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Bivalvia and paleoecology of the Fox Hills Formation (Upper Cretaceous) of North Dakota

Rodney M. Feldmann
University of North Dakota

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BIVALVIA AND PALEOEKOLOGY OF THE
FOX HILLS FORMATION (UPPER CRETACEOUS) OF NORTH DAKOTA

by

Rodney M. Feldmann
B. S. in Geology, University of North Dakota 1961
M. S. in Geology, University of North Dakota 1963

A Dissertation
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Doctor of Philosophy

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1967
This dissertation submitted by Rodney M. Feldmann in partial completion of the requirements for the Degree of Doctor of Philosophy in the University of North Dakota is hereby approved by the Committee under whom the work has been done.

[Signatures]

Dean of the Graduate School
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ABSTRACT

The bivalve fauna of the Fox Hills Formation, Maestrichian, of North Dakota was studied in an attempt to modernize the nomenclature of known bivalves, describe new forms, interpret the relationships of members of the formation, and establish the paleoecological setting in which the Fox Hills was deposited.

The Fox Hills Formation crops out in Logan, Emmons, Sioux, Morton, Burleigh, Kidder, Pierce, McHenry, Bottineau, and Bowman counties in North Dakota. It is best exposed along the Missouri River in south-central North Dakota. Traditionally, the formation has been subdivided into four members, all of which are exposed in the type area of the formation in north-central South Dakota. In North Dakota, however, the lowermost Trail City Member cannot be lithologically recognized and, therefore, only the Timber Lake, Bullhead, and Colgate members, in ascending order, have been recognized. Lithologically, the Timber Lake Member consists of medium- to fine-grained sandstone, which is either unconsolidated or loosely cemented. This unit becomes increasingly crossbedded toward the top. The Bullhead Member consists
of a sequence of intercalated sandstone and shale which is essentially devoid of bivalves. The uppermost member, the Colgate, consists of light colored greywacke sandstone.

Forty-two species of bivalves were identified from the Fox Hills Formation in North Dakota and arranged in twenty-five genera. This number included three new species, *Nucula emmonsensis, Modiolus siouxensis,* and *?Astarte hollandi.* Three other species which are characteristic of the Cretaceous of the Eastern Seaboard were identified for the first time from the Midcontinent.

Using ecological data derived by studying the ecology of recent bivalves of the same genera as those collected in the Fox Hills Formation and the sedimentologic data, it was concluded that the Fox Hills Formation in North Dakota represents the littoral and shallow subtidal margin of the retreating Cretaceous epicontinental seaway. Data from the bivalves indicated that, in general, water depth decreased from about 80 fathoms to 0 fathoms from the base of the formation to the top, an observation which is further strengthened by sedimentologic evidence. These data in conjunction with those derived from the presence of a volcanic ash bed occurring in several parts of Emmons, Sioux, and Morton counties, which transcends the member boundaries, indicate that the members were being deposited penecontemporaneously across
central North Dakota. At the time that the strand line, now represented by the Fox Hills-Hell Creek boundary, occupied the area of central Sioux County, the Pierre-Fox Hills boundary would have occupied an area in central Emmons County forty miles to the east. Deposition of the Timber Lake Member was normal marine whereas that in the area of Bullhead deposition was apparently brackish, probably as a result of restriction caused by development of barriers in the area of the upper Timber Lake Member. The Colgate Member represents the strand line of the Fox Hills seaway.
INTRODUCTION

Purpose.--In his book dealing with the evolution of North American geology, Philip B. King has chosen to refer to the geology of the Midcontinent as being "the science of gently dipping strata" (King, 1959, p. 23). In making such a reference to the geology of the central part of the United States, King indicates two things: first, that the structures encountered are not complex and, second, perhaps implied, that the geology of this area is less interesting and of less general appeal than that of the more complexly deformed parts of the country. This area has, however, had an extremely long and, in its own way, extremely complex history of geological development. Since the middle of the nineteenth century the area has been the subject of considerable study by geologists who, like Jame Hall, have realized that the key to more complex areas might well lie in the study of the relatively undeformed areas adjacent to them.

The present study is an attempt to unravel a portion of the history of the Fox Hills Formation in North Dakota. This unit, deposited in the last stages of marine inundation of the Midcontinent during the Cretaceous Period, represents not only a long sequence of deposition in the area of North
Dakota, South Dakota, Montana, Wyoming, and Colorado, but also affords some key to the development of the Rocky Mountains, which were tectonically active during this period and shed sediments to the east, forming the Fox Hills Formation.

During the summers of 1962-64, I studied the Fox Hills Formation throughout North Dakota, visiting virtually every known outcrop of that unit in the state. The purpose of the study is to describe the bivalve fauna of the Fox Hills Formation and to determine as nearly as possible the paleoecological setting in which the Fox Hills Formation was deposited. The study entailed carefully collecting all fossils that could be found, piecing together the stratigraphic sequence, identifying the fossils, and attempting to portray, as accurately as possible, the geological setting at the time of deposition of the formation. The work is, of necessity, restricted in that not all of the fossil groups represented in the formation have been studied, and in that the exposures of the Fox Hills in North Dakota, as first indicated by Leonard (1906, p. 75), are in no way extensive, resulting in considerable difficulty in piecing together a complete stratigraphic section.

Location and Physiography.--The outcrops of the Fox Hills Formation in North Dakota are widely scattered (Fig. 1).
Location map showing distribution of the Fox Hills Formation in North Dakota and collecting localities in south central North Dakota.

Distribution of the Fox Hills Formation has been modified from Jackson, et al. (1966), Harper (1966), Prince (1963), Brown (1960), Land and Mitchell (1952), and Miles (1948). Subdivision of the Fox Hills Formation is based on the authors' collection and analysis. 1961-65.
The most extensive area of Fox Hills exposure is in the south-central portion of the state in Sioux, Morton, Emmons, Burleigh, and Logan counties along the Missouri River. Two smaller areas in which the formation is seen, somewhat less well exposed, are the north-central portion of the state in Bottineau County and the extreme southwestern part of the state in Bowman County. In the latter two areas, however, exposures of the Fox Hills are extremely limited, no fossils were found, and only limited work could, therefore, be done.

The areas of Fox Hills outcrops lie within three different physiographic regions of the Midcontinent. The portion surrounding the Turtle Mountains occupies a small part of what has been called (Fenneman, 1931; 1938) the Western Lake Section of the Central Lowland Province. The area adjacent to the Missouri River as well as the area of outcrop of Bowman County in the southwestern portion of the state is in a physiographic region designated as the Missouri Plateau Section of the Great Plains Province. The former area is in the glaciated portion of the Missouri Plateau; the latter in the nonglaciated portion of the Missouri Plateau. The physiographic expression of these various areas plays a rather fundamental role in the study of the Fox Hills Formation in that the majority of the area has been glaciated. The result is a rather subdued topographic setting in which exposures of
bedrock are restricted. This cover is widespread enough that, in the regions surrounding the Turtle Mountains and adjacent to the Missouri River, exposures are found only along streams and highway ditches. Generally speaking, the area is given to agricultural usage and exposures of bedrock are limited to extremely small areas. The nonglaciated portion of the Missouri Plateau affords somewhat better exposures. However, the Fox Hills is considerably thinner and is apparently devoid of fossil material in the Turtle Mountains.

The areas in North Dakota in which the Fox Hills is exposed fall into two distinct climatic zones. The areas east of the Missouri River fall within the bounds of the interior subhumid lands (Trewartha, 1941, p. 168) and are characterized by an average annual precipitation in excess of 16 inches (Bavendick, 1941, p. 1053) and a tall grass prairie flora (Wheeler and Wheeler, 1963, p. 67). The area west of the Missouri River is characterized by semiarid climate (Thornthwaite, 1941, p. 178). Here, rainfall varies between 14 and 16 inches (Bavendick, 1941, p. 1053) and the flora is characterized by mixed and short grasses (Wheeler and Wheeler, 1963, p. 67).

Historical development.--The accumulation of knowledge about the Fox Hills Formation in North Dakota and closely related areas has been sporadic and, with the exception of
two periods nearly a century apart, extremely slow. Apparently the first recorded mention of the beds that were later to be called the Fox Hills Formation was that by Lewis and Clark on October 18, 1804. They noted (Thwaites, 1959, p. 198), "... above the mouth of the river Great numbers of Stone perfectly round with fine Grit. ...". The stones to which they referred were large sandstone concretions in the Timber Lake Member of the Fox Hills Formation. The river mentioned had earlier been named Le Boulet, or Cannonball, by French trappers (Thwaites, 1959, p. 198) who had also noticed the structures.

Observations similar to those by Lewis and Clark were made by Alexander Philip Maximilian in 1833 (Thwaites, 1909, p. 338). Not only did Maximilian observe the concretionary structures but he also noted the dip of the units to the northwest, into what is now called the Williston Basin. The observations of Maximilian were, however, apparently nothing more than minor points of interest and it was left for Edward Harris to make the first truly scientific observations.

Harris traveled up the Missouri River with John James Audubon in 1843 to study the birds and quadrupeds of the area. Although Harris was an agronomist, he had a remarkable ability to observe natural phenomena and made the first significant statements concerning the stratigraphy and structure of the area through which he passed. Notable among these are the
following comments concerning the beds that were later termed the Fox Hills:

About 40 miles below the Mandan Fort the shale & clay formation first noticed below the great Bend disappears below the bed of the river, the Stratum which overlies it I believe to be the brownish stone seen soon after leaving Fort Pierre, I have had no opportunity whatever of examining this Rock and cannot speak of its character. On passing the mouth of Cannon Ball river yesterday we noticed a remarkable formation of this stratum of round masses of the rock in the divisions of the strata many of them apparently perfectly spherical and from 18 inches to 30 inches in diameter, some are as perfect as cast balls and others appear to be flattened or composed of two sections of a sphere, from a smaller arc up to a hemisphere, joined together with mathematical nicety, and surrounded by a belt or zone at the junction, which zone corresponds with the line of division of two strata. (McDermott, 1951, p. 89-90.)

Unfortunately, although Harris was encouraged to publish his diary, he took no action in that direction. The first complete publication of his notes was not made until 1951 (McDermott, 1951, p. IX) and, therefore, his observations were not publicly available until long after other workers had completed far more extensive works.

Somewhat earlier than the work of Edward Harris, S. G. Morton published a paper (1839) describing several new species of organisms collected from the Cretaceous of the Midcontinent and at the same time proposed a correlation of the Cretaceous units located in the Midcontinent with those of the Eastern Seaboard. This work closely followed what has been described (Merrill, 1924, p. 117) as the first use of fossils for
correlation in the United States. His earlier work, published in 1828, was a study of the Tertiary sediments of the east coast. In his work in 1839, Morton attempted to piece together the record of the Cretaceous System as it was known in the country at that time. He did so by dividing the Cretaceous into three divisions, the "upper", "medial", and "lower". The upper unit was presumed to be the "Nummulite limestone" found in Alabama. It was characterized by an absence of ammonites but the presence of Nummulites and the cephalopod Nautilus. The medial Cretaceous Morton thought to be represented by deposits from Vincentown to Salem in New Jersey and correlated with the White Chalk in England and France. The medial Cretaceous was then characterized by the fossil Belemnites ambiguous. The lower unit consisted of a ferruginous sand from Martha's Vineyard to South Carolina and then west across the Mississippi River into the Midcontinent. This unit Morton correlated with deposits between the "White Chalk" and the "oolite" in Europe. The lower unit was characterized by an abundance of ammonites as well as the marine reptile Mososaurus. Although Morton also named a number of new species in this work, by far the most significant aspect of the study involved the observation that the Cretaceous deposits along the eastern seaboard were related, at least temporally, to those in the Midcontinent. Morton
did not present a stratigraphic section at this time but his work still stands as monumental in that he had, by this time, fully demonstrated the use of fossils for correlation in the United States.

Although several other explorers, trappers, and adventurers visited North Dakota and South Dakota during this same period and made significant contributions in the fields of paleobotany and vertebrate paleontology, nothing more was done with the Fox Hills stratigraphy and paleontology until 1853. In that year James Hall, State Geologist of New York, instructed Dr. Fielding Bradford Meek and Dr. Frederick Vandiveer Hayden to travel up the Missouri River to Fort Pierre and to study and collect the Cretaceous and Tertiary fossils of that region. Although the expedition was primarily designed for the collection of vertebrate fossils (Meek, 1876, p. XXII), many invertebrates were also collected along with detailed data concerning the stratigraphy of the area. This trip, and subsequent trips by Hayden, provided the nucleus of stratigraphic and paleontologic data from which was constructed the first comprehensive study of the Cretaceous and Tertiary of the Midcontinent. Their material was originally published as a series of taxonomic papers.

The first of these (Meek and Hall, 1856) also contained the first known stratigraphic section of the beds in North
Dakota and South Dakota (Fig. 2). Essentially the same section was given in 1857; however, at this time the original estimates of thickness were somewhat revised (Meek and Hayden, 1857, p. 63). These sections subdivided the Cretaceous System in the Midcontinent into five units of which the Fox Hills Formation, then referred to as Unit 5, was described as 100 to 150 feet of, "grey and yellowish arenaceous clays containing great numbers of marine Molluska with a few plants" (Meek and Hayden, 1857, p. 63). This section underwent still further modification and was published in final form, for the first time, in 1861 (p. 419). At this time the units, which had previously been given numerical designations, were assigned names based on areas of typical exposure. The names, Dakota, Fort Benton, Niobrara, Fort Pierre, and Fox Hills, formed the framework of the standard section of the Upper Cretaceous in the Midcontinent.

Following this short burst of activity, Hayden served as a doctor with the Union Army and Meek became involved in investigations for several state geological surveys. Further work on the Cretaceous of North Dakota was, therefore, not completed until 1876. In that year, Meek completed a monographic tome dealing with the stratigraphy and paleontology of the Cretaceous and Tertiary of the "upper Missouri country." This document, published under the auspices of Hayden's United
Gren, marl, etc., with remnants of Mesozoica. The entire thickness of formation is 51-130 feet.

Arctoceous clay passing into limy-arctoceous sandstone.

210-300 feet of plastic clay with calcareous concretions with numerous fossils.

This is the principle fossiliferous bed of the Cretaceous Formation upon the Upper Missouri.

Calcareous marl with three region, fish bones, etc.

Clay with few fossils.

Sandstone and clay.

Blue colored magnesian limestone of the Carboniferous Period.


Beds of clay, sandstone, etc., with remnants of terraces, and at places, vast numbers of plants, with land, fresh water, and sometimes marine or marine mollusks, 400-600 feet.


Grey and yellowish arctoceous clay containing great numbers of marine mollusks with a few plants. 100-150 feet.

Plastic clays with numerous marine mollusks, about 350 feet.

Grey and yellowish arctoceous sand, containing three region, fish bones, etc. 100-150 feet.

Greyish and lead colored clays having few fossils.

Sandstone and clay not known positively to belong to the Cretaceous System.

Lower fossiliferous zone with marine mollusks, with gypsum, etc.


Little Brown Creek, Bowman County, North Dakota.

Lower Fort Union or Dinosaur bearing beds.

Sedimente, light greenish grey, marl.

Sandstone beds, yellowish. Clay, sandy, fine laminite.

Penetriform concretions in the upper beds of the Pierre Formation.


Calcareous or Tertiary Limestone Formation.


Fig. 2. Summary of stratigraphic sections of the Fox Hills Formation in North Dakota. Vertical scale: 1 inch = 200 feet except in section provided from Meek and Hayden (1861) in which no thicknesses were given.


Sec. 16, T. 20 N., R. 29 E., S. Dak.
States Geological Survey of the Territories, is a thorough, well illustrated, modern treatment of all Cretaceous and Paleogene fossils known from the area to that date. It serves as a fitting tribute to Meek who died in the same year. It is still considered a standard paleontological reference for the area.

In the twenty years following the work of Meek and Hayden, little was done concerning the study of the Fox Hills in North Dakota. However, in 1879, Stevenson published a paper dealing with the Fox Hills group in Colorado, thus extending it about as far south and west as the unit had, to that point, been carried. The next work in North Dakota was that of Todd (1896). Todd studied the glacial deposits along the Coteau du Missouri and reported Fox Hills sandstone in several localities, in Kidder, Burleigh and Emmons counties. He also reported the presence of leaves collected from well cuttings in Kidder County and oysters in a coarse brown sandstone in Emmons County (1896, p. 56). Following the work of Todd, Babcock (1901) published the First Biennial Report of the North Dakota Geological Survey. In this report, Babcock discussed the occurrence of the Fox Hills Formation in North Dakota and reported it not only from the area adjacent to the Missouri but also mentioned that it could be found in the Turtle Mountains and west of Rugby, North Dakota. He further
reported that it is useful as a building stone near the Turtle Mountains and near Dickinson, North Dakota. Although the Fox Hills Formation is known to have provided building stone in Emmons County, no other reference to its use in the area of the Turtle Mountains is known and almost certainly the material referred to near Dickinson, North Dakota, comes, not from the Fox Hills Formation, but from one of the overlying units, possibly the Tongue River Formation of Paleocene age.

In 1902, Wilder presented the first known stratigraphic section of the deposits in North Dakota. He referred to the Fox Hills "stage" of the "upper Cretaceous series" and described it as being a sandstone. His main reference to previous work is to that of Todd (1896); however, he was skeptical of this identification and stated (Wilder, 1902, p. 42) that, "The reference of these elevated sandstones in Emmons, Burleigh, and Kidder Counties to the Fox Hills may fairly be regarded as very doubtful." Leonard (1904) considered the Fox Hills Formation in about the same vein as did Wilder in that he included in the formation the beds adjacent to the Cannonball River in Sioux and Morton counties, but considered the sandstones exposed on the eastern side of the Missouri River as being Laramie in age. He further stated that in the area of the Turtle Mountains the Fox Hills would be buried at some depth, thereby indicating that the observations of Todd in
1896 were incorrect. In a later study, Leonard (1906, p. 75) summarized the knowledge of the Fox Hills Formation in North Dakota as being extremely incomplete and stated that, "on account of the lack of exposures little is known of the character of the Fox Hills strata in this state."

He did, however, indicate some knowledge of the geological setting of the Fox Hills in this area by stating (1908, p. 234) that the Fox Hills represented the last advance of a seaway into North Dakota. He also indicated that the relationship between the Fox Hills Formation and the overlying units is one of unconformity, having noted an erosional surface at the top of the Fox Hills along Little Beaver Creek. This, to Leonard, indicated that the overlying sediments were, "... much younger geologically than those beneath" (Leonard, 1908, p. 234).

The publication of the last-mentioned paper represents the close of what might be considered the first stage in development of knowledge concerning the stratigraphy of the Fox Hills Formation in North Dakota. It had started essentially with the work of Meek and Hayden and at that time reached the peak of its development. From that time on, however, the unit had been restricted in lateral extent to the point that very little Fox Hills was recognized in the state by 1910.
The next publication dealing with the Fox Hills in North Dakota was that of Stanton (1910, p. 172-188) in which he discussed the uppermost Cretaceous in North Dakota, South Dakota and eastern Wyoming. Numerous detailed stratigraphic sections were given, although none was measured within the boundary of this state. Included with the sections are rather long lists of fossil species collected from the various localities and, for the first time, an indication that the fossils in the Fox Hills Formation may be used for something other than strictly stratigraphic study. In several places Stanton indicated that the environment in which the organisms lived could be interpreted by studying the sediments and the fossil remains. He suggested (p. 178), for example, that the top portion of the Fox Hills sandstone contained not only marine but, in many places, brackish water organisms, including oysters, Anomia and Corbicula and that, therefore, the beds represented a transition between the marine unit below and the predominantly fresh-water unit overlying the formation. He also suggested that the change in character and thickness of the unit from Colorado to North Dakota was a function of distance from source and variation in topographic expression of the source.

In the same year, Calvert (1910) published a paper dealing with the economic implications of lignite deposits in
eastern South Dakota, and, in discussing the general stratigraphy of the area, mentioned the occurrence of what he referred to as the "Colgate sandstone member of the Lance Formation". He continued by stating that this unit occupied the stratigraphic position of the Fox Hills Formation, but that information provided by plant fossil studies conducted by Knowlton indicated that age to be Tertiary rather than Cretaceous. This information coupled with the total absence of sandstone other than that which could be attributed to the Colgate Member, indicated to Calvert that the Fox Hills was definitely not present in Bowman County. Although further work with the plant fossils in the Colgate Member will be discussed below, suffice it to say here that the Colgate Member is now referred to the upper portion of the Fox Hills Formation and is considered Cretaceous in age.

Leonard (1911, 1912), summarized the fossils collected in the areas of the Cannonball River and Long Lake Creek and published what apparently was the first geologic map delimiting the extent of the Fox Hills Formation in south-central North Dakota. It is evident from the map that the earlier views mentioned by Leonard, regarding the extent of the unit, had been somewhat modified in that the majority of Emmons County in which sandstone is exposed at the surface is mapped as Fox Hills. He did, however, seem to restrict the surface exposure
of the unit somewhat more than would be done today; he showed
the most eastern extent of the unit as about ten miles west
of Linton in central Emmons County. The unit is now known
to extend as far east as the western third of Logan County.

Shortly after Leonard's map was published, Calvert, et al.
(1914) published a report on the geology of the Standing
Rock and Cheyenne River Indian Reservations in North Dakota
and South Dakota. This report included an extremely detailed
geologic map of the area portraying quite accurately the
extent of the Fox Hills Formation. They also concluded that
the Fox Hills Formation represented a shallow water unit which
is gradational with the Pierre Formation below and is not
separated from the overlying units by any considerable time
span, thus concurring with the earlier work of Stanton. It
might be noted that Calvert, et al. suggested two possible
origins for the numerous calcareous concretions present in
the formation. They suggested first that these accumulations
represent natural colonies on the shallow sea floor which were
formed, rather than being widely and evenly dispersed, as
small groups or clusters of organisms which were later buried
and preserved. Secondly, they suggested that it is possible
that these organisms represent accumulations that have been
brought together by wave or current action and rolled into
something resembling a mud ball. Although these concretions
have been studied since that time, apparently no universally acceptable origin has yet been discovered and the two theories mentioned above seem to be as reasonable as any that have subsequently been suggested. Following the work of Calvert, nothing was published directly related to the Fox Hills Formation in North Dakota until 1937; however, several papers were published dealing with other areas of Fox Hills exposure which deserve brief mention here.

Two of these papers (Stebinger, 1914; Bowen, 1915) dealt with determining the lateral extent and stratigraphic relationships within the Montana Group, a term which had previously been coined by Eldridge (1888, p. 93) and which included the Bearpaw Shale, Judith River Formation, Claggett Formation, Eagle Sandstone in Montana and related units in adjacent areas. Stebinger (1914, p. 67) indicated for the first time the temporal and lithologic continuity of three units: the Horsethief Formation, Lennep Formation and the Fox Hills Formation, and indicated that they were the uppermost formations of the Montana Group.

In 1916, Knowlton published a paper dealing with the flora of the Fox Hills Formation. He dealt primarily with collections from South Dakota and Colorado. The two most significant contributions of this paper were that the flora indicated a distinct Upper Cretaceous age for the unit, and
that the ecology of the flora indicated a warm, temperate
cclimate, probably one near sea level (Knowlton, 1916, p. 87).

In 1929, Dobbin and Reeside resurrected a problem which
had plagued students of the Cretaceous for some time. They
concerned themselves with the contact between the Fox Hills
Formation and the overlying unit which they referred to as
the Lance Formation. They concluded that, contrary to the
opinions held by several other workers at that time, no
evidence of unconformity exists between the Fox Hills
Formation and the overlying units, and that the variation in
thickness of the unit from Colorado to North Dakota was
original and did not represent an erosional interface. They
further demonstrated that the apparent discordant bedding
relationships between the beds of the Fox Hills and overlying
units represented either very minor erosional scour features
or cross-bedding or, in some cases, small local fault structures
which again did not represent a major erosional break. They
also made reference to the "Cannonball marine Member of the
Lance Formation" which had been named some time earlier (Lloyd,
1914, p. 248-249). The apparent similarity of the fauna of
the Cannonball and the Fox Hills further indicated to Dobbin
and Reeside that no major temporal break could have existed
between the time of deposition of these two units.

By this time the usage of the term "Fox Hills Formation"
was well established in the literature. The major problem that existed at this time involved determination of the precise location of the upper and the lower contacts of the unit. This problem arose for two reasons. The contact between the Pierre Formation and the Fox Hills Formation had long been recognized as transitional and deciding upon the precise position for the contact was, therefore, virtually impossible. Most workers apparently felt that the upper contact, although unconformable in local areas, did not represent any particularly long span of time. Lovering, et al. (1932, p. 702-703) attempted to define the boundaries of the unit and proposed the following definition of the contacts of the formation:

The base of the Fox Hills Formation shall be considered as the horizon below which the section is predominantly gray marine clay shales and sandy shales of Pierre age, and above which the section changes rapidly to a buff brown sandstone containing numerous large gray to brown, hard, sandy concretions. This lower concretionary member is commonly overlain by a series of light gray to brown sandstones and sandy shales.

The top of the Fox Hills Formation shall be considered as the horizon above which the section is composed predominantly of fresh, and brackish water deposits accompanied by coals and lignitic shales, and below which it is predominantly marine.

In a general sense, this definition is still usable today, and represents the consensus of opinion regarding the upper and lower contacts of the unit.
Several other papers dealing with areas outside of North Dakota are also significant. Bartram (1937) discussed the regional setting of the Upper Cretaceous adjacent to the Rocky Mountain front, and in so doing, mentioned the Fox Hills Formation as representing the uppermost marine unit in this sequence. Although he did not discuss the Fox Hills Formation in general, he did suggest (1937, p. 910) that the term "Fox Hills" should be used in a somewhat more general sense, and that local names, such as Horsethief, Milliken, Trinidad, and Lennep should be dropped from the literature. Although this suggestion seems to bear considerable merit, the preponderance of workers since Bartram have chosen to avoid his suggestion.

In the same year, Dane, Pierce, and Reeside discussed (1937) the Upper Cretaceous rocks in eastern Colorado and presented a series of faunal lists for the Fox Hills Formation. The majority of the species listed from Colorado correspond to those that have been noted in the type area of the Fox Hills Formation in South Dakota; however, some of the species collected in Colorado, notably Baculites grandis, indicate that the unit in Colorado is somewhat older than that in North Dakota. This species is characteristic of the upper portion of the Pierre Formation in North Dakota and South Dakota.

Following the period from about 1910 to 1940, very little
was done on the formation in North Dakota. A new surge of activity was then directed towards the study of the unit in this state. The first of these papers (Laird and Mitchell, 1942) was a study of the geology of southern Morton County and dealt, in part, with the stratigraphic relationships of the Fox Hills Formation. This work was essentially a continuation of the work by Calvert, et al. (1914) in Sioux County, south of Morton County. Laird and Mitchell mapped the units exposed in southern Morton County, described their stratigraphic relationships, and discussed the structure of the unit. A similar study was conducted by Fisher (1952) in Emmons County on the eastern side of the Missouri River and adjacent to the areas of Sioux and Morton counties. Fisher first applied the member terms, "Timber Lake" and "Trail City" to the lower two members of the Fox Hills Formation. Morgan and Petsch (1945) coined these terms for rocks in Dewey and Corson counties near the type area of the Fox Hills Formation in South Dakota. The mapping and stratigraphic information provided by Calvert et al., Laird and Mitchell, and Fisher provides much of the basic regional information upon which the present study is based.

Several other regional studies have been conducted in North Dakota since the work of Fisher (1952) in which at least brief mention of the Fox Hills Formation has been made.
These papers include Rau, et al. (1962), Clayton (1962), and Kume and Hansen (1965). These studies cover Kidder, Logan, McIntosh, and Burleigh counties in North Dakota. In all of these areas, a small amount of Fox Hills was noted and described and has since been restudied by the writer. Another work of regional scope is that of Lemke (1960), in which the Souris River area in north-central North Dakota was studied. He noted the presence of the Fox Hills Formation in two areas in McHenry and Pierce counties. The outcrop in McHenry County, northwest of Verendrye, is particularly significant in that it shows the relationship between the Fox Hills Formation and the next youngest overlying unit, the Cannonball Formation. In this area the Hell Creek Formation is totally absent or, if present, represents a very thin interval indicating that this location is very near the point where Fox Hills and Cannonball deposition was continuous.

The only other study concerning the Fox Hills Formation in North Dakota in recent years is that of Manz (1962) who discussed the pozzolanic properties of a volcanic ash deposit near Linton in Emmons County, North Dakota. This ash deposit, which had first been noted by Stanton (1917, p. 80-81) has since been recognized as having certain economic importance.

The work on the Fox Hills Formation in North Dakota in the past fifteen years has been considerably enhanced by
similar studies conducted in the type area of the Fox Hills in north-central South Dakota. Waage (1961, p. 229-240) has attempted a redefinition of the type area of the Fox Hills Formation. This was prompted by a study of the unit in the type area in which he found that the original, rather vague, definition of the type Fox Hills was not adequate to thoroughly describe the complex nature of the formation. He, therefore, re-defined the type area to include portions of the Fox Hills Formation which crop out in Dewey and Corson counties in north-central South Dakota. In doing so, he has attempted to circumscribe an area in which all four members presently recognized in this area are exposed. Three of the members, the Trail City, Timber Lake, and Bullhead, are typically exposed in this area; whereas, the uppermost member, the Colgate, which is typically exposed in eastern Montana, occurs in this area as thin, discontinuous lenticular bodies. Although Waage's study has not been completed, enough information is given to adequately characterize the unit in the type area. A subsequent paper by Waage (1964, p. 541-563) discussed the origin of the fossiliferous concretion zones which have been noted in the Fox Hills Formation in many areas. Waage concluded that the concretion layers are a result of a series of mass mortalities which occurred during the time of the Fox Hills deposition.
Although the studies that have been mentioned do not include all papers which have discussed the Fox Hills Formation in North Dakota, they do serve to point out that no work has been devoted strictly to the Fox Hills Formation in North Dakota. Previous work has been of one of two types, either considering the Fox Hills in regional aspect and only mentioning North Dakota occurrences in passing, or dealing with somewhat limited occurrences of the Fox Hills in North Dakota.
STRATIGRAPHY

Definition of Formation.--The Fox Hills Formation was named by Meek and Hayden (1862, p. 419-427) as a unit which consisted of a sequence of silty sands and sandstone and which represented the uppermost Cretaceous marine deposits in the Midcontinent. They stated that the formation was most typically exposed in the "Fox Hills", which is the eastern end of the divide between the Cheyenne and Moreau rivers in Ziebach and Dewey counties, north-central South Dakota. They further stated that the Fox Hills Formation could be seen in the area of Long Lake (since presumed to be the Long Lake in Burleigh County, North Dakota) and in the areas of Sage Creek, White River, Mussel Shell River and Milk River in Montana. The Fox Hills was also reported in the area of the North Platte River in Colorado and along the western margin of the Black Hills in Wyoming. On the basis of the enclosed fossils they correlated the unit with the "second Green Sand" in the New Jersey Cretaceous section (1862, p. 426). Prior to this time, the beds which are now called the Fox Hills, were called (Meek and Hayden, 1856, p. 63) unit "number five" in the Cretaceous section.
Meek and Hayden were rather cautious in pointing out that the contacts between the Fox Hills and the underlying Pierre Formation and the overlying unit, which they referred to in a later publication (Meek, 1876, p. XLVII) as the Judith River Group were gradational and extremely difficult to place. In regard to the lower contact Meek and Hayden (1862, p. 427) stated that,

"it [the Fox Hills Formation] is not separated by any strongly defined line of demarcation from the formation below, the change from the fine clays of the latter to the more sandy material above, being usually very gradual. Nor are these two formations distinguished by any abrupt change in the organic remains, since several of the fossils occurring in the upper beds of the Pierre Group pass up into the Fox Hills beds, while at some localities we find a complete mingling in the same bed of the forms usually found at these two horizons."

They further stated that, with equal justification, the contact between the Pierre and the Fox Hills formations could be placed below the fossiliferous unit which they placed at the top of the Pierre Formation. They did not do this, however, on the grounds that the greatest sedimentological changes occur within the fossiliferous horizon. This contact has been the subject of considerable controversy since the formation was named and it has now been established, by convention, that the contact shall be picked, rather than at the horizon selected by Meek and Hayden, below the lowest fossiliferous horizon.
The upper contact was also described as being conformable and representing a more or less continuous sequence of deposition. In 1876, Meek (p. XLVII), in discussing the overlying Judith River, stated that,

at the typical locality [of the Judith River Group], it evidently rests upon well-marked Cretaceous strata belonging to the horizon of the upper part of the Fox Hills Group; and both have been upheaved together in such a manner as to show conclusively that there is no discordance of stratification or, in other words, that they are conformable.

This statement, however, leaves one with some question as to whether Meek and Hayden ever truly recognized the upper contact of the Fox Hills Formation as it is presently defined. The contact which they discussed is apparently the contact between the upper part of the Claggett Formation and the lower Judith River Formation. In the area of the Judith River, in Fergus County, Montana, the Fox Hills Formation is not present; however, a relationship similar to that of the contact of the Fox Hills Formation with the overlying Hell Creek in the type area can be seen in the contact of the Claggett and Judith River formations. Although Meek and Hayden make no reference to the upper contact of the Fox Hills Formation in the Missouri Valley in North Dakota and South Dakota, it is almost certain that they must have seen the contact in that area. That this contact is conformable, and in many places gradational, has since been adequately demonstrated by Thom
and Dobbin (1924) and Dobbin and Reeside (1929).

The formation has undergone some redefinition since it was originally described. Both the upper and the lower contacts have been modified since the work of Meek and Hayden. The lower contact has, in general, been moved down in the section and now generally is taken to include a good bit of the transitional sequence between typical Pierre lithology and typical Fox Hills lithology. Lovering, et al. (1932, p. 702-703) were perhaps the first to formalize this modification. They described the lower contact of the unit in northeastern Colorado and stated that,

The base of the Fox Hills Formation shall be considered as the horizon below which the section is predominantly 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 large gray to brown, hard, sandy concretions. (Lovering, et al., 1932, p. 702)

This definition, as emphasized by Waage (1961, p. 229), was originally intended to apply only in northeastern Colorado and has since been somewhat freely interpreted (Wilmarth, 1938, p. 767) as applying to the entire area of outcrop of the Fox Hills Formation. Although this definition cannot be used everywhere, it does not seem to be significantly at odds with the definition used for the placement of the lower boundary in either the type area of the Fox Hills Formation or in the area of Fox Hills exposure in North Dakota. The
total interval of the Fox Hills Formation has been further increased at the upper boundary by the addition of the beds of the Colgate Member (Calvert, 1912). These beds, which are primarily marginal marine deposits, were, without question, included in the overlying "great lignite group" by Meek and Hayden.

**Definition of Members.**--Careful study of the Fox Hills Formation in the past fifty years has indicated that a number of members could be subdivided and readily recognized within the Fox Hills Formation. To date, five members have been named, of which four are recognizable within the type area of the Fox Hills Formation and have been traced into North Dakota.

**Trail City Member.**--The lowermost member of the Fox Hills Formation has been named the Trail City Member by Morgan and Petsch (1945, p. 13-14). They described (p. 13) the member as, "... usually a sandy brown or buff clay near its base, becoming more sandy in its upper parts near the contact with the overlying Timber Lake Member." They further stated that the member is characterized by three to five zones of dense blue limestone concretions. The lower contact of the member, and therefore, the lower contact of the formation, was picked above the highest "bentonite" [jarosite] in the Pierre Formation and below the first layer of fossiliferous concretions. This zone is within the
transitional zone between typical Pierre lithology and typical Fox Hills lithology. The zone of transition varies in thickness from three to twenty-five feet in the area of type occurrence of the Trail City Member. Morgan and Petsch did state, however, that no lithologic change could be seen within this zone, and used instead the uppermost "bentonite" as the horizon upon which the Fox Hills-Pierre contact was mapped. This contact has since been modified (Waage, 1961, p. 232) and has been placed at the lowest occurrence of jarosite in the sequence. This redefinition, then, provides a somewhat more tangible basis upon which the lower contact of the unit can be identified.

More recent work dealing with the Trail City Member (Waage, 1961) indicates that the concretionary layers noted by Morgan and Petsch can be traced over a considerable distance and consistently identified by the enclosed fossil material. Waage has subdivided the Trail City Member into five "zones" based on fossils. The lowermost "zone" has been named the "lower nicolleti" concretion layer. This layer, which occurs from one to eight feet above the lowermost contact of the unit, is characterized by an abundance of the cephalopod Scaphites (Hoploscaphites) nicolleti. The second layer, the "Limopsis-Gervillia" layer, is exposed about ten to eighteen feet above the lower nicolleti layer and is
characterized by the bivalves *Limopsis striatopunctatus* and *Gervillia recta*. About fifteen to twenty feet above the *Limopsis*-*Gervillia* layer, the "Protocardia" layer is exposed. This layer is characterized by an abundance of the bivalves *Protocardia subquadrata* and *Pteria nebrascana*. Above the "Protocardia" layer is a unit in which one or two layers of barren concretions crop out. The base of this layer is about fifteen to twenty feet above the "Protocardia" layer and extends upward in the section for about ten feet. The uppermost concretion layer is called the "abyssinus" layer and is found to contain the bivalve *Pteria linguaeformis* and the cephalopod *Discoscaphites abyssinus*.

These concretion layers are best developed near the eastern end of the divide between the Grand and Moreau rivers in the type area. As the layers are traced westward (Waage, 1961, p. 234) along the divide, the faunal assemblage of each of the zones appears to change and the characteristic fossils from which the zonal names were taken may be totally absent. As will be discussed later, this same situation seems to exist as the layers are traced northward into Sioux and Emmons counties in North Dakota. It should be further emphasized that although the names of the layers indicate an abundance of one or two particular species of organisms, these organisms may not be present in any one concretion or, indeed, may not be
found over a considerable extent of the zone in question.

