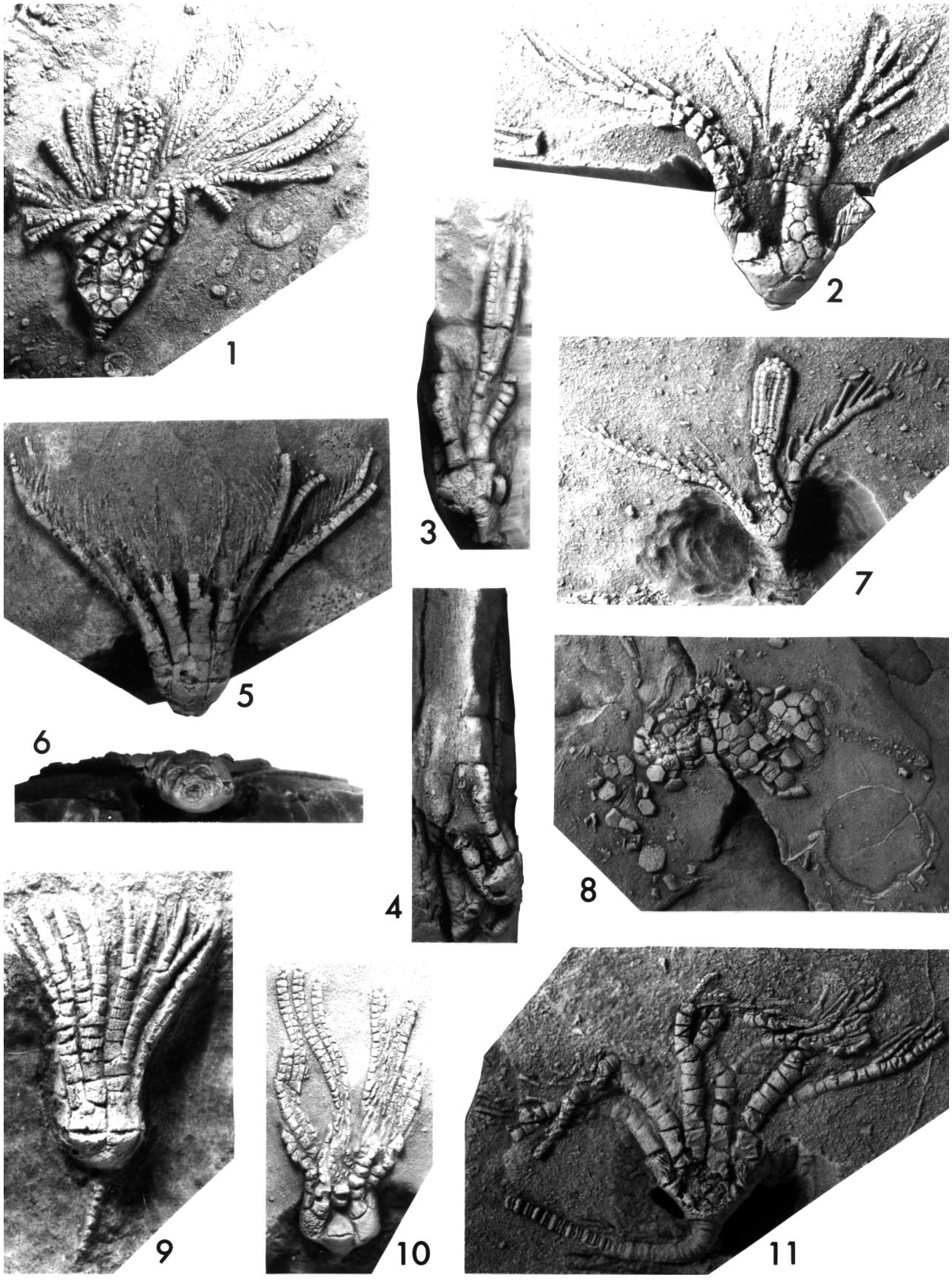
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Plate 8

Figure 1. Primitive poteriocrine *insertae sedis* n. gen., n. sp. Crown showing abundance of cirri on proximal part of stem, orientation uncertain, USNM 487241, X1.5.

Figures 2, 8. *Apokryphocrinus wellsvillensis* n. gen., n. sp. Posterior and A ray view of arms, holotype, USNM 487236, X3.

