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Pelecypoda from the lower Fox Hills Formation (Upper Cretaceous) of Emmons County, North Dakota

Rodney M. Feldmann
University of North Dakota

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PELECTIONS FROM THE LOWER FOXL HILLS FORMATION
(UPPER CRETACEOUS) OF EMONS COUNTY, NORTH DAKOTA

by

Rodney M. Feldman

B.S. in Geology, University of North Dakota 1961

A Thesis
Submitted to the Faculty
of the
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for the Degree of
Master of Science

Grand Forks, North Dakota
June
1963
This thesis submitted by Rodney M. Feldman in partial fulfillment of the requirements for the Degree of Master of Science in the University of North Dakota, is hereby approved by the Committee under whose work has been done.

F. D. Holland, Jr.
Chairman

[Signature]

Dean of the Graduate School

303897
ABSTRACT

PELECTYPODA FROM THE LOWER FOX HILLS FORMATION
(UPPER CRETACEOUS) OF RAINBOW COUNTY, NORTH DAKOTA

Rodney Feldmann

The thesis here abstracted was written under the direction of Dr. F. D. Holland, Jr., committee chairman, and approved by Drs. Holland, W. M. Moore, and G. C. Wheeler who served as members of the examination committee.

The Fox Hills Formation in Rainbow County, North Dakota, consists of 250-350 feet of medium to fine grained sand and sandstone with some shale interbeds. In Rainbows County, the four members, Waal City, Timber Lake, Bullhead, and Colgate are not as distinct lithologically as they are in the areas from which they were described; thus, the unit has been subdivided into a lower part consisting of crossbedded sand and sandstone with calcareous, fossiliferous concretions and an upper part consisting of interbeds of buff sand and chocolate shale.

The gradational change from Pierre Shale lithology to the sands of the overlying Fox Hills Formation have resulted in several different definitions of the contact. The most consistent criterion for defining the contact in Rainbow County is a zone of jasomite below the lowest fossiliferous concretion layer. The base of the jasomite zone has been arbitrarily selected as the division between the two formations.

Twenty-two species of paleocyopods were identified from the concretions of the lower part of the formation. The concretions were probably formed
as clay boulders along the strand line of the Fox Hills Sea and were later transported to their site of deposition farther offshore. The entire formation represents the shoreline and nearshore facies of the regressive Upper Cretaceous seaway.
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INTRODUCTION

Purpose.—The Fox Hills Formation in North Dakota and adjacent areas contains an abundant molluscan fauna which has received little study since the classic work on the Cenozoic and Cretaceous Systems of the Mid-continent in the mid-nineteenth century. During the summer of 1962, while employed by the North Dakota Geological Survey, I made extensive collections of fossils from the Fox Hills Formation in Benson County, North Dakota. This material will form the framework of a study of the paleontology of the Fox Hills Formation in North Dakota of which the present work on the Paleozpoda is a part. The primary purpose of this work is to present a modern study of the Paleozpoda from the lower part of the formation in Benson County. Secondly, the occurrence of the majority of the fossils in concretions will be discussed with regard to the ecology of the formation.

Location and physiography.—Benson County is located in the south-central part of North Dakota; it is bounded on the west by the Missouri River, on the north by Burleigh County, on the east by Logan and McIntosh Counties, and on the south by South Dakota (Fig. 1). Phyniographically, it lies in the Coteau Slope district of the glaciated Missouri Plateau section of the Great Plains province (Clayton, 1962, 1963, p. 14). Approximately 70% of the area of the county is covered by Pleistocene deposits; the remainder has Cretaceous and Paleocene bedrock either exposed at the surface or beneath very thin soil cover. In gross aspect, the county is a mature plateau which has only recently been secondarily dissected along its western border by the Missouri River.
Fig. 1. Index map of Benson County, North Dakota.
and its tributaries. The result is a gently rolling prairie, seldom
with relief in excess of 100 feet, except where dissected by the three
major tributaries to the Missouri River. These tributaries—Redger
creek, Beaver Creek, and Little Beaver Creek—provide the only natural
outcrops of bedrock in the county. Other outcrops are mostly the result
of highway development.

The climate of the area is semi-arid with rainfall averaging
approximately fifteen inches per year. The economy is entirely
agrarian. Several petroleum prospects have been drilled on the south-
est flank of the Williston Basin inPanora County but no production
has been established. A possible future source of income might result
in exploitation of extensive volcanic ash deposits that occur in the
Fox Hills Formation in eastern Panora County. Full details of this
deposit have been published by Nata (1962).

PRELIMINARY WORK.—The earliest work on the Upper Cretaceous in
the Mid-continent is summarized by Nata (1976). Prior to this time
the Cretaceous and Cenozoic formations in the area had been subdivided
into five units, of which the Fox Hills sandstone was unit number five.
Nata’s work, primarily paleontological, is a compendium of material
collected during several studies prior to that time. Type specimens
of several species collected by Hayden and described in this work are
recorded from the vicinity of Long Lake. The location of this type
area is still unknown, although I am confident that, if the present
Long Lake in Panora County is the locality cited, the name was used
in only a very general sense. No exposures are present in the area
of Long Lake, Panora County, that could have yielded the fauna described
from Peel's "Long Lake". This is, however, the only evidence available that any of the material collected by the early workers was taken from Benson County. In 1912, Leonard published a geologic map of the south-central portion of North Dakota in which the extent of the Pierre, Fox Hills, and Lance Formations are shown in Benson County. Even allowing for more modern interpretations of the formational boundaries, Leonard was far too conservative in portraying the extent of the Fox Hills in the county. Following Leonard's work, Stanton (1917) noted the presence of volcanic ash in the area surrounding Linton. Nothing more was done in the area until Fisher (1932) mapped Benson County. This was essentially an extension of work previously done by Calvert and others (1914) in Sioux County, and Laird and Mitchell (1942) in southern Morton County. Fisher not only drew a geologic map of the county but also constructed a structural contour map of the same area. Although the geologic map has proved to be reliable with regard to areal extent of the bedrock, the structure as mapped cannot be demonstrated in the field.

Following this work, Ovancara (1956) studied the Gastropoda of the Pierre Formation in Sisson Park, 3/4 of a mile southeast of Linton, North Dakota. This outcrop, located in Sec. 17, T. 136 N., R. 72 W., is a steep cutbank on the south side of Beaver Creek. As it is the best locality in central North Dakota to see the Pierre-Fox Hills contact, the outcrop has been much studied. The gradational nature of this contact has resulted in almost constant conflict with regard to placement of the contact. A more complete review of this problem is given below. Suffice it to say here that I believe the
gastropod fauna described by Cuvancara (1956) should be placed in the
Fox Hills Formation. This would be more consistent with the modern
definition of the lower limit of the Fox Hills.
STRATIGRAPHY

General.—The pre-Pleistocene surficial bedrock in Sioux County is made up of the Pierre, Fox Hills, and Hell Creek Formations in the Cretaceous System and the L龙湖 and Cannonball Formations in the Cenozoic System. In response to regional structure, the units have a general dip of 20 feet per mile to the northwest (Fisher, 1952, pl. 2). The stratigraphic column showing rocks cropping out at the surface is shown in Fig. 2.

As the structure in the area is minimal, the topography in the western half of the county is controlled almost exclusively by the lithology of the units exposed. From T. 134 N. to the southern border of the county the dominant element of topography is the upper part of the lower Fox Hills Formation (Fig. 3). Several thick, calcareous ledges crop out at this stratigraphic level and form the present general land surface. Above the general land surface, buttes and small hills are formed in the upper Fox Hills while the lower part of the section is exposed along valley walls. North of T. 134 N. the Fox Hills Formation crops out less frequently and the topography is controlled by the Hell Creek Formation. The lithology of the Hell Creek is such that it normally supports minimal vegetation with the result that buttes and bare slopes are far more common in this part of the county than farther south (Fig. 4).

East of R. 76 W. the dominant topographic features are glacial in origin and the effect is a more subdued topography than in the western part of the county.
Fig. 2. Stratigraphic column of rocks cropping out in Simmons County. Thicknesses, with the exception of that of the Fox Hills, are taken from Fisher (1952).
Fig. 3. View of the topography developed on the lower part of the Fox Hills Formation in Emmons County, North Dakota. The picture was taken from T. 13½ N., looking southeast.

Fig. 4. View of the topography developed on the Hell Creek Formation in Northern Emmons County, North Dakota. The picture was taken in Section 20, T. 136 N., R. 78 W.
Pierre Formation.—The Pierre Formation was named by Meek and
Hayden (1862, p. 449, 434) for exposures near old Ft. Pierre in either
Stanley or Hughes County, South Dakota. (The precise location is
apparently unknown). Subsequently the unit has been subdivided into
eight members (Grindall, 1950) of which only the Elk Butte Member is
exposed in Ramona County. Fisher (1952, p. 8) indicated that the
Netbridge Member may be present at the surface in the extreme south-
western part of the county but this has not been demonstrated. The
Elk Butte Member is a blue-gray, non-calcareous, fissile shale that
may be locally gyrophorous. In South Dakota, where it has been more
thoroughly studied, the member rarely produces fossils (Winge, 1961,
p. 232); Palmodinella sp. is the only species commonly encountered
(Gries, 1942, p. 32).

Following Fisher's placement (1952, p. 9) of the Pierre-Fox
Hills contact, Cuvancera (1956) considered the concretion layers in
Seeman Park, Linton, North Dakota, part of the Elk Butte Member and
thus listed a rather large suite of gastropods and mentioned other
mollusks from the member. As will be discussed below, I believe the
contact was placed higher in the section by both Fisher (1952) and
Cuvancera (1956) than modern interpretation allows. Although the
Pierre Formation is present at the surface in many places in Ramona
County, the only exposures that are not obscured by vegetation are in
the vicinity of Linton. Detailed examination of these exposures
yielded only a few unidentifiable paleoped fragments. At Seeman
Park, Fisher (1952, p. 3) reported 135 feet of Elk Butte sediments;
however, if the contact is placed below the above mentioned concretion
layers, the result is a reduction in thickness of exposed Pierre Formation to 90 feet and a corresponding increase in thickness of exposed Fox Hills.

Pierre-Fox Hills contact.—The change from the dark clay shales of the Pierre Formation to the buff sandstone of the Fox Hills Formation has been recognized as gradational since the early work was done on the units. Meek (1876, p. xxxv-xxxvi) summarized the problem by saying that

It the Fox Hills Formation is not separated by any strongly-defined line of demarcation from the Fort Pierre group below. . . indeed, it has sometimes been thought that we might, with almost equal propriety, on paleontological grounds carry the line separating these two groups down so as to include in the Fox Hills group the upper fossiliferous beds of the Fort Pierre group. Most of the known facts, however, especially when we take into consideration the change of sediments at or near where we have always placed the line between these two rocks, seem to mark this as about the horizon where we find evidences of the most marked change of physical conditions.

At that time no definite statement was made with regard to the criterion used to determine the exact contact and it was simply placed above the lowest concretion layer. They did, however, suggest another possible placement of the contact below this layer. Fisher (1932, p. 9) defined the contact in Wyoming County in relation to the lower concretion layers saying, "Where concretions are present the contact was placed at the top of that zone. These concretions are about two feet below the highest bentonite." This interpretation is not in accord with that of a committee of the Rocky Mountain Association of Petroleum Geologists (1932, p. 702-703) which concluded that the contact should be drawn at the "... horizon below which the section is predominately gray marine clay shales and sandy shales of Pierre
age, and above which the section changes rapidly to a buff to brown sandstone containing numerous gray to brown hard sandy concretions."

Using the same general definition, Morgan and Fetch (1945, p. 10) noted that

The interval between the top bentonite and the lowest concretionary layer varies from 3 to 25 feet. . . . When a decided lithological or color change appeared in this interval (usually an upward change from predominantly gray shale to more sandy material of yellow or buff tone) the Pierre Fox Hills contact was placed at this point. Where no apparent lithological change occurred in this interval the contact was assumed to be about intermediate between the topmost bentonite and the overlying concretionary layer.

