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The molluscan and brachiopod fauna of the Late Cretaceous Pierre Shale (Baculites compressus/Baculites cuneatus biozones) near Kremmling, Colorado

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The Molluscan and Brachiopod Fauna of the Late Cretaceous Pierre Shale (*Baculites compressus/Baculites cuneatus* biozones) near Kremmling, Colorado

by

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A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science
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Every journey begins with a simple plan – to travel along our path until we reach the destination. Along the way we may come across fellow travelers, maps and sometimes sideroads or shortcuts that influence the direction and outcome of our travels. The journey that became this paper began at the suggestion of Dr. Peter Harries who not only set my feet on this path, but provided direction along the way. The faculty, staff and fellow students of the USF Department of Geology offered encouragement whenever the road took a turn and the destination looked far distant.

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To everyone who said “Hang in there - you can do it” I now say a very sincere Thank You. This work is dedicated to you.
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This manuscript, while compiled by one, is really the work of many scientists who have studied the Western Interior region and laid the groundwork for this study as well as those who personally shared their knowledge to enhance the quality of the work presented here.
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The Molluscan and Brachiopod Fauna of the Late Cretaceous Pierre Shale 
(*Baculites compressus*/Baculites cuneatus* biozones) near Kremmling, Colorado

Lanora Ann Sava

ABSTRACT

The Kremmling Paleontological Resource Area (KPRA) contains one of the most fossiliferous units within the Late Cretaceous Western Interior Seaway of North America. It was deposited during the late Campanian *Baculites compressus/cuneatus* ammonite biozones (≈72.5 Ma) and records slightly less than one million years of depositional history. Examination of the fauna, its dominant preservational mode and taphonomy as well as the lithologic evidence from measured stratigraphic sections strongly suggests that the depositional environment of the KPRA was a shallow, relatively nearshore environment. A detailed taxonomic examination of the molluscan fauna was undertaken in order to re-evaluate past work as well as to more thoroughly document the fauna. Samples were collected from 79 locations within the ≈1 km² study area.

The molluscan fauna from the KPRA consists of 47 bivalve, 22 gastropod, and 13 cephalopod species; ten of these species are new. In addition, two inarticulate brachiopods and one serpulid are described. This highly diverse assemblage points to an increase in nearshore diversity as compared to faunas described from earlier intervals with similar environmental settings. The timing of this increase in species richness remains elusive, but may have initiated in the late Campanian and continued into the early Maastrichtian.
Introduction

The geology of the Western Interior Seaway (WIS) has been studied extensively since the first of the U.S. Geological Survey expeditions into the region during the mid to late 1800’s. These expeditions recognized and mapped many of the Cretaceous deposits throughout the region (the Hayden Survey of 1876, the Wheeler survey published in 1889). The description of the biota contained in these units also was begun at this time. Further refinement of both the stratigraphy as well as description of the biota has continued. The extent of the deposits left by this shallow inland seaway, exposed through periods of Cenozoic uplift, have provided researchers with unparalleled stratigraphic exposures for investigations of Cretaceous faunas – mostly marine – as well as opportunities to study the paleogeography, paleoclimate and paleoceanography of the Late Cretaceous of west-central North America.

The Pierre Shale in the area surrounding Kremmling, Colorado is approximately 1500 m thick and widespread with numerous outcrops that have been studied and mapped by researchers who noted the fossiliferous nature of the outcrops and described elements of the fauna they contained (Izett et al., 1971; Wolfe and Kirkland, 1986). However, the fauna from the region has not been described systematically.

The primary thrust of this study is an outcrop to the north of the city of Kremmling that falls within the late late Campanian *Baculites compressus/Baculites cuneatus* biozones. This outcrop is less than 1 km² and has been designated a Research Natural Area overseen by the Bureau of Land Management (BLM). The site is well known for the large ammonite specimens of *Placenticeras meeki* that can be found in the concretions at the top of the ridge, and is popularly known as the “Giant Ammonite Site” or the “Birdbath Ammonite Site” (so called because the molds of the large placenticerid ammonites hold water after a rain). Officially, it is known as the Kremmling Paleontological Resource Area (KPRA). Examination and description of the fauna of this portion of the Pierre Shale from this locality is of interest because of its nearshore setting. The deposits of such a setting are relatively scarce in the stratigraphic record because they are often eroded away when a drop in sea level exposes them. Furthermore, it will add additional data to the already extensive knowledge of the WIS and provide a foundation for further studies of paleoclimate, paleogeography and species richness and assemblages.

Purpose

This study was undertaken with the intent of investigating the marine molluscan faunal diversity at the KPRA. The site is renowned for the large placenticerids found in abundance within one the exposed concretionary layers, but it also has a diverse macrofauna that has not been the subject of a detailed taxonomic assessment.

Faunal studies of Cretaceous deposits both older and younger than the one at the KPRA have been done from surrounding regions and strata. For example, Kirkland’s (1996) study of the Cenomanian-Turonian fauna of the Greenhorn Cyclothem in and around Black Mesa and Speden’s (1971) study of the systematics of the Bivalvia of the Fox Hills Formation at its type locality are two of the most comprehensive studies from
the WIS. The fauna of these two studies pre- and postdate, respectively, the fauna described here, although both have several species in common with those described from the KPRA, despite the different ages. In addition, Stephenson’s (1941) study “The Larger Invertebrate Fossils of the Navarro Group of Texas (Exclusive of Corals and Crustaceans and Exclusive of the Fauna of the Escondido Formation” has the greatest similarity with the KPRA’s fauna. Together, these studies will supply researchers with valuable tools for studies concerning conditions, connections and changes in the WIS during the late Cretaceous.

The Western Interior Seaway of North America

During the Late Cretaceous much of west-central North America was covered by an epicontinental sea: the Western Interior Seaway (WIS). The WIS was created by the flooding of a large, relatively shallow foreland basin formed by isostatic loading associated with the Sevier Orogeny to the west (Armstrong, 1968). Although the early precursors of this shallow seaway flooded the northern portions of the basin in the Valanginian, it did not flood sufficiently to connect the northern and southern portions of the seaway until the Albian (Caldwell & Kauffman, 1993). The WIS persisted through a number of transgressive-regressive cycles culminating with the Paleocene Cannonball Sea (Caldwell & Kauffman, 1993) after which it permanently retreated from the continental interior. At its maximum extent, the WIS spanned from northern Canada to Central Mexico, connecting the Boreal Sea with the equatorial Tethys, a distance of more than 4800 km. Along an east-west transect, it extended from northeastern Nevada and southwestern Utah at the western margin to greater than 1600 km eastward and northeastward into southwestern Minnesota and Iowa (Kaufmann, 1977). In some areas of eastern Minnesota and Iowa, Cenomanian (early Late Cretaceous) outcrops are of normal-marine, shallow-water origin, suggesting that the basin periodically extended as far as the current Mississippi Valley (Kaufmann, 1977). However, the exact position of the eastern shore of the WIS is obscured by post-Cretaceous erosion (Izett et al., 1971).

Most sediment accumulated in this seaway appears to have originated from the west where the WIS was bordered by a structurally active orogenic belt. To the east, the WIS was bordered by the flat, stable cratonic interior of the continent, consequently receiving limited sediment input from the east (Figure 1) (Izett et al., 1971).
The Pierre Shale

The Pierre Shale consists of deposits of sand, silt and clay representing sedimentation in the deepest parts of the WIS during the Bearpaw and Clagett cyclothsms (Izett et al., 1971). Deposition of the Pierre Shale commenced in the Early Campanian and persisted until the Early Maastrichtian – a period of approximately 12 million years. Up to 3000 m of fine-grained sediment were deposited during this time (Figure 2) (Izett et al., 1971). During Laramide deformation much of the upper portions of the Pierre were removed through erosional processes (Izett et al., 1971). Along the
western margin of the WIS, shallow-marine to non-marine sediments form thick clastic wedges that thin and pinch out towards the east and intertongue with wedges of Pierre Shale – named separately as the Mancos Shale and the Lewis Shale – which are fine grained, more distal marine deposits. The sequence of marine shales and sandstones, such as the Carter and Hygiene Sandstones, beyond the eastern extent of these intertongued deposits is known collectively as the Pierre Shale and extends as far east as western Kansas (Figure 3).
Figure 3. Correlations of the Pierre Shale to the east and west of Kremmling, Colorado. KPRA is shown by box. (Edited from Izett et al., 1971)

The Pierre Shale near Kremmling, Colorado

Since it was first studied and mapped by Marvine in 1874 during one of the Hayden Surveys, the Pierre Shale near Kremmling has been known for its abundance of well-preserved fossils. Marvine (1874) associated these outcrops of marine shale with outcrops of the Cretaceous Pierre Shale of the Great Plains area. From the 1940’s to the late 1960’s, the Pierre Shale near Kremmling was studied in greater depth. Near Kremmling the Pierre Shale has been correlated with the Pierre Shale east of the Front Range, Colorado based on fossil evidence (Izett et al., 1971). Maps of the Pierre Shale surrounding Kremmling were created by Hail (1968) and Izett (1968) and show the extent of the Pierre outcrops in the region (Figure 4) (Izett et al., 1971). Deposits of Pierre Shale at the KPRA are dominantly sandy to silty shales with discrete horizons containing fossiliferous concretions or relatively nearshore sandstones. The thickness of the Pierre in this region is approximately 1500 m and is often divided into three sequences for ease of correlation and understanding (Izett et al., 1971).

The lower sequence is dominantly dark-gray to black marine shale and spans the *Baculites sp.* (identified by weak flank ribs) through *B. asperiformis* ammonite biozones. This section is approximately 460 m thick and includes the Sharon Springs Member, recognized by numerous bentonites. The Sharon Springs Member occurs approximately 335 m above the base of the lower member and is ≈ 14 m thick (Figure 3) (Izett et al., 1971). The middle sequence is approximately 1000 m thick and consists of alternating layers of sandy shale and sandstone. The sandstone layers are correlative to the
Mesaverde Group of northwestern Colorado. Izett et al. (1971) included the Kremmling, the Muddy Buttes, the Hygiene, and the Carter sandstones, as well as the Gunsight Pass Members, and several unnamed shale members as part of this section (Figure 3). The upper sequence consists of homogeneous dark marine shale with abundant limestone concretions. It is estimated to have been several thousand meters thick originally, but only about 60 m remain after uplift and erosion during the latest Cretaceous-Cenozoic Laramide Orogeny and subsequent post-Miocene orogenic rejuvenation (Izett et al., 1971).

Gu, Gunsight Pass Member, upper sandstone part
Gl, Gunsight Pass Member, lower sandstone part
C, Carter Sandstone Member
H, Hygiene Sandstone Member
M, Muddy Buttes Sandstone Member
K, Kremmling Sandstone Member
cz, concretion zone (Zones of Baculites compressus and B. cuneatus)

Figure 4. Distribution of the Pierre Shale near Kremmling, Colorado. Approximate location of KPRA shown. (edited from Izett et al., 1971)
The Kremmling Paleontological Resource Area

Of specific interest to this study is an unnamed shale member that occurs between the Carter Sandstone Member and the Gunsight Pass Member within the middle sequence discussed above. This unit, much of which is poorly exposed, is approximately 275 m thick and spans the *Baculites crickmayi* through *Baculites jenseni* ammonite biozones (Izett et al., 1971). The lower 115 m consists dominantly of poorly indurated, silty and sandy shale with occasional concretions that yield the index fossils *B. crickmayi*, and *Didymoceras stevensoni*.

Approximately 116 m above the top of the Carter Sandstone, is the most fossiliferous unit of the Pierre Shale in the Kremmling area and the focus of this study: the KPRA. This fossiliferous interval is well exposed north of Kremmling, Grand County, Colorado off Highway 40 (Figure 4). The Pierre Shale exposed at the KPRA is a silty shale interval containing calcite-cemented concretions that occur in discrete horizons. These concretions yield the vast majority of the well-preserved specimens of *B. compressus* Say, *Baculites* sp., *Placenticeras meeki* Böhm and several other ammonite species, as well as numerous other taxa (Izett et al., 1971). Work done by Wolfe and Kirkland (1986) outlined the stratigraphy of the KPRA by subdividing the section into 35 stratigraphic units. All the following descriptions are condensed from Wolfe and Kirkland (1986) except where otherwise noted.

The lowest zone is approximately 7 m thick (units 1-10) and is dominantly olive-gray, slightly sandy mudstone which coarsens upward into almost 1 m of argillaceous bioturbated sandstone with poorly preserved mollusks and undulating bedding. Calcareous concretion-rich horizons are common throughout this section. Unit 4 is a concretion horizon that yields numerous *Pseudopteria* as well as other diverse faunal elements. Units 6, 8 and 10 show a less diverse fauna, but large specimens of *Inoceramus sagensis* (as identified by Wolfe and Kirkland, likely is not “l” sagensis) and *Baculites compressus* are dominant.

Unit 11 is a barren concretion horizon overlain by 13 m of soft, olive-gray argillaceous sandstone and sandy mudstone designated Unit 12. Unit 12 lacks concretions but does contain scattered poorly preserved specimens of *I. sagensis* (identified by Wolfe and Kirkland, likely not “l” sagensis) and *Placenticeras* sp.

Unit 13 is the first significant marker bed identified at this site. The layer is a bioturbated sandstone that is green-stained and ≈65 cm thick. Faunal components of this layer include inoceramid bivalves and a locally diverse molluscan assemblage. Units 14-16 overlie this lower sandstone unit and are approximately 9 m thick. These units are a soft sandy mudstone of olive gray color. *Inoceramus sagensis* (identified by Wolfe and Kirkland, likely not “l” sagensis) was found in concretions near the base of this interval (Unit 15).

A second marker unit – designated the “middle concretionary sand” – is the next stratigraphically higher layer. Unit 17 is an argillaceous sandstone layer 65 cm thick that weathers into large concretions that contain a diverse faunal assemblage – including the stratigraphically lowest, well-preserved, large placenticerid specimens as well as other small, delicate, heteromorphic ammonites.

This fossiliferous sandstone is overlain by approximately 10 m of olive-gray sandy mudstone. This unit coarsens upward and grades into an argillaceous sandstone and encompasses units 18-24 with three fossiliferous, concretionary horizons (units 19, 21 and 23). These units include abundant *Inoceramus* spp. and *Baculites* spp., as well as a diverse, dominantly molluscan fauna.
This interval is overlain by the primary ‘Ridge-Forming Sandstone’ (RFS) concretionary layer (Unit 25). The concretions are generally large, oblate and contain a very diverse fauna including large well-preserved *Baculites* spp., *Inoceramus altus* (misidentified as *I. vanuxemi*), *I. altusiformis* (misidentified as *I. sagensis*) and placenticerids. Specimens of *Pinna*, rudistid bivalves as well as wood and plant remains are less common. This horizon is the first of the large “birdbath” concretionary horizons. The thickness of this bed varies from 0.75 to 2 m. This is considered to be the lower limit of the *Baculites cuneatus* biozone (Izett et al., 1971).

Several meters of soft argillaceous sandstone overlies the RFS and contains 10 identifiable layers (units 26-35) including at least two horizons of concretions containing dominantly *Placenticeras* (units 27 and 29). These concretions are generally formed around large (averaging 0.66 m in diameter) adult *Placenticeras meeki* macroconchs – presumed to be female - and often also contain the smaller microconch “male” *P. planum* as well as baculitids and inoceramids near the margins of the concretions.

Unit 31 consists of smaller concretions containing a very diverse fauna and is overlain by dark olive gray silty claystone (units 34 and 35) which is generally unfossiliferous and forms the uppermost 15 meters of the portion of the Pierre Shale set aside as the KPRA. This upper 15 m only outcrops in the Eastern part of the KPRA.

**Measured Stratigraphic Sections**

During the autumn of 2005, we visited the KPRA to map the concretionary zones and measure several sections (Figure 5) for comparison with the 35 units found by Wolfe and Kirkland (1986). We attempted to recreate the upper units of Wolfe and Kirkland’s report rather than the entire 35 units. We began with the unmistakable RFS and attempted to map the various horizons above and below (Figure 6). However, even with diligent searching for correlating layers, our results were significantly different. Below the RFS we could find only one and sometimes two concretionary layers. Most likely the horizons were covered by alluvium shed from the slope above. Above the RFS we were more successful in locating horizons but still had difficulty correlating our stratigraphic sequences with those of Wolfe and Kirkland (1986). It was often unclear if a horizon was really a horizon or simply a rubble zone left by portions of the concretions slumping down the slopes or remnants left by fossil hunters breaking up concretions. More work in the field is required before these inconsistencies can be resolved.
Section 1 (KRM2005-1)

The first section was on the east side of the KPRA near the southern end of the outcrop. We attempted to identify the numerous horizons identified by Wolfe and Kirkland (1986), but we could only identify nine units. They are as follows.

The lowest discernable horizon is Unit 1A. This horizon is 48 cm thick and consists of silty to sandy calcareous concretions containing abundant *Inoceramus altus* fossils and inoceramid prisms. Placenticerids, baculitids and scaphitids also were found.
in this horizon. The color of this unit ranges from medium gray to medium dark gray (N5 to N4).

Unit 1 is clayey sand, brownish gray in color (5YR4/1) with dark brownish-black (5YR2/1) burrows. Some specimens of *I. altus* were present. This unit is gradational into Unit 2 which is the major RFS. This unit is 153 cm thick and has a dark yellowish-brown (10YR4/2) to moderate yellowish brown (10YR5/4) weathered exterior but is olive gray (5Y4/1) when freshly exposed. These are dominantly sandy to silty calcareous concretions. The concretion bases are poorly cemented and display abundant burrows with decreasing presence upsection. The concretions are progressively better indurated from base to top and contain numerous inoceramids as well as their prisms. *Placenticeras meeki* also is frequently present in these concretions. The contact with Unit 1 is gradational while the contact with Unit 3 is more abrupt. Description for Unit 2 was combined from two concretions exposed in this section.

Unit 3 is 267 cm thick, but is covered by vegetation and debris from the higher slope. Most likely the lithology is sandy to silty shale, although no fresh rock was revealed while digging a trench down the slope. Unit 4 is another concretionary horizon with obvious burrows and a greater abundance of placenticerids. These concretions have fine depositional laminations in the texture of the rock. Burrow color is 5YR2/1 whereas fresh rock is olive gray (5Y4/1). Unit 5 (below) is lithologically identical to Unit 3.

Unit 6 is a 41 cm thick concretionary layer that displays no bioturbation or laminations and only rare burrow fills. The unit is flaggier than other concretionary horizons and the fresh surface color is olive gray (5Y4/1). Unit 7 is 104 cm thick and is lithologically identical to Unit 3 (see above). Unit 8 is the last of the concretionary horizons on this slope.

Section 2 (from 2002)

During fieldwork in the summer of 2002 a trench was excavated from the base of the RFS down the slope of the main KPRA ridge. The description of this section is combined from observations during the 2002 and the 2005 field seasons.

Unit 1 of this section is the lower slope that was mostly covered by vegetation and rubble, but the entire slope consists of fine sandy to silty shale. Unit 2 is the RFS layer. This unit is 93 cm thick with a gradational contact between the ground and the well-cemented upper portions of the concretions. In the softer material of the gradational contact zone inoceramid bivalves, baculitids and burrows are common. At this location, the stratigraphic sequence is repeated due to the presence of a small-scale, low-angle thrust fault (~30°) with approximately 5 m of vertical and 10 m of horizontal offset. This faulting resulted in the apparent appearance of two RFS layers at this location (Figure 5).

Unit 5 is above the RFS concretionary horizon and is lithologically similar to units 1 and 3. Units 5 and 6 are 277 cm thick, combined. Unit 6 is the highest layer in this section and is estimated to be 25 cm thick but true thickness is unknown because the concretions are relatively flat-lying atop the ridge. Scaphitids, placenticerids and baculitids are present in this layer.
Section 3 (KRM2005-2)

The bottom of the section was at 40º 13.920 N and 106º 23.212 W. Unit 1 at the base of the section is covered by vegetation but is most likely sandy siltstone. Unit 2 is a concretionary horizon 90 cm thick containing some large inoceramids but with little evidence of bioturbation. The texture of these concretions is flaggy, possibly a result of original lamination. Unit 3 is 368 cm thick and covered with vegetation and rubble from above, making it impossible to discern what, if anything, might be in situ.

Unit 4 is the RFS (Unit 2 in the previous section). Here, this unit is 68 cm thick and showed the identical lithologic characteristics to the previous section. The rock grades from poorly indurated at the base to well indurated at the top. Texture becomes flaggy near the top of the concretions where there is an abrupt transition to the next unit. Placenticerids as well as inoceramid bivalves and evidence of their prisms characterize the dominant biota found in this unit.

Unit 5 is lithologically indistinguishable from units 1 and 3 and is 279 cm thick. Unit 6 is possibly a third concretionary horizon but was not obvious with only a few smaller concretions appearing to weather out of the soil/shale. There is also a possibility that this is simply a rubble zone from the slope above with some partially buried concretions giving the appearance of a horizon. Unit 7 is 239 cm thick and similar to Units 1, 3 and 5. Unit 8 is a thin (27 cm) concretionary horizon with no visible laminations, rare burrows and almost barren of fossils except for sparse inoceramids near the top of the concretions. Unit 9 is a shale slope partially covered by vegetation and rubble. This unit is 137 cm thick. Unit 10 is a 22-cm-thick concretionary horizon that displays a greater degree of lateral variability than other concretionary units. Some concretions in this layer were inoceramid rich, whereas others were entirely barren.

Section 4 (KRM2005-3)

Unit 1 is a shaly soil occasionally exposed on a vegetation-covered slope. Unit 2 is a discontinuous horizon of large concretions (75-80 cm diameter) containing baculitids and inoceramids, with the latter being the dominant faunal element. No bioturbation is present and structure of the concretions is massive. Unit 3 is virtually identical to Unit 1 with a heavily bioturbated gradational contact with the overlying unit. Unit 4 is 59 cm thick and massive above the bioturbated contact zone. Rare inoceramids are present; otherwise the concretions are barren. Unit 5 is lithologically similar to Unit 1. The total thickness of Units 5 and 6 is 321 cm. Unit 6 is a possibly heavily weathered concretionary layer or a rubble zone. It was difficult to discern if the concretions were in situ or if they were remnants left by fossil hunters. Placenticerids, baculitids, and inoceramids are common in the rubble of these broken concretions.

Unit 7 is 226 cm thick and has a similar lithology to shaly units 1, 3, and 5. Unit 8 is 26 cm thick consisting of massive concretions with flaggy texture showing little bioturbation. This horizon is poorly exposed and may be significantly thicker than stated here. The top of section KRM2005-3 was at 40º 13.976 N and 106º 23.229 W at an elevation of 2410 m.
Boy Scout Ridge

Boy Scout Ridge is a public collection area adjacent to the KPRA. It is a slope that is disconnected from the KPRA by an area of low relief mirroring the regional structure and is set aside by the Colorado BLM for the public to collect fossils for personal use only.

In this area, there is no evidence of a lower concretionary horizon. The lower slope is vegetated and is littered with rubble from concretions located upsection but is devoid of concretionary horizons. Only the Ridge Forming Sandstone is comparable with the measured sections from the main ridges. The RFS on this slope is heavily bioturbated in the lower half with decreasing intensity upward. The lower half is also lighter in color than the upper half and less well indurated. The upper half of these
concretions is darker colored (mostly due to weathering) and well indurated. Inoceramids and possibly baculitids are present in the upper portions of the concretions.

**Materials and Preservation**

All specimens used for this study were collected within the KPRA. The majority were collected during August, 2004, although other collections also were made in May, 2002 and October, 2005. Specimens were loaned by the University of Colorado at Boulder (UCB), and compared with material contained within the United States Geological Survey at the Federal Center in Lakewood, Colorado.

In August, 2004 specimens were collected with the goal of gathering the largest diversity possible for this specific study. The site was searched for fossils which were then collected, given a location number corresponding to the latitude/longitude taken with a handheld Global Positioning System (GPS) receiver. Seventy-nine fossil collection localities were recorded across the outcrop (Figure 4). Some fossils were collected that had been weathered out of their original layers and are considered float.

In May, 2002, a group of students and Dr. Harries visited the KPRA and collected samples. The purpose of the samples collected during this trip was to conduct geochemical research. These specimens were collected and labeled according to the horizon from which they were taken. Not all specimens collected in 2002 were used for this study. All fossils collected in 2005 were float found while mapping the concretionary layers. Specimens collected in 2002 or 2005 were used if they were better preserved than, or not represented in, the 2004 collection.

Overall, the fossils were poorly to moderately well-preserved, with occasional specimens that were either very poorly or very well-preserved. The best-preserved specimens retained original shell material, or recrystallized shell material, that displayed all the original shell's morphologic features. In the poorest preserved specimens, no shell material remained and the resulting steinkerns were weathered to a point where species-level determinations were impossible. In all cases, the matrix was significantly harder than the fossil material, making fossil preparation difficult. The fossils were exposed using a Dremel engraving tool to clear away the encasing matrix. Because of the relative fragility of the shells as compared to the hardness of the matrix, it was impossible to remove the shells completely from the rock without damaging or destroying them. This resulted in descriptions focused almost exclusively on exterior features. Interior features were available for description only when the rocks broke in an advantageous way to expose the interior portions of the shells. Silicon casts were made of molds where needed to aid in identification and description. The fossils were coated with ammonium chloride prior to being photographed.

