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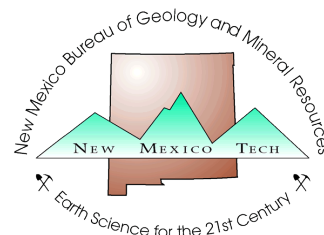
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Pennsylvanian crinoids of New Mexico

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Abstract

Crinoids from each of the five Pennsylvanian epochs are described from 26 localities in New Mexico. The crinoid faunas occupied diverse shelf environments around many intermontane basins of New Mexico during the Pennsylvanian. The crinoids described here include 29 genera, 39 named species, and at least nine unnamed species, of which one genus and 15 named species are new. This report more than doubles the number of previously known Pennsylvanian crinoid species from New Mexico; 17 of these species also occur in midcontinent faunas. New Mexico Pennsylvanian crinoids exhibit greater species richness than Pennsylvanian faunas from the intermontane basins of Colorado, Utah, and Arizona and show some generic affinity with Great Basin Pennsylvanian faunas. They indicate seaway connections were open, although perhaps intermittently, throughout the Pennsylvanian between the intermontane basins of New Mexico and midcontinent basins in Texas and Oklahoma.

New taxa introduced are: *Lekobikocrinus* n. gen., *Aaglaocrinus bowsheri* n. sp., *Diphucrinus borgesae* n. sp., *Goleocrinus chronici* n. sp., *Metacromyocrinus cedroensis* n. sp., *M. szaboi* n. sp., *Ulocrinus manzanitaensis* n. sp., *Moscovocrinus? rotundobasis* n. sp., *Endelocrinus globularus* n. sp., *Neoprotencrinus gutschicki* n. sp., *Euerisocrinus tijerasensis* n. sp., *Apographiocrinus rimosus* n. sp., *A. kietzkei* n. sp., *Metaffinocrinus noblei* n. sp., *Sciadiocrinus ornatus* n. sp., and *Paramphicrinus novamexicanus* n. sp.

Introduction

Crinoid remains are common constituents of many Pennsylvanian marine faunas in New Mexico, but with few exceptions, are stem fragments or isolated ossicles rather than the cups on which generic and specific identification are largely based. A few crinoid species have been cited in faunal lists, beginning with White (1881), and systematic studies, including description and illustration of crinoid taxa, are likewise limited to a small number of papers. The first illustration of a New Mexico Pennsylvanian crinoid was of a cup identified as *Cibolocrinus timidus* Moore and Plummer 1940 (= *Metacromyocrinus szaboi* n. sp. herein) in a master's thesis (Szabo 1953) from the Missourian part of the Madera Group from the Manzanita Mountains. Strimple (1969) described a cup from the Virgilian Jemez Springs Shale Member, Madera Group, north of Jemez Springs. Strimple (1980) described 13 taxa from the Sangre de Cristo and Sacramento Mountains, including: (1) specimens from the Morrowan part of the Gobbler Formation,

north of Alamogordo; (2) Morrowan and Atokan specimens from the La Pasada Formation in the Santa Fe area; and (3) a middle Desmoinesian species from the Alamos Formation, north of Pecos. Bowsher and Strimple (1986) described 15 late Desmoinesian or early Missourian crinoid species (several not named) from near the top of the Bug Scuffle Member of the Gobbler Formation south of Alamogordo in the Sacramento Mountains. Kietzke (1990) illustrated a Desmoinesian microcrinoid from the Flechado Formation near Talpa. Kues and Koubek (1991) reported two cups from the Desmoinesian Los Moyos Limestone, Madera Group, in the Manzanita Mountains, and Kues (1996) reported two crinoid cups from the Missourian–Virgilian part of the Madera Group in the Jemez Springs area.

Combined, these seven reports include crinoids from each of the five Pennsylvanian epochs and contain 22 genera, 23 named species, and 11 unidentified species (Table 1). The total diversity of the crinoids documented in these papers is moderate, but representatives of four major groups of Paleozoic crinoids are present: (1) camerates, two genera; (2) disparids, one genus; (3) cladids, 17 genera; and (4) flexibles, one genus. More than half of these (12 genera, 12 named species, and three unnamed species) are recognized in the fauna from the upper part of the Bug Scuffle Member of the Gobbler Formation (Bowsher and Strimple 1986).

Our collections, described here, add 14 genera, 32 named species, and more than 9 unnamed species of crinoids to those previously recognized in Pennsylvanian strata of New Mexico. Replacing one incorrectly identified genus and naming two unidentified species from the earlier reports brings the total to 35 genera, 55 species, and more than 18 unidentified species of Pennsylvanian crinoids (Table 1). In addition, our collections contain unidentifiable loose ossicles that represent a significant number of additional crinoid taxa that will add significantly to the total if recognized with better material in the future. We estimate that the loose cup plates in our collections represent a minimum of 25 additional species.

The crinoids described here, except for localities 25 and 26 (Appendix 1), were collected mainly by BSK during the course of New Mexico Pennsylvanian faunal studies over the past 30 yrs. Although the emphasis of these studies was the molluscan and brachiopod components of the faunas, collecting efforts were intensive, so that all

groups present on the outcrop were sampled, often repeatedly over the years. These collections, repositated at the University of New Mexico (UNM), testify to the rarity of identifiable crinoid cups and crowns in these assemblages, even in cases where crinoid stem elements are common. In nearly all collections, crinoid cups represent only a small fraction of 1% of the total identifiable specimens. The only exception is the fauna from the Missourian Sol se Mete Member, Wild Cow Formation, at Escabosa Quarry in the Manzanita Mountains (locality 10), where the 30 or so cups represent about 1% of the total specimens (Kues 1985). Collections from the Missourian–middle Virgilian sequence north of Jemez Springs (localities 3 and 4) are derived partly from BSK collections, but mainly from isolated specimens collected by various individuals over many decades, beginning in the 1930s, and placed in the UNM collections. Stratigraphic and locality information for these specimens is less precise than for the other collections reported here. These specimens represent an uncounted number of hours (actually days and weeks) of work by a number of professional geologists and students.

Crinoids from the Sandia Formation in the Mora area of the Sangre de Cristo Mountains (locality 25) were initially discovered by Ray Gutschick and some of his students in the 1950s, then collected by John Chronic and his students in the 1960s, and finally recollected by GDW in 1993. Recent study of Pennsylvanian stratigraphy in this area by Baltz and Myers (1999) indicates, based on fusulinid biostratigraphy, that the boundary between the Sandia and overlying Porvenir Formation is at or close to the Atokan–Desmoinesian boundary. Therefore, the crinoids from locality 25 are considered Atokan, and probably late Atokan in age. Specimens from the Gobbler Formation in the Sacramento Mountains near Alamogordo (locality 26) were collected by Art Bowsher, Larry Davis, and GDW in 1993 and again by GDW in 1999. Although earlier work (Pray 1961) suggested that the upper part of the Gobbler extended from Desmoinesian into early Missourian time, more recent studies (e.g., Raatz and Simo 1998) indicate that the upper Gobbler is entirely of late Desmoinesian age, and that is the age assigned to the crinoids from locality 26.

The purpose of this paper is to: (1) document a large number of Pennsylvanian crinoids previously unknown from New Mexico, including one new genus and 15

TABLE 1—Compiled list of Pennsylvanian crinoids from New Mexico. Taxa reported in previous publications (Strimple 1969, 1980; Bowsher and Strimple 1986; Kietzke 1990; Kues and Koubek 1991; Kues 1996) are in normal type. Taxa reported herein for the first time from New Mexico are in **bold** type.

Subclass Camerata:	<i>Ulocrinus?</i> sp.
Family Acrocrinidae	Cromyocrinids indeterminate
<i>Planacrocrinus ambix</i> Moore and Strimple 1969	Family Erisocrinidae
Family Platycrinidae:	<i>Erisocrinus typus</i> Meek and Worthen 1865. Bowsher and
<i>Platycrinites nactus</i> Bowsher and Strimple 1986. Late	Strimple 1986. Late Desmoinesian
Desmoinesian	<i>Erisocrinus</i> aff. <i>erectus</i> Moore and Plummer 1940. Bowsher
<i>Exsulacrinus alleni</i> Bowsher and Strimple 1986. Late	and Strimple 1986. Late Desmoinesian
Desmoinesian	<i>Erisocrinus obovatus</i> (Moore and Plummer 1940)
Subclass Disparida:	<i>Euerisocrinus tijerasensis</i> n. sp.
Family Allagecrinidae	<i>Euerisocrinus gordoplatus</i> n. sp.
<i>Kallimorphocrinus</i> sp. Kietzke 1990. Desmoinesian	Erisocrinid indeterminate
<i>Kallimorphocrinus bassleri</i> Strimple 1938	Family Protencrinidae
Subclass Cladida:	<i>Neoprotencrinus subplanus</i> (Moore and Plummer 1940)
Family Codiocrinidae	<i>Neoprotencrinus gutschicki</i> n. sp.
<i>Lecythiocrinus</i> sp. cf. <i>L. optimus</i> Strimple 1951. Strimple	<i>Protencrinus mutabilis</i> Knapp 1969
1980. Morrowan	Family Catacrinidae
<i>Lecythiocrinus sacculus</i> Bowsher and Strimple 1986. Late	<i>Delocrinus subhemisphericus</i> Moore and Plummer 1940
Desmoinesian	<i>Delocrinus ponderosus</i> Strimple 1949
Family Blothocrinidae	<i>Delocrinus</i> spp.
<i>Moscovicrinus? rotundobasis</i> n. sp.	<i>Endelocrinus bifidus</i> Moore and Plummer 1940. Bowsher
<i>Elibatocrinus?</i> sp.	and Strimple 1986. Late Desmoinesian
Family Laudonocrinidae	<i>Endelocrinus perasper</i> Bowsher and Strimple 1986. Late
<i>Anchicrinus planulatus</i> Moore and Strimple 1973. Strimple	Desmoinesian
1980. Morrowan	<i>Endelocrinus globularus</i> n. sp.
<i>Laudonocrinus subsinuatus</i> (Miller and Gurley 1894).	<i>Palmerocrinus profundus</i> Moore and Strimple 1973.
Bowsher and Strimple 1986. Late Desmoinesian	Strimple 1980. Morrowan
Family Agassizocrinidae	Family Apographiocrinidae
<i>Paragassizocrinus</i> sp. Strimple 1980. Morrowan	<i>Apographiocrinus decoratus</i> Moore and Plummer 1940
<i>Paragassizocrinus</i> sp. cf. <i>P. caliculus</i> Strimple 1980.	<i>Apographiocrinus typicalis</i> Moore and Plummer 1940
Morrowan	<i>Apographiocrinus rimosus</i> n. sp.
<i>Paragassizocrinus caliculus</i> (Moore and Plummer 1938)	<i>Apographiocrinus kietzkei</i> n. sp.
<i>Paragassizocrinus tarri</i> Strimple 1938 (as <i>P. kendrickensis</i>	Family Pirasocrinadae
Strimple and Knapp 1966). Strimple 1980. ?Morrowan	<i>Eirmocrinus brewi</i> (Webster and Lane 1970)
<i>Paragassizocrinus</i> sp. aff. <i>P. asymmetricus</i> Strimple 1960.	<i>Metaffinocrinus noblei</i> n. sp.
Strimple 1980. ?Morrowan	? <i>Perimestocrinus</i> sp. indet. Bowsher and Strimple 1986.
Family Cromyocrinidae	Late Desmoinesian
<i>Aglaocrinus</i> aff. <i>marquisi</i> (Moore and Plummer 1940). Late	<i>Plaxocrinus</i> sp. Strimple 1980. Morrowan
Desmoinesian	<i>Schistocrinus</i> sp. aff. <i>S. torquatus</i> Moore and Plummer
<i>Aglaocrinus sutherlandi</i> Strimple 1980. Middle	1940. Strimple 1969. Virgilian
Desmoinesian	<i>Sciadiocrinus</i> aff. <i>harrisae</i> Moore and Plummer 1940.
<i>Aaglaocrinus keytei</i> (Strimple and Moore 1973)	Bowsher and Strimple 1986. Late Desmoinesian
<i>Aaglaocrinus bowsheri</i> n. sp.	<i>Sciadiocrinus?</i> sp. Kues 1996. Missourian or Virgilian
<i>Aaglaocrinus</i> n. sp. undesignated	<i>Sciadiocrinus ornatus</i> n. sp.
<i>Diphuicrinus coalensis</i> Strimple and Moore 1971. Strimple	<i>Sciadiocrinus wipsorum</i> Webster and Houck 1998
1980. Atokan	<i>Stenopocrinus glaber</i> Bowsher and Strimple 1986. Late
<i>Diphuicrinus borgesae</i> n. sp.	Desmoinesian
<i>Diphuicrinus santafeensis</i> Strimple 1980. Atokan	Pirasocrinids indeterminate
<i>Goleocrinus chronici</i> n. sp.	Family Incertae sedis
<i>Metacromyocrinus</i> sp. Strimple 1980. Atokan	<i>Moundocrinus osagensis</i> Strimple 1939
<i>Metacromyocrinus?</i> sp. Kues and Koubek 1991. (= <i>M.</i>	Cladids indeterminate
<i>cedroensis</i> n. sp.)	Subclass Flexibilia:
<i>Metacromyocrinus percultus</i> (Knapp 1969)	Family Synerocrinidae
<i>Metacromyocrinus cedroensis</i> n. sp.	? <i>Synerocrinus</i> sp. indet. Bowsher and Strimple 1986. Late
<i>Metacromyocrinus szaboi</i> n. sp.	Desmoinesian
<i>Metacromyocrinus?</i> n. sp. undesignated	Family Mespilocrinidae
<i>Parethelocrinus watkinsi</i> (Strimple 1949)	<i>Cibolocrinus timidus</i> Moore and Plummer 1940 (=
<i>Parethelocrinus</i> sp.	<i>Metacromyocrinus szaboi</i> n. sp.)
<i>Parulocrinus?</i> sp. Kues and Koubek 1991 (= <i>Moscovicrinus?</i>	Family Dactylocrinidae
<i>rotundobasis</i> n. sp.)	<i>Aexitrophocrinus minuramulosus</i> Strimple and Miller
<i>Parulocrinus globatus</i> Bowsher and Strimple 1986. Late	1971
Desmoinesian	Family Euryocrinidae
<i>Ulocrinus?</i> sp. Kues, 1996. Missourian or Virgilian	<i>Paramphicrinus novamexicanus</i> n. sp.
<i>Ulocrinus sangamonensis</i> (Meek and Worthen 1860)	<i>Paramphicrinus?</i> sp.

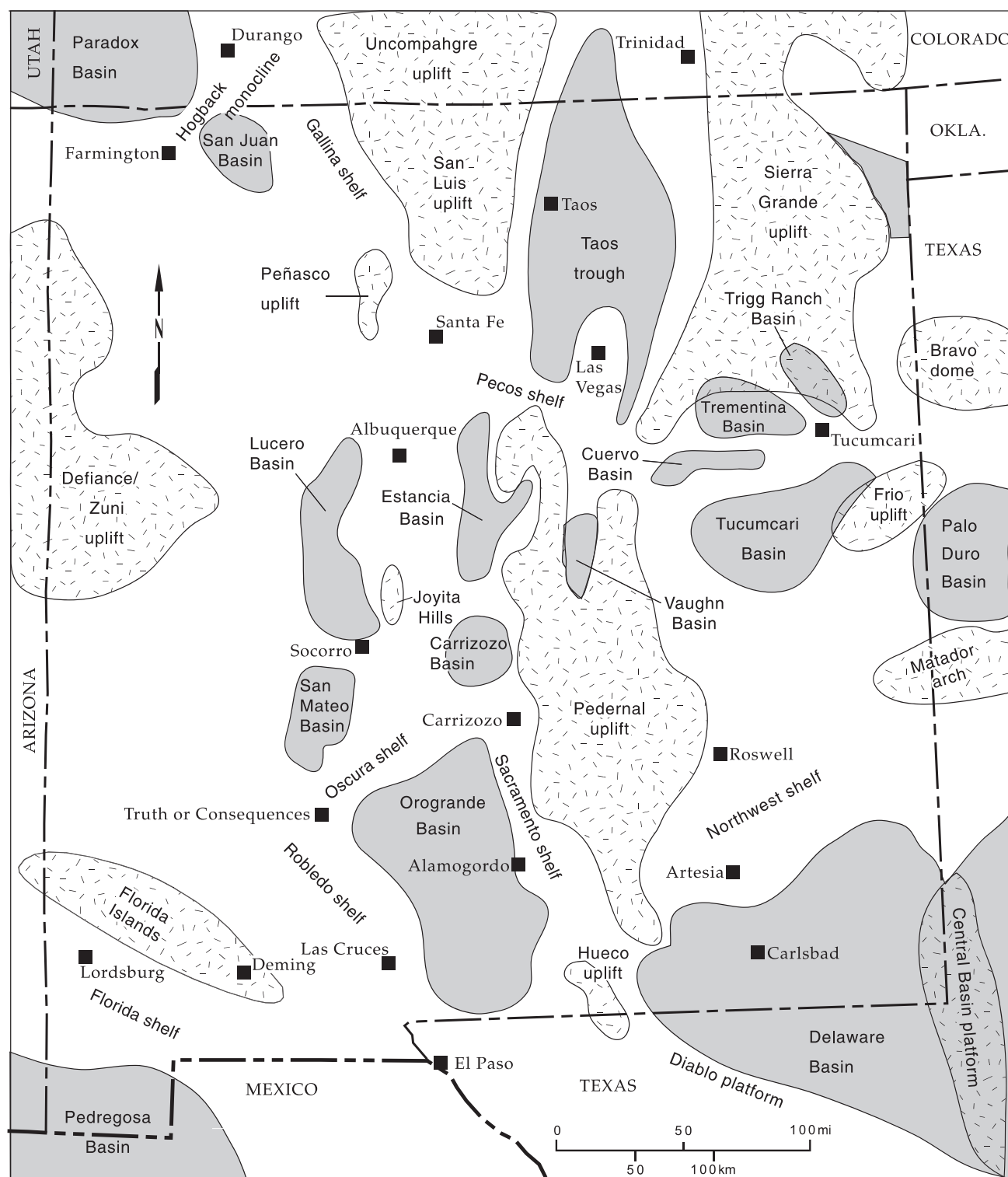


FIGURE 1—Pennsylvanian paleogeographic map for New Mexico, showing basins, land masses, and islands. From Kues and Giles (2004); reprinted by permission of the New Mexico Geological Society.

new species, as well as some others from new localities; (2) relate the new specimens to previously described materials from New Mexico and adjacent areas, and (3) interpret their paleoenvironmental setting within the intermontane basins of the western U.S.

Paleogeography and stratigraphic setting

During Pennsylvanian time New Mexico was situated within 10° north of the equator and mostly covered by marine environments. About a dozen basement-cored uplifts, ranging from small islands to land masses larger than New Hampshire and

resulting from Ancestral Rocky Mountains tectonism, shed siliciclastic sediments into adjacent seaways (Fig. 1). Several rapidly subsiding basins (e.g., Orogrande Basin, Taos trough) accumulated thick sequences of Pennsylvanian sediments, whereas more stable shelf areas between the land masses and basins experienced shallow-marine to shoreline, coastal plain, and

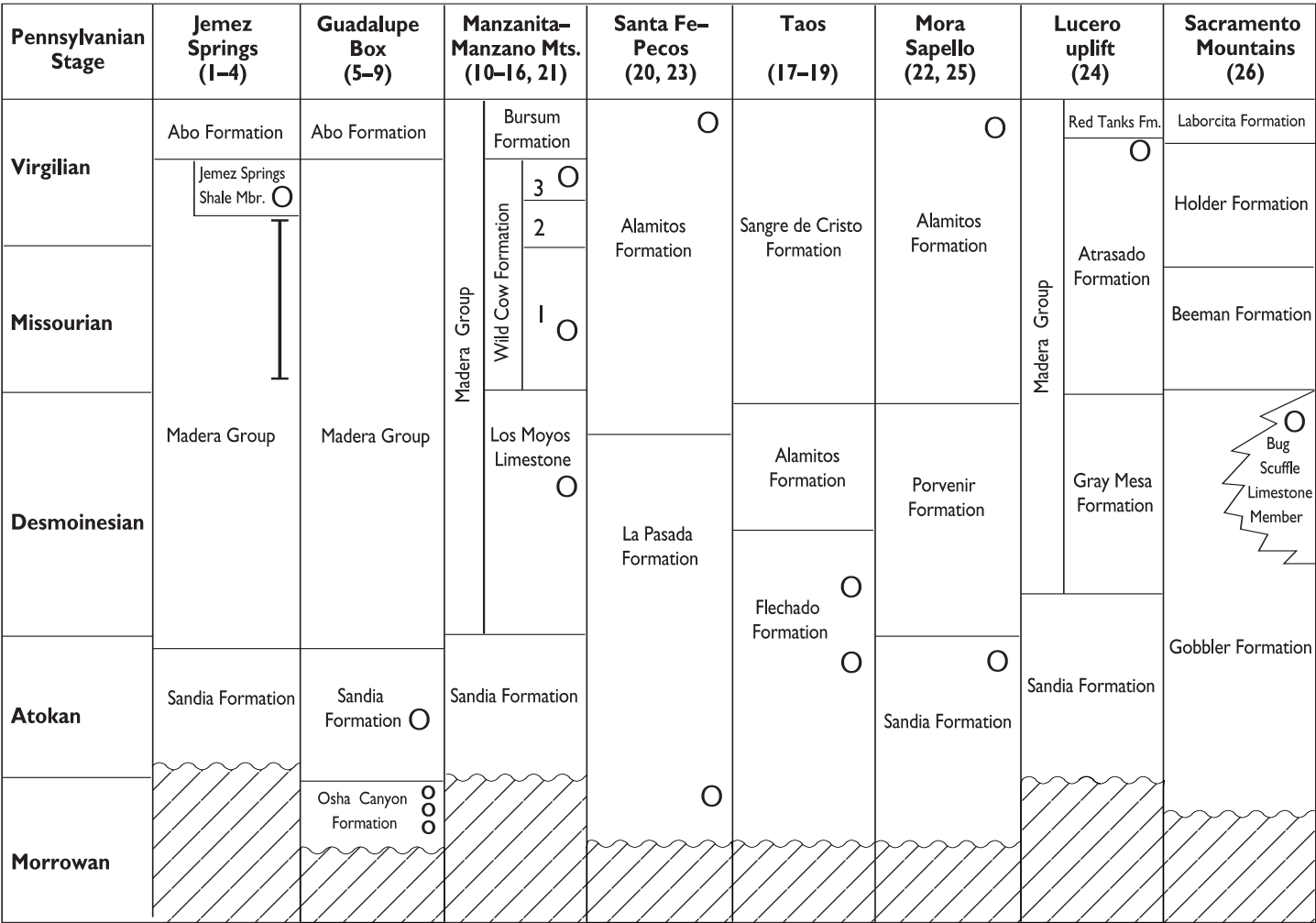


FIGURE 2—Pennsylvanian stratigraphy for those areas of New Mexico yielding the crinoids discussed in this report (after Kues and Giles 2004); numbers below area names are locality numbers given in Appendices 2 and 3 and Figure 3. Circles and vertical bar indicate horizons from which

crinoids were collected. Members of the Wild Cow Formation in the Manzanita-Manzano Mountains are 1, Sol se Mete; 2, Pine Shadow; and 3, La Casa.

deltaic deposition (Kues and Giles 2004). The interplay between sporadic and locally variable uplift and erosion of the land masses, climate changes, basin subsidence, and eustatic sea level fluctuations related to the Gondwana glaciation produced a complex series of shallow marine facies and environments across New Mexico through the Pennsylvanian. Most of these marine environments, which range from Morrowan to latest Virgilian (Early to latest Pennsylvanian) in age, supported communities of marine organisms, of which crinoids were often important constituents.

The Pennsylvanian stratigraphy of New Mexico reflects pronounced lateral facies changes related to the complex paleogeography and locally variable episodes of tectonism and was most recently surveyed by Kues and Giles (2004). Pennsylvanian stratigraphic sections for those areas from which crinoids discussed in this paper were collected are presented in Figure 2, and more detailed information concerning lithology and associated fauna at the crinoid localities is in Appendix 2.