The upper contact of the Trail City Member was stated by Waage (1961, p. 234) to be represented by a change from sandy clay to sand. This contact is, however, not at all distinct and is perhaps best defined on the basis of a relatively widely distributed layer of glauconitic sand which occurs at the top of the Trail City Member.

Timber Lake Member.--The member directly overlying the Trail City Member has been named (Morgan and Petsch, 1945, p. 15) the Timber Lake Member, and is typified by exposures in the vicinity of Timber Lake in Dewey County, South Dakota. The lower portion of the typical Timber Lake Member consists of greenish-yellow, medium grained, uncemented quartz sandstone. This uncemented sandstone grades upward vertically into a somewhat coarser grained, brownish sand which is characterized in many places by thin layers of orange or brown, limonitic claystone stringers. In many cases this upper zone is also well cemented and forms large calcareously cemented layers, or ledges, which are generally lenticular and change abruptly in thickness and stratigraphic position as they are traced laterally.

The fauna also varies vertically in the unit. Near the base of the member, the dominant species are Pteria linguiformis, a bivalve, and the large cephalopods Sphenodiscus
lenticularis, and Discoscaphites nebrascensis. A fourth species, the bivalve Cucullaea shumardi, is also characteristic of the lower part of the Timber Lake Member, but is not found consistently throughout the type area. The upper portion of the member is characterized by a general absence of the forms just listed, and the presence of the burrowing bivalve Tancredia americana and the filled tubes of the presumed decapod crustacean Ophiomorpha major.

The upper contact of the Timber Lake Member is apparently not well exposed in the type area (Waage, 1961, p. 236) but is readily recognizable on the basis of the change from the sand and sandstone of the Timber Lake Member to the interbedded sandstone and shale of the overlying Bullhead Member. This contact, as well as the contact of the Timber Lake Member with the underlying Trail City Member, is gradational.

Bullhead Member.--The Bullhead Member was named by Stevenson (1956) for exposures near the Indian village of Bullhead, Corson County, South Dakota. Prior to this time, the unit had been recognized as distinguishable from the underlying and overlying units and was referred to informally as the "Banded Beds" (Searight, 1931). The unit, in the type area, consists of about 135 feet of laminated sandstone and fissile shale. The beds of sandstone are light gray, medium or fine-grained and occasionally cross-bedded. They vary in
thickness from about one to fourteen inches and are inter-
bedded with somewhat thinner laminae of very fine-grained,
gray, fissile shale. The individual laminae of shale vary in
thickness from about one inch to about nine inches.

The fauna of the Bullhead Member is rather restricted,
and consists (Stevenson, 1956) of a limited Timber Lake fauna
near the base of the unit and, near the upper part of the
member, a few scattered occurrences of oysters. Waage (1961,
p. 237) also recorded the presence of the cephalopod
Discoscaphtes nebrascensis near the top of the unit.

The contact of the Bullhead Member with the overlying
Colgate Member is, in many places, gradational (Waage, 1961,
p. 237) although in some local areas outside the type area
(Laird and Mitchell, 1942, p. 6) local channeling may be
observed.

Colgate Member.--The uppermost member of the Fox Hills
Formation exposed in the Missouri Valley is the Colgate
Member. This unit was named by Calvert (1912, p. 194) for
an exposure of about 125 feet of white sandstone in the
vicinity of Colgate Station on the Northern Pacific Railroad
in Dawson County, Montana. The unit in its type area consists
of a relatively thick sequence of massive, white sandstone
with a few layers of interbedded buff or brown sandstone,
which contain fossil leaf impressions and fossil plant fragments.
In the Missouri Valley and, more specifically, in the type area of the Fox Hills Formation, the Colgate Member is considerably thinner and, although it retains its character and can be readily identified, is somewhat less well developed and not as extensive as it is in the type area of the member. The fauna of the Colgate Member is extremely restricted and for the most part is characterized by oysters of the genus *Crassostrea* and a few less common associated bivalves and gastropods. Cephalapods of the genus *Discoscaphites nebrascensis* occasionally occur in association with the oysters (Waage, 1961, p. 237).

The contact of the Colgate Member with the overlying Hell Creek Formation is generally conformable; however, as pointed out earlier, several areas can be noted which indicate a short erosional interval between the time of deposition of the Colgate Member and the overlying Hell Creek Formation.

**Milliken Member.**—A fifth member of the Fox Hills Formation was named the Milliken Member by Henderson (1920). This unit consists of about 100 to 150 feet of massive concretionary sandstone at the base of the Fox Hills Formation in the area of Milliken Station, Weld County, Colorado. This member would correspond approximately to the Timber Lake Member in the type area of the Fox Hills Formation, and as the term is not used in the area of North Dakota and South
Dakota, it will not be discussed further.

Fox Hills Formation in North Dakota.--The general aspect of the Fox Hills Formation in North Dakota changes only slightly from that of the type area in South Dakota. The upper three members, the Timber Lake, Bullhead, and Colgate, are present in North Dakota and have the same general appearance as they do in South Dakota. The lowermost member, the Trail City Member, however, is not at all well-defined in North Dakota. If the term were to be used in North Dakota, as did Waage (1961) in South Dakota, it would have to be restricted to a single outcrop in central Emmons County. Fisher (1953), therefore, subdivided the unit in North Dakota into an upper and a lower sequence rather than strictly adhering to the member terminology. The writer believes that the unit can best be defined by subdividing it into three members and considering the Trail City Member to be absent from the state (Fig. 3).

Pierre-Fox Hills Contact.--The contact between the Pierre Formation and the overlying Fox Hills Formation in North Dakota is totally gradational, as is also true in the type area. Fisher (1952, p. 8) referred the portion of the Pierre Formation in Emmons County to the Elk Butte Member of the Pierre and placed the contact just below the Limopsis-Gervillia "zone" of Waage (1961, p. 231).
The Pierre-Fox Hills contact in North Dakota is poorly exposed. However, from a study of this contact in two localities, near Linton, in Emmons County, and along the Little Missouri River in Bowman County, the present writer believes that a somewhat lower placement of the contact would be more consistent with the definition of the Fox Hills as used in the type area. The best exposure of the lower contact of the Fox Hills occurs in the north-facing cutbank of Beaver Creek in Seeman Park, one mile southeast from Linton, SE 1/4, sec. 17, T. 132 N., R. 76 W., Emmons County, North Dakota. At this locality the Pierre Formation is represented by about 68 feet of dark bluish-black shale, which is gypsiferous and iron-stained throughout.

The Pierre becomes somewhat siltier toward the top of the unit and, in places, contains small blebs of fine-grained sand. The contact at this locality can be selected by the occurrence of the first layers, or stringers, of jarosite. At the general level of the jarosite stringers, fine-grained sand is more abundant than the silt and clay of the Pierre Formation. This level is about ten to twelve feet below the lowest concretion layer which would, therefore, be placed in the Fox Hills Formation. Above the appearance of the first jarosite, the sequence changes rapidly from silty, sandy shale to fine to medium-grained buff sand with small
pods of jarosite. Although the lower ten feet of the unit might well be considered to be lithologically similar to the Trail City Member as defined in the type area, use of the term would seem to be impractical. This part of the section can be more conveniently referred to as a transition from the Elk Butte Member of the Pierre Formation to the Timber Lake Member of the Fox Hills Formation.

This definition of the contact between the Pierre and the Fox Hills formations is consistent with the definition used by Morgan and Petsch (1945) and Waage (1961). The assignment of the lower portion of the Fox Hills in North Dakota to the Timber Lake Member is, however, somewhat at odds with the interpretation of Waage. Morgan and Petsch originally defined the Trail City and Timber Lake members on the basis of their gross lithology and mentioned the occurrence of concretionary layers only incidentally. Waage, on the other hand, seemed to regard the concretionary layers as basic components of the Trail City Member. If this usage were to be strictly followed, the gross lithology of the Trail City Member would change from brown, sandy siltstone in the type area to definite fine or medium-grained sandstone in North Dakota. It would, therefore, seem to be more consistent with the original definition of the members to consider the concretions in this section to be enclosed in Timber Lake
lithology rather than to define the unit on the basis of presence or absence of concretionary structures. This usage would also tend to solve the dilemma, presented by Fisher (1952), in which the Trail City Member and Timber Lake Member, as he used them, were virtually indistinguishable on the basis of their gross lithology.

The foregoing remarks pertain to the Pierre-Fox Hills contact wherever it is seen in the Missouri Valley in North Dakota. The only other place in the state in which the contact is exposed is on the east flank of the Cedar Creek Anticline in Bowman County in southwestern North Dakota. The contact in this area differs in that the transition from typical Pierre lithology to typical Fox Hills lithology is somewhat more abrupt, and the fossiliferous concretionary layers noted in the Missouri Valley are absent. The only concretionary structures observed in this area are small concretions containing gypsum and cone-in-cone structure. These concretions occur within two feet of the top of the Pierre Formation. The best exposure of the contact in this area is found in the NW 1/4, NW 1/4, sec. 4, T. 131 N., R. 106 W., in Bowman County. At this locality the Pierre Formation is represented by a dark blue shale which weathers to a light gray color. This shale, typical of Pierre Shale throughout North Dakota, contains gypsum, some jarosite, and the scattered concretions mentioned
above. The contact between the Pierre and the overlying Fox Hills Formation is gradational through a sequence of about ten feet and represents a change from the dark blue shale to buff or yellow fine-grained sand with a few brownish shale or siltstone interbeds. Although the lower part of the Fox Hills Formation has never been assigned to any of the members of the unit, it has the general aspect of the Timber Lake Member, especially near the middle of the unit, and will be referred to as the Timber Lake Member in further discussions.

Timber Lake Member.--The Timber Lake Member is the lowest member which can be definitely identified in North Dakota. It varies in thickness from as little as 42 feet in Bowman County to more than 128 feet in Sioux County. Most of the unit is composed of fine to medium-grained lithic graywacke and sub-graywacke. Microscopic inspection indicates that the sorting of the sand grains is moderate to good. Most of the grains are angular, although rarely subrounded grains are encountered. The composition of the sandstone is somewhat variable; however, the only differences that can be noted are in regard to the cement and interstitial material. The sand grains themselves are, in general, divisible into four types. About twenty-five to thirty percent of the grains are quartz, zero to five percent are biotite, ten to fifteen percent are feldspar, and thirty-five to forty percent are rock fragments. Glauconite
occurs throughout the member in minor amounts. The remaining ten to thirty percent of the rock is composed of either interstitial limonite or a combination of limonite and calcite. Although the rock fragments were counted as though they were homogeneous, three different types could readily be recognized. The majority of the rock fragments are small, angular chert fragments, the remainder being either fine-grained igneous rock fragments or aggregates of quartz grains.

In gross aspect, the Timber Lake Member in North Dakota consists of buff to yellowish sand which weathers to yellowish or reddish brown. The member shows little bedding near the base but becomes distinctly cross-bedded near the top. Throughout the unit discontinuous ledges or lentils of reddish brown sandstone were observed. The ledges are cemented either by limonite-like material or a combination of limonite and calcium carbonate. In general, the ledges become more numerous near the top of the member. Two other features which are commonly observed in the Timber Lake Member are discontinuous stringers or layers of red or orange, brittle claystone and burrows of the decapod crustacean *Ophiomorpha*. Both of these features are abundant near the top of the Timber Lake and diminish in numbers downward so that they are rarely encountered below the middle of the member.

One of the most striking features of the lower part of
the Fox Hills Formation is the presence of fossiliferous concretions. In the type area of the formation, concretions are present in both the Trail City and Timber Lake members. Although the Timber Lake Member is the only one of these two members exposed in North Dakota, the concretionary structures are no less abundant than they are in the type area. These concretions can be subdivided lithologically into two general types. Discounting the fossil fragments, one group of concretions from the lower part of the member consists of about 50% fine silt and 15% sand, the composition of which is essentially the same as that of the surrounding Timber Lake matrix, and about 35% calcium carbonate cement. These concretions are normally dense, bluish structures which show no bedding characteristics, similar to the surrounding matrix, and are enclosed in a "jacket" of sandstone. The second group of concretions is lithologically quite similar to the surrounding matrix material and is more strongly cemented by limonite. In the type area of the formation, where the unit is somewhat better exposed, the concretionary structures have been precisely zoned by Waage (1961). In North Dakota, however, exposures of the Fox Hills Formation are limited to the point that this zonation can apparently not be accomplished without more thorough topographic coverage than presently exists. It can be stated, however, that the dense, blue concretions occur
only near the base of the formation, normally within 15 to 20 feet of the Pierre-Fox Hills contact, whereas the limonite-cemented concretions occur from this level to the top of the member.

The Timber Lake is by far the most fossiliferous member in North Dakota. The majority of the fossils collected from the unit occur in the concretions mentioned above. Less commonly, fossils occur in cemented sandstone ledges and, even more rarely, fossils are found free in the matrix material. Of particular note in regard to the last mentioned occurrence is an extremely fossiliferous layer which occurs near the top of the member in Morton and Sioux counties. This layer was first mentioned by Laird and Mitchell (1942, p. 7) who described it as a "coquinite". This layer, which will be discussed in detail in a later section, has now been traced as far south as south-central Sioux County and is everywhere characterized by an abundance of *Tancredia americana* and *Ophiomorpha*. One other area in which fossils occur abundantly in the matrix is in T. 132 N., R. 79 W., in Emmons County. Here, at the very top of the member, the oyster *Crassostrea glabra* and associated organisms occur in great profusion.

The general composition of the fauna changes markedly from the lower part of the member to the upper part, indicating a change from relatively deep water to very shallow, perhaps
even intertidal, conditions near the top of the unit.

The contact between the Timber Lake Member and the overlying Bullhead Member is gradational, from the glauconitic, crossbedded sand of the Timber Lake Member to the interbedded, fine-grained sandstone and siltstone of the Bullhead Member. This gradation, where observable, takes place within a stratigraphic interval of about two to three feet.

Bullhead Member.—Conformably overlying the Timber Lake Member in most areas in North Dakota is a sequence of beds which are lithologically identical to those named the Bullhead Member by Stevenson (1956). This member consists of a sequence of interbedded sand and siltstone and attains a thickness of about 97 feet in the vicinity of Redhorse Butte, SW 1/4, sec. 36, T. 130 N., R. 80 W., in Sioux County and 112 feet in SE 1/4, sec. 21, T. 134 N, R. 80 W., in Morton County (Laird and Mitchell, 1942, p. 6). The sand is a buff, finely laminated, fine-grained, subgraywacke which weathers to a reddish buff or buff, and often shows an irregularly cracked surface. The individual layers of sand vary in thickness from about one inch to eleven inches and are interbedded with chocolate brown siltstone and silty shale, which weathers to light gray or buff. The shale interbeds tend to be somewhat thinner than the associated sand layers, and vary in thickness from about one inch to seven inches. The overall color of the banded
beds is a light, dirty brown, which vaguely resembles the overlying Hell Creek beds. The Bullhead can normally be distinguished from the Hell Creek Formation, however, on the basis of color. The Hell Creek, at least in the lower portion, tends to be a somber gray rather than the buff or brown color of the Bullhead Member.

Fossils are relatively rare in the Bullhead Member in North Dakota. The only fossils noted were plant fragments, sharks teeth, otoliths, and oyster fragments. All of the oyster fragments that were collected are very small, broken fragments which occurred within the upper twenty five feet of the unit. The plant fossils were found throughout the member but are not well enough preserved to afford adequate material for identification. The otoliths and sharks teeth are extremely rare. Very thin lignite partings occur throughout the member and further indicate deposition of organic material.

The Bullhead Member varies in thickness throughout its area of outcrop. The first mention of this variation was made by Laird and Mitchell (1942, p. 6) when they correctly observed that the banded beds varied in thickness in an inverse relationship to the thickness of the overlying Colgate Member. In Bowman County, for example, in the SW 1/4, sec. 13, T. 132 N., R. 107 W., in a west-facing cutbank of Little
Beaver Creek, the Bullhead Member is totally absent and the Timber Lake Member is directly overlain by graywacke sandstone which can be referred to the Colgate Member. In Bowman County, the Colgate Member attains the maximum thickness observed in North Dakota, approximately 40 feet.

The contact between the Bullhead Member and the overlying Colgate Member is difficult to characterize in a general way. In places, for example, near Crowghost cemetery, NW 1/4, sec. 33, T. 134 N., R. 81 W., in Sioux County, a definite erosional interface can be noted between the two members. At this locality, about six feet of relief can be noted on the contact, suggesting that scouring took place prior to deposition of the Colgate sediments. That this disconformable relationship is, however, not general can be observed in several other localities throughout the Missouri Valley. Near the top of Redhorse Butte in Sioux County and in the SE 1/4, sec. 1, T. 134 N., R. 79 W., in Emmons County, the Bullhead Member appears to be conformable with, and gradational into the overlying Colgate sand. The conformable condition seems to be somewhat more predominant than the condition in which some scour or erosion is observed. Therefore, it can be stated that the contact between the two members is generally gradational. The erosional features observed do not suggest any long span of time.
Colgate Member.--The uppermost member of the Fox Hills Formation in North Dakota is the Colgate Member. Although the term was originally coined for beds along the west flank of the Cedar Creek Anticline, it has been widely used in the Missouri Valley area since the work of Laird and Mitchell (1942). This unit presents perhaps the greatest variation in lithology of any of the members of the Fox Hills Formation in North Dakota. Near the type area, along the east flank of the Cedar Creek Anticline, in Bowman County, the unit is quite similar to that seen in the type area and consists of 36 to 40 feet of medium-grained, white, graywacke sandstone with thin scattered layers and partings of lignitic shale. The most characteristic feature of the unit in this area is the fluted surface observed on all weathered exposures. The unit can also be seen in similar aspect near Crowghost cemetery in sec. 33, T. 134 N., R. 81 W., in Sioux County. As the unit is traced eastward and southeastward from this area, however, its character changes markedly and is normally characterized by less than ten feet, of well indurated, white to cream colored, flaggy sandstone. This condition is observable on Redhorse Butte in Sioux County in sec. 21, T. 134 N., R. 79 W., along the Cannonball River flood plain in Sioux County, as well as on many butte tops in Emmons and Logan counties.
Yet a third lithologic type, which I have referred to the Colgate Member, consists of a similar graywacke sandstone which forms the matrix of an oyster "hash" which occupies the same stratigraphic position at the top of the Fox Hills Formation. Wherever this feature is observed the unit is very thin, generally less than four feet. The occurrences of oyster fragments at the top of the Fox Hills are extremely widespread and perhaps can best be seen in secs. 16, 17, 20 & 21, T. 130 N., R. 80 W., in Sioux County, where oyster fragments festoon the surface of pasture lands. At only a few localities, for example, sec. 26, T. 133 N., R. 73 W., in Logan County and in sec. 31, T. 141 N., R. 72 W., in Kidder County, where oysters well enough preserved to allow identification. At the latter outcrop the oysters occur with a rather large fauna of associated brackish-water forms. Wherever the member has the same lithologic expression as the type Colgate, fossils appear to be absent, even to the exclusion of the plant fossils that have been described by Knowlton (1916) in Colorado and noted by Calvert (1912) in Montana.

Fox Hills-Hell Creek contact.—Consistent with the work of earlier workers (Laird and Mitchell, 1942; Fisher, 1952) the contact between the Fox Hills Formation and the overlying Hell Creek Formation was picked at the base of the first
prominent lignite or lignitic shale occurring above the predominantly marine section below. This contact has both practical and theoretical significance in that it not only serves as an excellent marker bed upon which to separate the two units, but also marks the approximate boundary between marine and brackish water deposits of the Fox Hills Formation and the predominantly fresh water and terrestrial deposits of the overlying Hell Creek Formation.

Field observations indicate that the contact may be expressed in one of two general ways. Where the contact is exposed along an essentially vertical face, the lignite at the base of the Hell Creek Formation tends to be a bit more resistant than the underlying sandstone of the Colgate Member of the Fox Hills Formation and, therefore, the Colgate forms a slight re-entrant below the lignite. In other areas, the top of the Fox Hills Formation has been stripped of all remnants of the Hell Creek and forms broad benches or flat surfaces capped by relatively resistant, flaggy Colgate sandstone. This condition can commonly be observed in the southern half of Sioux County, and on butte tops in Emmons and Logan counties.

The contact between the two formations is, in general, conformable; however, in some local areas relief can be noted on the contact, which would indicate at least a brief erosional
interval. This can perhaps best be seen near Crowghost Cemetery in Sioux County where the contact can be traced for several hundred yards and vertical relief of about six feet can be noted.

**Topographic Expression of the Fox Hills.**—Whereas the Fox Hills Formation in its type area in South Dakota forms high ridges and caps the surrounding countryside, the unit in North Dakota, in response to the regional dip into the Williston Basin, generally occupies lowland areas. This results in somewhat poorer exposures than are observed in the type area. The unit does, however, cover a large area in southcentral North Dakota, and, although it is not well exposed, certain general statements can be made regarding its topographic expression. Where the unit has not been deeply covered by glacial deposits, it forms gently rounded slopes and, when viewed from some distance, tends to give the impression of forming at least two relatively flat, bench-like, surfaces. The lower surface is formed at the approximate level of the top of the Timber Lake Member, and seems to be the result of abundant well-cemented sandstone ledges. This, however, should not be taken to mean that the top of the Timber Lake can everywhere be recognized on the basis of the presence of a topographic bench but it does serve to offer a general point of reference in the field.
The second bench is developed at the top of the formation on the flaggy, well-cemented Colgate Sandstone. This level is represented by rather broad benches in southeastern Sioux County and by scattered butte tops in Emmons and Logan counties. The Fox Hills, unfortunately, tends to support a relatively profuse vegetal cover by comparison with the Pierre Shale below and the Hell Creek Formation above, and therefore the slopes developed on the Fox Hills are frequently obscured.

Age and correlation.---The Fox Hills Formation in North Dakota represents one of the latest Cretaceous deposits in North America (Fig. 4). The unit has been correlated (Stevenson and Reeside, 1938, p. 1631; Cobban and Reeside, 1952, Chart 10b) with Maestrichtian deposits in Europe. It can, therefore, be considered a temporal equivalent of the Lennep and Horse Thief formations in Montana (Stebinger, 1914, p. 67) and the Corsicana and Kemp formations of the Navarro Group in Texas (Stephenson, 1941, p. 33). The Fox Hills is also equivalent in age to the Owl Creek Formation, Prairie Bluff Formation, and upper Ripley Formation in Mississippi, as well as the upper portion of the Monmouth Group in Maryland, Delaware, and New Jersey (Stephenson, et al., 1942, Chart 9). Jeletzky (1962, p. 1009) further summarized the correlation of the Fox Hills Formation with its adjacent
Figure 4. Correlation chart of the uppermost Cretaceous in selected areas of the United States. The column on the right is a result of the present work while the remainder have been modified from Cobban and Reeside, 1952.
units as well as with standard sections in several other parts of the world.

More careful study of the faunal assemblages collected in the Fox Hills in different areas of outcrop, however, indicates that the unit is not everywhere of the same age. The majority of data used to determine the age of the Fox Hills has been based on zonation of cephalopods, a group which has not been thoroughly studied in North Dakota. Preliminary investigation, however, indicates that the cephalopods in North Dakota are primarily members of the genera Discoscaphites and Sphenodiscus. These forms are characteristic of the upper portion of the Maestrichtian. On the other hand, cephalopods collected from the northeastern portion of Colorado (Bane, Pierce and Reeside, 1937, p. 232) include such species as Baculites grandis and Baculites ovatus as well as several species of Sphenodiscus. These species of Baculites are apparently not present in the Fox Hills Formation either in North Dakota or in the type area of the formation in South Dakota (Waage, 1961, p. 232). Rather, these forms are characteristic of the Elk Butte and Mobridge members of the Pierre Formation (Gill and Cobban, 1965, p. A4). This would indicate, then, that the Fox Hills Formation in eastern Colorado is a temporal equivalent of the Pierre Formation in central North Dakota. This interpretation is further supported
by the observation that the pelycopod *Inoceramus* is apparently absent from the Fox Hills Formation in North Dakota, although it has been reported from the Fox Hills in the type area (Waage, 1964, p. 549), and from the Pierre Formation and most other units that are somewhat older than the Fox Hills Formation in North Dakota (Stephenson and Reeside, 1938, Fig. 3).

The Fox Hills Formation appears to represent a littoral facies of the regressive Upper Cretaceous seaway in the Midcontinent, whereas the Pierre Formation represents a somewhat deeper water, offshore deposit. If this relationship is indeed true, it would demand that the Fox Hills Formation in the west would have to be equivalent in age to the Pierre Formation in some adjacent area to the east. Unfortunately, the amount of time involved in this regressive phase was so slight that fossil evidence indicates only a very general picture of this regression. For the purposes of correlation, then, it would seem that the Fox Hills Formation in North Dakota could be considered to be essentially the same age throughout its area of outcrop.

Determination of the age of the Fox Hills by means of bivalves can be done in only a very general way. Most of the clams are restricted to the Fox Hills. Their most closely related allies can be collected in the Navarro Group in Texas
and the Ripley Formation in Tennessee. Both of these units are Upper Cretaceous in age. A few Fox Hills species are closely related to species collected from Upper Cretaceous units along the Eastern Seaboard.

A few of the clams collected from the Fox Hills are members of the same species as those collected from the Cannonball Formation of Paleocene age. Stanton (1920, p. 11), for example, listed ten species of bivalves which occur in both the Cannonball and Fox Hills formations. More recent work on the Cannonball bivalves by Cvancara (1966) revealed that only six species from that unit can be referred to species known from the Fox Hills Formation in North Dakota. They are Nucula planomarginata, Nuculana evansi (Neilonella evansi? of Cvancara), Pteria linguaeformis, Crassostrea glabra, Corbicula cytheriformis, and Dosiniopsis deweyi. The remainder of the bivalves from the Fox Hills Formation, therefore, are restricted to the Upper Cretaceous.
PALEOECOLOGY

Boucout (1953, p. 25) defined paleoecology as an attempt, "...to reconstruct the total environment for the particular time and place in question, including the physical and biological factors that affect the life and relationships of organisms." Although the term "total environment" tends to pose an insurmountable limitation upon palaeocologists, the essence of the idea is sound. The task of the paleoecologist is to evaluate both sedimentologic and paleontologic data and assemble them into a coherent, logical picture of the conditions that existed at the time a particular stratigraphic unit was deposited. Paleoecology, then, forms the link between stratigraphy and paleontology in which the factors of both the rock record and the fossil record must be evaluated in order that a complete history be written.

Several lines of evidence are available from which paleoecological interpretations can be made for the Fox Hills Formation. Foremost among these is the fossil record. The Fox Hills contains a prolific molluscan fauna and, in particular, a rich and varied bivalve fauna. Although only the bivalves have been studied taxonomically in this work, the other mollusks--cephalopods, gastropods, and scaphopods--
as well as the small, but interesting associated fauna of vertebrates and other invertebrates can be used to determine the paleoecological setting. In addition to the fossil criteria, details of the stratigraphic record have also been employed. The relationship of the adjacent units, sedimentary structures within the Fox Hills, and sedimentologic features such as grain size, sorting, and composition have been used wherever observable.

Several assumptions must be made when undertaking work of this sort. The most important of these is uniformitarianism. Many of the species of bivalves collected from the Fox Hills are generically related to species living in the modern day oceans. By assembling data on the distribution of recent forms, it is possible to suggest the environment in which the fossil forms lived. Although this information is not in itself conclusive, it forms weighty evidence when assembled with other independent sources of information.

Another assumption that I believe can be made is that the fossil suites collected from various stratigraphic positions and geographic localities within the area of outcrop of the Fox Hills in North Dakota may well represent different ecological units rather than strictly indicating evolutionary development. This application, similar to the one which caused T. H. Huxley (1862, p. XLVI) to coin the term "homotaxis", 
is, in part, a result of the fact that the faunal sequences in the Fox Hills Formation in North Dakota, when arranged in ascending stratigraphic order, do not seem to indicate a general evolution of forms. Rather, the organisms collected in different stratigraphic horizons seem to represent totally different faunas and, therefore, might best be considered "facies fossils" which lived at the same time, but in different environments and in different geographic localities.

The present study is in part limited by the fact that the total fauna of the unit has not been studied taxonomically. This perhaps places too great an emphasis on the bivalves, the only group thoroughly studied, and seems to reduce the significance of the other elements of the fauna. Although the remainder of the fauna have been used to aid in the definition of environments of the deposition, the writer has not studied them taxonomically and no generic comparisons with recent forms has been attempted. Further, the extent and size of available outcrops in North Dakota is limited by glacial and vegetal cover. This forces one to extrapolate over considerable distances, making correlation difficult.

Along the same lines, the similarity of the sediments in different parts of the Timber Lake Member is so great that, unless other information is available, it is difficult to
accurately place a small, isolated outcrop in its correct stratigraphic position. This problem is further magnified by the general lack of a dependable stratigraphic marker horizon and the total absence of large-scale topographic maps. The only maps available of the area in question are North Dakota State Highway Department county road maps which have no topographic control and U.S. Army topographic maps (1:250,000). All correlation that was done between small outcrops was accomplished solely by means of a Paulin altimeter.

**Faunal assemblages.**--The assemblages of organisms collected from the Fox Hills can be placed in several general groups based on the stratigraphic position from which they are collected. If this is done, five groups yielding specific ecological data can be defined.

The lowermost subdivision includes the organisms collected in the basal thirty to forty feet of the Timber Lake Member. It is characterized by the bivalve genera *Crenella, Gervillia, Limopsis, Nemodon, Nucula, Nuculana, and Tellina*. These bivalves occur in association with several gastropods and a single cephalopod, *Scaphites* (*Hoploscaphites*) *nicoletti*. These organisms were collected from concretions in what Waage (1960; 1964) would refer to as the lowermost two concretionary layers of the Fox Hills Formation. The two concretionary levels have not been distinguished in North
this observation should be considered tenuous.

The upper portion of the Timber Lake Member is somewhat less fossiliferous than the lower two portions. In many places the upper part of the member is characterized chiefly by discontinuous ledges of cross-bedded sandstone which are apparently devoid of mollusks. In these areas the only fossils that have been collected in abundance have been burrows of the decapod crustacean *Opromorpha*. This fossil can truly be considered diagnostic of this horizon. In association with *Opromorpha*, two other fossils have been found. The first of these is a single specimen of *Hardouinia waagei*, a cassiduloid echinoid peculiar to the Fox Hills Formation (Holland and Feldmann, 1967). The other fossil collected in association with the rich *Opromorpha* beds is a poorly preserved, unidentified crab.

In other areas of the upper portion of the Timber Lake, generally where *Opromorpha* is less abundant, several other species of bivalves have been collected. Notable among these are *Panopea* and *Tancredia*. These two burrowing clams appear to be restricted to this portion of the formation. Yet a third fossil occurrence in the upper portion of the member is that of oyster banks in a few scattered outcrops in western Emmons County. These oyster beds generally consist of a network of *Crassostrea* shells with a smaller
number of shells including *Anomia* and *Corbicula*. Several other organisms have been collected in association with the oysters, including the gastropods *Polinices* and *Fasciolaria*, sharks' teeth, otoliths, and other vertebrate remains. The oyster shells are very commonly cemented together and give every impression of having formed banks or "reefs" at these localities during the time in which they lived (Plate 2, fig. 5).

The overlying Bullhead Member contains only scattered animal remains. Among these are sharks' teeth, otoliths, and occasional oyster fragments. This is the least fossiliferous member of the Fox Hills in North Dakota, and therefore, the most difficult to define ecologically.

The uppermost unit of the Fox Hills Formation, the Colgate Member, is unfossiliferous in most areas. In some localities in Sioux County, Logan County, and Kidder County, however, oyster banks, similar to those noted in the upper portion of the Timber Lake Member can be observed. At these localities the associations of *Crassostrea*, *Corbicula*, and *Anomia*, along with the gastropods *Polinices* and *Fasciolaria*, are essentially the same as those noted in the upper Timber Lake.

These five subdivisions seem to be separate and distinct enough that they can be considered discrete units when
considering such ecological factors as water depth, type of substrate, salinity, water currents, and temperature. The bivalves in these assemblages do not appear to have been transported any significant distance. Observation of the shells indicates that only a few at any locality indicate any degree of abrasion and, in many cases, conjoined valves are prevalent. This would seem to indicate that the organisms were buried immediately or were moved only slightly following death of the organism. The only exception to this general rule is in the occurrence of Panopea and Tancredia in the upper portion of the Timber Lake Member (Plate 2, fig. 7). These two fossils are rarely found with conjoined valves and in most cases are found with the long axis of the shells parallel to the bedding planes with their concave side down indicating that they have been moved at least slightly. These shells, similar to other shells from the formation, do not show any significant amount of abrasion, although they may show some etching or pitting from chemical action which is perhaps post-depositional.

Transportation of the shells enclosed in the concretions in the lower portion of the Fox Hills Formation could have taken place only if the concretions moved en masse because the vast majority of the shells display conjoined valves. Waage (1964) also suggested very little, if any, transportation of
the concretions.

**Water Depth.**—Several of the fossils collected from the Fox Hills Formation offer excellent indication of the depth of water in which they lived. This is fortunate in that the sedimentological changes in the formation are slight enough that very few conclusions can be drawn from this line of evidence. In general, as one proceeds up the section through the formation, the fossils indicate progressively shallower water until, near the top, the fauna changes from a distinctly marine fauna to one characteristic of brackish water. Although this observation has been made previously (see for example Waage, 1964, p. 542) it has apparently never been thoroughly documented in North Dakota.

Most of the conclusions that can be drawn concerning water depth at the time in which the Fox Hills was deposited must be made from depth records of recent analogs of the bivalve fauna collected from the formation. This information is summarized in Table 1. In addition to the information gathered from the bivalves, supplementary data concerning some of the associated fauna, notably the arthropod *Ophiomorpha* and the echinoid *Hardouinia waagei*, have also been used.

If the Fox Hills is subdivided into the five units discussed above, the gradual decrease in water depth can be illustrated. The lowermost portion of the Timber Lake Member
Table 1. Summary of ecological data on the bivalve genera that are found both in modern environments and in the Fox Hills Formation.

<table>
<thead>
<tr>
<th>Genus</th>
<th>Recent ecology</th>
<th>Morphological criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anomia</td>
<td>Intertidal or shallow, attached to stones or wood (Abbott, 1955, p. 332-477)</td>
<td>Byssus</td>
</tr>
<tr>
<td>Corbicula</td>
<td>Fresh water to .5% salt, sand or mud bottom (Sinclair and Ison, 1963, p. 12 and 13)</td>
<td>Pallial sinus, thick shell, strong hinge</td>
</tr>
<tr>
<td>Crassostrea</td>
<td>0-40 feet of water, fresh to normal salinity, most successful in brackish water (Butler, 1954, p. 479-489)</td>
<td>Cemented, thick shell, strong hinge</td>
</tr>
<tr>
<td>Crenella</td>
<td>3-100 fathoms, Arctic to North Carolina (Abbott, 1955, p. 332-477)</td>
<td></td>
</tr>
<tr>
<td>Limopsis</td>
<td>30-80 fathoms (Keen, 1963, p. 104-108)</td>
<td>Strong hinge</td>
</tr>
<tr>
<td>Nacella</td>
<td>Intertidal to 12 fathoms (Keen, 1963, p. 104-108)</td>
<td>Pallial sinus, strong hinge</td>
</tr>
<tr>
<td>Modiolus</td>
<td>Intertidal to 40 fathoms, attached to rocks or in sand (Keen, 1963, p. 104-108)</td>
<td>byssus</td>
</tr>
<tr>
<td>Nucula</td>
<td>Shallow to 500 fathoms, Labrador to Key West, Florida (Keen, 1963, p. 104-108)</td>
<td>Thick shell, strong hinge</td>
</tr>
<tr>
<td>Panopea</td>
<td>Intertidal, buried in about 3 feet of sand or mud (Keen, 1963, p. 104-108)</td>
<td></td>
</tr>
<tr>
<td>Pteria</td>
<td>Intertidal to 5 fathoms, attached to pilings or objects in the sand (Keen, 1963, p. 104-108)</td>
<td>Byssus</td>
</tr>
<tr>
<td>Tellina</td>
<td>Intertidal to 75 fathoms, in sand or mud (Keen, 1963, p. 104-108)</td>
<td>Pallial sinus</td>
</tr>
</tbody>
</table>
is characterized, at least in part, by three genera which are represented by species in modern oceans. The ecological data available concerning these three genera indicates that the water depth in the area in which they were deposited must have been between 30 and 80 fathoms. The three genera which were used in this determination are Pteria, Crenella, and Limopsis. All three of these genera are commonly found on the east and west coasts of the United States today, and some ecological data are available for them. Pteria apparently lives in water varying in depths from intertidal conditions to several fathoms whereas Crenella is typically found in water varying from 3 to 250 fathoms. The genus which is apparently most restricted in its range is Limopsis. Data provided by Keen (1963) indicate that the vertical range of this genus is between 30 and 80 fathoms. This depth range can then be taken as the approximate limit of depth in which the lower portion of the Fox Hills was deposited.

Higher in the section, near the middle of the Timber Lake Member, evidence for water depth is somewhat less specific although several genera are available from which the determination can be made. This portion of the section is best illustrated by the faunal suite collected at locality 131-78-2 (for a complete list of localities, refer to the appendix) where species Corbula, Pteria, Tellina, Mactra, Nucula, and
Nuculana were collected. Applying the same general procedure used in the previous determination, whereby the range of overlap of all depth data was used, one could conclude that the depth at which the organisms lived varied between ten and seventy-five fathoms. The considerable overlap between this range of depth with that of the basal portion of the unit is not in itself evidence of decreasing water depth. One other observation that is, however, important is the significant increase in the infaunal component of the bivalve fauna over that of the previous portion of the section. All of the bivalves collected at locality 132-76-6, near the base of the formation, were epifaunal, that is they lived on, or were attached to, the surface of the substrate. The organisms collected in the middle portion of the Timber Lake Member, however, were split almost evenly between infaunal and epifaunal species. At this stratigraphic position six species are definitely infaunal components, including Corbula monmouthensis, Tellina scitula, Mactra warrenana, Nuculana scitula, Goniomya americana, and Nuculana bisulcata. The remainder of this fauna, Pteria linguaeformis, Pteria nebrascana, Nucula cancellata, N. planomarginata, N. subplana, and N. emmonsensis are epifaunal organisms. Two other species of the genera Corbulamella and Protocardia, are probably best referred to the infaunal portion of the fossil suite.
It is very possible that the increase in infaunal components of this suite over that of the lower portion of the unit is a response to a somewhat more vigorous, shallower environment.