They were unable to pick an exact contact and resorted to the base of the "bentonite" for structural mapping purposes. The "bentonite" discussed by Morgan and Fetch has since been shown (Waage, 1961, p. 233) to be jarosite, a hydrous iron sulfate which is dull yellow to yellow brown in color. It normally occurs as druses of minute crystals which, combined with the dull lustre give the mineral an earthy appearance. Waage (1961, p. 232) solves this problem by designating the contact at the base of the jarosite (bentonite of Morgan and Fetch) in the same area. In Bannan Park the first occurrence of jarosite is ten feet below the lowest concretion layer. It then becomes more common until it forms persistent beds two to three inches thick above the lowest concretion layer.

The gradational nature of this contact by definition makes designation of an exact line of demarcation impossible. It is, however, advantageous to be able to select some arbitrary criterion, or set of criteria, which allow the field geologist to locate himself stratigraphically.
With this in mind, I have used the base of the first occurrence of jecesite to mark the base of the Fox Hills Formation in Ravene County. Not only is this consistent with the work presently being done in South Dakota, it is also extremely valuable in Ravene County where one can anticipate proximity to the contact, even in areas of poor exposures, merely by the presence of jecesite pods at the surface. Further, it restricts the occurrence of concretions to the Fox Hills Formation and leaves the Elk Butte Member as described—a sparsely fossiliferous unit.

**Fox Hills Formation**—The Fox Hills Formation was named by Meek and Hayden (1862, p. 419, 427) for exposures in the Fox Hills in South Dakota. The location of the Fox Hills is the divide between the Cheyenne and Missouri Rivers, South Dakota (Meek and Hayden, 1862, p. 127). As the area named by Meek and Hayden does not provide a complete section of the formation, Waage (1961, p. 230) has redefined the type locality to include parts of Dewey, Carson, and Zielsch Counties, South Dakota. A composite section of the unit can be pieced together in this area. Since the naming of the formation, four members have been recognized, three of which are typically exposed in this area.

**Trail City Member**—The lowermost member of the formation, the Trail City Member, was named by Morgan and Petch (1945, p. 13) for exposures at Trail City, Carson County, South Dakota. They describe the unit as "... usually a sandy tuff or buff clay near its base, becoming more sandy in its upper parts near the contact with the overlying Timber Lake sandstone member." Also mentioned are several layers of dense, blue limestone concretions with sandy "jackets".
These concretions are being studied in the type area by K. N. Wange (1962, oral communication) who has thus far been able to trace six concretion layers over a considerable part of the type area. The individual layers are identified not on lithology but on fossil content and have been so named. The term "zone" has been used (Wange, 1961) in reference to these layers but this is not in keeping with either the definition of d'Orbigny (1842) or that of Oppel (1856-1858). The more general term, layer, is used by the writer herein. The following concretion "zones" have been recognized by Wange (1961, p. 233-234):

1. The *Dicerasbiliae micalloti* "zone" occurs 1-8 feet above the base of the formation and is characterized by an abundance of the conoconite *D. micalloti*. This layer, and the overlying *Lumonina-Gervillia* layer, have definitely been identified in North Dakota in Seaman Park near Linton.

2. The *Lumonina-Gervillia* "zone" crops out about 18 feet above the base of the unit and is distinguished on the presence of abundant *Lumonina striata-vanuxemi* and *Gervillia recta*.

3. The *Protocordia* "zone*, 35-40 feet above the lower contact, contains abundant *Protocordia subquadrate* and *Porfa nontransana*.

4. Two barren concretion "zones" occur above the *Protocordia* "zone*. They are separated from each other by 10 feet; the lower of the two units lies 35-40 feet above the *Protocordia* layer. Lithologically, although they contain no fossils, the concretions of this layer appear to be composed of the same brittle, blue limestone as the concretions below.
5. The *Discosachithes abrassius* "zone", containing *D. abrassius*, occurs near the top of the Trail City Member. This is the most discontinuous layer in the type area.

This, unfortunately, is not the entire picture. Waage (1961, p. 234) points out that the character of the concretions as well as their enclosing matrix changes laterally; therefore, correlation by any means other than direct tracing is difficult. Some of the fossiliferous concretion layers become barren as they are traced laterally while the enclosing matrix may change from sandy silt to sand. Further, the layers are not identified strictly on the basis of the fossils mentioned above. The names applied to the layers are merely taken from fossils in their zone. Occurrence of species of *Discosachithes*, a genus presently being revised (Waage, 1962, oral communication), is important in making exact distinctions between layers. The contact of the Trail City Member with the overlying Timber Lake Member is designated (Waage, 1961, p. 234) as a thin bed of highly glauconitic sand.

**Timber Lake Member.**—The Timber Lake Member was named for exposures in and around Timber Lake, Deuel County, South Dakota (Morgan and Fetch, 1945, p. 15). The lower part of the unit consists of greenish-yellow, medium grained, friable or unconsolidated sandstone while the upper part is characterized by thin beds or stringers of orange to brown, well cemented, limonitic claystone in a matrix of buff sand. The presence of discontinuous, brown-weathering lodes of calcareously cemented sandstone makes at least the upper part of the unit readily distinguishable from the adjacent members. The Timber Lake becomes
finer grained as it is traced westward in the type area (Weage, 1961, p. 296). The fauna, characterized by an abundance of *Plinia linguiformis* and *Ephedriodes leptocystus*, occurs for the most part in punky, red-weathering, limestone concretions in the lower part of the member. Fossils in the upper Timber Lake are rarer than in the lower part of the member; species are generally restricted to the class *Immeridae americanus* and the supposed decapod crustacean burrow *Halymenites major*.

Notable in the upper Timber Lake Member are a number of calcareously cemented, sandstone ledges. In isolated outcrops the impression is gained that these harder sandstone layers would be easily traceable, but Morgan and Fetch (1945, p. 17) point out that "sandstones are often lenticular and change rapidly on strike, both as to thickness and lithologic character." This fact restricts their use as stratigraphic markers to very local areas.

**Bullhead Member.**—Overlying the Timber Lake Member is a sequence of interbedded olive-drab shales and thin sands named the Bullhead Member by Stevenson (1936) for exposures in the Bullhead Quadrangle, Carson County, South Dakota. The sequence had previously been referred to as the "Sanded Beds" (Morgan and Fetch, 1945; Fisher, 1952).

Although palynologic evidence indicates a definite marine origin for the two underlying members, proof of the environment of deposition of Bullhead sediments is scanty. Near the top of the member, sandstone becomes more prominent; and marine, or at least brackish water, fossils are found, including (Morgan and Fetch, 1945, p. 18) the oyster *Ctenoica glabra*.
Colgate Member.—Capping the Fox Hills sequence in the type area is a fine to medium grained, dirty sandstone that has been correlated (Mage, 1961, p. 237) with the Colgate Member named by W. R. Calvert (1912) for exposures near Colgate Station, Dawson County, Montana. Although in its type area the Colgate is a readily traceable unit, its distribution becomes more patchy in bureau County, South Dakota.

Fox Hills in Dawson County.—In Dawson County, all four members described from the type area have been recognized in local outcrops. The lithology of the lowermost member is, however, different enough from that in the type area that differentiation between the Trail City and Timber Lake Members is often impractical. Wherever the Trail City Member can be recognized on the presence of limestone concretions, the matrix material is medium grained sand resembling lower Timber Lake lithology so that Fisher (1932, p. 19) suggested that the formation could more readily be subdivided in Dawson County into a "... lower series of green-gray and brown sands and sandstone, and an upper sequence consisting chiefly of thin gray and brown shales and sand, with several thicker sandstones." This type of subdivision places the Trail City and Timber Lake Members in a lower part of the Fox Hills and the Bullhead and Colgate Members in an upper part. Although the Trail City and Timber Lake Members can be identified in local outcrops on the basis of presence or absence of limestone concretions and claystone stringers, lack of topographic control or extensive outcrops in the area makes lateral tracing of beds or concretion layers impossible. Pleistocene deposits and intense farming make it impractical to identify member lithologies except where actual
exposures are available and, even then, such identification is difficult as stated above.

The factor that most strongly speaks for a twofold division of the Fox Hills in Secman County is the lithologic change from the type area to Secman County. Although Fisher (1952, p. 12) stated that "no recognizable beds of these members Trail City and Timber Lake were found east of Range 73 West . . .", the finest outcrop of the lower Fox Hills is in Secman Park, in Range 76 West. At this locality both the B. nicaleti and Lippensia-Cerrillia concretion layers crop out. Their relation to the Pierre-Fox Hills contact is similar to that described for the type area. The lowest occurrence of jasperite is 7-10 feet below the B. nicaleti concretion layer and is separated from it by brownish, jasperite rich, silty shale. Above the B. nicaleti layer, however, the shale is rapidly replaced by buff, medium grained sand that has the same appearance as the sand of the lower Timber Lake Member in the type area.

This can be interpreted in one of two ways. Either the Trail City Member retains its approximate thickness but becomes coarser grained north of the type area, or the Trail City Member thins to about 12 feet at Linton and the Lippensia-Cerrillia concretion layer at Secman Park, North Dakota, is in the Timber Lake Member. Considering the variable lithology of the Fox Hills Formation throughout its area of exposure (Mango, 1964, p. 229) it seems more reasonable to conclude that the Trail City Member becomes coarser north of the area in which it was originally described, and that the Lippensia-Cerrillia layer is in the Trail City. This uncertainty, however, further strongly suggests
that the lower two members of the type area in South Dakota should be treated as a single unit in North Dakota.

Concretion layers have been found in several localities in Sumner County but, at present, their stratigraphic position in the formation is unknown. Neither lithology nor fauna have served to place these higher concretion layers in the section. The lithology of all the concretions above the *D. micropolli* layer is fairly uniform; and, at almost every locality collected, the fauna is different so that concretions will have to be found in vertical sequence before their relationships can be deciphered.

Thickness of the Fox Hills in Sumner County is questionable. Fisher (1952, p. 16) reports a thickness of 325 feet in the southwest corner of the county, an area in which the formation has been eroded away above the lower Fox Hills, and 196 feet in the vicinity of Linton, where the Fox Hills-Hell Creek contact is not exposed within a radius of 10 miles. Hence, both of these thicknesses, although called "measured sections" by Fisher, should probably be considered estimates. In T. 131 N., R. 78 W., both the Fox Hills-Hell Creek contact and a concretion layer in what appears to be lowermost Fox Hills are exposed. The upper contact, exposed at two localities with a horizontal separation of 1½ miles, shows vertical relief of 120 feet, probably due to pre-Hell Creek erosion. Total thickness of the formation, in this township may be as little as 260 feet or as much as 388 feet. These figures, obtained with a Paulin altimeter, have not been adjusted for structure as no reliable structural datum exists in the area.
The conflict between the two HLLITE position and the operative HLLITE
Fig. 5. Stratigraphic section of the Fox Hills Formation in Sumne County. The data was obtained from measured sections and represents as complete a section as can be pieced together in the county.
PABRONTOLOGY

Occurrence.—As discussed above, fossils in the lower Fox Hills in

Ravens County are restricted almost exclusively to concretions. Fifteen

localities were discovered in which pelocypod bearing concretions occurred

in place. The only pelocypod that was commonly encountered free in the

matrix was *Igyrycia americana*. Fragments of this animal were collected

at numerous localities throughout the county.

The most difficult feature of fossil occurrence is the presence of

highly fossiliferous concretions, predominately calcareous, in a sparsely

fossiliferous, non-calcareous matrix. Several alternative explanations

are possible. High concentrations of animals could have, upon death,

acted as centers about which more calcium carbonate was deposited.

This does not, however, explain those concretions in which no trace of

fossil material is found. Another possibility is that the only animals

that were preserved were those about which limestone was deposited.

In other words, those animal masses that, for one reason or another, did

not act as centers of carbonate deposition were subsequently leached out

of the matrix. This theory is weakened by the presence of unfossiliferous

concretions as well as the presence of excellently preserved fragments

of *Igyrycia americana* which show no evidence of leaching.

A third, and much more plausible, explanation is that the masses

formed in a manner similar to that described by Craben (1960, p. 711-712)

for the origin of "clay boulders." Craben describes this process in

action in the modern day along the coast of Scotland where fragments

of glacial clay are broken from cliffs, rolled about by waves, and
finally deposited in a more stable environment. During the process, pebbles of foreign material are incorporated into the rolling mass. Walther (1872, p. 237) and Præss (1872, p. 277) describe a similar process in which fine-grained material deposited along the Red Sea during high tide was dried, fragmented and later rolled about. The resulting structure was similar to that described by Graham in Scotland.