**Species Richness and Depositional Environment**

Species richness and environment are inextricably linked and by understanding faunal habits and assemblages, we can often gain insight into the environment the organisms inhabited. The specimens for this study were not collected in a way that enables detailed diversity examination, however some conclusions can still be drawn from the fauna, faunal assemblage and the lithology of the KPRA.

The fauna of the KPRA is dominated by shallow-water taxa that fed on organic-rich deposits on and within the substrate or on suspended particles or microorganisms within the water column (Table 1). The abundance of infaunal organisms indicates a soft substrate as does the extended apertural wing on *Drepanocheilus* sp. The algal feeders
indicate abundant vegetation on the substrate and the number of predators would seem to indicate a healthy ecosystem in which there is abundant prey. Most activity within this type of ecosystem occurs within the photic zone, again indicating a shallow marine, relatively low-energy environment.

Table 1. Life habits of the fauna of the KPRA.

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Mode of Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bivalvia</td>
<td></td>
</tr>
<tr>
<td>Acilia (Truncacila) chicotana Stephenson</td>
<td>epifaunal actively mobile deposit feeder$^4$</td>
</tr>
<tr>
<td>Anomia tellinoides Morton</td>
<td>epifaunal stationary suspension feeder$^1$</td>
</tr>
<tr>
<td>Astarte sp.</td>
<td>infaunal actively mobile deposit feeder$^6$</td>
</tr>
<tr>
<td>Corbula sp. 1</td>
<td>infaunal stationary suspension feeder$^3$</td>
</tr>
<tr>
<td>Corbula sp. 2</td>
<td>infaunal stationary suspension feeder$^4$</td>
</tr>
<tr>
<td>Crassatella franzeseii Sava, n. sp.</td>
<td>infaunal stationary suspension feeder$^{2,4}$</td>
</tr>
<tr>
<td>Creneilla sp.</td>
<td>semi-infaunal stationary suspension feeder$^4$</td>
</tr>
<tr>
<td>Cucullaea nebrascensis (Owen)</td>
<td>infaunal facultatively mobile suspension feeder$^4$</td>
</tr>
<tr>
<td>Cuspidaria ventricosa (Meek &amp; Hayden)</td>
<td>infaunal facultatively mobile suspension feeder$^4$</td>
</tr>
<tr>
<td>Diplodonta davisi Dailey &amp; Popenoe</td>
<td>epifaunal stationary suspension feeder$^4$</td>
</tr>
<tr>
<td>Eteo peasei Stephenson</td>
<td>epifaunal stationary suspension feeder$^{1,4}$</td>
</tr>
<tr>
<td>Exogyra sp.</td>
<td>epifaunal stationary suspension feeder$^{1,4}$</td>
</tr>
<tr>
<td><em>Inoceramus</em> altus Meek</td>
<td>epifaunal stationary suspension feeder$^{1,4}$</td>
</tr>
<tr>
<td><em>Inoceramus</em> altusformis Walaszczyk, Cobban &amp; Harries</td>
<td>epifaunal stationary suspension feeder$^{1,4}$</td>
</tr>
<tr>
<td><em>Inoceramus</em> oblongus Meek</td>
<td>epifaunal stationary suspension feeder$^{1,4}$</td>
</tr>
<tr>
<td>Laternula (?) sp.</td>
<td>epifaunal stationary suspension feeder$^{1,4}$</td>
</tr>
<tr>
<td>Lima janetae Sava, n. sp.</td>
<td>epifaunal mobile suspension feeder$^3$</td>
</tr>
<tr>
<td>Lima sp. 1</td>
<td>epifaunal mobile suspension feeder$^3$</td>
</tr>
<tr>
<td>Lima sp. 1</td>
<td>epifaunal mobile suspension feeder$^4$</td>
</tr>
<tr>
<td>Lyropecten (?) sp.</td>
<td>epifaunal mobile suspension feeder$^4$</td>
</tr>
<tr>
<td>Modiolus kremmlingensis Sava, n. sp.</td>
<td>semi-infaunal stationary suspension feeder$^{2,4}$</td>
</tr>
<tr>
<td>Modiolus meeki (Evans &amp; Shumard)</td>
<td>semi-infaunal stationary suspension feeder$^{2,4}$</td>
</tr>
<tr>
<td>Nemodon adkinsi Stephenson</td>
<td>semi-infaunal facultatively mobile suspension feeder$^4$</td>
</tr>
<tr>
<td>Nemodon harresii Sava, n. sp.</td>
<td>semi-infaunal facultatively mobile suspension feeder$^4$</td>
</tr>
<tr>
<td>Nucula percassa (Conrad)</td>
<td>infaunal actively mobile deposit feeder$^4$</td>
</tr>
<tr>
<td>Nucula sp. 1</td>
<td>infaunal actively mobile deposit feeder$^4$</td>
</tr>
<tr>
<td>Nucula sp. 2</td>
<td>infaunal actively mobile deposit feeder$^4$</td>
</tr>
<tr>
<td>Nuculana (Jupiteria) scitula Stephenson</td>
<td>epifaunal mobile deposit feeder$^2$</td>
</tr>
<tr>
<td>Nuculana sp.</td>
<td>infaunal mobile deposit feeder$^2$</td>
</tr>
<tr>
<td>Nymphalucina bourni Sava, n. sp.</td>
<td>infaunal facultatively mobile suspension feeder$^4$</td>
</tr>
<tr>
<td>Nymphalucina cleburni (White)</td>
<td>infaunal facultatively mobile suspension feeder$^4$</td>
</tr>
<tr>
<td>Opriteschma cuneatum (Meek &amp; Hayden)</td>
<td>epifaunal stationary suspension feeder$^{1,4}$</td>
</tr>
<tr>
<td>Ostrea subradiata Cragin</td>
<td>epifaunal stationary suspension feeder$^{1,4}$</td>
</tr>
<tr>
<td>Ostrea sp. 1</td>
<td>epifaunal stationary suspension feeder$^{1,4}$</td>
</tr>
<tr>
<td>Ostrea sp. 2</td>
<td>epifaunal stationary suspension feeder$^{1,4}$</td>
</tr>
<tr>
<td>Parallelodon sp.</td>
<td>infaunal facultatively mobile suspension feeder$^{1,4}$</td>
</tr>
<tr>
<td>Phelopteria lingueformis (Evans &amp; Shumard)</td>
<td>epifaunal stationary suspension feeder$^{1,4}$</td>
</tr>
<tr>
<td>Phelopteria ruppil Sava, n. sp.</td>
<td>epifaunal stationary suspension feeder$^{1,4}$</td>
</tr>
<tr>
<td>Pinna sp.</td>
<td>infaunal stationary suspension feeder$^{1,4}$</td>
</tr>
<tr>
<td>Propeamussium simplicus (Conrad)</td>
<td>semi-infaunal stationary suspension feeder$^{1,4}$</td>
</tr>
<tr>
<td>Propodaemusium sp.</td>
<td>semi-infaunal stationary suspension feeder$^{1,4}$</td>
</tr>
<tr>
<td>Protocardia barneyi Sava, n. sp.</td>
<td>semi-infaunal stationary suspension feeder$^{1,4}$</td>
</tr>
<tr>
<td>Pseudoperna inflatum Sava, n. sp.</td>
<td>semi-infaunal stationary suspension feeder$^{1,4}$</td>
</tr>
<tr>
<td>Sycyclonema travisanus Stephenson</td>
<td>semi-infaunal stationary suspension feeder$^{1,4}$</td>
</tr>
<tr>
<td>Tellina sp.</td>
<td>semi-infaunal stationary suspension feeder$^{1,4}$</td>
</tr>
<tr>
<td>Tenea parilis Conrad</td>
<td>semi-infaunal stationary suspension feeder$^{1,4}$</td>
</tr>
<tr>
<td>Teredo irregularis Gabb</td>
<td>semi-infaunal stationary suspension feeder$^{1,4}$</td>
</tr>
</tbody>
</table>

| Gastropoda | |
| Acmaea genetae Sava, n. sp. | epifaunal actively mobile herbivore$^3$ |
| Anisomyon aff. centrale Meek | epifaunal actively mobile pulmonate algae grazer$^3$ |
| Anisomyon centrale Meek | epifaunal actively mobile pulmonate algae grazer$^3$ |
| Bellifusus (?) sp. 1 | epifaunal actively mobile carnivore$^1$, $^4$ |
| Bellifusus (?) sp. 2 | epifaunal actively mobile carnivore$^1$, $^4$ |
| Creoneilla triplicata Wade | epifaunal actively mobile $^5$ |
| Drepanocheilus evansi Cossmann | epifaunal mobile deposit feeder/suspension feeder$^4$ |
Table 1. (Continued)

<table>
<thead>
<tr>
<th>Species</th>
<th>Habitat/Feeding Habits</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Drepanocheilus nebrascensis</em> (Evans &amp; Shumard)</td>
<td>epifaunal mobile deposit feeder/suspension feeder</td>
</tr>
<tr>
<td><em>Drepanocheilus obesus</em> Sohl</td>
<td>epifaunal mobile deposit feeder/suspension feeder</td>
</tr>
<tr>
<td><em>Drepanocheilus</em> sp.</td>
<td>epifaunal actively mobile carnivore</td>
</tr>
<tr>
<td><em>Eoacteon sublinearis</em> (Stephenson)</td>
<td>epifaunal actively mobile carnivore</td>
</tr>
<tr>
<td><em>Gyroides</em> sp.</td>
<td>epifaunal mobile deposit/suspension feeder</td>
</tr>
<tr>
<td><em>Mesolaniastes reesidei</em> (Stanton)</td>
<td>terrestrial</td>
</tr>
<tr>
<td><em>Natica</em> sp.</td>
<td>epifaunal actively mobile carnivore</td>
</tr>
<tr>
<td><em>Nonacteonina deflexa</em> Stephenson</td>
<td>epifaunal actively mobile ?</td>
</tr>
<tr>
<td><em>Nonacteonina triticea</em> Stephenson</td>
<td>epifaunal actively mobile ?</td>
</tr>
<tr>
<td><em>Oligopycha concinna</em> (Hall &amp; Meek)</td>
<td>epifaunal actively mobile ?</td>
</tr>
<tr>
<td><em>Sulcoretusa dominici</em> Sava, n. sp.</td>
<td>epifaunal actively mobile ?</td>
</tr>
<tr>
<td><em>Turritella</em> sp.</td>
<td>epifaunal mobile deposit/suspension feeder</td>
</tr>
<tr>
<td><em>Vanikoropsis nebrascensis</em> (Meek &amp; Hayden)</td>
<td>epifaunal actively mobile ?</td>
</tr>
<tr>
<td><em>Voysaa (?)</em> sp.</td>
<td>semi-infaunal deposit feeder</td>
</tr>
</tbody>
</table>

**Cephalopoda**

<table>
<thead>
<tr>
<th>Species</th>
<th>Habitat/Feeding Habits</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Anakinoceras reflexum</em> Stephenson</td>
<td>nekttonic actively mobile carnivore</td>
</tr>
<tr>
<td><em>Axonoceras compressum</em> Stephenson</td>
<td>nekttonic actively mobile carnivore</td>
</tr>
<tr>
<td><em>Baculites compressus</em> Say</td>
<td>nekttonic actively mobile carnivore</td>
</tr>
<tr>
<td><em>Baculites cuneatus</em> Cobban</td>
<td>nekttonic actively mobile carnivore</td>
</tr>
<tr>
<td><em>Eutrophoceras dekayi</em> (Morton, 1834)</td>
<td>nekttonic actively mobile carnivore</td>
</tr>
<tr>
<td><em>Hoploscaphites landesi</em> Riccardi</td>
<td>nekttonic actively mobile carnivore</td>
</tr>
<tr>
<td><em>Jeletzyktes brasii</em> (Meek)</td>
<td>nekttonic actively mobile carnivore</td>
</tr>
<tr>
<td><em>Jeletzyktes cf. nodosus</em> (Owen)</td>
<td>nekttonic actively mobile carnivore</td>
</tr>
<tr>
<td><em>Nostoceras</em> sp.</td>
<td>nekttonic actively mobile carnivore</td>
</tr>
<tr>
<td><em>Placenticeras costatum</em> Hyatt</td>
<td>nekttonic actively mobile carnivore</td>
</tr>
<tr>
<td><em>Placenticeras meeki</em> Böhm</td>
<td>nekttonic actively mobile carnivore</td>
</tr>
<tr>
<td><em>Placenticeras</em> sp.</td>
<td>nekttonic actively mobile carnivore</td>
</tr>
</tbody>
</table>

1 Landman et al., 2007
2 Atlas of Invertebrate Macrofossils, 1985
3 Kirkland, 1996
4 The Paleobiology Database (http://paleodb.org/cgi-bin/bridge.pl?user=Guest&action=startStartPrintHierarchy)

One of the basic tenets of diversity studies is the species-area effect which states that the larger the area sampled, the greater the species richness (e.g. Rosenzweig, 1995). Numerous studies devoted to the systematic description of macroinvertebrates, especially mollusks, have been published on the fauna of the Pierre Shale and other Late Cretaceous deposits. These studies initiated with the classic manuscripts of Meek and Hayden in the 1800’s. Most of these monographs document the fauna of entire formations over relatively broad areas rather than more limited stratigraphic intervals from specific localities. The KPRA encompasses <1 km² and represents less than 1 Ma of deposition based on ammonite biozones dates. The molluscan fauna from the KPRA consists of 47 bivalve, 22 gastropod, 13 cephalopod, and one serpulid species from 79 recorded localities and from float on the outcrop. Two brachiopod species also were found. By comparison, most other Cretaceous deposits represent much longer intervals of time and were collected over a much broader geographical area encompassing numerous localities (Table 2). The late Late Cretaceous to Tertiary (Paleogene) Manasquan River Basin of New Jersey (Landman et al., 2007) is the most comparable unit in faunal counts, outcrop extent and duration of deposition. However, the outcrop area is still approximately five times larger than the KPRA and the time of deposition is approximately twice as long. As can be seen in Table 1, only the gastropod species total is greater than the total for the KPRA, with bivalve species and cephalopod species from the KPRA outnumbering the Manasquan River Basin totals by 64% and 77%, respectively.
The most comparable deposit in regard to faunal content is the Navarro Group of Texas (Stephenson, 1941), the lower formations of which are virtually coeval with the KPRA. The two deposits have many species in common among all three primary molluscan groups investigated, with the most important being the cephalopod species. Cephalopod species found at both the KPRA and in the Navarro Group include *Anaklinoceras reflexum* Stephenson, *Axonoceras compressum* Stephenson, *Jeletzykes* (formerly *Scaphites*) *brevis* (Meek) and *Placenticeras meeki* Böhm. These species were collected from the Neylandville Marl Formation (the lowest unit of the Navarro Group). Stephenson originally placed deposition of the Navarro Group wholly within the Maastrichtian, however more recent studies and correlation of the ammonite biozones shows that deposition of the Neylandville Marl began in the middle to late Campanian. *Placenticeras meeki* occurs from the *Didymoceras cheyennense* to the *Baculites cuneatus* biozones of the Western Interior whereas *Anaklinoceras reflexum* and *Axonoceras compressum* are limited to the *Baculites compressus* biozone. *Jeletzykes brevis* is limited to the upper *Didymoceras cheyennense* to lower *Baculites reesidei* biozones (Larson et al, 1997).

### Table 2. Comparison of Late Cretaceous deposits.

<table>
<thead>
<tr>
<th></th>
<th>KPRA</th>
<th>Woodbine Formation of North and South Dakota</th>
<th>Fox Hills Formation of North and South Dakota</th>
<th>Greenhorn Cyclothem at Black Mesa</th>
<th>Navarro Group of Texas</th>
<th>Middle Vistula Valley, Poland</th>
<th>Manasquan River Basin of New Jersey</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of bivalve species</td>
<td>47</td>
<td>138</td>
<td>58</td>
<td>144</td>
<td>174</td>
<td>105</td>
<td>30</td>
</tr>
<tr>
<td>Number of gastropod species</td>
<td>22</td>
<td>117</td>
<td>46*</td>
<td>63</td>
<td>179</td>
<td>92</td>
<td>24</td>
</tr>
<tr>
<td>Number of cephalopod species</td>
<td>13</td>
<td>16</td>
<td>Unknown</td>
<td>71</td>
<td>39</td>
<td>Unknown</td>
<td>10</td>
</tr>
<tr>
<td>Outcrop Area</td>
<td>&lt; 1 km²</td>
<td>Outcrops in 6 counties in Texas, plus outcrops in Arkansas and Oklahoma</td>
<td>North and South Dakota, Montana and Wyoming</td>
<td>&gt;80 km²</td>
<td>4 formations extending from NE to SW Texas and into Arkansas and Mexico in a belt 1 to 23 miles wide.</td>
<td>~50 km²</td>
<td>~5 km²</td>
</tr>
<tr>
<td>Age range</td>
<td>late Campanian to early Maastrichtian</td>
<td>mid Cenomanian</td>
<td>mid to late Maastrichtarian</td>
<td>late Alban to middle Turonian</td>
<td>early late Campanian through Maastrichtian**</td>
<td>Campanian / Maastrichtian boundary to late Maastrichtian</td>
<td>latest Maastrichtian to Tertiary / Paleogene boundary</td>
</tr>
<tr>
<td>Time of deposition</td>
<td>~1 Ma</td>
<td>~12 Ma</td>
<td>~3 to 4 Ma</td>
<td>~11 to 12 Ma</td>
<td>~6 Ma</td>
<td>~6 to 7 Ma</td>
<td>~2 ma Shallow, nearshore marine</td>
</tr>
<tr>
<td>Origin</td>
<td>Shallow, nearshore marine</td>
<td>Fresh, brackish &amp; shallow marine</td>
<td>Near shore marine</td>
<td>Open marine</td>
<td>Marine &lt;200 meters</td>
<td>Shallow marine</td>
<td></td>
</tr>
</tbody>
</table>

1 Stephenson (1952)
3 Kirkland (1996)
4 Stephenson (1941)
5 Abdel-Gawad (1986)
6 Landman et al. (2007)
7 Akers and Akers (1997)

*Combined total from Mickel (1960) and Erickson (1974).** Stephenson (1941) originally placed the Navarro Group wholly within the Maastrichtian. However, more recent research has dated deposition of the Neylandville Marl (the lowest formation of the Navarro Group) as beginning in the early late Campanian.7

The condition of the KPRA fossils indicates that they are virtually autochthonous, with a small degree of transport. The fossils are sometimes in excellent condition and retain original shell material or recrystallized shell material that retains all the external characteristics of the original organism. The most common type of fossil preservation from this site is external or internal molds. The molds and steinkerns are generally in very good condition and can often be given generic assignment and even sometimes can be given species designation. The fineness of the detail that can be seen in the molds and casts of many of the fossils indicates that the shell material was dissolved after burial rather than worn by transport. Some articulated bivalve specimens were also found in the samples, indicating minimal or no transport. Fragile shells that would have been destroyed by transport were found in the samples; i.e. *Propeamussium simplicus* and *Mesolanistes reesidei*. *Mesolanistes reesidei* is a terrestrial snail (Stanton, 1916).
that still retains portions of its original shell material. This rare shell would have been destroyed by extensive transport.

Batt (1989) found that ammonoids of the Western Interior Greenhorn Cyclothem appear to be distributed among the facies in such a way as to allow correlations between shell morphotypes and marine environment. Ammonites were divided into 18 groups based on external features which were interpreted as characteristics reflecting differences in habitat and modes of life. He then plotted occurrences for each of his morphotypes on maps of the WIS to determine if patterns could be detected regarding the types and locations of the facies in which each morphotype was found. His findings suggest that the most common ammonite form from the KPRA - the involute, compressed disc-shaped placenticerids - is restricted to deposits of shallow-water nearshore mud facies and sand (figure 7).

Figure 7. Distribution of Placenticerid type Ammonite morphotypes in Greenhorn Cyclothem WIS deposits. The single data point near the center top (Black Hills area) may represent a shallow environment resulting from uplift in the Montana-Wyoming area. (from Batt, 1989)

Lithologically, the shale of the research area has a high sand content and is interbedded with massive sandstone concretionary layers that have few or no
depositional features, but are heavily burrowed. This lithology indicates deposition in a moderately high energy environment and the possibility that some of the sandstone layers represent storm deposits.

Analysis

When considered together these factors indicate that the depositional environment of the Pierre Shale at the KPRA was a shallow, nearshore environment with moderate energy. Comparison of species richness of the KPRA with species richness of other late Cretaceous deposits shows a high degree of diversity within a relatively small area. The species richness is comparable with modern nearshore environments which are known to yield the most diverse molluscan assemblages in the modern seas.

The interbedded layers of sand and sandy shale could indicate small scale changes in the position of the shoreline with the sand content representing proximity to the shore due to the slightly higher energy needed to transport fine sand grains. The interpretation of the KPRA as a shallow nearshore depositional environment is enhanced further by the condition of the fossils. Shells preserved with original shell material or with recrystallized shell material and shells that are represented by steinkerns still retain details that would not have been preserved if the shell had undergone extensive transport. The presence of articulated bivalves and the rare terrestrial species Mesolanistes reesidei is another means of interpreting the KPRA unit as a nearshore depositional environment. The presence of the large disc-shaped placenticerid ammonites gives further evidence nearshore deposition according to Batt (1989).

These factors present a convincing argument in favor of the interpretation of the KPRA as a shallow, nearshore depositional environment. However, further work and more detailed diversity studies must be done before the complete picture of the paleoenvironment and its inhabitants becomes clear.

Conclusions

The deposits of Late Campanian age at the KPRA yielded a rich molluscan fauna of 47 bivalve, 22 gastropod, 12 cephalopod, two inarticulate brachiopods, and one serpulid species. Ten of these species are new and include eight bivalve and two gastropod species. These were collected from 79 recorded localities as well as numerous specimens collected from float on the outcrop within an area of approximately 1 km². This is an extremely diverse assemblage that has been interpreted to represent a nearshore environment based on faunal content, assemblage, preservation and lithology of the deposits.

The species richness of the KPRA is high when compared to other WIS and Cretaceous deposits and will be valuable for studies of alpha diversity across latitudinal and temporal scales. In addition, species richness of the KPRA combined with information about coeval deposits within the WIS will advance regional (beta) diversity research. This will, in turn, add to the increasing global knowledge regarding species richness within the Cretaceous and enable comparisons of similar environments through time.
**Systematics**

Phylum **BRACHIPODA**
Class **INARTICULATA**
Order **ACROTRETIDA** Kuhn, 1949
Family **DISCINIDAE** Gray, 1840
Genus **DISCINISCA** Dall, 1871

**Discinisca sp.**
(Plate 1, Figure 1)

*Description.*— Small, round, patelliform brachial valve. Ornament is of fine concentric growth lines of variable width and spacing that spread from apex of valve.

*Dimensions.*— (approximately) 5 mm Diameter x 2 mm H.

*Discussion.*— Only two steinkerns of these very small specimens were found in the samples for this study. No shell material remained.

*Occurrence.*— *Discinisca* is a long ranging genus - from the Emsian to the Late/Upper Pliocene - that has been described from locations across the United States and from Great Britain, Hungary, Germany and Africa.

Subphylum **LINGULIFORMEA**
Class **LINGULATA**
Order **LINGULIDA** Waagen, 1885
Superfamily **LINGULOIDEA** Menke, 1828
Family **LINGULIDAE** Menke, 1828
Genus **LINGULA** Bruguiere, 1797

*Type Species.*— Lingula unguis Linnaeus (= L. anatina Lamarck).

**Lingula aff. L. subspatulata** Hall & Meek
(Plate 1, Figure 2)

*Lingula subspatulata* Hall and Meek, 1855, p. 380, Pl. 1, figs. 2a, 2b.
*Lingula subspatulata* Hall and Meek. White, 1877, p. 169, Pl. 15, fig. 4a.
*Lingula subspatulata* Hall and Meek. Whiteaves, ?1889, pp. 185, 186.
*Lingula subspatulata* Hall and Meek. Johnson, 1903, p. 113, Pl. 1, figs. 11a, 11b.
*Lingula subspatulata* Hall and Meek. Weller, 1907, p. 356, Pl. 27, figs. 20, 21.
*Lingula subspatulata* Hall and Meek. Dowling, 1917, p. 45 (listed only).
*Lingula aff L. subspatulata* Hall and Meek. Stephenson, 1941, p. 70, Pl. 3, figs. 7-9.

*Description.*— Small, elongate, ovate, compressed, polished. An almost perfect elongate oval outline with a slightly pointed beak. Lateral margins nearly straight to very broadly convex. Concentric growth lines are variably prominent and mirror the elongate
shape of the shell, staying closely spaced as they elongate but becoming progressively more widely spaced lengthwise with distance from the beak.