Depth information concerning the upper portion of the Timber Lake Member is somewhat more varied and perhaps more thoroughly documented. Three independent sources of information are available for determination of the water depth of this particular stratigraphic position. Two rather different suites of bivalve faunas are available from which depth information may be determined. One of these, typified by deposits at locality 134-71-1, contains abundant oyster fragments of the genus *Crassostrea*. This organism is typically associated with such other forms as *Corbicula*, *Pteria*, *Modiolus*, *Tellina*, *Mactra*, and *Nuculana*. A composite of depth information concerning these genera indicates that the water was indeed very shallow if not intertidal. All of the genera mentioned are commonly collected in intertidal water with the exception of *Nuculana*, which has an upper limit in the order of magnitude of three fathoms. Again, the infaunal component of the suite exceeds that of the epifaunal, with eight species occupying the former niche, and six occupying the latter. Of the epifaunal components, four are forms which attach themselves to a substrate by means of a byssus while the two species of *Crassostrea* are forms which cement
themselves to the substrate. If the same organisms were collected in a Recent marine situation there would be no doubt of their shallow water affinities.

A second faunal assemblage collected in the same general stratigraphic position is typified by fossils collected at locality 134-80-1. In this type of assemblage the oysters are absent and a large geoduck, Panopea, is present. Again the indications of depth that are available indicate deposition in water approaching intertidal depth. At this locality six of the nine species collected are infaunal components. Of the remaining three, two were probably attached to the substrate by byssal threads while the third, Nucula planomarginata, is a member of the vagile benthos.

Another species of bivalve commonly collected singly or in association with other organisms at this horizon is Tancredia americana. Although Tancredia is now extinct, morphological features such as a relatively deep pallial sinus and a broad posterior gape indicate that this is also a burrowing form which probably had essentially the same habit as Panopea.

A totally different line of evidence indicating very shallow water conditions during the time of deposition of the upper Timber Lake Member is offered by the decapod crustacean burrow Ophiomorpha. Weimer and Hoyt (1964)
indicated that this fossil is analogous to the recent species *Callianassa major*, which lives in intertidal and shallow neritic water along the east coast of the United States. They concluded (1964, p. 766) that the presence of *Ophiomorpha* indicates deposition in water of shallow neritic or littoral depth. This fossil is extremely important because it very often occurs in areas that are otherwise generally devoid of fossil material. At one locality, however, a single specimen of an echinoid was collected in association with *Ophiomorpha*. This echinoid, *Hardouinia waagei* Holland and Feldmann is a member of the family Faujasiidae, the members of which typically occupy very shallow water. The upper part of the Timber Lake Member, then, is probably the best documented area with regard to water depth with sources of information from bivalves, decapod crustacean burrows, and echinoids.

The Bullhead Member, overlying the Timber Lake Member, is nearly devoid of fossils and, therefore, is difficult to interpret. The only fossil remains that have been thus far identified from this member include sharks teeth, otoliths, and occasional oyster fragments. The only information that could possibly be significant in determining the depth of water in which the Bullhead Member was deposited would be the presence of very shallow, or possibly intertidal, sediments above and
below the unit. This would indicate that it also was deposited in relatively shallow water.

The uppermost portion of the Fox Hills Formation, the Colgate Member, is also generally devoid of fossils. At some localities, however, faunal suites can be collected which include oysters, or oyster fragments, along with the typically brackish-water bivalve Corbicula. At these localities, the only genus that would offer any indication of water depth would be the oyster Crassostrea, which normally lives in intertidal or relatively shallow water. Further, the position of the Colgate Member between marine or brackish-water sediments below and the predominantly terrigenous sediments of the Hell Creek Formation above suggest that the member is a beach deposit.

Substrate.--The character of the substrate must have varied considerably during the time of deposition of the Fox Hills Formation. Evidence for the condition of the substrate of the unit can be gathered from two independent sources, the character of the sediments and the fauna which is associated with the sediments. The basal portion of the Timber Lake Member is characterized by fine to medium-grained sand and silty sand with either horizontal bedding or no bedding at all and probably formed a relatively firm substrate. This interpretation is further strengthened by the observation that
several of the forms collected from this horizon, notably
*pteria linguaeformis*, *Gervillia recta*, and *Gervillia sub-
tortuosa* are forms which probably attached themselves to the
substrate by means of byssal threads. One would presume,
then, that such an attachment would presuppose either a rocky
substrate or a relatively firm, unconsolidated substrate.
There is certainly no evidence for the former condition.
Farther up in the member, the sediment becomes generally
coarser and increasingly more cross-bedding is observed.
This would tend to indicate that the substrate was somewhat
less compacted and more subject to disturbances by wave and
current action. This conclusion is further strengthened by
the abundance of infaunal constituents and the reduction in
number of forms which attach to the substrate by means of
byssal threads.

The upper portion of the Timber Lake is somewhat more
complex. The general presence of cross-bedding indicates
that the substrate was certainly agitated; however, it is
also characterized by a number of epifaunal constituents
which either attached to the substrate by means of a byssus
or by cementing to a relatively firm substrate. Such forms
as *Crassostrea* definitely require a firm, although not rock,
substrate and other forms, such as *Anomia* and *Pteria* again
indicate byssal attachment and, therefore, a substrate that
is somewhat firm.

In the areas in which *Ophiomorpha* is abundant perhaps a somewhat different situation existed. In these areas, one might envision the decapod burrows forming a network or framework which would tend to hold the substrate in place. Although some cross-bedding is also observed in the sequence in association with *Ophiomorpha*, it usually diminishes somewhat in the immediate vicinity of the burrows and becomes more prominent above or below the occurrence of *Ophiomorpha*. This would suggest an environment similar to that seen in the areas of the modern *Phoronopsis viridis* colonies on the California coast. Here, the *Phoronopsis* tubes are densely packed together and form a strong enough framework that the sediment surrounding the tubes is essentially trapped. In many places it can be observed that the surface in the areas of the colonies is elevated above the general surface surrounding them. Observations on *Callianassa major* (Weimer and Hoyt, 1964, p. 763) indicate that these organisms are restricted to "... the well-sorted sand in strongly wave-agitated waters." This conclusion would seem to be analogous with that drawn from other sources concerning the environment in which *Ophiomorpha major* lived.

The substrate in the area in which the Bullhead Member was deposited must have been quite variable in that the unit
consists of a sequence of interbedded sand and shale. If the environment in which this unit was deposited can indeed be interpreted as estuarine or, in some other way, restricted, the presence of the two different lithologic types would presuppose two things. First, a rather distinct change in regimen would be required to explain the alternate influx of fine and relatively coarse-grained materials and second, the presence of well-developed bedding would indicate that at no time were burrowing organisms extremely abundant. The change in regimen might well be corroborated by evidence from the overlying Hell Creek Formation which consists primarily of a sequence of interbedded sands and shales also. If this unit was deposited at the same time that the Bullhead Member was being deposited in some other area, one might assume that the variation in regimen observed in one unit was the result of the same set of circumstances causing changing regimen of the other. The general absence of burrowing organisms, however, is a bit more difficult to explain. That they were absent is strongly indicated by the fact that their activity would certainly have disrupted any bedding characteristics that were formed. It is difficult, however, to locate an analogous situation in the record of recent coastal deposits. Virtually all areas known to the writer are characterized by a profusion of small burrowing organisms. In the case of the
Bullhead sediments, a possible, although tenuous, suggestion could be that the alternating regimen of the environment might well have precluded establishment of a large fauna.

The sediments comprising the Colgate Member are generally cross-beded and in most areas probably formed a rather poorly consolidated beach deposit. In the areas where oyster development has been noted, however, the substrate must have been firm enough that the oysters could attach themselves to the substrate and form successful colonies. Some of the colonies of oysters obtain a maximum thickness of three to four feet indicating that they were certainly successful, at least locally.

**Salinity.**--In the area of deposition of the Fox Hills Formation, salinity varied considerably. All of the organisms collected from the lower and middle portions of the Timber Lake Member that have recent affinities apparently lived in water of normal salinity, that is about 32 parts per thousand dissolved solids. Near the upper portion of the member, however, the association of *Crassostrea* and *Corbicula* indicates conditions of generally reduced salinity. Butler (1954) has summarized the vast amount of literature concerning the occurrence of oysters, and concludes that although oysters tolerate salinities ranging from fresh water to 33 parts per thousand, they are most successful at a salinity of about
15 parts per thousand. This is a result of two factors. Oyster spats are most successful in areas of relatively high salinity, approaching 32 parts per thousand. During breeding, then, the majority of spats would tend to settle in water of near normal salinity and one might then suppose that this would be the area of greatest concentration of oysters. The largest single decimator of oyster populations, however, is predation by other invertebrates, notably gastropods, sponges, and starfish. For this reason, the most successful oyster colonies are not found in areas of normal marine water where these predators would be abundant, but in water of somewhat reduced salinity.

On the other end of the scale, oysters can tolerate extremely reduced salinities in the order of magnitude of zero to ten parts per thousand dissolved solids for only brief periods of time, and are generally not wholly successful under these conditions. It is safe to estimate, then, that the salinity in the area of Fox Hills oyster development would have been about ten to twenty parts per thousand. That oyster predators were present during the deposition of the Fox Hills is demonstrated by the presence of Polynices and Fasciolaria in association with the oysters. These genera have been listed (Butler, 1954; Wells, 1961) as major predators in modern oyster accumulations. Several fragmented oyster shells have also been found which showed considerable boring, possibly
Whether these sponges would have affected the health or vitality of the organism is doubtful.

The upper portion of the Fox Hills yields far less information concerning salinity. The Bullhead Member, devoid of abundant fossils, yields little information about salinity, but the Colgate Member at the top of the formation yields information similar to that for the area of oyster accumulations in the Timber Lake Member. In the Colgate, the association of *Crassostrea*, *Corbicula*, *Fasciolaria*, and *Polynices* indicates situations analogous to those found in the area of the upper Timber Lake Member.

**Currents.**—The only sedimentological evidence for current that has been noted in the Fox Hills is the presence of cross-bedding. It is much more prominent in the upper portion of the Timber Lake Member, increasing both in abundance and magnitude of sets toward the top of the member. In general, the evidence of cross-bedding in association with the fossil data concerning depth of water would indicate that the cross-beds were a result of submarine agitation caused by wave and current action. Generally, the crossbeds dip toward the east, indicating either wave or current source from that direction. This would indicate a general north-south trending shoreline. No detailed work on crossbed orientation has been completed at this time. Bedding observable in the Bullhead Member would
tend to indicate that some current must have been present to transport sediments over the considerable expanse of deposition at any one time, but that it was not strong enough to disrupt any bedding that had previously been formed. The only other evidence for water motion is seen in the abundant cross-bedding of the Colgate Member at the top of the unit. The orientation and general magnitude of the Colgate crossbeds is similar to that present in the Timber Lake Member below.

One other feature that might well be considered a result of some sort of current action is the abundant accumulation of fossils in concretions near the lower portion of the Timber Lake Member. These structures are characterized by an abundant and diverse fauna of mollusks and careful study of the concretions indicates that the orientation of the fossils is generally random. They do not appear to be either bedded or in living positions. This would indicate that, in one way or another, the material had been incorporated into the structure by some technique whereby the organisms were collected in small groups or piles and were later indurated into a dense mass.

The origin of the concretions is in considerable doubt. The latest attempted explanation was that they represent accumulations resulting from a series of mass mortalities (Waage, 1964). Whatever their origin, several facts emerge which are germane to the question of magnitude of currents
in the area in which the organisms lived. First, the organisms collected from the concretions show very little abrasion and are very often found with both valves of the pelecypod conjoined so that if the animals were transported at all, they must have been moved over very short distances. If the concretions themselves had been transported \textit{en masse}, one might suspect that other bedding features would also indicate this water activity. Where concretions are found, however, the bedding is usually either totally absent or confined to relatively horizontal, undisturbed bedding. Therefore, no strong currents are indicated. Finally, depth data for the bivalves in the concretions indicate that the organisms probably lived in relatively deep water. If they were transported any great distance, one might well expect them to reflect a somewhat different ecological setting from that of the sediments in which they are enclosed. Other indications, however, indicate that the lower part of the Timber Lake Member was indeed deposited in relatively deep water and, therefore, the fossil assemblages are consistent with the available sedimentological data. Whatever the cause of their death, one might well concur with Waage (1964, p. 545-546) that the concretions are a result of selective cementation of material around fossil accumulations, precipitated by the relatively large amount of organic matter surrounding the dead organisms. In other words, the concretions were not
transported along the bottom, and, therefore, do not indicate great current action.

**Temperature.**—Only meager evidence is available to suggest the temperature of the water at the time the Fox Hills was deposited. There seems to be a general relationship between number of species and number of individuals collected from warm water as opposed to cold water. Gunter (1957, p. 177) noted that eurythermal organisms tend to be distributed such that far fewer species are found in cold water than in warm water, but each individual species in cold water may be represented by a far larger number of individuals. If this statement could then be applied to the paleontological record as Gunter suggested, it would form rather dramatic evidence that the Fox Hills was deposited in at least relatively cool water. Cursory analysis of two other well studied Upper Cretaceous faunas, the Coon Creek fauna of the Ripley Formation in Tennessee and the Navarro fauna in Texas indicates that the Fox Hills sea must have been somewhat cooler than the seas in either of these areas. Wade (1926, p. 12) reported 114 species of bivalves from a single locality in the Ripley Formation. Stephenson (1941, p. 30) reported 174 species of bivalves from the Navarro Group. These figures contrast strongly with the bivalve fauna from the Fox Hills Formation in North Dakota where only 40 species have been
collected. Ecological data taken from a study of the distribution of recent organisms of the same genera as those collected in the Fox Hills, is not particularly illuminating. Most of the species which have persisted since the Cretaceous are now found in diverse situations ranging from tropical or subtropical waters to arctic water. Only two, Corbula and Limopsis, are generally found in cooler, marine water today. The remainder seem to be relatively tolerant of water temperature, at least on the generic level.

Another bit of evidence concerning water temperature is somewhat more confusing. Gunter (1957, p. 174) has summarized data accumulated by several other workers, and concludes that individuals of a given species tend to be somewhat smaller in tropical water than in temperate or cold water. This generalization is probably also true on the generic level. This information, however, cannot be readily correlated with the data collected from the Fox Hills Formation. Species of certain genera, notably Corbula, Crenella, and Gervillia do appear to be somewhat larger than comparable species in the Ripley and Navarro formations in the southern part of the United States. The remainder of the species, however, appear to be in the same order of magnitude of size as comparable species in these faunas. This evidence would tend to indicate that the water from which the Fox Hills was deposited was
either temperate or cold.

**Facies relationships.**—Throughout the study of the paleoecology of the Fox Hills, one recurrent theme seems to predominate over all other observations. This is the striking change from essentially normal marine conditions near the lower part of the Timber Lake Member to increasingly more shallow water, brackish conditions near the top of the Timber Lake and persisting through the Bullhead and Colgate members. The combination of this evidence along with the gradational nature of the contacts between the various stratigraphic units suggests that the members of the Fox Hills Formation as well as the overlying Hell Creek Formation and underlying Pierre Formation were being deposited at the same time in different areas and that they represent facies of one another. Study in other areas, including that of Waage (1961; 1964), has failed to disclose, however, any indication of the lateral relationships of these units other than the vague reference to facies. Indeed, in his latest work (1964) Waage suggests that the concretion layers to which he refers were everywhere formed at the same time. This would tend to suggest some sort of "pancake" situation rather than the more popular facies picture.

One small bit of evidence, not yet conclusive, suggests that there may be sufficient evidence not only to establish
definite facies relationships between the units of the Fox Hills but also to place them in lateral perspective. This evidence involves the distribution of volcanic ash in the Fox Hills Formation. T. W. Stanton (1917, p. 80-81) first recorded the presence of volcanic ash in the Fox Hills Formation. The exposure which he studied is located in the center of T. 133 N., R. 76 W., just north of Linton in Emmons County. At this locality the ash is extremely well developed and attains a maximum thickness of about 25 feet. Here, as in other areas where the ash has now been located, it is an extremely fine-grained massive unit and contains from 80-90% volcanic glass shards. Just north of Linton, the base of the ash is about 45 feet above the contact of the Pierre Formation (Fisher, 1952, p. 15) and if traced eastward into sec. 6, T. 132 N., R. 75 W. it rests upon sediments which appear to be very near the base of the formation. Fisher (1952, p. 15) indicated that he traced the bed to the southwestern corner of Emmons County where it lies about 15 feet above the top of the lower Fox Hills or the Timber Lake Member. This area is now heavily covered by vegetation and the outcrop is obscured. The ash, however, has been located in Sioux and Morton counties at several localities. An excellent exposure of the ash can be seen in the northwest corner of sec. 21, T. 134 N., R. 79 W. at the top of a small
butte overlooking the Cannonball River in Sioux County. It can also be observed just across the river in Morton County, in sec. 4, T. 135 N., R. 79 W. At these two localities, the ash is enclosed in sediments of the Bullhead Member. Still farther west in sec. 31, T. 134, N., R. 81 W., southeast of Breien, the ash is present at the contact between the Fox Hills and Hell Creek formations.

Petrographic study of the ash by the writer at the locality north from Linton and in the northeast corner of Sioux County indicates that there is very little, if any, difference in the lithology except that the ash in Sioux County is somewhat coarser than that in Emmons County. The ash is thickest near Linton and becomes thinner both to the east and to the west, thinning to about 4 feet in eastern Emmons County and in Sioux County near Breien. As the ash is traced from its easternmost extent to the west, it appears to progress steadily up section in the Fox Hills (Fig. 5).

Two possible interpretations emerge from these data. The first is that the various ash beds represent a series of at least four separate ash falls during the time of deposition of the Fox Hills. The second interpretation is that all of the ash beds represent the same ash fall and, therefore, form a time marker within the unit. Very little evidence supports the first of these hypotheses. Ash is neither repeated in the
Figure 5. Schematic diagram showing geographic and stratigraphic position of volcanic ash from the Fox Hills Formation. 1. Breien, Morton Co.; 2. Eastern Sioux Co.; 3. Southeastern Emmons Co. (Fisher, 1953); 4. Linton, Emmons Co.
section nor are deposits of ash randomly distributed in the formation. Rather, they progress steadily up section from east to west. At present, then, it would seem most likely that the ash beds represent accumulations of debris from one event of volcanism and that the discontinuity of the beds is a function primarily of area of deposition. Without more careful mineralogical investigation and, perhaps, subsurface tracing, the hypothesis would have to be considered somewhat tenuous. It does, however, lead to some rather interesting speculation in that, if the assumption of penecontemporaneity is true, one has an accurate means of determining the lateral extent of each of the facies of the Fox Hills Formation. At the time when the ash fall occurred, the strand line marking the contact between the terrigenous sediments of the Hell Creek and the marine and brackish-water sediments of the Fox Hills would have been located in the vicinity of Breien and the lower contact of the Fox Hills would have been in the area of eastern Emmons County so that the total width of deposition of Fox Hills-type sediments would have been about 40 to 50 miles.

Synthesis.--The Fox Hills Formation would appear to represent a sequence of beds deposited in the littoral and sub-littoral zone of a regressive seaway. It is intimately related to the deposition of the Hell Creek and Pierre formations with
the Hell Creek representing alluvial deposits of the coastline bordering the Cretaceous seaway and with the Pierre Formation representing somewhat deeper water deposition adjacent to the area of deposition of the Fox Hills (Fig. 6). The maximum water depth suggested by fossils near the base of the Fox Hills Formation was about 30-80 fathoms whereas fossils near the top of the Timber Lake Member and in the Colgate Member suggest deposition in either littoral or very shallow, sub-littoral conditions.

The general picture that emerges concerning the environments in which the various members of the Fox Hills were deposited is as follows. The Colgate Member seems to represent intertidal or very shallow water, perhaps a beach deposit, which in various localities supported a very profuse oyster growth. Farther offshore, the Bullhead Member was deposited in what must have been a rather brackish-water lagoonal, or estuarine environment. Presence of oysters in both the Colgate Member and the upper part of the Timber Lake Member would tend to support this suggestion.

Restriction of water circulation in the area in which the Bullhead Member was deposited was effected by the presence of an off-shore bar which is presently represented by the shallow water deposits of the upper Timber Lake Member. Presence of Ophiomorpha as well as Haradouinia and abundant oyster deposits
Figure 6. Hypothetical cross-section through Cretaceous sediments deposited in central North Dakota during the Maestrichtian. Total east-west distance about 100 miles. Vertical scale greatly exaggerated. Inset shows geographic distribution of same units. A = Hell Creek Fm. B = Colgate Mem. C = Bullhead Mem. D = Timber Lake Mem. E = Pierre Fm.
suggest the shallow water conditions. Cross-bedding in this same part of the stratigraphic section suggests moderate wave and current action.

The remainder of the Fox Hills Formation, the lower part of the Timber Lake Member, was deposited in increasingly deeper, less agitated water, indicated by the gradual disappearance of cross-bedding and the general decrease in grain size toward the bottom of the section. Finally, near the base of the Fox Hills, the sand which had been transported from the adjacent coastline was winnowed out and the finer grained silt and clay sediments were deposited as Pierre sediments.

The lagoonal situation represented by the Bullhead Member is not everywhere observed. In the western part of the state, along the Cedar Creek anticline no such beds were observed, and one might infer that in this case the Colgate Member represented beach and sub-beach deposits, and the Timber Lake sediments again represent offshore and gradually deepening conditions.

As the margin of the seaway progressed eastward and the seaway retreated, sediments of the various environments of deposition overlapped one another, yielding the stratigraphic section now observable. The only indication of the greatest extent of retreat of the Fox Hills seaway can be seen in the area of Verendrye, North Dakota, where Lemke (1960, p. 24)
suggested that the Fox Hills Formation can be found directly underlying the Cannonball Formation. If this interpretation is true, one might then suggest that the Fox Hills sea retreated as far northeastward as north-central North Dakota at which time the minor transgression of the Cannonball sea, of Paleocene age, began. Considerable careful study of the subsurface relationships of these two units in the area of Verendrye must be undertaken, however, before a definite statement in this regard can be made.

Although no evidence is available which would indicate the total length of time in which Fox Hills deposition took place in North Dakota, it must have been relatively brief. Study of the fossils in vertical section through the unit indicates very little, if any, evolutionary change in forms, but rather indicates changes in environments of deposition. The extinction of organisms and evolution of new species that can be observed are found when the Fox Hills is traced to the west into Wyoming and Colorado. Sufficient time for evolutionary change was apparently not available during the time of Fox Hills deposition in North Dakota.
Collection and preparation.--Fossil collections were made during the summers of 1962 through 1964, while the writer was employed by the North Dakota Geological Survey. In 1962, a field trip was taken into the type area of the Fox Hills. Under the leadership of Dr. K. M. Waage, Associate Professor of Geology at Yale University, and accompanied by Dr. F. D. Holland, Jr., Professor of Geology at the University of North Dakota, and C. I. Frye, University of North Dakota graduate student, I studied the stratigraphic and paleontologic details of the type area. Particular attention was given to the mode of occurrence and distribution of fossils in the sequence. At the same time, a small collection of fossils from the type area was obtained.

Following the study of the type area, I proceeded to traverse the areas of known exposure of the Fox Hills Formation in North Dakota. The summer of 1962 was spent entirely in Emmons County where the formation is exposed over the broadest area and is most fossiliferous. The following summers were spent in the remaining areas of outcrop throughout the state. During this period, all exposures identified as containing Fox Hills rocks were visited and
collected. A total of 151 sites was well enough exposed to merit study and collection.

Most of the fossils collected represented material that had weathered out of the outcrop and was lying free on the surface. This was not considered particularly disadvantageous, however, as most of the outcrops were of such limited vertical extent that the position of the fossils in the sequence could be determined with reasonable accuracy. Where fossils were found in place in the unit, observations were made concerning their orientation and relative abundance. In all cases, the stratigraphic horizon was determined, as closely as possible, and complete collections of the fauna were made.

Most of the fossils were collected in bulk, little or no preparation being attempted in the field. The specimens were returned to the paleontology laboratory at the University of North Dakota, where the specimens were cleaned and sorted.

A Bendix sonic cleaner was used to remove relatively loose material from the surface of fossils that were not collected in well indurated sediment and were not subject to damage by wetting. An S. S. White Dental Airdent Unit was also employed in an attempt to remove more tenacious material from the shells. It was, however, not very effective on Fox Hills material because the fossils were either so delicate that the air stream destroyed the prosopon, or the matrix
and shell material were of equal hardness and no selective cutting was possible. This instrument was most valuable in removing the few sand grains remaining on an otherwise well preserved specimen.

The most universally applied tool for cleaning the specimens was a portable dental drill with carbide bits. It could be used to remove sandy material from shells as well as to dissect limestone concretions to within about one millimeter of the enclosed fossils.

Material that remained on the specimens following the above procedures was removed with a Vibro-tool and dental picks under a binocular microscope.

Several of the fossils that were collected from limonite-cemented concretions were preserved as molds, with a very small amount of calcareous material adhering to the mold. These specimens were prepared by carefully dissolving away the calcareous material with dilute hydrochloric acid.

**Taxonomic procedures.**—The bivalves that were collected from the Fox Hills Formation were identified and described using, as a basis for identification, such standard works on the Cretaceous and Paleogene as Meek (1876), Stanton (1920), Stephenson (1941), and Richards (1958). The specimens were then re-evaluated using every taxonomic work known to the writer which made reference to the group in question. In
this manner, it is hoped that the most correct and modern interpretation has been established for each of the taxa, short of complete revision of each of the taxonomic groups. Specimens were then compared with material at the Philadelphia Academy of Science.

Suprageneric assignment of the species collected from the Fox Hills Formation was made according to the classification presented by Thiele (1929-1935). This system was used both because it seems to be in general accord with modern paleontologic usage and because the majority of criteria used by Thiele are observable on fossil material. Problems of suprageneric placement were, in general, beyond the scope of this work.

Generic placement was based on study and consideration of taxonomic revisions of family- and genus-groups. The merits of these modern revisions is discussed under the remarks concerning usage of each of the generic names. In general, it can be said that prevailing generic usage has been followed as closely as possible. When divergent opinions arose, the classification which was based on the most stable morphologic features was selected. In some cases, such as the Nuculidae, none of the present schemes of arrangement cover all of the morphologic types found in the Fox Hills fauna. In those instances the most nearly
applicable classification was selected and appropriate reservations were stated.

Principles governing assignment of trivial names to specimens, although implicit in the remarks concerning the individual species, deserve comment here. Considerable care must be exercised when deciding the latitude of intraspecific variation. It is, therefore, not enough to define one's concept of a species in terms of morphological similarity, genetic affinity, fecundity, or statistical unity. Although all of these factors must be considered when framing a working definition of a species, it is also important to consider the limits, or perhaps the latitude, which bound each of these characteristics.

Morphological similarity suggests that all members of a given species must share certain morphological characteristics. This philosophy is best illustrated by the strict typological approach. Upon analyzing this approach, however, it becomes immediately obvious that no other specimen ever collected will exactly match the features observable on the type specimen. At this point, then, some consideration of the latitude of similarity must follow.

In similar manner, genetic similarity must be defined on the basis of limits of variation because no two organisms possess precisely the same genetic material. Although the
implications of genetic variability form the foundation of the modern concept of speciation, the genetic composition of fossil organisms is virtually impossible to determine. For the paleontologist, then, the most significant aspect of the study of genetics is the understanding that much of the individual morphological variation mentioned above is a result of slight genetic variability. One must attempt to distinguish between slight genetic fluctuations, environmentally controlled morphological variations, and definite shifts in the genetic composition of a population. It is the last factor mentioned that must be considered when separating individuals into distinct species.

The ability of organisms to produce viable offspring has also been used to define the boundaries of species. Again, some latitude must be allowed in that all members of a species do not interbreed with all other members of that group. Rather, individuals of a given species should interbreed more or less at random so that the genetic composition remains relatively stable. This aspect of the concept of species is not available for paleontological investigation and the assumption is made, therefore, that a group of "morphologically similar" organisms that occupied the same area at the same time probably shared a common genetic pool.

Statistical analysis of fossil groups is nothing more
than a sophisticated method of arriving at morphological variation. The use of statistics demands that some variability exist in the character which is studied. Immediately upon embarking on a statistical study, therefore, one must define or determine the limits of variability that will be considered allowable within a species group. Limits can be established on either philosophical or statistical grounds. The philosophical approach, possibly less scientific than the statistical, involves selecting the degree of variation that will be tolerated within the framework of the species and then testing individuals to determine whether or not they conform to the limits as defined. The statistical approach is, however, not necessarily the more scientific. This technique would involve measuring parameters on many individuals, comparing them to one another, and statistically determining their degree of relatedness.

Several problems arise, however, when attempting to determine statistical unity without arbitrarily establishing limits of variation. Such a study will immediately be biased by the selection of the specimens to be studied. By making the decision that some of the specimens "obviously" did not belong to the species in question, the worker might well exclude part of the hypodigm from consideration. On the other hand, by studying all available specimens that might possibly
belong to the species, the worker might extend the limits of variability to the point that the character would be considered to be too variable to be taxonomically significant.

Therefore, when using statistical evaluation, the taxonomist must constantly bear in mind that the organisms being studied had no set intention of forming a mathematically unified group. It is a convenient means of describing and defining natural, genetically related groups of organisms. When statistics are used for any other purpose they tend to become an end, rather than a means to an end.

Another factor must be considered when dealing with fossil species, the factor of geological longevity of species. As with the amount of acceptable morphological variation, a cursory search of modern paleontological literature will reveal considerable difference of opinion. Some workers believe that the geological range of individual species is very short. If two groups of organisms are separated by a relatively short time interval, such as an epoch, this school would consider them two different species. This leads to the problem of having two separate species which are virtually indistinguishable on morphological grounds. Other workers hold that fossil species can be nothing more than morphologically definable groups and, therefore, should have little, if any, temporal restriction. Neither of these viewpoints seems
to be entirely satisfactory. Until satisfactory quantitative data are available to determine rates of evolution within a particular taxon, we might well adopt the course that species must remain morphologically distinguishable units that cannot be discontinuous in time. If the time interval that separates two fossil occurrences is considerably greater than an epoch, this temporal separation might well be considered to be due to an actual discontinuity between the two groups rather than strictly bias introduced by insufficient collecting.

With these factors and limitations in mind it is possible to consider a definition of species which seems to embrace the ideas and still remain functional. Perhaps the definition that best meets these requirements is that of Weller (1961, p. 1191-1192). He considers a species to be a group of organisms,

... consisting of a natural continuing population of individuals presumably closely related to each other and generally similar morphologically, that is distinct and distinguishable from all other contemporaneous populations, and separated from related ancestral and descendant populations at some convenient but arbitrarily selected boundaries.

Although the statement is a bit ponderous, it carefully expresses the framework in which one must place the concept of the species. It is this general philosophy which has governed the taxonomic decisions made herein.
Format of descriptions.--All of the species of bivalves collected from the Fox Hills Formation have been described using a format that follows a definite arrangement. This has been done to facilitate locating the remarks about a particular aspect of morphology.

Each of the species descriptions is preceeded by a generic diagnosis which characterizes the genus as it is used in this paper. If there are any points of divergence between the diagnosis and the concept of the genus as expressed herein, the differences are remarked upon following the diagnosis.

The synonymies that introduce each of the species description are in no way meant to be absolutely comprehensive. The purpose of the synonymies is to introduce all known name combinations that have been applied to the organisms as well as to list publications in which specimens that can be referred to the species have been illustrated.

The main body of the descriptive text includes the original description as well as a description of the specimens that have been collected from North Dakota and have been referred to the species. The form of the description of the Fox Hills material is arranged in a standard manner throughout. General features of size and thickness are presented first, followed in order by descriptions of shell outline, nature of
the hingement, musculature, pallial features, prosopon, and any special features that might be recognized on the specimens.

Following the description of the material, measurements of the most important dimensions of the specimens are given in tabular form. The dimensions are presented in one of three ways. If very few specimens are available, the dimensions of each specimen are listed individually. If a large number of specimens is available, the measurements are presented as the mean value. In a few cases, enough specimens were available so that some statistically valid mathematical analyses could be performed. In these instances the data form the basis of a somewhat more lengthy discussion. In no cases should the measurements be taken to be more than a convenient means of adding to the descriptive material concerning the species. All measurements are taken in millimeters.

Each of the species discussions is concluded by a series of remarks about the diagnostic characteristics, taxonomic placement, and geological occurrence of the species. These remarks do not, in general, include ecological data related to the species as this is more logically treated in the section devoted to that subject and is not normally related to problems of taxonomy.

Summary of results.--A total of 42 species of bivalves
were collected and described from the Fox Hills Formation in North Dakota. These species were distributed in 25 genera and 21 families. Of the 42 species, three have been referred to different genera, four represent new reports from the Fox Hills Formation, and three, *Nucula emmonsensis*, *Modiolus siouxensis*, and *?Astarte hollandi*, represent new species. A systematic list of the bivalves collected from the Fox Hills of North Dakota is given in Table 2.

A total of 72 distinct localities produced Fox Hills bivalves in North Dakota. Distribution of the fossils according to the localities from which they were collected is given in Table 3. As the organisms were tabulated according to locality, an estimate of their abundance was made by noting the number of specimens collected at each individual outcrop. The results of this estimate are also indicated on Table 3.
Table 2. Systematic list of the species of bivalves collected from the Fox Hills Formation in North Dakota.

Phylum: MOLLUSCA
Class: BIVALVIA
Order: TAXODONTA
Superfamily: NUCULOIDEA
Family: NUCULIDAE
Genus: Nucula
   Nucula planomarginata Meek and Hayden
   Nucula subplana Meek and Hayden
   Nucula obsoleta striata Meek and Hayden
   Nucula emmonsensis n. sp.
Subgenus: Nucula (Pectinucula)
   Nucula (Pectinucula) cancellata Meek and Hayden
Family: NUCULANIDAE
Genus: Nuculana
   Nuculana scitula (Meek and Hayden)
   Nuculana bisulcata (Meek and Hayden)
   Nuculana evansi (Meek and Hayden)
   Nuculana tarensis (Gardner)
Superfamily: PARALLELODONTOIDEA
Family: PARALLELODONTOIDEA
Genus: Nemodon
   Nemodon sulcatinus (Evans and Shumard)
Family: LIMOPSIDAE
Genus: Limopsis
   Limopsis striatopunctatus Evans and Shumard
Family: CUCULLAEIDAE
Genus: Cucullaea
Subgenus: Cucullaea (Idonearca)
   Cucullaea (Idonearca) shumardi Meek and Hayden
Order: ANISOMYARTA
Superfamily: MYTILOIDEA
Family: MYTILIDAE
Genus: Modiolus
   Modiolus galpinianus (Evans and Shumard)
   Modiolus siouxensis n. sp.
Genus: Crenella
   Crenella elegantula Meek and Hayden
   Crenella elegantula Meek and Hayden
Superfamily: PTERIOIDEA
Family: PTERIIDAE
Genus: Pteria
   Pteria linguaeformis (Evans and Shumard)
   Pteria nebrascana (Evans and Shumard)
Table 2. Continued.

Family: ISOGNOMONIDAE
Genus: Gervillia
  Gervillia recta Meek and Hayden
  Gervillia subtortuosa Meek and Hayden
Superfamily: PECTINOIDEA
Family: PECTINIDAE
Genus: Syncyclonema
  Syncyclonema halli
Superfamily: ANOMIOIDEA
Family: ANOMIIDAE
Genus: Anomia
  Anomia micronema Meek
Superfamily: OSTREAOIDEA
Family: OSTREIDAE
Genus: Crassostrea
  Crassostrea glabra (Meek and Hayden)
  Crassostrea subtrigonalis (Evans and Shumard)
  Crassostrea pallucida (Meek and Hayden)
Order: BULAMELLIBRANCHIATA
Superfamily: ASTARTOIDEA
Family: ASTARTIDAE
Genus: Vetericardia
  Vetericardia crenalirata (Conrad)
Genus: ?Astarte
  ?Astarte hollandi n. sp.
Superfamily: SPHERIOIDEA
Family: CORBICULIDAE
Genus: Corbicula
  Corbicula cytheriformis (Meek and Hayden)
  Corbicula moreauensis (Meek and Hayden)
Superfamily: CARDIOIDEA
Family: CARDIIDAE
Genus: Cardium
  Subgenus: Cardium (Ethmocardium)
  Cardium (Ethmocardium) whitei Dall
Genus: Protocardia
  Subgenus: Protocardia (Leptocardia)
  Protocardia (Leptocardia) subquadra (Evans and Shumard)
Family: VENERIDAE
Subfamily: SUNETTINAE
Genus: Dosiniopsis
  Dosiniopsis deweyi (Meek and Hayden)
Table 2. Continued.