Localities and crinoid associations

The crinoids reported herein are from 26 localities (Appendices 1–3; Fig. 3). Multiple taxa from a single locality are referred to as paleocommunities or faunas, because they came from one narrow or relatively narrow stratigraphic interval representing a paleo-environment of short time duration. None are considered to represent a living community, but they are considered part of a fossil assemblage consisting of the preserved remains of many associated organisms that were living during the short time interval of the stratigraphic unit.

With the exception of the Sandia fauna of locality 25, all single specimens and faunas are considered to represent deposition within or in proximity of the living site with minor or no post mortem transport. The taphonomic processes resulting in the loss of the arms and stem are uncertain but may have included scavenging and current reworking. Cups from the Sandia Formation (locality 25) were all transported an unknown distance from the living site and deposited in a strongly crossbedded silt-

stone. Disarticulated crinoid ossicles are common elements in all faunas.

The stratigraphic distribution of the Pennsylvanian crinoids reported here ranges from Morrowan to late Virgilian (Early to latest Pennsylvanian) time. Associated crinoid taxa from each locality are summarized in stratigraphic order together with the numbers of the specimens representing each taxon in Appendix 1. Detailed information on the stratigraphy and other invertebrate groups associated with the crinoids at each locality is summarized in Appendix 2.

Faunal analysis

Species of the three cladid superfamilies Cromyocrinacea, Erisocrinacea, and Pirasocrinacea are the most common elements in the Pennsylvanian faunas of New Mexico. Species of one or more of these three superfamilies are present in all 26 localities, except locality 21. Cromyocrinids are recognized in 19 of the 26 localities. The thick plates and large cups of the cromyocrinids are some of the better

preserved specimens found. Representatives of erisocrinids in one or more of the three families Erisocrinidae, Protencrinidae, and Catacrinidae are recognized in nine of the 26 localities but are probably present in the indeterminate cladid ossicles of five other localities. As a group they are second in numbers and generally in a good state of preservation. Disarticulated cup plates of the erisocrinids are not distinguishable from several other groups of Pennsylvanian cladids. Pirasocrinids are recognized in 10 of the 26 localities but may be present in the indeterminate cladid ossicles of one other locality. In most localities the pirasocrinids are disarticulated, but they may be recognized by the combined presence of spinose or bulbous brachials, spinose tegmen plates, and bulbous radials. If only tegmen plates or bulbous brachials are present, care must be used when identifying them because some other less common Pennsylvanian cladids, such as zeacrinids, also have bulbous brachials and spinose tegmen plates.

Dominance of the cromyocrinids, erisocrinids, and pirasocrinids in the faunas of New Mexico reflects their explosive evolution and prevalence in midcontinent Pennsylvanian faunas described in many papers in the past century (Moore and Plummer 1940; Strimple 1961; Pabian and Strimple 1985, among many others). However, the number of taxa of the midcontinent Pennsylvanian crinoid faunas found in deposits from Texas into Illinois is much greater than that of the New Mexico faunas. The mutual occurrence and approximate time equivalency of 12 species in the three dominant superfamilies and five cladid species in other superfamilies of the New Mexico crinoids and midcontinent crinoids implies that seaways were open, although perhaps intermittently, between midcontinent basins in Texas and Oklahoma and the intermontane basins of New Mexico throughout the Pennsylvanian. Seaway connections at the north and south ends of the Pederal uplift of central-southern New Mexico and to the south of the Hueco uplift on the Texas–New Mexico border (Kues and Giles 2004) provided the pathways for crinoid migrations between the midcontinent basins of Texas and Oklahoma and the intermontane basins of central New Mexico.

Pennsylvanian seaway connections between the intermontane basins of New Mexico and those of Colorado, southeastern Utah, and eastern Arizona, as discussed by Kues and Giles (2004), are also supported by the mutual crinoid occurrences of these areas. The mutual occurrences of *Neoprotencrinus rockensis* Webster and Houck (1998), *Sciadiocrinus wipsorum?* Webster and Houck (1998), and *Aaglaocrinus keyti* (Strimple and Moore 1973) in the Atokan–?earliest Desmoinesian Sandia Formation and the Minturn Formation of central Colorado implies open seaways

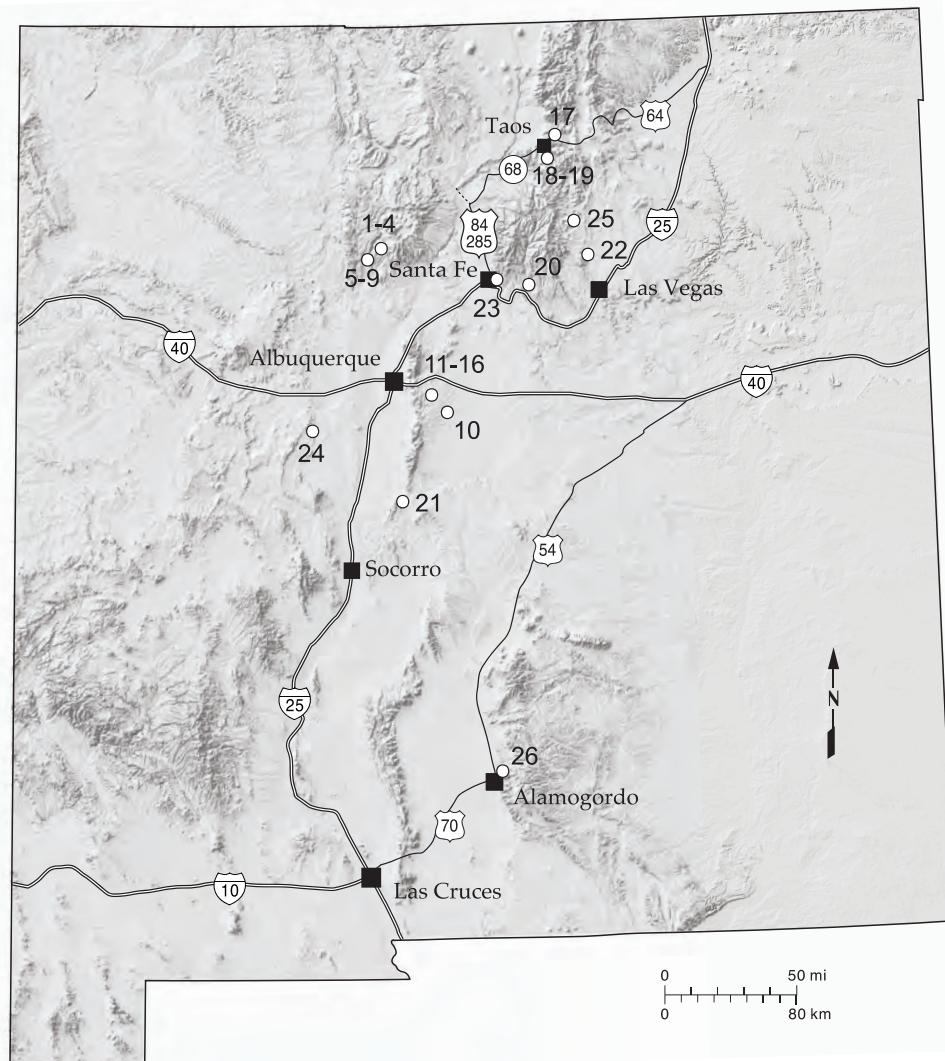


FIGURE 3—Map of New Mexico, showing Pennsylvanian crinoid localities discussed in this report.

between these regions. This is also supported by the dominance of the cromyocrinids, erisocrinaceans, and pirasocrinids in both faunas. Seaway connections between the intermontane basins of New Mexico and central Colorado are also indicated by the mutual occurrence of *Aexitrophocrinus minuramulosus* Strimple and Miller (1971) in the Sandia Formation (locality 25) and the Atokan–Desmoinesian boundary strata of the Pinkerton Trail Limestone of central Colorado (Strimple and Miller 1971). Desmoinesian crinoids have been reported from the Paradox Basin of southeastern Utah by White (1876, 1880) and Webster and Lane (1970). The mutual occurrence of *Erisocrinus typus* Meek and Worthen (1865) in the Desmoinesian of the Paradox Basin and the Gobbler Formation (locality 26) of the Orogande Basin of south-central New Mexico supports connections between these regions. The mutual occurrence of *Eirmocrinus brewi* Webster and Lane (1970) and two cromyocrinid genera in the Desmoinesian part of the Naco Formation of north-central Arizona and the Sandia Formation

(locality 25) of northern New Mexico indicates open seaway connections between these areas. Naco crinoids described by Webster and Lane (1970), Brew and Beus (1976), Webster (1981), Webster and Olson (1998), and Webster and Elliott (2004) are all of Desmoinesian age and are considered to be from midshelf biofacies as they are dominated by 10-armed cromyocrinids and contain 10-armed erisocrinids and pirasocrinids of more than 10 arms.

Although the seaway connections between the intermontane basins of New Mexico with the basins of Colorado and Utah may have been intermittent, the crinoid faunas probably did not migrate into the Colorado and Utah basins from the north or east because the Ancestral Rockies high (Front Range/Apishapa/Sierra Grande uplift) formed a barrier between marine environments of central Colorado and those to the east of this uplift throughout the Pennsylvanian (Mallory 1972). Overall, there are many more faunas and localities as well as a greater crinoid diversity recognized in the Pennsylvanian of New Mexico than in Colorado, Utah, or

Arizona. This is probably the result of the crinoids migrating from the midcontinent through New Mexico into the intermontane basins of these adjacent states and a greater potential for suitable habitat in New Mexico.

Pennsylvanian crinoids have been described from Morrowan strata of the Oquirrh Formation of central Utah (Washburn 1968) and Morrowan into Desmoinesian strata of the Bird Spring Formation in southern Nevada (Lane 1964; Webster and Lane 1970). Although no species are common, the shelf faunas from the Great Basin have five genera (*Kallimorphocrinus*, *Synarmocrinus*, *Goleocrinus*, *Endelocrinus*, and *Delocrinus*) in common with New Mexico faunas. Representatives of the erisocrinids, pirasocrinids, and cromyocrinids tend to dominate Great Basin faunas as they do New Mexico faunas.

During the Pennsylvanian New Mexico was a complex of several large landmasses and intermontane marine basins as noted above. All New Mexico Pennsylvanian crinoids are from shelf environments around the margins of landmasses. Most crinoids came from rather diverse, stenohaline, brachiopod/bryozoan/echinoderm/coral dominated faunas in limestones that are generally considered to be nearshore, moderate to higher energy deposits deposited above wave base. A few of the faunas are in dark-gray shale and siltstone (Sandia Formation and some Flechado Formation specimens) and represent lower energy, prodeltaic to deeper water deposits. In the Virgilian of central and northern New Mexico the marine deposits are interbedded with nonmarine clastics, as marine environments were being overwhelmed by the influx of terrigenous clastic sediment from the landmasses. The crinoid faunas are in several different environments, reflecting the tectonics and fluctuating sea level conditions, thus making it difficult to quantify their relative position to the shoreline.

About 40% of the named Pennsylvanian crinoid species now known from New Mexico (including the 15 new species established in this paper) have not been reported from outside the state. Thus, based on present knowledge, New Mexico Pennsylvanian crinoid faunas include a relatively large number of endemic species derived from midcontinent lineages. This is most likely a consequence of New Mexico's complex Pennsylvanian paleogeography, in which marine shelf environments were fragmented and separated by many land masses and islands, thus promoting the geographic isolation that enhances speciation. Endemism at the generic level, however, is low; *Exsulacrinus* is the only

endemic Pennsylvanian crinoid genus recognized in New Mexico.

In a study of Late Pennsylvanian crinoids in the midcontinent, Holterhoff (1997b) recognized 10 crinoid guilds based on feeding structure of the arms, with larger crowns with biserial brachials and multiple arms (>10) indicating higher energy environments and smaller crowns with uniserial brachials and fewer arms (10 or less) indicating lower energy environments. Holterhoff (1997b) also recognized five crinoidal biofacies, based on the co-occurrences of various crinoid taxa in Pennsylvanian cyclothems of the midcontinent. These biofacies extended across the shelf from higher energy paleoenvironments near shore (biofacies 1) to lower energy dysaerobic paleoenvironments offshore (biofacies 5). Although none of the guilds are specific to a single biofacies, the relative abundance of certain taxa combined with the overlapping occurrences allows recognition of the biofacies based on identified faunas. Details of the guilds and biofacies are extensive, and the interested reader is referred to Holterhoff (1997a,b). These guilds and biofacies are applicable to the New Mexico crinoid faunas.

Morrowan faunas from localities 5, 6, 8, and 11 contain *Paragassizocrinus caliculus* (Moore and Plummer 1938) (Holterhoff guild 10) and are considered to have been living in offshore paleoenvironments that may correspond to a maximum sea level highstand. The presence of cromyocrinids and pirasocrinids in localities 5 and 6 and pirasocrinids and acrocrinids in locality 8 suggests that these were not dysaerobic environments, which *P. caliculus* may indicate.

Ulocrinus (guild 2) occurs in association with *Paramphicrinus* (guild 7) in localities 4 and 11, suggesting a midshelf paleoenvironment of biofacies 2. The co-occurrence of pirasocrinids and cromyocrinids in locality 4 provides additional support for a paleoenvironment of biofacies 2. *Ulocrinus* occurs with a multiarmed pirasocrinid in locality 3, suggesting biofacies 1 or 2.

The presence of *Lecythiocrinus* (guild 7) and *Apographiocrinus* (guild 6) with erisocrinids (guild 2) in localities 10 and 26 suggests midshelf to offshore paleoenvironments in biofacies 2 or 3. Locality 10 has several *Apographiocrinus* species suggesting biofacies 3 (offshore, lower energy), whereas locality 26 also contains *Delocrinus*, erisocrinids, and multiple-armed camerates (*Platycrinites* and *Exsulacrinus*) suggesting slightly higher energy environments, probably biofacies 2 (midshelf).

All other Pennsylvanian localities contain solitary cromyocrinids or cromyo-

crinids in association with pirasocrinids or erisocrinids and suggest midshelf paleoenvironments of biofacies 2 but could overlap into offshore lower energy biofacies 3 or nearshore higher energy biofacies 1. Thus, all New Mexico Pennsylvanian crinoid occurrences are considered shelf environments along the sides of the deeper intermontane basins and represent a variety of biofacies. These crinoid faunas also reflect fluctuating sea level changes related to waxing and waning glacial conditions of Gondwana as recognized in the midcontinent (Haekel 1986, among others).

The presence of the platycrinids *Platycrinites nactus* Bowsher and Strimple (1986) and *Exsulacrinus allenii* Bowsher and Strimple (1986), a lecythiocrinid, and several cladids in the Bug Scuffle Member of the Gobbler Formation at locality 26 is considered a coeval northward extension of the fauna reported by Bowsher and Strimple (1986) from Grapevine Canyon approximately 25 mi south of Alamogordo. The Grapevine Canyon fauna is one of the most diverse Pennsylvanian faunas known from New Mexico. The presence of a platycrinid thecae in it is unusual in the Pennsylvanian as noted by Bowsher and Strimple (1986) and provides an evolutionary link to platycrinids in the Permian of southern Nevada (Webster and Lane 1967), Timor (Wanner 1916), and Western Australia (Webster and Jell 1992).

Acrocrinids, although relatively rare in most crinoid faunas, reached their acme during the Late Mississippian and Early to Middle Pennsylvanian. *Planacrocrinus* is most common in the Morrowan but extends into the Missourian. Its presence in locality 8 with *Paragassizocrinus* suggests that it may have environmental tolerance for slightly dysaerobic conditions.

Kallimorphocrinids are small crinoids, most are microscopic, and often overlooked when megacrinoids are found. The occurrences in the Desmoinesian Flechado Formation (Kietzke 1990) and Virgilian La Casa Member of the Wild Cow Formation (described below) show that they are present in New Mexico faunas. A systematic search for them in other faunas, especially in the microfaunas, would probably find that they are more widespread in New Mexico than these two occurrences.

Flexible crinoids are rarely in large numbers in most Paleozoic crinoid faunas but commonly are present in small numbers. Their occurrence in some of the Desmoinesian and Missourian or Virgilian faunas extends their geographic range into New Mexico.

Systematic paleontology

Terminology—Crinoid descriptive terms follow Moore and Teichert (1978) with the following exceptions: measurement terms follow Webster and Jell (1999); basal concavity and stem impression terminology follow Webster et al. (2004); radial facet condition and brachial types follow Webster and Maples (2005), and anal condition and terminology follow Webster and Maples (2006). Specimens are deposited in the New Mexico Museum of Natural History and Science (NMMNH) and University of New Mexico (UNM) in Albuquerque.

Class CRINOIDEA Miller 1821

Subclass CAMERATA Wachsmuth and Springer 1885

Order MONOBATHRIDA Moore and Laudon 1943

Suborder COMPSOCRININA Ubahgs 1978

Superfamily HEXACRINITACEA Wachsmuth and Springer 1885

Family ACROCRINIDAE Wachsmuth and Springer 1885

Subfamily PLANACROCRININAE Moore and Strimple
in Moore and Teichert 1978

Genus *PLANACROCRINUS* Moore and Strimple 1969

PLANACROCRINUS AMBIX Moore and Strimple 1969
Figs. 4.19–4.21; for synonymy see Webster (2003)

Description—Calyx small, length 4.4 mm, width 5 mm, high-bowl shape, no ornamentation. Horizontal bipartite basals with mutual suture aligned in A ray-posterior plane of symmetry, followed by 4 rows (7, 12, 10, 8 plates) of intercalaries. Bottom row of intercalaries consists of very small plates, many of which are triangular, all other intercalaries quadrangular or pentagonal. Plates masked with caliche. Radials 5, wider than long, with plenary radial facets. Primanal large, tapers distally, apex at radial summit.

Discussion—As initially described by Moore and Strimple (1969) *Planacrocrinus ambix* includes forms showing considerable variation in shape. This includes forms with medium-bowl-shaped cups with only two rows of intercalaries, high-bowl-shaped cups with four rows of intercalaries, and high-conical-shaped cups, with all forms having a flat base. As noted in the brief description above *P. ambix* belongs to the high-bowl-shaped forms. The small triangular-shaped bottom row of intercalaries in the Osha Canyon specimen may indicate immaturity. *Planacrocrinus ambix* was previously reported from the Wapanucka Limestone (Morrowan) of Oklahoma (Moore and Strimple 1969), and its range is here extended into New Mexico and supports a Morrowan age for the upper part of the Osha Canyon Formation.

Occurrence—Figured specimen, UNM 14,502, upper part of Osha Canyon Formation (Morrowan, locality 8).

Superfamily PLATYCRINITACEA Austin and Austin 1842

Family PLATYCRINITIDAE Austin and Austin 1842

Genus *PLATYCRINITES* Miller 1821

PLATYCRINITES NACTUS Bowsher and Strimple 1986

For synonymy see Webster (2003)

Discussion—A crushed, poorly preserved cup of *Platycrinites nactus* lacks parts of two rays, and retains only a small number of the tegmen plates.

Occurrence—NMMNH P-45622, Bug Scuffle Member, Gobbler Formation (late Desmoinesian, locality 26).

Genus *EXSULACRINUS* Bowsher and Strimple 1986

EXSULACRINUS ALLENI Bowsher and Strimple 1986

For synonymy see Webster (2003)

Discussion—A crushed theca shows the irregular ridges parallel to the plate boundaries on the radials and the nodes on the low tegmen plates. The anal tube and arms are lost. A second specimen shows the original shape of the cup, but the cup plates are mostly lost with weathering.

Occurrence—NMMNH P-45623 and 45624. Bug Scuffle Member, Gobbler Formation (late Desmoinesian, locality 26).

Subclass CLADIDA Moore and Laudon 1943

Order CYATHOCRINIDA Bather 1899

Superfamily CODIACRINACEA Bather 1890

Family CODIACRINIDAE Bather 1890

Subfamily CODIACRININAE Bather 1890

Genus *LECYTHIOCRINUS* White 1880

LECYTHIOCRINUS SACCULUS Bowsher and Strimple 1986
Figs. 4.5–4.8, 4.33–4.36; for synonymy see Webster (2003)

Emended description—Radial facet angustary, of medium complexity, divided into outer and inner areas by two small nodes in the position of the transverse ridge and separated by a slightly depressed surface extending from the intermuscular notch to the outer marginal area. Outer marginal area moderately wide with a small central depression on a slightly elevated surface, otherwise smooth; gently rounded outer margin rim. Inner area of two triangular-shaped muscle areas separated by deep V-shaped intermuscular notch with bordering ridges. Articulating surface bordered on each side by a large rounded protuberance separating it from the adjacent interradian notches. Internally to facet, surface of plate lower and wide smooth surfaces bordering intermuscular notch with continuation of border ridges end at oral orifice.

Discussion—This emended description supplements the original description by Bowsher and Strimple (1986). The radial facets of most specimens of *Lecythiocrinus sacculus* are abraded or solution weathered obscuring or destroying morphologic details. Only two of the crushed specimens from locality 26 show the details of the radial facets described above. An enlargement of the facet is illustrated for specimen NMMNH P-45626 (Fig. 4, no. 36). The facet morphology differs grossly from non-codiocrinid cladid facets. Unfortunately, the arms of *Lecythiocrinus* are unknown to relate to the facet and possible function.

Bowsher and Strimple (1986) reported five specimens of *Lecythiocrinus sacculus* from the late Desmoinesian (Raatz and Simo 1998) uppermost part of the Bug Scuffle Member of the Gobbler Formation in Grapevine Canyon, southern Sacramento Mountains. Specimens from the Bug Scuffle Member at locality 26 are considered coeval with the Grapevine Canyon specimens. All specimens from locality 26 are crushed, whereas all but one of the specimens from the Wild Cow Formation are uncrushed. Radial facets of the Missourian Wild Cow specimens (locality 10) are all abraded or solution weathered. The stratigraphic range of *L. sacculus* is extended upward into the Missourian.

Occurrence—Figured specimen NMMNH P-45626 and six others NMMNH P-45627 from locality 26, upper part of Bug Scuffle Member, Gobbler Formation, and figured specimen (UNM 14,493) and seven specimens (UNM 15,552) from locality 10, Sol se Mete Member, Wild Cow Formation, Madera Group.

Subclass DISPARIDA Moore and Laudon 1943

Superfamily ALLAGECRINACEA Carpenter and Etheridge 1881

Family ALLAGECRINIDAE Carpenter and Etheridge 1881

Genus *KALLIMORPHOCRINUS* Weller 1930

KALLIMORPHOCRINUS BASSLERI Strimple 1938
Figs. 4.9–4.12

Allagecrinus graffhami Strimple 1948, p. 3, pl. 1, figs. 1–11.
For additional synonymy see Webster (2003).

Discussion—A single cup 2.4 mm long and 4 mm wide retains a few granules on the C and D radials typical of *Kallimorphocrinus*

bassleri. The specimen has 14 arms with four in the A ray, three in the B ray, five in the D ray, and one each in the C and E rays. The basal circlet is poorly preserved but is visible in lateral view. *Allagecrinus graffhami* Strimple (1948) (transferred to *Kallimorphocrinus graffhami* by Lane and Sevastopulo 1982) was reported from Virgilian strata of Kansas. It was described as having four arms in the D ray (Strimple 1948), otherwise it has the same arm arrangement and shape as *K. bassleri*. We consider it a variation or a slightly younger growth stage and junior synonym of *K. bassleri*.

Occurrence—Illustrated specimen UNM 14,496, La Casa Member, Wild Cow Formation, Madera Group (Virgilian, locality 21).

Family BLOTHROCRINIDAE Moore and Laudon 1943

Genus MOSCOVICRINUS Jaekel 1918

MOSCOVICRINUS? ROTUNDOBASIS n. sp.

Figs. 4.1–4.4

Parulocrinus? sp. Kues and Koubek 1991, p. 60, figs. 2G–H.

Etymology—Referring to the round base of the cup.

Diagnosis—Distinguished by the roundness of the base and distal vertical walls of the cup.