**Dimensions.**— 8 mm L x 5 mm W.

**Discussion.**— There are only two representatives of this genus in the samples for this study: one complete valve and the posterior half of another valve. The shape and glossy appearance are easily recognizable. The two specimens are moderately well-preserved, but the limited number of specimens makes specific designation difficult.

**Occurrence.**— *Lingula* is a long ranging genus - from the Tremadoc to the Kaiatan - that has been described from deposits all around the world, including the United States, United Kingdom, China, Russia, New Zealand, South America and many other localities.

Phylum **ANNELIDA** Lamarck, 1809  
Class **POLYCHAETA** Grube, 1850  
Order **SERPULIMORPHA**  
Family **SERPULIDAE** Rafinesque, 1835  
Genus **SERPULA** Linnaeus, 1758  
Type Species.— *Serpula seminulum* Linnaeus, 1758, p. 786.

**Serpula cretacea** (Conrad), 1875  
(Plate 1, Figures 3 & 4)

*Diploconcha (Serpula?) cretacea* (Conrad)? Whitfield, 1892, p. 170, Pl. 20, fig. 25; p. 170, Pl. 20, fig. 25.  
*Dentalium (Falcula) falcatum* (Conrad). Whitfield, 1892, p. 169, Pl. 20, figs. 15-17.  
*Serpula whitfieldi* Weller, 1907, p. 308, Pl. 19, fig. 2.  
*Serpula cretacea* (Conrad). Stephenson, 1923, p. 67, Pl. 9, figs. 1-7, 10, 11 (questionably figs. 8, 9, 12).  
*Serpula cretacea* (Conrad). Adkins, 1928, p. 78.  

**Description.**— Single, paired or colonial calcareous tubes. Composed of numerous thin layers. Species distinguished by its sinuosity and extreme irregularity of shape. Tubes are circular in cross section with thin, fragile walls in the early stages and thicker in later stages.

**Discussion.**— The majority of the *Serpula cretacea* tubes found in the sample for this study are single tubes. Rare instances of small colonies of 2 to 3 tubes were found.

**Occurrence.**— *Serpula cretacea* was described from the Navarro Group of Texas, the Ripley and Owl Creek Formations of Mississippi, the Black Creek and Peedee Formation of North Carolina, the Navesink Marl of New Jersey, the Monmouth Formation of Maryland and questionably from Jamaica.
Subclass **PALAEOTAXODONTA** Korobkov, 1954  
Order **NUCULOIDA** Dall, 1889  
Superfamily **NUCULOIDEA** Gray, 1824  
Family **NUCULIDAE** Gray, 1824  
Genus **NUCULA** Lamarck, 1799  
Type Species.— *Arca nucleus* Linnaeus, 1758, p. 695.

**Nucula percrassa(?)** Conrad, 1858  
(Plate 1, Figure 5)

*Nucula percrassa* Conrad, 1858, p. 327, Pl. 35, fig. 4.  
*Nucula percrassa* Conrad. Weller, 1907, p. 369, Pl. 29, figs. 1-5.  
*Nucula percrassa* Conrad. Richards, 1958, p. 59, Pl. 10, figs. 1, 2, 4.

**Description.**— Small shell, sub ovate to sub trigonal, moderately inflated, somewhat thick for the size. Point of maximum inflation is anterior to umbone and about one-third the height of the shell from the umbone. Umbone moderately prominent, opisthogyrate, beak small to obscure. Anterodorsal margin longer than posterodorsal margin and with a slight convexity. Posterodorsal margin is short and straight. Ventral margin is broadly and evenly rounded. Anteroventral margin is smoothly rounded with a wider curvature than posteroventral margin which is sharply rounded. No lunules visible. Relatively wide escutcheon delimited by sharp umbonal ridge which weakens slightly before meeting the posterior margin. At the point where the umbonal ridge intersects the posterior margin it creates a sharply rounded posterior profile. Ornament consists of fine concentric growth lines. Growth lines are relatively regular in prominence, width and spacing, although no definite pattern can be detected. As the growth lines cross the umbonal ridge they sharply change direction, veer toward the umbone and become slightly less discernible. No radial ornament. Shell shows a polished finish where original material is intact and a nacreous interior layer where outer shell is missing.

**Dimensions.**— 8.5 mm L x 6 mm H; 8 mm L x 7 mm H.

**Discussion.**— Speden (1971) describes this species as variable in shape and length/height ratio but that cannot be confirmed with the small number of specimens found in this study.

**Occurrence.**— *Nucula percrassa* has been described from the Fox Hills Formation of South Dakota and the Ripley Formation of Tennessee. It has questionably been described from Maryland and New Jersey.

**Nucula sp. 1**  
(Plate 1, Figure 6)

**Description.**— Small shell, thin, mildly inflated, height about two-thirds length. Umbone prominent, prosogyrate, located about one-third the length of the valve from the anterior terminus; beak rounded. Point of maximum inflation is slightly anterior to midlength and about midheight. Anterodorsal margin steep, straight and short. Small depression anterior to umbone creates a small convexity along the anterodorsal margin. Anterior
terminal is a slightly rounded corner with an angle of >90°. Ventral margin is broadly convex. Posterior margin is more tightly curved. Posterodorsal margin is slightly sinuous - broadly convex at posterior-most end and straightens before reaching umbone. Escutcheon or lunules obscure. A weak umbonal ridge weakens before reaching posterodorsal margin. Ornament consists only of very fine concentric growth lines.

**Dimensions.**— 9 mm L x 7 mm H.

**Discussion.**— This description is taken from one relatively poorly preserved specimen in which most of the shell material is missing. A small amount of shell is preserved along the posteroventral and posterior margin. This specimen differs from *N. percrassa* in the less sinuous posterodorsal margin and slightly less prosogyrous umbone. Similar *Nucula* species were described by Speden (1971), *Nucula planomarginata*, and by Stephenson (1941), *Nucula microstriata*, but without more shell preserved, or a visible hinge, no specific identification could be determined.

**Nucula sp. 2**
(Unfigured)

**Description.**— Small shell, subovate, thin, inequilateral. Umbone moderately prominent, prosogyrate and positioned almost even with the anterior margin. Anterior margin straight to very slightly convex and merges with ventral margin in a broad curve. Ventral margin broadly convex to a closely rounded posterior margin. Posterodorsal to dorsal margin is straight to slightly convex. Lunules or escutcheons are obscured. Ornament is fine concentric closely spaced irregular growth lines.

**Dimensions.**— 8.5 mm L x 6 mm H.

**Discussion.**— This description is from one compressed specimen that retains the original shell material. The degree of inflation cannot be interpreted. This specimen was broken before a photograph was taken.

**Genus ACILA** H. & A. Adams, 1858

Type Species.— *Nucula divaricata* Hinds, by subsequent designation (Stoliczka, 1871, p. 325).

Subgenus TRUNCACILA Schenck, in Grant & Gale, 1931

Type Species.— *Nucula castrensis* Hinds

**Acila (Truncacila) chicotana** Stephenson, 1952
(Plate 1, Figure 7)

**Acila (Truncacila)? chicotana** Stephenson, 1952, p. 56, Pl. 10, figs. 23-25.

**Description.**— Medium-sized shell, moderately well inflated, subtrigonal, inequilateral. Umbone prominent, orthogyrate, rounded. Beak coincident with umbone. Maximum inflation is behind umbone and before midheight of the shell. Anterodorsal margin a long, almost straight line with a barely outwardly curved profile. Anterior end is sharply rounded. Ventral margin is broadly rounded. Posterior margin is slightly more sharply rounded than anterior end. Posterodorsal margin descends steeply from umbone to
posteroventral curve. Ventral margin is crenulate from anterodorsal curve to posterodorsal curve. Faint diagonal ridges run from the umbone to towards both the antero and posterodorsal margins. The anterior ridge weakens and disappears before reaching the anterodorsal curve. The posterior ridge is slightly stronger than the anterior ridge and weakens with distance from the umbone and intercepts the margin at the posterodorsal curve. A wide shallow triangular escutcheon is weakly outlined by the posterior ridge. Lacking lunules. Although the anterior and posterior ridges are weak, the shell curves steeply downward from the flank to the anterodorsal and posterodorsal margins. The anterodorsal margin curls slightly inward. The escutcheon and posterodorsal margin create a vertical profile.  

Concentric growth lines and undulations are fine to moderately coarse and of varying width, spacing and prominence. These lines cover the shell and curve down over the ridges where they become tightly spaced and curve toward the umbo. Radial ornament is of fine, regularly spaced broadly rounded ribs separated by fine incised grooves less the half the width of the ribs. These radial ribs create the crenulated margin. Within the concentric growth lines, but independent of the overall pattern, are very small zigzag lines that are raised in some places but smooth in general. The interior is mostly obscured by matrix material, but one specimen shows the interior edge of the anterodorsal curve. Fine crenulations or teeth can be seen but not well enough to describe.

**Dimensions.**—22 mm L x 16 mm H.

**Discussion.**—Stephenson (1952) defined this species based on the fine zigzag lines within the pattern of ornamentation being similar to what is seen on Acila banquerensis. He noted that the pattern on A. chicotana is finer and less conspicuous in the strength and magnitude of the undulations as compared to A. banquerensis.

**Occurrence.**—Acila (Truncacila) chicotana is previously described from the Woodbine Formation of Texas.

Family **NUCULANIDAE** H & A Adams, 1858  
Genus **NUCULANA** Link, 1807, sensu lato  
Subgenus **JUPITERIA** Bellardi, 1875  
Type Species.—**Nucula concava** Bronn, 1831, p. 618 by subsequent designation of Dall, 1898. p. 579.

**Nuculana (Jupiteria) scitula** (Meek & Hayden), 1856a  
(Plate 1, Figures 8, 9 & 10)

**Nucula scitula** Meek & Hayden, 1856a. p. 84.  
**Leda scitula** (Meek & Hayden). Meek & Hayden, 1860a, p. 185.  
**Leda (Yoldia) scitula** (Meek & Hayden). 1860b, p. 428.  
**Yoldia scitula** (Meek & Hayden). Meek, 1876, p. 110, Pl. 28, fig. 9.  
**Yoldia scitula** (Meek & Hayden). Whiteaves, 1885, p. 38, Pl. 5, fig. 2.  
**Yoldia scitula** (Meek & Hayden). Stanton, 1920, p. 21, Pl. 1, figs. 9 (= type specimen), 10.  
**Nuculana bisulcata** (Meek & Hayden). Whitfield. 1880, p. 407, Pl. 11, fig. 7.  
? Yoldia cupressensis Landes, 1940, p. 134, Pl. 1, figs. 7-8.

Description.— Small shell, elongate subtrigonal to subovate, inequilateral, thin, moderately inflated with length almost twice the height. Umbones moderately prominent, very slightly anterior to center and orthogyrate; beaks rounded, indistinct from umbones. Maximum inflation occurs slightly anterior to mid-length and about one-third the height of the shell from the umbone. Lunules and escutcheon, if present, are obscured by matrix. Anterodorsal margin is straight to very slightly concave. Anterior margin sharply rounded. Ventral margin broadly and smoothly convex. Posterior margin very sharply rounded. Posterodorsal margin slightly convex near posterior end, becoming very slightly concave near umbone. Flank of shell evenly convex from dorsal to ventral margin but flattening slightly towards both anterior and posterior margins. Ornamentation consists of fine concentric plicae. Plicae are regularly spaced over flank but are closer together just behind the umbone and near the ventral margin. Plicae fade out over umbone and just before reaching posterior margin. Profiles of plicae show vertical faces in the umbonal direction then declining in the opposite direction until meeting the vertical face of the next plicae. Exterior surface is glossy.

Dimensions.— 7 mm L x 4 mm H.

Discussion.— This description is taken from one well-preserved specimen that is very comparable to Speden’s (1971) description. A similar species was described by Stephenson (1941) from the Navarro Group of Texas (Nuculana corsicana). Other species of Nuculana have been described from New Jersey (Weller, 1907) under the genus names Leda and Yoldia.

Occurrence.— Nuculana (Jupiteria) scitula has been described from the Fox Hills Formation of South Dakota.

Nuculana sp.
(Plate 1, Figure 11)

Description.— Small, subovate, moderately inflated, inequilateral, equivalve. Greatest inflation at midlength and about one-third the height of the shell from the umbone. Umbone moderately prominent, slightly prosogyrate, inflated and positioned slightly anterior to midlength; beaks rounded. Anterodorsal margin somewhat excavated. Anterior margin closely rounded. Ventral margin broadly curved. Posterior margin sharply rounded. Posterodorsal margin straight to slightly convex. Escutcheons narrow, not well defined. Lunules obscured. No ornament visible.

Dimensions.— 6 mm L x 3 mm H. Total convexity of articulated valves: 2.5 mm.

Discussion.— Description is of one articulated steinkern with no remaining shell material. The overall shape and degree of inflation is strongly indicative of Nuculana.

Subclass PTERIOMORPHIA Beurlen, 1944
Order ARCOIDA Stoliczka, 1871
Family PARALLELODONTIDAE Dall, 1898
Subfamily PARALLELODONTINAE Dall, 1898

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Genus **PARALLELODON** Meek & Worthen, 1866  
Type Species.— By original designation, *Arca keyserlingii* d’Orbigny, 1850, p. 369.

**Parallelodon sp.**  
(Plate 1, Figures 12 & 13)

*Description.*— Small, inequilateral, slightly inequivalve, elongate subrhomboidal to subovate, moderately inflated. Point of greatest inflation is in the dorsal half, slightly posterior to umbone. Umbone mildly prosogyrate, positioned about one-third the length of the valve from the anterior end, moderately prominent, projecting slightly beyond hinge line. Hinge line long, straight. Anterodorsal margin excavated. Anterior margin sharply rounded. Ventral margin long, nearly straight with small concavity just anterior to midlength. Posterior margin sharply and uniformly rounded. Posteroventral margin meets posterior margin with an obtuse angle. Narrow well-defined nymphae; small lunules. Moderately sharp ridge originates on anterior side of umbone and curves up towards anterodorsal margin but weakens before reaching margin. Weak posterior ridge originates at umbone but does not reach posteroventral margin. A strong linear fold originates over umbone and terminates just anterior to midheight on the ventral margin, creating the slight concavity mentioned above. This fold widens slightly from umbone to ventral margin. Ornament is moderately prominent radial costae, crossed by fine concentric growth lines, creating a cancellate pattern.

*Dimensions of average specimens.*— 6 mm L x 3.5 mm H x 3 mm D (articulated steinkern).

*Discussion.*— This small species is scarce in the overall fauna of this study, but numerous in the locations at which it was found (location numbers 19 and 69). Nearly all of the specimens are articulated steinkerns. Ornament is described from exterior molds found with steinkerns.

Subfamily **GRAMMATODONTINAE** Bronson, 1942  
Genus **NEMODON** Conrad, 1869  
Type Species.— *Nemodon conradi* Johnson (= *N. eufalensis* Conrad); not *Arca* (*Macrodon*) *eufalensis* Gabb.

**Nemodon harriesi** Sava, n. sp.  
(Plate 1, Figures 14 - 18)

*Etymology.*— This species was named in honor of Dr. Peter Harries, my advisor and friend who has been the primary sounding board, consultant and editor for this project.

*Description.*— Large shell, thick, alate, inequilateral, equivalve, elongate. Outline subrhomboidal, moderately inflated with point of maximum inflation approximately midheight and midlength. Umbone rounded, slightly prosogyrate, moderately prominent and positioned about one-third the length of the shell from the anterior end. Umbone projects well over hinge line. Hinge line long and straight to very slightly concave. Hinge line slightly excavated anterior to umbone and meets anterior margin with a sharp angle – equal to or slightly greater than 90°. Anterior margin curves smoothly into ventral margin. Ventral margin near straight with a slight concavity about midlength. Posterior margin straight to slightly convex and meets hinge line at an angle of approximately 125°.
angle. A strong posterior ridge initiates at umbone and widens across the posterior flank before intersecting posteroventral margin. Posterior area bordered by the hinge line and the posterior ridge is a steep concave slope. The main flank of the shell is very slightly depressed to flat at about midlength. Ornament consists of fine irregularly spaced and variable width concentric growth lines. Fine radial lines intersect with the growth lines and create a faint reticulate pattern. The radial lines become more prominent in the posterior area and become the dominant ornament.

Dimensions.— (holotype) 34 mm L x 15 mm H; convexity about 6 mm; hinge line 26 mm.

Discussion.— This description is based on a mostly intact articulated specimen plus two well preserved steinkerns. The center of each valve is missing at the points of greatest convexity and small fragments are missing from some of the margins. Stephenson (1941) described *Nemodon grandis navarroensis* from Texas that has similar characteristics to this species but differs in the flat, or depressed area, about midlength. Stephenson describes the area in *N. grandis navarroensis* as “a broad shallow radial depression” that “divides the umbone and extends to about the middle of the ventral margin.” *Nemodon harriesi* does not show the depressed area beginning over the umbone, rather the flank is very slightly flattened about midlength. In addition the radial ornament on *N. grandis navarroensis* is the most prominent feature of the sculpture whereas on *N. harriesi* the growth lines are more prominent than the radial features, except on the posterior area.

*Nemodon adkinsi* Stephenson, 1941  
(Plate 1, Figures 19 & 20)

*Description.*— Small shells, thin, inequilateral, alate, well inflated with point of maximum inflation just behind and slightly posterior to umbones. Elongate subquadrangular outline. Umbones prominent with rounded beaks, very slightly prosogyrous, widely spaced and positioned about one-third the length of the shell from the anterior terminus. Dorsal margin straight, posterior margin sharply rounded and merges with ventral margin, producing a smoothly curved outline. Anterior margin slightly concave. Amphidetic with narrow wings. Shallow auricular sulci delineate both anterior and posterior auricles. Radial costae cover entire shell; less prominent over umbonal area, becoming more prominent as they approach the margins. Costae are more widely spaced as they meet the ventral margin, more narrowly spaced at anterior and posterior and over auricles. Scalloped margin produced by costae. Interspace and costae width are about equal. On some specimens fine concentric growth lines are also visible.

Dimensions.— 8 mm L x 6 mm H (average size specimen).

Discussion.— These shells are well represented and relatively well-preserved in the samples for this study, however they are very fragile and broke with only the slightest stress so no interior characteristics are available for description. These specimens are much smaller, more fragile and have stronger radial ornament than *N. harriesi* described above. *N. adkinsi* is also proportionately higher in relation to the length than *N. harriesi.*
Occurrence.— *Nemodon adkinsi* is previously reported from the Navarro Group of Texas.

**Family CUCULLAEIDAE** Stewart, 1930  
**Genus CUCULLAEA** Lamarck, 1801  

**Cucullaea nebrascensis(?)** Owen, 1852  
(Plate 1, Figures 21, 22 & 23)

*Cucullaea nebrascensis* Owen, 1852, p. 582, Pl. 8, figs. 1a, b.  
*Cucullaea nebrascensis* Owen. Stanton, 1920, p. 22.  
*Arca (Cucullaea) shumardi* Meek & Hayden, 1856a, p. 86.  
*Arca (Cucullaea) cordata* Meek & Hayden, 1856a, p. 86.  
*Cucullaea shumardi* (Meek & Hayden). Meek & Hayden, 1856c, p. 285.  
*Cucullaea shumardi* (Meek & Hayden). Stanton, 1920, p. 22, Pl. 2, figs. 1a, b.  
*Cucullaea cordata* (Meek & Hayden). Meek & Hayden, 1856c, p. 285.  
*Cucullaea fibrosa* Sowerby. Meek & Hayden, 1860b, p. 428.  
*Cucullaea (Ideonarca) shumardi* (Meek & Hayden). Meek, 1876, p. 86-87, Pl. 28, figs. 15a-g; Pl. 29, fig. 4.  
*Cucullaea (Ideonarca) nebrascensis* Owen. Meek, 1876, p. 88-89, Pl. 29. figs. 5a, b.  
*Cucullaea (Ideonarca?) shumardi* (Meek & Hayden). Meek, 1876, p. 89-90, Pl. 29, fig. 6.  
*Ireonarca shumardi* (Meek & Hayden). Whitfield, 1880, p. 405, Pl. 11, figs. 8-11.  
*Cucullaea nebrascensis* Owen. Speden, 1971, p. 49-56, Pl. 6, figs. 1-14; Pl. 7, figs. 1-6.

**Description.**— Small, subrounded to subrectangular in outline, closed, inequilateral. Greatly inflated, globose. Point of maximum inflation is about midlength and midheight of the disc. Left valve very slightly more inflated than right. Beaks rounded, prominent, prosogyrate and positioned centrally. Umbo inflated and distinct from disc. Anterodorsal margin short and excavated. Anterior margin broadly rounded to nearly straight. Ventral margin broadly rounded. Posteroventral margin is broadly convex. Posterior margin more sharply rounded than anterior margin. Escutcheon short, defined. Lunules very small. Faint muscle attachment scars anterior to beaks along anterodorsal margin. On articulated shell the muscular attachment scars are heart shaped. The scar on the left valve extends slightly further toward the umbo. A rounded, faint posterior ridge originates at the umbone and weakens before meeting the posteroventral margin. Along each side of ridge are radial lines that are stronger on posterior side of ridge and near the ventral and posteroventral margins. Radial costae weaken and disappear near slope of umbone. Very fine radial lines and crenulations along ventral margin.

**Dimensions.**— 6 mm L x 6 mm H. Total convexity of the articulated steinkern 5 mm.

**Discussion.**— The specimen described here is a near perfect steinkern of an articulated shell. The genus designation of *Cucullaea* is based on the degree of inflation and other morphological characteristics. The species designation is somewhat less certain. However, based on the overall shape of the steinkern and the upright profile, *C. nebrascensis* is most similar to the described species. *Ideonarca powersi* and *I. deatsvillensis* Stephenson (1941) are similar in exterior morphology but are more
proscline and show no evidence of the radial ribs surrounding the posterior ridge. For a full discussion of the relationship of *Cucullaea* and *Ideonarca* see Stephenson, 1941.

**Occurrence.**— *Cucullaea nebrascensis* had been described from the Fox Hills Formation of South Dakota.

**Order** MYTILOIDA Ferussac, 1822  
Superfamily MYTILOIDEA Rafinesque, 1815  
Family MYTILIDAE Rafinesque, 1815  
Subfamily CRENELLINAE Adams & Adams, 1857  
Genus CRENELLA Brown, 1827  

**Type Species.**— *Mytilus decussates* Montagu, 1808, p. 69 by monotypy.

**Crenella sp.**  
(Plate 2, Figure 1)

**Description.**— Small, ovate outline, well inflated. Point of maximum inflation is about midlength and midheight. Umbone positioned at one end of oval and mildly prosogyrate; beak small, rounded and projects slightly beyond dorsal margin. Umbone humped and inflated almost equal to maximum inflation. Just behind umbone is a very slight depression before the point of maximum inflation. Margins create a near perfect oval outline with anterior and posterior margins of equal length and convexity and dorsal and ventral margins also of equal length and convexity. A single weak ridge begins atop umbone and terminates at posteroventral margin.

**Dimensions.**— 11 mm L x 14 mm H (approximate).

**Discussion.**— This description is of a single right valve steinkern with no preserved shell material. The overall shape and terminal position of the umbone matches exactly with the description and figure of an unidentified *Crenella* species from the Navarro Group of Texas (Stephenson, 1941) and with the general descriptions of *Crenella* from the Fox Hills Formation of South Dakota (Speden, 1971).

**Subfamily** MODIOLINAE Keen, 1958  
**Genus** MODIOLUS Lamarck, 1799  

**Type Species.**— *Mytilus modiolus* Linnaeus, 1758, p. 706.

**Modiolus kremmlingensis** Sava, n. sp.  
(Plate 2, Figures 2, 3 & 4)

**Etymology.**— This species was named for the KPRA.

**Description.**— Small shell, inequilateral, equivalve, moderately inflated, modioliform. Umbones incurved, prosogyrous, moderately prominent, positioned at anterior end of dorsal margin. Maximum inflation is behind umbones in a generally posteroventral direction flattening towards margins. No nymphae. A sharp keel is formed by the meeting of the valves along the dorsal margin. A weak posterior ridge originates at the umbone and terminates at the posteroventral margin, producing an elongate posteroventral outline. Posterior area is somewhat triangular and resembles an auricle. Ornamentation consists of prominent, concentric plicae covering the entire shell. Plicae
are regularly spaced and do not vary in width or depth. Profiles of plicae show vertical faces in the umbonal direction then declining in the opposite direction until meeting the vertical face of the next plicae.

*Dimensions of holotype.*— 8 mm L x 6 mm H x 3.5 mm W (articulated valves).

*Discussion.*— These small shells are rare in the samples for this study, however those found are very consistent in overall shape and ornamentation. Speden (1970) discussed a similar ornamentation for small specimens of *Modiolus meeki* from the Fox Hills Formation but his figures do not show the distinct ornamentation pattern seen on this species. The general outline of Speden’s specimens is also slightly different and shows a smaller posterior area.