Superfamily: MACTROIDEA
   Family: MACTRIDAE
       Genus: Mactra
            Mactra warrenana Meek and Hayden
            Mactra formosa Meek and Hayden

Superfamily: TELLINOIDEA
   Family: TELLINIDAE
       Genus: Tellina
            Tellina equilateralis? Meek and Hayden
       Subgenus: Tellina (Eurytellina)
            Tellina (Eurytellina) scitula Meek and Hayden
            Tellina (Eurytellina?) cheyennensis Meek and Hayden

Family: TANCREDIDAE
   Genus: Tancredia
        Tancredia americana (Meek and Hayden)

Superfamily: LATERNULOIDEA
   Family: PHOLADOMYIDAE
       Genus: Goniomya
        Goniomya americana (Meek and Hayden)

Superfamily: MYOIDEA
   Family: HYATELLIDAE
       Genus: Panopea
        Panopea occidentalis Meek and Hayden

   Family: CORBULIDAE
       Subfamily: CORBULAMELLINAE
           Genus: Corbulamella
            Corbulamella inornata (Meek and Hayden)
       Subfamily: CORBULINAE
           Genus: Corbula
            Corbula monmouthensis Gardner
Table 3. List of bivalve species, by locality, collected from the Fox Hills Formation, with estimates of abundance. A = abundant, 10 or more specimens; C = common, 3-10 specimens; R = rare, 1-2 specimens; F = fragments only.

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>H</th>
<th>N</th>
<th>C</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nucula cancellata</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Nucula planomarginata</td>
<td>R</td>
<td>C</td>
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<td></td>
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<tr>
<td>Nucula obsoletastrita</td>
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<tr>
<td>Nucula emmonsensis</td>
<td>X</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nucula subplanani</td>
<td></td>
<td>X</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>Nuculana scitula</td>
<td>A</td>
<td>R</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Nuculana bisulcata</td>
<td>X</td>
<td>R</td>
<td></td>
<td></td>
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<tr>
<td>Nuculana evansi</td>
<td></td>
<td>R</td>
<td></td>
<td></td>
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<tr>
<td>Nuculana taresis</td>
<td>X</td>
<td>R</td>
<td></td>
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<tr>
<td>Memodont sulcatus</td>
<td>X</td>
<td></td>
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<tr>
<td>Limopsis striatopunctatus</td>
<td></td>
<td>C</td>
<td></td>
<td></td>
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<tr>
<td>Cucullaea shumardi</td>
<td></td>
<td>C</td>
<td></td>
<td></td>
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<tr>
<td>Modiolus galpinianus</td>
<td>X</td>
<td>R</td>
<td></td>
<td></td>
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<tr>
<td>Modiolus siouxensis</td>
<td>X</td>
<td>C</td>
<td></td>
<td></td>
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<tr>
<td>Crenella eleganta</td>
<td>X</td>
<td>C</td>
<td></td>
<td></td>
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<tr>
<td>Pteria linguiformis</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>C</td>
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<tr>
<td>Pteria nebrascana</td>
<td>X</td>
<td>C</td>
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<tr>
<td>Gervilla recta</td>
<td>X</td>
<td>C</td>
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<td></td>
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<tr>
<td>Gervilla subtortuosa</td>
<td>X</td>
<td>C</td>
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<tr>
<td>Pecten halli</td>
<td>X</td>
<td>C</td>
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<tr>
<td>Anomia micronema</td>
<td>X</td>
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<tr>
<td>Crassostrea glabra</td>
<td>X</td>
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<tr>
<td>Crassostrea subtrigonalis</td>
<td>X</td>
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<tr>
<td>Crassostrea pellucida</td>
<td>X</td>
<td>C</td>
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<td>Vetricardia crenalirata</td>
<td>X</td>
<td>C</td>
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<td></td>
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<tr>
<td>?Astarto hollii</td>
<td>X</td>
<td>C</td>
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<td></td>
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<tr>
<td>Corbicula cytheriformis</td>
<td>X</td>
<td>C</td>
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<tr>
<td>Corbicula moreaensis</td>
<td>X</td>
<td>C</td>
<td></td>
<td></td>
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<tr>
<td>Cardium whitei</td>
<td>X</td>
<td>C</td>
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<td></td>
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<tr>
<td>Protocardia subquadrata</td>
<td>X</td>
<td>C</td>
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<td></td>
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<tr>
<td>Dosiniopsis deweyi</td>
<td>X</td>
<td>C</td>
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<tr>
<td>Mactra warrenana</td>
<td>X</td>
<td>C</td>
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<tr>
<td>Mactra fornsa</td>
<td>X</td>
<td>C</td>
<td></td>
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<tr>
<td>Tellina equilateralis</td>
<td>X</td>
<td>C</td>
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<tr>
<td>Tellina scitula</td>
<td>X</td>
<td>C</td>
<td></td>
<td></td>
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<tr>
<td>Tellina cheyennensis</td>
<td>X</td>
<td>C</td>
<td></td>
<td></td>
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<tr>
<td>Tancredia americana</td>
<td>X</td>
<td>C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Panopea occidentalis</td>
<td>X</td>
<td>C</td>
<td></td>
<td></td>
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<tr>
<td>Goniosia americana</td>
<td>X</td>
<td>C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corbulamae inornata</td>
<td>X</td>
<td>C</td>
<td></td>
<td></td>
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<tr>
<td>Corbulamae monmouthensis</td>
<td>X</td>
<td>C</td>
<td></td>
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</tr>
</tbody>
</table>
SYSTEMATIC DESCRIPTIONS

Phylum: MOLLUSCA
Class: BIVALVIA
Order: TAXODONTA
Superfamily: NUCULOIDEA
Family: NUCULIDAE

Remarks.--The family Nuculidae has undergone such a large number of classification changes in recent years that a few comments are necessary to thoroughly understand the placement of the Fox Hills specimens. Early classifications of the family were excellently summarized by Schenck (1934). He proposed a classification of the Nuculidae which was based on marginal denticulations, surface prosopon, and nature of the hinge. This classification was generally accepted with a few subsequent modifications until recently.

In 1955, Van de Poel restudied the group and concluded (p. 1-2);


He then suggested that a more basic character could be used in nuculid classification than any others previously studied.
He noticed that all shells referable to the family could be subdivided into two groups on the basis of shell structure.

The first group includes the type species of the genus, *N. nucleus*. This group is characterized by having the ostracum formed of a series of baguettes, or bundles, or calcite. The second group displays no such structures. As opposed to many of the other taxonomic characteristics previously used, the structure of the ostracum apparently is consistent throughout groups that have traditionally been recognized. The two groups were considered genera; the first, *Nucula*; the second, *Nuculoma*. Although the change results in rearrangement of some of Schenck's genera and subgenera, most of the same basic taxa are used.

The present study of the Fox Hills nuculids indicates that only one of the species, *Nucula cancellata*, can be referred to any of Schenck's taxa with confidence. There are, for example, nuculids which have radial prosopon and other characteristics of *Nucula*, s.s., but these do not have a denticulate ventral margin. On the other hand, not all of the specimens can be placed in the subgeneric categories suggested by Van de Poel. Having surveyed the description of subgenera referred to the genus *Nucula* by Van de Poel, it becomes apparent that none of the groups admit to species with a striated ostracum and a smooth ventral margin. Further, none of the subgenera of *Nuculoma* have strongly
serrate ventral margins. *Nuculoma* (*Ennucula*) may have a weakly crenulate margin but it is so poorly developed that in Iredale's original description of the group (1931, p. 202) the margin was described as "nearly smooth".

It is evident, then, that the classification suggested by Van de Poel solves very few of the problems inherent in Schenck's classification. The generic units presented in Van de Poel's study, however, seem to be based on somewhat more fundamental features than do those of Schenck and will be used herein. The Fox Hills species, with the exception of *Nucula cancellata*, will not be assigned to subgenera because it appears that further work will have to be done on this level before proper assignments can be made.

**Genus: Nucula Lamarck**


*Type species.*—*Arca nucleus* Linnaeus, by monotypy.

*Description.*—Shell nacreous, to about 40 mm long, weakly to strongly inflated, trigonal or oval, inequilateral, not gaping. Umbones posterior (at 0.70 to 0.75 of length), appressed, opisthogyrate. Anterior end rounded to narrowly rounded to cuneiform. Posterior end broadly rounded to subangular. Ventral margin arcuate. Lunule and escutcheon not sharply defined; lunule narrow and elongate, escutcheon cordiform and short.

Hinge arcuate, bearing two series of crowded, chevron-
shaped teeth; anterior series longer, posterior series shorter. No external ligament; resilifer narrow, sub-triangular, inclined obliquely forward and downward. Adductor muscle imprints subequal, inconspicuous; pallial line entire.

Sculpture of radial or concentric costae or of subcutaneous radial lineations; inner margin crenulate. (Stenzel, Krause, and Twining, 1957, p. 43)

Remarks.--The above diagnosis of the genus is generally consistent with those given by other authors but should probably be altered slightly to be consistent with the classification of Van de Poel (1955). The only necessary addition would be to state that subcutaneous radial lineations are always present and that the inner margin may or may not be crenulate.

Subgenus: Pectinucula Quenstedt

Type reference.--Quenstedt, 1930, Geol. u. Palaon. Abh, n. f., Bd. 18, Heft 1, p. 112.

Type species.--Nucula pectinata (Sowerby) by original designation.

Diagnosis.--Nuculid pelecypods with crenulate ventral margins and strongly ribbed radial prosopon which generally does not cross the well-defined escutcheon or the weakly-outlined lunule.

Remarks.--This subgenus is apparently readily distinguished from other members of the genus Nucula on the basis
of the strong radial ribs. The type species and its close relatives are apparently widely distributed throughout the Cretaceous (Schenck, 1934, p. 24).

**Nucula (Pectinucula) cancellata** Meek and Hayden

Pl. 4, figs. 36-38

**Nucula cancellata** Meek and Hayden, 1856, Acad. Nat. Sci. Philadelphia, Proc., v. 8, p. 85; Meek, 1876, U.S. Geol. Survey Terr., v. 9, p. 102, pl. 28, fig. 13.

**Nucula (Pectinucula) cancellata** Meek and Hayden, Shimer and Shrock, 1944, p. 375, pl. 145, fig. 34.

**Original Description.**—Shell rather large and thick, ovate or subtriangular, ventricose, pearly within; anterior end short, obliquely truncate, posterior end longer, narrowly rounded; umbonal region gibbous; beaks somewhat elevated, slightly incurved; escutcheon lanceolate; lunule ovate, flattened, but scarcely impressed; surface ornamented by numerous flatly rounded, simple, closely arranged, radiating costae, which are crossed by small, irregular, concentric wrinkles, and finer indistinct lines of growth; border neatly crenulated. Length .93 inch; breadth .50 inch; height .65 inch.

**Locality and position.**—Moreau River, No. 5 of the series. (Meek and Hayden, 1856, p. 85)

**Description of material.**—Shell small to medium sized for the genus; ovoid or subtrigonal, moderately inflated, thin-shelled; anterior margin smoothly rounded; posterior margin slightly truncated, shorter than anterior margin, nearly straight; ventral margin smoothly and gently curved;
dorsal margin slopes anteriorad from the beaks in a nearly straight line and posteriorad from the beaks in a slightly concave curve; beaks posteriorad from the midline, inturned, elevated above the hinge, strongly opisthogyral; hinge long, divided at the beaks by a well-defined angle, taxodont; anterior series with about 14 teeth which become smaller near the beaks; posterior series with about 8 teeth which become only slightly smaller toward the beaks; chondrophore unknown; adductor muscle scars well-defined; posterior adductor ovoid small; anterior adductor slightly elongated dorsally, larger than posterior adductor and defined on the posterior margin by an arcuate ridge; median muscle scar about six times as long as wide, extending from just anteriorad of the beaks to the umbonal area; central muscle scar small, round, located anterio-ventrad from the ventral termination of the median muscle scar; four small punctiform muscle scars anteriorad from the central muscle scar; pallial line poorly defined, entire; surface marked by fine growth striae and stronger radial costae which do not seem to be developed on the lunule and escutcheon; costae are parallel to and lie directly upon the bundles, or rods, of calcite that make up the ostracum; inner margin of the shell denticulate.

**Remarks.**—This distinctive nuculid is the only species in the Fox Hills Formation which has a crenulate margin,
rod-like ostracum, and costate surface. In these respects it is similar to *N. pectinata*, the type species of the subgenus. This similarity was first noticed by Meek (1876, p. 85). According to Schenck (1934, p. 23), however, the latter has ribs which are about equal in width to the interspaces, whereas those of *N. cancellata* are much wider than the interspaces. Further, the escutcheon of *N. pectinata* is better defined and more distinct than that of *N. cancellata*.

Most nuculids are characterized by having a number of accessory muscles located in the umbonal area. Although no mention of their function has been noted, it is probable that they are associated with movement and adjustment of the foot. The terminology of these muscles has been suggested by Odhner (in Schenck, 1934, p. 21).

**Measurements.**—Three parameters were measured on all specimens that were well enough preserved to show at least two of the parameters. No mean could be determined for the thickness as only one specimen was available for measurement.

<table>
<thead>
<tr>
<th>Height</th>
<th>Length</th>
<th>Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.0</td>
<td>15.5</td>
<td>11.1 (both valves)</td>
</tr>
<tr>
<td>n=4</td>
<td>n=4</td>
<td>n=1</td>
</tr>
</tbody>
</table>

**Types.**—Hypotypes, University of North Dakota Cat. Nos. 9203 and 9204.

**Localities and stratigraphic position.**—Specimens were collected from the Timber Lake Member of the Fox Hills Formation at localities 129-78-6 and 131-78-2.
Nucula planomarginata Meek and Hayden

Pl. 4, Figs. 33-35, 41 & 42


Nucula planimarginata Meek and Hayden. Meek and Hayden, 1860, Acad. Nat. Sci. Philadelphia, v. 12, p. 429; Meek, 1876, U.S. Geol. Survey Terr., v. 9, p. 101, pl. 15, fig. 8 and pl. 28, fig. 16; Stanton, 1920, U.S. Geol. Survey, Prof. Paper 128, p. 19, pl. 1, figs. 2 & 3; Shimer and Shrock, 1944, p. 375, pl. 145, fig. 35.

Original description.—Shell ovate, somewhat compressed, pearly within; anterior end very short, obliquely truncate; posterior end long and narrowly rounded, dorsal and ventral margins forming, from the beaks backwards, elliptical curves; beaks much elevated; surface unknown; muscular impressions faint; border smooth. Length .95 inch; height .60 inch; breadth .26 inch.

We have only seen internal casts of this species, the shell being always left adhering to the matrix, from which we infer the surface was ornately marked. It may be at once distinguished from the last [N. cancellata] by its more compressed form and smooth border.

Locality and position.—Same as last. [Moreau River, No. 5 of the series] (Meek and Hayden. 1856, p. 85)

Description of material.—Shell moderately large for the genus, subtrigonal, moderately thick shelled, compressed; anterior margin rather tightly rounded with a minor angulation
formed at the point of junction of the anterior and dorsal margins; posterior margin declines obliquely from the beaks and is nearly straight along the length of the posterior tooth row, below which a small convex protuberance marks the smooth junction with the ventral margin; ventral margin smoothly rounded, becoming more tightly rounded along the anterior third of its length; dorsal margin smoothly and evenly convex from the beak to the junction of the anterior margin; beaks small, elevated above hinge, opisthogyral; hinge well defined but not significantly thickened, anterior portion with about 23 teeth which are triangular in dorso-ventral profile and are inclined with the apex slightly directed toward the beaks resulting in a chevron appearance, the anterior 19 teeth are uniform in size while the posterior four or five, located above the chondrophore, decrease in size toward the beak; posterior teeth, similar to the anterior ones in size and shape, total 12, and do not decrease in size toward the beak but terminate abruptly against the chondrophore; ligament internal, seated in an arcuate chondrophore which is narrow near the beaks and broadens abruptly near the internal edge of the tooth row; the axis of the chondrophore is strongly directed toward the anterior of the shell; adductor muscle scars well developed, the posterior one relatively small, located near the margin at the base of the tooth row and
deeply impressed into the shell along its anterior edge; anterior scar larger, nearly circular and less deeply impressed; median and central muscle scars deeply impressed, located along the dorso-ventral midline; three deeply impressed punctiform scars located in a line from central scar to anterior adductor scar; the interior surface is smooth and nacreous in well preserved specimens; ventral margin either smooth or very finely striate; exterior prosopon of fine, irregularly spaced growth lines and vague concentric undulations; lunule not defined; escutcheon a flattened area with prosopon similar to that of the rest of the shell and separated from the rest of the shell by a distinct flexure of the shell; in specimens on which the exterior has been eroded, the inner ostracum shows fine radial striae.

Remarks.--The above diagnosis of material collected by the writer conforms precisely with the original description as well as the subsequent descriptions and illustrations of Meek (1876) and Stanton (1920). The ornate markings suggested by Meek and Hayden, in their original description, probably result from the striated inner ostracum rather than the true shell surface. Meek (1876, p. 102) suggested that the striae seen on his specimens would not be visible on the shell exterior, an observation that is confirmed by the North Dakota specimens.
No confident subgeneric assignment can be made on this species because some specimens do not possess ventral serrations; however, it resembles \textit{Nucula} s.s. in other respects. The species is distinguished from other known species of the genus found in correlative strata by having a large, compressed shell with a relatively smooth ventral margin. \textit{Nucula subplana} from the Fox Hills Formation is much smaller and more inflated while \textit{N. obsoletistriata}, also a Fox Hills species, has a strongly depressed, concave escutcheon and a more thickened beak area.

There has apparently been some confusion concerning the spelling of the trivial name of this species. The original spelling is that given above. Meek and Hayden continued this usage in 1865 (p. 285) but later (1860, p. 429) spelled it \textit{N. planimarginata}. That this spelling might represent an unintentional error is suggested by noting that Meek (1876, p. 101) lists \textit{N. planimarginata} as the original spelling in the synonymies. Although some authors of this period seemed to consider a trivial name a transient thing subject to their whims, Meek closely followed the rules of taxonomy established by the British and American Associations (Meek, 1876, p. 71) which did not allow unjustified name changes. As none of these papers contains a clear statement of intention to change the name, the original spelling will
Measurements.--Four parameters were measured on the three single valves that were identified as belonging to this species. The molds of the interior were not measured as they were all partially broken.

<table>
<thead>
<tr>
<th>Height</th>
<th>Length</th>
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</thead>
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<tr>
<td>20.2</td>
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Types.--Hypotypes, University of North Dakota Cat. Nos. 9202 and 9363.

Localities and stratigraphic position.--Specimens were collected from the Timber Lake Member of the Fox Hills Formation at localities 129-76-1, 130-80-8 and 131-78-3, 133-75-2, and 134-80-1.

Nucula subplana Meek and Hayden

Pl. 4, Figs. 39 & 40


Original description.—Shell small, oval, compressed; anterior end obliquely subtruncated from the beaks a little more than half way down; posterior end round, base broadly rounded; beaks prominent, compressed, located about half way between the centre and the anterior end; surface (of cast) having a few faint indications of concentric undulations; teeth of hinge moderately long; border smooth. Length .25 inch; breadth .09 inch; height .20 inch.

Of this little Nucula we have only seen casts. It may be known from other species from these formations by its short compressed form and elevated beaks. It is rare.

Locality and position.—Yellow-stone River, one hundred and fifty miles above mouth, in a bed supposed to be upper part of No. 4 of series. (Meek and Hayden, 1856, p. 85)

Description of material.—Shell small for the genus, ovoid, thick shelled, compressed; anterior margin smoothly and rather tightly rounded; posterior margin slightly convex, truncated and rounding abruptly into the ventral margin; ventral margin smoothly and regularly rounded; dorsal margin slightly convex and terminating anteriorly with a slight angular flexure; beaks small, inturned, nearly touching, opisthogyral; hinge relatively strong, slightly thickened, with about 14 anterior teeth and 6 posterior ones; the anterior teeth decrease in size regularly from the anterior termination of the hinge to the posterior termination; posterior teeth more or less uniform in size but varying from straight at the posterior termination to slightly arcuate, dorsally concave, near the position of the chondrophore; ligament
internal, chondrophore unknown; adductor muscles apparently leave an extremely obscure scar on the shell as none was observed on the single mold of the interior; accessory muscle scars were similarly obscure; prosopon of relatively deeply impressed concentric striae which are more closely spaced and deeply impressed near the ventral margin; inner ostracum, visible where the shell is abraded, coarsely striate radially.

Remarks.--The shells here referred to *N. subplana* conform closely to the description given by Meek and Hayden (1856, p. 85) with two exceptions. The holotype is described as having elevated beaks and being extremely small. The original material was confined to molds of the interior which would explain both discrepancies. The beak area is thickened so that molds of the interior tend to show more elevated beak areas than is actually the case when the shell exterior is examined. The size of the mold would also be considerably smaller than that of the exterior.

The specimens referred to this species by Stanton (1920, p. 20) are placed here with the same reservation expressed by Stanton. All of his specimens were considerably larger than either the ones described by Meek and Hayden or those of the present study. They do, however, appear to have all of the other characteristics necessary to place them in the species.
The only species of *Nucula* which might be confused with *N. subplana* are *N. planomarginata* from the Fox Hills Formation and *N. nacatochana* Stephenson from the Neylandville and Nacatoch formations of Texas. It differs from the former in having a less depressed escutcheon, obscure adductor muscle scars, and few teeth. It differs from *N. nacatochana* in being larger and having a flattened, rather than keeled, lunule.

Both *N. subplana* and *N. planomarginata* served as prey for carnivorous gastropods. Specimen 9363 of the former species and specimen 9202 of the latter show conical holes similar to those drilled by modern gastropods. The hole in the right valve of *N. subplana* is 2.1 mm in diameter at the surface of the shell and tapers to 0.8 mm at the inner surface. It is located near the anterior end of the hinge and about one-third the height from the dorsal margin. That of *N. planomarginata* is about 4.3 mm in diameter at the surface and tapers to 2.7 mm at the inner surface and is located just beneath the beak of the right valve. The considerable difference in size of the holes as well as the different location on the shells might well indicate that two different predators were involved.

**Measurements.**—Three parameters were measured on both specimens referred to this species.
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**Types.**—Hypotypes, University of North Dakota Cat. Nos. 9261 and 9364.

**Localities and stratigraphic position.**—The two specimens of this species were collected from the Timber Lake Member of the Fox Hills Formation at localities 130-78-1 and 131-78-2.

*Nucula obsoletastriata* Meek and Hayden

*Pl. 4, Figs. 31 & 32*


*Nucula obsoletastriata* Meek and Hayden. Meek, 1876, U. S. Geol. Survey Terr., v. 9, p. 100, pl. 15, figs. 10 c and d.

**Original description.**—Shell thick, oval ovate, or elliptical, moderately compressed; surface ornamented with fine concentric striae and obscure traces of small closely arranged radiating lines; buccal end obliquely truncated from the beaks forward to a point nearly half way down the front border, where it is narrowly rounded; posterior end more broadly rounded; base semiovate, most prominent behind the center; cardinal border sloping from the beaks at an angle of about 120°. Beaks small rather depressed, nearly touching, and placed a little in advance of the middle; lunule narrow ovate, deeply impressed. Length 1.20 inch; height .81 inch; breadth .60 inch.
The cardinal edge is thinnest near the beaks, from which point it gradually thickens towards the extremities, especially towards the posterior end. We have had no opportunity of ascertaining whether or not the edge of the lower border is crenulated. As the radiating striae are very obscure, it is probable they are obsolete on worn specimens, though on the surfaces of internal laminae they are usually quite distinct. The anterior muscular impression is deeply impressed, of a narrow ovate form, and placed near the edge of the buccal extremity; while the posterior one if a little narrower, less deeply impressed, and located close up under the back end of the hinge. There are about thirty hinge teeth in each valve behind, and nearly half as many before the beaks, all of which are curved in crossing the edge, so as to present the concave sides towards the extremities.

Locality and position.--Great Bend of the Missouri, No. 4 of the series. (Meek and Hayden, 1856, p. 275)

Description of material.--Shell medium sized for genus, ovate, moderately inflated, thickened; anterior margin unknown but apparently smoothly rounded; posterior margin truncated, with a slightly concave outline from the beak to the midline of the shell where it curves abruptly into the ventral margin which is smoothly and evenly rounded; dorsal margin slightly convex from the beak to the anterior margin; beaks located slightly anteriorad from the midline of the shell, inturned, opisthogyral; hinge long, well developed; anterior portion of the hinge with 17 or more teeth which appear to be triangular in dorso-ventral cross-section and inclined with their apices directed toward the beaks, the posterior-most eight teeth on the anterior row terminate ventrally against the chondrophore and decrease in size.
regularly toward the beak; anterior tooth row with ten or eleven teeth, similar in shape to the anterior series but becoming more crowded toward the beaks and only slightly smaller in size; chondrophore very narrow beneath the beaks, becoming much larger near the anterior termination, entire structure strongly arcuate and anteriorly directed; posterior adductor muscle scar ovoid with a slight, arcuate reentrant along the dorsal margin, located near the base of the escutcheon, deeply impressed into the shell; anterior adductor scar very weakly developed, ovoid outline; ventral margin smooth; exterior of the shell with somewhat irregular growth lines and much larger, shallow concentric undulations; radial prosopon limited to faint expressions of the radial striae of the inner ostracum which are visible only on abraded areas of the shell.

Remarks.—This species, which is represented by a single, poorly preserved specimen, was originally described from the Pierre Formation and has never been reported from the Fox Hills. It so closely conforms to the original description, however, that there can be little doubt of its identity. It should be noted when comparing the diagnosis to the original description, however, that Meek and Hayden considered the truncated end of the shell to be anterior. This error was recognized and corrected by Meek (1876, p. 100) as the specimens discussed there were correctly oriented.
The only difference between the specimen described here and those studied by Meek and Hayden is the number of anterior teeth. The holotype has about thirty anterior teeth whereas the specimen from the Fox Hills Formation shows only 17 teeth. The anterior portion of the shell is broken, however, and more teeth may well have been present on the complete shell.

This species is readily distinguished from the other species of *Nucula* in the Fox Hills by its concave escutcheon, thickened shell, and adductor muscle scars. *Nucula planomarginata* is less inflated than *N. obsoletastriata* and has both anterior and posterior muscle scars depressed below the general interior level of the shell. *Nucula subplana*, which is smaller and thinner-shelled than either of the above species, has adductor muscle scars which are, at best, weakly defined and are not usually visible. The external shape of *N. obsoletastriata* most closely resembles that of *N. ciboloensis* Stephenson from the Kemp Formation but differs from it in lacking radial striae on the surface. Stephenson (1944, p. 73) attributed the incurving of the escutcheon to senility. He continued to say that *N. percrassa*, a related species, "... assumes old-age characters at an earlier stage ..." which seems unlikely. In the case of *N. obsoletastriata*, the entire escutcheon appears to be
convex so that the character definitely cannot be attributed to senility.

The original spelling of the trivial name is that given above; although, as with *N. planomarginata*, Meek (1876) altered the spelling, both in the title and in the synonymy. It appears that this subsequent spelling should be considered to be in error. He expressed no intent to correct an inadvertent error.

**Measurements.**--The single specimen referred to this species is broken along the anterior margin and, therefore, cannot be properly measured. The following dimensions represent measurements of the broken fragment with no allowance for the missing portion.

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<tr>
<th>Height</th>
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<tbody>
<tr>
<td>15.1</td>
<td>18.9</td>
<td>6.4</td>
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</table>

**Type.**--Hypotype, University of North Dakota Cat. No. 9365.

**Locality and stratigraphic position.**--The single specimen was collected from the Timber Lake Member of the Fox Hills Formation at locality 130-80-8.

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*Nucula emmonsensis* n. sp.

Pl. 4, Figs. 29 & 30

**Description.**--Shell medium sized for the genus, elliptical, compressed, rather thin shelled; anterior
margin attenuate and tightly rounded; dorsal margin straight
or slightly concave and relatively short; ventral margin
regularly and gently curved; dorsal margin slightly convex,
sloping from the beaks to the anterior margin; beaks
inturned, nearly touching, opisthogyral, located about
four-fifths the length from the posterior terminus of the
shell; hinge well-defined, anterior portion with about 23
teeth which are largest near the middle of the series and
decrease slightly toward the anterior and decrease to minute
denticles above the chondrophore; posterior series with
approximately 10 teeth which decrease in size regularly from
the ventral extreme to the chondrophore; chondrophore unknown;
posterior adductor muscle scar slightly impressed, elongate,
originating at the beaks and broadening toward the ventral
margin, forming an elongate, triangular scar, the outline
of the actual muscle at any one time being a dorso-ventrally
elongate ovoid at the base of the large scar; anterior
adductor scar poorly defined, ovoid, located near the anterior
termination of the hinge; median, central and punctiform
muscle scars not present; interior of shell with very weak
radial striae which become indistinct near the ventral margin
and about four low, poorly defined, concentric undulations;
exterior of the shell entirely unknown.
Remarks.--The above description was taken from a single slightly crushed mold of the interior which represents the total available sample. The description of most of the internal characters is accurate; however, the posterior tooth row was severely damaged by crushing and the number and description of teeth in that series should be taken simply as an estimate. To thoroughly study the hinge of this specimen, it was necessary to etch a small amount of calcite from the dorsal margin. Microscopic examination of this shell-material, prior to etching, indicated that the inner ostracum was smooth. It has been observed, however, that the dorsal margin of the shell often appears smooth in species which have an otherwise deeply striate inner ostracum.

This species seems to be very closely related to Nucula percrassa Conrad from the Cretaceous of the Atlantic and Gulf coasts (Wade, 1926, p. 40). The Fox Hills species differs from it, however, in being considerably smaller and thinner shelled. Further N. percrassa displays a distinctly serrate ventral margin while that of the species under consideration is smooth. Nucula slackiana from the Matawan and Monmouth formations is even larger and thicker shelled than N. percrassa (Gardner, 1916, p. 512). Other than these two species, none of the Cretaceous nuculids even closely approximate the form of this shell.
This species differs from all other nuculids in the Rock Hills Formation in regard to shape of the shell and arrangement of the anterior teeth. Specimens of the other species are nearly equidimensional whereas *N. emmonsensis* is only two thirds as high as it is long. Further, none of the other species have teeth in the anterior series that show a decrease in size toward the anterior terminus of the tooth row.

Although the species, which is unquestionably new, has been assigned to the genus *Nucula*, there is some question of the validity of this assignment in that none of the ostracum is preserved for examination. The only indication that, when better preserved material is found, it will be striated is that nearly the entire interior of the shell was apparently striate.

**Measurements.**—Four parameters were measured on the single mold of the interior referred to this species.

<table>
<thead>
<tr>
<th>Length</th>
<th>Height</th>
<th>Width</th>
<th>Distance from beaks to posterior margin</th>
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</thead>
<tbody>
<tr>
<td>15.0</td>
<td>10.1</td>
<td>5.9</td>
<td>2.6</td>
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</table>

**Type.**—Holotype, University of North Dakota Cat. No. 9366.

**Etymology.**—The trivial name was derived from Emmons, the name of the county in which the holotype was discovered.

**Locality and stratigraphic position.**—The holotype was collected from the base of the Timber Lake Member in the
fox Hills Formation in a road cut on the east side of the
road, NE 1/4 sec. 12, T. 131 N., R. 78 W. (locality 131-78-2),
Emmons County, North Dakota.

Family: NUCULANIDAE
Genus: Nuculana Link

Type reference.--Link, 1807, Rost. Samml., v. 3, p. 155.
Type species.--Arca rostrata Gmelin, by original desig-
nation.

Description.--Shell solid, porcellaneous, trans-
versonely elongate, rounded anteriorly, more or less
rostrate posteriorly; beaks proximate, commonly tumid,
feeably opisthogyrate; exterior surface concentrically
sculptured; hinge armature taxodont, the teeth arranged
in an anterior and a posterior series; chondrophore
subumbonal, trigonal; pallial line interrupted by a
shallow sinus corresponding to the short siphons of
the animal; inner ventral margins simple. (Gardner,
1926, p. 10)

Remarks.--The above diagnosis, taken from Gardner (1926)
was used by her as the description for the genus Leda. Both
of the genera, Leda and Nuculana, however, have the same
type species. The former, named by Schumacher in 1817, must,
therefore, be considered the junior objective synonym. This
practice has been followed reluctantly by most modern workers
(Olsson and Harbison, 1953, p. 28; Keen, 1963, p. 90).

Gardner's diagnosis incorporates most of the essential
characteristics mentioned by Verrill and Bush (1897, p. 54)
in their revision of the families Ledidae (Nuculanidae) and Nuculidae. She did not, however, suggest that all members of *Nuculana* have a bicarinate rostrum, a criterion suggested by both Verrill and Bush (1897, p. 54) and Olsson and Harbison (1953, p. 28). This feature seems to be of less significance than the depth of the pallial sinus and the general outline of the shell and will, therefore, not be considered of generic importance.

*Nuculana* is most readily confused with the genus *Yoldia* because both groups have small, concentrically striated, rostrate shells. They differ from one another in two rather basic features. The shells referred to *Nuculana* have a relatively shallow pallial sinus and are tightly closed posteriorly whereas those of *Yoldia* have a deep sinus and gape, at least slightly, posteriorly. Both genera have a chondrophore which serves to distinguish them from *Malletia* and related genera.

*Nuculana scitula* (Meek and Hayden)

*Pl. 4, Figs. 25-28*


Yoldia scitula (Meek and Hayden). Meek and Hayden, 1876, U. S. Geol. Survey Terr., v. 9, pl. 28, fig. 9; Stanton, 1920, U. S. Geol. Survey, Prof. Paper 128, p. 21, pl. 1, figs. 9-10; Shimer and Shrock, 1944, p. 379, pl. 146, fig. 42.

**Original description.**--Shell ovate, rather ventricose, rounded in front, somewhat contracted and narrowly rounded behind; umbonal region gibbous; beaks prominent, incurved, approximate, located in advance of the middle; surface marked with distinctly elevated, regular concentric lines, about equal to the spaces between, and stronger on the middle than towards the extremities of the valves; dorsal border marked by a distinct longitudinal groove behind the beaks. Length by a distinct longitudinal groove behind the beaks. Length .39 inch; breadth .21 inch; height .22 inch.

**Locality and position.**--Moreau River, No. 5 of the series. (Meek and Hayden, 1856, p. 84)

**Description of material.**--Shell small for genus, ovoid, attenuated, inflated, thin-shelled; anterior margin rounded and most tightly curved near the middle; posterior margin drawn out into a short rostrum and truncated at its terminus; ventral margin smoothly curved, greatest convexity near the midline; dorsal margin descending from the beaks in a slightly concave curve anteriorly and a pronounced concave curve posteriorly; beaks located slightly in front of the midline, elevated above the hinge line, inturned, weakly opisthogyral,
inflated; hinge with V-shaped taxodont teeth arranged in two series and separated by a subumbonal ligament pit; anterior series with about 12-14 teeth, posterior series with 14-16 teeth; the teeth of both series decrease in size toward the beaks and disappear at the junction with the resilifer; both series become reduced near their distal terminations also; resilifer relatively large, extending to the ventral margin of the hinge; triangular, only slightly excavated; adductor muscle scars unequal in size, anterior adductor scar relatively large, nearly circular, slightly impressed along the proximal margin; posterior adductor scar elongate parallel to the hinge, impressed deeply along the proximal margin and flush with the shell interior along the distal margin; a broad, poorly defined scar extends from the anteri-erio-ventral edge of the anterior adductor muscle scar in an arcuate path toward the beaks and then bifurcating just before terminating below the hinge; pallial line complete and well defined; pallial sinus short, well defined, term- inating in a sharp point; ventral margin smooth; surface of the shell with concentric growth striae which become somewhat more densely spaced near the ventral margin; lunule not defined; escutcheon poorly defined and represented simply by a flattened area posteriorad from the beaks; anterior and posterior margins closed, not gaping.
Remarks.--This species has been referred to the genus *Yoldia* since first assigned to it by Meek (1876, p. 110). This assignment was made, however, solely on the basis of external form, stating that (Meek, 1876, p. 110), "Some internal casts of our species show that its pallial line had a rather distinct sinus, though the sinus is not deeper than we sometimes see in the genus *Leda*." Since the characteristics of the pallial sinus and posterior gape are intimately related to the structure of the siphons, the nature of the sinus and posterior gape would seem to be more fundamental than external morphology and, therefore, more useful as taxonomic criteria.

*Nuculana scitula* is, in many ways, a generalized form. It is, therefore, quite similar to other Cretaceous and post-Cretaceous species of this genus. The distinguishing features of the species seem to be the well-defined pallial line, the distinct, V-shaped pallial sinus, and the impressed muscle scars. It is most closely related to *N. bisulcata*, however, the latter has a well defined escutcheon and is less gibbous. *N. coloradoensis* Stephenson, from the Kemp Formation, is also similar to *N. scitula* in external form. It differs from *N. scitula* in having a somewhat straighter posterio-dorsal margin and a well-defined lunule. The internal characters of the species are not known.
N. scituia possesses an arcuate scar extending from the anterior adductor muscle scar to the beak of each valve. To the writer's knowledge, this feature has been illustrated in only one other species, Voldia limatula (Verrill and Bush, 1897, p. 60, fig. 1, no. 12; Abbott, 1954, p. 337, fig. 71b). This species is common in cold water on both coasts of the United States. Unfortunately, no mention is made of the function of the structure although it probably represents the point of attachment of the pedal muscles. Whatever its function, the scar is consistently visible on molds of the anterior of N. scituia and is absent on other Cretaceous forms of Nuculanidae known from the Fox Hills Formation.

Measurements.--Four parameters were measured on all specimens that were well enough preserved to show all four of the dimensions. The measurement of width refers to width measured through both valves. Distance from the beaks to the anterior margin should be taken as an approximate measurement in that the precise location of the beaks was often difficult to determine and, in some cases, was estimated.

<table>
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Types.--Hypotypes, University of North Dakota Cat. Nos. 9206 and 9207.
Localities and stratigraphic position.--Specimens of this species were collected from the Timber Lake Member of the Fox Hills Formation at localities 129-78-6, 131-78-2, 131-78-4, and 133-77-2.

_Nuculana bisulcata_ (Meek and Hayden)

_Pl. 4, Figs. 23 & 24_


_Nuculana bisulcata_ (Meek and Hayden). Meek, 1864, Smithsonian checklist Cretaceous fossils N. Am., p. 8; Meek, 1876, U. S. Geol. Survey Terr., v. 9, p. 104, pl. 15, fig. 4.