Description—Cup medium-bowl shape with rounded base, vertical walls, thin plates, sutures flush, no ornament, length 4.9 mm, width 7.2 mm. Infrabasal circlet shallow basin, proximally horizontal with shallow stem impression, distally gently up- and out-flaring, visible in lateral view. Infrabasals 5, dart shaped, length 2 mm, width 1.8 mm. Basals 5, length and width 3.5 mm, DE, EA, and AB hexagonal, BC and CD septagonal, gently convex longitudinally and transversely, form major part of cup wall, proximal tip barely above basal plane, subvertical distally. Radials 5, pentagonal, except C radial hexagonal, length 2.5 mm, width 3.6 mm, straight longitudinally, gently convex transversely. Radial facets penepenary, facet width 3 mm, ratio facet width/radial width $3/3.6 = 0.84$, advanced type bearing narrow transverse ridge, narrow central ligament pit dipping under transverse ridge, narrow outer margin area, wide deep muscle areas, small central pit, short intermuscular furrow, and V-shaped intermuscular notch. Interradial notches narrow, lost internally as distal edges of radial facets join. Anals 3, menoplax 6 subcondition. Primal anal large, length 2.5 mm, width 1.4 mm, undercutting secundanal and not in contact with tertanal. Secundanal large, length 2.2 mm, width 1.4 mm, projecting distally above radial summit. Tertanal not preserved, only proximal tip below radial summit. Arms unknown. Stem facet roundly pentagonal, diameter 1.7 mm; crenularium $2/5$ radius, culmina coarse, short; areola smooth, flat; axial canal pentagonal, moderately large.

Discussion—The cup of *Moscovicrinus? rotundobasis* n. sp. is well preserved but partly coated with a thin layer of calcium carbonate, masking some of the radial facets, some cup sutures, and part of the stem facet. Although initially identified as *Parulocrinus?* sp. (Kues and Koubek 1991), the structure of the radial facets, thinness of the plates, and lack of impressed or stitched sutures precludes that assignment.

Plate structure of the cup is most similar to some bluthrocrinids, but the anals are in an advanced menoplax condition with the tertanal nearly out of the cup and not in contact with the primal anal, and the secundanal narrowly in contact with the CD basal as it is being undercut by the primal anal. The roundness of the base of the cup is interrupted only slightly by the horizontal stem facet. This degree of roundness is not common in Pennsylvanian cladids. Structure of the radial facets is similar to that of *Moscovicrinus*, to which it is questionably assigned, wherein the interradianal notches wedge out internally. The lack of the arms precludes comparison with those of the known species of the genus. None of the other species of *Moscovicrinus* have as round a base or as vertical distal walls as in *M.? rotundobasis*, which may represent a new genus. *Moscovicrinus* is reported from the Pennsylvanian (Yakovlev and Ivanov 1956) and Late Permian (Yakovlev 1977) of Russia and

Early Permian of the United States (Lane and Webster 1966) and Indonesia (Strimple and Yancy 1976).

Occurrence—Holotype, UNM 14,490, Los Moyos Limestone, Madera Group (Desmoinesian, locality 12).

Genus ELIBATOCRINUS Moore 1940

ELIBATOCRINUS? sp.

Figs. 4.37–4.38

Discussion—Pennsylvanian crinoids with an elongate-conical-shaped infrabasal circlet are *Hydriocrinus*, a small form, and *Elibatocrinus*, a larger form. Such infrabasal circlets were more common on Mississippian genera assigned to the Scytalocrinidae and Bluthrocrinidae. A weathered infrabasal circlet retaining the two proximal columnals and a single infrabasal plate, both from the Madera Group, are questionably referred to *Elibatocrinus*.

Occurrence—Figured infrabasal circlet (UNM 14,539), Madera Group (Missourian or Virgilian, locality 4); infrabasal plate (UNM 14,486) upper white limestone, Jemez Spring Member, Madera Group (Virgilian, locality 1).

Superfamily AGASSIZOCRINACEA S. A. Miller 1889

Family AGASSIZOCRINIDAE S. A. Miller 1889

Genus LEKOBIKOCRINUS n. gen.

Type species—*Paragassizocrinus calyculoides* Lane (1964), here designated.

Etymology—From the Greek *leko* (basin) and *biko* (bowl), referring to the combined shape of the base of the cup and the globose shape of the cup.

Diagnosis—Crown elongate; dorsal cup rounded bowl shape, plates thick, bearing fine papillae ornament; vestigial stem in immature stages, infrabasal circlet fused enclosing proximal 3 or 4 columnals in adults; plenary radial facets; large single anal directly above CD basal projecting well above radial summit; 2 primibrachials; isotomous branching, 10 arms, brachials rectilinear, nearly circular in plan view with deep V-shaped ambulacral groove.

Description—See Webster and Lane (1970, p. 292).

Discussion—Ettensohn (1980) redescribed the various species of *Paragassizocrinus* and placed a number of species in the synonyms of *P. asymmetricus* Strimple (1960), *P. calyculus* (Moore and Plummer 1938), and *P. tarri* (Strimple 1938) with which we agree. In addition, he rejected *P. calyculoides* (Lane 1964) as redescribed by Webster and Lane (1970) from the genus on the basis of the cup shape and morphology of the infrabasal circlet placing it in *Polusocrinus* Strimple (1951). Although there are some similarities between *P. calyculoides* and *Polusocrinus*, there are gross differences precluding assignment of *P. calyculoides* to *Polusocrinus*. The latter is a stemmed form throughout all growth stages, has non-fused infrabasals, 10–14 arms, and much thinner plates, whereas the former loses the stem in the adult stages, has fused infrabasals covering the stem in the adult stage, 10 arms, and much thicker plates. Accepting Ettensohn's (1980) argument for excluding *P. calyculoides* from *Paragassizocrinus* and rejecting his assignment to *Polusocrinus* we propose the new name *Lekobikocrinus*.

Ettensohn (1980) also suggested that the rounded shape of the base of the cup of some agassizocrinids reflected their living on a firmer substrate than the more elongate shapes that lived partly buried in softer substrates. Specimens of *Lekobikocrinus calyculoides* n. gen. n. comb. were found in carbonate grainstones and thin shales interbedded with carbonate grainstones supporting that interpretation. The age of *P. calyculoides* was reported by Webster and Lane (1970) as late Morrowan, occurring below the *Profusulinella* Biozone. More recent interpretations (H. R. Lane et al. 1972) of that part of the Bird Spring Formation place it in the *Eoschubertella* Biozone, considered early Atokan in age. Thus, *Lekobikocrinus* is considered to be an early Atokan taxon and was probably

derived from the Morrowan taxa *Paragassizocrinus caliculus* or the low-cone ecophenotype of *P. tarri* by additional lowering of the external part of the infrabasal cone.

Genus *PARAGASSIZOCRINUS* Moore and Plummer 1940

PARAGASSIZOCRINUS CALICULUS (Moore and Plummer 1938)

Figs. 4.13–4.14, 4.17–4.18, for synonymy see Webster (2003)

Discussion—The nine specimens recognized as *Paragassizocrinus caliculus* are all fused infrabasal cones. The smallest is 4.2 mm long, 6.2 mm wide, and the largest is 14 mm long and 18.5 mm wide. They all have the blunted bullet-shaped base and, where visible, a star-shaped central cavity as described by Etensohn (1980). One broken specimen shows the vestigial proximal stem enclosed by the fused overgrowth of the infrabasal circlet.

Occurrence—One broken specimen (UNM 14,517) from the upper part of the Osha Canyon Formation (Morrowan, locality 8) associated with *Planacrocricinus ambix*; four specimens (figured specimen UNM 14,506 and lot of three 14,550) from the lower part of the Osha Canyon Formation (Morrowan, locality 5); and two specimens (figured specimen UNM 14,509 and unfigured 14,551) from the La Pasada Formation (Morrowan, locality 23).

PARAGASSIZOCRINUS TARRI (Strimple 1938)

Figs. 4.15–4.16, for synonymy see Webster (2003)

Discussion—Etensohn (1980) described both a high-cone ecophenotype and low-cone ecophenotype for basal circlets that he referred to *Paragassizocrinus tarri*. Two specimens of the high-cone basal circlet of *P. tarri* are solution etched, especially on the basal tip, and poorly preserved but clearly show the elongate bullet shape and deep central cavity. One specimen of the low-cone basal circlet is very well preserved and shows the triangular depression on the interior junctions of the infrabasals. All three specimens occur in the middle part of the Osha Canyon Formation, and it is uncertain if the high-cone and low-cone represent ecophenotypes or variation.

Occurrence—Figured specimen UNM 14,500 and two other specimens (lot UNM 14,545) from the middle part of the Osha Canyon Formation, associated with loose ossicles of *Eimocricinus* sp. (Morrowan, locality 7).

Superfamily CROMYOCRINACEA Bather 1890

Family CROMYOCRINIDAE Bather 1890

Genus *AAGLAOCRINUS* Webster 1981

AAGLAOCRINUS KEYTEI (Strimple and Moore 1973)

Figs. 5.35–5.38, for synonymy see Webster (2003)

Discussion—One slightly distorted cup and two partial cups assigned to *Aaglaocrinus keytei* show a canting of the cup with the CD interray longer than the A ray. On one of the partial specimens this difference is 10.5 mm vs. 8 mm. Canting of the cup is present, but it was not reported by Webster and Houck (1998) for the specimens from the Minturn Formation. Canting of the cup is interpreted as an orientation feature in unidirectional stronger current environments and may also reflect tiering level position in crinoid colonies. The range of *A. keytei* is extended downward into the late Atokan.

Occurrence—Figured cup NMMNH P-45576 and two partial cups in lot NMMNH P-45577, Sandia Formation (late Atokan, locality 25).

AAGLAOCRINUS BOWSHERI n. sp.

Figs. 7.1–7.10

Etymology—Named for Art Bowsher in recognition of his contributions to the geology of New Mexico and work on crinoids.

Diagnosis—Distinguished from all other species of the genus by having a moderately deep basal concavity.

Description—Cup low-bowl shape, basal concavity moderately

deep, plates thick, sutures impressed with stitched appearance; ornamentation of fine granules on infrabasals and coarse short anastomosing or vermiform ridges on all other cup plates. Infrabasal circlet downflaring proximally with impressed stem facet, subhorizontal distally, visible around proximal columnals in basal view, not visible in lateral view. Infrabasals 5, dart shaped. Basals 5, DE, EA, and AB hexagonal, BC and CD septagonal, all wider than long, moderately convex transversely, strongly convex longitudinally, form basal plane of cup and lower part of cup wall. Radials 5, pentagonal, much wider than long, subvertical proximally, incurving slightly distally, moderately convex transversely and longitudinally, proximal tip above basal plane. Radial facets plenary, inclinate, bear dendritic transverse ridge, moderately deep ligament pit, deep ligament furrow, prominent outer ligament ridge, wide outer ligament furrow grading into gentle outer margin ridge grading into plate ornament, muscle areas large upflaring laterally. Anals normally 2, mesoplax 1 (most common), 3, or 4 subcondition; rarely 1 anal, opioptax 1 subcondition. Primanal large, undercutting or supporting secundanal. Secundanal large, incurving distally, may be in contact or not in contact with CD basal, may be out of cup with proximal tip at radial summit. Arms unknown. Proximal stem heteromorphic, N1 noditaxis, Columnals round; latus convex; crenularium narrow with coarse culmen; lumen pentagonal, large. Measurements follow.

Measurements in millimeters for *Aaglaocrinus bowsheri* n. sp.

Types	Holotype	Paratype 1	Paratype 2	Paratype 3
Cup length, A ray	20.3	17	14.2	8.9
Cup length, CD interray	18.2	13.9	12.4	8.4
Cup width maximum	45.5	42	39.2	23.2
Cup width minimum	44.5	41.4	37.2	22
Cup width average	45	41.7	38.2	22.6
Infrabasal circlet diameter	14.8	13.1	11.8	8.4
Infrabasal length (visible)	3.6	5	3	2
Infrabasal width (visible)	6.9	6.4	5.5	4
EA basal length	17.8	16.1	14.2	8.4
EA basal width	20.5	19.5	17	11
BC basal length	17.6	16.4	15	8.7
BC basal width	21.5	20.5	17.5	10.7
CD basal length	16.7	16.3	13.7	8.5
CD basal width	18.3	16	16	9.6
A radial length	15.4	12.7	11.6	8
A radial width	24.3	22.6	20.3	12.7
Primanal length	16.5	13.7	15	7.6
Primanal width	12.3	9	9.9	5.1
Secundanal length	10.7	10	9.4	5.2
Secundanal width	7	7.6	6	4
Diameter proximal stem	7	6.5	6	4.4

Discussion—Several of the 15 cups of *Aaglaocrinus bowsheri* n. sp. are slightly distorted with the radials pushed partly into the visceral cavity, and most specimens have lost most of the fine details of the ornamentation by abrasion or solution weathering. The cup is canted, a little longer in the A ray than in the CD interray. Although most specimens have two anals in the mesoplax 1 subcondition with the primanal undercutting the secundanal, the secundanal is still in contact with CD basal. Variation is noted in the anals, however, with the primanal positioned completely under the secundanal, and ultimately the secundanal is moved out of the cup. The holotype (largest specimen) and some of the other larger specimens have the mesoplax 1 subcondition anals as well as some of the smaller specimens.

Aaglaocrinus bowsheri is distinguished from all other species of the genus by having a moderately deep basal concavity instead of a shallow basal concavity.

Occurrence—Fifteen specimens, holotype NMMNH P-45578, paratypes 1–4 NMMNH P-45579–45582, and 10 other specimens in lot NMMNH P-45583, Sandia Formation (late Atokan, locality 25).

AAGLAOCRINUS n. sp. undesignated
Figs. 7.11–7.13

Discussion—A partial cup assigned to *Aaglaocrinus* n. sp. undesignated has a shallow basal concavity, two anals, subhorizontal radial facets, low anastomosing ridge ornament, and lacks the E, A, and B radials. It is considered a new species because the cup is relatively lower and the walls more rounded than any other species of *Aaglaocrinus*. However, the specimen is not suitable to serve as a holotype.

Occurrence—Figured specimen UNM 14,488, Flechado Formation (Atokan, locality 17).

Genus *DIPHUICRINUS* Moore and Plummer 1938

Discussion—*Diphuicrinus* was made the nominal genus of the Family Diphuicrinidae, Superfamily Erisocrinacea, by Strimple and Knapp (1966) on the basis of the low-bowl shape of the cup, having a basal impression, a single anal, and 10 uniserial arms. Although these characters are common to several other genera of the erisocrinacids, some other characters of *Diphuicrinus* were not considered in the classification. The cup plates are thick, have deeply impressed stitched sutures, bear coarse nodose ornament, and have bundled vermiform ridges on the cup plate articular facets radiating from the pores spaced along the sutures. The brachials are slightly cuneate, and there is a central discontinuous ridge running along the arms. These cup characters, except variation in the type of ornament, degree of depth of impression of the sutures, and presence or absence of a basal impression, are common to most genera of the Cromyocrinacea. The brachials are similar to those of *Dicromyocrinus*, from which *Diphuicrinus* was probably derived by loss of two anals, lowering of the cup, and development of a basal impression. *Diphuicrinus* is reassigned to the Cromyocrinidae, and Diphuicrinidae is considered a junior synonym of Cromyocrinidae. The other genus, *Graffhamicrinus*, assigned to the Diphuicrinidae is not a cromyocrinid and is reassigned to the Catacrinidae below.

Webster (2003) compiled 13 species currently assigned to *Diphuicrinus*, ranging in age from Morrowan into Virgilian, with most Morrowan (five) or Atokan (five), two from the Desmoinesian, and one from the Virgilian. Some of the Morrowan and Atokan species may be synonymous. Variation within the species is recognized in the length of the cup (mostly low bowls, few medium bowls), depth of the infrabasal concavity (shallow to deep), and ornamentation (fine to very coarse nodes, only one with fine ridges). A systematic revision of the genus is beyond the scope of this study.

DIPHUICRINUS BORGESAE n. sp.
Figs. 5.17–5.20

Etymology—For Barbara Borges Molles who found the specimen.

Diagnosis—Distinguished by the combination of a longer cup, coarse node ornament, and a deep basal concavity.

Description—Cup medium bowl, length 9.9 mm, width 20 mm, deep basal concavity, coarse nodose ornament, impressed stitched sutures, vertical distal walls. Infrabasal circlet downflaring, diameter 4 mm, not visible in lateral view. Infrabasals 5, steeply downflaring, do not reach base of cup. Basals 5, hexagonal, length 8.3 mm, width 8.5 mm, strongly convex longitudinally, moderately convex transversely, recurved, forming base of cup, distally vertical. Radials 5, pentagonal, length 6 mm, width 10.4 mm, gently convex longitudinally and transversely, do not reach base of cup, vertical. Radial facets plenary, slightly inclinate, advanced type bearing transverse ridge, ligament pit, narrow outer margin area, wide deep muscle areas, with details of morphology masked or obliterated. Single anal longer (3 mm) than wide (2.2 mm), opio-plax 2 subcondition, directly above CD basal, distal half above radial summit. Arms unknown. Stem impression round, diameter 2.5 mm; axial canal pentalobate. Stem unknown.

Discussion—The cup of *Diphuicrinus borgesae* n. sp. is moderately well preserved, lacks part of the E radial, is pitted by solution weathering, and retains some of the sand matrix on the oral surface. No other species of *Diphuicrinus* has the combined characters of a medium bowl cup with a deep basal concavity and coarse nodose ornament. The two most similar species are *D. typus* (Knapp 1969) and *D. aristatus* (Strimple 1949), both of which differ by having different ornamentation.

Diphuicrinus borgesae is the third species of the genus described from New Mexico and is the youngest. The two low-bowl cup Atokan forms are *Diphuicrinus santafeensis* Strimple (1980), which has medium node ornamentation, and *D. coalensis* Strimple and Moore (1971), which has a medium deep basal concavity and moderately coarse node ornamentation.

Occurrence—Holotype UNM 14,487, Alamos Formation (Virgilian, locality 20).

Genus *GOLEOCRINUS* Strimple and Watkins 1969

GOLEOCRINUS CHRONICI n. sp.
Figs. 5.13–5.16, 5.27–5.29

Etymology—Named for John Chronic, one of the first collectors of the locality.

Diagnosis—Distinguished by a lower globose cup.

Description—Cup low-globe shape with shallow basal concavity, thick inflated cup plates becoming more inflated with growth, impressed sutures with stitched appearance. Infrabasal circlet with deep stem impression. Infrabasals 5, quadrangular, dart shaped, proximally subhorizontal bearing stem impression, medially downflaring, distally subhorizontal, not visible in lateral view. Basals 5, DE, EA, and AB hexagonal, intermediate in size between septagonal larger BC and smaller CD basals, all recurved, downflaring proximally, forming basal plane medially, and upflaring distally forming lower part of cup wall, moderately convex transversely, strongly convex longitudinally. Radials 5, pentagonal, wider than long, moderately inflated transversely and longitudinally, vertical, proximal tips slightly above basal plane. Radial facets plenary, inclined, bear denticulate transverse ridge, narrow deep ligament pit, narrow outer ligament furrow, low rounded outer margin ridge, deep intermuscular furrow, wide muscle areas with fluted border along intermuscular notch. Anals 3, menoplax 3 or 6 subcondition. Primanal largest, in contact with BC and CD basals, undercutting or supporting secundanal, and supporting or not in contact with tertanal. Secundanal much smaller, elongate, below or mostly above radial summit. Tertanal smallest, proximal tip below radial summit. Arms unknown. Stem facet round; crenularium wide, denticulate. Measurements follow.

Measurements in millimeters for *Goleocrinus chronici* n. sp.

Types	Holotype	Paratype
Cup length	10	6.1
Cup width	24.9	14.4
Infrabasal circlet diameter	9.9	5.1
Infrabasal length (visible)	4.4	1.6
Infrabasal width (visible)	4.4	1.6
EA basal length	9.6	5
EA basal width	11.6	5.9
BC basal length	9.9	5.3
BC basal width	12.8	6.4
CD basal length	9.6	4.8
CD basal width	13	5.7
Radial length	7.4	4.8
Radial width	12	6.7
Primanal length	7.3	3.7
Primanal width	4.5	2.4
Secundanal length	3.9	3
Secundanal width	2	0.9
Diameter stem facet	3.4	2.4

Discussion—The two specimens of *Goleocrinus chronici* n. sp. are

moderately well preserved and provide comparison of the small immature paratype and larger holotype. With growth there is greater inflation of the cup plates, the secundanal loses contact with the CD basal, and the tertanal loses contact with the primanal. Unfortunately, there are insufficient numbers of specimens to know how consistent these characters are in a large population of the species.

Goleocrinus chronici has a shorter cup than all other species of the genus. The proximal tip of the radials of all other species is well above the basal plane of the cup, whereas the proximal tip of *G. chronici* is barely above the basal plane. Shortening of the cup is considered an advanced condition. *Goleocrinus chronici* is most similar to a Chesterian species reported from Alabama, *G. impressus* Burdick and Strimple (1973), which has deeply impressed sutures and is considered the probable ancestor by shortening of the cup and less impressed sutures.

Webster (2003) indexed the six named species of *Goleocrinus* from the Chesterian through Atokan of the United States and two unnamed species, questionably assigned to the genus, from the Desmoinesian of Japan (Hashimoto 1984) and Colorado (Webster and Houck 1998). Both unnamed species are here judged to belong to *Goleocrinus* because they have bowl-shaped medium cups, shallow basal impressions, impressed sutures, thick tumid plates, and three anals, all features typical of the genus.

Occurrence—Holotype NMMNH P-45584 and paratype NMMNH P-45585, Sandia Formation (late Atokan, locality 25).

Genus *METACROMYOCRINUS* Strimple 1961

METACROMYOCRINUS PERCULTUS (Knapp 1969) n. comb.

Figs. 7.34–7.38, for synonymy see Webster (2003)

Discussion—Two infrabasal circlets with proximal columnals, three disarticulated basals, four associated (crushed) basals and a partial radial, two radials, and one axillary primibrachial all have aligned coarse node ornamentation that are judged to belong to *Metacromyocrinus percultus*. These are the largest ossicles in the Sandia fauna and would have formed a large globe-shaped cup with gently upflaring infrabasals. The plates are relatively thin for their large size, and the large size of the viscera should have been a prime food source for scavengers, resulting in disarticulation with transport or scavenging and subsequent disarticulation.

The cups of *Metacromyocrinus* and *Ulocrinus* are both large globe-shaped structures, with the former ornamented with nodes or ridges and the latter lacking ornamentation. Thus, *Ulocrinus percultus* is reassigned to *Metacromyocrinus*.

Metacromyocrinus is known from the Atokan and Desmoinesian strata of the United States. The ornamentation of the cup plates is quite distinctive allowing identification of loose ossicles and making the species of regional biostratigraphic use.

Occurrence—Illustrated infrabasal circlet NMMNH P-45586, basal plate P-45587, radial plate P-45588, and axillary primibrachial P-45589, and lot P-45590 consisting of all other specimens, Sandia Formation (late Atokan, locality 25).

METACROMYOCRINUS CEDROENSIS n. sp.

Figs. 5.1–5.4

Metacromyocrinus? sp. Kues and Koubek 1991, p. 60, fig. 2, nos. E–F.

Etymology—From Cedro Canyon where the specimen was found.

Diagnosis—Distinguished by the high-bowl shaped cup, distinct pattern of coarse nodes along the edges and some within the interior of the cup plates, and a more rounded base.

Description—Cup high-bowl shape, length 11.8 mm, width 16.5 mm, deeply impressed stitched sutures, walls vertical distally, base rounded. Infrabasal circlet upflaring, visible in lateral view of cup, diameter 9.1 mm. Infrabasals 5, dart shaped, length 4.8 mm, width 4.7 mm, bear 3 nodes each, one at each apice with basals, slightly depressed centrally, gently convex longitudinally and transversely, proximally horizontal bearing shallow stem impres-

sion, distally gently upflaring. Basals 5, EA, AB, and DE hexagonal, BC and CD septagonal, moderately convex longitudinally and transversely, form most of cup wall, vertical distally; BC basal length 7.4 mm, width 8.7 mm. Radials 5, pentagonal, gently convex longitudinally, moderately convex transversely, vertical with declivate shoulder below radial facets; A radial length 6.4 mm, width 8.2 mm. Radial facets plenary, horizontal, advanced type bearing denticulate transverse ridge, deep wide ligament pit sloping under transverse ridge, denticulate outer ligament ridge, sharply inset outer ligament furrow, angular outer margin ridge, obtuse V-shaped intermuscular notch, deep narrow intermuscular furrow ending in non-expanded central pit, large moderately concave muscle areas upflaring internally. Anals 2, mesoplax 1 subcondition. Primanal quadrangular, large, length 5.5 mm, width 3.4 mm, undercutting secundanal. Secundanal pentagonal, length 4 mm, width 3 mm, distally adjoins first tube plate at radial summit. Arms unknown. Stem facet round, diameter 3.1 mm; axial canal pentalobate. Stem unknown.