This description adequately explains the nature of Fox Hills concretions. Lithologically, they are composed of a dense, structureless limestone core that may or may not contain fossils. Surrounding the core is a "jacket" of partially cemented medium sand with a composition similar to that of the matrix. Occasionally the fossils in the concretions show evidence of having been transported while in the concretion. Edges of shells near the periphery of the structure are often worn and broken while those in the interior show no signs of attrition.

It is probable, then, that these concretions formed at, or very near, the strand line of the Fox Hills sea by wave agitation. As they were rolled about, some of them incorporated animals. Eventually they rolled out of the area of formation into an environment of low enough energy that they could come to rest.

Whether the site of deposition was near or far from the area of formation cannot be demonstrated at this time. It is also difficult to state conclusively that the original mud forming the concretion was as highly calcareous as the masses are at present; although, if the carbonate was secondary, limestone deposition as cement in the matrix material might be expected. If the limestone was primary, the term
Concretion (in the strict sense) is perhaps inappropriate; however, before they are referred to as concretions a thorough petrographic study should be made.

Collection and processing.—Bulk collections of concretions were made only after field work had progressed to the point that some evaluation of stratigraphic position could be made. Prior to making the collections I visited the type area of the Fox Hills Formation where, under the leadership of Dr. L. H. Waage, the layers as noted by Morgan and Fetch (1945) and described by Waage (1961) were examined. Lack of Pleistocene cover made tracing the layers in the type area easier. The fossil fauna in the type area is apparently much like that noted in Johnson County.

Collections were made in Johnson County and notes on lithology of the concretions and matrix were taken; they have so far yielded no clue as to the exact stratigraphic position of the various layers. Some of the nodes were broken in the field; however, it was noted that many specimens were destroyed in the process. Most of the material was brought back as bulk samples to be processed in the laboratory.

Several techniques were tested to extract the fossils from the enclosing stone without destroying specimens. None was wholly successful. Having tried an acid bath, dental drill, and ultrasonic cleaner, it was concluded that patient work with a small hammer and chisel was most efficient although many specimens were lost in the process. Once the specimens were removed from the concretions a dental drill and an ultrasonic bath were used to further clean the specimens in preparation for study and photography. Specimens to be photographed were whitened with ammonium chloride vapor.
Localities.—Fifteen localities provided specimens for the present study, each of which represents only one stratigraphic horizon. To reduce repetition in the systematic descriptions, the localities are listed below, with an index number that will be repeated in the description of each species.

3-0-1. Trail City (?) lithology in road cut, east side of road, SW¼, Sec. 7, T. 129 N., R. 78 W., Summons County, North Dakota.

3-0-2. Trail City (?) lithology on top of hill overlooking new road, NE¼, Sec. 15, T. 129 N., R. 78 W., Summons County, North Dakota.

3-0-3. Trail City (?) lithology in road cut on east side of road, NE¼, Sec. 33, T. 130 N., R. 78 W., Summons County, North Dakota.

3-0-4. Trail City (?) lithology at base of road cut, SW¼, NE¼, Sec. 3, T. 130 N., R. 78 W., Summons County, North Dakota. This locality is about 20-25 feet higher stratigraphically than locality 3-0-2.

3-0-7A. Trail City (?) lithology at same locality as described for 3-0-7. The concretions at this locality occur about five feet higher than those described from locality 3-0-7.

3-1-2. Trail City (?) lithology in road cut, east side of road, NE¼, Sec. 12, T. 131 N., R. 78 W., Summons County, North Dakota.

3-1-3. Timber Lake (?) lithology at top of small stream valley, tributary to Little Beaver Creek, NE¼, Sec. 7, T. 131 N., R. 78 W., Summons County, North Dakota. At this locality the concretions were ferruginous rather than calcareous.

7-3-7. Trail City (?) lithology in ditch, north side of road at corner where road turns north, SE Cor., Sec. 27, T. 133 N., R. 77 W., Summons County, North Dakota.
7-4-2. Timber Lake (?) lithology in ditch, north side of road, 34, SW1, Sec. 35, T. 134 N., R. 77 W., Sessions County, North Dakota.

7-4-1. Trail City (?) lithology, 34, Sec. 2, T. 129 N., R. 76 W., Sessions County, North Dakota.

6-2-3. Lower concretion layer at base of Fox Hills, Trail City (?) lithology, 34, Sec. 17, T. 132 N., R. 76 W., Seeman Park, SW of Linton, Sessions County, North Dakota.

6-2-9. Trail City (?) lithology about 10-15 feet above base of Fox Hills Formation, at top of hill at east edge of dump grounds SW of Linton, 34, Sec. 6, T. 132 N., R. 76 W., Sessions County, North Dakota.

6-2-13. Second concretion layer, approximately 15 feet above base of Fox Hills Formation, Trail City (?) lithology, 34, Sec. 17, T. 132 N., R. 76 W., Seeman Park, SE of Linton, Sessions County, North Dakota.

6-3-6. Timber Lake (?) lithology in road cut, east side of road, 34, Sec. 27, T. 133 N., R. 76 W., Sessions County, North Dakota.

Measurements.—Each of the species descriptions is followed by a series of measurements which, where applicable, include length, height, thickness, and hinge length. All dimensions are taken to be maximum along the given axis. Length is herein defined as the greatest length measured parallel to the hinge line or the hinge extremities if the hinge is curved. Height is the greatest height measured in the plane of commissure, perpendicular to the hinge line. Thickness is the greatest thickness measured perpendicular to the other two axes. Measurements of thickness are, except where otherwise stated, measured across both valves. Hinge length is a straight line distance between the extremities of the hinge. The only other measurement used herein is
giant height which is the distance from the beak to the farthest point of the posterior border.

**Paleontology.**—The fossils from the Fox Hills Formation indicate that at the time of burial the area in question was the site of a cool, shallow sea. The strand line probably lay a short distance east of Fannin County.

That the environment was marine is readily demonstrated by the abundance of cephalopods and gastropods in the fauna. Water depth and temperature are a bit more vague. If the Navarro Group is time correlative with the Fox Hills Formation, a comparison of faunas can be made that indicates cool water. Two general lines of evidence are available. Bergman's Rule (Allan, et al., 1949, p. 119) states that shelled invertebrates tend to be larger in warmer water. Although this is an empirical rule it is probably true generally. Visual, non-quantitative inspection of the fauna of the Navarro Group as illustrated by Stephenson (1941) indicates that the plesacypods and gastropods from his study are generally larger than those in the Fox Hills Formation. Secondly, it has been observed (Lockman, 1957, p. 154) that larger numbers of genera and species inhabit warm temperate and tropical water than cooler water. The Macatoch Sand, a unit in the Navarro Group which is similar, lithologically, to the Fox Hills, contains 135 species of Pseudopoda while only 25 species were noted by the writer from the Fox Hills Formation. These two bits of evidence are further fortified by the observation (Mirkland, 1962, oral communication) that the acanthite fauna of the Fox Hills is quite similar to that of Greenland while it is distinct from that of the Gulf Coast.
Water depth may be deduced from the type of sediments as well as
one member of the fauna, Halocyathus major. When Halocyathus was named
by Lesquereux, it was considered an algae, an interpretation that has
persisted until work by Hayasaka (1935) pointed out their similarity
to Recent neritic decapod crustacean burrows. H. major occurs in the
form of anastomosing tubes composed of medium to coarse-grained sand
grains cemented by limonite. They are more resistant to erosion than
the matrix material and are often found nearly covering an outcrop.
Their surface is lumpy suggesting that they were formed as a number
of discrete spheroidal masses. As discussed in the section on Fox
Hills stratigraphy, the formation is composed primarily of cross-bedded
sand and sandstone. This type of sedimentation would not be expected
if the sediments were deposited below wave base. The presence of
Halocyathus is even more restrictive. Recent decapod burrows have been
observed (Hayasaka, 1935) that open at the surface as much as 40 cm.
above sea level. If this was the case in the Cretaceous form, they
offer an excellent index to the position of the strand line at the time
of their formation. As indicated above, concretions were probably
being deposited a short distance offshore.

The gross structural picture of the Fox Hills Formation has not
been thoroughly worked out; however, it appears to represent the shore-
line and nearshore facies of the retreating Cretaceous seaway. Further
work with the Pierre, Fox Hills, Wall Creek, and Cannonball Formations and
their stratigraphic relationships is necessary before a final statement
can be made in this regard.
CONCLUSIONS

On the basis of the work thus far completed on the Fox Hills Formation, several conclusions can be drawn:

1. To maintain a consistent usage of the definition of the contact between the Pierre and Fox Hills Formations from the type area in South Dakota to Eddy County, North Dakota, the contact should be placed at the first occurrence of jasperite below the lowest concretion layer.

2. The concretion layers, as defined by Wages (1961) in the type area, cannot definitely be placed in stratigraphic sequence in Eddy County at this time due to difficulties in tracing stratigraphic horizons.

3. Thickness of the Fox Hills Formation in Eddy County is 250-350 feet, where measurable.

4. Lower Fox Hills concretions were probably formed as "bad balls" in a relatively high energy environment and were transported to their site of deposition, a lower energy environment.

5. The Fox Hills Formation probably represents the shoreline and nearshore facies of the retreating Midcontinent Cretaceous seaway.

6. Due to northward coarsening of the lower Fox Hills sediments, it is impossible in many cases to distinguish between the Trail City and Homer Lake Member lithologies in Eddy County. At this time, therefore, it seems best to divide the formation in Eddy County into upper and lower parts and to avoid using member terminology in the strict sense.

7. Twenty-two species of paleojeods were collected and described from the Fox Hills Formation in Eddy County. Gastropods, cephalopods, and scaphopods were also collected but were not described.
3. Future work on the Fox Hills Formation in North Dakota should include tracing the formation into adjacent areas, attempting to trace the members from the type area in South Dakota into North Dakota, and identifying and studying the remainder of the rich molluscan fauna. Such work would shed considerable light on the history of deposition and on the paleoecology of the unit.
The paleoypea described herein were identified using Reek (1876) as a basic reference. Stephenson (1923, 1941) and Richards (1953, 1962) were also frequently consulted. Names of taxa above the family level are those of Rhiele (1935) while family assignments are those of Stephenson (1941) and Richards (1953). No new names are proposed in this work.

In general, the descriptions of species in Reek (1876) are quoted. Many of the animals covered in this work have not been considered from a taxonomic standpoint since that time; in all cases his descriptions are both modern and succinct. Additional information concerning description and occurrence of the specimens collected in Monroe County is given in the discussion following each description.
Phylum MOLLUSCA
Class PULMONATA
Order TAGEONTA
Superfamily NUCULACEA
Family NUCULIDAE
Genus Nucula Lamarek 1799

Nucula plantarcrinata Neek and Hayden 1856
Plate 1  Figures 4-5


Nucula plantarcrinata Neek and Hayden, Neek, 1876, U. S. Geol. Survey Terr., v. 9, p. 101, pl. 15, fig. 3.


Nucula plantarcrinata Neek and Worthen, Shimer and Shrock, 1944, p. 375, pl. 145, fig. 35.

Neek (1876, p. 101) described the species thus:

Shell transversely subovate or subelliptic, compressed; posterior or shorter side obliquely truncated above, and abruptly rounded or subangular below the middle; anterior or longer side cuneate and rather narrowly rounded; base forming a regular semi-elliptical curve, not crenate within; dorsum declining gently with a gradual convex curve, from near the beaks to the anterior extremity; beaks small, incurved, nearly contiguous, and located about half way between the middle and the posterior side; surface marked by very fine, irregular, radiating, and minute concentric striæ; hinge forming at the beaks an angle of about 110°, having in the adult some twenty-six or twenty-seven denticles on the longer or anterior side of the beaks, and about ten behind, in each valve; lunule-like area behind the beaks lanceolate, flattened along each side, and a little convex in the middle.

Discussion. Individuals of this species were found at only one locality. One of the three specimens collected was found free in the matrix
while the other two were extracted from a concretion. Shell material was present only on the isolated specimen; however, both shell and mold of the interior displayed the characteristic features of the species including smooth ventral margin. Near the anterior margin, where the outer layer of shell material has been eroded away, concentric striæ are visible on one of the inner laminae. These striations are not expressed on the inner or the outer surface of the valve.