Original description.--Shell small, transversely subovate; gibbous in the central region; anterior side narrowly rounded; base semi-elliptical, with a slight sinousity near the posterior extremity; anal end narrow and subangular in outline; dorsal border sloping from the beaks at an angle of about 135°; beaks rather obtuse, nearly central, or located slightly in advance of the middle; posterior umbonal slopes distinctly angular, the angles extending back to the anal extremity, where they terminate in a small obscure fold; escutcheon lanceolate, concave along the middle, and strongly defined by the umbonal sulcus, extending from the beaks to the posterior end of the shell; lunule not defined; surface ornamented by small, rather distinctly elevated, regularly arranged concentric striae.

Length, 0.31 inch; height, 0.16 inch; convexity, 0.13 inch.

Locality and position.--Deer Creek, near North branch Platte River, in lower part Fox Hills beds, or the upper beds of Fort Pierre Group of the Nebraska Cretaceous Section (Meek and Hayden, 1861, p. 440)
Description of material.—Shell small for genus, ovoid, moderately inflated; anterior margin evenly rounded; posterior margin drawn out into a short, poorly defined, rostrum which is tightly rounded at its extremity; ventral margin smoothly and evenly rounded; dorsal margin sloping away from the beaks into two, nearly straight elements; beaks located slightly anteriorad from the midline, small, inturned, orthogyral; hinge with taxodent teeth, about 11 teeth in the anterior series and 12 in the posterior series, separated by a rather broad resilium; muscle scars poorly defined, anterior adductor muscle scar moderately large, nearly circular, located at the anterior extremity of the shell; posterior adductor muscle scar not well defined; pallial line and pallial sinus are not impressed into the shell; exterior of the shell unknown; posterior rostrate area entirely closed, not gaping.

Remarks.—The diagnosis of this species is taken from four, poorly preserved molds of the interior. In gross aspect the fossils appear to be *Nuculana scitula* but, upon closer examination, display several features which are so significantly different from it as to demand separate placement. By contrast to *N. scitula*, *N. bisulcata* does not show the well developed pallial sinus, impressed adductor muscle scars, and pedal? muscle scars. The rostrum of *N. bisulcata*
is also not as well developed as that of *N. scitula*. Finally, *N. scitula* has 12-14 teeth in the anterior series and 14-16 teeth in the posterior series whereas *N. bisulcata* has only 11 teeth in the anterior series and 12 teeth in the posterior series.

The description of the species, given by Meek and Hayden, was based on shell exteriors and is, therefore, not strictly comparable to the diagnosis given above. The placement of these specimens in this species is based primarily on the general size and outline of the specimens, which closely correspond to those in the original description. The poor preservation of the specimens does not permit careful comparison with other members of the genus.

**Measurements.**—Length, height, and distance from the beaks to the anterior margin were measured on three of the specimens referred to this species.

<table>
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<td>9268</td>
<td>8.0</td>
<td>5.1</td>
<td>2.8</td>
</tr>
<tr>
<td>9369</td>
<td>9.9</td>
<td>6.4</td>
<td>4.1</td>
</tr>
</tbody>
</table>

**Types.**—Hypotypes, University of North Dakota Cat. Nos. 9212 and 9268.

**Locality and stratigraphic position.**—The specimens
were collected from the Timber Lake Member of the Fox Hills formation at locality 131-78-2.

Nucleana evansi (Meek and Hayden)
Pl. 4, Figs. 20-22


Yoldia evansi (Meek and Hayden). Meek, 1876, U. S. Geol. Survey Terr., v. 9, p. 111, pl. 28, fig. 10; Shimer and Shrock, 1944, p. 377, pl. 146, figs. 40 and 41; Whitfield, 1880, Rept. Geol. and Resources, Black Hills, Dakota, p. 409, pl. 11, fig. 1; Stanton, 1920, U. S. Geol. Survey, Prof. Paper 128, p. 21, pl. 1, fig. 11.

Original description.—Shell elongate, narrow elliptical, thin moderately convex; cardinal margin nearly straight, marked with a distinct longitudinal groove on each valve; extremities rounded, posterior end compressed and slightly gaping; inferior border forming an elliptical curve with sometimes a faint impression near the middle; beaks very small, not much elevated, located in advance of the centre; surface polished and marked with faint lines of growth; muscular impressions indistinct; teeth of the hinge numerous, closely interlocked. Length .72 inch; breadth .22 inch; height .32 inch.
Locality and position.—Moreau River, No. 5 of the series. (Meek and Hayden, 1856, p. 84)

Description of material.—Shell small for genus, rectilinear, elongate, moderately compressed; anterior margin short, strongly rounded near the dorsal margin and gently rounded near the ventral termination; posterior margin smoothly rounded, subtruncate; ventral margin nearly straight and parallel to the hinge line, smoothly rounded at the anterior and posterior termini; dorsal margin consists of two straight elements declining from the beaks at an angle of about 140°; beaks located about two-fifths the total length from the anterior margin, slightly elevated, inturned, moderately prosogyral; hinge taxodont, with teeth divided into two series and separated by a subumbonal resiliifer; anterior series of teeth V-shaped with the apex pointing toward the beak, about 15-17 teeth; posterior series of teeth slightly modified from the basic V-shape, with a distinct ridge developed on the posterior-dorsal side of each tooth on the right valve and a corresponding socket on the anterior-dorsal part of each tooth on the left valve, about 28 teeth; ligament internal, seated on a resilifer which does not extend beyond the hinge margin; adductor muscle scars are apparently not impressed into the shell and are not distinguishable on molds of the interior; pallial line complete, very indistinct; pallial sinus indistinct, smoothly curved extending about
one-third the distance from the posterior end of the shell to the anterior; ventral margin smooth; exterior surface entirely unknown; anterior and posterior margins of the valves with a very slight gape, which is absent in some specimens.

Remarks.—This species, which has previously been referred to the genus Yoldia, appears to have much stronger connections to Nuculana. The prevailing concept of the genus Nuculana demands that members of the genus possess a relatively shallow pallial sinus, and that they have a closed commissure. Verrill and Bush (1897, p. 62) further suggested that members of the genus have a resilifer which does not extend beyond the margin of the hinge. Yoldia, on the other hand, has a deep pallial sinus, gaping commissure, and very large resilifer. When applying these three criteria to N. evansi, it becomes apparent that the species cannot be considered a member of the genus Yoldia.

Nuculana evansi possesses a pallial sinus which is intermediate in depth between the two genera. The sinus is, however, of about the same general size and shape as that of N. houstoni Stephenson (1941, p. 77) which would suggest that it is not too large to be included in the genus. Further, the anterior and posterior gapes must be considered variable characters. The original description of the species
mentions a posterior, but no anterior, gape. Specimens here referred to the species show this condition as well as that in which both anterior and posterior margins are entirely closed. In any event, the gape is very slight, and might well be overlooked upon casual observation. Finally, none of the specimens collected in this study showed a resilifer which extended beyond the margin of the hinge. Although only molds of the interior were available, this feature would have been visible as a depression on the mold in the area of the beaks. None was observed.

Although none of the other Fox Hills nuculanids approach the rectilinear outline of *N. evansi*, one other Cretaceous form seems to be rather closely related. *Nuculana houstoni* Stephenson (1941, p. 77) from the Nacatoch Formation of Texas is quite similar to the Fox Hills species but differs from it in being somewhat smaller, less attenuated posteriorly, and more depressed in the beak area. *Yoldia cliffwoodensis* Weller, not *Nuculana cliffwoodensis* (Weller), was originally classified by Weller (1905, p. 331) as *Yoldia* cf. *Y. evansi*. The two species are, however, quite distinct and have not been confused subsequently. *Yoldia cliffwoodensis*, from the Magothy Formation, has only 20 teeth in the posterior series, has a curved ventral margin, and has much more abruptly rounded posterior margin.
Measurements.--Four parameters were measured on the two specimens that were well enough preserved to show all the dimensions.

<table>
<thead>
<tr>
<th>Specimen number</th>
<th>Height</th>
<th>Length</th>
<th>Width (both valves)</th>
<th>Distance from beak to anterior margin</th>
</tr>
</thead>
<tbody>
<tr>
<td>9370</td>
<td>7.1</td>
<td>14.7</td>
<td>4.8</td>
<td>4.9</td>
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<td>9371</td>
<td>6.6</td>
<td>12.9</td>
<td>4.2</td>
<td>4.8</td>
</tr>
</tbody>
</table>

Types.--Hypotypes, University of North Dakota Cat. Nos. 9370 and 9371.

Locality and stratigraphic position.--Specimens were collected from the Timber Lake Member of the Fox Hills Formation at localities 133-76-7 and 133-77-9.

Nuculana tarensis (Gardner)

Pl. 4, Figs. 18 & 19

Leda tarensis Gardner, 1923, N. Car. Geol. and Economic Survey, v. 5, p. 82, pl. 11, fig. 11.

Original description.--Shell moderately elongated, rather strongly convex anteriorly, and sloping regularly to the compressed posterior extremity, which is rostrate. The beaks protrude rather prominently above the hinge line and are situated about two-fifths the length of the shell from the anterior extremity; they are approximate and appear to be directed neither forward nor backward. Dimensions of the type, a nearly perfect left valve (Pl. 11, fig. 11): Length 10.5 mm., height 5.5 mm., convexity 2.5 mm.

Angle of the antero-dorsal slope with the postero-dorsal slope immediately back of the beak about 140
degrees. Postero-dorsal margin slightly concave.
Lunule narrow, concave, distinct. Escutcheon distinct,
long, relatively deep and about 1 mm. wide at its
broader point, which is about halfway between the
beak and the extremity. Lunule and escutcheon each
divided longitudinally by a sharp keel formed by the
slightly raised margins of the two valves; escutcheon
subdivided on some specimens by a low, longitudinal
ridge extending from near the beak backward about two-
thirds the distance to the extremity, but this ridge
is variable in the strength of its development.
Anterior margin regularly rounded with a tendency to
subangularity above where it passes into the antero-
dorsal margin; ventral margin broadly rounded ante-
riorly, becoming slightly truncated where it passes
upward to the sharply rounded posterior extremity.

The surface presents numerous distinct, regular,
but not prominently developed, concentric ridges.
(Gardner, 1923, p. 82-83)

Description of material.--Shell relatively small for
genus, ovoid, attenuate, moderately inflated, thin-shelled;
anterior margin rather tightly rounded; posterior margin
drawn out into a rostrum which is truncated at the posterior
extremity; ventral margin smoothly and evenly rounded; dorsal
margin straight anteriorad from the beaks and sloping down-
ward from the beaks to the anterior margin, concave from the
beaks to the posterior margin; beaks located about two-fifths
the total length from the anterior margin, small, slightly
elevated above the hinge line, weakly opisthogyral; hinge
taxodont, divided into two series; anterior series with about
27 V-shaped teeth; posterior series with about 19 teeth which
are generally larger than the teeth in the anterior series;
teeth in both series decrease in size toward the beaks; resilifer internal, separating the two tooth series, small, circular, not extending to the margin of the hinge; adductor muscle scars unequal; anterior adductor scar weakly impressed; circular, located beneath the anterior extremity of the hinge; posterior adductor scar smaller than the anterior scar, elongate parallel to the hinge line and about one-third as long as the hinge, moderately impressed along the dorsal edge; pallial line complete, distinct; pallial sinus moderately deep, margins of the scar are straight, termination distinctly V-shaped; remainder of shell interior smooth, porcellaneous; exterior of shell with distinct growth striae which are more widely spaced near the ventral margin than on the rest of the shell; lunule small, distinct, very slightly raised above the remainder of the shell surface; escutcheon long, lanceolate, smooth, depressed below the general shell surface; dorsal shell margin forms a low, but distinct, keel along the midline of both the lunule and the escutcheon; anterior commissure closed, posterior commissure gaping slightly at the terminus of the rostrum as a result of minor flaring of the rostrum of both valves.

Remarks.—The specimens from the Fox Hills Formation that are referred to *N. tarentis* agree so closely with the description of that species, given by Gardner (1923), that
little comment is necessary. The only possible differences between the North Carolina forms and those from North Dakota are the characters of the lunule and prosopon. The lunule on the type specimen of *N. tarensis* is described as being concave whereas the Fox Hills specimens referred to this species have a slightly elevated, flat lunule. The prosopon on the type specimen also seems to differ slightly from the North Dakota specimens. Gardner (1923, p. 83) described the ornamentation as being composed of "numerous distinct, regular, but not prominently developed, concentric ridges". The illustration of the specimen (Gardner, 1923, pl. 11, fig. 11), however, indicates that Gardner merely emphasized the positive areas whereas the writer emphasized the striae between the positive areas. Under any circumstances, these differences are not significant enough to justify separating the two groups.

None of the other Fox Hills species of *Nuculana* are readily confusable with *N. tarensis*. *Nuculana evansi* is less rostrate and broader posteriorly. *Nuculana bisulcata* and *N. scitula* have no gape at the posterior margin and fewer hinge teeth. *Nuculana scitula* also has deeply impressed adductor muscle scars and a strong pedal muscle scar. *Nuculana mansfieldi* (Stanton) from the Cannonball Formation appears to be the most closely related species from the
midcontinent. This species closely resembles *N. tarensis* but differs from it in having a much straighter ventral margin and different prosopon. The concentric sculpture of *N. mansfieldi* is composed of ridges and grooves of about equal size whereas the striae on *N. tarensis* are considerably narrower than the intervening spaces.

Gardner (1923, p. 83) suggested that *N. tarensis* was most closely related to *N. gabbana* (Whitfield) from the Mt. Laurel and Naresink formations. The latter species, however, has a more rounded posterior margin and relatively indistinct prosopon.

On the basis of posterior gape, this species might be placed in the genus *Voldia*. Examination of the features of the interior of the shell, however, indicate a closer relationship to *Nuculana*. The pallial sinus is well developed but not particularly deep and the internal ligament support is small and does not extend beyond the margin of the hinge. These features would seem to be more basic than a slight posterior gape and have been given preference in determining generic assignment.

**Measurement.**—All of the specimens of this species that were well enough preserved were measured to determine length, height, and distance from the beaks to the anterior margin.
The size of individuals varied considerably; for example, the length varied from 4.2 mm in the smallest specimen to 12.5 mm in the largest specimen. Although not enough specimens were available to perform any type of statistical measurements, other than arithmetic mean, the ratio of length to distance of beak from the anterior margin was determined. This computation was prompted by the visual observation that the beak seemed to be more centrally located in younger individuals. As can be noted from the results tabulated below, this is only generally true and more specimens would be necessary to make any general statement.

<table>
<thead>
<tr>
<th>Length</th>
<th>Height</th>
<th>Distance from beak to anterior margin</th>
<th>Ratio of length to beak position</th>
</tr>
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<tbody>
<tr>
<td>4.2</td>
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</tr>
<tr>
<td>6.6</td>
<td>3.5</td>
<td>3.5</td>
<td>1.89</td>
</tr>
<tr>
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<td>3.9</td>
<td>4.1</td>
<td>1.85</td>
</tr>
<tr>
<td>12.3</td>
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</tr>
<tr>
<td>12.5</td>
<td>6.6</td>
<td>5.9</td>
<td>2.11</td>
</tr>
</tbody>
</table>

\[ \bar{x} = 7.5 \quad \bar{z} = 4.0 \quad \bar{z} = 3.7 \]

Types.—Hypotypes, University of North Dakota Cat. Nos. 9372 and 9373.
Locality and stratigraphic position.—Specimens were collected from the Timber Lake Member of the Fox Hills Formation at locality 134-71-1.

Superfamily: PARALLELODONTOIDEA
Family: PARALLELODONTIDEA
Genus: Nemodon Conrad


Type species.—Nemodon conradi Johnson, 1905 (=N. eufalensis Conrad, 1869); not Nemodon eufalensis (Gabb), 1860.

Description.—Equivalve, thin, hinge line long and straight, or slightly curved under the umbo; hinge in the left valve with three linear teeth parallel with the anterior cardinal margin; posterior lateral tooth double, very long, linear; under the apex a few granular teeth. (Conrad, 1869, p. 97)

Nemodon sulcatinus (Evans and Shumard)

Pl. 4, Figs. 1-4


Nemodon sulcatinus (Evans and Shumard). Meek, 1876, U. S. Geol. Survey Terr., v. 9, p. 82, pl. 15, fig. 6;

Shimer and Shrock, 1944, p. 379, pl. 146, fig. 48.

Original description.—Shell small, sub-rhomboid, length almost double the height; beaks situated in
advance of the middle, rather prominent, incurved, distant; umbones oblique, angulated posteriorly, moderately convex, having a distinct sulcus, which passes obliquely from the beak to the palleal margin, cutting the latter at about the middle of the shell, sulcus most deeply impressed on the right valve; buccal margin short, forming nearly a right angle with the cardinal edge; anal margin obliquely truncate; ligamentary area rather large, elongate-ovate; surface with from 18-20 radiating striae, with accessory ones in the intervals.

Length, 4 lines; height, rather more than 2 lines; thickness, 1 2/3 lines;

All specimens of this species in our collection are internal casts.

Locality.--It was found with the preceding species on Wood's fork, 3 miles from Grand River. (Evans and Shumard, 1857, p. 39)

Description of material.--Shell small for genus, elongate, subrhombic, moderately inflated, thick; anterior margin curves posteriorly from the hinge in a gently increasing curve, sometimes nearly straight; posterior margin smoothly rounded and projected slightly posteriorly; ventral margin long and nearly straight; dorsal commissure very long, about 9/10 the total length, and straight; beaks prominent, located about one-third the total length from the anterior, elevated, inturned, prosogyral; hinge long, straight, with about five transverse teeth located beneath and beaks and anterior and posterior teeth which are parallel to the hinge, the posterior teeth are about four times the length of the anterior ones, the number of anterior and posterior teeth
indeterminate; minute transverse striae are visible on one of the posterior teeth of a single specimen; adductor muscle scars subequal, the posterior one being a bit larger than the anterior, both are subtriangular and are separated from the medial portion of the shell by a very low, narrow septum or ridge; pallial line entire, slightly sinuous where it crosses the median ridge of the shell; a low ridge extends from the beaks to the midpoint of the ventral margin on the interior surface; the ridge is usually unequally developed on the two valves, the more prominent ridge being on either the right or left valve; the remainder of the interior is marked by about 20 radiating striae with one or two smaller radiating striae in the intervening spaces; prosopon consists of about 50 radiating ribs which correspond in position to the large and small striae on the interior of the valves; the number of ribs increases slightly toward the margin by intercalation; the ribs are crossed by uniformly spaced growth lines which give an overall reticulate sculpture; the internal ventral margin is slightly crenulate as a result of the radiating striae which appear to flare beyond the pallial line.

Remarks.--This species is represented by only four specimens from one locality in the Fox Hills of North Dakota. All of the specimens are molds of the interior;
however, one of the specimens has a fragment of about one fourth of the right valve adhering. Apparently the remainder of the specimens of this species collected, to date, have been similarly preserved. Evans and Shumard (1857, p. 39) and Meek (1876, p. 83) refer only to molds of the interior. The initial deductions on prosopon were, therefore, made using this material. Observations of actual shell material reveals that, although the striae on the interior of the shell are of two different magnitudes, the external ribs are relatively uniform in size.

With this in mind, there seems to be little, if any, difference between _N. sulcatinus_ (Evans and Shumard), 1857 and _N. eufalensis_ (Gabb), 1860. The latter species is common in Maestrichtian deposits along the Atlantic and Gulf coasts. (Richards, 1958, p. 70; Wade, 1926, p. 42; Stephenson, 1941, p. 83; and 1955, p. 108). The two species were previously differentiated on the basis of prosopon; _N. sulcatinus_ presumably has about twenty major ribs with a similar number of intervening smaller ribs while _N. eufalensis_ has forty to fifty uniform ribs. The latter condition is apparently true in both species. Nemodon eufalensis (Gabb) would then become the junior synonym of _N. sulcatinus_ (Evans and Shumard). As the type specimens of neither of these species have been seen, however, _N. eufalensis_ has not been listed in the synonymies.
Measurements.--Three parameters were measured on all four specimens of this species.

<table>
<thead>
<tr>
<th>Height</th>
<th>Length</th>
<th>Width</th>
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<td>11.1</td>
<td>4.7</td>
</tr>
<tr>
<td>n=4</td>
<td>n=4</td>
<td>n=4</td>
</tr>
</tbody>
</table>

Types.--Hypotypes, University of North Dakota Cat. Nos. 9200 and 9201.

Locality and stratigraphic position.--Specimens were collected from the base of the Timber Lake Member of the Fox Hills Formation at locality 132-76-6.

Family: **LIMOPSIDAE**

Genus: **Limopsis** Sassi


**Type species.**--*Arca aurita* Brocchi, 1814 by original designation.

**Diagnosis.**--Shell rounded, small size, inequilateral. Ligament pit deep, situated under the beaks; teeth equal, regularly aligned on the cardinal shelf and ctenodont; margin of the valves smooth. (Translated from Dechaseaux, 1952, p. 269)
Limopsis striatopunctatus Evans and Shumard

Pl. 4, Fig. 43; Pl. 5, Figs. 10 & 12


Original description.--Shell small, ovate, subquadrate, usually transverse, moderately gibbous, subangular behind, rounded before and below, posterior margin oblique, slightly arcuate; umbones rather prominent, a very shallow depression behind; beaks moderately prominent, extending above the cardinal margin, and situated nearest the anterior extremity; substance of the shell moderately thick; hinge with strongly set teeth; surface ornamented with fine concentric lines of growth, crossed by fine, longitudinal, flexuous striae, which are minutely puncate at the points of intersection.

Dimensions.--Length, 5 lines; height, about 4 lines; thickness, about 3 lines.

Localities.--Moreau and Grand Rivers, Nebraska Territory (Evans and Shumard, 1860, p. 38)

Description of material.--Shell small to medium sized for genus, ovoid, moderately inflated, thin-shelled; anterior margin rounded, with the area of greatest curvature located near the middle of the anterior margin; posterior margin obliquely truncated, nearly straight, rounding abruptly into the dorsal and ventral margins; ventral margin smoothly and evenly curved; dorsal margin straight; beaks located slightly anteriorad from the midline, elevated above the hinge line, inturned, prosogyral; hinge about half the total length of the shell, taxodont, well developed; teeth divided into two
series separated by a median resilifer; anterior series with six to eight arcuate teeth so arranged that those near the resilifer are nearly perpendicular to the hinge and those near the extremity of the hinge are nearly parallel to the hinge, the teeth are largest near the middle of the series; posterior series with about eight teeth of similar size, shape, and orientation to those of the anterior series; resilifer located beneath the beaks, primarily internal but probably slightly visible from the exterior, triangular; entire hinge plate straight along the dorsal margin and arcuate along the ventral margin so that the widest parts of the hinge are near the anterior and posterior extremities; adductor muscle scars and pallial line not visible on molds of the interior; ventral margin smooth; exterior of the shell with numerous, regularly spaced growth striae and three or four, irregularly spaced, coarser, growth lines; radial prosopon consists of extremely fine striae which are visible over the entire shell; at each of the intersections of the radial and the concentric striae a small pit, or puncta, is developed; lunule and escutcheon absent.

Remarks.—*Limopsis stratopunctatus* is reported to be extremely abundant in the lower part of the Fox Hills Formation in the type area of South Dakota (Waage, 1961, p. 233). In North Dakota, however, the species was found
at only one locality and, there, it is not abundant, but is far outnumbered by another small clam, Protocardia subquadrata.

The shells collected from North Dakota are similar in all respects to those collected by the writer in South Dakota. None of the specimens diverge strongly from the characteristics given in the type description. A second species, L. parvula, however, was described (Meek and Hayden, 1856, p. 85) from the Fox Hills Formation but does not seem to be present in any of the North Dakota collections. The two species seem to be very closely related in that they differ from one another only in size, prosopon, and number of hinge teeth. Limopsis parvula is smaller than L. striatopunctatus and has more obscure radial prosopon which becomes indistinct on the anterior part of the shell. Further, L. parvula has only three or four teeth in each of the anterior and posterior series whereas L. striatopunctatus appears to have about eight in each series.

The species which is perhaps most readily confused with L. striatopunctatus, however, is Protocardia subquadrata, also from the Fox Hills. Although there are profound differences in the internal characteristics of the two species, the exteriors are quite similar. The two species are about the same size and have similar outlines so that the only external
feature that can be used in many cases is the nature of the
commissure. The junction of the valves in Protocardia
subquadrata is crenulate in the posterior area whereas it
is straight and smooth in L. straitopunctatus. Further,
on some specimens of P. subquadrata the posterior crenulations
are reflected as ridges on the posterior third of the shell.
This feature is, however, not displayed on all specimens and
cannot be used consistently. Finally, P. subquadrata does
not show any evidence of surficial punctation.

Measurements.--Most of the specimens of this species
are crushed and distorted so that only three specimens
could be measured with confidence.

<table>
<thead>
<tr>
<th>Specimen number</th>
<th>Height</th>
<th>Length</th>
<th>Thickness (Both valves)</th>
<th>Hinge length</th>
</tr>
</thead>
<tbody>
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<td>8.4</td>
<td>9.7</td>
<td>5.7</td>
<td>5.1</td>
</tr>
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<td>9376</td>
<td>12.1</td>
<td>13.9</td>
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</tbody>
</table>

Types.--Hypotypes, University of North Dakota Cat.
Nos. 9213, 9375, and 9376.

Locality and stratigraphic position.--Specimens were
collected from the Timber Lake Member of the Fox Hills
Formation at locality 132-76-6.
Family: CUCULLAZIDAE

Genus: Cucullaea Lamarck


Type species.—Cucullaea auriculifera Lamarck, 1801, by the subsequent designation of Children, 1823.

Diagnosis.—Shell large, heavy, inflated, rhomboidal or cordiform, equi- or subequivalve; umbones prominent, incurved, separated by a rather wide cardinal area sculptured with divergent ligamentary grooves; external sculpture dominantly radial; hinge taxodont; medial teeth transverse or slightly oblique to the hinge margin; distal teeth subparallel to it; posterior adductor supported by a radial buttress; inner ventral margins crenate. (Gardner, 1915, p. 528)

Remarks.—Specimens of this genus are widely distributed throughout the Timber Lake Member of the Fox Hills Formation. They are readily distinguished from other bivalves by their large, thick shells and the characteristic grooved ligament area. The taxonomic problems on the generic level, however, are great.

There is no doubt that the Fox Hills specimens conform to the description cited above. Several authors have, however, preferred to refer similar forms to the genus Idonearca Conrad (Cook, 1868, p. 376; Conrad, 1868, p. 725; Whitfield, 1885, p. 98; Stephenson, 1941, p. 89). This genus is similar to Cucullaea but differs from it in being thicker, having fewer transverse teeth, and having a slightly less prominent
posterior adductor muscle scar (Meek, 1876, p. 84). Other workers prefer to consider *Idonearca* a subgenus of *Cucullaea* (Meek, 1876, p. 85; Shimer and Shrock, 1944, p. 379). Although Nicol (1954, p. 97) recognized *Idonearca* as a valid taxon, he made no reference to its status as a genus or subgenus. In a paper concerning the origin of the Glycymeridae (Nicol, 1950), he referred to the "genus" *Idonearca* in several places in the text and illustrated a specimen (pl. 21, fig. 9) called *Cucullaea* (*Idonearca*) *capax*.

Most modern workers (Wade, 1926, p. 43; Gardner, 1915, p. 529; 1933, p. 125; Richards, 1958, p. 75) have used the generic name *Cucullaea* with a broad enough definition to include species identified as *Idonearca*. Considering Nicol's comprehensive study of the family (1954), however, *Idonearca* will here be considered a valid subgeneric taxon. The differences between it and *Cucullaea* do not seem to be significant enough to warrant generic distinction.

**Subgenus: Idonearca Conrad**


*Type species.*—*Cucullaea tippana* Conrad, by the subsequent designation of Dall (1898, p. 603).
Diagnosis.--Shell similar to Cucullaea, s.s, but differs from it in having a somewhat thicker shell, wider ventral margin, fewer transverse teeth, and longer lateral teeth.

Cucullaea (Idonearca) shumardi Meek and Hayden

Pl. 4, Figs. 44-47


Cucullaea (Idonearca) shumardi (Meek and Hayden). Meek 1876, U. S. Geol. Survey Terr., v. 9, p. 86, pl. 28, fig. 15, pl. 29, fig. 4.

Idonearca shumardi (Meek and Hayden). Whitfield, 1880, Rept. Geol. and Resources of Black Hills, Dakota, p. 405, pl. 11, figs. 8-11.
Original description.--Shell oval, ovate, somewhat globose, rather thin, obliquely subtruncated behind, rounded before, and forming an elliptic curve below; umbones very gibbous, oblique, moderately elevated, incurved, and located a little in advance of the centre; surface ornamented by distinct lines of growth, crossed by numerous, rather indistinct radiating costae; ligamentary area straight, narrow, moderately excavated, grooved and striated longitudinally; hinge having in each valve three or four transversely striated, oblique, lateral teeth on each side, and small, irregular, intermediate transverse ones in the centre; border smooth. Length (specimen about four times the medium size) 1.67 inches; breadth 1.28 inches; height 1.40 inches.

Locality and position.--Same as last [Moreau Trading Post, No. 5 of series]. (Meek and Hayden, 1856, p. 86)

Description of material.--Shell medium to large sized for the genus, moderately thick, rectangular to ovoid in outline, left valve slightly larger than the right, inflated; anterior margin gently and smoothly rounded, diverges from the hinge line at either a right or slightly obtuse angle; posterior margin truncate, nearly straight, diverges from the hinge line at an angle of about 120°, rounded abruptly into the ventral margin; ventral margin nearly straight or smoothly and regularly curved; dorsal margin long and straight at commissure above which are large triangular ligament areas and prominent, inturned, slightly prosogyral beaks which are located just anteriorad from the midline; hinge narrow, moderately thickened, about 68 percent of the total length of the shell, provided with about 9-11 transverse teeth which
converge slightly at their dorsal extremities and three anterior and posterior lateral teeth which are nearly parallel to the hinge line; the lateral teeth become progressively smaller ventrally; both medial and lateral teeth are regularly and evenly serrate on their sides. Ligament area large, triangular, slightly concave in lateral aspect, and crossed by four to eight deep chevron-shaped striations which are nearly parallel to the anterio-dorsal and posterio-dorsal margins of the area; smaller, secondary chevrons may be formed in some individuals; the entire ligament area is crossed by finer striations parallel to the hinge line; adductor muscle scars large and well defined; anterior one ovoid, dorsally attenuate, only moderately impressed, situated near the hinge line; posterior adductor scar larger than anterior, ovoid, dorsally attenuate, and defined along its anterior edge by a prominent, arcuate, ridge, or plate; the entire posterior muscle attachment appears to be a shelf built out above the general level of the shell interior and separated from the remainder of the interior by the ridge; pallial line smooth, entire; ventral margin broad and smooth; that of the left valve slightly longer than the right valve and equipped with a broad, shallow recess for the reception of the margin of the right valve; prosopon on adult shells consists of regular growth lines which may form slight rugosities in larger individuals;
when conjoined valves are viewed in posterior aspect it may be noted that the posterior commissure is slightly undulatory, that of the left valve slightly concave, that of the right, convex.

 Remarks.--Considerable difficulty was encountered in attempting to determine whether the cuculaelids from North Dakota were *C. shumardi* or the related species, *C. nebrascensis*. Meek (1876, p. 89) pointed 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 carefully studied on all specimens on which the hinge was preserved and on only one specimen were as few as four divaricating grooves observed. This is, presumably typical of *C. shumardi*. Only one specimen was observed that had eight grooves. Eight to ten divaricating grooves are typical of *C. nebrascensis*. The majority of the specimens observed had either five or six grooves. This characteristic, then, does not seem to distinguish the two species satisfactorily.

Length, thickness, slant length, and hinge length were measured on all 24 specimens from locality 130-78-7 to test the general shape of the shells. Slant length was measured
from the beak to the posterio-ventral extremity. To minimize
the effect of size, ratios of length versus hinge length and
length versus slant length were computed and coefficients
of variability (v) 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
\( v = 4.21 \). Similar results were obtained by considering all
the specimens of the genus collected from the Fox Hills
Formation in North Dakota. The coefficient of variability
of length to slant length is within the range of expected
variability for a homogenous group, indicating that if there
were two species present the character analyzed would not
distinguish between them. The value obtained from the ratio
of length to hinge indicates either that the character
analyzed 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, it was concluded
that intraspecific variability of hinge length is too great
to be of taxonomic value.

Having studied the original and subsequent descriptions
of both of the species in question, it was concluded that
all of the specimens from North Dakota could best be referred
to \( C. \) shumardi, provided the description is slightly altered
to account for individual variation. \( C. \) nebrascensis probably
represents a separate species, not known from North Dakota.
C. shumardi is also closely related to C. vulgaris
Norton from the Marshalltown, Navesink, and Hornerstown
formations in New Jersey. The former is, however, less
attenuate posteriorly, thicker, and has one less posterior
lateral tooth.

Measurements.--Four parameters were measured on all
specimens that were well enough preserved to show at least
three of the dimensions.

<table>
<thead>
<tr>
<th>Height</th>
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<th>Thickness</th>
<th>Hinge length</th>
</tr>
</thead>
<tbody>
<tr>
<td>38.0</td>
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<td>29.6</td>
</tr>
<tr>
<td>n=29</td>
<td>n=55</td>
<td>n=55</td>
<td>n=23</td>
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</table>

Types.--Hypotypes, University of North Dakota Cat.
Nos. 9309, 9358, and 9359.

Localities and stratigraphic position.--Specimens were
collected from the Timber Lake Member of the Fox Hills
Formation at localities 129-76-1, 130-78-2, 130-78-7,
130-80-11, 130-80-12, 131-80-5, and 133-76-8.

Order: ANISOMYARIA
Superfamily: MYTILOIDEA
Family: MYTILIDAE
Genus: Modiolus Lamarck

Type reference.--Lamarck, J. B., 1799, Prodrome d'une
Paris Mem., p. 87.
Type species.--*Mytilus modiolus* Linnaeus, by monotypy.

Description.--Shell, oval, oblong, or elongate, sub-transverse, equiva lve, generally inflated anteriorly, compressed posteriorly, inequilateral, anterior region very short and straighter than the posterior; ventral margin slightly gaping in the anterior portion for the passage of the byssus. Surface of the valves smooth, concentrically striate, rarely radially costellate, but, in several species, weakly striate on the posterior margin. Shell thin, covered exteriorly by a more or less thick epidermis, often filamentous, sometimes hirsute. Interior of the valves nacreous. Beaks obtuse, small, anterior, but rarely terminal, inclined toward the anterior margin which, very short, forms an expansion in front of the beaks which is entirely smooth.

Ligament nearly internal, placed in a marginal groove. Hinge entirely devoid of teeth both in front of, and behind the ligament.

Impression of the anterior adductor muscle very small, but nevertheless larger than in *Mytilus*; posterior impression very large, composed of a long, straight portion which corresponds to the muscles of the byssus and a rounded portion (not projecting above as in *Mytilus*) which is the impression of the posterior adductor muscle. Retractor muscle of the foot rudimentary. Pallial impression indistinct.
Internal border smooth. (Translated from Lamy, 1936, p. 253)

Remarks.—Considerable controversy has risen concerning the use of the generic name _Modiolus_ in preference to _Volsella_. Scopoli named the genus _Volsella_ in 1777, and included in it several species which Lamarck later demonstrated to be members of the genus _Mytilus_. In fact, the only species that he could not refer to _Mytilus_ was _Volsella modiolus_ (Linnaeus) which Linnaeus had originally referred to the genus _Mytilus_ (Meek, 1876, p. 71). Lamarck then erected a new genus, _Modiolus_, based on this single species.

According to the strictest application of the International Code of Zoological Nomenclature, therefore, the generic name _Modiolus_ should be suppressed as a junior synonym. Subsequent workers, however, seem to have favored Lamarck's name over that of Scopoli so that in 1955, the International Commission of Zoological Nomenclature voted to conserve _Modiolus_ and to place _Volsella_ on the Official List of Rejected Names (ICZN, 1955, no. 791).

_Modiolus_ is distinguished from other genera of the _Mytilidae_ by having subterminal, rather than terminal, beaks in combination with an edentulous hinge.
*Mciodulus galpinianus* (Evans and Shumard)

Pl. 4, Figs. 7 & 8; 11-15


_Volosella galpiniana_ (Evans and Shumard). Meek, 1876, U.S. Geol. Survey Terr., v. 9, p. 73, pl. 28, fig. 7.

Original description.--Shell sub-ovate, arcuate, 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.

Dimensions.--Length 7.5 lines, width 15 lines, thickness 6 lines. The only specimen we have of this species is partly denuded of its shell, so that some of the characters given above may have to be slightly modified, when more perfect specimens are obtained for examination.

Locality.--Fox Hills, Nebraska. For this species we are indebted to the politeness of Mr. Galpin, agent of the Amer. Fur Co., in charge of Fort Pierre Chouteau, and to him it gives us pleasure to dedicate it. (Evans and Shumard, 1854, p. 164)

Description of material.--Shell small to medium sized for genus, arcuate, elongate, thin; anterior margin tightly curved from the anterior extremity of the hinge to the gently curved ventral margin; posterior margin smoothly curved; ventral margin only slightly curving with a moderate re-entrant which is most pronounced at a point opposite the
posterior extremity of the hinge line; dorsal margin gently curving from a point just anterior of the beaks to its posterior terminus; beaks about one-fifth the distance from the anterior extremity of the hinge to the posterior extremity, slightly elevated above the hinge line prosogyral; hinge about two-fifths the total length, straight posteriorad from the beaks and rounded anteriorad from the beaks, edentulous, ligament situated in a narrow groove which extends from the posterior extremity of the hinge to just behind the beaks, separated from the exterior of the shell by a narrow ridge so that the ligament was probably predominately internal, hinge area in front of beaks slightly thickened; posterior muscle scar attenuate, composed of an ovoid portion (posterior adductor) located near the posterior margin which is drawn out antero-dorsally into a long, narrow scar (byssal muscles); anterior adductor scar indistinct; pallial line weakly developed, located about one-third of the distance from the ventral margin to the midline of the shell, entire, merging into the ventral extremity of the posterior adductor scar without evidence of a pallial sinus; prosopon consists of fine, weak growth lines which are most distinct near the posterior of the shell, becoming less distinct near the beaks; a gently rounded ridge extends from the beaks to the posterio-ventral margin of the shell and the antero-ventral portion
of the shell thins abruptly forming a slightly convex external surface.