Discussion—Kues and Koubek (1991) first reported *Metacromyocrinus cedroensis* n. sp. as part of an invertebrate fauna from the Los Moyos Formation from the Manzanita Mountains. The specimen is well preserved and differs from other species of the genus by having a higher bowl-shaped cup, distinct pattern of the coarse nodes along the edges of all cup plates and below the declivate shelf adjacent to the radial facets, and a more rounded base.

Occurrence—Holotype UNM 11,835, Los Moyos Limestone, Madera Group (Desmoinesian, locality 12).

METACROMYOCRINUS SZABOI n. sp.

Figs. 7.30–7.33

Cibolocrinus timidus Moore and Plummer 1940. Szabo 1953 (sic), p. 119, pl. 1, fig. 1.

Etymology—For Ernest Szabo who found the specimen.

Diagnosis—Distinguished by the irregular roughened surface ornament of all cup plates and intermediate length of the cup.

Description—Cup medium bowl, length 15.5 mm, width 30.1 mm, impressed stitched sutures, walls subvertical distally, irregular roughened surface on all cup plates. Infrabasal circlet slightly upflaring distally, diameter 12.7 mm, barely visible in lateral view. Infrabasals 5, dart shaped, length 7.4 mm, width 6.9 mm, moderately convex longitudinally and transversely. Basals 5, DE, EA, and AB hexagonal, BC and CD septagonal, moderately convex longitudinally and transversely, form lower half of cup wall; DE basal length 12.4 mm, width 12.9 mm. Radials 5, pentagonal, much wider than long, moderately convex longitudinally and transversely, subvertical; E radial length 8.7 mm, width 15 mm. Radial facets plenary, subhorizontal, advanced type bearing denticulate transverse ridge, shallow ligament pit, rounded outer margin ridge above declivate shelf, widely obtuse V-shaped intermuscular notch, wide muscle areas. Anals 2, mesoplax 1 subcondition. Primanal quadrangular, large, length 11 mm, width 7.3 mm, undercutting secundanal. Secundanal pentagonal, length 7 mm, width 6.3 mm, projects slightly above radial summit. Arms unknown. Stem facet round, diameter 4.4 mm. Stem unknown.

Discussion—The holotype of *Metacromyocrinus szaboi* n. sp. lacks part of the EA and BC basals, most of the AB basal, and parts of the A and B radials, and weathering has obscured many details of the radial facets. No other species of *Metacromyocrinus* has the coarse roughened ornament or an intermediate length of cup as present in *M. szaboi*.

Occurrence—Holotype UNM 2499, Madera Group (?Missourian, locality 13).

METACROMYOCRINUS? n. sp. undesignated

Figs. 5.25–5.26

Description—Partial cup medium bowl, length 10.6 mm, width 22 mm, moderately impressed sutures. Infrabasal circlet upflaring,

visible in lateral view. Infrabasals 5, dart shaped, proximally horizontal with shallow stem impression, distally gently upflared, estimated length 5.4 mm, width 5.6 mm. Basals 5?, hexagonal, gently convex longitudinally and transversely, outflaring form major part of cup wall; AB basal length 9 mm, width 10.6 mm. Radials 5?, pentagonal, gently convex longitudinally and transversely, gently outflaring distally. Radial facets plenary, morphologic details lost. Anals and arms unknown. Stem facet round, diameter 4.5 mm. Stem unknown.

Discussion—The partial cup of *Metacromyocrinus*? n. sp. undesigned lacks the C and D ray basals, radials, and anals and is weathered with the loss of ornamentation and other details of morphology. Without the anals, the generic assignment is uncertain. It has a longer bowl with gently outflaring walls distally than all other Atokan species of *Metacromyocrinus*, which have incurving walls distally and shorter bowls. Younger species of the genus have higher bowls. Thus, it is thought to represent a new species, but the cup is not of quality to serve as a holotype.

Occurrence—Figured specimen UNM 14,501, Sandia Formation (Atokan, locality 9).

Genus *PARTHELOCRINUS* Strimple 1961

PARTHELOCRINUS WATKINSI (Strimple 1949)

Figs. 5.32–5.34, for synonymy see Webster (2003)

Description—Cup medium bowl shape, impressed stitched sutures, basal concavity moderately shallow, walls vertical distally, length 14.5 mm, width 29.7 mm. Infrabasal circlet horizontal with shallow central stem impression, not visible in lateral view. Anals 2, mesoplax 1 subcondition. Stem impression round.

Discussion—Two cups are assigned to *Parethlocrinus watkinsi*. One cup is not distorted but has lost parts of all basals, radials, and anals by fracturing along calcite cleavage planes within the recrystallized ossicles and has matrix covering the infrabasals and oral surface. The second cup shows the infrabasal circlet but is crushed with the radials distorted into the cup cavity with loss of some parts of the radials, basals, and anals by fracturing along calcite cleavage planes.

Occurrence—Figured specimen, uncrushed cup, UNM 11,672, (locality 15); crushed cup, UNM 6,747 (locality 14), both Los Moyos Limestone, Madera Group (Desmoinesian)

PARTHELOCRINUS sp.

Fig. 5.31

Description—Crown with arms splaying slightly distally, length 67.3 mm, width 52.3 mm, cylindrical when enclosed. Cup medium bowl, length 11.9 mm, width maximum 25 mm, minimum 18 mm, average 21.5 mm, basal impression, ornamentation unknown, impressed sutures stitched. Infrabasal circlet confined to basal concavity, not visible in lateral view. Basals hexagonal, recurved, forming base of cup and nearly half of cup wall. Radials pentagonal, vertical distally. Radial facets plenary. Anals uncertain, minimum one, distally extending above radial summit. Arms biserial with chisel-shaped brachials, pinnulate. Single primibrachials axillary. Single secundibrachials axillary in some half rays. All branching isotomous. Arms 14, A and D rays 3, B and E rays 2, C ray 4. Proximal stem round, heteromorphic, diameter 3.7 mm.

Discussion—The crown of *Parethlocrinus* sp. was partly exposed and then cleaned with an air abrasive unit destroying any ornamentation and perhaps some outer morphologic relationships that might have been present. The cup is distorted with the infrabasal circlet pushed into the visceral cavity, and the CD and DE basals and any radials below the one at the radial summit are lost with weathering.

Named species of *Parethlocrinus* are reported from Morrowan (based on cups) and Desmoinesian (based on crowns) rocks of the midcontinent (Webster 2003). Unnamed species have also been reported from Desmoinesian and Missourian rocks of the same

region (Webster 2003). Desmoinesian species have 12 or 16 arms. The extra arms on *Parethlocrinus* sp. are in the A, C, and D rays as in the 16-armed *P. ellipticus* Strimple (1961) from the Desmoinesian of Oklahoma. The specimen could be a variant of *P. ellipticus* or may represent a new species. The specimen is from an unknown horizon in the Madera Group at Cedro Canyon, and the age is uncertain but probably is Middle Pennsylvanian. The over zealous preparation has left the specimen unsuitable for serving as a holotype.

Occurrence—Figured specimen UNM 9358, Madera Group, unknown horizon (Desmoinesian or Missourian, locality 16).

Genus *PARULOCRINUS* Moore and Plumer 1940

PARULOCRINUS GLOBATUS Bowsher and Strimple 1986

Figs. 5.21–5.24, for synonymy see Webster (2003)

Discussion—A bowl-shaped cup, length 8.9 mm, width 14.8 mm, lacking parts of the A, C, D, and E radials, is only slightly deformed, but otherwise well preserved showing the globose shape typical of *Parulocrinus globatus*.

Occurrence—Figured specimen NMMNH P-45628; Bug Scuffle Member, Gobbler Formation (late Desmoinesian, locality 26).

Genus *ULOCRINUS* Miller and Gurley 1890

ULOCRINUS SANGAMONENSIS (Meek and Worthen 1860)

Figs. 5.9–5.12, 5.39–5.42, for synonymy see Webster (2003)

Description—Cup medium bowl, length 8.4 mm, width 13.8 mm, slightly impressed stitched sutures, no other ornament. Infrabasal circlet upflared gently, diameter 6.1 mm, barely visible in lateral view. Infrabasals 5, dart shaped, length 3 mm, width 2.8 mm, proximally bear moderately impressed stem impression, distally upflared. Basals 5, DE, EA, and AB hexagonal, BC and CD septagonal, gently convex longitudinally and transversely, form major part of cup wall; AB basal length 6 mm, width 8.7 mm. Radials 5, pentagonal, gently convex longitudinally and transversely, distally vertical. Radial facet plenary, subhorizontal to slightly declivate, advanced type. Anals 2, mesoplax 1 subcondition. Primanal quadrangular, length 4.9 mm, width 6.6 mm, undercutting secundanal. Secundanal pentagonal, length 4.1 mm, width 3.1 mm, distal tip at radial summit. Stem impression pentagonal, diameter 2.6 mm; axial canal pentalobate with short lobations. Arms and stem unknown.

Discussion—Three specimens are assigned to *Ulocrinus sangamonensis*, which is reported from Missourian strata of the midcontinent. The three specimens are from the Madera Group and initially assigned a Missourian or Virgilian age. Thus, they suggest a Missourian rather than Virgilian age. The uncrushed figured cup was used for measurements and description. The largest cup (26.1 mm long, 39 mm diameter) lacks the E and A radials and most of the EA basal; although the surface is weathered the sutures are more deeply impressed in the gerontic stage.

Occurrence—Figured specimen UNM 8140 (locality 3); figured specimen UNM 6021 (locality 4); other specimen, UNM 6037 (locality 4), all from Missourian–Virgilian upper part of Madera Group.

ULOCRINUS MANZANITAENSIS n. sp.

Figs. 5.5–5.8

Etymology—From the Manzanita Mountains where the specimen was found.

Diagnosis—Distinguished by the shallowly impressed sutures and elongate petals on the pentalobate axial canal.

Description—Cup high bowl, length 23.2 mm, width 18 mm, slightly asymmetrical, shallowly impressed stitched sutures, no ornamentation. Infrabasal circlet upflared, diameter 8.5 mm, visible in lateral view. Infrabasals 5, dart shaped, length 5 mm, width 4.8 mm, proximally horizontal bearing moderately deep stem impression, distally outflaring at approximately 45°. Basals 5, DE,

EA, and AB hexagonal, BC and CD septagonal, gently convex longitudinally and transversely, vertical distally, forming major part of cup wall; CD basal length 8.2 mm, width 9 mm. Radials 5, pentagonal, gently convex longitudinally and transversely, gently outflaring to vertical distally; E radial length 7.1 mm, width 8.7 mm. Radial facets plenary, subhorizontal, advanced type with narrow sharp transverse ridge, large deep ligament pit sloping under transverse ridge, shallow outer ligament furrow, rounded outer marginal ridge, large concave muscle areas, wide intermuscular notch with short V-notch intermuscular furrow. Anals 2, mesoplax 1 subcondition. Primanal quadrangular, length 7 mm, width 3.8 mm, undercutting secundanal. Secundanal pentagonal, length 7 mm, width 4.3 mm, distal half above radial summit, adjoining 2 plates distally. Stem facet pentagonal, diameter 4.9 mm; axial canal pentalobate with elongate petals.

Discussion—The cup of *Ulocrinus manzanitaensis* n. sp. is well preserved with some slickensides on the A to C rays and calcite and matrix films on many plates masking sutures. The asymmetry of the cup may be the result of distortion with preservation. *Ulocrinus manzanitaensis* is most similar to *U. zeschi* Strimple and Watkins (1969) from the Atokan Big Saline Formation of Texas, differing by the less impressed sutures and a pentagonal proximal columnal with the elongate petals of the pentalobate axial canal.

Occurrence—Holotype UNM 14,492, Los Moyos Formation, Madera Group (Desmoinesian, locality 11).

ULOCRINUS? sp.
Fig. 5.30

Description—Infrabasal circlet formed of 5 equal plates, gently upflared, undulating surface, diameter 12.5 mm; visible length of plates 2.9 mm; sutures impressed with stitched appearance. Columnals round, heteromorphic; diameter of largest 5.6 mm; latus roundly convex; crenularium approximately one-third of radius; areola flat; lumen pentalobate.

Discussion—The specimen is well preserved, with some solution weathering of the exposed surfaces of infrabasals. It is questionably assigned to *Ulocrinus* because it apparently lacks surface ornament.

Occurrence—Figured infrabasal circlet NMMNH P-45591, Sandia Formation. (late Atokan, locality 25).

CROMYOCRINIDS indeterminate

Discussion—Cromyocrinids are one of the most common elements in most Pennsylvanian crinoid faunas of North America. Disarticulated cup plates are present in several horizons and localities in New Mexico Pennsylvanian strata. They are easily recognized by the generally large size, coarse nodose ornament, impressed stitched sutures, and the bundled radiating vermiform ridges on the intracup plate articular surfaces. Unfortunately, the latter are often destroyed by weathering processes. When in abundance disarticulated plates may lead to the discovery of articulated cups and crowns laterally along bedding planes.

The intracup plate articular surfaces have not been mentioned or referred to by most describers of cromyocrinid genera and species. The bundled vermiform ridges on the articular surface are an internal extension of the “stitched” appearance of the sutures on the cup exterior, because the vermiform ridges radiate internally along the articular surface away from the surface pore. In addition, they are spaced at regular intervals along the suture. Unfortunately, they are not visible on articulated cups without disarticulation, and they are so small that they are often lost with weathering processes on disarticulated ossicles. The significance and function of the bundled vermiform ridges are not understood. They may be of significance for evolutionary and classification purposes, a study beyond the scope of this work.

Generic identification of disarticulated cromyocrinid plates is generally uncertain because both similar nodose ornamentation and no ornamentation occur on several genera of the cromy-

ocrinids as noted by Webster (1981). These genera must be identified on other features of the cup or arms. A listing of the localities with disarticulated ossicles is included for completeness of the Pennsylvanian faunas.

Locality 7: UNM 14,514. Coarsely nodose to short ridge ornamented fragment of a basal plate, cromyocrinid indeterminate. Osha Canyon Formation (Morrowan).

Locality 5: UNM 14,510. Coarsely nodose to short ridge ornamented radials, basals, anals, infrabasal circlet, and plate fragments of a large bowl-shaped cup, [*Dicromyocrinus?* sp.]; and a coarsely nodose basal, radial, and brachial plate of a large cup with a basal concavity, possibly *Synarmocrinus?* sp. Osha Canyon Formation (Morrowan).

Locality 5: UNM 14,508. Coarsely nodose fragmentary radial and basal, cromyocrinid indeterminate. Osha Canyon Formation (Morrowan).

Locality 19: UNM 14,494. Coarsely nodose radials and basals representing one indeterminate cromyocrinid genus. Flechado Formation (Desmoinesian).

Locality 18: UNM 14,495. Coarsely nodose to short ridge ornamented basals and an axillary brachial representing one genus, probably same taxon as in locality 19. Flechado Formation (Desmoinesian).

Locality 4: UNM 6020. Unornamented 2 basals and 2 radials representing one indeterminate genus. Madera Group (Missourian or Virgilian).

Locality 4: UNM 6026. Unornamented 3 basals and 11 radials of two genera, one with the sides of the radials parallel and the other with the sides narrowing distally, 2 indeterminate genera, one same as UNM 6020. Madera Group (Missourian or Virgilian).

Locality 4: UNM 6029. A disarticulated infrabasal circlet and associated infrabasal circlet, basals, radials, and columnals, all except columnals with fine vermiform ridge ornament. One indeterminate genus, probably same as UNM 6020. Madera Group (Missourian or Virgilian).

Locality 4: UNM 6035. Finely papillate ornamented infrabasal circlet representing one indeterminate genus. Madera Group (Missourian or Virgilian).

Locality 22: UNM 14,499. Coarsely nodose basals and radials representing one indeterminate genus. Alamitos Formation (Virgilian).

Locality 1: UNM 14,541. Unornamented 3 radials, 7 basals, representing one indeterminate genus, *Ulocrinus?* sp. Upper white limestone, Jemez Springs Member, Madera Group (Virgilian).

Superfamily ERISOCRINACEA Wachsmuth and Springer 1886

Discussion—The Erisocrinacea, as interpreted by Moore, Strimple, and Lane (*in* Moore and Teichert 1978), include nine families. Hagdorn (1988) included the Triassic Family Encrinidae in the Order Encrinida, removing it from the Erisocrinacea. This left the Erisocrinacea with eight families ranging from Early Mississippian into Late Permian. The families were defined on morphologic characters of the cup (shape, presence or absence of basal cavity, ornamented or unornamented, and one or no anal) and the 10 arms (uniserial or biserial). While identifying the New Mexico erisocrinids it became apparent that several genera within the Erisocrinacea did not conform to the defining characters of the assigned family or that they possessed additional characters relating them to other families within or outside the Erisocrinacea. Examples are given below.

In the Family Graphiocrinidae, *Holcocrinus* differs from all other graphiocrinids by having cuneate brachials and lacking a basal concavity. These characters are found in genera (*i.e.* *Decadocrinus*, *Zostrocrinus*) of the Decadocrinidae, although the Decadocrinidae are defined as normally having three anals in the cup (Moore and Teichert 1978, p. 685). *Acylocrinus* is a decadocrinid with a basal concavity and a single anal, otherwise it is very similar to *Hol-*

cocrinus. *Holcocrinus* is here transferred to the Decadocrinidae.

The Diphuicrinidae, defined as having uniserial brachials (Moore and Teichert 1978), includes two genera, *Diphuicrinus* and *Graffhamicrinus*. *Diphuicrinus* has thick plates, impressed stitched sutures, coarse nodose ornament, bundled anastomosing ridges on the intracup plate articular facets, and uniserial cuneate brachials like some genera of the Cromyocrinidae to where it is here assigned. The Family Diphuicrinidae is considered a junior synonym of the Cromyocrinidae. *Graffhamicrinus* has biserial brachials and is described (Moore and Teichert 1978, p. 712) as "Cup similar to that of *Delocrinus* but surface of plates rugose." The arms and tegmen of *Graffhamicrinus* are virtually identical to those of *Delocrinus*, which lacks the rugose ornament and may have enlarged bulbous or spinose axillary primibrachials. *Delocrinus* is assigned to the Catacrinidae, a family in which the described genera lack cup ornamentation. These two genera are probably derived from a common ancestor, or *Graffhamicrinus* is derived from *Delocrinus* (perhaps polyphyletically) by the addition of ornamentation on cup plates. *Graffhamicrinus* is here transferred to the Catacrinidae, which is emended to include ornamented taxa.

Several Erisocrinacea genera are based on cups lacking the arms. The five genera of the Paradelocrinidae are all based on cups, and no mention of the arms is given in the generic characters of each, yet the family characters are given as 10 arms distally biserial (Moore et al. in Moore and Teichert 1978). The monotype genus of the Arkacrinidae, *Arkacrinus*, has a distinct cup shape that incurls at the top of the radials, has diminutive infrabasals in a deep basal concavity, and enlarged basals that are concave transversely. It has been included in the erisocrinaceans because it has a single anal on the posterior basal or above it on an interior notch on the C and D radials. *Bronaughocrinus* has the same cup morphology, but three anals. *Arkacrinus* is probably derived from *Bronaughocrinus* by loss of two anals from the cup and is here transferred to the Phanocrinidae as an advanced evolutionary form. The Phanocrinidae is emended to include taxa with a single anal.

Placing Diphuicrinidae in the synonymy of the Cromyocrinidae and Arkacrinidae in the synonymy of the Phanocrinidae reduces the Erisocrinacea to five families. They are the Erisocrinidae, Graphiocrinidae, Paradelocrinidae, Protencrinidae, and Catacrinidae. Erisocrinaceans are abundant and common elements in Late Mississippian into Late Permian faunas worldwide. They are of stratigraphic and paleoecologic value as noted by Knapp (1969), Pabian et al. (1989), Holterhoff (1997a,b) among others. A detailed revision of the Erisocrinacea is beyond the scope of this study, but must include lineage relationships.

Family ERISOCRINIDAE Wachsmuth and Springer 1886

Genus ERISOCRINUS Meek and Worthen 1865

ERISOCRINUS OBOVATUS (Moore and Plummer 1940)

Figs. 4.39–4.41; for synonymy see Webster (2003)

Discussion—*Erisocrinus obovatus* has the deepest (but still rather shallow) basal concavity of all species of *Erisocrinus*. Two cups from the Sol se Mete Member of the Wild Cow Formation are well preserved and match the descriptions and figures of the original description by Moore and Plummer (1940). The largest cup is 4.9 mm long and 8.6 mm wide; the smallest cup is 3 mm long and 6.5 mm wide. A total of 12 specimens range in size from 3 mm to 7 mm in length and from 6.4 mm to 16.1 mm in diameter. They show an increasingly deeper (but still relatively shallow) basal cavity with growth. The infrabasals are nearly subhorizontal in the basal plane in the smaller specimens, becoming more downflaring distally with growth. The proximal tips of the basals are in the basal plane in the smaller specimens and within the basal concavity in the larger specimens.

Erisocrinus obovatus is reported from several Missourian formations in the midcontinent from Nebraska to Texas. This is the first report of *E. obovatus* from New Mexico.

Occurrence—Twelve specimens, figured specimen UNM 14,529, others UNM 14,546, Sol se Mete Member, Wild Cow Formation, Madera Group (Missourian, locality 10).

Genus *EUERISOCRINUS* Strimple 1939

EUERISOCRINUS TIJERASSENSIS n. sp.

Figs. 4.42–4.44

Etymology—From the town of Tijeras in the Manzanita Mountains, near where the specimen was found.

Diagnosis—Distinguished by having a relatively larger infrabasal circlet, lesser amount of the anal plate within the cup, and walls that slope outward at a greater angle.

Description—Cup low-bowl shape, length 4.5 mm, width 8.5 mm, sutures flush, no ornamentation, shallow basal concavity, walls expanding distally. Infrabasal circlet confined to basal concavity, diameter 3.2 mm. Infrabasals 5, dart shaped, length 1.6 mm, width 1.5 mm, subhorizontal, not visible in lateral view, bearing round stem impression on proximal half. Basals 5, pentagonal, proximally horizontal forming base of cup, distally upflared forming lower one-third of cup wall, moderately convex longitudinally and transversely; AB basal length 2.3 mm, width 2.8 mm. Radials 5, pentagonal, wider than long, gently convex longitudinally, moderately convex transversely; C and D radials with small facet for primanal on distal ends of mutual suture; A radial length 3.7 mm, width 4.9 mm. Radial facets plenary, horizontal, bearing narrow transverse ridge, deep ligament pit, and narrow outer margin area. Anals 1, opiolax 3 subcondition, in small notch on C and D radials. Stem impression circular, 1.7 mm diameter; axial canal pentagonal.

Discussion—The cup of *Euerisocrinus tijerasensis* n. sp. is moderately well preserved but slightly solution weathered, and the oral surface is masked with matrix. The matrix mask obscures the sutures. It differs from *E. waysidensis* Strimple (1939) by having a relatively larger infrabasal circlet, lesser amount of the primanal within the cup, and greater outward slope to the walls.

Occurrence—Holotype UNM 14,527, Los Moyos Limestone, Madera Group (Desmoinesian, locality 15).

EUERISOCRINUS GORDOPLATUS n. sp.

Figs. 6.24–6.26

Etymology—From the Spanish, *gordo* and *plata*, meaning fat plate, referring to the bulbous basal plates.

Diagnosis—Distinguished by the bulbous basals, moderate basal concavity, and shagreen and low tubercle ornamentations.

Description—Cup low-bowl shape, length 3.7 mm, width 7.5 mm, faint shagreen ornament with scattered low tubercles, moderate basal concavity, walls expanding distally. Infrabasal circlet confined to basal concavity, diameter 3.1 mm. Infrabasals 5, proximally with stem facet, medially downflaring, distally horizontal, not visible in lateral view. Basals 5, hexagonal, slightly wider than long, bulbous, with inflations forming base of cup, strongly convex longitudinally and transversely; AB basal length 2.8 mm, width 3 mm. Radials 5, pentagonal, wider than long, gently convex longitudinally and transversely, gently outflaring; C and D radials bear small notch on distal end of mutual shoulders; A radial length 3.3 mm, width 4.1 mm. Single anal, opiolax 3 subcondition, on distal shoulders of C and D radials. Arms unknown. Stem facet covered by matrix.