**Modiolus meeki** (Evans & Shumard), 1857
(Plate 2, Figure 5)


*Description.*— Small, thin, subovate to subrhomboidal, inequilateral, well inflated but not globose, modioliform. Maximum inflation at midlength and slightly dorsal to midheight. Umbone moderately prominent, rounded, positioned at anterior end of dorsal margin. Hinge line long. Dorsal margin somewhat sinuous. Anterior margin straight to broadly convex with sulcus creating a distinct excavation. Anteroventral curve sharply rounded. Ventral margin sinuous with broad concavity from just below anteroventral curve to about midlength. Posterior margin somewhat broadly rounded to dorsal margin. Dorsal margin and posterior margin meet at an obtuse angle. A faint shallow radial depression begins just over the umbone and widens toward the ventral margin, creating a flattened area on the flank of the shell and the abovementioned concavity along the margin. A modest posterior ridge originates at the umbone and weakens before reaching posteroventral margin. Posterior area slightly flattened and resembles a narrow auricle. Ornament is fine irregular growth lines. Lines are variable in width, spacing and prominence.

*Dimensions.*— 6.5 mm L x 3 mm H.

*Discussion.*— This species is represented by one small left valve with about half the original shell material remaining. While the growth lines on this specimen seem more defined and sharp than what is figured by Speden (1971) the general characteristics closely resemble his description and figures. Possibly the sculpture differences are simply related to the size of the specimens as his are much larger than the specimen from this study. Speden also described and figured *M. uddeni* Stephenson from the Fox Hills Formation but that species has an even more rounded posterodorsal profile and does not as closely resemble the described specimen.

*Occurrence.*— *M. meeki* is reported from the Fox Hills Formation of South Dakota and the Pierre Shale of Colorado and the Black Hills.
Order **PTERIOIDA** Newell, 1965  
Superfamily **PINNOIDEA** Leach, 1819  
Family **PINNIDAE** Leach, 1819  
Genus **PINNA** Linnaeus, 1758  
Type Species.— *Pinna rudis* Linnaeus, 1758

**Pinna sp.**  
(Plate 2, Figures 6 & 7)

*Description.*— Small to large shells, thin, elongate subtrigonal in outline. Valves are near straight in lengthwise direction and moderately convex perpendicular to length. Ventral margins do not meet. Umbone and beak remain covered by matrix. Coarse radial ribs on larger specimen. Ribs are much narrower than interspaces with tops moderately pointed. Interspaces are smooth and curved.

*Dimensions.*— (approximate) Small specimen 23 mm L x 7 mm H; Large impression 200 mm L x 100 mm H.

*Discussion.*— Description is from two small, partially covered specimens and from a photograph of an exterior impression of a large specimen at the research area. Given the fragile nature of *Pinna* shells it is most likely that poor preservation may have influenced the small number of specimens found.

Suborder **PTERIINA** Newell, 1965  
Superfamily **PTERIOIDEA** Gray, 1847  
Family **BAKEVELLIIDAE** King, 1850  
Genus **PHELOPTERIA** Stephenson, 1953  
Type Species.— *Pteria? dalli* Stephenson (original designation), 1936, p 389-390.

**Phelopteria ruppii** Sava n. sp  
(Plate 2, Figures 8 & 9)

*Etymology.*— This species was named in honor of Frank Rupp of the Bureau of Land Management (Kremmling office) whose interest in, and support of, paleontological and anthropologic research throughout the region has been instrumental to this study and numerous additional projects.

*Description.*— Small to large shells, oblique with strong edge along hinge line. Slightly inequivalve, inequilateral, moderately inflated with greatest inflation approximating the growth axis from umbone towards posterior margin, slightly anterior to midwidth. Axial angle ($\angle A$) is approximately 35°, but intraspecific variation is common. Height-to-length ratio is variable, reflecting $\angle A$. Shape is generally pterioid. Ventral margin is broadly rounded with thin edges. Hinge line creates a long, straight dorsal margin with both posterior and anterior auricles. Posterior auricle is much larger than anterior auricle. Umbones are prosogyrous, positioned anterior to the midpoint and project only slightly above dorsal margin. Anterior auricles on right valves are delimited from disc by a shallowly to deeply impressed auricular sulcus which is slightly deeper than the anterior auricular sulcus of the left valve. Posterior auricles are more strongly delimited on left valves than on right valves where there is very little separation from the disc.
Growth lines are fine and follow the oblique shape of the shell. Lines on the disc are more widely spaced and fine. Lines on the auricles and along the dorsal margin are more closely spaced and prominent. The growth lines are irregularly spaced and of uneven width across the entire disc and auricles. On large specimens growth rugae are sometimes present, most often seen paralleling the posteroventral margin. Overprinted on this configuration is a pattern of growth threads that are concentric with the growth lines but are consistently spaced and of equal prominence across the disc, auricles and margin.

No interior description is available.

Dimensions of an average specimen.— 18 mm L x 15 mm H. Convexity approximately 5 mm.

Discussion.— Exterior ornamentation within the genus *Phelopteria* is not generally used as a diagnostic character because of the high degree of intraspecific variability. However, *P. ruppii* shows unusual and consistent ornamentation across many specimens which otherwise show the morphologic variability that is associated with this genus. This pattern is seen on specimens of all sizes and on both left and right valves. Despite the lack of interior features for use in identification and description, the unusual ornamentation of these *Phelopteria* specimens is sufficient to warrant species status.

*Phelopteria linguaeformis* (Evans & Shumard), 1854

(Plate 2, Figures 10 & 11)

*Avicula linguaeformis* Evans & Shumard, 1854, p. 163.
*Avicula linguaeformis* Evans & Shumard. Meek, 1859, p. 183, Pl. 1, fig. 6.
*Pteria linguiformis* (Evans & Shumard). Meek, 1876, p. 32, Pl. 16, figs. 1, a,b,c,d.
*Avicula linguaeformis* Evans & Shumard. Stanton, 1899, p. 637.
*Pteria linguiformis* (Evans & Shumard). Dowling, 1917, pp. 27, 45, Pl. 21, figs. 5, 5b.
*Pteria? linguaeformis* (Evans & Shumard). Stephenson, 1941, p. 102, Pl. 12, figs. 7, 8.
*Phelopteria linguaeformis* (Evans & Shumard). Speden, 1971, p. 71, Pl. 12, figs. 3-10; Pl. 13, 1-12.

Description.— Small to large shells, strongly oblique with an acute angle of obliquity – about 28 degrees. Inequilateral and moderately convex. Greatest inflation behind umbones to about half the length of the disc and anterior to midpoint. The area of greatest inflation is not coincident with the growth line pattern. Shell appears relatively thick for this genus. Hinge line is straight and long, creating anterior and posterior auricles on either side of umbone. Anterior auricle is triangular and small with a very narrow, shallow sulcus separating it from the disc. The dorsal edge of the anterior auricle curls inward slightly. The posterior auricle is also triangular but much larger than the anterior auricle and is delimitated from the disc by a broad, shallow sulcus. The margin of the posterior auricle rounds broadly and merges with the margin of the disc. Umbones are barely prosogyrate, moderately inflated, and not prominent, showing very slight projection above the hinge line. Positioned anteriorly about three-fourths the length of the hinge line. Growth lines curve sinuously as they originate at the edge of the ears and follow the oblique shape of the shell. Growth lines are variable in both
thickness and spacing but are slightly thicker and more prominent towards the ventral margin. Ventral margin is moderately to sharply rounded. Anteroventral margin is broadly curved. Posteroventral margin roughly parallels anteroventral margin from the jointure of the ear to the ventral margin curve. No interior description is available.

Dimensions of an average specimen.— 24 mm L x 25 mm H.

Discussion.— The shells representing this species are relatively well-preserved but often are missing the auricles or the margins of the shell are broken. Speden (1971) observed a large range of variability in the angle of obliquity in his sample, but the specimens from this study largely fall into the category of strongly oblique. However the specimens from this study differ from the described and figured specimens of Speden (1971) and Stephenson (1941) in that the anterior auricle is considerably smaller. Eventually these specimens may prove to belong to a new species of *Phelopteria*, but in consideration of the already complex synonymy and degree of morphological variability seen in *Phelopteria* these specimens are designated as *P. linguaeformis* until further study and interior features can provide additional data supporting their inclusion in a distinct taxon.

Occurrence.— *P. linguaeformis* is described from the Fox Hills Sandstone of South Dakota and the Navarro Group of Texas.

Family INOCERAMIDAE Giebel, 1852
Genus INOCERAMUS Sowerby, 1814


“Inoceramus” altus Meek, 1871
(Plate 2, Figures 12 - 15)

*Inoceramus altus* Meek, 1871, p. 301.
*Inoceramus altus* Meek. Meek, 1876a, p. 43, Pl. 14, fig. 1.
non *Inoceramus altus* Meek. Whitfield, 1880, p. 391, Pl. 9, fig. 11 (=Mytiloides sp.).
*Inoceramus altus* Meek. Logan, 1898, p. 506, Pl. 107, fig. 1.
“Inoceramus” altus Meek. Walaszczyk, Cobban & Harries, 2001, p. 214, Pl. XXII, figs. 1-8; Pl. XXIII, figs. 1, 3-5; Pl. XXIV, fig. 1.

Description.— Large shells, oblique, inequilateral, equivalent, strongly inflated. Point of maximum inflation slightly anterior to umbone and about one-third the height of the valve. Umbone prominent, prosogyrate and projecting above hinge line slightly. Beak slightly rounded, incurved. Dorsal margin straight to end of posterior auricle. An angle of >90º marks the end of the posterior auricle where the posterior margin is broadly rounded. Posterior, ventral and anterior margins merge together in a somewhat elongate, widely rounded curve. Anterodorsal margin straightens slightly before passing onto the umbone. Angle of obliquity (∠A) approximately 55º. Hinge line long and straight. Posterior auricle wide and extends along hinge line. Auricle separated from disc by a distinct auricular sulcus that is somewhat variable in depth between specimens. Ornament is strong concentric rugae with asymmetrical profile. Rugae have a longer, shallower slope on dorsal side, with shorter, steeper slope on ventral side.
Rugae are weak to non-existent over umbone and on posterior auricle. Geniculation of the valves is found on some specimens of this species.

**Dimensions of described specimens.**—
broken articulated valves; 50 mm L (ventral margin broken) x 57 mm H (posteroventral margin broken) x about 19 mm convexity.
37 mm L x 35 mm H (posterodorsal margin broken) x about 9 mm convexity.

**Discussion.**— According to Walaszczyk et al. (2001) this species is unique from all other species of the Upper Campanian. The most similar species is “*Inoceramus* altusformis” which is less slender and has a smaller, less distinct posterior auricle.

**Occurrence.**— Occurrence of this species is limited to the US Western Interior within the *Didymoceras cheyennensis*, *Baculites compressus* and *Baculites cuneatus* zones. One occurrence in the Upper Campanian of the Central Poland Vistula section has been reported (Walaszczyk et al., 2001).

“Inoceramus” *altusformis* Walaszczyk, Cobban & Harries, 2001
(Plate 3, Figures 1, 2 & 3)

Inoceramus vanuxemi Meek & Hayden?. Stephenson, 1941, p. 99, Pl. 13, fig. 1.

**Description.**— Medium to very large sized, thin, subtrigonal outline, somewhat oblique, moderately inflated. Umbone about one-fifth of length from anterior end to near equal with anterior margin, prominent, inflated. Beak rostrate, strongly incurved, prosogyrate. Anterior margin broadly convex merging into rounded ventral margin. Posterior margin near straight to very weakly convex. Hinge line long and straight. Weak posterior auricle. Ornament is of prominent growth undulations that become progressively more widely spaced and weaker with distance from umbone. In large specimens the ornament disappears within about 15 cm of umbone.

**Dimensions of described specimens.**—
41 mm L x 46 mm H;
56 mm L x 67 mm H;
19 cm L x 23 cm H x 66 mm total convexity of articulated valves;
37 cm L x 50 cm L x 14 cm total convexity of articulated valves.
All specimens are steinkerns and have broken margins so measurements are minimum values.

**Discussion.**— This species is common in the fauna from the research area and is by far the largest bivalve. “*Inoceramus* altusformis” resembles “*Inoceramus* altus” in some characteristics but is more trigonal in outline where “*Inoceramus* altus” is more subovate. “*Inoceramus* altus” is also less convex and has a more pronounced posterior auricle than “*Inoceramus* altusformis.”

**Occurrence.**— This species has been described from the *Baculites compressus* zone of the Western Interior and from the Navarro Group of Texas.
“Inoceramus” oblongus Meek, 1871
(Plate 4, Figure 1)

Inoceramus oblongus Meek, 1871, p. 297, Pl. XXVI, figs. 2, 5; Pl. XXVII, figs. 1, 3; Pl. XXVIII; Pl. XXXI, fig. 5.
Inoceramus oblongus Meek. White, 1879, p. 285, Pl. 2, fig. 1.
“Inoceramus” oblongus Meek. Walaszczyk, Cobban & Harries, 2001, p. 224, Pl. XXVI, figs. 2, 5; Pl. XXVII, figs. 1, 3; Pl. XXVIII; Pl. XXXI, fig. 5.

Description.— Medium to large sized valves, thin, oblique, inequilateral, inequivalve, moderately inflated. Point of greatest inflation is slightly posterior to and just behind umbone. Subovate to subtrigonal in outline. Umbone moderately prominent, positioned at anterior end of dorsal margin, orthogyrate; beaks rounded. Dorsal margin long, straight to slightly convex and elongated in the posterior direction. Posterodorsal curve pronounced. Posterior margin closely rounded. Ventral margin broadly rounded, merging smoothly into anterior margin then anterodorsal margin with no distinct breaks. Ornament is of strong, irregularly spaced concentric growth undulations that follow the oblique shape of the valve. Undulations are even on both faces and are about of equal widths.

Dimensions of described specimens.—
46 mm L x 39 mm H, angle of obliquity approximately 27°.
44 mm L x 29 mm H, angle of obliquity approximately 25°.

Discussion.— This species shows a great deal of variability in both the height to length ratio and the prominence and variability of the ornament. “I.” oblongus was reported previously by Walaszczyk, Cobban and Harries (2001) from only the Baculites reesidei zone. This finding extends the range of “I” oblongus into the B. compressus/B. cuneatus zone.

Occurrence.— Reported from the Western Interior of North America. Questionably from the uppermost Campanian of Europe.

Order PECTINOIDA Newell & Boyd, 1995
Superfamily PECTINOIDEA Rafinesque, 1815
Family ENTOLIIDAE Korobkov, 1960
Genus SYNCYCLONEMA Meek, 1864
Type Species.—Pecten rigida Hall & Meek, (1856, p. 381) by original designation (non Sowerby, 1818) = Pecten hallii Gabb, 1861, p. 214
Syncyclonema haeggi Dhont, 1971, p. 48

Syncyclonema travisanus Stephenson, 1941
(Plate 4, Figure 2)

Pecten (Syncyclonema) travisanus Stephenson, 1941, p. 135, Pl. 22, fig. 1, 2.

Description.— Small shells, very thin, auricular, subcircular to subovate in outline, low convexity. Umbone moderately prominent and located slightly posterior to center of hinge line. Beak small, orthogyrate. Point of greatest inflation is directly behind beak to about one-half the height of the disk. Dorsal margin is straight with only a very slight
projection of the beak. Outline of the main disk of the shell is subtrigonal with the
umbone creating an angle of about 90° and the anteroventral margin to the
posteroventral margin being slightly more than one-half of a circle. Anterior auricle is
long and appears to be offset from disk by deep auricular sulcus that reaches from
umbone to shell margin. Byssal notch is pronounced and shows a distinct separation
of the anterior auricle from the disk. Posterior auricle is broken. Ornament is fine
concentric growth lines over the entire shell with regular fine radial ornament beginning
about half the height of the disk and extending to margins. Radial lines are flat on top
with narrow incised interspaces that are about half or less than half the width of the
raised radial ornament. Disk margin is finely scalloped.

Dimensions.— 6 mm L x 6.5 mm H.

Discussion.— This species is represented by very few fairly poorly preserved
specimens. Except for one specimen in which the anterior auricle was present, all
auricles are missing, but some are represented by a mold of the auricle. This species
designation was based on the presence of the fine radial ornament which is virtually
identical to that described and illustrated by Stephenson (1941, Plate 22, Fig. 1) for the
left valve of his holotype.

Occurrence.— Syncyclonema travisanus was described from the Navarro Group of
Texas.

Family PROPEAMUSSIIDAE Abbott, 1954
Genus PROPEAMUSSUM de Gregorio, 1884
Type Species.— Pecten ceciliae de Gregorio, 1884

Propeamussium simplicus (Conrad), 1860
(Plate 4, Figures 3 & 4)

Pecten simplicus Conrad, 1860, p. 283, Pl. 46, fig. 44.
Sincyclonema simplicius (Conrad). Gabb, 1876, p. 319.
Amusium simplicum (Conrad). Whitfield, 1885, p. 51, Pl. 7, figs. 11, 12.
Pecten simplicius Conrad. Weller, 1907, p. 480, Pl. 51, fig. 6.
Pecten simplicius Conrad. Stephenson, 1923, p. 199, Pl. 55, figs. 6-11.
Pecten simplicius Conrad. Wade, 1926, p. 62, Pl. 20, fig. 7.

Description.— Small shells, very thin, auricular, subcircular to subovate in outline,
inequalateral, low convexity. Umbone moderately prominent and located slightly anterior
to center of hinge line. Beak small, orthogyrate. Point of greatest inflation is directly
behind beak to approximately one-third the height of the disk. Dorsal margin is straight
with only a very slight projection of the beak. Outline of the main disk of the shell is
subtrigonal with the umbone creating an angle of about 90° and the anteroventral margin
to the posteroventral margin being slightly more than one-half of a circle. Auricles are
relatively small. Anterior auricle is subrectangular with rounded outer corners and offset
from disk by deep auricular sulcus that reaches from umbone to shell margin. Byssal
notch is pronounced and shows a distinct separation of the anterior auricle from the disk.
Posterior auricle is smaller and more trigonal in shape. The posterior auricular sulcus is
shallower than the anterior auricular sulcus and weakens progressively from the umbone toward the margin. Ornament is fine concentric growth lines that cross the auricular sulci and become slightly heavier and more pronounced on the auricles. No radial ornament.

**Dimensions.**— 6 mm L x 6.5 mm H; 8.5 mm L x 9 mm H.

**Discussion.**— Pectinid taxonomy is in a state of significant confusion and differences of opinion. The characters used herein to define various genera follow those used by D’hont (1971).

**Occurrence.**— *Propeamussium simplicus* is a widespread and long-ranging taxon that has been described from the Navarro Group of Texas, the Nacatoch Sand and Arkadelphia Clay of Arkansas and throughout the Coastal Plain of the eastern United States.

**Propeamussium sp.**
(Plate 4, Figures 5 & 6)

**Description.**— Small shells, very thin, auricular, slightly elongate outline, inequilateral, depressed convex. Umbone moderately prominent and located slightly anterior to center of hinge line. Beak small, orthogyrate. Point of greatest inflation is directly behind beak to about one-third the height of the disk. Margins of the disk are noticeably flat, possibly correlating with the pallial line. Dorsal margin is straight with only a very slight projection of the beak. Outline of the main disk of the shell is subtrigonal with the umbone creating an angle of \(<90^\circ\) and the anteroventral margin to the posteroventral margin being slightly more than one-half of a circle. Auricles are relatively large. Anterior auricle is larger than posterior auricle and is offset from disk by deep auricular sulcus that reaches from umbone to shell margin. Byssal notch is shallow. The posterior auricular sulcus is shallower than the anterior auricular sulcus and weakens progressively from the umbone toward the margin. Interior details are shown by one specimen in which it appears that the adductor muscle scar is located just behind and slightly anterior to the umbone. Ornament is fine concentric growth lines overprinted with strong concentric folds that become more prominent near the margins of the disk. The fine growth lines cross the auricular sulci and become slightly more coarse on the auricles. Radial ornament lacking.

**Dimensions.**— 5 mm L x 5.5 mm H; 6 mm L x 6 mm H; 8 mm L x 8 mm H.

**Discussion.**— These fragile shells closely resemble *Syncyclonema halli* (Gabb) described by Speden (1971) or *Pecten (Syncyclonema) archeri* as described and illustrated by Stephenson (1941) but cannot be specifically assigned because of their poor preservation.

**Genus CHLAMYS** Röding, 1798  
**Subgenus LYROPECTEN** Conrad, 1862  
**Type Species.**— *Pallium estrellatum* Conrad, 1856; S.D. Dall, 1898.
Lyropecten(?) sp.
(Plate 4, Figure 7)

Description.— Small specimen, depressed convex with strong radial ornamentation. Twelve to 14 radial ribs initiate at the umbone and extend to the margins of the disk. At the umbone the ribs are closely spaced with the ribs and the interspaces about equal. As the ribs extend over the disk they become more widely spaced and it appears that the interspaces are approximately 1.5 times as wide as the ribs. Margin is scalloped. Auricles are broken. Umbone obscure.

Dimensions.— 6 mm L x 6 mm H.

Discussion.— This description is taken from only one weathered steinkern, leaving even the genus designation questionable. However, even weathered, the ornament of this specimen is distinctly different from all other pectinid specimens in the study area. Stephenson’s (1941) description and figure of Pecten (Pecten?) venustus Morton shows distinct similarities to this specimen.

Superfamily ANOMIOIDEA Rafinesque, 1815
Family ANOMIIDAE Rafinesque, 1815
Genus ANOMIA (Linnaeus, 1758) Müller, 1776
Type Species.— Anomia ephippium Linnaeus, 1758, p. 701.

Anomia tellinoides Morton, 1833
(Plate 4, Figures 8, 9 & 10)

Anomia ephippium (Lamarck)? Morton, 1830, p. 284.
Anomia tellinoides Morton, 1833, p. 294, Pl. 5, fig. 11.
Anomia tellinoides Morton, 1834, p. 61, Pl. 5, fig. 11.
Anomia sellaeformis Conrad, 1858, p. 330, Pl. 34, fig. 6.
Diploschiza cretacea Conrad, 1866, p. 77.
Anomia tellinoides Morton. Whitfield,1885?, p. 43, Pl. 43, fig. 12, 13?.
Diploschiza cretacea Conrad. Whitfield, 1886, p. 43, figs. 4-8.
Anomia argentaria Morton. Weller, 1907, p. 496, Pl. 54, fig. 15.

Description.— Valves subovate to subround with irregular outline and a tendency to be roughly triangular. Consisting of thin nacreous layers. Variable morphologies with growth lines rarely visible or weak radiating costae. Some specimens show overlapping lamellae. Left valves generally broadly convex, right valve flattened. Anterior most strongly inflated with posterior more compressed. Umbones poorly defined but show a slight beak. Hinge located along dorsal margin in front of beak. Lower valves with byssal foramen. Monomyarian muscle scar is large in proportion to the shell, roughly subtriangular.

Dimensions.— 23 mm L x 24 mm H.
Discussion.— This genus is known to be highly variable and irregular. It is possible that some specimens from this study should be referred to *A. argentaria* but most specimens are poorly preserved and the observable characteristics appear to match *A. tellinoides* more closely. *A. tellinoides* generally has no radial ornament and when present it is very weak. The beak is more pointed and closer to the dorsal margin than in *A. argentaria* and the hinge of *A. tellinoides* is also more marginal.

Occurrence.— *Anomia* is a wide-ranging genus with a cosmopolitan distribution. *A. tellinoides* has been previously described from the Neylandville Marl of the Navarro Group of Texas and from the Atlantic Coastal Plain of the United States.

Order **LIMOIDA**
Superfamily **LIMOIDEA** Rafinesque, 1815
Family **LIMIDAE** Rafinesque, 1815
Genus **LIMA** Bruguière, 1797

Type Species.— *Ostrea lima* Linnaeus, 1758

*Lima janetae* Sava, n. sp.
(Plate 4, Figures 11 & 12)

Etymology.— This species was named for my sister and friend, Janet McIntire who encouraged and supported me in every step of this journey.

Description.— Small valve, slightly oblique, auricular, strongly inflated, subtrigonal. Umbone is very prominent and narrow, prosogyrate. Beak incurved. Maximum inflation is directly behind umbone. Posterior auricle is moderately wide; auricular sulcus is obscured. Anterior auricle is obscured. Posterior margin is broadly convex, almost straight. Curve of posterior margin into ventral margin is somewhat sharply rounded. Ventral profile is broadly rounded and merges into anterior margin. Anterior margin is shorter than posterior margin. Ornament is strong radial ribs originating at beak. Ribs are more prominent on flank, less prominent over umbone and along anterior and posterior margins. Ribs are flat topped and about twice as wide as the interspaces.

Dimensions of the holotype.— 5 mm L x 7 mm H x ≈ 3.5 mm convexity.

Discussion.— This description is from one fairly well-preserved specimen. It resembles *Lima whitfieldi* Weller in the general shape but the umbone is much more prominent and narrow and the posterodorsal/posteroventral/ventral curve is slightly sharper. The degree of inflation is high for this genus – no other species appears to have the same high convexity.