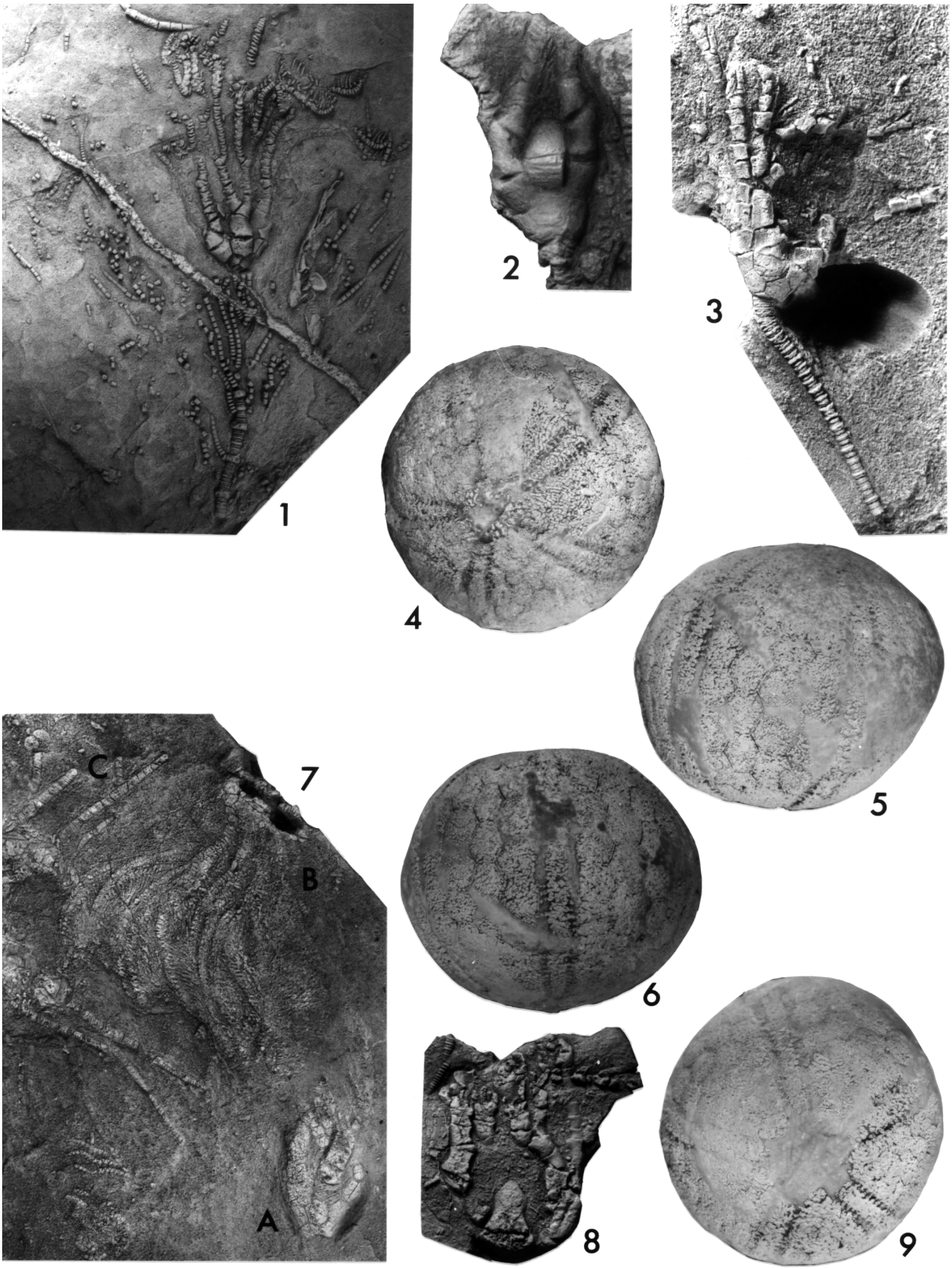
Figure 3. *Adiakritocrinus oviatti* n. gen., n. sp. A ray view, holotype, UNMH IP 2245, X3.

Figures 4-6, 9. *Aarchaeocidaris strawberryensis* n. gen., n. sp. Adapical, side, side, and oral views, holotype, USNM 487247, X2.4.

Figure 7A. *Blothrocrinus* n. sp. undesignated. view of poorly preserved partial crown, BYU 3167, X2.

Figure 7B. Rhodocrinitid? indet. View of arms and distal part of calyx, orientation uncertain, BYU 3166, X2.

Figure 7C. *Archaeocidaris?* sp. Scattered corona plates and spines, of crushed specimen, BYU 3168, X2.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