Remarks.—Although specimens of this species were found at four localities in North Dakota, they were extremely rare as two specimens were collected from only one site. Four of the specimens consist of molds of the interior whereas the fifth specimen is a nearly complete left valve. One of the specimens, UND No. 9215, appears to be a juvenile form and, whereas the adults of the species are elongate, the juvenile specimens tend to be nearly equidimensional. This observation is further confirmed by a study of the growth lines on the preserved shell. The rate of growth along the antero-posterior axis seems to increase throughout the life of the organism.

Two other species of this genus have been reported from the Fox Hills Formation (Meek, 1876, p. 72 & 74) but neither was collected by the writer in North Dakota. *M. galpinianus* appears to be most closely related to *M. meeki*; however, the latter is less arcuate and less attenuate. A species reported from Delaware and New Jersey (Richards, 1958, p. 153), "*Volsella* burlingtonensis" (Whitfield), 1886, appears to agree in all essential characteristics with *M. galpinianus* and may, therefore, be a junior synonym. The specimens discussed by Richards, however, are described as being so poorly preserved that no conclusive evidence can be given.
Measurements.--Three parameters were measured on all the specimens that were well enough preserved to show at least two of the dimensions.

<table>
<thead>
<tr>
<th>Height</th>
<th>Length</th>
<th>Hinge Length</th>
</tr>
</thead>
<tbody>
<tr>
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<td>13.1</td>
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<td>n=5</td>
<td>n=5</td>
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</table>

Types.--Hypotypes, University of North Dakota Cat. Nos. 9215, 9346, and 9347.

Localities and stratigraphic position.--Specimens were collected from the Timber Lake Member of the Fox Hills Formation at localities 129-76-1, 130-78-7, 131-80-5, 134-71-1.

Modiolus siouensis n. sp.

Pl. 4, Fig. 16

Description.--Shell medium sized for genus, subrectangular, very elongate, moderately inflated, thin shelled; anterior margin short, regularly and tightly rounded; posterior margin long, nearly straight near the middle and rounding smoothly into the dorsal and ventral margins; ventral margin slightly concave with the apex of the concavity located about one-fourth the total length from the posterior terminus; dorsal margin straight or very slightly concave; beaks sub-terminal, located about one-seventh the total length from the anterior margin, slightly elevated above the hinge,
inturned, strongly prosogyral; hinge about two-thirds the total length of the shell with a narrow, shallow groove for the reception of the ligament extending from just anterior of the beaks to the posterior termination of the hinge; muscle scars apparently very weakly defined; pallial line unknown; ventral margin of the shell smooth; prosopon appears to consist solely of growth lines; a broad, low umbonal ridge extending from the beaks to the posterio-ventral portion of the shell divides the exterior into two parts; a more or less inflated anterior portion and a compressed, flaring posterio-dorsal portion.

Remarks.—The above description was based on a single specimen which represents the total sample. It consists of a nearly perfect mold of the interior of the left valve and a badly crushed mold of the interior of the right valve. The only shell material preserved was a small fragment on the posterio-dorsal margin of the right valve.

This species has been referred to the genus Modiolus on the basis of the long, edentulous hinge, subterminal position of the beaks, and general outline. It differs from all known species of the genus in having an extremely compressed, flaring posterio-dorsal area. It differs from the only other species of Modiolus found in the Fox Hills formation in North Dakota, N. galpinianus, in a number of
other aspects. *M. siouxensis* has much straighter dorsal, ventral, and posterior margins as well as more prominent beaks. *Volsella* uddeni Stephenson (1944, p. 152, pl. 25, figs. 18 & 19) from the Navarro Group of Texas is smaller, less elongate, and lacks the posterior-dorsal flare. *M. siouxensis* is morphologically quite similar to *M. julia* from the Merchantville and Woodbury formations (Richards, 1958, p. 154 as *Volsella julia*) from which it differs in being larger, more elongate, and more flaring in the posterior region. Specimens of the latter are commonly preserved as molds of the interior in the Merchantville and Woodbury formations in New Jersey.

**Measurements.**—All measurements were made on the left valve of the holotype. The right valve is too badly crushed to provide adequate measurements.

<table>
<thead>
<tr>
<th>Height</th>
<th>Length</th>
<th>Thickness (left valve)</th>
<th>Distance from beak to anterior margin</th>
</tr>
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<tbody>
<tr>
<td>22.6</td>
<td>47.8</td>
<td>about 6.4</td>
<td>6.6</td>
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**Type.**—Holotype, University of North Dakota Cat. No. 9361.

**Etymology.**—The trivial name was derived from Sioux, the name of the county in which the holotype was discovered.

**Locality and stratigraphic position.**—The holotype was collected from the upper part of the Timber Lake Member of the Fox Hills Formation in a west facing cutbank of the Cannonball River, SW 1/4 sec. 26, T. 134 N., R. 80 W.; locality 134-80-1.
Genus: Creseilla Brown

Type reference.--Brown, 1827, Illustrated Conch. Great Britain and Ireland, pl. 31, fig. 12.

Type species.--Mytilus decussatus Laskey, by original designation.

Description.--Shell orbicular or slightly oval, equi-valve, more or less globose, slightly elongate and only weakly inequilateral; the anterior margin is not distorted. The external surface is ornamented by a trellis-pattern formed by radial costellae, bifurcating in a large number of species, and by well marked concentric striae. The valves are covered by a thin, strongly adherent, cornaceous epidermis; the interior is always nacreous. The beaks are not prominent. The margin of the shell is finely and regularly crenulate.

In the region in which the prodissococonch is found, the two crenulate bands of the provinculum thicken and differentiate into a true cardinal platform, at first divided into two symmetrical halves separated by the primitive ligament groove. Then, because of the rotation of the beaks, and the overlapping of the anterior margin onto the posterior margin, the posterior crenulate band is reduced and ends by disappearing under the anterior band. Following this, the dysodont teeth develop on the cardinal platform and are placed in
regular series with the crenulations of the anterior margin. In effect, the ligament remains internal and does not encroach on the total length of the cardinal platform; the primitive crenulations, which are not aborted, and the dysodont teeth are seen above it.

On the anterior margin, the dysodont teeth are arranged in a fan-shape, very analogous to that of the Pectunculidae. On the posterior margin they are arcuately arranged and form, therefore, chevrons which point anteriorly as in the Ledidae.

There are two nearly equal muscle impressions, the anterior being nearly as large as the posterior, a character by which *Crenella* differs from *Modiolus*. The pallial impression, is indistinct and simple.

The mantle is open anteriorly and forms a sessile anal tube posteriorly. The foot is vermiform and terminates in a disc which emerges as a sort of shaft. (Translated from Lany, 1937, p. 52-53)

Remarks.--There seems to have been little confusion caused by the genus *Crenella* as compared to most of the other genera of the Mytilidae. It is readily distinguished from other members of the family on the basis of shape and hinge-ment. Of all the mytilids, *Crenella* is the only one that tends to be oval rather than elongate. The distinctly crenulate hinge line further tends to distinguish it. Most
species of Crenella are considerably smaller than other
mollusks. The largest specimens mentioned by Stephenson
(1941, p. 153-54), Richards (1958, p. 155-156), and Keen
(1963, p. 53) are about 10 mm long. However, the specimens
here referred to the genus attain a maximum size of about
17 mm. This is consistent with the type specimen of the
species in question, C. elegantula, which is about 14 mm long.
Individuals of this species are larger than any other species
of Crenella known to the author.

_Crenella elegantula_ Meek and Hayden

Pl. 4, Figs. 5, 9, 10

_Crenella elegantula_ Meek and Hayden, 1861, Acad. Nat. Sci.
Philadelphia, Proc., v. 8, p. 441; Meek, 1876, U.S.
Geol. Survey Terr., v. 9, p. 75, pl. 28, fig. 6; Weller,
1907, New Jersey Geol. Survey Paleont. Ser., v. 4, p.
511, p. 56, fig. 6; Gardner, 1916, Md. Geol. Survey,
p. 625, pl. 36, fig. 19; Wade, 1926, U. S. Geol Survey,
Prof. Paper 137, p. 71; Shimer and Shrock, 1944, p.
413, pl. 164, figs. 20-21; Groot, Organist and Richards,
1954, Delaware Geol Survey Bull., v. 3, p. 45; Richards,
1958, p. 156, pl. 25, fig. 10.

_Original description._—Shell small, very thin and
pearly, obliquely ovato-cordate, ventricose; postero-
basal margins rounded; dorsal border sloping posteriorly
with an arcuate outline, and rounding into the anal margin behind; anterior border rounding obliquely backwards into the base; umbonal region of both valves very gibbous; beaks prominent, terminal, pointed, distinctly incurved and directed obliquely forward at the extremities; hinge margin smooth; free border minutely crenulated. Surface (as seen by the aid of a magnifier) beautifully ornamented by extremely fine regular, closely-arranged, radiating striae, which increase chiefly by bifurcation, and continue of uniform size on all parts of the shell; crossing these are numerous equally fine, but much less distinct, concentric lines, and occasional stronger marks of growth.

Length, measuring obliquely forward and upward from the base to the beaks, 0.55 inch; diameter, from base to hinge, measuring at right angles to the greatest length, 0.40 inch; convexity, 0.37 inch.

Locality and position.---Same as last [Deer Creek, near North Branch of Platte River in lower part of Fox Hills beds]. We also have a fragment of apparently the same species from the Yellow Stone River, in upper part Fort Pierre Group. (Meek and Hayden, 1861, p. 441-442)

Description of material.---Shell small, very thin, ovate-elongate, left valve slightly larger than the right one; anterior margin short, sloping gently toward the ventral margin with which it merges in a smooth, even curve; posterior margin forming a parabolic curve; ventral margin gently curving; dorsal margin nearly straight, beaks terminal, strongly prosogyral, incurved so that they nearly touch over the hinge line; hinge about one-third the total length of the shell, straight; ligament internal and nearly the entire length of the hinge; teeth unknown; muscle scars and pallial line indistinct; prosopon consists of extremely fine radiating
striae which are most distinct in the umbonal area and near the margin of the shell where they form very fine crenulations and concentric growth lines which are less regularly spaced and are coarser than the striae; the overall appearance of the prosocion is that of a very fine reticulate pattern.

Remarks.--Specimens here referred to the species, C. elegantula differ only slightly from the description given by Meek and Hayden (1861, p. 441). Nearly all of the specimens are larger than those mentioned in the original description and are much larger than those described by Wade (1926, p. 71) and Richards (1958, p. 156). Further, the concentric striae mentioned in the original description are only rarely seen on the specimens at hand so that the dominant concentric elements are growth lines. The other characteristics of the specimens so closely fit the description, however, that there is little doubt that they are correctly assigned.

With the exception of one specimen, UND No. 9216, the species is represented only by molds of the interior. The single specimen in which shell material is preserved, however, is of particular interest in that not only the calcareous portion of the shell is present but also part of the periostracum is preserved as a thin, carbonaceous layer. Microscopic examination of this carbonized layer indicates that the striae were more strongly developed on the periostracum.
than on the underlying calcareous layer. Lany (1937, p. 32, stated that the periostracum in *Crenella* is strongly adherent to the remainder of the shell. Leaching of the calcareous layer below the carbonized material has been sufficiently restricted that the periostracum now stands slightly above the general level of the shell.

The species seems to be most closely related to *C. serica* Conrad from the Marshalltown and Red Bank formations; however, the latter is much smaller and has better defined, more uniform growth lines.

**Measurements.**—Four parameters were measured on all specimens that were well enough preserved to show all the dimensions.

<table>
<thead>
<tr>
<th>Height</th>
<th>Length</th>
<th>Hinge length</th>
<th>Thickness (both valves)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>15.1</td>
<td>10.0</td>
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</tr>
<tr>
<td>n=12</td>
<td>n=12</td>
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</tr>
</tbody>
</table>

**Types.**—Hypotypes, University of North Dakota Cat. Nos. 9216, 9218, and 9220.

**Localities and stratigraphic position.**—Specimens were collected from the base of the Timber Lake Member of the Fox Hills Formation at localities 132-76-6 and 132-76-8.
?Crenella eleganula Meek and Hayden

Pl. 4, Fig. 6

Remarks.--During the investigation of specimens referred to the species Crenella eleganula, one specimen was observed which was somewhat different from the others in both shape and position of the beaks. All the specimens described above are ovate-elongate in outline and have terminal beaks. A single specimen, UND No. 9219, is nearly circular in outline, has a hinge line nearly as long as the total length of the shell and displays medial, prosogyral beaks. A small portion of the shell was found on the specimen which showed ornamentation similar to that of known specimens of C. eleganula.

Three alternatives regarding the taxonomy of this specimen seem to be possible. The specimen may represent a different genus and species; the specimen might be a different species of Crenella; or it might simply represent an aberrant individual of C. eleganula. A t-test was applied to the measurements of hinge length versus total length, comparing known specimens of C. eleganula with the single specimen in question (Simpson, Roe, and Lewontin, 1960, p. 183) which demonstrated that the probability that the specimen was part of the population of C. eleganula was .43. Such a low correlation suggests that there is little chance that the
specimen conforms to the "normal" population of *C. elegantula*; therefore, the three possibilities mentioned above remain to be analyzed.

The first possibility, that the specimen represents a different genus and species is supported by the position of the beaks with respect to the hinge line. Species of *Crenella* usually show terminal or subterminal beaks whereas this specimen has the beaks located subcentrally. This, however, seems to be a tenuous view in that the musculature and surficial ornamentation so closely resemble those of other members of the genus. Further, its characteristics are such that it cannot readily be referred to any other genus of the Mytilidae.

The possibility that the specimen represents a different species of *Crenella* seems to be even less likely than the former hypothesis in that, if the characters of the hinge are considered of taxonomic significance and not just a mutation, they would probably have to be considered generic, rather than trivial, characteristics.

The most plausible explanation appears to be that the specimen represents an aberrant form of *C. elegantula*. As long as the nature of the hinge remains poorly known, the musculature and ornamentation must be taken as the most important criteria. In these features, the specimen compares
closely with the more typical specimens. Further, it would seem pointless to erect a new taxonomic unit based on a single, poorly preserved specimen which was collected at the same locality as a number of similarly preserved individuals that can be assigned to a recognized genus.

Measurements.--Four parameters were measured on the specimen.

<table>
<thead>
<tr>
<th>Height</th>
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</thead>
<tbody>
<tr>
<td>16.8</td>
<td>15.7</td>
<td>13.5</td>
<td>14.0</td>
</tr>
</tbody>
</table>

Type.--Hypotype, University of North Dakota Cat. No. 9219.

Superfamily: PTERIOIDEA

Family: PTERIIDAE

Genus: Pteria Scopoli

Type reference.--Scopoli, J. A., 1777, Introductio ad Historian naturalem . . .; p. 397.

Type species.--Mytilus hirundo Linnaeus, by monotypy.

Description.--Shell nacreous, small (to about 75 mm long and 65 mm high); outline subovate to subrhomboidal, oblique, and aruncate. Valves moderately equilateral; left valve a little larger and slightly more inflated than the right; byssal notch shallow in left valve and deep in right valve, immediately ventral of the anterior auricle; anterior auricle smaller than posterior one. Umbones small, inconspicuous, prosogyrate, anterior (at about 0.2 to 0.3 of length). Ventral margin broadly and smoothly arcuate, posterior margin sigmoid, and dorsal margin long and straight.
Hinge long, narrow, and straight; right valve with two small, blunt toothlike swellings separated by a pit, directly beneath the umbo, and left valve with one swelling and two pits fitting into those of right valve; left valve has a long, narrow channel in the hinge posterior of the umbo into which the right valve fits. Ligament area triangular, narrow to exceedingly narrow, nearly as long as the dorsal margin, and divided into an anterior and a posterior triangle by an oblique line which extends from umbo to hinge; the posterior triangle is sunk with reference to the former. Ligament marginal, partly internal, partly external, opisthodetic. The single adductor muscle imprint subcentral and ill defined.

Valves smooth in early stage; weakly sculptured in the adult stage by imbricating laminae; in some species the edges of the laminae extend into thin, long squamae, and the individual squamae of successive growth imbrications are aligned in radiating rows which superficially resemble radial ribs. (Stenzel, Krause, and Twining, 1957, p. 80-81)

Remarks.—The genus *Pteria*, as here defined, ranges from the Silurian to the Recent. Furthermore, it is a rather simplified form which seems to vary considerably within individual species and is, therefore, of very little value as an index fossil. Closely related, if not synonymous, species have been found in Upper Cretaceous deposits throughout the United States (Stevenson, 1941, p. 102; Richards, 1958, p. 100) as well as in India (Meek, 1876, p. 32).

This genus has also been referred to as *Avicula* Klein, 1753 (Dechaseaux, 1952, p. 274). The first time this name was used in accordance with the rules of binomial nomenclature, however, was by Bruguierre in 1792, fifteen years after Scopoli named the genus *Pteria*.
**Pteria linguaeformis** (Evans and Shumard)

Pl. 5, Figs. 26-28


**Pteria linguiformis** (Evans and Shumard), Meek 1864, Smithsonian checklist N. Am. fossils, p. 9; Meek, 1876, U.S. Geol. Survey Terr., v. 9, p. 32, pl. 16, fig. 1; Whitfield, in Newton and Jenny, 1880, Geology and resources of the Black Hills of Dakota, p. 384, pl. 7, figs. 2-3; Morgan and Petch, 1945, S. Dak. Geol. Survey, Rept. of Invest. 49, pl. 5, fig. 4, nos. 3 and 6, pl. 6, fig. 3, no. 3.

**Pteria linguaeformis** (Evans and Shumard), Stanton, 1920, U. S. Geol. Survey, Prof. Paper 128, p. 24, pl. 3, fig. 1; Shimer and Shrock, 1944, Index fossils of N. Am., p. 391, pl. 152, fig. 6; Cvancaza, 1966, Mich. Mus. Paleontology, v. 20, no. 10, p. 319, pl. 3, fig. 7.

**Pteria? linguaeformis** (Evans and Shumard), Stephenson, 1941, U. of Texas Pub. 4101, p. 102, pl. 12, figs. 7-8.
**Original description.**—Shell very oblique, elongated linguiform, moderately convex; surface smooth; cardinal line straight, about equal to the greatest width of the shell; posterior 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 position; posterior edge sigmoid, forming an obtuse angle with the cardinal margin; anterior and basal edges convex; beaks pointed, projecting a little above the cardinal border, situated about one-fourth the length of 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.

Length one inch, width at cardinal border 10 lines, length from extremity of anterior wing to posterior inferior extremity 19 lines.

This species is rather common in the septaria of the cretaceous group at Sage Creek, Nebraska, but perfect specimens are procured with difficulty. (Evans and Shumard, 1854, p. 163)

**Description of material.**—Shell medium size for genus, thin, obliquely elongate, ovoid, dorsally truncate, left valve more inflated than right one; anterior and posterior margins form sigmoid curves which terminate dorsally in wings which are prolongations of the hinge line; anterior wing generally larger than posterior, terminated in a narrowly rounded tip; posterior wing more sharply terminated; both wings separated from the most inflated part of the shell by distinct changes in convexity; ventral margin smoothly rounded; dorsal margin straight, slightly longer than the rest of the shell; beaks prosogyrical, located about one-third of the total
length from the anterior terminus; hinge long, straight, with two small teeth under the beak in the right valve which are directed outward defining a small, triangular pit for the reception of the single tooth in the left valve; muscle scar and pallial line distinct; surface of shell smooth and nacreous or with indistinct growth lamellae.

Remarks.--This species is widely distributed throughout the Timber Lake Member but is only rarely well preserved. Most specimens are partial molds of the interior with small fragments of shell material adhering. It is, however, readily identified on the basis of its external shape. Specimens from any one locality vary considerably in general outline which led Stevenson (1941, p. 103) to suggest that the species might be further subdivided. The shape variations, however, appear to form a continuous sequence and, therefore, probably are more properly considered a single, highly variable species. Meek and Hayden (1860, p. 180) named another species, *Avicula (=Pteria) subgibosa*, which Meek later (1876, p. 33) placed in synonymy with *P. linguaeformis*. He apparently did this because further material demonstrated an intergradation between the two species.

Some authors (Wade, 1926, p. 51; Richards, 1958, p. 100) have suggested that *P. linguaeformis* is the same as, and therefore the junior synonym of, *P. petrosa* (Conrad) from
the Nagothy and Wanonah formations. Unfortunately, the holotypes of both species have been lost (Stevenson, 1941, p. 102-103) so that it seems inadvisable at this time to suppress the name *P. linguiformis* which has been in wide usage throughout the Midcontinent since it was named. The two species are very closely related and, if type material were designated, they might well be placed in synonymy.

**Measurements.**—Three parameters were measured on all specimens that were well enough preserved to show all of the parameters.

<table>
<thead>
<tr>
<th>Length</th>
<th>Hinge length</th>
<th>Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>24.0</td>
<td>21.2</td>
<td>20.5</td>
</tr>
<tr>
<td>n=4</td>
<td>n=4</td>
<td>n=4</td>
</tr>
</tbody>
</table>

**Types.**—Hypotypes, University of North Dakota Cat. Nos. 9223 and 9286.

**Localities and stratigraphic position.**—Specimens were collected from the Timber Lake Member of the Fox Hills formation at localities 129-76-1, 129-78-6, 129-78-7, 130-78-2, 130-78-7, 130-80-11, 130-80-12, 131-78-2, 131-78-4, 131-80-6, 132-76-6, 133-76-3, 133-77-2, 134-71-1, 134-80-1, 134-80-2, 134-80-4, and 134-80-7.
Pteria nebrascana (Evans and Shumard)

Pl. 5, Fig. 25

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

Pteria nebrascana (Evans and Shumard), Meek, 1864, Smithsonian checklist Cretaceous fossils N. Am., p. 9.

Pteria (Oxytoma) nebrascana (Evans and Shumard), Meek, 1876, U. S. Geol. Survey Terr., v. 9, p. 34, pl. 28, fig. 11;

Shimer and Shrock, Index fossils of N. Am., p. 391, pl. 152, fig. 5.

Original description.—Shell compressed, thin; cardinal margin straight, rather wide; buccal margin rounded, retreating; anal edge long, concave above and arched below; posterior wing triangular; very slightly concave, pointed; anterior wing small; umbo convex, not gibbous; beak small, projecting very slightly above the cardinal edge; surface marked with radiating, thread-like, simple striae. At four lines from the beak, there are about eight of these striae in the space of two lines; towards the paliéal border the number is increased by implantation; the interspaces are about double the width of the striae, and are marked with very fine longitudinal lines. With the aid of a lens, very fine, closely arranged, waved lines of growth are perceptible.

Occurs in the Cretaceous Formation, near Moreau River, Nebraska Territory. (Evans and Shumard, 1857, p. 38)

Description of material.—Shell small to medium size for genus, thin compressed; anterior margin smoothly rounded up to the anterior wing which is small, flattened, and separated from the rest of the shell by a shallow furrow which terminates
ventrally in the well defined byssal notch; posterior margin
with a somewhat larger, less well defined wing; ventral margin
smoothly rounded, dorsal margin straight; beaks located
anteriorad from the midline, prosogyral, extending slightly
above the hinge line; hinge line simple with a long groove for
the reception of the ligament and a small, shallow, triangular
pit beneath the beak of the left valve; teeth reduced or
absent; muscle scars and pallial line unknown; exterior of
left valve with faint growth lines and more prominent
radiating ridges which are about half as wide as the inter-
spaces, increasing in number from the beak to the ventral
margin by intercalation; surface of right valve smooth or
with microscopic reticulations.

Remarks.—This species is distinguished from P. linguae-
formis by having radiating sculpture on the left valve, and
by being less oblique. The obliquity of the valves and the
development of the byssal sinus are the essential character-
istics of the subgenus Oxytoma Meek, 1864, to which P.
nebrascana has been referred.

Meek (1876, p. 35) stated that the right valve of the
species displays a microscopic reticulate prosopon; however,
the specimens here referred to this species may or may not
show radiating sculpture on the right valve. The specimens
which were well enough preserved to display prosopon were
young organisms and may not have acquired ornamentation. Similarly, the characteristics of the hinge were taken from youthful specimens.

This species is widely distributed throughout the Timber Lake Member of the Fox Hills but is usually preserved only as partial molds of the interior. Well preserved shell material was found at only two localities, 130-80-12 and 134-71-1.

Measurements.--Three parameters were measured on all specimens that were well enough preserved to show at least two of the dimensions.

<table>
<thead>
<tr>
<th>Length</th>
<th>Hinge length</th>
<th>Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.1</td>
<td>7.6</td>
<td>9.1</td>
</tr>
<tr>
<td>n=10</td>
<td>n=7</td>
<td>n=10</td>
</tr>
</tbody>
</table>

Types.--Hypotypes, University of North Dakota Cat. Nos. 9224, 9341, 9342, and 9343.

Localities and stratigraphic position.--Specimens were collected from the Timber Lake Member of the Fox Hills Formation at localities 130-80-8, 130-80-12, 131-78-2, 131-78-14, 131-80-5, 132-76-2, 132-76-6, 133-77-2, and 134-71-1.
Family: ISCONOMONIDAE

Genus: Gervillia De France, 1820


Type species.--Gervillia solenoides De France, by the subsequent designation of Meek (1876, p. 64).

Description.--Shell obliquely-elongated, ensiform or subtrigonal, very inequilateral; beaks oblique and placed near or at the anterior extremity; left valve more convex than the other; anterior margins a little gaping, but without a byssal emargination in either valve; cardinal margin straight, more or less extended, and somewhat alate posteriorly, and less so in front, provided with a flat, diverging, or gaping area or hinge-plate, crossed in each valve by three to about six distinct pits for the reception of the cartilage, which was exposed externally; hinge generally with a more or less numerous series of irregular fold-like teeth under the area, ranging obliquely forward and upward; muscular and pallial impressions as in Avicula. (Meek, 1876, p. 64)

Remarks.--This genus has undergone some modification since Meek wrote the diagnosis cited above. In 1885, Whitfield (p. 73) named a new genus, Gervilliopsis, which included Gervillia-like forms which lacked teeth on the posterior portion of the hinge. The type species of this genus is Gervillia ensiformis Conrad. The description of the genus, however, indicates that the hinge is equipped with "oblique corrugations". These corrugations would not be unlike the folds referred to as teeth in G. solenoides. The only essential
difference between the two genera, then, is the shape of the anterior margin, which is truncated in Gervilliopsis and pointed in Gervillia. The similarities, therefore, seem to outweigh the differences between the two genera. This situation has led to several confusing assignments. Wade (1926, p. 51), for example, cited eighteen authors who have assigned the type species of Gervillia to the genus Gervilliopsis.

Although the problem has not been resolved, Stephenson (1952, p. 96) stated that, "the American Upper Cretaceous shells heretofore referred to Gervilliopsis Whitfield properly belong to Gervillia." This statement seems to reverse the opinion of most modern workers, for example Stephenson (1923), Wade (1926), and Richards (1957), who seem to use Gervilliopsis to the exclusion of the older genus. Neither of the species here referred to Gervillia could in any way be considered members of Gervilliopsis and, therefore, the only immediate problem is that of retaining Meek's type designation of Gervillia.

_Gervillia recta_ Meek and Hayden

Pl. 5, Figs. 18 & 19

_Gervillia recta_ Meek and Hayden, 1861, Acad. Nat. Sci. Philadelphia, Proc., v. 13, p. 441; Meek, 1876, U. S. Geol. Survey Terr., v. 9, p. 66, pl. 29,
fig. 1; Whitfield, 1830, Rept. Geol. and Resources

Black Hills Dakota, p. 359, pl. 4, fig. 3.

Original description.--Shell small, rather thin, obliquely elongate-oblone; antero-basal margin nearly straight, or slightly convex in outline; postero-dorsal border parallel to the under margin; anal extremity rounded or subtruncate; hinge comparatively short, terminating in an acute angle in front, and ranging at an angle of thirty to thirty-five degrees above the oblique longitudinal axis of the shell; cardinal area scarcely gaping, provided with three small cartilage pits; beaks small, very oblique, placed about half way between the middle and the anterior extremity of the hinge; surface smooth, or only marked with fine obscure striae of growth. Left valve convex, but flattened along the middle so as to give the shell a cuneate appearance posteriorly, and produce an obscure ridge along the upper and lower margins of the flattened portion; above the upper of these ridges, the posterior portion of the hinge is strongly compress or subalate. Right valve flat.

Length, measuring from the posterior extremity obliquely forward to the anterior end of the hinge, 2 inches; breadth, at right angles to the length, 0.66 inch; convexity, 0.30 inch; length of hinge, 0.81 inch.

Locality and position.--Same as last Deer Creek, near North branch Platte River, in lower part Fox Hills beds, or the upper beds of Fort Pierre Group of the Nebraska Cretaceous Section. Very numerous. (Meek and Hayden, 1861, p. 441).

Description of material.--Shell medium to large sized for genus, ovoid, elongate, posteriorly attenuate, strongly inequivalved with the left valve much more inflated than the right, thin shelled; anterior margin very short, slightly attenuated along the hinge and sharply rounded into the ventral margin; posterior margin smoothly and evenly rounded or very slightly truncated; ventral margin smoothly convex; dorsal margin
straight along the hinge and slightly concave from the posterior extremity of the hinge to where it merges with the posterior margin; beaks small and not extending above the hinge, that of the left valve more strongly defined than that of the right, strongly prosogyral, located near, but not at, the anterior margin of the hinge; hinge about half the length of the entire shell, totally edentulous, with three or four large pits for reception of the ligament irregularly spaced along the hinge, the first three situated on the anterior half of the hinge, the spaces between the anterior three pits being about the same width as the pits whereas the posterior pit is separated by a greater distance; adductor muscle scars unequal in size, the posterior one, located near the posterior extremity of the hinge and above the midlines of the shell, is large, elongate, nearly triangular, with the apex directed toward the anterior of the shell, impressed slightly into the shell; anterior adductor very small, circular, deeply impressed, located on a line from the beak to the anterior extremity of the shell, more deeply impressed in the left valve than in the right; a series of about six very small, circular muscle scars extends from the beak of the right valve parallel to the ventral margin for a distance of about one-third the total length of the shell, unknown on the left valve; pallial line unknown; exterior of shell with
Another feature evident on the G. retusa, which is also present on the
anterior margin of the antecostae, is the row of minute, conical, sharp
points. The presence of this scar is confirmed by the fact that
seen on the antecostae, G. retusa, this scar is represented less
imperfectly. In G. retusa, the scar is more clearly impressed into the shell,
whereas, in G. retusa, the scar is represented less imperfectly.

The antecostae of G. retusa also resemble the antecostae of G. retusa,
and the anterior adductor
meat muscle scar is small and deeply impressed into the shell.

Another feature of the antecostae is the sharp, conical, sharp,
points. The presence of this scar is confirmed by the fact that
seen on the antecostae, G. retusa, this scar is represented less
imperfectly. In G. retusa, the scar is more clearly impressed into the shell,
whereas, in G. retusa, the scar is represented less imperfectly.

The antecostae of G. retusa also resemble the antecostae of G. retusa,
and the anterior adductor
meat muscle scar is small and deeply impressed into the shell.

Another feature of the antecostae is the sharp, conical, sharp,
points. The presence of this scar is confirmed by the fact that
seen on the antecostae, G. retusa, this scar is represented less
imperfectly. In G. retusa, the scar is more clearly impressed into the shell,
whereas, in G. retusa, the scar is represented less imperfectly.
it seems likely that they served for the attachment of the byssus. Presence of a byssus, however, has not been thoroughly demonstrated. The description of the genus admits to a gape in the anterior-ventral margin which is not considered a byssal gape. Specimens collected from the Fox Hills Formation are so poorly preserved that the presence of a byssal gape can only be inferred; however, the presence of the muscle scars along the umboinal ridge strongly suggests the presence of byssal threads. It is also significant that other clams which attach to the substrate by a byssus, Mytilus edulis for example, show distinct scars of attachment but do not have a significant byssal gape.

The only species which seems to be closely related to G. recta is G. wells., Stephenson (1944, p. 97, pl. 10, fig. 9). The latter species, from the Navarro Group of Texas, is similar to G. recta in outline but differs from it in convexity. G. wells., is described by Stephenson as being extremely compressed whereas G. recta has a strongly inflated left valve. A description of the interior of G. wells., is not available.

Measurements.--Four parameters were measured on two specimens that were well enough preserved to show all of the dimensions.

<table>
<thead>
<tr>
<th>Length</th>
<th>Height</th>
<th>Slant length</th>
<th>Hinge length</th>
</tr>
</thead>
<tbody>
<tr>
<td>24.1</td>
<td>19.4</td>
<td>27.4</td>
<td>11.3 right valve</td>
</tr>
<tr>
<td>31.8</td>
<td>27.3</td>
<td>38.9</td>
<td>20.1 right valve</td>
</tr>
</tbody>
</table>
**Gervillia subrotusosa** Meek and Hayden

Pl. 6, Fig. 22, 27-30

Gervillia subrotusosa Meek and Hayden, 1856, Acad. Nat. Sci. Philadelphia, Proc., v. 8, p. 276; Meek, 1876, U. S. Geol. Survey Terr., v. 9, p. 65, pl. 16, fig. 7;
Shimer and Shrock, 1944, p. 389, pl. 150, fig. 20;

**Original description.**—Shell thick, lanceolate, tortuous and laterally curved. Beaks terminal? pointed? posterior end narrow, the widest part being at the back end of the hinge; hinge line straight, forming an angle of about 20° with the longitudinal axis of the shell; ligament fossae about six, nearly equalling the spaces between. Surface unknown.

**Locality and position.**—Three hundred miles above Fort Union, on the Missouri, No. 4 of the series. (Meek and Hayden, 1856, p. 276)

**Description of material.**—Shell large for genus, apparently ovoid, very elongate, compressed right valve and moderately inflated left valve, relatively thick shelled; anterior margin very short and sharply rounded; posterior
margin tightly and evenly rounded; ventral margin slightly convex near the posterior end and more tightly curved near the anterior; dorsal margin straight from the anterior terminus to the posterior end of the hinge and sloping downward in a concave curve to the posterior of the shell; beaks small and not elevated above the hinge, prosogyral, nearly terminal; hinge about two-fifths the total length of the shell, straight, totally edentulous, with five or six arcuate pits for reception of the ligament, the pits become more widely spaced toward the posterior part of the hinge, ligament external; adductor muscle scars unequal in size; anterior adductor scar small, ovoid, slightly impressed into the shell, located near the anterior extremity of the shell; posterior adductor scar large, somewhat irregular, ovoid, impressed only along the ventral margin, located below the posterior termination of the hinge and oriented with the long axis of the scar at an angle of about 40° with the hinge end, nearly parallel to the long axis of the shell; accessory scars (byssal?) extend from the beaks of both valves along the axis of the shell to a point near the anterior termination of the posterior adductor muscle scar; entire interior of shell irregularly cut by shallow furrows which are parallel to the long axis of the shell; exterior of shell with distinct growth lamellae which are most closely spaced along the ventral margin
and most widely spaced along the posterior margin; right valve flattened, left valve considerably inflated along the long axis of the shell but becoming compressed near the hinge; entire shell, when viewed from the dorsum, is twisted so that the portion of the shell posterior of the hinge is curved toward the left valve.

Remarks.—This species of Gervillia differs markedly from G. recta, both internally and externally. Gervillia subtortuosa is much larger and thicker than G. recta and is laterally twisted. Internally, the outline of the adductor muscle scars is quite different. Both scars in G. subtortuosa are ovoid whereas the anterior scar of G. recta is circular and the posterior scar is triangular. Finally, the byssal attachment scars are present only on the left valve of G. recta but are found on both valves of the larger species.

The original description of this species did not discuss the nature of the exterior nor were the byssal scars mentioned. It is probable that neither of these features was visible on the original material. It might also be pointed out that the only known subsequent diagnosis of the species (Meek, 1876, p. 65) erroneously described the right valve as the more convex. The correct relationship is mentioned in the discussion following the diagnosis.
This species is represented, in the Fox Hills Formation in North Dakota, by numerous fragments from a single locality. Only one specimen has been collected that shows the entire outline of the shell. The interiors of the shells are nacreous and the exteriors lamellose so that most of the specimens have exfoliated.

**Measurements.**—Only one specimen, UND No. 9311, was complete enough to allow accurate measurement. This specimen is somewhat smaller than the remainder of the shells, but its dimensions are given below to give some indication of the size of individuals of this species.

<table>
<thead>
<tr>
<th>Height</th>
<th>Length</th>
<th>Slant length</th>
<th>Hinge length</th>
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<tbody>
<tr>
<td>39.8</td>
<td>63.5</td>
<td>71.2</td>
<td>27.1</td>
</tr>
</tbody>
</table>

**Types.**—Hypotypes, University of North Dakota Cat. Nos. 9226, 9227, and 9311.

**Locality and stratigraphic position.**—The specimens were collected from the basal part of the Timber Lake Member of the Fox Hills Formation at locality 132-76-6.

**Superfamily:** PECTINOIDEA

**Family:** PECTINIDAE

**Genus:** Flecten Muller

Type species.--Ostrea maxima Linnaeus by the subsequent designation of Schmidt, 1818.