*Lima sp. 1*
(Plate 4, Figure 13)

Description.— Small valve, moderately inflated, slightly oblique. Subtrigonal in outline. Umbone prominent with beak rostrate. Small auricle on posterior of beak, most likely also present on anterior but not preserved. Anterodorsal margin is longer than the posterodorsal margin. Ornamentation consists of approximately 18 radiating ribs, prominent on flank but weak or obscure on umbo and postero- and anterodorsal margins. Ribs are evenly spaced with interspaces slightly wider than the ribs. Edges are crenulated.
**Dimensions.**— 5 mm L x 6 mm H (possibly incomplete external mold).

**Discussion.**— This shell is described from a single exterior mold with no original material for identification. The dorsal/hinge margin is broken away so no hinge characteristics can be used for specific determination. It most closely resembles *Lima reticulata* (Lyell and Forbes, 1945).

**Lima(?) sp. 2**
(Plate 4, Figure 14)

**Description.**— One small, broken shell appears to be a *Lima* based on the ornament, inflation and shape of the fragment. This fragment is about one-half of a disk with broken or no auricles. Moderately inflated. Moderately heavy radial ribs extend from umbone to margin, becoming thicker toward the margin. Margin is scalloped.

**Dimensions.**— 4 mm L x 5 mm H.

**Suborder OSTREINA Ferussac, 1822**
**Superfamily OSTREOIDEA Rafinesque, 1815**
**Family GRYPHAEIDAE Vialov, 1936**
**Subfamily EXOGYRINAE Vialov, 1936**
**Genus EXOGYRA Say, 1820**

**Exogyra sp.**
(Plate 4, Figure 15)

**Description.**— Small shell, inequilateral, highly inflated, subcircular. Beak strongly opisthogyrate, almost spiral. Strong umbonal ridge extends along anterodorsal margin to point opposite umbone on ventral margin. The umbonal ridge creates a close-to vertical plane along the anterior margin that is almost as tall as the shell is convex. Maximum convexity is on top of the shell bordering the umbonal ridge. Sculpture is irregular, unevenly spaced, variable in height and thickness, roughly concentric folds that follow the twist of the shell. The overall appearance is bumpy and wrinkled. From the point of maximum convexity, the inflation declines gradually over most of the flank until near the posteroventral margin where it slopes steeply to the margin. The edge of the posteroventral margin is relatively flat. No right valve is available for description.

**Dimensions.**— 9 mm L x 10 mm H x 6 mm convexity (steinkern); 14 mm L x 10 mm H (internal mold); 8 mm L x 8 mm H (internal mold).

**Discussion.**— This description is of steinkerns only. This genus designation is based on the incurved appearance of the umbones of these steinkerns. All specimens are very small-reaching approximately 20 mm in longest direction.

**Occurrence.**— *Exogyra* have been found in Cretaceous deposits throughout North America and described by Stephenson (1941, 1952), Anderson (1958) and Richards et al. (1962) to name a few. The largest number of species seems to occur in the units found in Texas and Mississippi (Anderson, 1958). The specimens described here are too small and worn to identify to the species level.
Family **OSTREIDAE** Rafinesque, 1815
Subfamily **LOPHINAE** Vialov, 1936
Genus **PSEUDOPERNA** Logan, 1899
Type Species.— *Pseudoperna rugosa* Logan, 1899a

**Pseudoperna inflatum** Sava, n. sp.  
(Plate 4, Figures 16 - 19)

*Etymology.*— This species was named for its strong inflation.

*Description.*— Medium to large shells, thin, very inflated, subtrigonal. Inequilateral and inequivalve with right valve being significantly less inflated. Umbone prominent, orthogyrate and positioned about one-fourth the length of the shell from the anterior end. Beak small, rostrate. Point of maximum inflation is about mid-height and in the anterior one-fourth of the valve. Posterodorsal margin is straight to very slightly sinuous with a small concavity just below the umbone and another just before the posterior point. Posterior margin is very sharply rounded. Ventral margin is broadly convex. Anteroventral margin to anterodorsal margin makes a broad smooth curve—a half sphere. Shell is thin, fragile, nacreous and breaks in layers. Ornament is irregular low growth undulations. Muscle scars of one specimen are preserved and show a roughly subquadrate scar about one third the length of the anterodorsal margin from the umbone and about one-half the thickness. Another scar is about mid-height of the valve and originates just behind the umbone. This scar is crescent shaped but truncate on the posterior end which is about midlength of the posterodorsal margin.

*Dimensions.*— 14 - 33 mm L x 11 - 25 mm H.

*Discussion.*— This species is represented by three left valve steinkerns and one articulated steinkern, all with fragments of shell material retained. The right valve of the articulated specimen remains embedded in the matrix for the most part with only a portion of the ventral margin exposed. The shape is similar to *Cuspidaria* but without the noticeable constriction that produces the narrowing posterior projection typical of the genus. Rather, this species has an even taper of both margins. The shell material is very similar to that seen in *Anomia* in its fragility and preservation. The valves show some variability in morphology — i.e. the larger valve is noticeably curved along the dorsal margins from anterior to posterior whereas the smaller valve is flat — but not as much variability as seen in many ostreids. This is a very inflated species, unlike most *Ostrea*, but retains the thin, nacreous shell rather than having a thick, more resilient shell like other highly inflated ostreids, such as *Gryphaea* or *Exogyra*.

Genus **OSTREA** Linnaeus, 1758
Type Species.— *Ostrea edulis* Linnaeus, 1758, p. 645, 696.

**Ostrea subradiata** Cragin, 1893  
(Plate 5, Figure 1)

*Ostrea carica* Cragin (in part), 1893, p. 200. (Not plate 45, figure 11).  
*Ostrea subradiata* Cragin. Stephenson, 1952, p. 75, Pl. 18, figs. 7-11.

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Description.— Large valve, fragile, subcircular to broadly ovate outline, moderately inflated. Maximum inflation about one-third the height of the valve behind the umbone and about midlength. Umbone small, compressed, positioned about midlength or slightly anterior to midlength. Outer surface rough, irregular with growth undulations and radiating ornament. The most prominent undulation is about one-third the height of the valve behind the umbone. Radial ornament is somewhat sinuous costae, irregularly spaced and of variable widths and heights. Sinuosity produced mainly when radial costae cross a growth line or undulation and show a slight change in trend. Costae are more prominent ventral to the largest undulation.

Dimensions.— (approximate) 24 mm L x 28 mm H.

Discussion.— This description is of a single well-preserved left valve. Dimensions are approximate because some marginal area is still covered by matrix. The intraspecific variability characteristic of all Ostrea species makes specific assignment difficult. This particular specimen shows distinct ornamentation which agree with Stephenson’s (1952) description of this species. Ostrea leveretti Stephenson (1952) is very similar in ornamentation, but is described as “thick and sturdy” (p. 76) with beaks “twisted a little toward the rear” (p. 76) - characteristics not exhibited in this specimen. Other Ostrea species are similar in some characteristics but without a greater number of specimens to study this designation best fits the specimen.

Occurrence.— Ostrea subradiata is described by Stephenson (1952) from the Woodbine Formation of Texas.

Ostrea sp. 1
(Plate 5, Figure 2)

Description.— Small to medium sized, fragile, subround to subquadrangular outline, depressed convex to moderately inflated. Overall shape is extremely variable. Umbone generally non-prominent but may have very slightly pointed beak. Shell morphology is dependant on growth conditions and space and may be rough and undulating or smooth and of somewhat uniform convexity. Interior muscle scar large and positioned centrally relative to length and about one-third the height of the valve from the umbone.

Dimensions of described specimens.— 9 mm L x 7 mm H; 4 mm L x 4 mm H; 15 mm L x 11 mm H (ventral margin broken); 8 mm L x 5 mm H (steinkern).

Discussion.— This small species is very common in the samples for this study, but because of the fragile nature and morphological variability of these shells it is very difficult to obtain a clear representation of the true characteristics of this Ostrea species.

Ostrea sp. 2
(Plate 5, Figures 3 & 4)

Description.— Large sized, moderately thick, subovate to elongate sub trigonal outline, low convexity. Ventral end wider than dorsal end. Umbone small, non-prominent; beak slightly pointed. Height approximately twice length. Uniformly convex to randomly undulating. Some valves have low concentric growth rugae that become weaker with distance from the umbone. Muscle attachment scars not visible or not preserved.
Dimensions of described specimens.— 23 mm L x 38 mm H (portion of posteroventral margin covered).

Discussion.— This Ostrea species is more robust and much larger than the Ostrea species described above but is not as numerous in the samples. A number of the specimens of this species have a prominent rounded ridge that runs from the umbone toward the posteroventral margin. This ridge very gradually expands in both width and height, but not in proportion to the growth of the shell. Since this is not seen on all of the specimens it was interpreted as a parasite scar similar to the Hohlkehle features sometimes seen in inoceramid shells (for discussion see Toots, 1964).

Subclass HETERODONTA Neumayr, 1884
Order VENEROIDA H. Adams & A. Adams, 1856
Suborder LUCININA Dall, 1889
Superfamily LUCINOIDEA Fleming, 1828
Family LUCINIDAE Fleming, 1828
Genus NYMPHALUCINA Speden, 1971

Type Species.— Tellina occidentalis Morton, 1842, p. 210, Pl. 11, fig. 3.

Nymphalucina bourni Sava, n. sp.
(Plate 5, Figure 5)

Etymology.— This species was named for Troy Bourn who found the vast majority of the specimens collected for this study and provided assistance in the lab as well.

Description.— Small-to medium-sized valves, subcircular to ovate in outline, slightly inflated. Maximum inflation posterior of umbones to midheight. Umbones prominent, slightly prosogyrate and mildly inflated, positioned about midlength of the disc; small moderately rostrate beaks. Long, narrow ligamental nymphae posterior to umbones. Anterodorsal margin straight to very slightly convex. Anterior and posterior margins closely rounded with posterior margin slightly more sharply rounded. Ventral margin broadly rounded. From point of maximum inflation disc descends to a narrow, flattened marginal edge. Exterior ornamentation is not well-preserved on any specimen, but appears to consist of fine concentric growth lines, unevenly spaced and of varying widths. Growth lines are most prominent from the umbones to the point of maximum inflation, becoming very fine as they approach the margins of the disc. No interior features are available for description.

Dimensions of described specimens.— 10 mm L x 9 mm H.

Discussion.— This species is represented mostly by steinkerns with only a few examples of valves with preserved shell material. Shape of N. bourni is less ovate, valves are very slightly less inflated and umbonal ridge is weaker than on Nymphalucina occidentalis (Morton). N. bourni also has a more pronounced flattening along the margins than N. occidentalis. In consideration of these differences a new species designation is warranted.
**Nymphalucina cleburni** (White)  
(Plate 5, Figures 6 & 7)


*Description.*— Small valves, subcircular to ovate in outline, slightly inflated. Maximum inflation posterior of umbones to midheight. Umbones prominent, slightly prosogyrate and mildly inflated, positioned roughly midlength of the disc; small moderately rostrate beaks. Long, narrow ligamental nymphae posterior to umbones. Anterodorsal margin short and straight to very slightly convex. Anterior and posterior margins closely rounded with posterior margin slightly more sharply rounded. Ventral margin broadly rounded. From point of maximum inflation disc descends to a narrow, flattened marginal edge. Exterior ornamentation is not well-preserved on any specimen, but appears to consist of concentric growth rugae. Rugae are spaced more closely over umbone and become progressively more widely spaced until about midheight where the prominent rugae disappear and only fine concentric growth lines continue to margins. Rugae have a shallower slope on the dorsal side with a steeper face ventrally. No interior features are available for description.

*Dimensions.*— 13 mm L x 6 mm H x 5 mm (total convexity of articulated specimen).

*Discussion.*— Speden (1971) described and figured *N. cleburni* from the Fox Hills Formation of South Dakota but noted that the only difference between *N. cleburni* and *N. occidentalis* is the presence of the prominent growth rugae. He suggested that the two species may actually be the same and simply represent phenotypic variation. Based on the exterior differences this specimen was included as a separate species in this report.

*Occurrence.*— *Nymphalucina cleburni* has been previously reported from the Fox Hills Formation of South Dakota.

**Family UNGULINIDAE** H. & A. Adams, 1857  
**Genus DIPLODONTA** Brown, 1831  
**Type Species.**— *Venus lupinus* Brocchi = ?*Tellina rotundata* Montagu

*Diplodonta davisi* Dailey and Popenoe, 1966  
(Plate 5, Figure 8)

*Description.*— Small shell, subcircular, moderately inflated. Ventral margin is broadly rounded and grades imperceptibly into the slightly less broadly convex anterior and posteroanterior margins. Posterior margin somewhat truncated with straightened margin subvertical. Beak is small, low and very slightly prosogyrate. Position is just anterior to the midpoint. Shell material is thin and fragile, preserved over most of specimen. Ornamentation is very simple – minute growth lines cover most of the shell until near the basal margin a pronounced growth ruga appears to be an exterior manifestation of the pallial line. Outermost edges are noticeably flattened. Narrow escutcheon marked by a low lateral welt. Siphonal region discerned by very shallowly concave area differentiated from posterior flank by a low, obscure posterior ridge. Distinct ligamental suture extends almost to posterodorsal margin.
Dimensions.— 11 mm L x 10 mm H.

Discussion.— This description is of one well-preserved valve in which most exterior characteristics are preserved and exposed.

Occurrence.— Dailey and Popenoe (1966) described Diplodonta davisi from the Late Campanian to Early Maastrictian Jalama Formation of California and note that this genus has rarely been found from the Cretaceous worldwide and their report was the first North American occurrence of this genus.

Order CARDITOIDA Dall, 1889
Superfamily CRASSATELLOIDEA Ferussac, 1822
Family ASTARTIDAE d'Orbigny, 1844
Subfamily ASTARTINAE d'Orbigny, 1844
Genus ASTARTE J. Sowerby, 1816
Type Species.— Venus scotica Maton & Rackett, 1807 (= Pectunculus sulcatus DaCosta, 1778, var. scotica Maton & Rackett, 1807).

Astarte sp.  
(Plate 5, Figure 9)

Description.— Small, subtrigonal, depressed convex. Umbone prominent, rounded, slightly prosogyrate. Umbone projects well above dorsal margin and positioned about one-third valve length from anterior end. Point of maximum inflation is just behind umbone to about one-third the height of the valve. From point of maximum inflation the valve becomes very depressed convex and margins are near horizontal. Anterodorsal margin long and broadly concave with excavation near umbone and a relatively straight section before meeting anterior margin at an obtuse angle. Anterior margin rounded. Ventral margin broadly convex. Posterior margin steep, broadly curved before meeting steep, straight posterodorsal margin. A weak umbonal ridge begins on posterior side of umbone and terminates at posterodorsal margin. No lunules. Weak elongate trigonal escutcheon. Ornament of strong concentric growth rugae that follow the shape of the valve. Rugae are weaker and more closely spaced over umbone and become stronger and more widely spaced with distance from umbone.

Dimensions.— 12 mm L x 10 mm H; 7 mm L x 7 mm H.

Discussion.— This genus is represented by a few small steinkerns. No samples have been found that retain any shell material. The unique shape of the long concave anterior margin and projecting umbone is sufficient for generic assignment. Ornament is described from the impression on the steinkern.

Superfamily CRASSATELLOIDEA Férrussac, 1822
Family CRASSATELLIDAE Férrussac, 1822
Subfamily CRASSATELLINAE Férrussac, 1822
Genus CRASSATELLA Lamarck, 1799
Type Species.— Crassatella tumida Lamarck, 1805, p. 408-409 = Crassatella gibba Lamarck, 1801, p. 119 = Venus ponderosa Gmelin, 1791, p. 3280 (non Mactra cygnea Chemnitz, 1782, pl. 21, fig. 207).
**Crassatella franzeseii** Sava n. sp.
(Plate 5, Figure 10)

*Etymology.*— This species was named in honor of Michael Franzese, my partner and champion in all things.

*Description.*— Large shell, moderately inflated with greatest convexity just behind umbo to midflank. Shape is subtrapezoidal. Umbo is positioned about one third the length of the shell from the anterior and is very slightly prosogyrate. Beak is somewhat rostrate. A very rounded, gentle umbonal ridge originates at the umbo and trends along the posteroventral margin, resulting in a subquadrate outline. The portion of the shell posterior to the ridge is approximately one third the total area of the disc. The anterior margin from umbo to anteroventral margin is straight and shifts to gently convex along the ventral margin. At the termination point of the posterior ridge the posteroventral margin is sharply rounded and becomes very gently curved until it meets the dorsal margin which is relatively straight. Ornamentation consists of growth lines that are irregularly spaced and variable in both thickness and prominence. Small escutcheon visible from the center of the dorsal edge to near the end of the dorsal margin, but may be larger as some matrix remains around this margin. Small anterior face also visible but partially covered by matrix.

*Dimensions.*— 27.5 mm L x 25 mm H.

*Discussion.*— This description is based on exterior morphology of several exceptionally well-preserved specimens. Stephenson (1941) and Wingard (1993) depict *C. vadosa* as a highly variable species of *Crassatella* from the Maastrichtian of the Gulf and Atlantic Coastal plains with external characteristics similar to those of *C. franzeseii*. However, upon close examination, the two species show marked differences such as a more quadrate ventral margin and the umbonal ridge in *C. franzeseii* is located farther from the dorsal/posterodorsal margin than in *C. vadosa*.

Superfamily **CARDIOIDEA** Lamarck, 1809
Family **CARDIIDAE** Lamarck, 1809
Genus **PROTOCARDIA** (Beyrich), 1845
Type Species.— *Cardium hillanum* Sowerby, 1812, p. 41, Pl. 14, fig. 1.

**Protocardia barneyi** Sava, n. sp.
(Plate 5, Figure 11)

*Etymology.*— This species is named in honor of my father, Barney Sava, who always believed in me and told me that I could accomplish anything I wanted to.

*Description.*— Small shell, moderately inflated. Subround in outline. Umbo moderately prominent with rounded beak, slightly prosogyrate. Posterior margin broadly rounded. Anterior margin more sharply rounded. Slight excavation on either side of umbo, with the anterior side excavation slightly deeper, forming a weak ridge which fades before reaching midheight. Very small lunule. Ornamentation consists of very fine concentric growth lines on central disc. Fine radial ribs appear on the flank about one half the distance from the point of maximum inflation. The fine cancellate pattern produced can be seen under magnification. The posterior portion shows more prominent radial
ribbing, but with no distinct line of demarcation separating the two types of ornamentation. Margins are finely scalloped. No spines or spine scars are found on this specimen.

*Dimensions.*— 6 mm L x 4.5 mm H.

*Discussion.*— This very small valve is exceptionally well-preserved with original shell material that retains a glossy finish. It differs from *P. subquadrata* in having a less prosogyrate umbone and a steeper slope on the posterior flank. *P. subquadrata* has an area adjacent to the posterior margin that is slightly concave, or flattened whereas *P. barneyi* is convexly sloped to the margin.

Superfamily **TELLINOIDEA** Blainville, 1814  
Family **TELLINIDAE** Blainville, 1814  
Subfamily **TELLININAE** Blainville, 1814  
Genus **TELLINA** Linnaeus, 1758  
Type Species.— *Tellina (Tellinimera) eborea* Conrad, 1860, p. 278; 1870, p. 73.

**Tellina sp.**  
(Plate 5, Figures 12, 13 & 14)

*Description.*— Small- to medium-sized valves, elongate, ovate, inequilateral, depressed convex. Umbone non-prominent and anterior to midlength; beak very slightly prosogyrate. Anterior margin broadly rounded. Dorsal margin broadly convex. Posterior margin weakly rostrate. Weak ridge runs from umbone toward anterior margin, but fades before meeting anterodorsal margin. Narrow nymphae. Faint concentric growth lines are the only ornament.

*Dimensions.*— 26 mm L x 13 mm H.

*Discussion.*— Several specimens were found in the material for this study, however most are steinkerns and poorly preserved. One specimen retains shell material only along the anterodorsal and posterodorsal margins. Shells of the genus *Tellina* are difficult to identify even with recent or well-preserved specimens (Afshar, 1969), with only steinkerns it is impossible to identify a *Tellin* to the specific level.

*Occurrence.*— *Tellinidae* have been described from the Navarro Group and Woodbine Formations of Texas; the Fox Hills Formation of South Dakota and most Cretaceous deposits worldwide.

Superfamily **ARCTICOIDEA** Newton, 1891  
Family **ARCTICIDAE** Newton, 1891  
Genus **ETEA** Conrad, 1873  
Type Species.— *Etea carolinensis* Conrad, 1873.

**Etea peasei** Stephenson, 1941  
(Plate 6, Figures 1, 2 & 3)

*Etea peasei* Stephenson, 1941, p. 172, Pl. 26, figs. 13, 14.
**Description.**— Small to medium sized valves, inequilateral, moderately inflated, subovate to subquadrate. Umbone prominent, prosogyrate; beak rounded, incurved. Point of maximum inflation occurs just behind umbone and about midlength. A very slight depression or flattening occurs about midheight and midlength. Anterodorsal margin short, excavated. Anterior margin closely rounded. Ventral margin broadly convex. Posterior margin truncate and meets ventral margin at a >90º angle and slopes toward the umbone. Posterodorsal margin near straight to broadly convex and long. Escutcheon and lunule, if present, obscured. A straight prominent umbonal ridge stretches from the posterior side of umbone to posterior margin. Ornament is concentric growth lines of varying width and prominence that follow the shape of the margin but with no definite pattern.

**Dimensions.**— 8 mm L x 4 mm H; 20 mm L x 11 mm H x 9 mm convexity of articulated valves; 12 mm L x 9 mm H.

**Discussion.**— This description is of one complete steinkern with only a very small fragment of shell remaining along the posterodorsal margin. The steinkern retains many exterior characteristics which make this designation relatively sure. Stephenson (1941) also described *Etea corsicana* but noted that this species has a straighter anterodorsal margin and a more curved posterodorsal margin whereas the type species of *Etea carolinensis* has a shorter posterior truncation and a more arched posterodorsal margin.

**Occurrence.**— This species was previously described from the Nacatoch Sand of the Navarro Group of Texas.

**Genus TENEA Conrad, 1870**

Type Species.— *Tenea parilis* Conrad, 1860, p. 278.

**Tenea parilis** Conrad, 1860

(Plate 6, Figures 4, 5 & 6)

*Mysia parilis* Conrad, 1860, p. 278, Pl. 46, fig. 16 (called Diplodonta parilis in plate explanation, p. 298).

*Tenea parilis* Conrad, 1870, p. 73, Pl. 3, fig. 12.

*Tenea parilis* Conrad, ?1875, p. 8, Pl. 2, fig. 25.

*Mysia (Tenea) parilis* (Conrad). Tryon, 1884, p. 216, Pl. 119, fig. 72.

*Tenea pinguis* Conrad. Whitfield, 1885, p. 163, Pl. 22, figs. 1-3.


*Tenea parilis* Conrad. Stephenson, 1941, p. 217, Pl. 42, figs. 9-12.

**Description.**— Moderately small, shell thin, subcircular outline, equivale, inequilateral, inflated. Greatest inflation occurs just behind umbone at about midlength. Umbone prosogyrate, moderately prominent, positioned about midlength; beaks prominent, incurved. Anterodorsal margin slightly excavated. Anterior, ventral and posterior margins uniformly curved, forming almost a circle. Posteroventral margin broadly
convex. Ornament is of fine growth lines, somewhat variable in width and spacing and with occasional resting periods. Surface glossy.

**Dimensions.**— 9 mm L x 9 mm H x 7 mm W (articulated valves).

**Discussion.**— Two well-preserved specimens are the only representatives of this species found in the samples. One specimen retains most of the original shell material and is unbroken except for a small chip out of the posterior margin.

**Occurrence.**— *Tenea parilis* has been described from the Nacatoch Sand of Arkansas; the Ripley Formation (Coon Creek tongue) of Tennessee; the Ripley and Owl Creek Formations of Mississippi; the Navarro Group of Texas; East-central Alabama into Georgia; the Matawan and Monmouth Formations of Maryland; and the Woodbury Clay, Navesink Marl and Red Bank Sand of New Jersey.

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<td>Type Species</td>
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**Corbula sp. 1**
(Plate 6, Figure 7)

**Description.**— Small shell, subtrigonal, moderately inflated, inequilateral. Umbone prominent, prosogyrous and positioned about one-third the length of the shell from the anterior end. Point of maximum inflation is about mid-height of the shell and slightly posterior to umbone. Anterodorsal margin is broken. Anterior outline is sharply rounded. Ventral margin is relatively straight. Posterior margin is very sharply rounded. Posterodorsal margin is slightly broken but appears to have a narrow auricle with a relatively strong marginal ridge. Auricle is separated from main body of shell by a shallow auricular sulcus. A sharp umbonal ridge begins on posterior side of umbone and weakens only slightly before reaching the posteroventral margin where it creates the sharply rounded margin. A less prominent anterior ridge begins on the anterior side of the umbone and weakens quickly. The anterior ridge does not meet the anterior margin. Ornament appears to be irregular and uneven concentric growth lines that follow the shape of the margin.

**Dimensions.**— 6 mm L x 4 mm H.

**Discussion.**— This description is of a single steinkern with no remaining shell material, making even the genus designation something of a guess.