**Measurements.**—The figured specimen, right valve only, had the following measurements:

<table>
<thead>
<tr>
<th>UNM Cat. No.</th>
<th>Length (mm)</th>
<th>Height (mm)</th>
<th>Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9202</td>
<td>20.0</td>
<td>16.9</td>
<td>9.2</td>
</tr>
</tbody>
</table>

**Locality.**—Locality 4542; Trail City, (?) lithology in the lower Fox Hills Formation.

*Enalia cancellata* Week and Hayden 1956

Plate 1  Figures 31-33


*Enalia cancellata* Week and Hayden, 1956, U. S. Geol. Survey Terr., v. 9, p. 102, pl. 20, fig. 13.

*Enalia* (Zeitingsula) *cancellata* Week and Hayden, Shiner and Shrock, 1944, p. 375, pl. 145, fig. 76.

Week (1956, p. 102) described the species thus:

*Shell transversely ovaæ-subtrigonal, rather gibbous; posterior or shorter side obliquely truncated above, and subangular below, the middle; anterior or longer side a little...*
more rounded at the extremity; basal margin semi-elliptical or semi-ovate in outline, nearly ovoid in outline; dorsum declining with a gently convex outline in front of the beaks, and sloping more abruptly behind; lunule-like area behind the beaks oblique, flattened, or a little concave, and bounded on each side by a very slight ridge; escutcheon-like area in front of the beaks lance-ovate and moderately well defined; beaks rather gibbous, incurved, nearly touching, and located a little nearer the middle than the posterior side; surface marked by numerous small, regular, simple, radiating striae, which are broader than the linear depressions between, near the lower border, and crossed on all parts of the valves by smaller, more irregular, concentric costae, so as to form a neat sub-cancellate style of sculpturing; hinge thick, forming an angle of near 120° at the beaks, and provided with about seventeen to nineteen teeth in front, and about twelve behind the beaks, in each valve of an adult.

Discussion.—This species is readily distinguished from H. planispina in that the former has a finely serrate ventral margin and tends to be more elongate. It is most closely related (Meck, 1876, p. 102) to H. rectinata which has larger costae and a deeper lunule than H. cancellata. This similarity with H. rectinata probably explains the assignment by Shimer and Shrock (1943, p. 375) of H. cancellata to the subgenus Rectinata Can. 1939 (Geol. Pal. Abh., 3.3., v. 18, no. 1, p. 112, non lecto).

Measurements.—The figured specimen, a mold of the interior, has the following measurements:

<table>
<thead>
<tr>
<th>UND Cat. No.</th>
<th>Length (mm)</th>
<th>Height (mm)</th>
<th>Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9203</td>
<td>17.3</td>
<td>12.5</td>
<td>10.2</td>
</tr>
</tbody>
</table>

Hypotypes.—Univ. of N. Dak. Cat. Nos. 9203 and 9204 (figured hypotypes), 9262-9263 (4 unfigured specimens).

Localities.—2-1-2 and 2-9-4. Trail City (?). Lithology in the lower Fox Hills Formation.
Family MUCULINIDAE

Genus Koldia Meekler 1892

Koldia scitula (Meek and Hayden) 1896

Plate 1  Figures 6-11


*Koldia scitula* (Meek and Hayden), Meek, 1876, U. S. Geol. Survey Terr., p. 118, pl. 26, fig. 9.

*Koldia scitula* (Meek and Hayden), Stanton, 1920, U. S. Geol. Survey, Prof. Paper 128, p. 21, pl. 1, fig. 9-13.

*Koldia scitula* (Meek and Hayden), Shimer and Shrock, 1944, p. 379, pl. 144, fig. 42.

Meek (1876, p. 110) described the species thus:

"Shell transversely subovate, gibbous in the central and umbonal regions; anterior extremity rather narrowly rounded; posterior side narrower and more compressed, subangular or very narrowly rounded in outline, the most prominent part being above the middle; base forming a semicircular curve, sometimes very slightly sinuous near the middle; dorsum declining from the beaks; cardinal border of each valve having a distinct marginal groove behind the beaks, which forms, when the valves are united, a lanceolate, ascension-like depression; beaks rather obtuse, not oblique, placed a little in advance of the middle; surface marked by regular, fine, distinct, concentric lines, which are nearly equal to the grooves between, and more strongly defined on the middle than toward the extremities of the valves."
Discussion.—The specimens collected in the present study resemble those described by Geik that there is no doubt that they are members of the same species. At locality 8-9, several small concretions were collected that contained vast numbers of this species, almost to the exclusion of other species. Their preservation in the limestone masses made extraction difficult; but, several excellent specimens of articulated valves and molds of the interior were obtained. In other localities in the county they occur as minor constituents of the fauna.

Measurements.—The figured specimens have the following measurements:

<table>
<thead>
<tr>
<th>UMD Cat. No.</th>
<th>Length (mm)</th>
<th>Height (mm)</th>
<th>Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9205</td>
<td>8.4</td>
<td>4.4</td>
<td>4.0</td>
</tr>
<tr>
<td>9206</td>
<td>7.5</td>
<td>5.0</td>
<td>3.0</td>
</tr>
<tr>
<td>9207</td>
<td>8.7</td>
<td>4.0</td>
<td>4.0</td>
</tr>
</tbody>
</table>

Hypotypes.—Univ. of M. Dak. Cat. No. 9205-9207 (figured hypotypes), 9204-9207 (unfigured specimens).

Localities.—8-9, 9-1-3, 7-3-7, and 8-1-2. Timber Lake (?) and Trail City (?) lithology in the Lower Fox Hills Formation.

Genus *Muculana* Loven 1907

*Muculana hirsutata* (Meek and Hayden) 1961

Plate 1 Figure 12


*Muculana hirsutata* (Meek and Hayden), Meek, 1964, Smithsonian checklist Cretaceous Foss. N. Am., 3 [Side Meek, 1976, p. 1047].

*Muculana hirsutata* (Meek and Hayden), Meek, 1976, U. S. Geol. Survey TERR., v. 9, p. 104, pl. 15, fig. 4.
Appendix 1

The following question was followed up by the following question:

How many times has the question been asked?

In the present study, the question was asked of the participants in the general orientation of the orientation module. The results indicate that the participants were asked on average 3.0 times.

The appendix provides information on the frequency of questions asked during the orientation module, including a detailed breakdown of the number of times each question was asked. This information is critical for understanding the effectiveness of the orientation module and the level of engagement among the participants.
All other specimens of this species are broken, some to the point that their generic assignment is in question. They were not measured.

**Locality.**—Univ. of N. Dak. Cat. No. 9212 (figured hypotype), 9268-9269 (unfigured specimens).

**Locality.**—3-1-2. Trail City (?), lithology in the lower Fox Hills Formation.

**Superfamily** ARCACEA

**Family** CUCULLAZIDAE

**Genus** Cucullaea Lamarck 1804

*Cucullaea* *shumardi* Meek and Hayden 1936

*Plate 1* Figures 29-30


*Cucullaea (Idonea) shumardi* (Meek and Hayden), Meek, 1924, v. 3.

Geol. Survey Terr., v. 9, p. 36, pl. 28, Fig. 15, pl. 39, fig. 4.

*Cucullaea shumardi* (Meek and Hayden), Stanton, 1920, v. 3. Geol. Survey, Prof. Paper 128, p. 22, pl. 2, fig. 1.

*Cucullaea shumardi* (Meek and Hayden), Morgan and Patch, 1945, S. Dak.


*Cucullaea shumardi* (Meek and Hayden), Fisher, 1952, S. Dak. Geol. Survey, Bull. 26, pl. 6, fig. 5.
Keen (1876, p. 36) gives the following description of the species:

Shell transversely subcircular, very slightly inequivalve, entirely closed, rather thin; anterior margin rounded, sometimes intersecting the hinge above so as to form an obtuse angle, rounding more or less obliquely into the base below; basal margin semi-ovate in outline, the most prominent part being behind the middle, not crenulate within; posterior side obliquely truncated above, and narrowly rounded below; hinge less than three-fourths the entire length of the shell; cardinal area rather narrow, marked by very fine longitudinal striae, and about four strong, oblique, diverging grooves; beaks gibbous, moderately elevated, incurved nearly at right angles to the cardinal line, and located slightly in advance of the middle. Surface marked by concentric striae, which are crossed on young shells by small, obscure, radiating costae, which become nearly or quite obsolete on adult specimens.

Discussion.—Considerable difficulty was encountered in distinguishing between S. shumardi and the related species S. nebrascensis Owen. Keen (1876, p. 39) points out that the latter can be "readily distinguished on its longer hinge area, thicker shell, and more oblique form." Making separations on the three characters independently, however, invariably led to different groupings. Hinge characteristics were most carefully studied and in none of the specimens were as few as four diverging grooves, mentioned by Keen as typical of S. shumardi, found. Nor were any specimens found which had eight or more divergences, typical of S. nebrascensis.

Length, thickness, slant length, and hinge length were measured on all 24 specimens of the genus collected from locality 3-3-2 to test shape. To minimise the effect of size, ratios of length versus hinge length and length versus slant length were computed and coefficients of variability were calculated for the two ratios. A value of $V = 29.4$ was obtained for the ratio of length to hinge length while the ratio of length to slant length resulted in a $V$ of $4.21$. The latter value is an
expected variability for a homogenous group, indicating that if there were two species present the character analysed would not distinguish between them. The value obtained from the ratio of length to hinge length indicates either that the character analysed is too variable to be of taxonomic value or that the sample is not homogenous. A frequency histogram of the ratios showed no natural break; therefore, I conclude that if there is a significant shape difference between the two species in question more than twenty-four specimens would be required to test it. As the shape of the hinge and the general outline more closely approximate C. rhombea than C. nebrascensis the specimens are referred to the former species.

**Measurements.**—Mean values of the length and thickness of the specimens collected at locality 3-0-2 were computed. Mean length of twenty-six specimens was 40.4 millimeters while mean thickness of twenty-one specimens was 31.3 millimeters. Height could not be measured in most cases as a result of breakage, especially in the area of the beaks. The figured specimens have the following measurements:

<table>
<thead>
<tr>
<th>UNM Cat. No.</th>
<th>Length (mm)</th>
<th>Height (mm)</th>
<th>Thickness (mm)</th>
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</thead>
<tbody>
<tr>
<td>9208</td>
<td>46.2</td>
<td>39.5</td>
<td>35.6</td>
</tr>
<tr>
<td>Mold of the interior</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9209</td>
<td>48.3</td>
<td>39.4</td>
<td>35.9</td>
</tr>
<tr>
<td>Mold of the interior</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9210</td>
<td>45.3</td>
<td>38.0</td>
<td></td>
</tr>
<tr>
<td>9211</td>
<td>39.6</td>
<td>34.9</td>
<td>34.3</td>
</tr>
</tbody>
</table>
**Hypopora**.—Univ. of N. Dak. Cat. Nos. 9208-9211 (figured hypotypes)
9270 (measured series), 9271-9274 (unfigured specimens).

**Localities.**—3-0-2, 3-1-2, and 3-0-7. Trail City (?) lithology in
the lower Fox Hills Formation.

**Family GRAMMATODONTIDAE**

**Genus Hexodon** Conrad 1869

**Hexodon sulcatus** (Evans and Shumard) 1857

Plate 1  Figures 1-3

**Arca sulcata** Evans and Shumard, 1857, Acad. Sci. St. Louis, Trans.,
v. 1, p. 39.

**Hexodon sulcatus** (Evans and Shumard), U. S. Geol. Survey
Terr., v. 9, p. 32, pl. 15, fig. 6.

**Hexodon sulcatus** (Evans and Shumard), Shimer and Shrock, 1945, p. 279,
pl. 136, fig. 43.

**Week (1876, p. 92-93) described the species as follows:**

Shell small, transversely rhombic-trapezoidal, about half as
high as long; beaks rather depressed, and placed a little in ad-
vance of the middle, incurved and somewhat distant; posterior
umbonal slope oblique, prominent or sub-angular; cardinal
margin straight, equaling about five-sixths the length of the
valves; basal margin parallel to the dorsal, nearly straight,
or more or less sinuous near the middle; anterior margin rounding
up a little obliquely, so as to intersect the hinge above at
slightly less than a right angle; posterior margin truncated
from the abruptly-rounded or subangular posterior basal
extremity, a little obliquely forward and upward, with a
slightly sinuous outline, so as to connect with the end of the
hinge at rather more than a right angle; cardinal area unknown;
free margin finely eroded within; internal casts showing a
broad, deep sulcus starting from each beak, and descending,
with a slight backward obliquity to the most sinuous part of
the base. Surface with radiating striae.