Discussion—The cup of *Euerisocrinus gordoplatus* n. sp. is moderately well preserved, with solution weathering destroying some of the ornamentation, especially on the basals. The base of the cup is formed by the bulbous nature of the basals, thus appearing to sit on five rounded knobs without the stem. This suggests that the small stem may have been a tether in the adult stage and that the cup may have rested on the substrate on the basals as recognized in the Permian calceolispongids from Australia described by

Teichert (1949) and in some Permian blastoids from Timor described by Wanner (1924b). *Euerisocrinus gordoplatus* differs from *E. waysidensis* Strimple (1939) and *E. tijerasensis* by the presence of a deeper basal concavity, bulbous basals, and shagreen and low tubercle ornamentation.

Occurrence—Holotype UNM 14,530, Sol se Mete Member, Wild Cow Formation, Madera Group (Missourian, locality 10).

Genus *NEOPROTENCINUS* Knapp 1969

Discussion—*Neoprotencrinus* is removed from the Protencrinidae because the type genus, *Protencrinus*, has cuneate uniserial arms. *Neoprotencrinus* is here transferred to the Erisocrinidae because it has biserial arms and fits all other morphological characters of the family as given by Moore et al. (in Moore and Teichert 1978, p. 705).

NEOPROTENCINUS SUBPLANUS (Moore and Plummer 1940)

Figs. 6.27–6.30, 6.35–6.36

Erisocrinus typus Meek and Worthen 1865. Bowsher and Strimple 1986, p. 16, figs. 42a–i, 61a–f.

For additional synonymy see Webster (2003).

Discussion—The 16 specimens assigned to *Neoprotencrinus subplanus* agree with the original description given by Moore and Plummer (1940). They are considered growth stages, with the smallest cup having a width of 10.8 mm and the largest 18.8 mm. Plate relationships and cup shapes are uniform throughout the specimens. There are minor amounts of variation in the depth of the stem impression into the infrabasal circlet, but the distal tips of the infrabasals are horizontal and near, but not within, or barely touch the basal plane of the cup.

Neoprotencrinus subplanus is very similar to *N. rockensis* Webster and Houck (1998) from the Minturn Formation of Colorado but has an angular pentagon shape to the infrabasal circlet instead of the pentalobate shape of *N. rockensis*.

Occurrence—Fifteen cups, figured specimen NMMNH P-45592, smallest P-45594, largest P-45593, and 12 other specimens in lot NMMNH P-45595 from the Sandia Formation (late Atokan, locality 25); and figured specimen NMMNH P-45629 and a second poorly preserved specimen P-45630 from the Bug Scuffle Member of the Gobbler Formation (late Desmoinesian, locality 26).

NEOPROTENCINUS GUTSCHICKI n. sp.

Figs. 6.4–6.6, 6.18–6.20, 6.33–6.34

Etymology—Named for Ray Gutschick who collected some of the specimens.

Diagnosis—A *Neoprotencrinus* distinguished by the combination of a deeper basal concavity, wider basal/basal sutures, and sutures that are not impressed.

Description—Cup low bowl, roundly pentagonal outline in oral or basal view, moderately deep basal cavity, walls slightly outflaring distally, no ornament. Infrabasal circlet downflaring, mostly covered by proximal columnals. Infrabasals 5, confined to basal cavity, dart shaped, proximally horizontal, distally downflaring, distal tips do not reach basal plane. Basals 5, hexagonal, slightly wider than long, straight to slightly concave transversely, strongly convex longitudinally, proximally downflaring, medially horizontal, distally upflaring, forming basal plane, distal tips barely visible in lateral view. Radials 5, pentagonal, wider than long, moderately convex transversely, strongly convex longitudinally, proximal tips in basal plane. Radial facets plenary, gently inclined; possess denticulated transverse ridge widest medially; narrow moderately deep ligament pit; narrow outer ligament furrow; angular outer marginal ridge; wide muscle fields inclined except upflaring adjacent to anal; and wide angular intermuscular notch. Single anal interior, opioptax 4 subcondition, in notch on mutual shoulders of C and D radials. Column round, proximally invaginated into infrabasal circlet. Arms and stem unknown. Measurements follow.

Measurements in millimeters for *Neoprotencrinus gutschicki* n. sp.

Types	Holotype	Paratype 1	Paratype 2
Cup length	6.5	6.4	7.1
Cup width	17	14.8	19.2
Infrabasal circlet diameter	4	2.3	3.2
EA basal length	4.7	4.1	4.5
EA basal width	4.7	3.9	5.8
CD basal length	4.7	4.2	4.9
CD basal width	4.4	3.8	5.5
A radial length	5.9	5.8	7.5
A radial width	9.6	8.8	11.5
Diameter stem impression	3	2.3	3.2
Depth basal impression	1.9	1.5	1.4

Discussion—The 22 cups of *Neoprotencrinus gutschicki* n. sp. are moderately well preserved, but most have the basal cavity infilled and radial facets are covered with calcareously cemented micaceous silt. Some variation is present in the length of the basal/basal sutures on individual specimens, and the depth of the basal cavity ranges from moderately deep to deep, with most of the depth external to the proximal columnal invagination.

Neoprotencrinus gutschicki is most similar to *N. brachiatus* (Moore and Plummer 1940), which also has a moderately deep basal cavity. However, *N. brachiatus* has impressed radial/radial sutures and shorter basal/basal sutures that may approach a pinpoint. All other species of *Neoprotencrinus* have shallow basal cavities.

Occurrence—Twenty-two cups, holotype NMMNH P-45596. Paratypes 1–9 P-45597–45605 and 12 other specimens in lot P-45606, Sandia Formation (late Atokan, locality 25).

Family PROTENCINIDAE Knapp 1969

Discussion—The Family Protencrinidae is restricted to the genus *Protencrinus* with the transfer of *Neoprotencrinus* to the Erisocrinidae.

Knapp (1969) distinguished the Paradelocrinidae from the Protencrinidae on the basis of the former having a deeper basal concavity. The concavity of some species assigned to the genera of these two families is variable when multiple specimens are available from a single locality. Unfortunately, the arms of type specimens of genera of the Paradelocrinidae are unknown, although given as biserial by Moore et al. (in Moore and Teichert 1978, p. 709), as mentioned above. If the arms of all genera of the Paradelocrinidae are indeed biserial, they could fit the description of the Erisocrinidae. However, it is possible that some genera of the Paradelocrinidae have uniserial arms and, thus, could be combined with the Protencrinidae. If *Paradelocrinus* has uniserial arms, then the Protencrinidae would be a junior synonym of Paradelocrinidae by page priority.

Genus *PROTENCINUS* Jaekel 1918

PROTENCINUS MUTABILIS Knapp 1969

Figs. 6.11–6.14, for synonymy see Webster (2003)

Description—Cup low-bowl shape, smooth, deep basal invagination. Infrabasals downflaring, confined to basal invagination. Some infrabasals in truncated or point contact with radials. Basals quadrangular, proximally in basal concavity, medially recurved forming base of cup with proximal tips of radials, distally upflared, barely visible in lateral view. Radials large, form most of cup wall. Radial facets plenary. Anal confined to internal notch between posterior radials. Round stem impression.

Discussion—Two cups are assigned to *Protencrinus mutabilis*. The largest is 6.6 mm long and 19 mm wide with a basal invagination 2.7 mm deep. It has two infrabasals in truncated contact with radials, two separated from the radials by short basal/basal contacts, and one in point contact with the overlying radial. The distorted smallest cup is 4 mm long and averages 10.9 mm wide with a basal invagination 1.3 mm deep. It has two basals in truncated contact

and three basals in point contact with the overlying radials. These two specimens are from the Desmoinesian part of the Flechado Formation, perhaps different stratigraphic levels, and extend the range of the species upward into the Desmoinesian. Lacking a large population of specimens, it is uncertain if the differences in infrabasal to radial contact is of stratigraphic or specific significance. The differences between the infrabasal, basal, and radial contacts within each of the two cups are not considered of specific significance at this time.

Occurrence—Figured specimen, large cup, UNM 14,489 (locality 18); small cup, UNM 14,522 (locality 19), both Flechado Formation (Desmoinesian).

Family CATACRINIDAE Knapp 1969

Emended Diagnosis—Cup smooth or ornamented.

Discussion—Transfer of *Graffhamicrinus* to the Catocrinidae requires emendation of the diagnosis to include forms with ornamented cups. Genera of the Catocrinidae bearing a single anal visible in lateral view of the cup may be the progenitors of genera of the Erisocrinidae and Paradelocrinidae, which have the anal positioned on a notch on the inner side of the C and D radials and not visible in lateral view of the cup.

Genus *DELOCRINUS* Miller and Gurley 1890

DELOCRINUS SUBHEMISPHERICUS Moore and Plummer 1940

Figs. 4.22–4.24, for synonymy see Webster (2003)

Description—Cup smooth, low-bowl shaped, length 6.1 mm, width 16 mm, with deep basal concavity, subvertical walls distally. Infrabasal circlet downflaring, diameter 2.6 mm. Five large recurved basals form base of cup. Five large radials have proximal tips slightly above base of cup, distally subvertical. Radial facets plenary, bearing moderately wide non-denticulate ridge, shallow ligament pit, faint outer ligament pit ridge, narrow outer ligament furrow, angular outer margin ridge, narrow lateral furrows, wide gently upflaring muscle areas, and widely obtuse intermuscular notch. Single anal on truncated slightly extended CD basal, opio-plax 2 subcondition.

Discussion—Two cups assigned to *Delocrinus subhemisphericus* are moderately well preserved. Solution weathering has destroyed details of the radial facets on the larger specimen (length 6.1 mm, width 16 mm). Recrystallization and solution weathering have destroyed some of the surficial parts of the smaller specimen (length 5.6 mm, width 14.8 mm). The cups compare favorably with illustrated neoparatypes (Moore et al., in Moore and Teichert 1978) in shape, plate arrangement, and morphologic details. *Delocrinus subhemisphericus* is one of the most widespread species of the genus. It is known from Missourian and Virgilian formations of Illinois, Iowa, Missouri, Nebraska, Kansas, Oklahoma, and Texas (Webster 2003).

Occurrence—Figured specimen UNM 8108, Atrasado Formation (late Virgilian, locality 24); listed specimen UNM 14,497, Jemez Springs Shale, Madera Group, (Virgilian, locality 2);

DELOCRINUS PONDEROSUS Strimple 1949

Figs. 6.21–6.23, for synonymy see Webster (2003)

Discussion—The cup of *Delocrinus ponderosus* is solution weathered and of poor quality. The rounded cross-sectional shape with the walls outflaring distally is the identifying characteristic of the species as most species of *Delocrinus* have subvertical walls. Strimple (1949) reported *D. ponderosus* from the Virgilian Brownville Formation of eastern Oklahoma.

Occurrence—Figured specimen UNM 14,544, Jemez Springs Shale, Madera Group (Virgilian, locality 2).

DELOCRINUS spp.

Discussion—A fractured poorly preserved cup of *Delocrinus* from

the Madera Group is slightly distorted and weathered and not assigned to a species. A second fragmentary cup lacking the A through C rays and an associated partial set of arms of *Delocrinus* are from the Bug Scuffle Member, Gobbler Formation, and are not assigned to a species.

Occurrence—Specimen UNM 14,526, Madera Group (Desmoinesian, locality 15); specimen NMMNH P-45631, Bug Scuffle Member, Gobbler Formation (late Desmoinesian, locality 26).

Genus *ENDELOCRINUS* Moore and Plummer 1940

ENDELOCRINUS GLOBULARUS n. sp.

Figs. 4.25–4.28

Etymology—In reference to the globular shape of the basals and radials.

Diagnosis—Distinguished by the very deep apical pits and bulbous basals and radials.

Description—Cup low-bowl shape, length 4.3 mm, width 9.7 mm, moderately deep basal concavity, deep apical pits emphasized by greatly inflated basals and radials. No other ornamentation. Infrabasal circlet downflaring, diameter 2.1 mm, confined to basal concavity, not visible in lateral view. Basals 5, pentagonal, strongly convex longitudinally and transversely, form base of cup, proximally in basal concavity, medially recurved, distally vertical forming lower half of cup walls; AB basal length 3.2 mm, width 3.5 mm. Radials 5, pentagonal, much wider than long, strongly convex longitudinally and transversely, proximal tips above basal plane, subvertical with distal tips slightly incurved; A radial length 3.1 mm, width 5.1 mm. Radial facets plenary, subhorizontal, bearing transverse ridge, narrow ligament pit dipping under transverse ridge, narrow outer margin, wide intermuscular notch, short intermuscular furrow ending in indistinguishable central pit. Single anal on truncated CD basal, opio-plax 2 subcondition. Arms unknown. Stem facet circular, diameter 1.3 mm.

Discussion—*Endelocrinus globularus* n. sp. is distinguished by the very deep apical pits and bulbous basals and radials. This is the most extreme development of these characters within the genus. The holotype lacks the anal, D radial, and part of the E radial, but is easily recognized by the bulbous plates and plate arrangement in the cup.

Occurrence—Holotype UNM 14,519, Flechado Formation (Atokan, locality 17).

ERISOCRINID indeterminate

Figs. 4.29–4.32

Description—Partial cup low bowl, length 6.3 mm, width 13 mm, shallow basal concavity, plates smooth, sutures flush. Infrabasals downflaring slightly with distal tips at basal plane, not visible in lateral view. Basals 5, proximal tips in basal concavity, medially forming basal plane, distal tips upflaring, visible in lateral view. Radials 5, pentagonal, proximal tips barely above basal plane, distally vertical, moderately convex longitudinally, gently convex transversely. Radial facets plenary, features vague, but bearing transverse ridge, ligament pit, outer margin area and muscle fields. Stem roundly pentagonal, lumen pentagonal. Arms unknown.

Discussion—The cup of Erisocrinid indeterminate is broken, lacking one radial, parts of two other radials, and parts of two basals. It is unknown if an anal was present or not. Weathering has destroyed the details of the radial facets. The specimen may belong to *Neoprotencrinus* or one of the catocrinids.

Occurrence—Figured specimen UNM 14,528, Los Moyos Limestone, Madera Group (Desmoinesian, locality 15).

Superfamily APOGRAPHIOCRINACEA Moore and Laudon 1943

Family APOGRAPHIOCRINIDAE Moore and Laudon 1943

Discussion—The Superfamily Apographiocrinacea is defined as

having peneplenary radial facets by Moore and Strimple (*in* Moore and Teichert 1978). Of the two genera assigned to the family, *Apographiocrinus* has peneplenary radial facets, whereas *Parapographiocrinus* has plenary radial facets. Other differences between these two genera, such as five arms and rectilinear brachials on *Parapographiocrinus* and 10 arms and slightly cuneate brachials on *Apographiocrinus*, suggest these two genera were derived from different lineages and should not be included in the same family. *Apographiocrinus* is probably derived from *Pachylocrinus* Wachsmuth and Springer (1880) by reduction of the number of anals (from three to one), primibrachials (from two to one), and arms (from 40 or more to 10). The lineage of *Parapographiocrinus* is less certain, but may have been derived from *Morrowcrinus* Moore and Plummer (1938) by reduction of the number of anals (from three to one) and arms (from 10 to five) and by modification of the cup into a bowl from a cone.

Parapographiocrinus is considered to be closely allied to *Parspaniocrinus* Strimple 1971 and *Spaniocrinus* Wanner 1924a, all of which have five arms and rectilinear brachials. *Spaniocrinus* has no anal in the cup and is hyperpinnulate. *Parapographiocrinus* and *Parspaniocrinus* have a single anal and a single pinnule per brachial. *Parapographiocrinus* is here transferred to the Family Spaniocrinidae.

Genus *APOGRAPHIOCRINUS* Moore and Plummer 1940

APOGRAPHIOCRINUS DECORATUS Moore and Plummer 1940 Figs. 6.7–6.10

Apographiocrinus angulatus Strimple 1948, p. 11, pl. 2, figs. 5–8; fig. 2.
Apographiocrinus obtusus Strimple 1948, p. 8, pl. 2, figs. 1–4; fig. 1.
Strimple and Duluk 1971, p. 244, figs. 5–7.

Apographiocrinus rotundus Strimple 1948, p. 8, pl. 2, figs. 9–12; fig. 3.
For additional synonymy see Webster (2003).

Discussion—Two low-bowl-shaped cups with the characteristic nodose ornament, including nodes on the sloping area below the radial facets, and interradial notches are referred to *Apographiocrinus decoratus*. Both cups are well preserved, but the larger (4.8 mm long, 11 mm wide) lacks the distal part of the anal and the smaller (4 mm long, 9.9 mm wide) lacks the E radial and anal.

Apographiocrinus decoratus was reported from the early Missourian Keechi Creek Member of the Mineral Wells Formation of northern Texas (Moore and Plummer 1940). Strimple (1948) reported *A. angulatus*, *A. obtusus*, and *A. rotundus* from the late Desmoinesian Oologah Formation of Oklahoma. Strimple (1948) considered these different species on the basis of slightly deeper basal concavities, all of which are relatively shallow based on just that form. The depth of the basal concavity is: *A. angulatus* very shallow (smallest specimen), *A. obtusus* slightly deeper (intermediate-sized specimen), and *A. rotundus* the deepest (largest specimen). They are here considered growth stages with the slightly deeper basal concavity the result of greater convexity of the basals with growth. All are considered junior synonyms of *A. decoratus*. Thus, the range of *A. decoratus* is considered to be from late Desmoinesian into early Missourian, and the geographic range is considered to be from the southern part of the midcontinent into the southern part of the intermontane basins.

Occurrence—Figured specimen NMMNH P-45632, mentioned specimen P-45633. Upper part of Bug Scuffle Member, Gobbler Formation (late Desmoinesian, locality 26).

APOGRAPHIOCRINUS TYPICALIS Moore and Plummer 1940 Figs. 6.15–6.17, for synonymy see Webster (2003)

Discussion—Four low-bowl-shaped cups assigned to *Apographiocrinus typicalis* lack ornamentation, have a deep basal concavity resulting from downflaring infrabasals distally and a deeply impressed stem facet, and have interradial notches. The specimens are well preserved and range in size from the smallest with a length of 3.8 mm and width of 8.1 mm to the largest with a length of 5 mm and width of 13.1 mm. The stratigraphic range of *A. typ-*

icalis is from Missourian into Virgilian, and the geographic range is from the midcontinent to the southern part of the intermontane basins of the U.S. It has the widest stratigraphic range of all species of the genus.

Occurrence—Figured specimen UNM 14,531 and three other specimens (UNM 14,547) Sol se Mete Member, Wild Cow Formation, Madera Group (Missourian, locality 10).

APOGRAPHIOCRINUS RIMOSUS n. sp. Figs. 6.31–6.32

Etymology—Referring to the rim on the infrabasal circlet around the stem impression.

Diagnosis—Distinguished by the presence of a flange or collar on the infrabasal circlet around the stem impression.

Description—Cup low bowl, length 4.8 mm, width 9.4 mm, with shallow basal concavity, slightly impressed sutures, shallow apical pits, flange or collar on infrabasals around stem impression, otherwise plates smooth. Infrabasal circlet horizontal, diameter 2.9 mm. Infrabasals 5, dart shaped, proximally with shallow stem impression, centrally with flange or collar around stem impression, distally flat, length 1.6 mm, width 1.3 mm. Basals 5, hexagonal, AB basal length 2.7 mm, width 3.3 mm, strongly convex longitudinally, moderately convex transversely, proximally in basal concavity, medially form base of cup, distally upflaring; AB basal length 2.7 mm, width 3.3 mm, CD basal length 3.7 mm, width 3.9 mm. Radials 5, pentagonal, B radial length 3.2 mm, width 4.3 mm, gently convex longitudinally, moderately convex transversely. Radial facet angustary, width 3.2 mm, ratio radial facet width/radial width $3.2/4.3 = 0.74$, subhorizontal, complex, with narrow transverse ridge, ligament pit dipping under transverse ridge, narrow outer margin area, wide muscle areas, V-shaped intermuscular notch. Primanal on distal tip of slightly extended CD basal, extending above radial summit. Arms unknown. Stem facet round.

Discussion—The cup of *Apographiocrinus rimosus* n. sp. lacks the DE basal, D and E radials, and anal; otherwise, it is well preserved and distinguished by the flange or collar around the stem impression. No other species of *Apographiocrinus* has such a feature. The smooth cup plates show affinity with the unornamented species of *Apographiocrinus* from which it was probably derived.

Occurrence—Holotype UNM 14,532, Sol se Mete Member, Wild Cow Formation, Madera Group (Missourian, locality 10).

APOGRAPHIOCRINUS KIETZKEI n. sp. Figs. 6.1–6.3

Etymology—For Kenneth Kietzke, who collected the specimen.

Diagnosis—Distinguished by the shagreen ornamentation.

Description—Cup low bowl, length 5 mm, width 10.6 mm (deformed), shallow basal concavity, with shallow apical pits and shagreen ornamentation of small nodes to vermiform ridges. The infrabasal circlet is downflaring with a deeply impressed stem facet. The 5 basals are strongly convex longitudinally and moderately convex transversely, forming the basal plane of the cup and lower part of the cup walls; AB basal 3.8 mm long, 4 mm wide; CD basal 4.5 mm long, 5 mm wide. The 5 radials are moderately convex longitudinally and transversely and bear peneplenary radial facets; A radial 3.5 mm long, 5.6 mm wide; C radial 3.5 mm long, 4.8 mm wide. Radial facets peneplenary, width 4.4 mm; ratio radial facet width/radial width $4.4/4.8 = 0.92$; facet morphology similar to those of *A. rimosus*. Interradial notches narrow. Single anal on truncated tip of slightly extended CD basal. Stem facet round.

Discussion—The partial cup of *Apographiocrinus kietzkei* n. sp. is slightly deformed by crushing and fractures and lacks the anal and most of the B radial. The ornamentation distinguishes it from all other species of the genus.

Occurrence—Holotype UNM 14,533, Sol se Mete Member, Wild Cow Formation, Madera Group (Missourian, locality 10).

Superfamily PIRASOCRINACEA Moore and Laudon 1943
Family PIRASOCRINIDAE Moore and Laudon 1943
Genus *EIRMOCRINUS* Strimple and Watkins 1969

EIRMOCRINUS BREWI (Webster and Lane 1970)
Figs. 7.23–7.29, for synonymy see Webster (2003)

Discussion—Three cups, three axillary primibrachials, and eight tegmen spines (three still in association) are assigned to *Eirmocrinus brewi* (Webster and Lane 1970). The cups show variation in the anals. The largest cup (27.8 mm diameter, 5.5 mm length) has two anals in the cup (mesoplax 4 subcondition) with the primanal below the secundanal, separating it from the extended CD basal. The secundanal has less than half of its length below the radial summit. The proximal end of the tertanal rests on the primanal at the radial summit and is not included in the cup.

The second largest cup (26.5 mm diameter, 5.9 mm length) has less than half the length of the primanal (opioplax 2 subcondition) below the radial summit. It supports two plates distally, both well above the radial summit. Most of the anals have been lost on the smallest cup (23.3 mm diameter, 4.7 mm length). What is left of the primanal on the extended CD basal appears to have supported the proximal part of the secundanal below the radial summit. The tertanal was not in contact with primanal and entirely above the radial summit. These three cups also show some variation in the inflation of the cup ossicles as the smaller specimen has more bulbous plates than either of the two larger specimens. Some differences are also noted within each of the cups in the length of the basal/basal sutures. Differences among these three specimens are considered intraspecific variation. Similar variations have been observed in the anal plates of other cladid species as reported by Wright (1920, 1927, 1934) as summarized by Webster and Maples (2006). The range of the species is extended downward into the late Atokan.

Occurrence—Three cups (figured specimens NMMNH P-45607 and P-45608 and unfigured cup P-45609), four axillary spinose primibrachials (lot P-45610), and eight tegmen spines (lot P-45611), all lacking the distal part of the spine, from the Sandia Formation (late Atokan, locality 25).

Genus *METAFFINOCRINUS* Knapp 1969

METAFFINOCRINUS NOBLEI n. sp.
Figs. 6.37–6.39

Etymology—Named for E. A. Noble who found the specimen.

Diagnosis—Distinguished by the gently declivate radial facets and presence of elongate spines on the primibrachials.