Description.--Shell approximately equilateral, inequilvalve, usually suborbicular, auriculate; right valve, as a rule, the more convex, not adherent but attached by a byssus. Hinge line straight. Resilium central, internal, triangular. Interlocking grooves and ridges diverging from the apex of the resilial pit. Pallial line simple. Mononyarian; adductor impression rounded, posterior. (Gardner, 1926, p. 43)

Subgenus: Syncyclonema Meek

Type reference.--Meek, 1864, Smithsonian checklist

Cretaceous fossils N. Am., p. 31.

Type species.--Pecten halli Gabb (=P. rigida Hall and Meek) by original designation.

Description.--Shell small, compressed, nearly equi-valve, vertically ovate, the height being greater than the transverse diameter; hinge-line very short; ears very small, the anterior being larger than the other; margins closed all around; no defined byssal sinus in either valve; surface only showing concentric ridges on the right valve. (Meek, 1876, p. 26)

Remarks.--This taxon was originally considered a genus by Meek, who designated Pecten rigida Hall and Meek, 1854, as the type. Pecten rigida is, however, the junior homonym of P. rigida Sowerby, 1818. For this reason, therefore, Gabb (1861, p. 153) renamed the type of Syncyclonema as P. halli.

As suggested in the foregoing description, the prosopon is more ornate on the right valve than on the left. This led Stevenson (1941, p. 133) to suggest that the two valves
described by Meek might actually belong to individuals in two different genera. He did, however, continue to use the
v.axon as a subgenus, at least tentatively, and named three
new species in the subgenus.

_Pecten (Syncyclonema) halli_ Gabb

_Pl. 8, Figs. 1 & 2_

_Pecten rigida_ Hall and Meek, 1854, Am. Acad. Arts and Sciences, n. s., v. 5, p. 381, pl. 1, figs. 4 a-c. (not _P. rigida_)
Sowerby, 1818.

_Pecten hallii_ Gabb, 1861, Cat. Cretaceous fossils, p. 158.

_Syncyclonema rigida_ (Hall and Meek). Meek, 1864, Smithsonian checklist Cretaceous fossils N. Am., p. 7; Meek, 1876, U. S. Geol. Survey Terr., v. 9, p. 27, pl. 16, fig. 5.

_Pecten (Syncyclonema) halli_ Gabb. Shimer and Shrock, 1944, p. 407, pl. 161, figs. 15 & 16.

**Original description.**—Shell obovate, height greater than length, very gradually narrowing toward the hinge;
valves equally convex; hinge line short; wings minute, nearly equal, anterior one truncate, posterior one pointed, striated upon the surface; left [right] or inferior valve marked by strong, concentric undulations;
superior [left] valve smooth, or marked in the exfoliated shell by faint radiating striae. Length,.19 inch;
height,.23 inch.

The strong concentric undulations of the inferior valve are likewise conspicuous on the cast, and are there crossed by radiating striae. The superior valve, which has the shell partially exfoliated, shows only faint radiating striae without concentric undulations as in the
other valve. Perfect specimens may perhaps show other markings on the superior valve not visible in these.

Locality and position.—Sage Creek, Nebraska. Upper part of division No. 4 of Cretaceous Strata. (Hall and Meek, 1854, p. 361)

Description of material.—Shell small for genus, ovoid, slightly higher than wide; anterior, posterior, and ventral margins smoothly and regularly rounded; dorsal margin short and straight, beaks small, orthogyral; anterior auricle short, vertically truncated; posterior auricle broken; hinge of left valve straight, about half as wide as total width, edentulous but with two tooth-like ridges radiating from the beaks to the ventral edge of the hinge area which define the position of the resilial pit; interior of left valve smooth, with nacreous layer covering about half of the interior surface, muscle scar indistinct; exterior of left valve with faint radial striations and extremely weak growth lines; right valve unknown.

Remarks.—The description above is based on a single, well-preserved left valve which is complete except for the partially broken posterior auricle. This specimen so closely fits the description given by Hall and Meek (1854, p. 361) that it has been assigned to this species with confidence.

This species most closely resembles P. simplicius (Conrad) from the Cretaceous of the Atlantic and Gulf coasts. It
differs from *P. simplicius* by lacking a byssal notch and having more distinct radial prosopon.

Measurements.--The single left valve referred to this species has the following dimensions:

<table>
<thead>
<tr>
<th>Height</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.6</td>
<td>5.8</td>
</tr>
</tbody>
</table>

*Type.*--Hypotype, University of North Dakota Cat. No. 9372.

Locality and stratigraphic position.--The single specimen was collected from the Timber Lake Member of the Fox Hills Formation at locality 134-71-1.

Superfamily: ANOMIOIDEA

Family: ANOMIIDAE

Genus: *Anomia* Linnaeus


*Type species.*--*Anomia echinipum* Linnaeus, by subsequent designation of Schmidt, 1818.

Description.--Shell subrounded but generally irregular or distorted in form, thin or translucent, subnacreous. The upper, free or left valve is generally more convex than the other, its surface smooth, ribbed or sulcated. Attachment is by a byssus which passes through a large, rounded hole in the beak or umbo of the right valve, its posterior margin bearing the ligament more heavily calcified. Interior of upper or left valve carries a central patch, white and somewhat more
heavily limed, and bearing three muscle scars, the upper and central ones being for the attachment of the byssal muscles, the lower or posterior for that of the adductor muscle. Interior of right valve has but a single muscle scar, that of the adductor. Ligament internal; in the byssal valve seated on the dorsal edge of a heavily calcified plate; in the left valve on a semilunar scar in the cavity of the beak (Olson and Harbison, 1953, p. 61)

Remarks.—This common genus of the Anomiidae is distinguished by the subcentral, heavily calcified area which shows three scars of attachment of muscles and by the byssal sinus in the right, or attached, valve. Stenzel, Krause, and Twining (1957, p. 97-93), in describing the genus, stated that the posterior-ventral scar is the adductor, the anterior-ventral scar is the posterior pedal retractor, and the large dorsal scar is an attachment for both the anterior pedal retractor and byssal muscles. This arrangement of three muscle scars distinguishes the genus from Pododesmus which has only one or two small scars in the muscle area (Keen, 1963, p. 51). The byssal sinus is well developed in Anomia and may even be reflected as a hole near the dorsal margin of the right valve. This condition is in contrast to that of Placuna and Placunopsis in which a byssal sinus is present only in the early stages of development.

The byssal foramen in Anomia is a circular or ovoid opening in the right valve through which the byssus passes. The byssus is terminated by a striate, conical byssal plug
which is occasionally preserved as a fossil (Stensel, Krause and Bading, 1957, p. 99). None was found in the Fox Hills Formation.

**Acanthia micronema Meek**

Pl. 5 Figs. 13 & 14

*Acanthia micronema Meek, 1875, U. S. Geol. Survey Terr., Bull. no. 1, second ser., p. 43; Hayden, 1883, U. S. Geol. and Geog. Survey Terr., Twelfth Ann. Rept., p. 57-58; pl. 23, fig. 2; Shimer and Shrock, 1944, Index Fossils of N. Am., p. 409, pl. 163, fig. 17.


**Original description.**—Shell of medium size, thin, subcircular, subovate, or somewhat irregular; upper valve moderately convex, more or less depressed, and nearly but not quite marginal; cardinal margin generally a little truncated, and slightly thickened; surface ornamented by very fine, regular, often deflected, radiating striae, and small, sometimes regularly disposed concentric marks of growth. Under valve unknown.

**Locality and position.**—From a shaft sunk on the Kansas Pacific Railroad, two hundred miles east of Denver, Colo., 45 feet below the surface, from beds of the age of the Wyoming Bitter Creek Coal series. (Meek, 1875, p. 43)

**Description of material.**—Shell medium size for genus, subcircular, generally irregular, very thin; anterior, posterior, and ventral margins irregularly rounded; dorsal margin somewhat straighter, divided into two segments which
most at an obtuse angle just posteriorad from the beak; hinge of left valve weakly developed, edentulous, with a resilifer which is elongate parallel to the hinge line and indented along its dorsal margin forming a triangular to rectangular re-entrant; three circular muscle attachments present on a subcircular muscle area which is considerably thickened, located dorsad from the center of the shell; the posterio-ventral scar (adductor) smallest, the anterio-ventral scar (posterior pedal retractor) about twice as broad and located directly anteriorad from the adductor scar, the dorsal scar (anterior pedal retractor and byssal) about 1 l/2-2 times as large as the posterior pedal retractor, a fourth scar (byssal?) located just anteriorad from the resilifer and curving around its anterior terminus; right valve unknown; prosopon of irregular growth lamellae and occasional growth lines; most show simple, radiating ribs which become stronger and more widely spaced toward the ventral margin and are often interrupted at their intersections with growth lamellae.

Remarks.--This easily recognized species has been found at three localities in the Fox Hills Formation, all in association with Crassostrea. At locality 141-73-1 the specimens are abundant while they were only occasionally encountered at the other two localities. No right valves or byssal plugs have been identified in the Fox Hills Formation in North Dakota.
The measurements of the species that were well enough preserved to show at least one axis of the specimen as well as the orientation:

<table>
<thead>
<tr>
<th>u</th>
<th>v</th>
<th>w</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>15</td>
<td>0.4</td>
</tr>
<tr>
<td>20</td>
<td>5</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Measurements: Two parameters were measured on all specimens in other respects.

The two types are selected varieties of the same species. The two types are distinct and clearly separated. The smooth and rubbed forms can most reliably be identified by the presence of two slightly elongated more rubbly forms. All three localities are not show typical form of the species. Rubby type is clearly distinguished from the other type.

Although all specimens collected do not show the characteristic, also appear to be more deeply impressed. The muscle impression is close to the ventral margin. The muscle impression is situated between the inner surface and the inner surface of the muscle. The muscle impression is located over the inner surface and muscle impression is similar to the monomorph and rubby form. The right and lower corners are rounded. The right and lower corners are rounded, and the right corners are rounded from the abdomen.

Value where the right and lower corners are rounded. The right and lower corners are rounded. The right and lower corners are rounded to the ventral part of the right and lower corners are rounded.

Common upper clavicular forms on the back of the propom and the other parts of the propom and...
Localities and stratigraphic position.—Specimens were collected at localities 132-79-1 and 132-79-4 and from the Colgate Member of the Fox Hills Formation at locality 141-73-1.

Superfamily: OSTRECIDEA
Family: OSTREIDAE
Genus: Crassostrea Sacco, 1897

Type reference.—Sacco, Federico, 1897, I molluschi del terreni terziarii del Piemonte e della Liguria: Clausen, Torino, v. 22, p. 15.

Type species.—Ostrea virginica Gmelin, by original designation.

Description.—Prodissocoche inequivalve, inequilateral; anterior ligament outside cardinal area; short hinge bears two toothlike denticles at each end. Adult shell variable in form, large in size, elongate along midline, straight to curved; left valve larger and more massive than right. Radial ornament unequally developed on left and right valves. Surface of left valve smooth to finely and irregularly plicate or costate. Right valve smooth to faintly plicate, flat. Left valve deeply cupped dorsally and centrally; valves normally show subcardinal cavities. Cardinal area of left valve composed of well-defined central triangular resiliifer and subequal triangular lateral cardinal folds or plates. Cardinal area of right valve composed of midcardinal fold or central plate and subequal lateral cardinal troughs or plates. Adductor muscle scar ventroposterior, normally colored, large, shallow, semicircular to semi-elliptical; flat side dorsal and nearly perpendicular to midline. Mesozoic forms have simple ovoid to elongate denticles; Cenozoic forms have nondenticulate adult valves. Shell lamellate. (Sohl and Kauffman, 1964, p. 27)
Remarks.—The generic distinction between *Crassostrea* and *Ostrea* has been studied by many students of Recent clams, owing to their great economic value. Summary articles have been written by Thompson (1954) and Gunter (1950) who suggest that the separation of the two genera can be made on the basis of about ten hard characteristics. Comparison of the two genera is presented in tabular form below.

Comparison of features of the common oyster genera, *Ostrea* and *Crassostrea* (Modified from Gunter, 1950)

<table>
<thead>
<tr>
<th>Crassostrea</th>
<th>Ostrea</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Average size large.</td>
<td>Average size small.</td>
</tr>
<tr>
<td>2. Eggs shed into water; fertilization and larval development take place in the water, cavity and gills.</td>
<td>Eggs retained; larval development in mantle.</td>
</tr>
<tr>
<td>3. Eggs small; up to 50,000,000 per spawn.</td>
<td>Eggs large; approximately 1,000,000 per spawn.</td>
</tr>
<tr>
<td>5. Proximal chamber present.</td>
<td>No proximal chamber.</td>
</tr>
<tr>
<td>7. Muscle closer to opening between valves; scar pigmented.</td>
<td>Muscle nearly central; scar not pigmented.</td>
</tr>
<tr>
<td>8. Lower valve more cupped.</td>
<td>Lower valve flatter.</td>
</tr>
</tbody>
</table>
9. Shape variable, more elongate.  Shape subcircular, more constant.

10. Prodissocochoch hinge short, two crenulations at each end; ligament anterior, outside the cardinal plateau; valves dissymmetrical.
Prodissocochoch hinge long, two crenulation at each end; ligament at level of the cardinal plateau; valves symmetrical.

When studying fossil forms, several of these characteristics are applicable. Size, shape and convexity are valuable if one has adequate comparative material. The two most valuable characteristics, however, are adductor muscle position and presence or absence of a subcardinal cavity. The muscle scar is posterioral from the midline in Crassostrea whereas it is generally located along the midline in Ostrea. The displacement of the muscle scar from the midline in Crassostrea may be controlled by the same factor that determines the presence of the subcardinal cavity. Members of the genus Crassostrea possess a proymal chamber which is a semi-enclosed area associated with the mantle cavity. To accommodate the proymal chamber, the left valve becomes more concave; the adductor muscle shifts to a posterior position, and a small cavity arises below the hinge area. In members of the genus Ostrea no proymal chamber is present and, therefore, the muscle location and general configuration of the left valve are not altered.


Glaesastrea glabra (Meek and Hayden)

Pl. 5, Figs. 1-6

Glaesastrea glabra, Meek and Hayden, 1857, Acad. Nat. Sci., Proc., v. 9, p. 146; Meek and Hayden, 1876, U. S. Geol. Survey Terr., v. 9, p. 509, pl. 40, fig. 2; Cuvancara, 1966, Mich. Mus. Paleontology, v. 20, no. 10, p. 320, pl. 4, figs. 3-6, Pl. 5, figs. 10-12.

Original description.—Shell elongate-ovate, rather irregular, usually curving to the left, but sometimes to the right; generally narrower near the beaks than at the other extremity, most frequently turned abruptly to the left; umbonal (sic.) region sometimes a little distorted by the cicatrix of attachment. Upper valve flat, or a little concave; beak truncated at the extremity. Surface smooth, or only marked by very small, faint concentric wrinkles of growth. Length about 3 inches; breadth 1.50 to 2 inches.

Locality and position. Mouth of Judith River, in sandstone of formation No. 1? of general section. (Meek and Hayden, 1857, p. 146-147)

Description of material.—Shell large, irregularly ovate-elongate, thin; left valve moderately concave, right valve nearly flat; anterior and posterior margins sinuous in forms whose growth was unrestricted, ventral margin evenly rounded, dorsal margin generally drawn out into a pointed beak which is usually slightly twisted posteriorly; hinge reduced to a centrally located, triangular resilifer and lateral cardinal folds on the left valve and a central triangular midcardinal
feld and lateral cardinal troughs in the right valve; denticles absent; shallow subcardinal cavity generally present below hinge; single adductor muscle reniform with narrow end directed toward the dorsum, located near the posterior margin and slightly ventrad from the dorso-ventral midline; prosopon limits to irregular growth lamellae which may, in local places, show faint radial undulations.

Remarks.—Specimens of this species were collected from fourteen localities in the Fox Hills Formation in North Dakota. In ten of these sites, they were so common that they appear to have constituted small banks. Although a few fragments were collected which showed some evidence of fouling by boring sponges, the animals apparently lived in an area where the salinity was low enough so that there were few predaceous and fouling organisms. Fasciculata sp. has been found associated with G. glabra similar to the association with G. virginica in the Gulf of Mexico found by Wells (1961).

The species is referred to the genus Grassostrea on the basis of the position of the adductor muscle scar, shape, and possession of the subcardinal chamber. Contrary to the generic diagnosis of Schl and Kauffman (1964, p. H7) the species does not show denticles in the region of the hinge. The suggestion that Schl and Kauffman made (1964, p. H7) that Mesozoic forms are denticulate does not seem to be universally applicable.
For all specimens of this species display a pronounced subcardinal cavity. Fifty-two left valves from six localities were examined and 36 possessed a definite re-entrant below the hinge whereas the remaining 13 showed only a slight indentation or no indentation at all. Separating the sample on this characteristic alone, however, appears to be quite unnatural as the shells were otherwise identical.

**Measurements.**—Five parameters were measured on all specimens which were well enough preserved to display at least three of the parameters. The orientation of the measurements is similar to that suggested by Schl and Kauffman (1964, p. 59).

<table>
<thead>
<tr>
<th>Height</th>
<th>Length</th>
<th>Resilifer width</th>
<th>Height of cardinal area</th>
<th>Maximum diameter of muscle scar</th>
</tr>
</thead>
<tbody>
<tr>
<td>57.6</td>
<td>35.5</td>
<td>6.1</td>
<td>9.5</td>
<td>13.29</td>
</tr>
<tr>
<td>n=73</td>
<td>n=74</td>
<td>n=74</td>
<td>n=75</td>
<td>n=40</td>
</tr>
</tbody>
</table>

**Types.**—Hypotypes, University of North Dakota Cat. Nos. 9207, 9330, and 9303.

**Localities and stratigraphic position.**—Specimens were collected from the Timber Lake and Colgate members of the Fox Hills Formation at localities 130-80-9, 130-80-10, 130-83-11, 130-80-14, 131-78-4, 132-79-1, 132-79-2, 132-79-4, 133-73-1, 133-77-6, 133-78-2, 133-78-4, 134-71-1, 134-72-1, and 141-73-1.
*Crassoseus subtrigonalis* (Evans and Shumard)

**Pl. 5, Fig. 7**


**Original description.**—Shell elongate, ovate subtrigonal, very inequivale; superior valve flattened, convex on the umbo, concave or plane towards the palleal margin; inferior valve convex; umbo strongly subangulated, declining rapidly to the lateral edges, and rounded towards the palleal margin; beak elongated, acute, slightly arched laterally, scarcely incurved; surface presenting some imbricating, concentric lines of growth, and on some specimens a few indistinct radiating costae.

**Locality.**—It occurs in greenish-gray calcareous siliceous sandstone, at a butte in the vicinity of Owl Butte, between Mooreau and Grand Rivers. It occupies a higher geological position than the preceding species. (Evans and Shumard, 1857, p. 40)

**Description of material.**—Shell small for genus, ovoid, thin; anterior and posterior margins gently arcuate, ventral margin somewhat truncated, dorsal margin drawn out into a small, pointed beak which is directed posteriorad; hinge of left valve with central triangular resilifer and lateral cardinal folds, with about five small pits along the anterio-dorsal and posterior-dorsal margins adjoining the hinge, subcardinal cavity well developed; right valve unknown; adductor muscle scar pear-shaped, located dorsad from the dorso-ventral midline; prosocon limited to growth lamellae.
Remarks.—Only one specimen was collected which can be referred to this species. It is smaller than the specimen described by Meek and Hayden (1876, p. 510) which has a length of 1.82 inches. The species differs from C. glabra in that it is smaller, has a less concave left valve, has its muscle scar located more dorsad, and has a regularly pitted hinge line. It differs from immature specimens of C. glabra in the position of the muscle scar and in the nature of the hinge line, which is never pitted in C. glabra. Meek and Hayden (1876, p. 510) in describing a specimen which they questionably referred to this species, described the lateral margins as "crenate and sometimes a little furrowed". In other respects, however, their description overlaps that of Evans and Shumard (1857) which leaves little doubt that the species is distinct, although poorly represented.

Measurements.—Five parameters were measured on the single immature specimen. They were oriented in a manner similar to that suggested by Schl and Kauffman (1964, p. 45).

| Parameter                      | Value  
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<tbody>
<tr>
<td>Height</td>
<td>10.9</td>
</tr>
<tr>
<td>Length</td>
<td>8.0</td>
</tr>
<tr>
<td>Resilifer width</td>
<td>0.5</td>
</tr>
<tr>
<td>Height of cardinal area</td>
<td>1.6</td>
</tr>
<tr>
<td>Maximum diameter of muscle scar</td>
<td>2.4</td>
</tr>
</tbody>
</table>

Type.—Hypotype, University of North Dakota Cat. No. 5329.

Locality and stratigraphic position.—The specimen was collected from the top of the Timber Lake Member of the
Fox Hills Formation at locality 134-71-1.

_Crassostrea Pollucida_ (Meek and Hayden)

Pl. 5, Figs. 15-17

_Crassostrea Pollucida_ Meek and Hayden, 1878, U. S. Geol. Survey

_Crassostrea Pollucida_ Meek and Hayden, 1876, U. S. Geol. Survey

_Crassostrea Pollucida_ Meek and Hayden, 1876, U. S. Geol. Survey Fourth Ann. Rept., p. 296, p. 50, Figs. 5 & 6;

_Crassostrea larva_ Hall and Meek, 1834, Mass. Ann. Sci. and Arts,

_Crassostrea larva_ Hall and Meek, 1834, Mass. Ann. Sci. and Arts,

_Crassostrea larva_ Hall and Meek, 1834, Mass. Ann. Sci. and Arts,

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_Crassostrea larva_ Hall and Meek, 1834, Mass. Ann. Sci. and Arts,

_Crassostrea larva_ Hall and Meek, 1834, Mass. Ann. Sci. and Arts,
to form a slight concavity on the posterior margin; ventral margin gently rounded; dorsal margin terminated by slightly pointed beaks which curve posteriorly; hinge with a triangular resilifier in the left valve and a midcardinal fold in the right valve; subcardinal cavity shallow; adductor muscle scar ovoid, indistinct, located posteriorad from the midline; prosocon of weak growth lamellae and coarse undulations on the antero-dorsal and posterio-dorsal margins which become obscure about one-third of the distance to the midline; surface of attachment of the left valve extends from the beak to a position in the middle of the valve, ovoid in outline.

Remarks.—Specimens of this species were collected at four localities in North Dakota where they were the only oysters present. The specimens conform closely to the description cited above. The species is readily distinguishable from other oysters in the formation in that it is the only species that shows regularly undulating lateral margins. It also has a characteristic base of attachment on the left valve rather than the irregular attachment shown on _C. clabra_ and _C. subtrigonalis_.

The specimen selected by Meek and Hayden as the holotype is the same specimen which had previously been identified as _Ostrea larva_ (Meek and Hayden, 1856, p. 15). Meek later
(1868, p. 429) listed it as Q. translucida without describing
the species and subsequently (1873, p. 15) described and
figured the same specimen as the type of Ostrea bellica.
It appears, then, that Q. translucida is a nomen nudum.

Measurements.--Four parameters were measured on all
specimens which were well enough preserved to display at
least three of the parameters. All of the measured specimens
were collected at locality 130-80-6. The orientation of the
measurements is similar to that suggested by Sohl and Kauf-

<table>
<thead>
<tr>
<th>Valve</th>
<th>Height</th>
<th>Length</th>
<th>Resilifer width</th>
<th>Height of cardinal area</th>
</tr>
</thead>
<tbody>
<tr>
<td>left</td>
<td>27.8</td>
<td>20.3</td>
<td>2.4</td>
<td>3.7</td>
</tr>
<tr>
<td>left</td>
<td>26.1</td>
<td>21.3</td>
<td>2.1</td>
<td>3.4</td>
</tr>
<tr>
<td>right</td>
<td>26.9</td>
<td>17.6</td>
<td>---</td>
<td>2.2</td>
</tr>
</tbody>
</table>

Types.--Hypotypes, University of North Dakota Cat. Nos.
9331 & 9332.

Locality and stratigraphic position.--Specimens were
collected at localities 130-80-6, 131-80-2, 131-80-4, and
134-80-7.
Order: SCALPELLIBRANCHIA
Superfamily: ASTANTIDIDA
Family: ASTARTIDIDAE
Genus: Vatericardia Conrad

Type reference.--Conrad, T. A., 1869, Observations on the genus Astarta, with descriptions of three other genera of Crassatellidae; American Jour. Conch., v. 5, p. 48. In this work, Conrad spelled the generic name Vatocardi. In a subsequent work (Conrad, T. A., 1872, Descriptions and illustrations of genera of shells; Acad. Nat. Sci. Philadelpia Proc. for 1872, p. 52) he corrected the spelling to Vatericardia which has been followed by subsequent workers.

Type species.--Astarta crenalizans Conrad, by original designation.

Diagnosis.--Shells generally small, subtriangular or subelliptical; internal characteristics like Astarte with well developed cardinals and reduced or obsolete laterals; muscle scars subequal, faintly impressed; pallial line complete; surface marked by both radial and concentric prosopon which may be developed in varying degrees.

Remarks.--The placement of this genus has been the subject of considerable controversy. The general definition
of the Astartidae does not admit genera which are radially sculptured. This view was held by Dall (1913, p. 472) and Franz (1960, p. 2093). Other workers, including Wade (1926, p. 76), Stephenson (1941, p. 175), and Richards (1958, p. 184), were of the opinion that the characteristics of the hinge are more important than those of prosopon and, therefore, refer the genus to the Astartidae. The very close resemblance of the hingement of this species to that of Astarta seems to leave little doubt that placement in the Astartidae is valid.

**Vetocardiidae crenulirata** (Conrad)

**Pl. 6, Figs. 6 & 7**

**Astarta crenulirata** Conrad, 1850, Acad. Nat. Sci. Philadelphia, Jour., 2nd ser., v. 4, p. 262, pl. 46, fig. 25.

**Astarta crenulirata** Conrad. Gabb, 1861, Synopsis of the Mollusca of the Cretaceous formation, p. 100.

**Astarta crenulata** Conrad. Meek, 1864, Checklist of the invertebrate fossils of North America, Cretaceous and Jurassic, p. 11.


**Vetocardiidae crenulirata** (Conrad). Conrad, 1869, American Jour. Conch. v. 5, pl. 1, fig. 23.

**Vetocardiidae crenulirata** (Conrad). Whitfield, 1885, U. S. Geol. Survey, Mon. 9, p. 138, pl. 18, figs. 5-7.
Sci. Philadelphia, Proc. for 1872, p. 52, pl. 1, fig. 4;
Keller, 1907, New Jersey Geol. Survey, Paleontology,
v. 4, p. 365, pl. 52, figs. 9, 10; Stephenson, 1914,
U. S. Geol. Survey, Prof. Paper 157, p. 72,
pl. 24, figs. 12 & 13; Richards, 1956, New Jersey
Geol. Survey, p. 184, pl. 31, figs. 6-8.

Original description.--Triangular convex; costae
about 20, concentric, very prominent, slightly incurved,
crenulated by minute radiating lines; margin within
crenulated, crenae rounded on the posterior margin, and
the rest tuberculiform. (Conrad, 1860, p. 232)

Description of material.--Shell very small for genus,
cylindrical, inflated, thickened; anterior and posterior margins
nearly straight, ventral margin gently and regularly curving;
dorsal margin terminates acutely in a moderately prominent,
inturned, prosogyral beak which is located just anterior of
the midline of the shell; hinge of right valve thickened,
well defined; two or three cardinal teeth, the posterior one
is elongate and parallel to the margin of the shell and is
finely serrate on its ventral edge; other cardinal teeth
occupy a position just beneath the beak and just posterior
to it; a small, arcuate socket bounds the anterior limit
of the cardinal teeth; anterior lateral apparently reduced to
minute undulations on the shell margin, or absent; posterior
adductor is a short ridge which is oriented in line with the
axis of the posterior cardinal tooth, rather diminutive;
ligament external, occupying a narrow, shallow, arcuate
groove which extends from the beak to the posterior extremity
of the posterior lateral tooth; left valve unknown; adductor
muscle scars dorso-ventrally elongate, nearly equal in size,
located very near the margins and connected by a smooth,
arcuate pallial line; a small, circular pedal muscle scar is
located above the posterio-dorsal margin of the anterior
adductor; entire inner surface thickened by a porcellaneous
layer except the ventral margin which is thin and strongly
crenulate; prosopon consists of 19 radiating costae which are
crossed by about 30 broad, concentric striations which are
smaller and more closely spaced near the beak; the combined
effect of the radial and concentric prosopon is that of
radiating costae which are ornamented by transversely elongate
nodes; some of the nodes seem to be excavated along their
ventral margins resulting in small, scale-like processes;
prodissoconch smooth or only crossed by growth lines as
is the deeply impressed lunule; escutcheon not defined.

Remarks.--Only one specimen, a complete right valve,
of this species has been collected from the Fox Hills
Formation and, as far as I known, from the Cretaceous of the
Midcontinent. It was found at a locality dominated by the
oyster, Crassatrea glabra.
adductor is a short ridge which is oriented in line with the
axis of the posterior cardinal tooth, rather diminutive;
ligament external, occupying a narrow, shallow, arcuate
groove which extends from the beak to the posterior extremity
of the posterior lateral tooth; left valve unknown; adductor
muscle scars dorso-ventrally elongate, nearly equal in size,
located very near the margins and connected by a smooth,
arculate pallial line; a small, circular pedal muscle scar is
located above the posterior-dorsal margin of the anterior
adductor; entire inner surface thickened by a porcellaneous
layer except the ventral margin which is thin and strongly
crenulate; prosopon consists of 16 radiating costae which are
crossed by about 30 broad, concentric striations which are
smaller and more closely spaced near the beak; the combined
effect of the radial and concentric prosopon is that of
radiating costae which are ornamented by transversely elongate
nodes; some of the nodes seem to be excavated along their
ventral margins resulting in small, scale-like processes;
prodissococonch smooth or only crossed by growth lines as
is the deeply impressed lunule; escutcheon not defined.

Remarks.--Only one specimen, a complete right valve,
of this species has been collected from the Fox Hills
Formation and, as far as I known, from the Cretaceous of the
Midcontinent. It was found at a locality dominated by the
oyster, Crassostrea glabra.
Several other related species have been described in
North America. *V. webberiillensis* Stephenson from the
Ceresiana and Kemp formations differs in having radial and
concentric sculpture of about equal magnitude which results
in cancellate sculpture, whereas *V. crenalirata* has some-
what stronger radial sculpture. *Vasericardia subcircular*
Wade, from the Ripley Formation, and *V. gregaria* (Meek and
Hayden), from the Pierre Formation, are devoid of radial
sculpture.

Measurements.—Three parameters were measured on the
single right valve.

<table>
<thead>
<tr>
<th>Height</th>
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<th>Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5</td>
<td>2.4</td>
<td>0.7</td>
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</tbody>
</table>

*Type.*—Fyptotype, University of North Dakota Cat. No.
9355.

*Locality and stratigraphic position.*—The single specimen
was collected from the Timber Lake Member of the Fox Hills
Formation at locality 134-72-1.

Superfamily: ASTARTOIDEA

Family: ASTARTIDAE

Genus: Astarte Sowerby

*Type reference.*—Sowerby, C. B., 1818, *Mineral conchology
of Great Britain*, v. 2, p. 33, pl. 137.
Nile snails. -- *Venus seneca* Manton = *Pectunculus sulcatus* Dr. Costa, by original designation.

**Description.** -- Shell rounded to trigonal, subsolid, inequivalve. Umbilicus low with the umbilical wall facing forward. Lamellae and escutcheon present. Hinge with 3 cardinals in each valve, the middle right, and the middle and interior left strong, the others small or obsolete. Laterals small one in each, right anterior and left posterior. Ligament external, attached to a narrow nuchal. Aductus scars distinct, subequal, connected by a simple pallial line. Ventral margins crenulated. Externally covered with a brown or dark-colored periostracum. Northern waters. (Olsom and Harbison, 1953, p. 63)

**Remarks.** -- The general diagnosis given above seems to agree with those given by other workers. It is, however, a bit restrictive. The internal characters are so variable, in fact, that Ball (1903, p. 1436) was prompted to make the following remarks concerning recognition of the genus:

A certain variability in characters usually stable is a marked feature of the genus. After much study of recent species and the diagnoses of groups found in the literature, I am of the opinion that these variations for the most part are such as can not be properly used for the subdivision of the genus. The crenulation of the margin of the valves is not more than of specific value; the obsolescence of the terminal cardinal teeth of the hinge, the greater or less prominence of the lateral laminae are characters which in this genus I have found inconstant even in the species. The flattening of the umbones, which is so conspicuous a character in many of the fossil species when a series of species is studied, is seen to be so gradually modified between one species and another as to admit of no hard and fast line being drawn between those with and those without this character. By taking a single recent species to compare with some fossil form it may chance that marked discrepancies may be noted, but if a series
of species be compared, these discrepancies will be found inconsistent.

The single right valve of a new species assigned to the genus *Distans* which was collected from the Fox Hills Formation in North Dakota conforms closely to the description given above, with a single exception. The ventral margin shows no evidence of pseudulations, a character which is not considered critical by Bell.

*Distans hollandi* n. sp.

Pl. 8, Figs. 3 & 4

Description.—Shell large for genus, moderately compressed, subtrigonal, thick; anterior margin smoothly and tightly rounded; posterior margin obliquely truncated dorsally and tightly rounded ventrally; ventral margin smoothly and gently rounded; dorsal margin slopes away from the beaks in two, nearly straight, elements at an angle of about 115°; the posterior element of the dorsal surface intersects the posterior truncation near the posterior terminus of the posterior adductor muscle scar at an angle of about 135°; anterior element of the dorsal surface intersects the anterior margin in a smoothly increasing curve; beaks located just anteriad from the midline, small, inturned, prosogyral; hinge moderately broad, thickened, well developed; hinge of the right valve with a large, triangular tooth that projects posterior-
ventrally from the beak, very broad at the base and narrowing to a ridge, bounded dorsally and posteriorly by a shallow, narrow socket and anteriorly by a deep, triangular socket whose long axis is oriented parallel to the dorso-ventral axis; a small, elongate thickening just anteriorad from the anterior socket probably represents a diminutive anterior cardinal tooth; anterior lateral portion of the hinge provided with a broad, flat area which is bounded on the anterior margin by an elongate swelling which is the remnant of an anterior lateral tooth; posterior lateral element of the hinge edentulous, narrowing rapidly toward the posterior terminus; ligament external, seated on an ovoid scar which is located posteriorad from the beaks and is raised to the general level of the exterior of the shell; adductor muscle scars subequal, anterior scar smoothly rounded ventrally and attenuated dorsally; the dorsal half of the scar is deeply impressed into a thickened portion of the shell that occupies the area from the middle of the hinge to the anterior terminaton of the hinge; posterior adductor muscle scar larger than the anterior scar, nearly circular, indistinct; a moderately large pedal retractor muscle scar is deeply impressed into the thickened antero-dorsal portion of the shell just dorsad from the dorsal termination of the anterior adductor muscle scar; prosopon consists of fine growth lines
which are obscure in the area of the beaks and which are best
developed in the posterio-dorsal region; posterio-dorsal
region separated from the rest of the shell by a sharp
umbonal ridge which proceeds from the beak to the ventral
termination of the posterior truncation; lunule and escutcheon
apparently not developed.

Remarks.—This species has presented a perplexing problem
with regard to its taxonomic placement. It has been described
from a single right valve which, although badly broken, is
well preserved. All of the characteristics of the shell tend
to indicate placement in the genus *Ascutia* except that of
size. All specimens of the genus known to the writer are
small, whereas the specimen from the Fox Hills is about 150
mm long. In general size and outline, the shell more closely
resembles *Tivela* but it lacks the pallial sinus and prominent
anterior lateral tooth characteristic of that genus.

The species is undoubtedly new and completely different
from any other Cretaceous or Paleogene species. It has been
compared with specimens in the collection of the University
of North Dakota and the Academy of Natural Sciences of
Philadelphia and no specimens which could even be considered
closely related were found. Dr. Horace Richards (oral communi-
cation, 1966) concurred with the identification with the same
reservations in regard to size. It has, therefore, question-
species has the following dimensions:

<table>
<thead>
<tr>
<th>Length</th>
<th>Height</th>
<th>Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>147.8</td>
<td>102.8</td>
<td>ca. 26</td>
</tr>
</tbody>
</table>

Type.—Holotype, University of North Dakota Cat. No. 9379.

Etymology.—The trivial name was given in honor of Dr. F. D. Holland, Jr., Professor of Geology at the University of North Dakota.

Locality and stratigraphic position.—The single specimen of this species was collected from the Timber Lake Member of the Fox Hills Formation in sec. 26, T. 134 N., R. 71 W., Logan County at locality 134-71-1.

Superfamily: SPHERICOCIDA
Family: CORBICULIDAE
Genus: CORBICULA MÜHLFELDT

Type reference.—Mühlfeldt, Megerle von, 1811, Entwurf eines neuen Systems der schalthiserehäuser: Magazin der Gesellschaft Naturforschender Freunde, 5ter Jahrgang, Berlin p. 56.

Type species.—Cerithia plumarius Müller, by original designation.
Description.--Shell usually heavy, sub-trigonal or cordate; not markedly unequal; umbones sub-central, high and prominent; lunule and escutcheon not defined; external surface smooth or concentrically furrowed; epidermis polished; cardinals three in each valve, diverging fan-like beneath the umbones; both anterior and posterior laterals developed, finely striate transversely; pallial line little or not at all sinuated. (Gardner, 1933, p. 154)

Remarks.--Corbicula ranges from the Cretaceous to the Recent and is generally found associated with fresh and brackish-water forms. Recent forms live almost exclusively in Asia but in the past few years have been introduced into the United States, probably in association with the Japanese sees oyster, Ostrea gigas (Sinclair and Isom, 1963, p. 17). Fossil species are common in North America and Europe (Gardner, 1933, p. 154).