**Corbula sp. 2**
(Plate 6, Figure 8)

**Description.**— Small shell, subtrigonal, moderately inflated, inequilateral, inequivalue. Umbone prominent, prosogyrous and positioned almost even with anterior terminus.
Point of maximum inflation is about mid-height of the shell and about one-third the shell length posterior to umbone. Anterodorsal margin rises slightly above umbone, but is relatively straight. Ventral margin is relatively straight. Posterior margin is very sharply rounded – truncate pointed. Posterodorsal margin is moderately convex. The right valve is more inflated than the left valve and has a sharp umbonal ridge that begins on posterior side of umbone and weakens only slightly before reaching the posteroventral margin where it creates the sharply rounded margin. The umbone of the right valve appears to be slightly posterior to and less prominent than the umbone of the left valve. The umbonal ridge of the left valve has a sharper keel and is closer to the dorsal margin than is the ridge of the right valve. The inequality of the ridges makes the escutcheons appear lopsided. Lunules possibly present but unclear. Ornament appears to be somewhat strong, irregular and uneven concentric growth lines that follow the shape of the margin.

Dimensions.— 6.5 mm L x 4.5 mm H x 3 mm total depth of articulated valves.

Discussion.— This description is of a single slightly deformed steinkern with no remaining shell material, making even the genus determination somewhat problematic.

Suborder PHOLADINA H & A Adams, 1858
Superfamily PHOLADOIDEA Lamarck, 1809
Family PHOLADIDAE Lamarck, 1809
Genus OPERTOCHASMA Stephenson, 1952

Type Species.— Opertochasma venustum Stephenson, 1952, p. 139, Pl. 34, figs 13-16.

Opertochasma cuneatum (Meek & Hayden), 1858
(Plate 6, Figures 9 & 10)

Pholas cuneata Meek & Hayden, 1858, p. 53.
Pholas (Martesia) cuneata Meek & Hayden, 1860b, p. 424.
Martesia cuneata (Meek & Hayden). Meek, 1876, Pl. 30, figs. 8a, b.
Opertochasma cuneatum (Meek & Hayden). Stephenson, 1952, p. 139.
Opertochasma cuneatum (Meek & Hayden). Speden, 1971, 148, Pl. 37, figs. 9-16; Pl. 38, figs. 1-5.

Description.— Small shell, subconical shape, equivalet. Strongly tapered posterior with truncate pointed terminus. Anterior end subspherical. Umbones prominent with beaks strongly prosogyrate. Curvature of beaks creates conical shaped concavities. Lanceolate-shaped metaplast covers gap between valves and fits into a convexity behind the umbones. Two radial grooves originate at umbones and extend diagonally to ventral margin. The anterior groove is narrow, sharply defined but shallow and meets the ventral margin just forward of midlength of the shell. The posterior groove is wider and deeper but with less well defined edges and does not extend all the way to the ventral margin. Anterior muscle insertion scar visible as a thin furrow above the anterior groove that does not extend to either margin. Other muscle insertion scars are shallowly incised, as is the pallial line. No exterior ornamentation is available for description.

Dimensions.— 7 mm L x 4 mm H x 4 mm W (total thickness of articulated valves).
**Discussion.**— Description for this species is based on a relatively well-preserved steinkern. The terminal points of both posterior and anterior are broken away. Preserved shell material is insufficient to allow description of external features.

**Occurrence.**— *Oproctasma cuneatum* has been described from the Fox Hills Formation of South Dakota and the Navarro Group of Texas.

Family **TEREDINIDAE**, Rafinesque, 1815  
Subfamily **TEREDININAE**, Rafinesque, 1815  
Genus **TEREDO** Linnaeus, 1758  
Type Species.— *Teredo irregularis* Gabb, 1860, p. 393.

**Teredo irregularis** Gabb, 1860  
(Plate 6, Figure 11)

*Teredo tibialis* Morton, 1834, p. 68.  
*Teredo irregularis* Gabb, 1860, p. 393, Pl. 68, fig. 19.  
*Teredo contorta* Gabb, 1861, p. 323.  
*Teredo irregularis* Gabb, 1861, p. 270 (174).  
*Teredo contorta* Meek, 1864, p. 16.  
*Teredo irregularis* Meek, 1864, p. 16.  
*Teredo contorta* Conrad, 1868, p. 727.  
*Teredo irregularis* Conrad, 1868, p. 727.  
*Teredo irregularis* Whitfeld, 1886, p. 191, Pl. 25, figs. 18-19.  
*Teredo irregularis* Johnson, 1905, p. 18.  
*Teredo contorta* Johnson, 1905, p. 18.

**Description.**— Thin-walled calcareous tubes are preserved within the wood into which they are bored. Tubes are tortuous and increase in diameter from the point of origin. Walls have irregular contours, smooth texture and show no ornamentation or growth lines. These calcareous burrows are sometimes referred to as the ichnogenus *Teredolites* Leymerie.

**Dimensions of described tubes.**— 39 mm L x 5 mm D.

**Discussion.**— This designation and description is of the tubes produced by this wood boring bivalve. No actual shells were found for description.

**Occurrence.**— *Teredo irregularis* is described from the Merchantville clay-marl of New Jersey and from Arkansas.

Subclass **ANOMALODESMA** Dall, 1889  
Order **PHOLADOMYOIDA** Newell, 1965  
Superfamily **PANDOROIDEA** Rafinesque, 1815  
Family **LATERNULIDAE** Hedley, 1918  
Genus **LATERNULA** (Bolten) Röding, 1798  
Type Species.— *Solen anatinus* Linnaeus, 1758.
**Laturnula(?) sp.**  
(Unfigured)

*Description.*— Small shell, inequivalve, inequilateral, moderately inflated, ovate. Maximum inflation is behind umbones about one-third the width of the shell. Posterior very slightly narrower than anterior. Left valve more inflated than right valve. Umbones moderately prominent. Beaks small, slightly opisthogyrate. Anterior and posterior margins closely rounded. Ventral margin broadly curved. Very small lunule anterior to beaks. Appears to have very narrow nymphs along dorsal margin. Both valves have a flattened posterodorsal margin that does not close, forming a pedal gape. Ornament appears to be concentric growth lines, variably spaced and of variable width. Some may be strong enough to form small folds within the growth pattern. Some very fine radiating lines can be seen on right valve in the anterodorsal quarter. These may be elements of ornament but this cannot be stated confidently.

*Dimensions.*— 4 mm L x 6 mm H x 5 mm total convexity of articulated valves.

*Discussion.*— Description is of a single articulated steinkern. No species determination could be made and even this genus designation is questionable.

Order **SEPTIBRANCHIDA** Pelseneer, 1888  
Superfamily **POROMYACEA** Dall, 1886  
Family **CUSPIDARIIDAE** Dall, 1886  
Genus **CUSPIDARIA** Nardo, 1840  
Type Species.— *Tellina cuspidata* (Olivi), 1792, p. 101.

*Cuspidaria ventricosa(?)* (Meek & Hayden), 1856  
(Plate 6, Figure 12)

*Corbula ventricosa* Meek & Hayden, 1856a, p. 83.  
*Leda ventricosa* (Meek & Hayden), 1856c, p. 284.  
*Neaera ventricosa* (Meek & Hayden), 1860a, p. 185.  
*Neaera ventricosa* (Meek & Hayden). Meek, 1876, p. 238, Pl. 30, figs. 3a-e.  
(?) *Cuspidaria ventricosa* (Meek & Hayden). Weller, 1907, p. 533, Pl. 58, figs. 16,17.  
(?) *Cuspidaria ventricosa* (Meek & Hayden). Richards,1958, p. 172, Pl. 28, fig. 2.  

*Description.*— Very small valves, caudate with strong inflation in the anterior and central portions. Umbo nearer anterior end, barely prosogyrate, beak prominent. Posterior end elongated into a narrow and sharply rounded projection. The posterior slope is sharp to the umbonal fold where the projection begins. Ventral and anterior margins are broadly rounded.

*Dimensions.*— 5 mm L x 4 mm H; 4 mm L x 3 mm H.

*Discussion.*— These very small valves are not common in this study. The preservation is mostly steinkerns, but a couple of specimens retain fragments of shell material and one external mold was found. Species designation was based on description by Speden (1971). If better preserved specimens are found, this specific designation could be verified.
Occurrence.—*Cuspidaria ventricosa* was described from the Fox Hills Formation of South Dakota.

Subclass **EOGASTROPODA** Ponder & Lindberg, 1996
Order **ARCHAEOGASTROPODA** Thiele, 1925
Suborder **DOCOGLOSSA** Troschel, 1866
Superfamily **ACMAEOIDAE** Forbes, 1850
Family **ACMAEIDA** Forbes, 1850
Genus **ACMAEA** Eschscholtz, 1833

Type Species.—*Acmaea mitra* Eschscholtz, 1833.

**Acmaea geneteeae** Sava, n. sp.
(Plate 6, Figure 13 & 14)

Etymology.—This species is named in honor of my mother, Genette Sava, who offers unconditional support and encouragement for everything I do.

Description.—Small to medium sized shells, patelliform, circular to subcircular in outline, broadly conical, moderately thick shelled. Dimensions of holotype are 15 mm in diameter and about 4 to 4.5 mm in height. Apex situated approximately 1/3 the diameter of the shell from the anterior margin and roundedly pointed. Apex does not appear to point either anteriorly or posteriorly. Anterior slope is short, steep and broadly convex. Posterior slope is long, less steep and broadly, but not smoothly, convex. A small shallow depression just behind the apex causes a minute flattening in the profile from anterior to posterior. Profile from left edge to right edge is equilateral, very slightly concave from margin to about half the height of the shell then becoming broadly convex in the upper half before reaching the roundly pointed apex. Edges are slightly flattened around entire circumference. Shell material is fragile and tends to break in layers. The outer layer is the thickest layer and when it breaks away a very thin inner layer is left that reproduces the interior features of the shell. The exterior of the shell is smooth with fine concentric growth lines centered around the apex. Very faint radial ribs originate just downslope from the apex and swirl clockwise very slightly. A very shallow fold just inward from the margin runs along the posterior end from slightly anterior to, and left and right of, the apex, creating a horseshoe shaped feature. This corresponds to the point of maximum concavity in the lower half of the shell seen in the lateral profile. Just above this fold is another fold of about the same prominence and shape. This higher fold corresponds to the “break” where the profile shape changes from concave to convex. The shell material is broken away from the anterior portion of the best preserved specimen, showing that the uppermost fold is created by the muscle attachment. On both the left and right anterior ends of this attachment scar is a series of subvertical elongate “s” shapes that begin approximately even with the apex and extend to left and right posterior to the apex. These can easily be seen on the innermost layer but are obscure on the small amount of exterior layer preserved over this area.

Dimensions.—9 mm D.

Discussion.—This differs in important ways from each of the previously described *Acmaea* species. *A. pilleolus* from the Woodbine Formation of Texas (Stephenson, 1952) has thinner shell material and is more oval in outline and less compressed than *A.
genetteae. Sohl (1960) described *A. galea* from the Ripley Formation of Tennessee as having nearly straight slopes and no exterior evidence of the depression just behind the apex on the posterior slope. *A. occidentalis* has been described from the Navarro Group of Texas (Stephenson, 1941) and the Western Interior (Hall & Meek, 1856) as being thin shelled, subcircular with the apex about one-fourth the length of the shell from the anterior margin and straight slopes with the exception of a slight humping in the posterior slope. The differences in shape, height, shell thickness, position of the apex and curvature of the slopes of *A. genetteae* from other species are significant and substantiate the naming of a new species.

Order **CAENOGASTROPODA** Cox, 1959  
Suborder **NEOTAENIOGLOSSA** Haller, 1882  
Section **DISCOPODA** Fisher, 1884  
Superfamily **CERITHIOIDEA** Ferussac, 1819  
Family **CERITHIIDAE** Fleming, 1822  
Subfamily **CERITHIINAE** Fleming, 1822  
Genus **VOYSA** Stephenson, 1952  

**Type Species.** — *Voysa planolata* Stephenson, 1952, p. 170, Pl. 39, figs. 47-50.

**Voysa(?) sp.**  
(Plate 6, Figure 15)

*Description.* — Small, turriform, very high spire with 12 whorls including protoconch. Whorls are weakly convex to straight sided. Sutures narrow and channeled. Ornament is of axial ribs that are straight to very slightly opisthocline intersected by strong spiral ribs, creating a strong nodular cancellate pattern. Spiral ribs are somewhat stronger than axial ribs making the nodes more sharply defined on the spiral rib sides than on the sides bordered by axial ribs. Four spiral ribs on each whorl with the uppermost rib on each whorl being the narrowest and appearing somewhat squeezed against the suture line. Twelve is the number of whorls uncovered, but more may still be embedded in matrix. Aperture obscured.

*Dimensions.* — 16 mm L x 4 mm W.

*Discussion.* — This description is from one well-preserved specimen with recrystallized shell material. It resembles many of the turriform species described from Cretaceous deposits; such as *Pachymelania* from the Fox Hills (Erickson, 1974) and *Turritella* from Texas, Mississippi, Tennessee and many other locations. However, Stephenson's designation of the genus *Voysa* for turriform shells with noded structure seems to best encompass the range of characteristics exhibited by this specimen.

*Occurrence.* — *Voysa* was described from the Woodbine Formation of Texas.

Family **TURRITELLIDAE** Loven, 1847  
Genus **TURRITELLA** Lamarck, 1799  

**Type Species.** — *Turbo terebra* Linnaeus, 1758.
**Turritella sp.**  
(Plate 6, Figure 16)

*Description.*— Small shell, turriform, 6 to 7 whorls. Whorl sides are rounded with near horizontal ramps. Sutures most likely impressed. Aperture obscured. No shell material remains for ornament description.

*Dimensions.*— 9 mm H x 2 mm W (body whorl diameter).

*Discussion.*— Description is of a single internal cast which can be generically assigned with confidence, but insufficient external morphologic characters are available for specific assignment.

Superfamily **CAPULOIDEA** Fleming, 1822  
Family **CAPULIDAE** Fleming, 1822  
Subfamily **TRICHOTROPINAE**  
Genus **TURBINOPSIS** Conrad, 1860  
Type Species.— by monotypy, *Turbinopsis hilgardi* Conrad, 1860.

**Turbinopsis(?) sp.**  
(Unfigured)

*Description.*— Very small, turbinate, umbilical, rapidly expanding. Whorls round sided with wide, round shoulders and ramps. Deeply channeled sutures give the impression that the whorls are detached from one another. Aperture obscured. No shell material remains to describe ornament.

*Dimensions.*— 3 mm H x 3 mm W (broken).

*Discussion.*— Description is of a single internal mold of a small broken specimen which may belong to this genus. The overall morphology and shape of the whorls are reflective of the general features of this genus. Unfortunately, the single specimen was broken before a photograph was taken.

*Occurrence.*— This genus is described from the Prairie Bluff Chalk of Mississippi and the Navesink Marl of New Jersey.

Superfamily **STROMBOIDEA** Rafinesque, 1815  
Family **APORRHAIDAE** Morch, 1852  
Subfamily **ARRHOGINAE** Popene, 1983  
Genus **NUDIVAGUS** Elder, 1990  
Type Species.— *Nudivagus? cooperensis* Stephenson, 1941, p. 293.

**Nudivagus cooperensis** Stephenson, 1941  
(Plate 6, Figures 17 - 20)

*Nudivagus cooperensis* Stephenson, 1941, p. 293, Pl. 54, figs. 11,12.  
Description.— Large shell, fusiform, with slightly convex spire whorls. High spired, sutures closely appressed. Apical angle approximately 18º. Remaining shell material shows transverse ornamentation of closely spaced growth lines of variable width and proximity. Under magnification very fine spiral threads are visible. Aperture is incomplete but appears to be elongate, moderately narrow.

Dimensions.— 54 mm H x 30.5 mm W (largest specimen – protoconch and lower whorl(s) are broken); 21 mm H x 9.5 mm W.

Discussion.— The specimens found at the study locality for this paper are rare and somewhat poorly preserved. The steinkerns retain some original shell material near the sutures but it is mostly worn away on the whorls. Identification is based on the convexity of the whorls and overall morphology. Elder (1990) ascribed a new genus, Tibiaporhais to cooperensis after studying better preserved plesiotypes from the Kemp and Neylandville members of the Navarro Group of Texas. This basis for this new designation is the presence of two extensions of carinae on the outer lip of the aperture into spine-like shapes. The few specimens in this study do not have any type of extensions or carinae, but may be juveniles or simply too poorly preserved to enable recognition of these features. Therefore, until better preserved specimens are found that show these features, the author has retained Stephenson’s original genus designation.

Occurrence.— Nudivagus cooperensis has been described from the Navarro Group of Texas.

Superfamily STROMBACEA
Family APORRHAIDAE
Genus DREPANOCHIELUS Meek, 1864
Type Species.— Rostellaria americana Evans & Shumard, 1857, p. 42 = Drepanocheilus evansi, Cossmann, 1904.

Drepanocheilus evansi Cossmann, 1904
(Plate 6, Figures 21 & 22)

Rostellaria americana Evans and Shumard, 1857, p. 42.
Aporrhais americana (Evans and Shumard). Meek and Hayden, 1860, p. 423.
Aporrhais sublevis Meek and Hayden, 1860, p. 428.
Anchura (Drepanochilus) americana (Evans and Shumard). Meek, 1876, p. 324, Pl. 32, figs. 8a,b.
Anchura? sublevis (Meek and Hayden). Meek and Hayden, 1876, p. 327, Pl. 19, figs. 3a,b.
Anchura americana (Evans and Shumard). White, 1879, p. 185.
Anchura americana (Evans and Shumard). Whiteaves, 1885, pp. 48-9.
Arthoges (Drepanochilus) evansi Cossmann, 1904, p. 75.
Anchura (Drepanochilus) americana (Evans and Shumard), 1921, p. 37, Pl. 6, fig. 13.
Drepanochilus (Drepanochilus) americanum (Evans and Shumard). Gastropoda in Schindewolf, 1938, p. 912, fig. 2683.
Drepanochilus americanum (Evans and Shumard). Shimer and Shrock, 1944, p. 497, Pl. 203, fig. 24.
Drepanochilus evansi (Cossmann). Sohl, 1960, p. 100, Pl. 11, figs. 23, 26.
Description.— Small shells, high spired with broad extended hook-shaped apertural lip. Body whorl about one-third total length of shell. Whorls broadly convex with no definition of shoulders or ramps. Generally six whorls including body whorl. Sutures are moderately impressed. Moderately and evenly spaced opisthocline growth ribs strongly defined on 3rd, 4th and 5th whorls but virtually disappearing on body whorl. Fine spiral lines cross ribs at \( \neq 90^\circ \) angles. Spiral lines become more prominent ribs on body whorl with axial ribs represented only as nodes on the two largest spiral ribs. The uppermost of the two prominent spiral ribs on the body whorl develop into a pronounced narrow ridge on the outside of the broad, hook shaped lip. A narrow channel on the inside follows the ridge on the outside. Aperture obscured.

Dimensions.— 12–15 mm H x 6–7 mm W not including extended apertural lip.

Discussion.— Drepanocheilus is common throughout the Western Interior region and some species are known from Europe as well. The lengthy and involved synonymy is due to the cosmopolitan distribution of this genus. Most specimens from this study are fragments or steinkerns. *D. evansi* is a smaller and slimmer shell than *D. obesus* and has a wider and more upwardly curved apertural extension than *D. nebrascensis*.

Occurrence.— *D. evansi* has been described from Texas by Stephenson (1941); from the Fox Hills Formation by Erickson (1974); and from the Pierre Shale at Red Bird, Wyoming by Sohl (1967).

Drepanocheilus obesus Sohl, 1967
(Plate 6, Figure 23)

Anchura (*Drepanochilus*) nebrascensis (Evans & Shumard). Whitfield, 1880, p. 429, Pl. 12, figs. 2, 3.

Description.— Small shells, high spired with broad extended hook shaped apertural lip. Body whorl about one-third total length of shell. Whorls broadly convex with no definition of shoulders or ramps. Most complete specimen has seven whorls including body whorl. Sutures are shallowly impressed. Somewhat closely and evenly spaced opisthocline growth ribs strongly defined on all spire whorls but virtually disappearing on body whorl. Fine spiral lines cross ribs at \( \neq 90^\circ \) angles creating a rhomboidal reticulate pattern. Spiral lines become more prominent ribs on body whorl with axial ribs represented only as nodes on the largest spiral ribs. The uppermost of the two prominent spiral ribs on the body whorl develop into a pronounced narrow ridge on the outside of the extended hook shaped lip. Inside of lip is smooth with a narrow channel that follows the ridge on the outside. Aperture obscured.

Dimensions of most complete specimen.— 9 mm L x 7 mm W not including extended apertural lip.

Discussion.— Drepanocheilus obesus is less common in the fauna from this area than *D. evansi*. One partial steinkern and a mostly complete specimen with some shell material remaining are all that could be identified with confidence. Very likely this species was more common than the numbers would indicate since most *Drepanocheilus*
in the collection are poorly preserved and are fragmentary. Without having relatively complete specimens it is very difficult to distinguish between *Drepanocheilus* species.

**Occurrence.**— *D. obesus* is described from the Pierre Shale near Red Bird, Wyoming.

**Drepanocheilus nebrascensis** (Evans & Shumard), 1854  
(Plate 6, Figure 24)

*Rostellaria nebrascensis* Evans & Shumard, 1854, p. 164.  
*Anchura (Drepanochilus) nebrascensis* (Evans & Shumard). Meek & Hayden, 1864, p. 19.  
*Anchura (Drepanochilus) nebrascensis* (Evans & Shumard). Meek (part), 1876, p. 326, Pl. 13, figs. 5a, b, c (figures questionably assigned to species).  
*Anchura nebrascensis* (Evans & Shumard). Knight, 1900, p. 154, Pl. 9, fig. 7 (copy of Meek’s 1876 figures).  
*Arrhoges (Drepanochilus) nebrascensis* (Evans & Shumard). Cossman, 1904, p. 77.  

**Description.**— Small shells, high spired with thin somewhat short extended spike shaped apertural lip. Body whorl approximately one half total length of shell. Whorls rounded with rounded shoulders and very narrow near horizontal ramps. Six whorls including body whorl. Sutures are moderately to deeply impressed. Widely spaced opisthocline growth ribs strongly defined on fourth and fifth whorls but becoming extremely faint on body whorl. A single strong spiral rib on the body whorl develops into a pronounced slightly upturned spike on the apertural margin. Aperture obscured.

**Dimensions of described specimen.**— 11 mm H x 5 mm W, not including apertural spike.

**Discussion.**— This description is of a single steinkern. While it appears that this species is not well represented in the research area, it is most likely that this small species is not well-preserved and the fragments are not identifiable. *D. nebrascensis* has been described from the Pierre Shale near Red Bird, Wyoming by Sohl (1967); from the Fox Hills Formation of South Dakota by Erickson (1974).

**Occurrence.**— *D. nebrascensis* has been described from the Pierre Shale near Red Bird, Wyoming by Sohl (1967); from the Fox Hills Formation of South Dakota by Erickson (1974).

**Drepanocheilus sp.**  
(Plate 6, Figures 25 & 26)

**Description.**— Several wing molds are preserved that show a larger wing than described on the other species of *Drepanocheilus*. The wing looks most similar to *D. evansi* but is more flared from the anterior margin than seen on *D. evansi* or other species of *Drepanocheilus*. The hook is curved upward into an extended spike. Ornamentation is quite strong on the wings with spiral ribs extending off the body whorl and following the arch of the hook upward. Vertical undulations give the wing a sinuous appearance.
Order SORBEOCONCHA
Superfamily VANIKORIODEA Gray, 1840
Family VANIKORIDAE Gray, 1840
Genus VANIKOROPSIS Meek, 1876
Type Species.— Natica tuomyana [sic] Meek & Hayden, 1856, p. 270 by original designation.

Vanikoropsis nebrascensis (Meek & Hayden), 1856
(Plate 6, Figure 27)

Natica? ambigua Meek & Hayden, 1856, p. 64. (non Morris and Lycett, 1854).
Fossar? nebrascensis Meek & Hayden, 1860, p. 423.
Vanikoro ambigua (Meek & Hayden). Meek, 1864, p. 18.
Vanikoro ambigua (Meek & Hayden). Meek, 1876, p. 330, Pl. 19, figs. 12a-d.
Vanikoro ambigua (Meek & Hayden). Whitfield, 1880, p. 430, Pl. 12, fig. 14.
Natica haydeni Cossmann, 1899, p. 36.
Natica praenominata Cossmann, 1920, p. 69.
Vanikoro ambigua (Meek & Hayden). Cossmann, 1925, p. 165.
Vanikoropsis nebrascensis (Meek & Hayden). Sohl, 1967, p. B22, Pl. 5, figs. 1, 5-10, 12, 14, 17.

Description.— Small shell, naticiform. Spire is about one-third total height and has a domed protoconch. Whorls are rounded and lack shoulders. Sutures are moderately impressed. Aperture is subovate to auriform. Ornament is spiral ribbons that are wider than the interspaces over the main part of the whorl.