Description—Cup low to flat bowl, length 4.5 mm, width 21.7 mm (B ray–DE interray), 19.3 mm (A ray–posterior), 20.5 mm (average), shallow basal concavity, wide anal interarea, plates smooth. Infrabasal circlet horizontal, diameter 6 mm, confined to basal concavity. Infrabasals 5, dart-shaped, length 3.5 mm, width 3.4 mm, proximally bear shallow stem impression, not visible in lateral view. Basals 5, DE, EA, and AB hexagonal, BC and CD septagonal, gently convex to slightly concave transversely, moderately convex longitudinally, proximally in basal concavity, medially form base of cup, distally upflaring gently, barely visible in lateral view; AB basal length 4.9 mm, width 6.5 mm; CD basal length 5.2 mm, width 5.5 mm. Radials 5, pentagonal, slightly inflated, gently convex longitudinally and transversely, proximal tip at base of cup; A radial length 5.6 mm, width 11.6 mm. Radial facets advanced type, slightly declivate, peneplenary, width 9 mm, ratio radial facet width/radial width $9/11.6 = 0.78$; bearing wide denticulate transverse ridge, narrow deep ligament pit sloping under transverse ridge, narrow outer margin area, rounded outer margin ridge, wide deep muscle areas undulatory, approximately right angle intermuscular notch, no intermuscular furrow or central pit. Radial notches obvious in oral or basal view. Anals 3, menoplax 3 subcondition; primanal largest, slightly undercutting secundanal on posterior basal. Axillary single primibrachials bear elongate

spine near distal tip. Stem facet round, diameter 3.7 mm; lumen pentalobate. Arms, 10 minimal if all arms branch only on first primibrachial; first branching isotomous; distal branching unknown. Tegmen and stem unknown.

Discussion—The cup of *Metaffinocrinus noblei* n. sp. is well preserved and has at least two associated primibrachials, one with the spine fractured, but preserved. The two other species of *Metaffinocrinus*, *M. dornickensis* (Strimple 1949) and *M. perundatus* (Moore and Plummer 1940), have more declivate radial facets and lack spines on the single primibrachial. In addition, *M. dornickensis* has a deeper basal concavity. Both *M. dornickensis* and *M. perundatus* are of Desmoinesian age. Thus, the stratigraphic range of *Metaffinocrinus* is extended upward into the Missourian or Virgilian, and the geographic range is extended into the intermontane basins of New Mexico.

Occurrence—Holotype UNM 6017, Madera Group (Missourian or Virgilian, locality 3).

Genus *SCIADIOCRINUS* Moore and Plummer 1938

SCIADIOCRINUS ORNATUS n. sp.
Figs. 7.20–7.22

Etymology—From the Latin, *ornamentum*, referring to the ornament.

Diagnosis—Distinguished by ornamentation of anastomosing low ridges.

Description—Cup discoid, length 7.3 mm, width 26.6 mm, deep basal concavity, ornamented with anastomosing low rounded ridges and gently impressed sutures. Infrabasals downflaring, not exposed in deep basal concavity. Basals 5, hexagonal, length 7.2 mm, width 7.8 mm, recurved, proximally downflaring, medially forming basal plane, distally upflaring forming part of cup wall, distal tips barely visible in lateral view, strongly convex longitudinally, slightly convex transversely; CD basal extended distally supporting primanal. Radials 5, pentagonal, much wider than long, length 8.4 mm, width 15.5 mm, gently convex transversely and longitudinally. Radial facets peneplenary, strongly declivate, width 13.2 mm, ratio facet width/radial width $13.2/15.5 = 0.85$; bear denticulate transverse ridge, narrow outer margin area, other facet details covered. Anals 3, menoplax 5 subcondition; primanal small, length 4.6 mm, width 2.2 mm, undercutting secundanal, in contact with C radial, CD basal, and supporting secundanal and tertanal (narrowly); secundanal larger, length 8.8 mm, width 4.4 mm, widest at radial summit, not in contact with CD basal. Tertanal proximal tip barely below radial summit. Arms and stem unknown.

Discussion—The partial cup of *Sciadiocrinus ornatus* n. sp. lacks the D radial and most of the E radial, the oral surface is mostly covered by matrix, and the basal cavity is crushed inward and mostly covered. The ornamentation is well preserved on all cup plates above the infrabasals including the anals. All other species of *Sciadiocrinus* have smooth plates lacking ornamentation except *S. plautus* Strimple (1975), which has granular ornamentation and may be the progenitor of *S. ornatus*.

Occurrence—Holotype NMMNH P-45612, Sandia Formation (late Atokan, locality 25).

SCIADIOCRINUS WIPSORUM Webster and Houck 1998
Figs. 7.14–7.16, 7.39–7.42, for synonymy see Webster (2003)

Discussion—Four partial and two complete cups are assigned to *Sciadiocrinus wipsorum* Webster and Houck (1998). In general they are well preserved and represent part of a growth series of intermediate to gerontic specimens. The small complete cup is 6.4 mm in length and 18.4 mm in width with a basal concavity of 1 mm depth. The largest complete cup is 7.3 mm in length and 25 mm in width with a basal cavity of 3 mm depth. The specimens have some variation in the inflation, or lack thereof, in the distal tips of the infrabasals, and in the degree of inflation of the basals, radials,

and anals. In addition, the distal tips of the infrabasals vary from subhorizontal to slightly downflaring. The three anals have variation in the length of the primanal/secundanal and primanal/tertanal sutures from very short to moderate length. The primanal is nearly separating the secundanal from contact with the CD basal. The holotype of *S. wipsorum* was the single specimen reported by Webster and Houck (1998). Thus, no variation was recognizable for the species at that time. The range of the species is extended downward into the late Atokan.

Occurrence—Six cups, figured specimens NMMNH P-45613 and P-45614, and four partial specimens in lot P-45615. Sandia Formation (late Atokan, locality 25).

PIRASOCRINIDS indeterminate

Discussion—Disarticulated ossicles of pirasocrinids are abundant at some localities in the Pennsylvanian strata of New Mexico. These plates are recognized by their thickness and spinose nature. Especially abundant are coarse spinose axillary brachials and the blade-shaped spines of the tegmen ring. Normally they cannot be identified to genus because of the similarity of these plates among different genera that are recognized on the morphology of the cup and arm branching patterns. Again they are listed for completeness and for providing some paleoenvironmental and paleoecologic information.

Locality 7: UNM 14,515. *Stenopocrinus?* sp.; radials, spinose axillary brachials, and tegmen spine fragments. Osha Canyon Formation (Morrowan).

Locality 8: UNM 14,503. *Stenopocrinus?* sp.; radials, spinose axillary brachials, and tegmen spine fragments, probably same taxon as 14,515. Osha Canyon Formation (Morrowan).

Locality 6: UNM 14,504. *Stenopocrinus?* sp.; radials, spinose axillary brachials, and tegmen spine fragments, probably same taxon as 14,515. Osha Canyon Formation (Morrowan).

Locality 5: UNM 14,513. Pirasocrinids indeterminate, possibly 3 genera, tegmen spines and spinose axillary brachials. Osha Canyon Formation (Morrowan).

Locality 5: UNM 14,548. *Stenopocrinus?* sp.; spinose axillary brachials, probably same taxon as UNM 14,515. Osha Canyon Formation (Morrowan).

Locality 19: UNM 14,523. *Eirmocrinus?* sp.; radials, spinose axillary primibrachials, spinose distal brachials, tegmen spines. Flechado Formation (Desmoinesian).

Locality 18: UNM 14,520. *Eirmocrinus?* sp.; basal, radial, spinose axillary primibrachial, distal brachials, and a tegmen spine, probably same taxon as UNM 14,523. Flechado Formation (Desmoinesian).

Locality 4: UNM 14,535. Pirasocrinid indeterminate; tegmen spines (3), 1 radial. Madera Group (Missourian or Virgilian).

Locality 4: UNM 14,540. Pirasocrinid indeterminate; 20 radials, 6 axillary spinose primibrachials, 8 tegmen spines; same taxon as UNM 14,535. Madera Group (Missourian or Virgilian).

Locality 1: UNM 14,542. Pirasocrinid indeterminate; 4 radials, 14 axillary spinose primibrachials, 10 tegmen plates (blade type). Upper white limestone, Jemez Springs Member, Madera Group (Virgilian).

Family INCERTAE SEDIS

Genus *MOUNDOCRINUS* Strimple 1939

MOUNDOCRINUS OSAGENSIS Strimple 1939

Figs. 7.17–7.19

Description—Partial crown slender, small, length 7.4 mm, width 9.3 mm (average). Cup medium bowl, length 4.8 mm, width 10.2 mm maximum, 8.4 mm minimum, 9.3 mm average, moderately deep basal concavity, plates smooth, sutures flush. Infrabasal circlet downflaring with deeply impressed stem facet, relatively large, diameter 3.1 mm. Infrabasals 5, dart shaped, visible length

1.1 mm, width 1.2 mm, proximally covered by columnals, medially downflaring, distally flaring laterally, do not reach base of cup. Basals 5, hexagonal, slightly wider (3.8 mm) than long (3.5 mm), proximally in basal concavity, medially recurved forming base of cup, distally upflaring forming approximately two-fifths of cup wall, transversely moderately convex, longitudinally strongly convex; CD basal slightly extended, truncated distally for anal attachment. Radials 5, pentagonal, wider (5 mm) than long (3 mm), gently convex longitudinally and transversely, gently outflaring. Radial facets plenary, subhorizontal, advanced type bearing transverse ridge, deep ligament pit, wide outer margin area, inner margin covered. Large single anal square, 2.5 mm length and width, distal end at radial summit, directly above CD basal, opioplx 2 subcondition. Primibrachials large, narrowing distally, straight longitudinally, strongly convex transversely. Remainder of arms unknown. Proximal columnals pentastellate, diameter 1.2 mm, short, with wide crenularium bearing coarse culmina; axial canal pentalobate.

Discussion—The partial crown of *Moundocrinus osagensis* is slightly distorted by fracturing with each of the preserved B to E primibrachials partly lost. The D primibrachial retains a small part of the distal facet on the right side. The facet bears short ridge denticulation along the outer margin, and the surface of the facet is sloping gently upward toward the center of the plate. This suggests that the primibrachial was axillary and bore two arms above the primibrachial. This is supported by the presence of a two-lobed ambulacral groove on the interior. Other primibrachials are broken off closer to the proximal ends and bear an ambulacral groove of only one lobe. If all arms branch on the single primibrachial there would be 10 arms minimally. Thus, we interpret this small specimen to represent a 10-armed cylindrical crown that may be an immature specimen.

Moundocrinus osagensis was originally described from the Missourian Stanton Limestone of Oklahoma (Strimple 1939). Thus, the occurrence in the Madera Group, may support a Missourian age for the questionable Missourian or Virgilian age currently assigned to the locality. Otherwise the stratigraphic range is extended upward into the Virgilian. The geographic range is extended into New Mexico.

Occurrence—Figured specimen UNM 14,498, Madera Group (Virgilian, locality 2)

CLADIDS indeterminate

Discussion—Most localities contain disarticulated echinoderm ossicles. Commonly they are unidentifiable to genus with exceptions where distinctive ornamentation or other morphologic characters may be of use. However, these specimens commonly give a more accurate relative number of the echinoderm fauna that is overlooked when reporting taxa based exclusively on the much rarer articulated cups and crowns. Loose ossicles are summarized and reported below.

Locality 8: UNM 14,518. Cladids indeterminate; radials and basals, minimum of five genera. Osha Canyon Formation (Morrowan).

Locality 5: UNM 14,511. Cladids indeterminate; radials, basals, and brachials, minimum of nine genera. Osha Canyon Formation (Morrowan).

Locality 25: NMMNH P-45619. Cladids indeterminate; radials, basals, brachials, and tegmen spines, minimum of five genera. Sandia Formation (late Atokan).

Locality 19: UNM 14,524. Cladids indeterminate; radials, basals, brachials, and columnals, minimum of three genera. Flechado Formation (Desmoinesian).

Locality 10: UNM 14,534. Indeterminate set of cladid arms and infrabasal circlet, and indeterminate crushed partial cup, possibly *Lecythocrinus sacculus*. Sol se Mete Member, Wild Cow Formation, Madera Group (Missourian).

Locality 4: UNM 6019. Cladids indeterminate; two axillary

brachials, one tegmen spine, possibly two genera. Madera Group (Missourian or Virgilian).

Locality 4: UNM 14,536. Cladid indeterminate; two radials, three basals, two brachials, two genera minimally. Madera Group (Missourian or Virgilian).

Locality 4: UNM 6023. Cladids indeterminate; six radials, two brachials, one tegmen spine, four genera minimally. Madera Group (Missourian or Virgilian).

Locality 4: UNM 6026. Many radials, basals, brachials, and a few infrabasal circlets, anals, and tegmen spines, four genera minimally. Madera Group (Missourian or Virgilian).

Locality 4: UNM 6032. Cladids indeterminate; seven radials, one basal, two brachials, five genera minimally. Madera Group (Missourian or Virgilian).

Locality 3: UNM 6033. Cladids indeterminate; radials, a basal, a primibrachial, two genera minimally. Madera Group (Missourian or Virgilian).

Locality 4: UNM 6034. Cladids indeterminate; radials, three genera. Madera Group (Missourian or Virgilian).

Locality 1: UNM 14,543. One infrabasal circlet, one basal, four radials, and five brachials, three genera minimally. Upper white limestone, Jemez Springs Member Madera Group (Virgilian).

Locality 21: UNM 14,549. Cladids indeterminate, minimum of three genera. La Casa Member, Wild Cow Formation, Madera Group (Virgilian).

Subclass FLEXIBILIA Zittel 1895
Order SAGENOCRINIDA Springer 1913
Superfamily SAGENOCRINACEA Roemer 1854
Family DACTYLOCRINIDAE Bather 1899

Genus *AEXITROPHOCRINUS* Strimple and Watkins 1969

AEXITROPHOCRINUS MINURAMULOSUS Strimple and Miller 1971

Figs. 8.1–8.2, for synonymy see Webster (2003)

Discussion—One fragmentary set of arms and four partial crowns are assigned to *Aexitrophocrinus minuramulosus* Strimple and Miller (1971), which was reported from Atokan–Desmoinesian boundary strata of the Pinkerton Trail Formation in Colorado. The Mora specimens are mostly flattened or still retain part of the curvature of the bowl-shaped cup and consist of the cup and proximal parts of the arms. The specimens show variation in the amount of exposure of the distal tips of the basals beyond the large stem facet. Only the distal-most tips of the basals are exposed in the smaller specimens, except for the CD basal that is extended for support of the primanal. The larger specimens have 1.3 mm to 2 mm of the distal tips of the basals extended beyond the stem facet.

Occurrence—Five specimens, figured specimens NMMNH P-45616, and P-45617, three others in lot P-45618, Sandia Formation (late Atokan, locality 25).

Family EUYOCRINIDAE Moore and Strimple 1973
Genus *PARAMPHICRINUS* Strimple and Moore 1971

PARAMPHICRINUS NOVAMEXICANUS n. sp.
Figs. 8.4–8.6

?*Paramphicrinus* sp. Strimple 1975, p. 704, pl. 1, figs. 10–12.

Etymology—From the Latin for New Mexico.

Diagnosis—Distinguished by the combination of variable number of tertibrachials, no collar around the stem, and fewer numbers of intertertibachials.

Description—Crown moderately large, wide-bowl-shaped, arms incurving distally, plates gently inflated. Cup discoid, proximally impressed with stem covering infrabasals and all except distal tip of some basals, distally upflaring. Distal tip of CD basal and one or more other basals extending beyond stem impression. Radials 5, septagonal, wider than long, with 2 proximal facets against basals

covered in stem impression, A radial wider than C and D radials. Radial facet plenary. Primanal hexagonal, adjoining 2 plates distally; anal series 1-2-2-2-?. First primibrachial hexagonal, axillary second primibrachial pentagonal. Three secundibrachials. Variable number of tertibrachials, 6 in B ray, 4 in C ray, and 5 in D ray. All brachials wider than long, becoming more equidimensional distally. Branching isotomous on second primibrachial and third secundibrachial. Heterotomous biendotomous branching on axillary tertibrachials. Arms free with second or third tertibrachial. Minimum 8 arms per ray. Interprimibrachial series 1-2-2-2-?. Intersecundibrachials 1 to 3 elongate plates. Single intertertibachial in some rays. Stem round, proximal columnals homeomorphic, very short. Crenularium narrow, culmina short, moderately coarse; areola wide, surface ornament finely granulate becoming coarsely vermiciform ridges next to pentalobate lumen. Measurements follow.

Measurements in millimeters of *Paramphicrinus novamexicanus* n. sp.

Type	Holotype	Paratype
Specimen length	41.7	
Specimen width	49.6	
Crown length	35.2 (incomplete)	11.2 (incomplete)
Crown width	49.6 (fractured)	32.3 (incomplete)
A radial length		2.9 (visible)
A radial width		5.6
C radial length	5.1 (visible)	2.5 (visible)
C radial width	5.7	5.2
D radial length		2.8 (visible)
D radial width		4.8
C ray first primibrachial length	4.5	
C ray first primibrachial width	4	
Primanal length	3.4	3.5
Primanal width	3	3.7
Length proximal stem	7	
Diameter proximal stem	7	7

Discussion—The holotype of *Paramphicrinus novamexicanus* n. sp. is a fractured partial crown with attached proximal stem and lacks the distal parts of the arms. The paratype is a well-preserved partial crown showing the gently inflated plates and lacks all parts of the arms beyond the second secundibrachials. The third specimen is a partial crown that is encrusted and lacks most of two rays and all parts of the other rays beyond the first or second secundibrachial. Variation is noted in the shape of the primanal with that of the holotype in contact with the C ray primibrachial and that of the paratype in contact with the D ray primibrachial. Also minor variation occurs in the number of interbrachial plates at various levels in the different interrays.

Paramphicrinus novamexicanus differs from *P. poundi* (Strimple 1939) by lacking the collar around the stem impression and differs from *P. magnus* Moore and Strimple (1973) and *P. oklahomaensis* (Strimple 1939) by having fewer numbers of interbrachial plates and differing numbers of tertibrachials. *Paramphicrinus* is reported from the Morrowan, Missourian, and Virgilian of the midcontinent. The occurrence of *P. novamexicanus* in the Desmoinesian and Missourian or Virgilian of New Mexico partially fills the stratigraphic range of the genus and extends the geographic range into the intermontane basins.

Occurrence—Holotype UNM 6024, upper part of Madera Group (Missourian or Virgilian, locality 4); paratype UNM 14,525, from the Los Moyos Limestone, Madera Group (Desmoinesian, locality 11); and specimen UNM 14,491, Los Moyos Limestone, Madera Group (Desmoinesian, locality 15).

PARAMPHICRINUS? sp.
Fig. 8.3

Discussion—A partial set of distal arms is questionably referred to *Paramphicrinus?* sp. Branching of the arms is probably endotomous.

Occurrence—Specimen UNM 14,537, upper part of Madera Group (Missourian or Virgilian, locality 4).

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Appendix 1

Crinoid associations found at each of the 26 localities.

Localities arranged in stratigraphic sequence from oldest to youngest for each of the Pennsylvanian epochs.

Morrowan taxa

Locality 5 (lower part of Osha Canyon Formation)

Pirasocrinid indet. (UNM 14,505); *Cromyocrinid* indet. [*Dicromyocrinus?* sp.] (UNM 14,510); *Cladids* indet. (minimum of nine genera) (UNM 14,511); *Synarmocrinus?* sp. (UNM 14,512); *Paragassizocrinus caliculus* (Moore and Plummer 1938) (UNM 14,506, 14,550); *Cromyocrinid* indet. (UNM 14,508); *Pirasocrinid* indet. (UNM 14,513, 14,548).

Locality 7 (middle part of Osha Canyon Formation)

Paragassizocrinus tarri (Strimple 1938) (UNM 14,500, 14,545); *Cromyocrinid* indet. (UNM 14,514); *Pirasocrinid* indet. [*Stenopecrinus?* sp.] (UNM 14,515).

Locality 6 (upper part of Osha Canyon Formation)

Pirasocrinid indet. (UNM 14,504); *Cladids* indet. (three genera) (UNM 14,516).

Locality 8 (upper part of Osha Canyon Formation)

Planacocrinus ambix Moore and Strimple 1969 (UNM 14,502); *Paragassizocrinus caliculus* (Moore and Plummer 1938) (UNM 14,517); *Pirasocrinid* indet. (UNM 14,503); *Cladid* indet. (UNM 14,518).

Locality 23 (La Pasada Formation)

Paragassizocrinus caliculus (Moore and Plummer 1938) (UNM 14,509; 14,551).

Atokan taxa

Locality 9 (Sandia Formation)

Metacromyocrinus? n. sp. (UNM 14,501).

Locality 17 (Flechado Formation)

Aaglaocrinus n. sp. undesignated (UNM 14,488); *Endelocrinus globularis* n. sp. (holotype, UNM 14,519).

Locality 25 (Sandia Formation)

Aaglaocrinus keytei (Strimple and Moore 1973) (NMMNH P-45576–45577); *Aaglaocrinus bowsheri* n. sp. (NMMNH P-45578–45583); *Goleocrinus chronici* n. sp. (NMMNH P-45584–45585); *Metacromyocrinus percultus* (Knapp 1969) n. comb. (NMMNH P-45586–45590); *Ulocrinus?* sp. (NMMNH P-45591); *Neoprotencrinus subplanus* (Moore and Plummer 1940) (NMMNH P-45592–45595); *Neoprotencrinus gutschicki* n. sp. (NMMNH P-45596–45606); *Eirmocrinus brevis* (Webster and Lane 1970) (NMMNH P-45607–45611); *Sciadiocrinus ornatus* n. sp. (NMMNH P-45612); *Sciadiocrinus wipsorum?* Webster and Houck 1998 (NMMNH 45613–45615); *Aexitrophocrinus minuramulosus* Strimple and Miller 1971 (NMMNH 45616–45618); *Cladids* indet. (minimum of five genera) (NMMNH P-45619).

Desmoinesian taxa

Locality 18 (Flechado Formation; early Desmoinesian)

Protencrinus mutabilis Knapp 1969 (UNM 14,489); *Cromyocrinid* indet. (UNM 14,495); *Pirasocrinid* indet. (UNM 14,520); *Cladid* indet. (UNM 14,521).

Locality 19 (Flechado Formation; early Desmoinesian)

Cromyocrinid indet. (UNM 14,494); *Protencrinus mutabilis* Knapp 1969, (UNM 14,522); *Pirasocrinid* indet. [*Eirmocrinus?* sp.] (UNM 14,523); *Cladids* indet. (minimum of three genera) (UNM 14,524).

Locality 11 (Los Moyos Limestone, Madera Group)

Ulocrinus manzanitaensis n. sp. (holotype, UNM 14,492); *Paramphicrinus novamexicanus* n. sp. (paratype, UNM 14,525)

Locality 12 (Los Moyos Limestone, Madera Group)

Metacromyocrinus cedroensis n. sp. (holotype, UNM 11,835); *Moscovicrinus?* *rotundobasis* n. sp. (UNM 14,490).

Locality 14 (Los Moyos Limestone, Madera Group)

Parethelocrinus watkinsi (Strimple 1949) (UNM 6747).

Locality 15 (Los Moyos Limestone, Madera Group)

Parethelocrinus watkinsi (Strimple 1949) (UNM 11,672); *Delocrinus* sp. (UNM 14,562); *Paramphicrinus novamexicanus* n. sp. (holotype, UNM 14,491); *Euerisocrinus tijerasensis* n. sp. (UNM 11,527); *Erisocrinid* indet. (UNM 14,528).

Locality 26 (Bug Scuffle Member, Gobbler Formation; late Desmoinesian)

Platycrinites nactus Bowsher and Strimple 1986 (NMMNH P-45622); *Exsulacrinus allenii* Bowsher and Strimple 1986 (NMMNH P-45623–45624); *Lecythiocrinus sacculus* Bowsher and Strimple 1986 (NMMNH P-45626–45627); *Parulocrinus globatus* Bowsher and Strimple 1986 (NMMNH P-45628); *Neoprotencrinus subplanus* (Moore and Plummer 1940) (NMMNH P-45629–45630); *Delocrinus* sp. (NMMNH P-45631); *Apographiocrinus decoratus* Moore and Plummer 1940 (NMMNH P-45632–45633).