**Discussion.**—The description and the illustration in Week will
characterize the specimens collected in this study, as does a description
by Julie Gardner (wade, 1926, p. 42) in a discussion of Nannofusculina (dabb) 1960, a name that has been widely applied to specimens from the Gulf Coast and the Eastern Seaboard (Stephenson, 1941, p. 33; Richards, 1958, p. 70). The specimens collected in this study are molds of the interior and on only one specimen is any shell material preserved. This is unfortunate because Evans and Shumard (Wade, 1976, p. 83) describe the prosopon of J. sulcata as consisting of "... 16 to 20 radiating striae, with accessory ones in the intervals," while J. fusculina has prosopon of 30-50 radial threadlets (Wade, 1926, p. 42). Not enough shell material is present on any of the specimens to make a definite distinction between the two types, but if the density of striae seen on the fragment was to persist across the shell, the number of striae would greatly exceed 20. Until good shell material is discovered the specimens might well be assigned either to J. sulcata or J. fusculina with equal propriety. They are here assigned to the former species on geographic, not biologic grounds.

Measurements.—The figured specimens have the following measurements:

<table>
<thead>
<tr>
<th>UND Cat. No.</th>
<th>Length (cm)</th>
<th>Height (cm)</th>
<th>Thickness (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9200</td>
<td>12.3</td>
<td>7.9</td>
<td>5.2</td>
</tr>
<tr>
<td>9201</td>
<td>11.0</td>
<td>6.5</td>
<td>5.0</td>
</tr>
</tbody>
</table>

Thickness measured on specimen No. 9201 includes the shell material attached to the mold. With this exception, all measurements are of molds of the interior.

Specimens.—Univ. of M. Dak. Cat. Nos. 9200 and 9201 (figured specimens), 9275 (2 unfigured specimens).
Locality.—6-2-3. Trail City (?) lithology in the lower Fox Hills Formation.

Family LIMOSIDAE

Genus Limonia Sassi 1927

Limonia carvala (Meek and Hayden) 1926

Plate 2  Figures 33-39


Limonia carvala (Meek and Hayden), Meek, 1976, U. S. Geol. Survey, Terr., v. 9, p. 77, pl. 23, fig. 17.

Meek (1926, p. 77) gave the following description of the species.

Shell very small, obliquely rhombo-cuboidal, moderately compressed; anterior side rounded, usually a little more prominent above than below, base forming a rather broad curve, sometimes nearly straight in the middle; posterior side obliquely truncated above, and more or less narrowsly rounded below; paliial margin faintly crenulate within; hinge somewhat arched on the inside, generally equalling nearly half the length of the shell, and provided with three or four teeth on each side of the small triangular pit for the reception of the ligament; cardinal area small but well defined; beaks moderately elevated, pointed, and incurved at right angles to the hinge, located slightly in advance of the middle. Surface marked by fine lines and occasional stronger marks of growth, crossed by exceedingly obscure, fine radiating, subrugulate striae, which are usually nearly or quite obsolete on the anterior part of the shell.

Discussion.—Although this species is extremely common in the type area of the Fox Hills (Wange, oral communication), Seaman Park was the only locality in Toombs County from which specimens were collected. At this locality they did not comprise a large part of the fauna as they do
in the type area, but were vastly outnumbered by another small paelocyoid, *Poteardia subculus* which is distinguished from *Le. parvula* on the presence of a renulate posterior margin. The specimens identified as *Le. parvula* diverge from Mook's description only in regard to size. Mook (1976, p. 97) stated that typical specimens are about .25 inches long while those found at Seaman Park range in size one-third to two-thirds inch long.

**Measurements.**—The specimen illustrated has the following dimensions:

<table>
<thead>
<tr>
<th>UNM Cat. No.</th>
<th>Length (mm)</th>
<th>Height (mm)</th>
<th>Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9213</td>
<td>9.5</td>
<td>3.4</td>
<td>5.0</td>
</tr>
</tbody>
</table>

**Occurrence.**—Univ. of U. S. Cat. No. 9213 (figured specimen), 7276 (17 unfigured specimens).

**Locality.**—S-2-14, Trail City (?) lithology in the lower Fox Hills Formation.

Order ANICONTARIA

Superfamily MYTILOCERA

Family MYTILIDAE

Genus Veligella Scopoli 1777

- Veligella calaminaria (Evans and Shumard) 1854

Plate 1, Figures 14-16


Volcella calcinulana (Ewans and Shumard), Meek, 1876, U. S. Geol. Survey Terr., v. 9, p. 73, pl. 23, fig. 7.

Ewans and Shumard (1874, p. 164) described the species thus:

Shell sub-ovate, aruncate, inflated, surface smooth, or marked only by five indistinct concentric lines of growth; umbones prominent, rounded, anterior side short; beaks nearly terminal, muscular impression small, placed near the anterior extremity; posterior side broad, extremity rounded.

Meek (1876, p. 72) added further to this description.

Shell transversely aruncate-subovate, gibbose along the umbonal slopes, and cuneate posteriorly; surface marked only with five concentric striae; anterior end very short; beaks very oblique, placed over the anterior margin, and somewhat compressed; hinge-marginal a little straightened for near half the length of the valves, and rounding off imperceptibly into the posterior margin, which curves obliquely to the narrowly-rounded posterior basal extremity; basal margin strongly aruncate along the middle, near which the flanks are compressed and contracted below the umbonal ridge; anterior muscular impression distinct.

Discussion.—Members of this species were found at three localities; however, they are always a minor constituent of the fauna. Three of the four specimens collected conform nicely to the general outline described by Meek. The fourth specimen is more abruptly terminated posteriorly resulting in foreshortened version of the more normal individuals. In two of the specimens the posterior muscle scar is visible, though quite indistinct. It is aruncate in shape and occupies a position in the posterior-dorsal part of the valve. The anterior end of the scar narrows rapidly and terminates just posterior to the hinge.

Measurements.—The specimens illustrated have the following dimensions:

<table>
<thead>
<tr>
<th>Und Cat. No.</th>
<th>Length (mm)</th>
<th>Height (mm)</th>
<th>Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9214</td>
<td>33.0</td>
<td>22.6</td>
<td>9.2</td>
</tr>
<tr>
<td>9215</td>
<td>20.7</td>
<td>16.1</td>
<td>3.4</td>
</tr>
</tbody>
</table>

9277 (unfigured specimen).

Localities. — 69-1, 3-0-2, and 3-1-3. Trask City (1) and Timber Lake (1) lithologies in the lower Fox Hills Formation.

Genus Grevillea Brown 1827

Grevillea elegansula Meek and Hayden 1861

Plate 7 Figures 1-6


Grevillea elegansula Meek and Hayden, Meek, 1876, v. 3. Geol. Survey Terr., v. 3, p. 75, pl. 23, fig. 6.

Grevillea elegansula Meek and Hayden, Suller, 1907, New Jersey Geol. Survey Palaeont. Ser., v. 4, p. 511, pl. 56, fig. 6.


Grevillea elegansula Meek and Hayden, Shimer and Shrock, 1934, p. 512, pl. 154, figs. 20-21.


Grevillea elegansula Meek and Hayden, Richards, 1953, p. 156, pl. 23, fig. 10.

Meek's description of the species (1876, p. 75-76) was as follows:

Shell nearly vertically ovate-ovate, very thin, ventricose; posterior basal and basal margins rounded; dorsal slope abruptly behind, with a convex outline above, and rounding into the base below; anterior margin sinuous just under the beaks; moderately prominent near the middle, and rounding
into the base below; ventral region of both valves very gibbous; beaks prominent, anterior, or subterminal, pointed and incurved, with a forward obliquity at their extremities; hinge-margins thin and apparently smooth, or only very minutely serrate; surface marked by extremely fine regular, closely-arranged, radiating striae, which appear to increase chiefly by bifurcation, and continue of uniform size on all parts of the shell; crossing these, there are less regular, more distant, small, concentric marks of growth.

Discussion.—Specimens of this species were collected at only two localities, both in the vicinity of Linton. Stratigraphically they are found less than ten feet above the Pierre-Fox Hills contact. Those specimens found at locality 6-2-9 by Dr. F. K. Holland, Jr. occurred in an argillaceous lens in a shaley matrix while the single specimen collected from locality 6-2-14 was found in a concretion. The specimen from locality 6-2-14 had shell material preserved which shows the delicate nature of the proconch while the remainder of the specimens are molds of the interior.

Measurements.—The specimens measured are intended to represent the widest range of shape variation noted in the individuals assigned to this species.

<table>
<thead>
<tr>
<th>UNO, Cat. No.</th>
<th>Length (mm)</th>
<th>Height (mm)</th>
<th>Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9216</td>
<td>20.4</td>
<td>17.9</td>
<td></td>
</tr>
<tr>
<td>9217</td>
<td>14.3</td>
<td>16.0</td>
<td>12.3</td>
</tr>
<tr>
<td>9218</td>
<td>17.2</td>
<td>16.4</td>
<td>12.7</td>
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<tr>
<td>9219</td>
<td>15.4</td>
<td>16.1</td>
<td>19.5</td>
</tr>
<tr>
<td>9220</td>
<td>13.9</td>
<td>12.9</td>
<td>16.6</td>
</tr>
</tbody>
</table>

Remarks.—Univ. of M. Dak. Nos. 9216-9220 (figured specimens), 9276 (1) unfigured specimens.
Locality. — 6-2-9 and 6-2-14. Near the base of the Fox Hills Formation in Trail City (?) lithology.

Superfamily PTERIACEA

Family PTERIIDAE

Genus Pteria Scopoli 1777

Pteria lineusiformis (Evans and Shumard) 1854

Plate 1  Figures 17-20

*Atypa lineusiformis* Evans and Shumard, 1854, Proc., v. 7, p. 163.

Pteria lineusiformis (Evans and Shumard), Meek, 1854, Smithsonian check-list N. Am. Cretaceous fossils, p. 9 [Streel Meek, 1876, p. 32].

Pteria lineusiformis (Evans and Shumard), Meek, 1876, U. S. Geol. Survey Terr., v. 9, p. 32, pl. 15, fig. 1.

Pteria lineusiformis (Evans and Shumard), Whitfield, in Newton and Jenny, 1880, Geology and resources of the Black Hills of Dakota, p. 324, pl. 7, figs. 2-3 [Streel Stanton, 1920, p. 20].


Pteria petrosa (Conrad), Wellar, 1907, New Jersey Geol. Survey, Palaeontology, v. 4, p. 429 [Streel Stanton, 1920, p. 28].

Pteria lineusiformis (Evans and Shumard), Stanton, 1920, J. S. Geol. Survey, Prof. Paper 129, p. 26, pl. 3.

Pteria? lineusiformis (Evans and Shumard) ?, Stephenson, 1941, W. of Texas, Pub., 4101, p. 102, pl. 12, figs. 7-3.

Pteria lineusiformis (Evans and Shumard), Shimer and Shrock, 1944, p. 391, pl. 152, fig. 6.
Pteria lineataforma (Evans and Shumard), Morgan and Fetch, 1945, 3. Dak.

Geol. Survey, Rep. of Invest. 40, pl. 5, fig. 4, nos. 3 and 6.
pl. 6, fig. 1, no. 3.

Evans and Shumard (1894, p. 163) described the species thus:

Shell very oblique, elongated, linguiform, moderately convex; surface smooth; cardinal line straight, about equal to the greatest width of the shell; posterior wing triangular, acute, anterior wing triangular, separated from the body of the shell, by the continuation of a shallow groove which surrounds its most gibbous portion; posterior edge sigmoid, forming an obtuse angle with the cardinal line from the anterior extremity. The mould of the shell exhibits a line of small tubercles, commencing at the point of the beak and extending in a curve to the base of the posterior muscular impression; the latter is very large and somewhat reniform.