Dimensions.— 4 mm H x 3.5 mm W.

Discussion.— For a detailed discussion of the complicated synonomy of this species see Sohl (1967) and Erickson (1974). This species is described from a single steinkern with fragments of original shell material remaining. The distinctive ornament and globose shape are preserved well enough to make a species designation.

Occurrence.— Vanikoropsis nebrascensis was described from the Fox Hills Formation of South Dakota.

Superfamily NATICOIDEA Gray, 1840
Family NATICIDAE Gray, 1840
Subfamily NATICINAE Forbes, 1838
Genus NATICA Scopoli, 1777
Type Species.— Nerita vitellus Linnaeus, 1758.

Natica sp.
(Plate 6, Figure 28)

Description.— Small shell, low spired and conispiral. Shell walls are thick, no ornamentation is visible. Steinkern revealed where recrystallized shell material is broken away. Three whorls intact, apex broken away, dextrally coiled. Whorls are broad and rapidly expanding. Shoulders are very slightly flattened and sutures are slightly
appressed (observation taken from the shape of the steinkern rather than the exterior shell morphology). Aperture is not exposed on available specimens.

*Dimensions.*— 6 mm H x 7 mm W.

*Discussion.*— Based on descriptions of *Natica* species by several authors (e.g., Stephenson, 1941; Abdel-Gawad, 1986) the author considers the genus designation to be accurate. Because the apertures are obscured, however, proper species level designation is not possible. The shoulders are more prominent and rounded than those *N. striaticostata*, or *N. traski*, but less prominent than *N. humilis*. Spire is not as high as *N. humilis* or *N. rivulana*, but higher than *N. traski*, *N. dorothiensis* or *N. pendula*. Sutures are less impressed than in *N. rivulana* or *N. humilis*, but more so than in *N. striaticostata*. Assignment to the species *N. dorothiensis alveata* or *N. cretacea* is possible based on external features.

*Occurrence.*— *Natica* has been described from Texas, the eastern Coastal Plain and the Western Interior of the United States.

Family **AMPULLINIDAE** Cossmann, 1918
Subfamily **GYRODINAE** Wenz, 1941
Genus **GYRODES** Conrad, 1860

Type Species.— *Rapa supraplicata* Conrad, 1860 = *Natica (Gyrodes) crenata* Conrad, 1860.

**Gyrodes sp.**
(Plate 6, Figure 29)

*Description.*— Small, subglobose, low spired. Whorls are rapidly expanding, low, with rounded sides that are wider in the middle section than near the sutures. Shoulders are near square with ramps wide and near horizontal. Ramps round slightly near sutures. Sutures are deeply impressed, possibly channeled.

*Dimensions.*— 9 mm W.

*Discussion.*— Two whorls of a steinkern is all that can be seen of this specimen. However, the strong-near square-shoulders of this genus are quite recognizable.

*Occurrence.*— *Gyrodes* is a widespread genus and is described from lower Cretaceous through upper Cretaceous deposits of the Atlantic and Gulf Coastal plains, locations throughout the Western Interior of the United States and Canada, and South Africa and western Europe.

Superfamily **BUCCINOIDEA** Rafinesque, 1815
Family **FASCIOLARIDAE** Gray, 1853
Subfamily **FASCIOLARINAE** Gray, 1853
Genus **BELLI FUSUS** Stephenson, 1941

Type Species.— by original designation, *Odontofusus curvicostata* Wade, 1926.
Bellifusus(?) sp. 1  
(Plate 7, Figure 1)

Description.— Small, fusiform, moderately inflated. Whorls are broadly rounded. Body whorl about twice as long as penultimate whorl. Sutures are moderately impressed. Shoulders are rounded and ramps are near horizontal. Sculpture of strong, slightly opisthocline varices that originate just below suture and remain of consistent strength on the upper whorls but weaken anteriorly on the body whorl. Varices are moderately widely spaced. Aperture obscured.

Dimensions.— 12 mm H x 6 mm W (incomplete).

Discussion.— This description is of a single internal mold with the upper whorls broken. This genus designation is questionable but is based on the overall shape of the shell and the whorls and the strength and spacing of the ornament.

Occurrence.— Bellifusus has been described from the Navarro Group, Kemp Clay and Woodbine Formation (questionable) of Texas; from the Ripley Formation of Tennessee, Alabama and Mississippi; the Owl Creek Formation of Mississippi; Navesink Formation of New Jersey (questionable).

Bellifusus sp. 2  
(Plate 7, Figure 2)

Description.— Small shell, turbiniform with presumed high spire based on size of unbroken whorls. Proportionately large body whorl. Ornamentation shows strong, somewhat sharp varices on all whorls. Varices on body whorl fade before reaching the lower area of the whorl. Whorls are convex and have weak, narrow shoulders. Base of body whorl appears to form siphonal canal. Sutures are deeply impressed.

Dimensions.— 5 mm H x 3 mm W.

Discussion.— The specimen on which this designation is based is a steinkern with minute traces of the shell material remaining around the sutures. Upper two to three whorls and tip of siphonal canal are broken off. The aperture is obscured by matrix. The varices of this specimen are sharper, shorter and slightly more widely spaced than the varicies described from Bellifusus sp. 1.

Subclass ORTHOGASTROPODA Ponder & Lindberg, 1997  
Superorder HETEROBRANCHIA Gray, 1840  
Superfamily PYRAMIDELLOIDEA Gray, 1840  
Family PYRAMIDELLIDAE Gray, 1840  
Genus CREONELLA Wade, 1917  
Type Species.— Creonella triplicata Wade, 1917, p. 303.

Creonella triplicata Wade, 1917  
(Plate 7, Figure 3)

Creonella triplicata Wade, 1917, p. 303, Pl. 19, fig. 8.  
Creonella triplicata Wade, 1926, p. 173, Pl. 58, figs. 8, 25.
Creonella triplicata Wade. Stephenson, 1941, p. 264, Pl. 48, figs. 8, 9.
Creonella triplicata Wade. Sohl, 1964, p. 310, Pl. 50, fig. 28.

Description.— Small shell, turriiform, thick shelled, slim. Apical angle <10°. Whorls are flat sided with incised sutures. Body whorl with rounded basal periphery and steep basal slope. Shell is smooth and glossy with no ornament. Aperture is obscured. Protoconch is broken.

Dimensions.— 8 mm H x 2 mm W (incomplete).

Discussion.— This species is similar to C. whitei and to C. deusseni but is more slender. Stephenson (1941) and Sohl (1964) describe differences in the apertures of these species as well but this cannot be verified.

Occurrence.— This species is described from the Ripley Formation in Tennessee, Mississippi, Georgia and Alabama and from the Nacatoch Sand and Neylandville Marl of Texas.

Subclass OPISTHOBRANCHIA Milne-Edwards, 1848
Order CEPHALASPIDEA Fischer, 1883
Suborder TECTIBRANCHIATA
Family ACTEONIDAE d’Orbigny, 1835
Genus NONACTEONINA Stephenson, 1941
Type Species.– Nonacteonina graphoides Stephenson, 1941, p. 382.

Nonacteonina triticea Stephenson, 1941
(Plate 7, Figure 4)

Nonacteonina triticea Stephenson, 1941, p. 384, Pl. 73, figs. 20, 21.

Description.— Small, inflated shell obconical with a short spire –about one-third total height of the shell. Top whorl broken, three remain. Body whorl broadly convex and elongated. Whorls are rounded and broadly convex and narrow slightly near top. The upper whorls have closely rounded shoulders and near horizontal ramps. The body whorl and the penultimate whorl taper toward sutures and lack shoulders and ramps. Sutures are shallowly channeled. Ornamented by flattened spiral lines, regularly spaced, but of various widths separated by lines of punctae of varying depth and diameter. Aperture could not be observed on specimen.

Dimensions.— 7.5 mm H x 3 mm W (slightly deformed).

Discussion.— This specimen is lacking the “noticeable crowding of several of the ribs in a narrow band just below the suture” (p. 384) as described by Stephenson, 1941. However, considering the variability in rib widths, it appears to be the same species in regard to the rest of the description.

Occurrence.— Nonacteonina triticea is described from the Navarro Group of Texas.
Nonacteonina deflexa Stephenson, 1941
(Plate 7, Figure 5)

Nonacteonina deflexa Stephenson, 1941, Pl. 73, figs. 26, 27.

Description.— Small shell, elongate with moderate spiral height and moderate thickness. Body whorl about two-thirds the length of the shell and broadly convex from suture to anterior end. Widest about midheight of the body whorl. Whorls are broadly convex on the sides with rounded shoulders and almost horizontal ramps. Sutures appear to be narrowly impressed but sharp. Protoconch broken away. Four whorls remain, including the body whorl. Aperture obscured. Sculpture is of prominent spiral ribs covering all whorls. Smoother, less pronounced on whorls of spire, becoming thicker and more prominent on body whorl. Ribs on upper whorls appear to be fairly regularly spaced. Ribs on body whorl are more closely spaced on the upper half of the whorl and become progressively more widely spaced on the lower half of the whorl. Anterior-most spiral ribs change direction and slope steeply downwards towards siphonal canal. More than 20 ribs can be seen on body whorl. Penultimate whorl appears to have approximately 10 ribs. Fine prosocline growth lines intersect with spiral ribs producing a fine cancellate, or possibly punctate, pattern. Terminus of the siphonal canal is broken away.

Dimensions.— 11 mm H x 4.5 mm W.

Discussion.— This specimen is a well-preserved steinkern with fragments of shell material remaining on the body whorl and spire. The penultimate whorl is much taller than on N. triticea and the sutures are impressed. The upper whorls do not have the pronounced shoulders of N. triticea.

Occurrence.— N. deflexa was described from the Navarro Group of Texas.

Genus EOACTEON Stephenson, 1955
Type Species.— Solidulus linteus Conrad, 1858, p. 334.

Eoacteon sublinearis (Stephenson), 1941
(Plate 7, Figure 6)

Troostella sublinearis Stephenson, 1941, p. 381, Pl. 72, figs. 1, 2.

Description.— Small to medium-sized shell, relatively thin, height about twice the width, moderately inflated. Spire low. Body whorl large and fairly globose. Five whorls preserved, but apex broken. Whorls are inflated, broadly convex and lack shoulders. Sutures are located at the bottom of a shallow, narrow channel. Spiral ornament is consistent on all whorls and consists of incised lines that are evenly spaced and equally prominent. There are approximately 20 incised lines on the bottom whorl. Lines are faintly punctate with interspaces about twice as wide as the lines. As lines near anterior the interspaces narrow, but remain wider than the lines. Aperture and anterior are obscured and broken, respectively.

Dimensions.— 7 mm H x 4.5 mm W (slightly damaged).
Discussion.— The described specimen varies from the species described by Stephenson (*Troostella sublinearis*, 1941) in the regularity of the ornament, but otherwise fits the general characteristics very well.

Occurrence.— *E. sublinearis* is described from the Navarro Group of Texas.

Order **OPISTHOBRANCHIA** Milne Edwards, 1848  
Suborder **CEPHALASPIDEA** Fischer, 1883  
Superfamily **PHILINOIDEA** Gray, 1850  
Family **RETUSIDAE** Thiele, 1925  
Genus **SULCORETUSA** Burch, 1945  
= *Sulcularia* Dall, 1921, not *Sulcularia* Rafinesque, 1831

Type Species.— by original designation (Dall, 1921, p. 61, 202) *Bulla sulcata* d’Orbigny, 1841.

*Sulcoretusa dominici* Sava, n. sp.  
(Plate 7, Figures 7 & 8)

Etymology.— This species was named in honor of my newborn nephew, Dominic McIntire, who was also very tiny at the time.

Description.— Small, involute, slender shell with moderately thick shell material for the size. When viewed dorsally the shape is cylindrical with a faint widening in the anterior half. Apical end is almost flat and anterior end is quite sharply rounded with a wider curve on the left side than on the right. Apex is obscured by matrix. When viewed from the front the aperture is narrow and straight but expands at the anterior end. Outer lip is thin, straight. Regularly spaced and evenly prominent opisthocline growth capillae cover the surface of the shell. Growth capillae become thicker and more prominent in the apical one-fourth of the shell length. Growth capillae curve into the columella as they approach the anterior end.

Dimensions.— 5 mm L x 2.5 mm W; 4.5 mm L x 2 mm W.

Discussion.— This very small gastropod closely resembles the general description by Sohl (1963, 1964) for shells found in middle to late Maastrichtian deposits of the Gulf Coastal Plain in the eastern United States. However, the prominence of the growth capillae in the upper portion is what sets this species apart from previous taxa included in *Sulcoretusa*. This is the first reported presence of this genus from the late Campanian to early Maastrichtian.

Superfamily **RINGICULOIDEA** Phillipi, 1853  
Family **RINGICULIDAE** Phillipi, 1853  
Genus **OLIGOPTYCHA** Meek, 1876

Type Species.— *Actaeon concinnus* Hall & Meek, 1854, p. 390 by original designation.

**Oligopycha concinna** (Hall & Meek), 1854  
(Plate 7, Figure 9)

*Actaeon concinnus* Hall & Meek, 1854, p. 390, Pl. 3, fig. 4.  
*Avellana subglobosa* (Meek & Hall). Meek & Hayden, 1856, p. 64.
**Cinulia concinna** (Hall & Meek). Meek & Hayden, 1860, p. 424.
*Oligoptycha* concinna* (Hall & Meek). Meek, 1876, p. 284, Pl. 31, figs. 6a, b, c.
*Oligoptycha concinna* (Hall & Meek). Cossmann, 1895, p. 121, Pl. 7, fig. 15.
*Oligoptycha concinna* (Hall & Meek). Erickson, 1974, p. 225, Pl. 20, figs. 11, 12.

**Description.**— Very small, globose shell with a very low spire. Spire is rounded, barely discernable above the body whorl. Sutures are incised. Ornament consists of strong spiral ribbons that are consistent in spacing and strength over the entire shell. Aperture is obscured.

**Dimensions.**— 2.5 mm H x 2 mm W.

**Discussion.**— This description is of a single steinkern that closely matches the descriptions of Sohl (1964) and Erickson (1975) for the external characteristics of this species. The specimen described here is very small, even for this small genus, but, without the ability to view the apertural characters, it can only be assumed this is a juvenile specimen. For a more complete description see Sohl (1964). *Oligoptycha americana* (Wade) is a very similar species described by Stephenson (1941) found in Texas and Tennessee. Since the exteriors of the two species are virtually identical, it seems more likely that *O. concinna* is the proper species designation, because this species had previously been described from the Pierre Shale whereas *O. americana* is known from eastern U.S. deposits. If correct, this will extend the range of *O. concinna* to the *Baculites compressus/Baculites cuneatus* biozones of the Pierre Shale.

**Occurrence.**— This species has been described from the Red Bird Section of the Pierre Shale in Wyoming; the Pierre Shale and Fox Hills Sandstone in South Dakota; the Bearpaw Shale in Montana; the *B. reesidei* and *B. jenseni* zones of the Pierre Shale in Colorado; the Bearpaw Shale in Canada.

Subclass **EUTHYNEURA** Spengel, 1881
Order **BASOMMATOPHORA** A. Schmidt, 1855
Superfamily **SIPHONARIOIDEA** Gray, 1840
Family **SIPHONARIIDAE** Gray, 1840
Genus **ANISOMYON** Meek & Hayden, 1860

Type Species.— by subsequent designation *Helcion patelliformis* Meek & Hayden, 1860, p. 33-35 (= *Anisomyon patelliformis* Meek & Hayden).

**Anisomyon centrale** Meek, 1871
(Plate 7, Figures 10 & 11)

*Anisomyon centrale* Meek, 1871, p. 312.
*Anisomyon centrale* Meek. White, 1877, p. 194, Pl. 18, figs. 8a & b (assignment questionable).
*Anisomyon centrale* Meek. White, 1879, p. 206, 225, 303, Pl. 9, fig. 1a-d.
*Anisomyon centrale* Meek. Whiteaves, 1885, p. 47, Pl. 7, figs. 1, 1a, 2, 2a.
*Anisomyon centrale* (Meek). Dowling, 1917, p. 30, Pl. 28, figs. 12-12b.
Description.— Small, patelliform with short, straight to slightly convex anterior slope and long, broadly convex posterior slope. Apex approximately central to width, but approximately one-third the length of the valve from the anterior end. Height and width are approximately equal. Posterior slope is ornamented by a cluster of moderately strong carinae that radiate from the apex. One carina is more prominent than the others. The carinae are absent from the rest of the shell except for a single strong ridge in the left anterior quadrant.

Dimensions.— 6 mm L x 4 mm W x approximately 5 mm depth.

Discussion.— Description is of a single steinkern with fragments of shell material around the margin. Given the variability of this species described by Sohl (1967) and the similarity to his figured specimens this species designation is probably correct.

Occurrence.— Sohl (1967) described this species from the Red Bird Formation of Wyoming and noted that it had also been described from the Pierre Shale of Colorado.

Anisomyson aff. centrale Meek, 1871
(Plate 7, Figure 12)

Description.— Small shell, patelliform, thin walled, possibly ovate in outline. Described specimen is distorted by mechanical squeezing, but is not crushed. Description is based on interior mold and exposed interior of original shell. Exterior of shell is encased in matrix. Interior height is about 12 mm, but length and width are not measurable because some margin area is broken. Shell profile in longest direction of distorted mold is of straight sided slopes from apex to margin. Perpendicular to this measurement the profile is broadly convex on both slopes with a slightly increased steepness and narrowing near the apex. Position of apex in relation to length, width or margins cannot be interpreted. The tip of the apex is broken away. Six variably prominent but relatively evenly spaced radial folds run from apex to margin all around the shell, creating a widely scalloped ornament. No other exterior features are available for description. A small muscle attachment scar is positioned about half the height of the slope almost wholly within the second most prominent of the radial folds.

Dimensions.— 11 mm L x 5 mm W x 7 mm H (apex broken).

Discussion.— The specimen described here closely corresponds to the description of A. centrale by Sohl (1967) considering the variability of this species. One difference which might cast doubt on this assignment is the lack of the strong anterior groove. However, one of the radial folds is appreciably deeper than the others, some of which are simply shallow radial depressions, and could be considered the main groove. The relatively even spacing of the radial features on this specimen also casts doubt on this assignment since Sohl reports them as discontinuing towards the posterior with the exception of a single carination on the right posterior slope. More and better preserved specimens are needed before a determination can be made if this is a new species.
Mesolanistes reesidei (Stanton), 1916
(Plate 7, Figures 13, 14 & 15)

Mesolanistes reesidei (Stanton), 1916, Pl. LXXXIII, figs. 12, 13.
Mesolanistes reesidei (Stanton). Yen, 1954, Pl. 19, figs. 27, 28.

Description.— Large, elongated sinistrally coiled shell with very low spire. Spiral is 1.5 rotations. Shape outline is subovate with broadest area near the top of the shell, just below the shoulders of the body whorl. The top of the shell is nearly flat. Nucleus does not rise above the profile of the body whorl. Body whorl is large and inflated, but not globose. From the widest point the profile rounds broadly toward the anterior canal. Seen from the dorsal side, the base profile narrows rapidly along the left side and appears to terminate at the anterior canal with a slight outward curl. One the right side the outer lip creates a broadly convex, near vertical profile until making a broad curve into the anterior terminus. The profile makes the shell appear as if it is wider from the axis to the margin on the right side than on the left. Sutures impressed but not deep. Shoulders are short and steep. Ramps low and near flat. Aperture not exposed, but may be elongate reniform based on what can be seen of the front side of the shell. Outer lip may flare slightly. Shell may have a recurved anterior canal. Sculpture consists of opisthocline growth costellae. The costellae are variably spaced and of varying widths and heights. Greater than half of the costellae show a unique sculptured pattern with the side of the costellae farthest from the aperture creating a smooth line and the side closest to the aperture having a wave pattern with the tips of the waves pointing toward the aperture.

Dimensions.— 40 mm H x 29 mm W x 17 mm D (slightly deformed).

Discussion.— This shell is a terrestrial snail and provides good evidence that this was a nearshore environment. Preservation of the shell is moderately good with the body of the shell slightly deformed but not crushed and the spire and shoulders retaining shell material with some ornament preserved. Below the spire the body of the shell is steinkern. Anterior is broken off and aperture is mostly obscured. The morphology of this shell is unique and not likely to be confused with any other.

Occurrence.— Mesolanistes reesidei has been found in the Fruitland Formation – a Cretaceous coal deposit in the San Juan Basin of New Mexico and in southwestern Colorado.

Class CEPHALOPODA Cuvier, 1798
Order AMMONOIDEA Zittel, 1884
Suborder AMMONITINA Hyatt, 1889
Superfamily HOPLITACEAE Douville, 1890
Family PLACENTICERATIDAE Hyatt, 1900
Genus PLACENTICERAS Meek, 1870
Type Species.— Ammonites placenta DeKay, 1828, p. 278, by original designation by Meek, 1876, p. 462.
Placenticeras meeki Böhm, 1898
(Plate 8, Figures 1, 2 & 3)

Placenticeras placenta (DeKay). Meek (in part), 1876, p 466, text fig. 65.
Placenticeras placenta (DeKay). Whiteaves (in part), ?1885, p. 53.
Placenticeras meeki Böhm. 1898, p. 200.
Placenticeras whitfieldi Hyatt, 1903, p. 22, pl. 45, figs. 3-16; pl. 46; pl. 47, figs. 1-4.
Placenticeras whitfieldi Hyatt, 1910, p. 218, figs. 1493, 1494.
Placenticeras meeki Böhm. Reeside, 1926, pp. 1-5, pl. 1, figs. 1-7, 13; pl. 2, figs. 1-5.
Placenticeras meeki Böhm. Reeside, 1927, p. 29, pl. 22, figs. 5-7; pls. 23, 24; pl. 25, figs. 1, 2.
Placenticeras meeki Böhm. Link and Childerhose, ?1931, pp. 1238, 1241, text figs. 9, 11.

Description.— Small to very large, laterally compressed, strongly involute, discoidal. Whorl diameter is much larger than cross-sectional width at umbilical shoulder. Narrow venter, flat to slightly concave in smaller specimens, flat or closely rounded on larger specimens; sharp marginal angles on both sides of younger specimens, rounded in large specimens. Flanks flat to very slightly convex. Umbilicus narrow with steeply sloping walls and a slightly angular umbilical shoulder. No ornamentation. Most specimens are very weathered and do not retain suture patterns, but some fragments show a complex suture pattern of elongate, intricately branching saddles and lobes.

Dimensions of described specimens.— 140 mm D x ~ 25 mm W; 100 mm D; some specimens seen at the field site, but not collected, had diameters exceeding 500 mm.

Discussion.— Most specimens from this study are poorly preserved and broken—the body chamber is almost always missing and the venter is often broken. The lack of ornamentation as well as the compressed shape and sharp venter readily allow the recognition of this species.

Occurrence.— Placenticeras meeki has been described from Late Cretaceous deposits throughout the Western Interior area and the Navarro Group of Texas.

Placenticeras costatum Hyatt, 1903
(Plate 9, Figures 1, 2 & 3; Plate 10, Figures 1 & 2)

Placenticeras costatum Hyatt, 1903, figs. 1-3, 9-24.
Placenticeras costatum Hyatt. Larson et al., 1997, p. 70.

Description.— Small to large, laterally compressed, strongly involute, discoidal. Whorl diameter is much larger than cross-sectional width at umbilical shoulder. Narrow venter, flat to slightly concave in smaller specimens, flat or closely rounded on larger specimens; sharp marginal angles on both sides of younger specimens, rounded in large specimens. Flanks flat to very slightly convex. Umbilicus narrow with steeply sloping walls and a rounded umbilical border. Ornamentation consists of a row of sharply
pointed tubercles ventrally of the umbilical shoulder. These are sharpest and most prominent in smaller specimens but remain prominent through ontogeny. Another row of lower, rounded tubercles occurs about two thirds the height of the flank from the umbilicus. These tubercles are also more prominent and sharper in the younger stages, becoming low undulations in large specimens. Ventral clavi border both sides of the venter. Most specimens are very weathered and do not retain suture patterns, but some fragments show a complex suture pattern of elongate, intricately branching saddles and lobes.

Dimensions.—
235 mm D, umbilicus 35 mm D, whorl height 115 mm, whorl breadth ≈60 mm.
200 mm D, umbilicus 30 mm D, whorl height 100 mm, whorl breadth ≈50 mm.
130 mm D, umbilicus 17 mm D, whorl height 65 mm, whorl breadth ≈30 mm.
115 mm D, umbilicus 20 mm D, whorl height 49 mm, whorl breadth 23 cm.

Discussion.— P. costatum differs from P. intercalare only in the ornamentation. P. intercalare has fewer clavi along the ventral edge than P. costatum. The prominence of the ornament differs between specimens, and large specimens of the two species could possibly be misidentified, but the smaller specimens are very easy to differentiate. P. intercalare is presumed to be ancestral to P. costatum.

Occurrence.— P. costatum has been described from throughout the Western Interior of the United States.