Missourian taxa

Locality 10 (Sol se Mete Member, Wild Cow Formation, Madera Group)

Lecythiocrinus sacculus Bowsher and Strimple 1986 (UNM 14,493, 15,552); *Erisocrinus obovatus* (Moore and Plummer 1940) (UNM 14,529, 14,546); *Euerisocrinus gordoplatus* n. sp. (holotype, UNM 11,530); *Apographiocrinus typicalis* Moore and Plummer 1940 (UNM 14,531, 14,547); *Apographiocrinus rimosus* n. sp. (holotype, UNM 14,532); *Apographiocrinus kietzkei* n. sp. (holotype, UNM 14,533); *Cladid* indet. (UNM 14,534).

Missourian(?) taxa

Locality 13 (Madera Group)

Metacromyocrinus szaboi n. sp. (holotype, UNM 2499).

Locality 16 (Madera Group, unknown horizon)

Parethelocrinus? sp. (UNM 9358).

Missourian–Virgilian taxa

Locality 3 (upper part of Madera Group)

Metaffinocrinus noblei n. sp. (UNM 6017); *Cladids* indet. (minimum of two genera) (UNM 6033); *Ulocrinus sangamonensis* (Meek and Worthen 1860) (UNM 8140).

Locality 4 (upper part of Madera Group)

Cladid indet. (possibly two genera) (UNM 6019); *Cromyocrinid* indet. (UNM 6020); *Pirasocrinid* indet. (UNM 14,535); *Cladid* indet. (minimum of one genus) (UNM 14,536); *Paramphicrinus?* sp. (UNM 14,537); *Ulocrinus sangamonensis* (Meek and Worthen 1860) (UNM 6021, 6037); *Cladids* indet. (minimum of four genera) (UNM 6023); *Paramphicrinus novamexicanus* n. sp. (holotype, UNM 6024); *Cladids* indet. (minimum of four genera) (UNM 6026); *Cromyocrinid* indet. (UNM 14,538); *Elibatocrinus* sp. (UNM 14,539); *Pirasocrinid* indet. (UNM 14,540); *Cromyocrinid* indet. (UNM 6029); *Cladids* indet. (minimum of five genera) (UNM 6032); *Cladids* indet. (three genera) (UNM 6034); *Cromyocrinid* indet. (UNM 6035).

Virgilian taxa

Locality 1 (Upper white limestone bed, “Jemez Springs Shale Member,” Madera Group)

Elibatocrinus sp. (infrabasal plate) (UNM 14,486); *Cromyocrinid* indet. [*Ulocrinus?* sp.] (UNM 14,541); *Pirasocrinid* indet. (UNM 14,542); *Cladids* indet. (minimum of three genera) (UNM 14,543).

Locality 2 (“Jemez Springs Shale Member,” Madera Group)

Delocrinus subhemisphericus Moore and Plummer 1940 (UNM 14,497); *Delocrinus ponderosus* Strimple 1949 (UNM 14,544); *Moundocrinus osagensis* Strimple 1939 (UNM 14,498).

Locality 20 (Alamitos Formation)

Diphuicrinus borgesae n. sp. (holotype, UNM 14,487).

Locality 21 (La Casa Member, Wild Cow Formation, Madera Group)

Kallimorphocrinus bassleri Strimple 1938 (UNM 14,496); *Cladids* indet. (UNM 14,549).

Locality 22 (Alamitos Formation)

Cromyocrinid indet. and *cladids* indet. (10 genera minimally) (UNM 14,499).

Locality 24 (uppermost Atrasado Formation, Madera Group)

Delocrinus subhemisphericus Moore and Plummer 1940 (UNM 8108).

Appendix 2

Summary of stratigraphy, fauna, and depositional environments at the crinoid localities.

Localities 1–4, Jemez Springs area

Many crinoid remains from the Jemez Springs area are derived from an approximately 250-ft-thick sequence of the upper part (Missourian to middle Virgilian) of the Madera Group, which is nearly continuously exposed in the slopes along NM-4, from Jemez State Monument on the northern edge of Jemez Springs town, northward for approximately 6 mi. This sequence contains diverse lithologies, ranging from bioclastic marine limestone to brown, mollusc-rich shale and nonmarine red shale, all deposited relatively close to the Peñasco uplift to the west. The exact locality and/or stratigraphic position for many collections (see locality 4) are not known, but most collections were probably derived from strata immediately north of Jemez Monument, a well-known collecting area for many decades. Faunal diversity and abundance are high in some limestone beds (see Kues 1996 for paleontologic and stratigraphic information) that have characteristic stenohaline faunas. Some of the crinoid specimens have bioclastic limestone matrix associated with them, and it is interpreted that all or most of the crinoid taxa from these localities were living in shallow, agitated, nearshore, normal-marine environments.

Localities 5–8, Guadalupe Box

The Morrowan Osha Canyon Formation was described (DuChene et al. 1977) based on an 82-ft-thick type section in Guadalupe Box, on the east side of the Nacimiento Mountains, and the fauna is currently under study by BSK (e.g., Kues 2005). The lower part of the formation consists mainly of light-gray, locally almost coquina thin limestone beds; the middle part of the Osha Canyon is thin limestone beds separated by gray to maroon shale; and the upper part is a gray to greenish-gray sequence of shale with many nodular limestone beds. The fauna of the lower and middle limestones (localities 5, 7) includes more than 30 species of brachiopods (especially *Composita*, *Hustedia*, *Anthracospirifer*, *Punctospirifer*, *Sandia*, *Schizophoria*, *Desmoinesia*, and *Rhipidomella*) together, especially in the lower part, with bryozoans (e.g., *Prismopora*), several genera of tabulate corals, many crinoidal skeletal elements, and low numbers of solitary rugose corals and echinoid fragments. Molluscs are rare. This stenohaline assemblage reflects deposition in shallow normal-marine environments, above wave base.

The upper shaly part of the Osha Canyon is not well exposed at the type section (locality 6), but a roadcut (30 ft thick) approximately 4 mi north of Guadalupe Box (locality 8) yields a rich variety of brachiopods (26 species, of which approximately 60% of the specimens are *Neochonetes*, with *Punctospirifer*, *Hustedia*, *Anthracospirifer*, and *Parajuresania* moderately common). Solitary rugose corals are common, as are crinoid and echinoid fragments. Bivalves and gastropods, though uncommon, are more abundant than in the lower parts of the Osha Canyon Formation. Most of the fossils are derived from a few thin, argillaceous limestone beds in this mainly shale sequence, but many of the same brachiopods are present in both lithologies, as are crinoid remains. This locality is also known as a source of large edrioasteroids (Bell 1974; Sumrall and Bowsher 1996).

The fauna and lithology of the upper Osha Canyon indicate a change in depositional environments from those of the lower and middle parts. An influx of siliciclastic fine-grained sediments replaced shallow-marine carbonates, and these shales were deposited in quiet conditions, perhaps somewhat farther from the shoreline. The entire formation may represent a western arm of the narrow Morrowan seaway in which the La Pasada Formation was deposited around the southern end of the San Luis/Uncompahgre land mass (Santa Fe area).

A single crinoid specimen was also collected from a brachiopod-rich limestone in the overlying Sandia Formation, of Atokan age, above the Osha Canyon type section (locality 9).

Locality 10, Escabosa Quarry, Manzanita Mountains

Crinoids from the Sol se Mete Member, Wild Cow Formation (Madera Group) at Escabosa Quarry occur in a 13-ft-thick sequence of brown to gray, platy, argillaceous limestone and calcareous shale at the floor of the quarry. The Sol se Mete Member is Missourian in age (Myers 1973), and the fauna, studied by Kues (1985), is diverse and dominated by brachiopods, fenestrate and encrusting bryozoans, solitary rugose corals, and crinoid fragments. Some thin local horizons consist mainly of fragmented crinoid debris. Brachiopods (28 species) are by far the most abundant and diverse elements of this fauna, but 67% of the brachiopod specimens belong to only four genera (*Hystriculina*, *Chonetinella*, *Composita*, and *Neospirifer*). Gastropods and fusulinids are uncommon, and bivalves and trilobites are rare. Crinoid cups are unusually common, making up approximately 1% of the total identifiable macroinvertebrate specimens.

The predominance of stenohaline marine groups, fragmentation of delicate fossils such as fenestrate and ramose bryozoans and crinoids, the preponderance of massive and encrusting bryozoans, and the presence of thin beds of bioclastic shell debris all suggest that this assemblage lived a moderate distance offshore, in shallow water of normal-marine salinity, in an environment above wave base where skeletal elements were transported (Kues 1985).

Localities 11–16, Cedro Canyon, Manzanita Mountains

Beginning approximately 2 mi south of the town of Tijeras, and extending for approximately 4 mi along NM-337, the Desmoinesian Los Moyos Limestone, Madera Group (Myers 1973), crops out predominantly as a massive, cliff-forming, gray limestone, locally with thin calcareous shale and thin-bedded limestone intervals. The exact locality and stratigraphic position of some of the crinoids reported here (based on a master's thesis by Szabo 1953; localities 13–15) are not precisely known, but two faunas within the Los Moyos Limestone in this area have been studied. At a locality unusually rich in trilobites (locality 11) Kues (1982) documented a stenohaline marine fauna dominated by brachiopods (especially *Desmoinesia* and *Hustedia*), bryozoans (chiefly well preserved fenestrate fronds), crinoid stem fragments, and solitary rugose corals in a thin (2-ft-thick) horizon of dark gray, splintery, argillaceous limestone and dark-gray to brown calcareous siltstone. Molluscs are rare in this horizon. Kues interpreted the environment as quiet, moderately deep (below wave base), and possibly many kilometers from the shoreline.

A second assemblage (locality 12) was collected (Kues and Koubek 1991) from a thin (1.5-ft-thick) gray shaly interval within a roadcut of massive gray limestone that is 40–50 ft stratigraphically above the “trilobite locality” and is of late Desmoinesian age. Brachiopods (especially *Phricodothyris*, *Hustedia*, and *Punctospirifer*) dominate this assemblage, which also includes abundant bryozoans, crinoid stem fragments, solitary rugose corals, but few molluscs. This thin shale interval probably represents either a small-scale eustatic sea level change or a transitory influx of terrigenous siliciclastic material to a localized area of the carbonate shelf represented by the massive limestones above and below. This assemblage lived in a shallow, normal-marine environment on a muddy substrate influenced by a moderate level of agitation.

Localities 17–19, Taos area, Sangre de Cristo Mountains

Crinoids from the late Atokan to early Desmoinesian part of the Flechado Formation near Taos and Talpa are rare constituents of a mollusc-dominated fauna within a sequence of dark-gray shale and siltstone with minor argillaceous limestone and local beds of fan-delta channel sandstones. Most of this sequence represents shallow prodeltaic and interdistributary environments near the eastern shoreline of the Uncompahgre uplift. Gastropods are prolific and diverse, numbering more than 150 species (Kues and Batten 2001), and bivalves are abundant as well. Brachiopods (see

Sutherland and Harlow 1973) are moderately diverse but much less abundant than molluscs (Kues 2004b), and they tend to be limited to limy parts of the sequence, as are tabulate and solitary rugose corals and bryozoans.

Locality 20, Pecos

The single cup (*Diphuicrinus borgesae*, n. sp.) came from a thin (2-ft-thick) sequence of light-gray, locally bioclastic, massive to platy limestones in the upper part (Virgilian) of the Alamitos Formation at Sutherland and Harlow's (1973) section 98 (unit 3). This limestone bears a fauna of moderate diversity dominated by brachiopods, with less common solitary rugose corals, fenestrate and encrusting bryozoans, and crinoid stem fragments. Molluscs are rare. Of the 10 genera of brachiopods, *Composita* is by far the most abundant, followed by *Neospirifer*, *Wellerella*, and *Punctospirifer*. This is a normal-marine assemblage from a fairly nearshore, shallow carbonate environment above wave base. Beds above and below the limestone unit include nonmarine sandstones deposited around the southern margin of the Uncompahgre uplift.

Locality 21, Abo Pass, southern Manzano Mountains

This Virgilian assemblage from the La Casa Member, Wild Cow Formation (Madera Group) was derived from a thin unit of locally bioclastic, light greenish-gray, calcareous shale. Brachiopods and bryozoans, including fenestrate and unusually large (60-mm-diameter) mound-shaped forms, dominate this assemblage; solitary rugose corals and crinoid remains are moderately common, and molluscs are rare. Brachiopods are represented by at least 13 genera, of which *Composita*, *Punctospirifer*, *Hystriaculina*, *Neospirifer*, and *Neochonetes* are most common. This appears to be a normal-

marine assemblage from a shallow-marine environment above wave base.

Locality 22, Sapello, southeastern Sangre de Cristo Mountains

The small roadcut near Sapello consists of a 50-ft-thick sequence of orange-brown shale near the top of the Alamitos Formation, which is in fault contact with Desmoinesian strata along the roadcut. The Alamitos beds yield a Virgilian fauna (first reported by Baltz and Myers 1999) dominated by gastropods (e.g., *Pharkidonotus* and other bellerophonitoids, *Pseudozygopleura*, *Goniasma*) and bivalves, especially *Myalina* (*Orthomyalina*). Brachiopods (especially *Composita*, *Linoproductus* and other productoids, and *Isogramma*) are moderately common, as are orthocerid nautiloids, ramose bryozoans, and crinoid stem fragments. The abundance of molluscs, particularly bellerophonitoids and *M.* (*Orthomyalina*), and muddy substrate indicate quiet conditions very close to the shoreline, as influx of terrigenous siliciclastics was terminating marine deposition.

Locality 24, Carrizo Arroyo, Lucero uplift

The uppermost Atrasado Formation (Virgilian) in Carrizo Arroyo includes a 10-ft-thick limestone unit below the basal part of the Red Tanks Formation that is locally bioclastic and contains a stenohaline marine assemblage with brachiopods (e.g., *Neospirifer*, *Composita*, *Neochonetes*, and *Hystriaculina*), several groups of bryozoans, and crinoid debris. This limestone is within a sequence (studied by Kues 2004a) that includes marginal-marine and nonmarine siliciclastic units representing intensifying sedimentation from the Zuni uplift to the west.

Appendix 3

Locality register

Jemez Springs area, Jemez Mountains, Sandoval County, New Mexico

1. Upper white limestone bed, "Jemez Springs Shale Member," Madera Group (middle Virgilian), slopes west of NM-4, opposite entrance to Camp Shaver, 4.7 mi north of Jemez State Monument (UNM 14,486).
2. "Jemez Springs Shale Member," Madera Group (Virgilian), slopes just east of NM-4, approximately 0.3 mi north of Jemez State Monument (UNM 14,497, 14,498).
3. Upper part of Madera Group (Missourian-Virgilian), Church Canyon, just north of Jemez State Monument, east of NM-4 (UNM 6033, 8140).
4. Upper part of Madera Group (Missourian-Virgilian), "Jemez Springs area," probably mostly from slopes east of NM-4, between Jemez State Monument and Jemez Ranger Station (UNM 6019, 6020, 6023, 6024, 6026, 6027, 6029, 6032, 6034, 6035, 9358).

Guadalupe Box, east side of Nacimiento Mountains, Sandoval County, New Mexico

5. Lower part of Osha Canyon Formation (Morrowan), units 1-4 of type section (DuChene et al. 1977), Guadalupe Box (UNM 14,505, 14,506, 14,507, 14,508).
6. Upper part of Osha Canyon Formation (Morrowan), across arroyo just to west of type section, along jeep trail ("west hill locality"), Guadalupe Box (UNM 14,504).
7. Middle part of Osha Canyon Formation (Morrowan), same as #6 (UNM 14,500).
8. Upper part of Osha Canyon Formation (Morrowan), roadcut along U.S. Forest Road 376, approximately 4 mi north of Guadalupe Box (UNM 14,502, 14,503).
9. Sandia Formation (Atokan), above Osha Canyon type section, Guadalupe Box (UNM 14,501).

Cedro Canyon, Manzanita Mountains, Bernalillo County, New Mexico

10. Sol se Mete Member, Wild Cow Formation, Madera Group (Missourian), Escabosa Quarry, 1.5 mi south of village of Escabosa, just east of NM-337 (UNM 14,493 lot).
11. Los Moyos Limestone, Madera Group (Desmoinesian), roadcut just west of NM-337, 3.1 mi south of Tijeras ("trilobite locality"), NW¼ NW¼ sec. 2 T9N R5E (UNM 14,492).
12. Los Moyos Limestone, Madera Group (Desmoinesian), roadcut along west side of NM-337, 2.8 mi south of Tijeras, SW¼ SW¼ sec. 35 T10N R5E (UNM 11,835, 14,490).
13. Madera Group (Missourian?), Cedro Canyon, Tunnel Canyon, approximately 2.7 mi south of Tijeras, W¼ sec. 35 T10N R5E (UNM 2499).
14. Los Moyos Limestone, Madera Group (Desmoinesian), approximately 3 mi south of Tijeras, just east of NM-337, opposite locality 11 (UNM 6747).
15. Wild Cow Formation, Madera Group (Desmoinesian), Cedro Canyon, near NM-337, exact

- locality unknown, but probably 3–5 mi south of Tijeras (UNM 11,672, 14,491).
16. Madera Group, unknown horizon, Cedro Canyon, south of Tijeras (UNM 9358)

Taos area, Taos County, New Mexico

17. Flechado Formation (Atokan), slopes just north of US–64, near mouth of Taos Canyon, and just east of Taos, section 67, unit 9 of Sutherland and Harlow (1973) (UNM 14,488).
18. Flechado Formation (lower Desmoinesian), slopes just east of NM–518, approximately 1.5–2.5 mi south of Talpa (Northrop and Smith collections) (UNM 14,489, 14,495).
19. Flechado Formation (lower Desmoinesian), slopes just east of NM–518, approximately 2.5 mi south of Talpa (UNM 14,494).

Other localities

20. Alamitos Formation (Virgilian), north side of Pecos, San Miguel County, bluffs along south side of Pecos River, just west of NM–63; section 98, unit 3 of Sutherland and Harlow (1973) (UNM 14,487).
21. La Casa Member, Wild Cow Formation, Madera Group (Virgilian), roadcut on west side of US–60, 2.4 mi southeast of junction of US–60 and NM–47, just west of Abo Pass, Socorro County (UNM 14,496).
22. Alamitos Formation (Virgilian), roadcut on east side of NM–94, just north of its intersection with NM–266, 1 mi west of Sapello, San Miguel County (UNM 14,499).
23. La Pasada Formation (Morrowan), Santa Fe Quarry, Santa Fe; section 61, unit 11 of Sutherland and Harlow (1973) (UNM 14,509).
24. Uppermost Atrasado Formation, Madera Group (upper Virgilian), Carrizo Arroyo, Lucero uplift, NW¼ sec. 7 T6N R2W, Valencia County (UNM 8108).
25. Sandia Formation, Desmoinesian; 3-m-thick dark-gray to black crossbedded siltstone with abundant crinoidal debris in meander bend of narrow canyon of dry creek bed just north of spring, approximately 1 km north of NM–518 (N35° 58' 10" latitude, W105° 16' 46" longitude; NMMNH P-45576–P-45619).
26. Gobbler Formation, Bug Scuffle Member, Desmoinesian; Gray to black shale on north wall of dry wash, exposed in and along old ranch road dropping into canyon on north side of junior college on northeast corner of Alamogordo (NW¼ sec. 9 T16S R10E) and on the flat 50 m north of canyon along the old road where it was being covered by a housing development (NMMNH P-45622–P-45633).

FIGURE 4—Pennsylvanian camerate, disparid, and cladid crinoids.

- 1–4, *Moscovocrinus? rotundobasis* n. sp., oral, A ray, posterior, and basal views of cup, UNM 14,490, X4.
- 5–8, *Lecythiocrinus sacculus*, oral, A ray, posterior (anal opening obscured by matrix), and basal views of cup, UNM 14,493, X1.5.
- 9–12, *Kallimorphocrinus bassleri*, oral, A ray, posterior, and basal views of cup, UNM 14,496, X4.
- 13–14, *Paragassizocrinus caliculus*, oral and lateral views of infrabasal circler, UNM 14,506, X2.
- 15–16, *Paragassizocrinus tarri*, oral and lateral views of infrabasal circler, UNM 14,500, X2.
- 17–18, *Paragassizocrinus caliculus*, oral and lateral views of infrabasal circler, UNM 14,509, X2.
- 19–21, *Planacocrinus ambix*, A ray, posterior and basal views of calyx, UNM 14,502, X5.
- 22–24, *Delocrinus subhemisphericus*, oral, posterior, and basal views of partial cup, UNM 8108, X2.
- 25–28, *Endelocrinus globularus* n. sp., oral, E ray, posterior, and basal views of holotype, UNM 14,519, X4.
- 29–32, Erisocrinid indeterminate, oral, A ray, posterior, and basal views of cup, UNM 14,528, X2.
- 33–36, *Lecythiocrinus sacculus*, B ray, DE interray (anal opening to upper right), oblique DE interray, and enlargement of DE interray views of crushed cup, NMMNH P-45626, X2, enlargement X6.
- 37–38, *Elibatocrinus* sp., lateral and basal views of infrabasal circler and attached proximal columnal, UNM 14,539, X2.
- 39–41, *Erisocrinus obovatus*, A ray, posterior, and basal views of cup, UNM 14,529, X4.
- 42–44, *Euerisocrinus tijerasensis* n. sp., A ray, posterior, and basal views of holotype, UNM 14,527, X4.

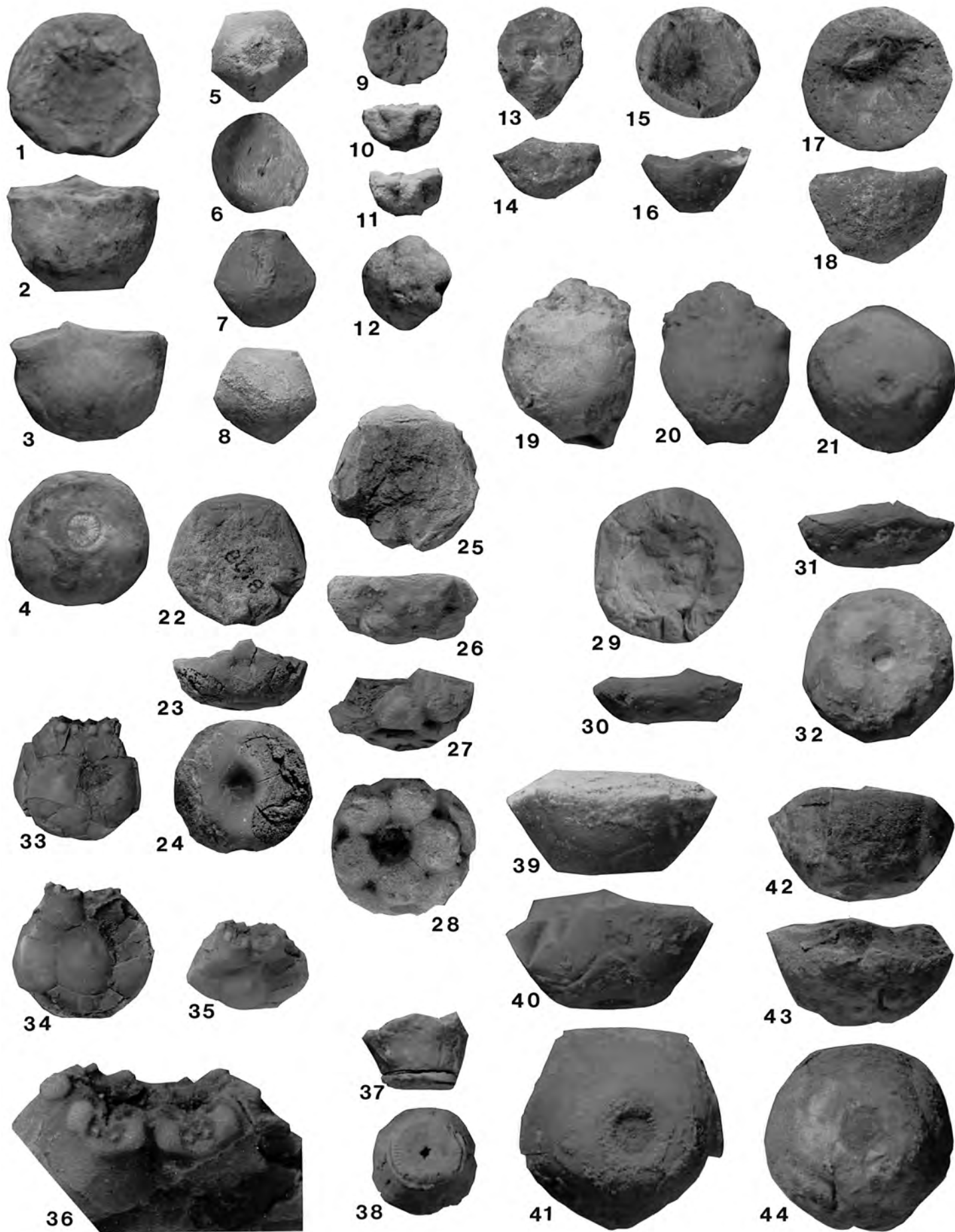


FIGURE 5—Pennsylvanian cromyocrinids.