Discussion.—This is perhaps the most widespread and abundant fossil in the Fox Hills Formation in Crooks County. Although it varies considerably in outline, it is easily recognised even when fragmentary. The shell material tends to exfoliate readily so that most specimens consist of a mold of the interior with fragments of shell material attached. Need (1876, p. 32) misspelled the name of the species which has led to some confusion subsequently. There is considerable question as to whether P. lineataforma is a junior synonym of P. petrara (Conrad). Stanton (1926, p. 25) considered the problem and concluded that the type material of P. petrara was so imperfectly preserved that it is best to say that the two species are closely related but not synonymous. Richards (1958, p. 100) considered the two synonymous but, until comparison of the types is made, the common midwestern name will be maintained.
Measurements.—The specimens illustrated have the following dimensions:

<table>
<thead>
<tr>
<th>UNCat. No.</th>
<th>Length</th>
<th>Wing Length</th>
<th>Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>9221</td>
<td>25.3</td>
<td>21.0</td>
<td>22.3</td>
</tr>
<tr>
<td>9222</td>
<td>15.5</td>
<td>14.5</td>
<td>13.7</td>
</tr>
<tr>
<td>9223 left</td>
<td>24.2</td>
<td>24.2</td>
<td>21.3</td>
</tr>
<tr>
<td>valve</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9223 right</td>
<td>30.3</td>
<td>24.9</td>
<td>24.7</td>
</tr>
</tbody>
</table>

Hypotypes.—Univ. of N. Dak. Cat. Nos. 9221, 9222 (figured hypotypes), 9279, 9283 (unfigured specimens).

Localities.—3-1-3, 3-0-4, 3-1-2, 3-0-7, 3-0-2, and 5-2-14. The lower Fox Hills Formation in both Trail City (?) and Timber Lake (?) lithologies.

Phoria (Corytoma) nebrascana (Evans and Shumard) 1857

Plate 1 Figure 27

Articula nebrascana Evans and Shumard, 1857, St. Louis Acad. Sci., Trans., v. 1, p. 38.

Phoria nebrascana (Evans and Shumard), Meek, 1864, Smithsonian check-list Cretaceous fossils N. Am., p. 9 [side Meek, 1876, p. 34].

Phoria (Corytoma) nebrascana (Evans and Shumard), Meek, 1876, U. S. Geol. Survey Tech. v. 9, p. 34, pl. 20, fig. 11.

Phoria (Corytoma) nebrascana (Evans and Shumard), Shimer and Shrock, 1924, p. 391, pl. 152, fig. 5.

Meek (1876, p. 34) defined the species thus:

Shell small, rather compressed, obliquely oval exclusive of the wings, distinctly inequivalve, the left valve being more convex, with its ventral margin and posterior wing projecting apparently beyond those of the other; hinge generally, if not
always, less than the length of the valves. Left valve with anterior wing small, triangular, compressed, generally about rectangular or sometimes a little more obtusely angular, not defined by a marginal sinus, and apparently never quite as long as the margin below; posterior margin, decidedly longer than the other, but not as long as the posterior margin, compressed, gently angular at the extremity, and defined by a rather deep, broadly-rounded sinus; posterior basal margin rather narrowly rounded; basal margin forming a broad semicircular curve, being more prominent posteriorly, and rounding up obliquely anteriorly into the regularly-rounded front; beak moderately oblique, scarcely rising above the hinge margin, and placed about halfway between the middle and the anterior end of the same; surface ornamented by numerous small, threadlike, radiating lines, less at and near the free margins, than the breadth of the spaces between, in some of which latter a smaller line is often intercalated; very minute concentric striae are also to be seen on well-preserved specimens by the aid of a magnifier. Right valve with a broad compressed alation behind, that seems not to extend into a defined wing; posterior margin truncated and nearly or quite straight; anterior wing very small, and defined by the usual deep, sharply-cut byssal sinus of the subgenus Oxytoma; surface appearing nearly smooth, but when examined under a good magnifier, showing obscure traces of small, radiating costae, crossed by extremely fine, regular, crowded, concentric striae; beak more compressed than that of the other valve, and a little less prominent.

Discussion.—Although this is a widespread and common species, it is seldom well preserved. It commonly occurs as molds of the interior in ferruginous concretions from Niaber Lake (?) lithology; their extraction is nearly impossible. The general outline of P. nebrascana is far less variable than that of P. linguiformis and is distinguished from it by the radial striae and less oblique outline.

Measurements.—The figured specimen has the following dimensions:

<table>
<thead>
<tr>
<th>UNO Cat. No.</th>
<th>Length (mm)</th>
<th>Hinge Length (mm)</th>
<th>Height (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9224</td>
<td>14.5</td>
<td>11.6</td>
<td>11.1</td>
</tr>
</tbody>
</table>

Hypotype.—Univ. of N. Dak. Cat. No. 9224 (figured hypotype)

9237-9239 (unfigured specimens).
Localities:—3-1-3, 3-1-2, 6-2-14, and 7-3-7. Timber Lake (?) and Trail City (?) lithologies in the Lower Fox Hills Formation.

Family PEDALICHOIDEAE

Genus Gervilla Defrance 1920

Gervilla subtortuosa Meek and Hayden 1856

Plate 2 Figures 31–34


Gervilla subtortuosa Meek and Hayden, Meek, 1876, U. S. Geol. Survey Terr. v. 9, p. 65, pl. 16, fig. 7.

Gervilla subtortuosa Meek and Hayden, Shimer and Shrock, 1944, p. 389, pl. 150, fig. 20.


Meek (1876, p. 65) gave the following description of the species:

Shell thick, obliquely sublanseolate, tortuous, and laterally curved; right valve distinctly convex, left nearly flat; posterior side elongate, narrow, widest at its junction with the posterior extremity of the hinge; cardinal border straight, rather long, and forming an angle of about 20° with the longitudinal axis of the shell; cardinal area rather broad; carapace-pits about six, nearly as wide as the intervals between; hinge-teeth nearly obsolete; scar of the adductor and posterior pedal muscles large, obliquely elongate, and placed nearly centrally above the middle of each valve; anterior scar small, very deep, and located close under the anterior extremity of the hinge. Surface unknown.

Discussion.—Meek included two species, Gervilla subtortuosa and G. recta in the genus Gervilla as represented in the Midcontinent. They are distinguished on size, shell thickness, convexity and general outline. The individuals of the genus collected from the Limekiln-Gervilla
layer in Seeman Park conforms to the description of *G. substrictiss* in all respects except convexity. The specimens in the present study possess a nearly flat right valve and a convex left valve, characteristic of *G. patella*. However, the entire configuration of the shell is so irregular that it is probable that convexity as well as the other factors of shell shape are a function of environmental crowding. The specimens show no signs of deformation. This being the case, characters of the hinge and musculature are probably more accurate criteria of species recognition than shape. Meek's material was poorly preserved and no description of the exterior of the shell was possible. Shell exterior is preserved in specimen 9226 of the present study. The surface is generally smooth and is traversed only by slightly irregular, concentric growth lines, more crowded antero-ventrally than posteriorly which indicates that most of the growth of the animal tended toward posterior elongation.

**Measurements.**—None of the elements of the shells in the specimens illustrated is complete so that total measurements are impossible. As an indication of general size, however, specimen 9226 has a segment of hinge preserved that is approximately 53 mm long, while the preserved hinge on specimen 9227 is 47.5 mm long. If an extrapolation of shell outline is made similar to that of Meek (1876, pl. 16) total length would be in excess of 100 mm.

**Holotypes.**—Univ. of N. Dak. Cat. Nos. 9226 and 9227 (figured).

**Locality.**—6-2-14. Trail City (?) lithology in the lower Fox Hills Formation.
Superfamily OSTREACEA

Family OSTREIDAE

Genus Ostrea Linnaeus 1758

Ostrea sp.

Plate 1  Figure 13

Ness (1976, p. 10) gives the following generic description:

Shell irregular, laminated, subnacreous, attached by the left or under valve; surface sometimes nearly smooth, but more frequently provided with more or less prominent imbricating laminae and smaller marks of growth, or plicated, and very rarely armed with projecting root-like processes. Upper valve flat or concave, and often plane; lower valve convex, and having a prominent beak. Ligament occupying a medial longitudinal furrow, extending to the beaks in a kind of cardinal area marked by transverse striae. Muscular impression subcentral.

Discussion.—Oysters are apparently very rare in the lower Fox Hills of Ramsey County. Two specimens were discovered at locality 8-10 in a ferruginous concretion. Both were small but had the same general outline as that of the larger G. glabra of the upper Fox Hills. As the hinge and muscle impression on both specimens is obscured I can only refer them to the genus Ostrea.

Measurements.—The specimens illustrated are so irregular and incomplete that only the length of the long axis was measured. Specimen 9225A is 25.0 mm. long and specimen 9225B is 23.9 mm. long.

Ostrea.—Univ. of N. Dak. Cat. No. 9225.

Locality.—8-10. Timber Lake (?) lithology in the lower Fox Hills Formation.
Order BULIMELLIBRANCHIA
Superfamily LUCINACEA
Family TANGARIDAE
Genus Icestrea Lycett 1850

Icestrea americana (Meek and Hayden) 1856

Plate 2 - Figures 23-30

Icestrea americana (Meek and Hayden), Meek, 1876, J. S. Geol. Survey Terr., v. 9, p. 142, pl. 33, fig. 1.
Icestrea americana (Meek and Hayden), Shimer and Shrock, 1904, p. 423, pl. 168, fig. 20.

Meek (1876, p. 142–143) gave the following description of the species:

Shell thick, ovate-subtrigonal, moderately gibbous in the umbral region; posterior and broader than the other, obliquely truncated and gaping above, rather narrowly rounded or subangular below; anterior half narrow, compressed and presenting a more or less restricted aspect, subangular, or very narrowly rounded at the extremity; basal margin forming a broad semi-circular curve, being more prominent posteriorly and in the middle, than toward the front; dorsal border elevated in the region of the beaks, from which it slopes forward with a slightly convex outline, while it is convex just behind the beaks, then declining abruptly; beaks small, rather approximate, located a little behind the middle of the shell. Surface marked by fine lines of growth, and sometimes a few, faint, irregular, stronger, concentric furrows.

Discussion—The specimens found in this study and referred to this species fit the description above. They do not, however, have the same appearance as the specimen illustrated by Meek (1876, pl. 36, fig. 1) or Shimer and Shrock (1904, pl. 168, fig. 20), who repeated Meek's figure.
some of the figures shows the posterior gap as well developed as it is described or as it is seen on the specimen here discussed. To my knowledge the species has not been illustrated elsewhere.

This is one of only two species of plescyprid that was found free in the Timber Lake (?) matrix. At no time was a complete, unbroken specimen found; the figured specimen is the only complete specimen found in Kansas County. It was pieced together from several fragments.

Measurements.—The figured specimen, left valve only, has the following measurements:

<table>
<thead>
<tr>
<th>UNM Cat. No.</th>
<th>Length (mm)</th>
<th>Height (mm)</th>
<th>Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9223</td>
<td>49.0</td>
<td>35.0</td>
<td>12.9</td>
</tr>
</tbody>
</table>

Remarks.—Univ. of N. Dak. Cat. No. 9223.

Locality.—6-3-6, Timber Lake (?) lithology in the lower Fox Hills Formation.

Superfamily CARDIACEA

Family CARDIIDAE

Genus Protocardiidae (Heynich 1945)

Protocardiidae (Leptocardiida) subcardidae (Evans and Shumard) 1857

Plate 2  Figures 7-10


Sculina (Protocardiida?) subcardidae Evans and Shumard, Reck, 1869, Smithsonian check-list Cretaceous fossils, p. 79.

Protocardiidae (Leptocardiida) subcardidae (Evans and Shumard), Reck, 1876, U. S. Geol. Survey Terr., v. 9, p. 175, pl. 29, fig. 3.
**Protoceratia subquadrate** (Evans and Shumard), Shimer and Shrock, 1944, p. 425, pl. 169, figs. 14-15.