Placenticeras sp.
(Plate 10, Figure 3)

Description.— This species is represented by two broken umbilical sections with one specimen displaying a cross section. One section is a single, shallow-sided whorl; the other shows one small inside whorl and one later whorl. The umbilici are moderately steep sided. The cross section shows a more round shouldered whorl than seen in P. meeki. Width is about half height. No suture preserved.

Dimensions.— largest diameter of umbilicus, 6 mm; whorl width, 9 mm.

Discussion.— With so little material for description a species designation is near impossible. These specimens could possibly represent P. intercalare Meek & Hayden, which has been found in the B. compressus zone of the Western Interior, but more and better preserved specimens are needed before a designation can be made with confidence. P. intercalare has a more open umbilicus than P. meeki.

Family NOSTOCERATIDAE Hyatt, 1894
Genus NOSTOCERAS Hyatt, 1894
Type Species.— Nostoceras stantoni retrosum Hyatt (emend: Nostoceras stantoni Hyatt).
**Nostoceras sp.**  
(Plate 11, Figure 1)

*Description.*— A section of a whorl 45 mm long and 17 mm wide is the only representative of this genus from the study area. The segment is widely curved and has a very slight twist. Evenly spaced sharp crested ribs cover the surface. The ribs are about half as wide as the interspaces and are stronger on the sides, becoming very weak on the venter. A double row of nodes line the venter, marking the transition from strong flank ribs to weak venter ribs. The nodes are prominent, somewhat unevenly spaced and are about the width of two ribs and the dividing interspace. Interspaces are U-shaped. No sutures or cross sections are available for description.

*Occurrence.*— *Nostoceras* species have been described from the Navarro Group of Texas, the Western Interior and East Coast of the United States.

**Genus ANAKLINOCERAS** Stephenson, 1941  
*Type Species.*— *Anaklinoceras reflexum* Stephenson, 1941, p. 414.

**Anaklinoceras reflexum** Stephenson, 1941  
(Plate 11, Figure 2)

*Anaklinoceras reflexum* Stephenson, 1941, p. 414, Pl. 83, figs. 1-5.  
*Nostoceras (Anaklinoceras) reflexum* Stephenson. Wright (Treatise), 1957.  

*Description.*— Small conch with a moderately high sinistrally coiled tapered inner spire of four complete volutions. Initial stage of volutions is covered or broken. The last spiral whorl extends slightly beyond the penultimate whorl and then is reflected up the side of the spire and wraps around the initial spire. The specimen from this study is broken just past the bend over the top of the spire. Ornament is of sharp crested prosocline axial ribs that cover the entire surface of the conch. In the early whorls the ribs are relatively weak and closely spaced. The ribs become stronger and more widely spaced over the spiral coil and continue the trend on the reflected whorl. Interspaces are about twice the width of the ribs. Ribs are somewhat irregular in strength and spacing on reflected whorl. Near the start of the reflected whorl, a double row of faint nodes can be seen on the venter of the whorl. As the whorl extends up the side of the spiral the nodes become larger and more numerous. Nodes initially occur on randomly spaced ribs, but become more regular with progress of the whorl.

*Dimensions.*— Total height 27 mm; Whorl height 6 mm.

*Discussion.*— A single well-preserved steinkern, broken just after reflected whorl bends over spiral, and with fragments of shell material remaining and an additional short section of a reflected whorl are the only representatives of this species found at the study area. This morphology is unique and unlikely to be confused with other taxa.

*Occurrence.*— This species has been reported from the Navarro Group of Texas as well as from New Jersey and Israel.
Family **DIPLOMOCERATIDAE** Spath, 1926
Subfamily **DIPLOMOCERATINAE** Spath, 1926
Genus **AXONOCERAS** Stephenson, 1941
Type Species.— *Axonoceras compressum* Stephenson, 1941, p. 422.

**Axonoceras compressum** Stephenson
(Plate 11, Figures 3 - 6)

*Axonoceras compressum* Stephenson, 1941, p. 422, Pl. 89, figs. 1-5.


**Description.**— Small, fragile, serpenticone with round whorls. First whorl is open, creating a loop. Largest specimen from this study is about two volutions. Successive volutions are very close, but not joined, to earlier whorls. Ornament consists of sharp topped ribs that vary in width, spacing and prominence. Ribs are straight to slightly sinuous and some bifurcate, but without discernable pattern. A double row of sharp topped ventral nodes becomes more prominent but fewer with growth. Suture not exposed.

**Dimensions of most complete specimen.**— 16 mm D, whorl diameter 5 mm, umbilical perforation 5 mm.

**Discussion.**— This delicate species is represented in this study by one specimen that is approximately half present and exposed; approximately one-fourth of both whorls is broken and approximately one-fourth is still obscured by matrix. In addition there are several external molds and numerous fragments of whorls. The ribs of *A. compressum* are finer than those of *A. pingue* and the nodes are larger and more widely spaced than is seen on *A. multicostatum* Stephenson (1941).

**Occurrence.**— *A. compressum* has been described from the Navarro Group of Texas and previously from the KPRA.

Family **BACULITIDAE** Gill, 1871
Genus **BACULITES** Lamarck, 1799
Type Species.— *Baculites vertebralis* Lamarck, 1801, p. 301 by subsequent designation of Meek, 1876, p. 391.

**Baculites compressus** Say, 1820
(Plate 11, Figures 7, 8 & 9)

*Baculites compressus* Say, 1820.

*Baculites compressus* Say. Meek, 1876, pp. 400-404, Pl. 20, figs. 3a-c, text figs. 55, 56.

*Baculites compressus* Say. Reeside, 1928.

*Baculites compressus* Say. Adkins, 1932.

**Description.**— Small- to large-sized, moderately tapering, smooth flanks and venter, compressed elliptical cross section. Dorsum broadly rounded, venter narrowly rounded.

**Dimensions.**— 54 mm L x 37 mm H x 19 mm W (fragment).
Discussion.— This species is extremely abundant in the research area. As with most species of Baculites, complete specimens are rarely found and this study is no exception. A few large fragments were found but generally the fragments were only a few centimeters and no ammonitellas were found. Some fragments retain a few suture pattern elements and one fragment retains exceptional suture pattern, but overall the specimens are recognizable only by the compressed cross sectional profile and smooth, unornamented flanks.

Occurrence.— Baculites compressus is found throughout the Western Interior of the United States and Canada and is also reported from the Taylor Formation of Texas, but not in the same abundance as in the Western Interior.

Baculites cuneatus Cobban, 1962
(Plate 12, Figure 1)

Baculites compressus Say. Meek, 1876, text figs. 55, 56.
Baculites compressus Say. Warren, 1931, Pl. 2, figs. 1, 2.

Description.— Cross section broadly ovate. Moderately weak arch shaped ribbing on flanks.

Dimensions.— 55 mm L x 17 mm W; 157 mm L x cross sectional measurements 43 mm x 32 mm (fragments).

Discussion.— This species is poorly represented in the samples for this study. One long fragment is identified as B. cuneatus by the broadly ovate cross section and one external mold shows the weak flank ornament.

Occurrence.— Baculites cuneatus is described from the Western Interior of the United States and Canada.

Superfamily SCAPHITACEAE Gill, 1871
Family SCAPHITIDAE Gill, 1871
Subfamily SCAPHITINAE Gill, 1871
Genus HOPLOSCAPHITES Nowak, 1911
Type Species.— Ammonites constrictus J. Sowerby, 1817.

Hoploscaphites landesi Riccardi, 1983
(Plate 12, Figures 2 - 8)


Description.— Small to medium sized, phragmacone involute with body chamber extended slightly past phragmacone. Umbilical margin short with only a slight gap between phragmacone and body chamber. Umbilicus small, steep sided. Flanks compressed on phragmacone, inflating slightly at beginning body chamber. Venter broadly arched. Ornament on phragmacone is sinuous, sharp, prosocline ribs that are
narrower than the interspaces and cover the entire shell. Near umbilicus the ribs are well separated and form low bullae on the umbilical shoulder. Ribs radiate from umbilicus in a slightly prorsiradiate direction and curve into rursiradiate direction. Ribs begin to bifurcate about one-third the width of the flank from the umbilicus. Venter is evenly rounded over phragmacone but develops a slightly squared profile over body chamber with ventrolateral tubercles that become larger and more prominent with growth of the body chamber. No sutures are preserved for description or illustration.

Dimensions.—
55 mm D, 20 mm whorl width (body whorl damaged and unmeasurable), 31 mm whorl height.
45 mm D, whorl width unmeasurable, 25 mm whorl height.
46 mm D, 16 mm whorl width (body whorl damaged and unmeasurable), 28 mm whorl height.

Discussion.— H. landesi is very similar to H. gilli Cobban and Jeletzky (1965) which is known from the Baculites perplexus to the Didymoceras stevensoni biozones but differs in the slightly more compressed whorl section. Ventrolateral tubercles seem to be a constant element on H. landesi, but are not as consistent on H. gilli. The number of ribs radiating from the umbilicus is fewer on H. landesi than on H. gilli.

Occurrence.— H. landesi is described from the Didymoceras cheyennense through the Baculites cuneatus zones of the Western Interior and the Bearpaw Formation of the Western Interior of Canada.

Genus JELETZKITES Riccardi, 1983
Type Species.— Scaphites nodosus Owen, 1852.

Jeletzkytes cf. nodosus (Owen), 1852
(Plate 13, Figures 1 - 7)

Description.— Medium to large sized, inflated, rapidly expanding, involute with body chamber extended beyond phragmacone. Umbilicus small, deep and steep sided. Flanks and venter each broadly convex but producing a slightly squared profile at the ventrolateral shoulder. Entire shell covered with strong, relatively sharp topped ribs, evenly spaced and two rows of tubercles. Ribs on phragmacone straight to very slightly sinuous. No bifurcation. Interspaces are about twice as wide as ribs and U-shaped. One row of tubercles is about one-third the width of the flank from the umbilicus, is very small on phragmacone, becoming more prominent with growth. The second row of tubercles is on the ventrolateral shoulder, is larger than tubercles on flank and also becomes more prominent with growth. Sutures are moderately complex as shown in figure 8.

Figure 8. Typical suture pattern of Jeletzkytes nodosus.
(from Riccardi, 1983)
Dimensions.—
95 mm D, whorl height 54 mm, whorl breadth 51 mm.
39 mm D, whorl height 24 mm, whorl breadth 24 mm.

Discussion.— This species is described from one nearly complete large specimen missing only the aperture of the body chamber and one small, most likely juvenile specimen. This specimen resembles *J. nodosus* in overall appearance but has several distinct characteristics, notably, the placement of the lateral tubercles and the rib pattern, that make the designation less than certain. Riccardi (1983) described the ventrolateral tubercles of *J. nodosus* as beginning “half a whorl before the end of the phragmacone” (p. 16) whereas on this specimen the ventrolateral tubercles are present even in the juvenile stage. In addition, the ribs on the described specimen are more widely spaced, non-bifurcating and straighter than Riccardi’s specimens show.

Occurrence.— *Didymoceras cheyennensis* to *Baculites cuneatus* zones of the Pierre Shale.

**Jeletzkytes brevis(?)** (Meek), 1876
(Plate 14, Figures 1, 2 & 3)

*Scaphites nodosus*? var. Meek, ?1859, p. 185, Pl. 2, figs. 7-8.
*Scaphites nodosus* var. brevis Meek, ?1876, p. 426, Pl. 25, figs. 1a-c.
*Scaphites nodusos* Meek. Whitfield, 1880, p. 441, Pl. 13, fig 12.
*Scaphites nodosus* var. brevis Meek. Whitfield, 1880, p. 443, Pl. 13, figs. 8-9.
*Scaphites nodosus* var. brevis Meek. Logan, ?1898, p. 511, Pl. CVII, fig. 3 (Meek’s Pl. 25, fig. 1b redrawn).
*Scaphites nodosus* Meek. Logan, ?1899, Pl. XXII, fig. 2; Pl. XXIII, figs. 1-4, 6-12.
*Scaphites binodosus* F.A. Roemer var. brevis Meek. Frech, 1915, p. 560, fig. 7.
*Acanthoscapheites nodosus* var. brevis Meek. Elias, 1933, p. 321, Pl. XXXVII, fig. 2; Pl. XLI, fig. 3.
*Scaphites brevis* Meek. Stephenson, 1941, p. 426, Pl. 90, figs. 7-8.
*Scaphites brevis* Meek. Jeletzky, 1970, Pl. XXII, figs. 9a-b.
*Hoploscaphites nodosus* brevis (Meek & Hayden). Kauffman, ?1977, Pl. 32, fig. 9 (holotype refigured).

Description.— Medium to large conchs, moderately compressed to inflated with rounded venter, rapidly expanding. Umbilicus small. Venter wide and rounded and bordered on larger specimens with rows of ventrolateral tubercles. Tubercles begin on phragmacone and become larger approaching the body whorl but weaken on the body whorl itself. Specimens show a high degree of variability in ornamentation with fine, closely spaced ribs and wider, more distantly spaced ribs. Across venter, ribs curve broadly in the direction of the body chamber. Ribs are sharp topped and slightly sinuous. The ribs initially curve away from the body chamber as they radiate from the umbilicus, but at about one-third the height of the whorl they curve back toward the body chamber. Some ribs also bifurcate at about this same point. As ribs radiate from the umbilicus some are more prominent and develop umbilical bullae. Typical suture pattern shown in figure 9.
Figure 9. Typical suture pattern of *Jeletzkytes brevis* (from Riccardi, 1983)

**Dimensions.**—
41 mm D, whorl height 25 mm, whorl breadth 25 mm.
36 mm D, whorl height 23 mm, whorl breadth 22 mm (venter slightly crushed on last whorl, measured at point just before breakage).
Body whorl fragment (slightly deformed); whorl height 35 mm, whorl breadth 35 mm.
Fragment; whorl height 26 mm, whorl breadth 28 mm.

**Discussion.**— Only two juvenile specimens or specimens that are broken before the body chamber have the phragmacone, all others are fragments of the body chamber and all are questionably assigned to this species. In his description of this species Riccardi (1983) indicated a high degree of variability in the spacing and sinuosity of the ribs and placement and strength of the tubercles. All specimens fall within the variability parameters of Riccardi.

**Occurrence.**— *J. brevis* is described from the Bearpaw Formation of the Western Interior of Canada; the *Didymoceras cheyennense* to the *Baculites cuneatus* zones of the western interior of the United States; the Navarro Group of Texas.

**Jeletzkytes sp.**
(Plate 14, Figure 4)

**Description.**— A single fragment of a *Jeletzkytes* species shows a broad, very rounded venter and fine ribs. Flanks appear to be broadly rounded. Ribs are closely spaced, sharp topped and only slightly narrower than the interspaces. Ribs are continuous from flanks to across venter and slightly sinuous on flanks near umbilicus. Small tubercles are widely spaced on ventrolateral shoulders and seem to be non-uniform in strength or spacing, although with a larger specimen a pattern might be discerned.

**Dimensions.**— 60 mm L x 29 mm H.

**Discussion.**— This fragment is fairly weathered and crushed and would have been left out of the systematics except for the unusually fine ornamentation. The ribs are extremely fine and closely spaced and resemble no other specimens, warranting inclusion in this study. The fragment may be the body chamber of the conch since one of the “ends” has a smooth, rather than jagged, margin.

Subclass **NAutiloidea** Agassiz, 1847
Order **NAutilida** Agassiz, 1847
Superfamily **NAutilaceae** de Blainville, 1825
Family **NAutilidae** de Blainville, 1825
Genus **Eutrephoceras** Hyatt, 1849
Type Species.— *Nautilus dekayi* Morton, 1833, p. 291.
Eutrephoceras dekayi (Morton), 1833  
(Plate 14, Figures 5 – 9)

Nautilus dekayi Morton, 1833, p. 291, Pl. 8, fig. 4.  
Nautilus perlatus Morton, 1834, p. 33, Pl. 13, fig. 47.  
Nautilus dekayi montanaensis (Morton). Meek, 1876, p. 498, Pl. 27, figs. 2a-e.  
Eutrephoceras dekayi (Morton). Hyatt, 1894, pp. 555-558, 560, 587, Pl. 13, figs. 4-8; Pl. 14, fig. 1.  
Eutrephoceras dekayi (Morton). Stephenson, 1923, p. 96, Pl. XCVI, figs. 3, 4.  
(?) Eutrephoceras alcesense (Morton). Reeside, 1927, p. 7, Pl. 1, figs. 1-3; Pl. 2, fig. 1; Pl. 3, figs. 1-5; Pl. 5, figs. 1, 2.  
Eutrephoceras dekayi (Morton). Richards et al, 1962, pp. 102-111, Pl. 65, figs. 1-6; Pl 66, figs. 1, 2; Pl 67, figs. 1-9.  
For a more complete synonymy see Richards, 1962.

Description.— Medium to large, involute, near spherical, rapidly expanding. Aperture width is about twice height. Siphuncle located about one fourth to one-third the height of the whorl from the dorsum. Smooth, unornamented exterior with occasional sinuous irregularly spaced growth lines that follow the sinuosity of the suture pattern.

Dimensions of two mostly complete specimens.— 56 mm W x 68 mm D; 47 mm W x 48 mm D.

Discussion.— The specimens from this study include two near complete specimens which retain fragments of shell material and two broken samples that show the position of the siphuncle which is a good diagnostic character for distinguishing the species of Eutrephoceras.

Occurrence.—This species is extremely widespread in the late Cretaceous and has been found in Texas, the east coast and Gulf coast states and the Western Interior. Worldwide occurrences include Saudi Arabia, England, Colombia, Italy, India, New Zealand and Antarctica to name a few.
Explanation of Plates

Scales

1 mm = - - -
5 mm = ————
10 mm = ————
50 mm = ————
100 mm = I——— I
Plate 1

1. *Discinisca* sp., external mold
2. *Lingula aff. subspatulata* Hall & Meek
3. *Serpula cretacea* (Conrad)
4. *Serpula cretacea* (Conrad)
5. *Nucula percrassa* Conrad
6. *Nucula* sp. 1
7. *Acila (Truncacila) chicotana* Stephenson
8. *Nuculana (Jupiteria) scitula* (Meek & Hayden)
9. *Nuculana (Jupiteria) scitula* (Meek & Hayden)
10. *Nuculana (Jupiteria) scitula* (Meek & Hayden)
11. *Nuculana* sp.
12. *Parallelodon* sp.
13. *Parallelodon* sp.
14. *Nemodon harriesi* Sava, n. sp.
15. *Nemodon harriesi* Sava, n. sp.
16. *Nemodon harriesi* Sava, n. sp.
17. *Nemodon harriesi* Sava, n. sp.
18. *Nemodon harriesi* Sava, n. sp.
19. *Nemodon adkinsi* Stephenson
20. *Nemodon adkinsi* Stephenson
21. *Cucullaea nebracensis* Owen
22. *Cucullaea nebracensis* Owen
23. *Cucullaea nebracensis* Owen
Plate 2

1. *Crenella* sp.
2. *Modiolus kremmlingensis* Sava, n. sp.
3. *Modiolus kremmlingensis* Sava, n. sp.
4. *Modiolus kremmlingensis* Sava, n. sp.
5. *Modiolus meeki* (Evans & Shumard)
7. *Pinna* sp.
8. *Phelopteria ruppii* Sava, n. sp.
10. *Phelopteria linguaeformis* (Evans & Shumard)
11. *Phelopteria linguaeformis* (Evans & Shumard)
12. “*Inoceramus*” altus Meek
13. “*Inoceramus*” altus Meek
14. “*Inoceramus*” altus Meek
15. “*Inoceramus*” altus Meek
Plate 3

1. “Inoceramus” altusiformis Walaszczyk, Cobban & Harries
2. “Inoceramus” altusiformis Walaszczyk, Cobban & Harries
3. “Inoceramus” altusiformis Walaszczyk, Cobban & Harries
Plate 3
Plate 4

1. “Inoceramus” oblongus Meek
2. Syncyclonema travisanus Stephenson
3. Propeamussium simplicus (Conrad)
4. Propeamussium simplicus (Conrad)
5. Propeamussium sp.
6. Propeamussium sp.
7. Lyropecten ? sp.
8. Anomia tellinoides Morton
9. Anomia tellinoides Morton
10. Anomia tellinoides Morton
11. Lima janetae Sava, n. sp.
12. Lima janetae Sava, n. sp.
13. Lima sp. 1
14. Lima sp. 2
15. Exogyra sp.
16. Pseudoperna inflatum Sava, n. sp.
17. Pseudoperna inflatum Sava, n. sp.
18. Pseudoperna inflatum Sava, n. sp.
19. Pseudoperna inflatum Sava, n. sp.
Plate 5

1. Ostrea subradiata Cragin
2. Ostrea sp. 1
3. Ostrea sp. 2
4. Ostrea sp. 2
5. Nymphalucina bourni Sava, n. sp.
6. Nymphalucina cleburni (White)
7. Nymphalucina cleburni (White)
8. Diplodonta davisi Dailey & Popenoe
9. Astarte sp.
10. Crassatella franzeseii Sava, n. sp.
11. Protocardia barneyi Sava, n. sp.
12. Tellina sp.
13. Tellina sp.
14. Tellina sp.
Plate 6

1. *Etea peasi* Stephenson
2. *Etea peasi* Stephenson
3. *Etea peasi* Stephenson
4. *Tenea parilis* Conrad
5. *Tenea parilis* Conrad
6. *Tenea parilis* Conrad
7. *Corbula* sp. 1
8. *Corbula* sp. 2
9. *Opertochasma cuneatum* (Meek & Hayden)
10. *Opertochasma cuneatum* (Meek & Hayden)
11. *Teredo irregularis* Gabb
12. *Cuspidaria ventricosa?* (Meek & Hayden)
13. *Acmaea genetteae* Sava, n. sp.
14. *Acmaea genetteae* Sava, n. sp.
15. *Voysa?* sp.
16. *Turritella* sp.
17. *Nudivagus cooperensis* Stephenson
18. *Nudivagus cooperensis* Stephenson
19. *Nudivagus cooperensis* Stephenson
20. *Nudivagus cooperensis* Stephenson
21. *Drepanochilus evansi* Cossmann
22. *Drepanochilus evansi* Cossmann
23. *Drepanochilus obesus* Sohl
24. *Drepanochilus nebrascensis* (Evans & Shumard)
25. *Drepanochilus* sp.
27. *Vanikoropsis nebrascensis* (Meek & Hayden)
29. *Gyroides* sp.
Plate 7

1. *Bellifusus (?)* sp. 1
2. *Bellifusus* sp. 2
3. *Creonella triplicata* Wade
4. *Nonacteonina triticea* Stephenson
5. *Nonacteonina deflexa* Stephenson
6. *Eoacteon sublinearis* (Stephenson)
7. *Sulcoretusa dominici* Sava, n. sp.
8. *Sulcoretusa dominici* Sava, n. sp.
9. *Oligoptyca concinna* (Hall & Meek)
10. *Anisomyon centrale* Meek
11. *Anisomyon centrale* Meek
12. *Anisomyon aff. centrale* Meek
13. *Mesolanistes reesidei* (Stanton)
14. *Mesolanistes reesidei* (Stanton)
15. *Mesolanistes reesidei* (Stanton)
Plate 8

1. *Placenticeras meeki* Böhm
2. *Placenticeras meeki* Böhm
3. *Placenticeras meeki* Böhm
Plate 9

1. *Placenticeras costatum* Hyatt
2. *Placenticeras costatum* Hyatt
3. *Placenticeras costatum* Hyatt
Plate 10

1. *Placenticeras costatum* Hyatt
2. *Placenticeras costatum* Hyatt
3. *Placenticeras* sp.
Plate 11

1. *Nostoceras* sp.
2. *Anaklinoceras reflexum* Stephenson
3. *Axonoceras compressum* Stephenson
4. *Axonoceras compressum* Stephenson  
   (silicon cast of external mold)
5. *Axonoceras compressum* Stephenson
6. *Axonoceras compressum* Stephenson
7. *Baculites compressus* Say
8. *Baculites compressus* Say
9. *Baculites compressus* Say
Plate 12

1. *Baculites cuneatus* Cobban
   (silicon cast of external mold)
2. *Hoploscaphites landesi* Riccardi
3. *Hoploscaphites landesi* Riccardi
4. *Hoploscaphites landesi* Riccardi
5. *Hoploscaphites landesi* Riccardi
6. *Hoploscaphites landesi* Riccardi
7. *Hoploscaphites landesi* Riccardi
8. *Hoploscaphites landesi* Riccardi
Plate 13

1. Jeletzkytes cf. nodosus (Owen)
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6. Jeletzkytes cf. nodosus (Owen)
7. Jeletzkytes cf. nodosus (Owen)
8. Jeletzkytes cf. nodosus (Owen)
Plate 14

1. *Jeletzkytes brevis* (?) Meek
2. *Jeletzkytes brevis* (?) Meek
3. *Jeletzkytes brevis* (?) Meek
4. *Jeletzkytes* sp.
5. *Eutrephoceras dekayi* (Morton)
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### Appendix A. Latitude and Longitude of Sample Locations.

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