- 1–4, *Metacromyocrinus cedroensis* n. sp., oral, A ray, posterior, and basal views of holotype, UNM 11,835, X1.5.
- 5–8, *Ulocrinus manzanitaensis* n. sp., oral, A ray, posterior, and basal views of holotype, UNM 14,492, X1.5.
- 9–12, *Ulocrinus sangamonensis*, oral, A ray, posterior, and basal views of cup, UNM 8140, X2.
- 13–16, *Goleocrinus chronici* n. sp., oral, A ray, posterior, and basal views of holotype, NMMNH P-45584, X1.
- 17–20, *Diphuicrinus borgesae* n. sp., oral, A ray, posterior, and basal views of holotype, UNM 14,487, X1.5.
- 21–24, *Parulocrinus globatus*, A ray, posterior, and basal views of cup, NMMNH P-45628, X1.5.
- 25–26, *Metacromyocrinus?* n. sp. undesignated, D ray and basal views of cup, UNM 14,501, X1.5.
- 27–29, *Goleocrinus chronici* n. sp., A ray, basal, and posterior views of paratype, NMMNH P-45585, X1.5.
- 30, *Ulocrinus* sp., basal view of infrabasal circlet and proximal columnals, NMMNH P-45591, X1.5.
- 31, *Parethelocrinus* sp., AE interray view of crown, UNM 9358, X1.4.
- 32–34, *Parethelocrinus watkinsi*, C ray, posterior, and basal views of cup, UNM 11,672, X1.25.
- 35–38, *Aaglaocrinus keytei* n. sp., oral, A ray, posterior, and basal views of holotype, NMMNH P-45576, X2.
- 39–42, *Ulocrinus sangamonensis*, oral, B ray, posterior, and basal views of partial cup, UNM 6021, X1

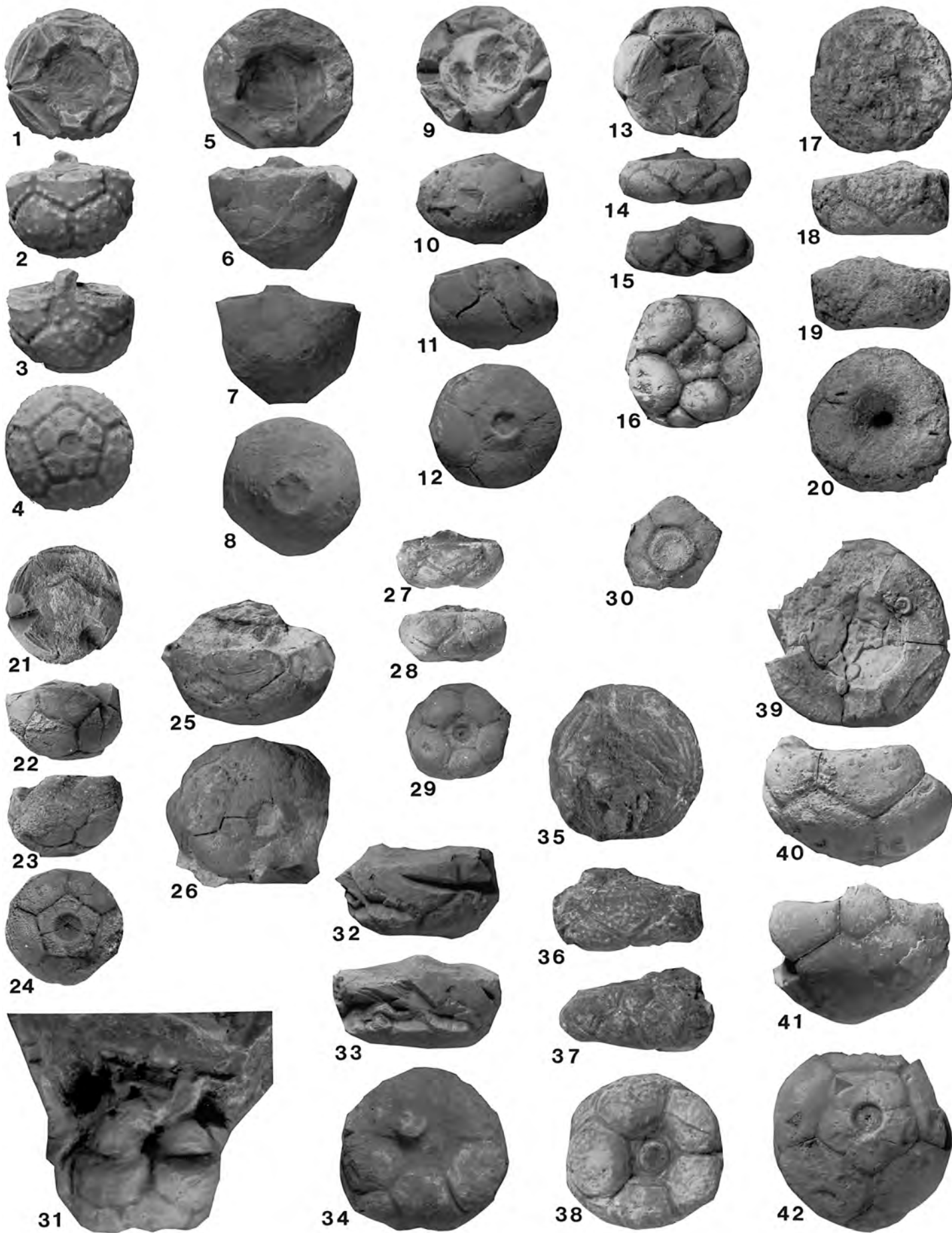


FIGURE 6—Pennsylvanian erisocrinids and pirasocrinids.

- 1–3, *Apographiocrinus kietzkei* n. sp., E ray, posterior, and basal views of holotype, UNM 14,533, X2.
4–6, *Neoprotencrinus gutschicki* n. sp., oral, A ray, and basal views of paratype 1, NMMNH P-45597, X2.
7–10, *Apographiocrinus decoratus*, oral, A ray, posterior, and basal views of cup, NMMNH P-45632, X2.
11–14, *Protencrinus mutabilis*, oral, A ray, posterior, and basal views of cup, UNM 14,489, X1.5.
15–17, *Apographiocrinus typicalis*, oral, A ray, and basal views of cup, UNM 14,531, X4.
18–20, *Neoprotencrinus gutschicki* n. sp., oral, A ray, and basal views of holotype, NMMNH P-45596, X2.
21–23, *Delocrinus ponderosus*, A ray, posterior, and basal views of partial cup, UNM 14,544, X2.
24–26, *Euerisocrinus gordoplatus* n. sp., A ray, posterior, and basal views of holotype, UNM 14,530, X4.
27–30, *Neoprotencrinus subplanus*, oral, A ray, posterior, and basal views of cup, NMMNH P-45629, X2.
31–32, *Apographiocrinus rimosus* n. sp., B ray and basal views of holotype, UNM 14,532, X4.
33–34, *Neoprotencrinus gutschicki* n. sp., A ray and basal views of paratype 2, NMMNH P-45598, X2.
35–36, *Neoprotencrinus subplanus*, A ray and basal views of cup, NMMNH P-45592, X2.
37–39, *Metaffinocrinus noblei* n. sp., A ray, posterior (inverted), and basal views of holotype UNM 6017, X1.6.

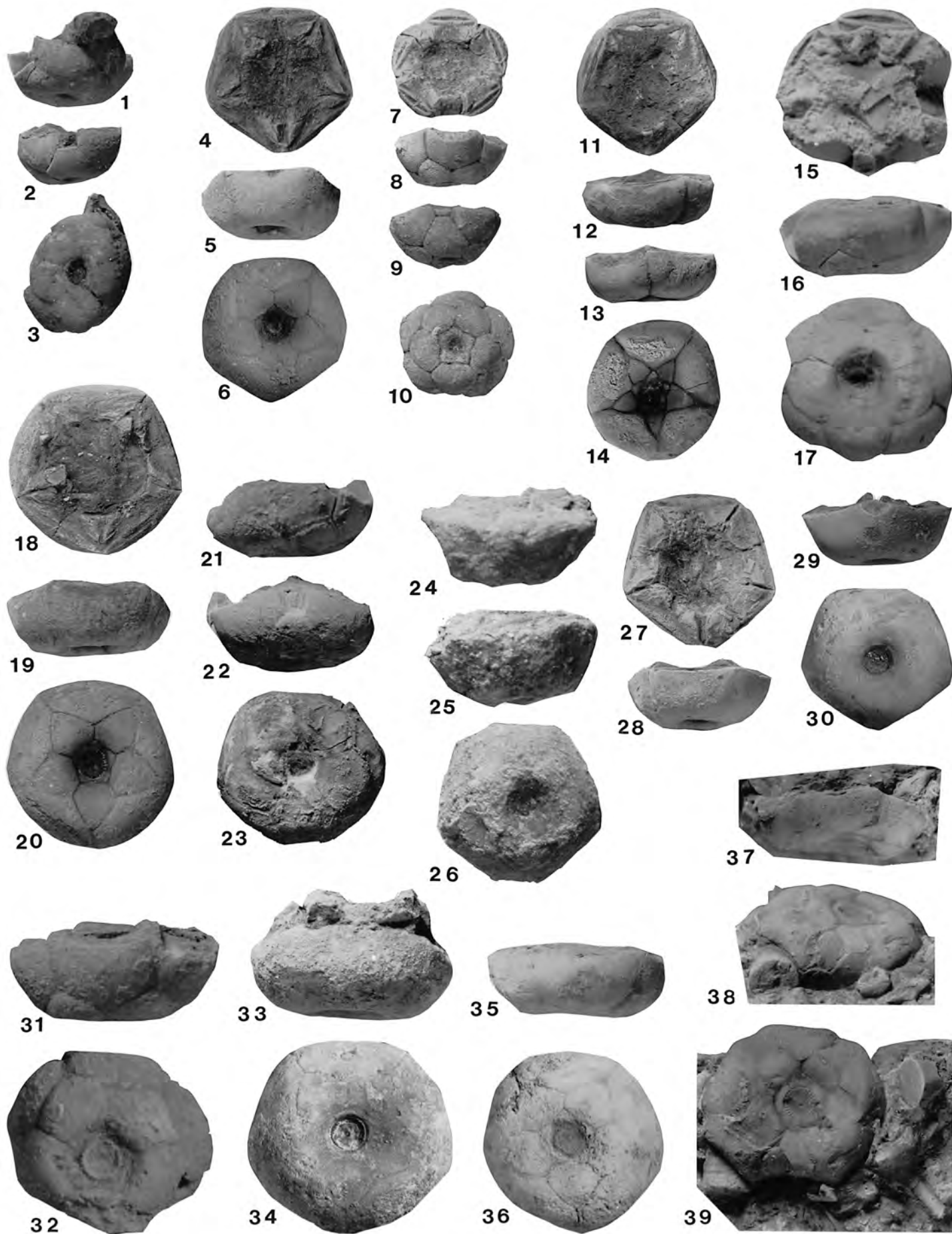


FIGURE 7—Pennsylvanian cromyocrinids and pirasocrinids.

1–10, *Aaglaocrinus bowsheri* n. sp.:

1–3, A ray, posterior, and basal views of paratype 2, NMMNH P-45580, X0.7;

4–7, oral, A ray, posterior, and basal views of paratype 1, NMMNH P-45579, X0.7;

8–10, A ray, posterior, and basal views of holotype, NMMNH P-45578, X0.7.

11–13, *Aaglaocrinus* n. sp. undesignated, basal, posterior, and C ray views of partial cup, UNM 14,488, X1.5.

14–16, *Sciadiocrinus wipsorum*, A ray, posterior, and basal views of cup, NMMNH P-45614, X1.

17–19, *Moundocrinus osagensis*, A ray, posterior, and basal views of cup, UNM 14,498, X2.

20–22, *Sciadiocrinus ornatus* n. sp., B ray, posterior, and basal views of holotype NMMNH P-45612, X1.

23–29, *Eirmocrinus brewi*:

23–25, A ray, posterior, and basal views of cup, NMMNH P-45607, X1;

26–29, A ray, oral, posterior, and basal views of cup, NMMNH P-45608, X1.

30–33, *Metacromyocrinus szaboi* n. sp., oral, A ray, posterior, and basal views of holotype, UNM 2499, X1.1.

34–38, *Metacromyocrinus percultus* n. comb.:

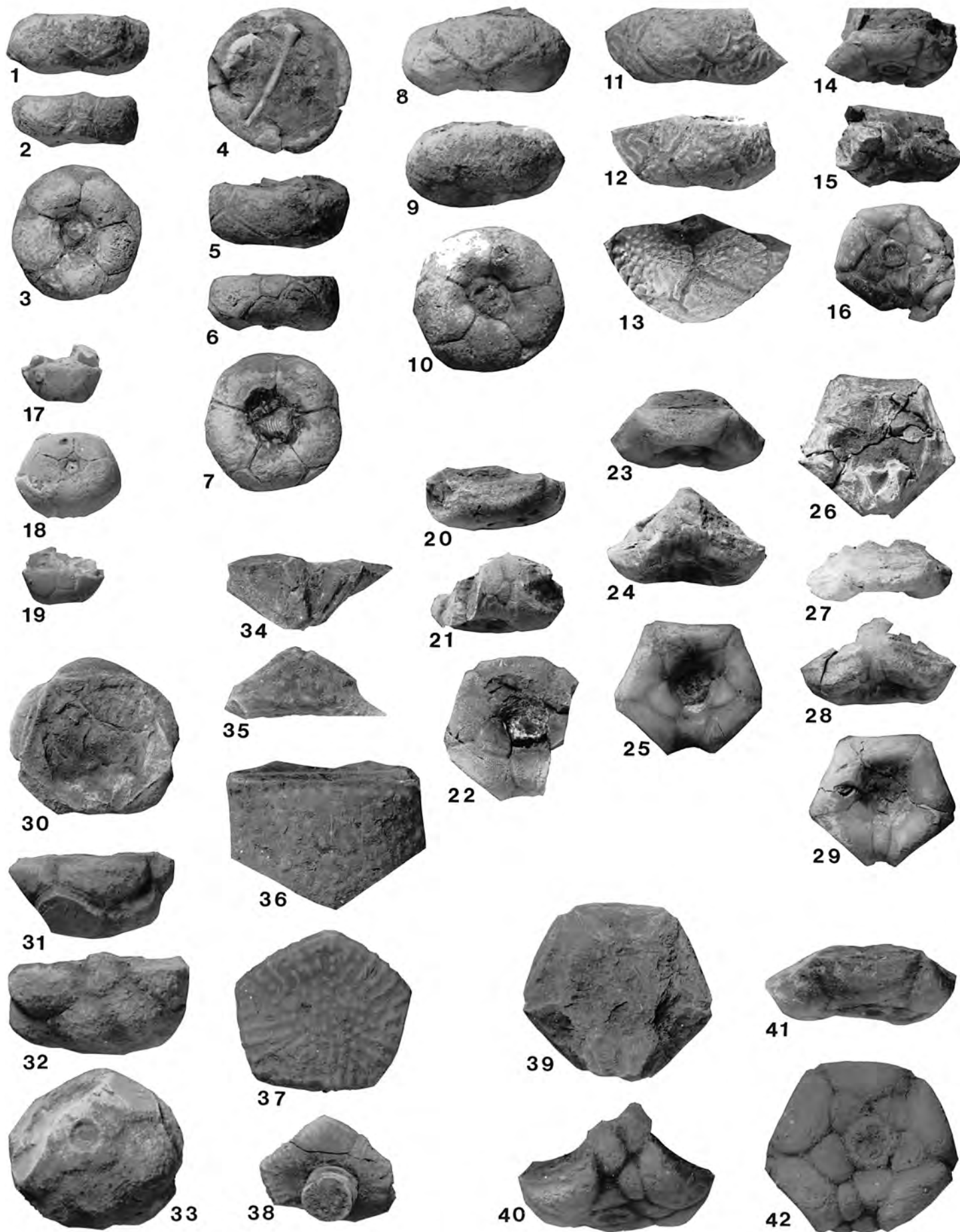
34, basal view of infrabasal circlet and proximal columnals, NMMNH P-45586, X1;

35, lateral view of basal plate, NMMNH P-45587, X1.5;

36, lateral view of radial plate, NMMNH P-45588, X1.5;

37–38, lateral and oral views of axillary primibrachial, NMMNH P-45589, X1.5.

39–42, *Sciadiocrinus wipsorum*, A ray, oral, posterior, and basal view of cup, NMMNH P-45613, X2.



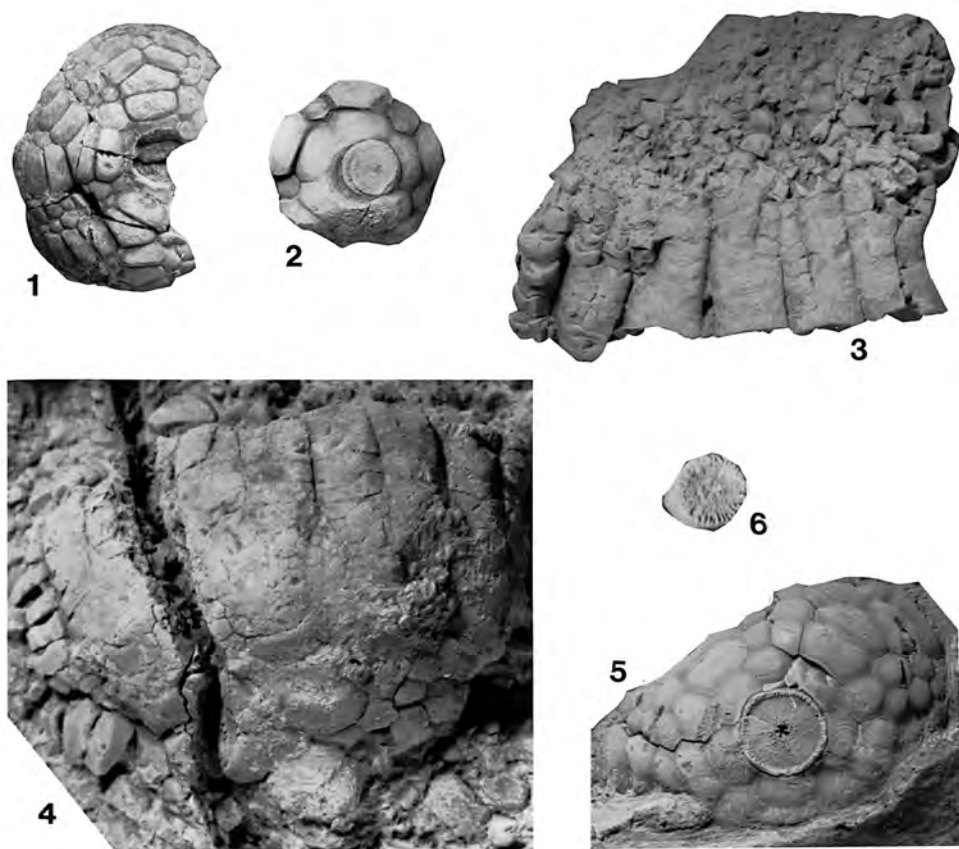


FIGURE 8—Pennsylvanian flexible crinoids.

1–2, *Aexitrophocrinus minuramulosus*:

1, basal view of partial crown NMMNH 45617, X1;

2, basal view of partial crown with attached proximal columnals, NMMNH P-45616, X1.

3, *Paramphicrinus?* sp., lateral view of partial set of arms, UNM 14,537, X1.5.

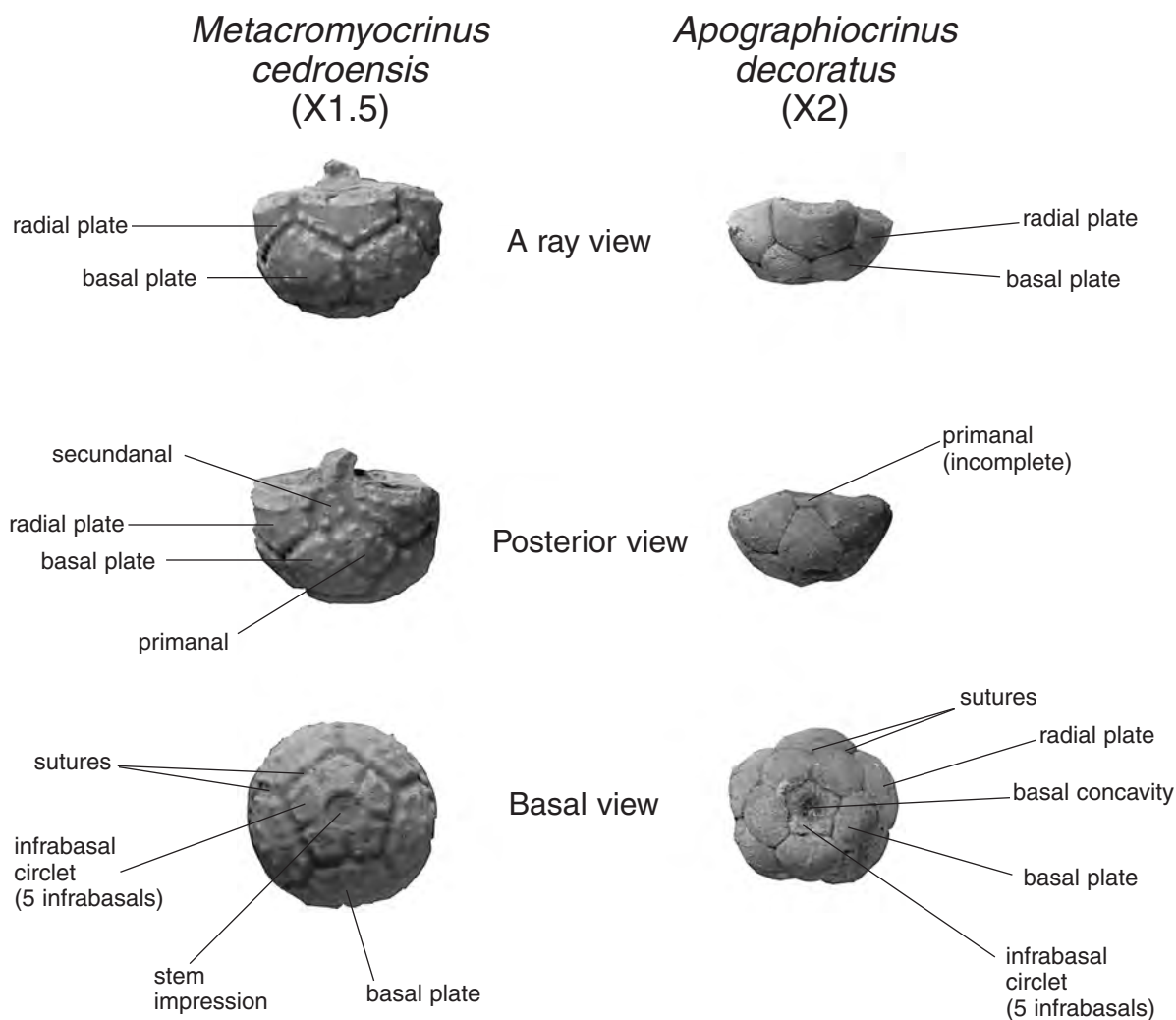
4–6, *Paramphicrinus novamexicanus* n. sp.:

4, lateral view of crown, UNM 6024, X1.5;

5–6, basal view of partial crown and associated columnal, UNM 14,525, X1.5

Gallery of Geology

Fossil crinoid structural features



The views are from "Pennsylvanian crinoids of New Mexico," this issue. *Metacromyocrinus cedroensis* views are from Figures 5.2–5.4. *Apographiocrinus decoratus* views are from Figures 6.8–6.10.