**Protoceratia subquadrate** (Evans and Shumard), Fisher, 1952, U.S. Geol. Survey, Bull. 26, p. 16, pl. 5, fig. 3.

Evans and Shumard (1857, p. 39) gave the following description of the species:

Shell small, subquadrate, length greater than the height, gibbous; anterior margin rounded, posterior margin truncated, very slightly arched; umboe prominent, large, obtusely subangulated; beaks nearly equal, rather obtuse, and extending but little beyond the cardinal margin; substance of the shell thin, surface with fine concentric striae of growth, waved and dentate posteriorly, where they are crossed by obscure longitudinal ribs.

**Discussion.**—Foss (1876, p. 175-176) described two species of *Protoceratia*, *P. subquadrate* and *P. rara*, which occur in the Fox Hills. They are distinguished on external shell characteristics including length, thickness and costation. As all of the specimens in the present study are molds of the interior, only the characteristics of the costae are applicable. The vast majority of specimens studied are more or less heavily costate on the posterior half of the animal. This is reflected in a crenulate posterior-ventral margin which makes them readily distinguishable from *Jasonida carolina*, another small pelecypod in the fauna. The specimens collected were subjected to bimetric analysis to determine any possible shape groupings. None were noted.

**Measurements.**—The figured specimens have the following dimensions:

<table>
<thead>
<tr>
<th>UM Cat. No.</th>
<th>Length (mm)</th>
<th>Height (mm)</th>
<th>Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9229</td>
<td>13.3</td>
<td>12.1</td>
<td>9.6</td>
</tr>
<tr>
<td>9230</td>
<td>16.5</td>
<td>14.6</td>
<td>9.7</td>
</tr>
</tbody>
</table>
Brookes.—Univ. of M. Dak. Cat. Nos. 9239 and 9230 (figured specimens), 9234-9235 (measured specimens), 9236-9339 (unfigured specimens).

Localities.—S-9-4, 7-3-7, S-0-71, S-2-14, S-0-7, S-0-2, and S-1-3.

Fisher Lake (?) and Trail City (?) lithologies of the lower Fox Hills Formation.

Superfamily VENERACEA

Family VENERIDAE

Genus Triannoncillaureau 1930

Triannoncillaureau dewyi (Meek and Hayden) 1856

Plate 1 Figures 21-22

Cathetera dewyi Meek and Hayden, 1856, Proceed. Acad. Nat. Sci.

Philadelphia, v. 8 p. 83.

Hermitia dewyi (Meek and Hayden), Meek and Hayden, 1866, Acad. Nat.

Sci. Philadelphia, Proc., v. 12, p. 133 [Check Meek, 1876, p. 182].

Callista dewyi (Meek and Hayden), Meek and Hayden, 1861, Acad. Nat. Sci.


Diama dewyi (Meek and Hayden), Meek, 1864, Smithsonian check-list N. Am.

Cretaceous fossils, p. 15.

Callista (Conodonta?) dewyi (Meek and Hayden), Meek, 1876, U. S. Geol.

Survey Terr., v. 9, p. 182, pl. 17, fig.

Callista (Oxymonas) dewyi (Meek and Hayden), Stanton, 1920, U. S.

Geol. Survey, Prof. Paper 128, p. 31, pl. 5, figs. 11-12.

Triannoncillaureau dewyi (Meek and Hayden), Shimer and Shrock, 1934, p. 427

pl. 179, figs. 6-7
(1876, p. 102) gave the following description of the species:

Shell subcircular, or very broad-suboval, rather thin, moderately convex; lateral margins rounded, the posterior side being a little broader than the other; dorsal slopeing gradually with a slightly convex outline behind the beaks, and concave and more abrupt in front; base semi-oval; esuthecal lanceolate; beaks not very prominent, somewhat gibbose, incurved, nearly touching, and placed a little in advance of the middle; muscular impressions shallow, anterior one narrow-oval, posterior one broad-oval; sins of the pallial impression broad, triangular, its sides converging at an angle of about 35°, extending obliquely forward and upward nearly to the middle of the valves, very slightly oblique at the immediate antevexit. Surface marked by fine, regular, prominent lines of growth.

Memoran---Only one specimen of this species was found. Since it is poorly preserved the only characteristics that could be used for identification were general shape, shell thickness, and prosopon. In these characteristics, it conforms strictly to the above description.

The Cretaceous forms of the genus (or subgenus) *Imminens* have been referred to the genus *Tricospallita* Sennec. They have a more trigonal outline, slightly different dentition, and a more pronounced pallial sinus than the Cenozoic forms that are retained in the genus *Imminens*. As no internal material is available, only outline can be used in making the assignment to *Tricospallita*.

**Measurements**---The figured specimen has the following dimensions:

<table>
<thead>
<tr>
<th>USD Cat. No.</th>
<th>Length (mm)</th>
<th>Height (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9371</td>
<td>19.2</td>
<td>16.9</td>
</tr>
</tbody>
</table>

**Exuviae**---Univ. of N. Dak. Cat. No. 9371.

**Locality**---3-0-7A, Trail City (7) lithology in the lower part of the Fox Hills Formation.
Superfamily MACRAGIN

Family MACRITIDAE

Genus Cambachora Cobb 1869

Cambachora varrenana (Meek and Hayden) 1856

Plate 2  Figures 35-37


Meek and Hayden, 1856. J. S. Geol. Survey Terr., v. 9, p. 205, pl. 30, fig. 7.

M. varrenana (Meek and Hayden), Shimer and Shrock, 1904, p. 531, pl. 171, Figs. 21-22.

M. varrenana (Meek and Hayden), Fisher, W. Dak. Geol. Survey, 1932, Bull. 16, pl. 6, figs. 1-3.

Meek gave the following description of the species:

Shell rather thin, subtrigonal, moderately gibbous; cardinal border sloping from the beaks in front and rear, at an angle of about 110°; posterior slope slightly more convex than the anterior; extremities subangular, the anal end being a little more obtuse than the other; base forming a broad, regular curve; beaks moderately elevated, incurved, and approximate, rather gibbous and nearly central; immae lanceo-oval, large, faintly impressed at the margins, and extending from the beaks nearly or quite to the anterior extremity; escutcheon having the same form, but still larger, and bounded on each side by a faint ridge, which passes from the beaks to the lower part of each side by a faint ridge, which passes from the beaks to the lower part of the anal border, to the outline of which it imparts a very slight angularity. Surface marked by faint, irregular lines of growth, which become more regular and distinct on the immae and escutcheon. Muscular impressions not very deep, the anterior one narrow-ovate, pointed above, and a little breached, the other ovate; sinus of the pallial impression moderate, and rounded at the extremity.

Discussion.—Specimens of this species were found at seven localities so that they are one of the dominant paleoypods in the Fox Hills
fauna. Preservation varied from fair in the Trail City (?) lithology to poor in Timber Lake (?) lithology. In most cases, only molds of the interior were preserved in the Timber Lake (?) lithology.

In general, the specimens showed very little variation in shape, but shell thickness was less constant. As described above, the shell was thin in all cases. It varied from a fraction of a millimeter thick to one millimeter. A complete series of intergrades are also present which indicates that shell thickness should not be used taxonomically except to say that it is generally thin.

Measurements.—The figured specimens have the following dimensions:

<table>
<thead>
<tr>
<th>UNM Cat. No.</th>
<th>Length (mm)</th>
<th>Height (mm)</th>
<th>Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9232</td>
<td>37.0</td>
<td>29.3</td>
<td></td>
</tr>
<tr>
<td>9233</td>
<td>34.7</td>
<td>29.0</td>
<td>20.2</td>
</tr>
<tr>
<td>9234</td>
<td>36.1</td>
<td>29.1</td>
<td>19.7</td>
</tr>
</tbody>
</table>

Examiners.—Univ. of N. Dak. Cat. Nos. 9232 (mold of interior), 9233 (mold of interior), (3th valves), 9235-9243 (51 unfigured specimens).

Localities.—8-9-1, 8-9-4, 3-3-2, 3-3-7, 8-1-2, 8-1-3, and 6-9-1. Trail City (?) and Timber Lake (?) lithologies in the lower Fox Hills Formation.
Superfamily TELLINACEA

Family TELLINIDAE

Genus Tellina Linnaeus 1758

Tellina articula Meek and Hayden 1856

Plate 2  Figures 15-17


Tellina (Turbonula?) articula Meek and Hayden, Meek, 1876, C. S. Geol. Survey Terr., v. 9, p. 197, pl. 30, fig. 1.

Tellina articula Meek and Hayden, Fisher, 1952, S. Dak. Geol. Survey, Bull. 16, pl. 5, fig. 2.

Meek (1876, p. 197) described the species thus:

Shell subelliptical, compressed, thin, a little curved laterally so as to make the left valve slightly more convex than the right; anterior side somewhat broader than the other, but rather narrowly rounded; base nearly straight, or forming a broad semi-elliptical curve; posterior side very obliquely subtruncate above, subangular at the extremity below, and with a moderately defined umbonal ridge in the right valve; dorsum declining almost equally before and behind, from the beak, which are small, compressed, and generally located slightly behind the middle; surface ornamented by fine, regular, equidistant, concentric striae; anterior muscular impression narrow-ovate, posterior broader; pallial line distinct, and provided with a nearly horizontal sinus, which extends beyond the middle of the valves, and is rounded at the extremity.

Discussion.—Several specimens of this common species were found; however, none were well preserved. The extreme thinness of the shell results in rapid destruction or crushing, of the shell material at most localities. Pallial markings and muscle impressions are indistinct, and cannot be seen at all in most specimens. With one exception, the fossils ranged in size from 13 mm to 20 mm long. This is in agreement with
the size reported by Meek (1876, p. 195). A single specimen has a
length of 3.3 mm. This specimen, a mold of the interior, conforms to
the description of the species except that it is somewhat more inflated
and has slightly more prominent keel. Although this might be enough
difference to consider it a new species, it might simply be a factor of
age. Meek questionably assigned L. cantulus to the subgenus _Poromna_
on the basis of shell outline. _Poromna_ is distinguished by having a
more elliptical shell, shorter, rounded anterior border, subacuminate
posterior, and obsolete lateral teeth. Meek's material as well as that
of the present study did not show characters of the hinge so that
subgeneric assignment was questionable. In the large specimen
mentioned above, the elements of the hinge are preserved on the mold and
weak lateral teeth are present. The significance of this cannot be
known until better preserved material similar to the large specimen is
collected.

_Measurements._—The figured specimen has the following dimensions:

<table>
<thead>
<tr>
<th>UND Cat. No.</th>
<th>Length (mm)</th>
<th>Height (mm)</th>
<th>Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9234</td>
<td>23.0</td>
<td>14.3</td>
<td>5.1</td>
</tr>
</tbody>
</table>

_Habitat._—Univ. of N. Dak. Cat. Nos. 9234 (mold of interior with
some shell material on right valve), 9245-9253 (24 unfigured specimens).

_Locality._—3-1-2, 3-1-3, 3-0-2, 3-0-4, and 7-3-7. Trail City (?)
and Timber Lake (?) lithology in the lower part of the Fox Hills Formation.
**Jellina chevannensis** Meek and Hayden 1876

Plate 2  Figures 11-14


*Jellina (Aracanaria?) chevannensis* Meek and Hayden, Meek, 1876, G. S. Geol. Survey Terr., v. 9, p. 607, pl. 17, fig. 16.

Meek (1876, p. 607) described the species as follows:

Shell transversely ovate, compressed, very thin; anterior margin rounded; posterior margin faintly subtruncated, or rounding from above to the very narrowly rounded or sub-angular posterior basal extremity; basal outline semiovate; beaks rather prominent, placed a little in advance of the middle; umbonal slopes prominently rounded from the umbo to the posterior basal extremity; surface ornamented with fine lines of growth, and somewhat stronger little ridges and furrows near the lower margins.

**Discussion.**—Meek (1876, p. 607) was hesitant about placing this species in the genus *Jellina* because characters of the hinge were not visible on his material. Although this is also the case with the specimen found in this study, I have no doubt that the generic assignment is correct. There is, however, some question on the species assignment in that the above description does not perfectly describe the external shape. No subsequent descriptions have been published. In profile, the present specimen conforms to the description; but, if viewed in neutral position, it is quite distinctive. The line of juncture of the two valves, rather than being straight, is a very gentle sigmoid curve. The left portion of the left valve which is anterior to the beak is slightly convex while the same area on the right valve is the area of greatest anterior-posterior convexity. There is no sign of deformation of the specimen. The specimen illustrated by Meek (1876, pl. 17, fig. 16) shows
the right valve with the rest of the fossil still imbedded in the matrix.
If this was the only specimen available to him it is probable that this
curvature would not have been apparent.

**Measurements.**—The specimen illustrated has the following dimensions:

<table>
<thead>
<tr>
<th>UMD Cat. No.</th>
<th>Length (mm)</th>
<th>Height (mm)</th>
<th>Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9254</td>
<td>25.3</td>
<td>16.2</td>
<td>5.6</td>
</tr>
</tbody>
</table>

**Hymenops.**—Univ. of S. Dak. Cat. No. 9254.

**Locality.**—3-9-4. This specimen was found in Trail City (?)
lithology in the lower Fox Hills Formation.

**Tellina sp.**

**Plate 2  Figures 13-19**

**Discussion.**—One specimen of palaeopyg, definitely of the genus
Tellina but unassignable to species, was found in an isolated outcrop in
Timber Lake (?) lithology. In most respects it resembles *J. scitula*;
however, the beaks are located anterior of the midline of the shell.
The shell is moderately proascline. Preservation of the specimen is
very poor so that details of proascline are limited to faint suggestions
of growth lines.

**Measurements.**—The specimen illustrated has the following dimensions:

<table>
<thead>
<tr>
<th>UMD Cat. No.</th>
<th>Length (mm)</th>
<th>Height (mm)</th>
<th>Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9253</td>
<td>25.3</td>
<td>16.2</td>
<td>5.6</td>
</tr>
</tbody>
</table>

**Hymenops.**—Univ. of S. Dak. Cat. No. 9253.

**Locality.**—7-4-2. Timber Lake (?) lithology in the lower Fox
Hills Formation.
Superfamily MYCETEA
Family CORBULIDAE
Genus Carinula Bruguière 1792
Carinula aequalis Meek and Hayden 1896
Plate 2  Figures 20-25
Carinula aequalis Meek and Hayden, Proc., v. 9, p. 205, pl. 10, fig. 4.
Meek described the species thus:

Shell small, oval-subtrigonal, very gibbous, distinctly inequivalve; anterior side of right or larger valve irregularly rounded or obliquely truncate above, and subangular below; anterior side of smaller valve more narrowly rounded; posterior side of both obliquely truncate above, and more or less distinctly angular below; basal margins of each nearly straight, or but slightly convex in outline, a little warped laterally, and not corunculated within; beaks subcentral, that of right valve considerably elevated above the other, flattened or depressed on top, incised, and sometimes truncated at the point by pressure against that of the other valve. Surface nearly smooth, or only marked by very obscure lines of growth, and a few indistinct, irregular undulations.

Discussion.—Seven specimens of this species were collected at three localities. All of them conform to the above description except that weathering of the shell material has made the growth lines more distinct than those described by Meek.

Measurements.—The figured specimens have the following dimensions:

<table>
<thead>
<tr>
<th>UND Cat. No.</th>
<th>Length (mm)</th>
<th>Height (mm)</th>
<th>Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9236</td>
<td>3.7</td>
<td>3.4</td>
<td>4.3</td>
</tr>
<tr>
<td>9237</td>
<td>3.4</td>
<td>6.0</td>
<td>4.5</td>
</tr>
</tbody>
</table>
Superfamily ANATIRACHA
Family PHELADONIDAE
Genus *Gastornia* Agassiz 1836

*Gastornia americana* Meek and Hayden 1896

Plate 2  Figures 26-27


*Pheladoncata americana* (Meek and Hayden), 1861, Synop. Moluscs Cretaceous fls., p. 164.

*Gastornia americana* Meek and Hayden, 1896, J. S. Geol. Survey Terr., v. 9, p. 221, pl. 30, fig. 12.

*Gastornia americana* Meek and Hayden, Morgan and Fetsch, 1945, S. Dak. Geol. Survey, Rept. of invest., 49, pl. 3, fig. 4, no. 2.

Meek (1896, p. 221) described the species thus:

... the curve of its line of growth indicate a transversely oblong or narrow-oval outline, with a narrow- round anterior, and a subtrunngated posterior margin. Laterally, the valves appear to be rather compressed. The beaks are small, depressed, and placed in advance of the middle. The costae are moderately distinct, though not very prominent, and at the deflection along the flanks form angles of from 20° to 30°. These near the two extremities, although converging and passing down parallel to the others, do not meet to form angles along the flanks before they intersect the base. The surface shows obscure concentric markings of growth, which are crossed by the usual regular, equidistant, radiating rows of extremely minute granules, which appear, as seen under a magnifier, like minute drops of amber. The substance of the shell is very thin.
Discussion.—The chevron-like prosopon of Conusgra makes this one of the most easily identified palecypods in the Fox Hills fauna. This species is rare in Penrose County; only one broken specimen was found. In the type area of the Fox Hills Formation they are more common (Wang, 1962, oral communication). On the basis of the specimen at hand, little can be added to Neek's description except that the beak is located in the anterior quarter of the shell. The specimen illustrated by Morgan and Fetsch (1945, pl. 5, fig. 4, no. 2) is nearly rectilinear in outline.

Measurements.—The figured specimen has the following dimensions:

<table>
<thead>
<tr>
<th>USNM Cat. No.</th>
<th>Length (mm)</th>
<th>Height (mm)</th>
<th>Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9304</td>
<td>25.4</td>
<td>27.9</td>
<td>12.3</td>
</tr>
<tr>
<td>(broken)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Holotype.—Univ. of N. Dak. Cat. No. 9304.

Locality.—8-1-2. The only specimen found during this study was collected in Trail City (?) lithology in the lower Fox Hills Formation.
LITERATURE CITED


Oppel, Albert, 1856-1858, Die Juraformation in Deutschland, Frankreichs und des südwestlichen Deutschlands: Stuttgart [non visa].


Stephenson, L. W., 1941. The larger invertebrates of the Navarro Group of Texas: Univ. of Texas, Pub. 4101, 641 p.


<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-3</td>
<td>40</td>
</tr>
<tr>
<td>Neoplectana salpinaura</td>
<td>40</td>
</tr>
<tr>
<td>1. UMD No. 9200, Left lateral view, X3.</td>
<td>1. UMD No. 9200, Left lateral view, X3.</td>
</tr>
<tr>
<td>2. UMD No. 9201, Dorsal view, X2.</td>
<td>2. UMD No. 9201, Dorsal view, X2.</td>
</tr>
<tr>
<td>3. UMD No. 9201, Right lateral view, X1.</td>
<td>3. UMD No. 9201, Right lateral view, X1.</td>
</tr>
<tr>
<td>4-5</td>
<td>31</td>
</tr>
<tr>
<td>Neoplectana planinarcgata</td>
<td>31</td>
</tr>
<tr>
<td>4. UMD No. 9202, Interior of right valve, X1.</td>
<td>4. UMD No. 9202, Interior of right valve, X1.</td>
</tr>
<tr>
<td>5. UMD No. 9202, Interior of right valve, X1.</td>
<td>5. UMD No. 9202, Interior of right valve, X1.</td>
</tr>
<tr>
<td>6-11</td>
<td>36</td>
</tr>
<tr>
<td>Jolidia sp.</td>
<td>36</td>
</tr>
<tr>
<td>6. UMD No. 9206, Left lateral view, X3.</td>
<td>6. UMD No. 9206, Left lateral view, X3.</td>
</tr>
<tr>
<td>7. UMD No. 9206, Dorsal view, X3.</td>
<td>7. UMD No. 9206, Dorsal view, X3.</td>
</tr>
<tr>
<td>8. UMD No. 9206, Anterior view, X3.</td>
<td>8. UMD No. 9206, Anterior view, X3.</td>
</tr>
<tr>
<td>9. UMD No. 9207, Left lateral view, X3.</td>
<td>9. UMD No. 9207, Left lateral view, X3.</td>
</tr>
<tr>
<td>10. UMD No. 9207, Left lateral view, X3.</td>
<td>10. UMD No. 9207, Left lateral view, X3.</td>
</tr>
<tr>
<td>11. UMD No. 9207, Dorsal view, X3.</td>
<td>11. UMD No. 9207, Dorsal view, X3.</td>
</tr>
<tr>
<td>12 Neoplectana bisexpertata</td>
<td>35</td>
</tr>
<tr>
<td>12. UMD No. 9212, Left lateral view, X3.</td>
<td>12. UMD No. 9212, Left lateral view, X3.</td>
</tr>
<tr>
<td>13 Ostracop sp.</td>
<td>53</td>
</tr>
<tr>
<td>16 Volopala calvinae</td>
<td>43</td>
</tr>
<tr>
<td>15. UMD No. 9214, Dorsal view, X1.</td>
<td>15. UMD No. 9214, Dorsal view, X1.</td>
</tr>
<tr>
<td>16. UMD No. 9215, Hold of interior of left valve, X1.</td>
<td>16. UMD No. 9215, Hold of interior of left valve, X1.</td>
</tr>
<tr>
<td>40 Pteria linguaformis</td>
<td>47</td>
</tr>
<tr>
<td>17. UMD No. 9221, Left lateral view, X1.</td>
<td>17. UMD No. 9221, Left lateral view, X1.</td>
</tr>
<tr>
<td>18. UMD No. 9222, Right lateral view, X1.</td>
<td>18. UMD No. 9222, Right lateral view, X1.</td>
</tr>
<tr>
<td>19. UMD No. 9223, Right lateral view, X1.</td>
<td>19. UMD No. 9223, Right lateral view, X1.</td>
</tr>
<tr>
<td>20. UMD No. 9223, Left lateral view, X1.</td>
<td>20. UMD No. 9223, Left lateral view, X1.</td>
</tr>
<tr>
<td>82 Triangulollista divers</td>
<td>57</td>
</tr>
<tr>
<td>22. UMD No. 9331, Dorsal view, X1.</td>
<td>22. UMD No. 9331, Dorsal view, X1.</td>
</tr>
</tbody>
</table>
**Plectra rhinacea**

- 23. UMD No. 9224, Mold of interior of left valve, X1.

**Oculina ahuawai**

- 25. UMD No. 9211, Right lateral view, X1.
- 26. UMD No. 9209, Mold of interior of left valve, X1.
- 27. UMD No. 9209, Anterior view, X1.
- 29. UMD No. 9208, Dorsal view, X1.
- 30. UMD No. 9210, Right lateral view, X2/3.

**Macuta cancellata**

- 31. UMD No. 9204, Right lateral view, X2.
- 32. UMD No. 9203, Right lateral view, X2.
- 33. UMD No. 9203, Dorsal view, X2.
Crenella elegansula .................................................. 45
1. UMD No. 9216, Left lateral view, X1.  
2. UMD No. 9216, Ventral view, X1.  
3. UMD No. 9219, Left lateral view, X1.  
4. UMD No. 9218, Left lateral view, X1.  
5. UMD No. 9217, Left lateral view, X1.  
6. UMD No. 9220, Left lateral view, X1.  

Protosarda subquadrata .................................................. 55
7. UMD No. 9230, Dorsal view, X1.  
8. UMD No. 9230, Right lateral view, X1.  
9. UMD No. 9229, Dorsal view, X1.  
10. UMD No. 9229, Left lateral view, X1. 

Tellina chrysopoda .................................................. 63
11. UMD No. 9234, Dorsal view, X1.  
12. UMD No. 9234, Anterior view, X1.  
13. UMD No. 9234, Left lateral view, X1.  
14. UMD No. 9234, Ventral view, X1.  

Tellina actina .................................................. 61
15. UMD No. 9244, Left lateral view, X1.  
16. UMD No. 9244, Dorsal view, X1.  
17. UMD No. 9244, Right view, X1.  

Tellina sp. .................................................. 66
18. UMD No. 9255, Dorsal view, X1.  
19. UMD No. 9255, Left lateral view, X1.  

Corbulina antennata .................................................. 65
20. UMD No. 9256, Anterior view, X3.  
21. UMD No. 9256, Left lateral view, X3.  
22. UMD No. 9256, Right lateral view, X3.  
23. UMD No. 9257, Anterior view, X3.  
24. UMD No. 9257, Left lateral view, X3.  
25. UMD No. 9257, Right lateral view, X3.
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