Corbicula cytheriformis (Meek and Hayden)

Pl. 5, Figs. 23 & 24


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Original description.—Shell broad trigonal ovate, varying to subcircular, rather thick and strong; extremities more or less rounded; base semiovate, usually more prominent before than behind themiddle; dorsal outline sloping from the beaks, the anterior slope being more abrupt than the other, and slightly concave, while the posterior is convex; beaks rather elevated, moderated gibbous, located in advance of the middle; surface marked by fine lines of growth, which sometimes show a slight tendency to gather into small irregular concentric wrinkles. Length, inches; height, inch; thickness, inch sic.

Locality and position.—Estuary beds, near mouth of Judith River (Meek and Hayden, 1860, p. 176).

Description of material.—Shell ovoid, medium size for genus, thick; anterior margin slightly concave, sloping abruptly away from the beaks; posterior margin convex, sloping gently away from the beaks; ventral margin gently rounded; dorsal margin terminating in prosogyral beaks which vary from rather sharply pointed to thickened and gently rounded; hinge well-developed, curving abruptly posteriorad of the cardinal teeth; three cardinal teeth in each valve, anterior and medial ones in the left valve well developed and equal, posterior cardinal narrower and leff well defined, anterior tooth of the right valve weakly developed, medial
and posterior ones well developed and equal; anterior and posterior lateral teeth well developed in the left valve, very weakly striate or smooth; external ligament occupies a narrow groove from just behind beaks to near dorsal end of posterior lateral tooth (left valve) and socket (right valve); muscle scars nearly equal in size, posterior adductor slightly larger, both are ovoid, anterior adductor scar slightly impressed into shell along its inner margin, posterior one level with the inner surface of the shell; pallial line entire; pallial sinus either very weakly developed or absent entirely; prosopon variable, consisting of uniform, concentric growth lines or considerably thickened, forming an undulatory surface of regular or irregular, concentric furrows.

**Remarks.--**Specimens of this species were found at four localities in the Fox Hills Formation in North Dakota. In all cases they were found in association with the oyster, *Crassostrea glabra*. *Corbicula* typically inhabits fresh water; however, a few species seem to prefer brackish water (Sinclair and Isom, 1963, p. 13). *Corbicula cytheriformis* seems to be one of the latter types in that its association with oysters precludes fresh water. Oysters have been reported in water varying in salinity from 2.5 to 33 parts per thousand dissolved solids; however, they probably cannot survive indefinitely at salinities less than 9 parts per thousand
(Churchill in Hopkins, 1934). The size of the oyster banks in the Fox Hills indicates that the oysters existed for a long enough time so that a salinity higher than 9 parts per thousand might be inferred. The presence of Corbicula indicates that the salinity was not as high as for normal marine water. The two genera in association with each other, then, offer an excellent indication of marginal, estuarine conditions.

The specimens here referred to this species conform closely to the descriptions cited above except for the transversely striate lateral teeth. A slight indication of striations can be noted on some of the specimens but most of them appear to be so corroded that any subtle surface structures that might have been present are obscured.

There appears to be considerable intraspecific variation in C. cytheriformis. The outline of individuals may vary from nearly ovoid to posteriorly attenuated. Further, the valves may be considerably thickened. Finally, the thicker specimens are commonly ornamented by concentric undulations whereas the thinner specimens show only growth lines. Such gross shape variations seem to be characteristic of Corbicula (Sinclair and Isom, 1963, p. 3) which indicates that shape cannot be used for purposes of identification. Instead, characteristics of the hingement must be used.
Measurements.--Three parameters were measured on all specimens which were well enough preserved to display at least two of the parameters.

<table>
<thead>
<tr>
<th>Height</th>
<th>Length</th>
<th>Width</th>
<th>Valve</th>
</tr>
</thead>
<tbody>
<tr>
<td>21.9</td>
<td>20.8</td>
<td>8.6</td>
<td>5 left</td>
</tr>
<tr>
<td>n=8</td>
<td>n=7</td>
<td>n=7</td>
<td>3 right</td>
</tr>
</tbody>
</table>

Types.--Hypotypes, University of North Dakota Cat. No. 9326 (left valve) and 9333 (right valve).

Localities and stratigraphic position.--Specimens were collected from the Timber Lake and Colgate members of the Fox Hills Formation at localities 132-79-1, 132-79-2, 134-71-1, and 141-73-1.

Corbicula moreauensis (Meek and Hayden), 1856

Pl. 5, Fig. 20


Corbicula subelliptica, var. moreauensis (Meek and Hayden); Meek, 1876, U. S. Geol. Survey Terr., v. 9, p. 524, pl. 43, figs. 1 and 2c.
Original description.--Shell ovate, nearly elliptical, compressed, extremities rounded; anterior end narrower than the posterior, base semi-ovate, most prominent behind the middle; beaks not much elevated, placed a little in advance of the centre; surface marked with fine distinct lines of growth; cardinal edge rather thick, and having under the beaks three diverging center teeth in each valve, the anterior of which is the smallest; lateral teeth two, (in the left valve) long, parallel to the cardinal edge, and fitting into corresponding grooves in the other valve; muscular impression deep. Length about .90 inch; breadth .36 inch; height .66 inch.

Each of the cardinal teeth has, in its upper end, a small notch which is occupied, when the valves are closed, by a small projection between the teeth of the other valve. The anterior later tooth appears to be larger and approaches the central tooth more nearly than the posterior. Our specimens are generally more or less worn, and thickly coated with firmly adhering sand.

Locality.--Near Moreau river, in a sand bed, associated with bone of Titanotherium? Probably a distant outlier of the White river bone beds. (Meek and Hayden, 1856, p. 115-116)

Description of material.--Shell small for genus, compressed, elliptical, thick; anterior margin smoothly rounded from dorsal to ventral margins; posterior margin less tightly curved, subtruncate below the posterior lateral socket; ventral margin evenly rounded; dorsal margin consists of two nearly straight elements which converge at the apex which is just posteriorad from the position of the cardinal teeth; beaks small, slightly anterior of the midline, prosogyral; hinge long, consisting of two elements parallel to the straight portions of the dorsal margin; anterior portion of left
valve consists of three cardinal teeth and a lateral socket; the cardinals radiate from beneath the beaks and do not coalesce at their dorsal ends, the intervening spaces are filled by a secondary calcareous deposit; the medial and posterior cardinal teeth are about equal in size and are well developed, the anterior one is a small dorso-ventral swelling on the posterior termination of the ridge which defines the anterior lateral socket; intervening cardinal sockets of left valve located just behind the corresponding teeth and of similar proportions; anterior lateral short, deep, and crossed by small striae; posterior portion of hinge of left valve composed of a single lateral socket about the same size as the anterior lateral socket and similarly striate, separated from the cardinal teeth by a distance almost equal to the length of the lateral socket; ligament external, located in a narrow, shallow, arcuate pit extending from the beak almost to the anterior end of the posterior lateral socket; right valve unknown; adductor muscle scars ovoid and equal in size; the axial edge of both scars is deeply impressed into the shell so that the scars are nearly perpendicular to the plane of commissure; three small, indistinct scars are located under the hinge between the anterior adductor and the midline of the shell; pallial line complete, distinct; pallial sinus a shallow, arcuate reentrant; a low ridge on the
interior of the shell extends from below the cardinal teeth posterio-ventrad, disappearing at about the junction of the midline of the shell and the pallial line; prosopon consists of concentric growth lines, which are distinct on all parts of the shell except the beaks from which they have been eroded.

Remarks.--The single specimen here referred to this species closely conforms to the original description. The type specimen of the species was poorly preserved and, hence, did not show the internal ridge (Meek, 1876, p. 524). Specimens later obtained by Meek did, however, show the ridge which prompted him (1876, p. 524) to consider the group a variety of a previously named species, *C. subelliptica*. This taxonomic placement was continued by many subsequent authors (Stanton, 1910, p. 175, 179, 180, 184; Calvert, *et al.*., 1914, p. 14; Bowen, 1915, p. 114). There are, however, several features which appear to be so significant on *C. moreauensis* that it should be distinguished from *C. subellipticum*. Most important, the highest part of the shell of the former is posteriorad from the beaks whereas in *C. subellipticum* the highest part of the shell is in line with the beaks. This variation in shape significantly alters the arrangement of the hingement so that in *C. moreauensis* a distinct flexure occurs just behind the cardinal teeth which is absent in
C. subellipticum. Further, the lateral teeth of C. moreauensis seem to be more strongly striate than those of C. subellipticum. Finally, the latter is a larger, thinner shell than C. moreauensis. For these reasons, then, the two species are considered distinct.

To the writer's knowledge, these are the only two species of Corbicula which show an internal ridge such as the one described. It is, therefore, difficult to determine other species which might be closely related. The only other species of Corbicula in the Fox Hills Formation of North Dakota is C. cytheriformis which differs markedly in outline and does not possess the internal ridge.

Measurements.--Three parameters were measured on the single left valve referred to this species.

<table>
<thead>
<tr>
<th>Height</th>
<th>Length</th>
<th>Width (single valve)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.6</td>
<td>16.6</td>
<td>4.2</td>
</tr>
</tbody>
</table>

Types.--Hypotype, University of North Dakota Cat. No. 9349.

Locality and stratigraphic position.--The specimen was collected from the Timber Lake Member of the Fox Hills Formation at locality 134-71-1.
Superfamily: CARDIOIDEA

Family: CARDIIDAE

Genus: Cardium Linnaeus

**Type reference.**—Linnaeus, C., 1758, Systema naturae, ed. 10.

**Type species.**—Cardium costatum Linnaeus, by subsequent designation of Children, 1823.

**Description.**—Shell large, orbicular, strongly inflated, of medium thickness, equivale, subequilateral widely gaping behind. Sculpture strong, formed by high, narrow, hollow-crested or triangular ribs separated by wide, flattened intervals, except laterally where the ribs are reduced to small radial cords on the anterior slope and somewhat scabrous riblets on the posterior. Hinge strong, the right valve having two pointed or hook-shaped cardinal teeth, with corresponding sockets in the other valve. Laterals strong in both valves. Ligament external, seated on a large nymphal plate. (Olsson and Harbison, 1953, p. 99)

Subgenus: Ethnocardium White


**Type species.**—Cardium speciosum Meek and Hayden, 1857.

This name, however, was preoccupied by *C. speciosum* Adams and Reeve, 1850. A subsequent study of the family prompted Dall (1901, p. 384) to change *C. speciosum* Meek and Hayden to *C. whitei*. 
Description.--This subgenus is characterized by lines of deep pits on the internal pallial area, and these lines correspond to the intercostal channels of the external surface. The internal pits extend through the shell wall or are covered outwardly only by a thin film of shell which, in some cases, may have been destroyed in fossilization; at any rate the pits appear externally as rows of perforations between the costae of most specimens. (Stephenson, 1941, p. 195)

Remarks.--There is little difficulty identifying members of this subgenus because of the distinctive pitted interior. Apparently little weathering is necessary to perforate the shell at these points and all of the specimens from the Fox Hills Formation have fenestrate areas. This condition was first noted by Meek (1856, p. 275). Meek apparently considered this a trivial character whereas White used it as the basis for a new subgenus.

This subgenus is apparently restricted to the Upper Cretaceous as the only two species which have been referred to it are Cardium (Ethmocardium) whitei and C. (E.) welleri, both of this age. A cursory study of other cardiids from the Cretaceous and Tertiary did not reveal any other forms that might, even questionably, be so assigned.

Cardium (Ethmocardium) whitei Dall
Pl. 5, Figs. 21 & 22

Cardium (Acanthocardia) speciosum Meek and Hayden. Meek, 1864, Smithsonian check-list Cretaceous fossils, p. 12.

Cardium (Criocardium) speciosum Meek and Hayden. Meek, 1876, U. S. Geol. Survey Terr., v. 9, p. 169, pl. 37, fig. 4.


Original description.--Shell circular or round oval, higher than long, gibbous in the central and umbonal regions; buccal border a little more rounded than the anal; base regularly rounded; beaks elevated, slender, pointed, incurved and nearly central, very slightly oblique; surface ornamented with numerous simple, slender, radiating costae, alternating with rows of elevated points of about their own breadth; border crenulated? Length .57 inch; height .67 inch; breadth .48 inch.

Locality and position.--Bad Lands of Judith River, from a sandstone, the position of which is doubtful, but probably No. 1 of the series. (Meek and Hayden, 1856, p. 274-275)

Description of material.--Shell very small for genus, nearly circular, inflated, very thin; anterior and ventral margins smoothly and evenly rounded; posterior margin slightly truncated, nearly straight; dorsal margin smoothly rounded, with rather prominent, centrally located, inturned, proso-gyral beaks; hinge short, not thickened; hinge of left valve with a large, conical cardinal tooth located below the beak and a smaller, elongate cardinal tooth located above and...
slightly posteriorad from the anterior cardinal; a large triangular socket separates the two teeth and a second cardinal socket occupies a position anteriorad from the anterior cardinal tooth; anterior lateral tooth elongate, highest at its midpoint with a lateral socket along its dorsal margin; posterior lateral located farther from the cardinal teeth than is the anterior, highest near the posterior termination, not bounded by sockets; hinge of right valve with cardinal teeth similar to those of opposite valve except that the posterior tooth is the most prominent; anterior lateral area with a prominent socket bounded by low ridges which may act as lateral teeth; posterior lateral area with a prominent socket bounded ventrally by an elongate tooth and dorsally by the dorsal shell margin which is narrow and tooth-like; adductor muscle scars weakly defined, apparently about equal in size, ovoid, and dorso-ventrally elongate; paliialine entire, distant from the ventral margin; entire inner surface covered by small pits which are best developed in the posterior half of the shell; in the posterior portion of the shell many of the pits have been excavated to the point that small holes perforate the shell; inner margin regularly crenulate; prosopon primarily of about 35 strong radial ribs which are most prominent in the medial part of the shell; the ribs are crossed at regular intervals by fine growth lines; the
perforations mentioned above penetrate the shell in the flat-bottomed grooves between the ribs; the grooves are about the same width as the adjoining ribs, both becoming narrower near the anterior and posterior margins of the shell.

Remarks.--This species, which has been reported from several areas in the midcontinent, is not found in any abundance in the Fox Hills Formation in North Dakota. Only two specimens at one locality have been collected.

Several interesting observations have been made concerning the pits and holes observed in the shell of this subgenus. Meek and Hayden (1856, p. 275) were aware of them when the species was first described and noted that, on molds of the interior, they had much the same appearance as the bryozoan genus Fenestella. In 1876, Meek (p. 169) again mentioned their presence and referred to them as "tubercles", stating that he could not tell whether the tubercles ever became prominent enough to produce short spines. The exteriors of the shells collected in North Dakota show no evidence of tubercles but appear to be simply holes that have resulted from weathering of the exterior of the shell. The orientation of the holes is determined by the placement of pits on the interior.

Apparently the only closely related species is C. (E.) welleri Stephenson from the Nacatoch Formation of the
Navarro Group in Texas. The only differences apparent from Stephenson's description and illustrations (1941, p. 195, pl. 54, figs. 13-17) are size of the shell and position of the pits. *C. welleri* is considerably larger than *C. whitei* and the pits are located in a more central position. The depressions in *C. whitei* are almost entirely restricted to the posterior half of the shell whereas those of *C. welleri* are more centrally located.

**Measurements.**—Only one of the two specimens was preserved well enough that measurements could be made.

<table>
<thead>
<tr>
<th>Length</th>
<th>Height</th>
<th>Width</th>
</tr>
</thead>
<tbody>
<tr>
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<td>1.8</td>
</tr>
<tr>
<td>n=1</td>
<td>n=1</td>
<td>n=1 left valve</td>
</tr>
</tbody>
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**Types.**—Hypotypes, University of North Dakota Cat. Nos. 9356 and 9357.

**Locality and stratigraphic position.**—The specimens were collected from the Timber Lake Member of the Fox Hills Formation at locality 134-71-1.

**Subfamily:** PROTOCARDIINAE

**Genus:** Protocardia Beyrich

**Type reference.**—Beyrich, 1845, *Zeitschrift fur Malacologie*, p. 17.

**Type species.**—*Cardium hillanum* Sowerby, by original designation.
Description.--Shell thin, inflated, orbicular-quadrato; radial sculpture upon the posterior area sharply differentiated from that upon the medial and anterior portions of the shell; a small anterior and larger posterior cardinal in the right valve, a large anterior and smaller posterior cardinal in the left valve; both anterior and posterior laterals develop in each valve; posterior muscle scar prominent; an incipient pallial sinus frequently present; inner margin finely fluted at least upon the posterior area. (Gardner, 1933, p. 180)

Subgenus: Leptocardia Meek

Type reference.--Meek, 1876, U. S. Geol. Survey Terr., v. 9, p. 172.

Type species.--Cardium subquadratum Evans and Shumard, by original designation.

Original description.--Shell small, very thin, about as long as high; hinge weak; surface nearly smooth, the posterior radiating costae being obsolete, or often only indicated by crenulations along the posterior third of the free margins within; pallial line with two shallow sinuses. (Meek, 1876, p. 172).

Protocardia (Leptocardia) subquadrata (Evans and Shumard)

Pl. 5, Figs. 8, 9, 11


Protocardia (Leptocardia) subquadraata (Evans and Shumard).

F. E. Beck, 1875, U. S. Geol. Survey Terr., v. 9, p. 175, pl. 29, fig. 3.


Original description.--Shell small, subquadrangular, length greater than the height, gibbous; anterior margin rounded, posterior margin truncated; very slightly arched; umbones prominent, large obtusely subangulated; beaks nearly medial, 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.

Dimensions.--Length, 5 1/2 lines; height 4 3/4 lines; thickness, nearly 4 lines.


Description of material.--Shell small to medium sized for genus, ovoid, slightly longer than high, thin-shelled, inflated; anterior and posterior margins smoothly and uniformly rounded; ventral margin very gently rounded; dorsal margin sloping away from the beaks in an approximately straight line toward the posterior margin and in a concave line toward the anterior margin; beaks small, located slightly anteriorad from the midline, inturned, prosogyral; hinge of the left valve with two cardinal teeth, the anterior
one large, triangular, oblique, the posterior one located beneath the beak, smaller, subtriangular; the two teeth are separated by a large triangular socket; a second, smaller socket is located along the anterio-dorsal margin of the anterior cardinal tooth; anterior lateral tooth located near the extremity of the hinge, elongate, ovoid, well developed; anterior lateral socket located along the dorsal edge of the anterior lateral tooth; posterior lateral tooth less distinct than the anterior one, elongate, situated near the terminus of the hinge; posterior lateral socket poorly defined, located adjacent to the ventral margin of the posterior lateral tooth; hinge of right valve poorly known but presumably with a large posterior cardinal tooth, smaller anterior cardinal tooth, and anterior and posterior lateral teeth; ligament external, weak, situated in a short groove behind the beaks; anterior adductor muscle scar well defined; ovoid, dorso-ventral axis slightly elongate, slightly impressed along the inner margin; posterior adductor muscle scar slightly larger, nearly circular; pallial line complete, well defined; pallial sinus consists of two, shallow, arcuate re-entrants; inner margin smooth along the anterior and ventral margins and coarsely crenulate on the posterior margin; exterior of shell with concentric growth lines and some coarser concentric undulations; radial prosopon limited to the posterior third of the shell where
three to five weak ribs extend from near the beaks to the posterior margin; occasionally the radial prosopon is so reduced that it is reflected only as weak undulations on the ventral margin; lunule and escutcheon absent.

Remarks.-- This species is, without question, the most abundant member of the Fox Hills fauna in North Dakota. Although its distribution is primarily limited to the middle of the Timber Lake Member, it occurs there in large numbers. It is, in fact, the only species that was collected in large enough numbers to warrant any type of biometric analysis. The results of the analysis are briefly discussed below.

The only species which appears to be closely related to \textit{P. subquadrata} is \textit{P. rara} (Evans and Shumard). The latter species is extremely thin-shelled, porcellaneous, and has an equidimensional posterior adductor muscle scar (Meek, 1876, p. 176). Although this species was originally described from the Fox Hills Formation, it has not been identified from that unit in North Dakota.

\textit{Protocardia pertenuis} (Meek and Hayden), also described from the Fox Hills Formation, differs markedly from the species discussed above. It is higher than long, has a nearly straight posterior margin, and up to twenty costae on the posterior part of the shell. Other species of the genus, described from the Cretaceous of the United States, differ
Protocardia jerrynensis Weller from the Merchantville Formation, for example, is subquadrilateral in outline, has erect beaks, and extremely fine growth lines (Richards, 1958, p. 214-215). Protocardia parahillana Wade from the Ripley Formation is characterized by having radial sculpture developed over the entire shell (Wade; 1926, p. 87). This species has subsequently (Stephenson, 1941, p. 203) been referred to the genus Brevicardium Stephenson.

Measurements.--Length, height, and thickness were measured on 97 specimens of this species collected from two localities. All of the specimens were cleaned in dilute hydrochloric acid to remove small bits of shell material that were left on the molds of the interior. Results of the study indicate that, although length of the specimens varied from 5.5 mm to 17.5 mm, the ratio of length to height and length to thickness varies only slightly. The measurements below represent the mean values of length, height, and thickness determined from the total sample.

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<tr>
<td>n=97</td>
<td>n=96</td>
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Types.--Hypotypes, University of North Dakota Cat. Nos. 9230 and 9377.
Localities and stratigraphic position.--Specimens were collected from the Timber Lake Member of the Fox Hills Formation at localities 129-78-6, 130-78-2, 130-80-11, 131-75-2, 131-78-4, 132-76-6, 133-77-2, 134-71-1, 134-80-1, 134-80-2, and 134-80-6.

Superfamily: VENEROIDEA
Family: VENERIDAE

Remarks.--The Veneridae is one of the largest and most widespread families of bivalves in Cenozoic and Mesozoic sediments. It has, however, received a disproportionately small amount of attention. Apparently the most recent revisory work is that of Frizzell (1936) who suggested that the family, as defined by Dali (1902), Jukes-Browne (1914), and Thiele (1934), be elevated to superfamily status. He also suggested that nine families should be referred to the Veneroidea. All of the nine families had previously been included within the broader family definition. This classification has not been generally accepted by malacologists as indicated by Tremlett (1953), Vokes (1954), and Keen (1963). Although a thorough study of the family has not been undertaken, there seems to be no reason to distinguish, on the family level, organisms which are as closely related as are those of the Veneridae, s.l. The classification
of the group will, therefore, be patterned after that of Tremlett (1953) and Keen (1962).

Subfamily: SUNETTINAE

Genus: Desiniopsis Conrad


Type species.--Cytherea lenticularis meaki Conrad, by original designation.

Description.--Suborbicular compressed, almost smooth. Lunule indistinct. Escutcheon sometimes present, circumscribed and depressed. Ligament long, more or less sunk. Hingeplate oblique, bearing a very long prominent AII. 2a very thin, straight, prominent. 2b wide, triangular, with a sharp, raised posterior edge; on the anterior side bevelled and grooved; a ridge connects its base with that of 2a. 4b long, thin, oblique. PI and PII distinct from cardinals. AI long, thick, ill defined. AIII long and thin. A groove connects the sockets of AII and 2a. 3a thin, straight, almost parallel to 1, which is triangular, bevelled and grooved on the posterior side. 3b long, fairly oblique, bifid. Pallial sinus short, strongly ascendant, triangular. (Tremlett, 1953, p. 7)

Remarks.--The above description agrees with those given by Jukes-Brown (1908, p. 151) and Palmer (1927, p. 213), with one exception. Both of these authors described granular nymphs near the ends of the hinge which are neither mentioned by Tremlett (1953) nor are present on the Fox Hills specimens.
This genus seems to be most similar to *Pitar* Römer (amended to *Pitaria* by Dall, 1902, p. 353). As a matter of fact, the descriptions given by Palmer (1927, p. 214 and 215) do not allow one to distinguish between the two genera. Tremlett (1953, p. 7 and 55) mentioned characters of the hinge which are slightly different in the two genera and, therefore, allow differentiation. The specimens from the Fox Hills agree with Termlett's diagnosis in all respects.

The specimens here referred to *Dosinopsis* have also been assigned to the genus *Trigonocallista* Rennie, 1930 (Shimer and Shrock, 1944, p. 427). *Trigonocallista* is characterized (Rennie, 1930, p. 197) by having a large, well defined escutcheon, a feature which is not observable on the Fox Hills specimens. Further, the left posterior cardinal tooth of *Trigonocallista* is joined to a nymph, whereas it is free in *Dosinopsis*. Finally, *Trigonocallista* has a decidedly trigonal outline and a small, horizontal, pallial sinus. *Dosinopsis*, on the other hand is ovoid and has a large, ascending pallial sinus. Cvancara (1966) has drawn the same conclusion in regard to specimens from the Cannonball Formation.
Dosiniopsis deweyi (Meek and Hayden)

Pl. 6, Fig. 13


Callista (Dosiniopsis?) deweyi (Meek and Hayden). Meek, 1876, U. S. Geol. Survey Terr., v. 9, p. 182, pl. 17, fig. 15.

Callista (Dosiniopsis) deweyi (Meek and Hayden). Stanton, 1920, U. S. Geol. Survey, Prof. Paper 128, p. 31, pl. 5, figs. 11-12.

Trigono callista deweyi (Meek and Hayden). Shimer and Shrock, 1944, p. 427, pl. 170, figs. 6-7.


Original description.--Shell subcircular or slightly ovate, somewhat compressed; beaks moderately elevated, a little in advance of the centre; surface
ornamented by distinct irregular lines of growth; lunule small, narrow, oval or broad lanceolate, not very distinctly impressed; muscular impressions shallow, anterior one narrow ovate; posterior broad ovate, acutely angular above; pallial impression having a rather deep triangular sinus, forming at the apex an angle of 55°; border smooth. Length .96 inch; breadth .51 inch; height .85 inch.

Locality and position.—Moreau River, No. 5 of the series. (Week and Hayden, 1856, p. 83)

Description of material.—Shells medium-sized for genus, ovoid or nearly circular, thin; anterior margin smoothly and evenly rounded; posterior margin similar to the anterior one but slightly more abruptly rounded near the middle; ventral margin smoothly and gently rounded; dorsal margin regularly curved and convex posteriorad from the beaks and irregularly curved and concave anteriorad from the beaks, with the most prominently curved portion just in front of the beaks; beaks slightly anteriorad from the midline, small, elevated slightly above the hinge, inturned, prosogyral; hinge of the right valve with three cardinal teeth and anterior and posterior lateral teeth; the anterior cardinal tooth is long and slender and joins, at its ventral terminus, the anterior lateral tooth; the median cardinal tooth is large, triangular, and separated from the anterior cardinal along its entire length by a very narrow socket; posterior cardinal tooth long, grooved but not truly bifid, relatively slender, and separated from the median cardinal by a large
socket; anterior lateral tooth long, slender, poorly developed, located dorsad from a narrow, well-developed socket; ventrad from the socket the hinge margin thickens and forms what might serve as a rudimentary tooth; posterior lateral tooth oriented nearly parallel to the hinge and located near the posterior end of the hinge and poorly developed; well developed posterior lateral socket lies ventrad from the tooth; the posterio-ventral portion of the hinge is thickened similar to the anterio-ventral margin; hinge of left valve with three cardinal teeth, a poorly defined posterior lateral tooth and a well-defined anterior lateral tooth; anterior cardinal tooth very slender located beneath the beak and joined to the median cardinal tooth at its dorsal terminus; median cardinal tooth large, triangular; posterior cardinal tooth parallel to the hinge, separated from the median cardinal tooth by a broad, medially ridged, socket and separated from the thick, poorly developed posterior lateral tooth by a shallow groove; anterior lateral tooth ovoid, well-developed, located near the anterior terminus of the hinge; ligament groove long, slender, deep, external, adductor muscle scars approximately equal in size, anterior scar dorsally attenuated, posterior scar ovoid, dorso-ventrally elongate; pallial line complete, distinct; pallial sinus large, extending nearly to the middle of the shell, ascending,
tightly rounded at its terminus; exterior of shell with
growth lines, some of which are more strongly developed than
others; lunule moderately large, indistinct, separated from
the rest of the shell by a fine groove; escutcheon absent.

Remarks.—Specimens of this species are rare in Emmons
County but are abundant and excellently preserved in many
areas of Sioux County. Most of the specimens were collected
from beds very near the top of the Timber Lake Member.

Meek (1876) cited three species of *Callista* (*Dosiniopsis*)
which were collected from the Fox Hills Formation. The only
species which was collected by the writer was *D. deweyi*. The
other two species, *C. (D.) owenana* and *C. (D.) nebrascensis*,
were originally collected from Montana and Nebraska respect-
ively, and it is probable that they do not occur in North
Dakota. Both of the latter species are considerably heavier
than *D. deweyi* and have narrower and longer pallial sinuses.
The most closely related species seems to be *Callista? bellula*
from the Pierre Formation. It is, however, considerably
thinner and more compressed than *D. deweyi* and has a much
more pointed pallial sinus. Nothing is known of the hinge-
ment of this species.

Wade (1926, p. 89) referred *D. deweyi* to the genus
*Meretrix* and suggested that it is similar to *M. eufaulensis*.
*Meretrix*, however, is characterized by having an indistinct
lunule, short ligament attachment, corrugated hinge terminations, and shallow pallial sinus (Jukes, Browne, 1915, p. 69); features which are not present on D. deweyi. Wade's placement is not included in the synonymy because he did not treat D. deweyi taxonomically but merely mentioned it in his discussion of Meretrix eufaulensis.

Measurements.--Four parameters were measured on all specimens that were well enough preserved to show at least three of the dimensions.

<table>
<thead>
<tr>
<th>Height</th>
<th>Length</th>
<th>Length from beak to anterior margin</th>
<th>Width</th>
</tr>
</thead>
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<td>n=14</td>
<td>n=13</td>
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</table>

Types.--Hypotypes, University of North Dakota Cat. Nos. 9367 and 9368.

Localities and stratigraphic position.--Specimens of this species were collected from the Timber Lake Member of the Fox Hills Formation at localities 130-78-2, 130-80-8, 130-80-10, 130-80-11, 130-80-13, 130-80-15, 134-80-1, 134-80-2, 134-80-3, and 134-80-4.
Superfamily: MACTROIDEA

Family: MACTRIDAE

Genus: Mactra Linnaeus

Type reference.--Linnaeus, 1767, Systema naturae, ed. 12, p. 1125.

Type species.--Mactra stultorum Linnaeus, by the subsequent designation of Bray, 1847.

Description.--Shell ovate to subtrigonal, large or small, often convex, white, thin or thick, equivalve and subequilateral. Posterior-dorsal areas often defined by a small line. Hinge: hinge plate usually wide and often heavy; in the middle is a deep, wide chondrophore pit bordered anteriorly by a small inverted V-shaped cardinal, and strong equidistant lateral teeth. There is a small, external ligament, partly immersed but visible from the exterior and attached to a small scar just behind the beak and above the resilial scar of the chondrophore, and from which it may be separated by a small ridge or lamina. Laterals smooth or striated. Muscle scard distinct, connected by the pallial line carrying a well-marked sinus. (Olsson and Harbison, 1953, p. 139)

Remarks.--The genera of the Mactridae are defined primarily on the structure of the ligament and its support. All members of the family have an internal ligament support and most have a weakly developed external ligament. Mactra has a small external ligament which is separated from the internal ligament by a ridge.

A very closely related genus is Cymbophora. The only significant difference between the two genera seems to be
that the lamellae which bound the chondrophore in *Cymbophora*
are elevated above the hinge plate, the posterior one of
which does not completely separate the chondrophore from
the external ligament. Meek (1876, p. 204) considered
*Cymbophora* a subgenus of *Mactra* whereas later workers do not.
Dall (in Eastman, 1913, p. 498) referred *Cymbophora* to the
genus *Spicula* which is characterized by having the internal
and external elements of the ligament joined at their dorsal
extremities. Stephenson (1941, p. 229) considered *Cymbophora*
a distinct genus. This classification seems to have been
followed by later workers (Richards, 1958, p. 243). Regardless
of the placement of the genus *Cymbophora*, the specimens
from the Fox Hills Formation are probably more correctly
referrable to the genus *Mactra*. Careful study of the hinge
of the Fox Hills species indicates that in all the specimens
available for study the two ligament areas are completely
separated by a lamella.

**Mactra warrenana** Meek and Hayden

Pl. 6, Figs. 12, 26, 31-35


*Mactra (Cymbophora?) warrenana* Meek and Hayden. Meek, 1876,
U. S. Geol. Survey Terr., v. 9, p. 203, pl. 30, fig. 7.
Cymborhena warrenana (Meek and Hayden). Shimer and Shrock
1944, p. 431, pl. 171, figs. 21-22; Fisher, 1952,
N. Dak. Geol. Survey, Bull. 26, pl. 6, figs. 1-3.

Original description.--Shell triangular oval, moderately compressed; cardinal border sloping from the beaks at an angle of about 110°; anterior end narrowly rounded; posterior end wider, rounded or very slightly truncate, and gaping a little at the extremity; base forming a broad curve; beaks elevated, rather small, incurved, nearly central; surface marked with fine lines of growth, which become stronger and more regular on the large lanceolate lunule and escutcheon. Length 1.55 inch; height 1.20 inch; breadth .83 inch.

The muscular impressions are oval or ovate; the anterior one being rounded below, and contracted and prolonged above. The sinus of the palpeal impression is small, obtuse at the extremity and nearly horizontal.

Locality and position.--Yankton trading post, No. 5 of the accompanying section. (Meek and Hayden, 1856, p. 271)

Description of material. Shell medium sized for genus, thin, trigonal, inflated; anterior margin smoothly and tightly rounded; posterior margin forms a slight angle at the base of the escutcheon; ventral margin smoothly curved; dorsal margin curves down abruptly from the beaks forming a straight or slightly convex curve behind the beaks and a slightly concave curve in front of the beaks; beaks elevated, inturned, prosogyral, located just posteriorad from the midline; hinge of right valve with a deep triangular resilial pit extending posterior-ventrally from beneath the beaks and outlined on the
anterior and posterior margins by thin laminae which do not extend as high above the hinge plate as do the teeth; anterior rad from the chondrophore is a large triangular socket and a thin cardinal tooth which appears to be the posterior termination of the anterior lateral socket; anterior lateral elements consist of a deep, elongate socket and a thin lateral tooth, the highest part of the tooth is located at the anterior end of the tooth; posterior lateral elements of two lateral teeth and an intervening socket; the dorsal tooth is shorter and thicker than the ventral posterior lateral; external ligament groove consists of a short, poorly defined groove located just behind the beak and separated from the internal ligament by the posterior lamella of the chondrophore; left hinge unknown; muscle scars about equal in size, rounded on the ventral margin and attenuated dorsally, the portion of the scar that is directed toward the midline is slightly depressed into the shell in both anterior and posterior scars; pallial line smooth, complete, distinct, terminated posteriorly by a well developed sinus which may be either tightly curved or slightly pointed at its apex; prosopon consists of concentric growth lines which are best developed in the areas of the large lunule and escutcheon and weakest in the area of the beaks; lunule and escutcheon defined by well defined grooves.
Remarks.--This species is common at several localities in the Fox Hills Formation in North Dakota. In many cases, however, it occurs as poorly preserved molds of the interior. These are, nevertheless, easy to recognize on the basis of the characteristic elevated beaks, well defined pallial sinus and impressed muscle scars. Only one specimen was found which could be prepared to show the hingement. This specimen is a badly crushed right valve but all of the hinge elements are present, although some of them are slightly displaced. All of the specimens that show good exteriors are preserved in dense limestone concretions and are impossible to extract. Two of these specimens, UND Nos. 9234 and 9241 show a pattern of concentric color bands which appear to represent original color patterns. Both of the specimens seem to become progressively darker from the beaks to the ventral margin.

This species has commonly been referred to the genus Cynbophora (Shimer and Shrock, 1944, p. 431; Fisher, 1952, pl. 6) but none of the specimens illustrated seem to show the nature of the hinge which is necessary for proper assignment. The single specimen from this study which shows the hinge indicates that not only are the internal and external elements of the ligament separate but also that the laminae that bound the chondrophore project only slightly above the
general level of the hinge plate. They are not as elevated as the cardinal and lateral teeth. The assignment to the genus *Mactra*, therefore, is necessary until further specimens are found that indicate that the lamellae in this single specimen are abnormally small.

Measurements.--Four parameters were measured on all specimens that were well enough preserved to show at least two of the parameters.

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</thead>
<tbody>
<tr>
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<td>right valve</td>
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<tr>
<td>30.5 n=22</td>
<td>30.9 n=22</td>
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Types.--Hypotypes, University of North Dakota Cat. Nos. 6232, 9234, 9241, and 9353.

Localities and stratigraphic position.--Specimens were collected from the Timber Lake Member of the Fox Hills Formation at localities 129-76-1, 139-78-6, 129-78-7, 129-79-4, 130-78-2, 130-78-7, 130-80-6, 130-80-8, 130-80-11, 130-80-13, 131-78-2, 131-78-4, 131-80-4, 134-71-7, 134-80-1, and 134-80-2.

*Mactra formosa* Meek and Hayden

Pl. 6, Figs. 14 & 15

Natica (Cymbophora) formosa Meek and Hayden. Meek, 1876,

J. S. Geol. Survey Terr., v. 9, p. 207, pl. 39, fig. 7.

Original description.—Shell thin, triangular oval, somewhat compressed; cardinal border sloping from the beaks at an angle of about 115°, straight in front, and slightly convex behind the beaks; extremities narrowly rounded, almost angular, nearly alike; base forming a broad regular curve; beaks small, elevated, approximate, central or a little in advance of the middle; surface marked with fine lines of growth, which become stronger and more regular on the large lanceolate lunule and escutcheon. Length 1.70 inches; breadth .82 inch; height 1.36 inches.

The lunule and escutcheon extend from the beaks to the extremities of the shell, the former being slightly impressed, and the latter bounded by a very obscure ridge. By grinding down upon the cardinal edge of a right hand valve, we found it thin, and having under the beaks apparently an oblique cardinal tooth and a small ligamentary pit, the former being divided into two diverging parts; while the anterior and posterior portions of the edge have each a long groove, probably for the reception of slender lateral teeth in the other valve.

Locality and position.—Same as last. This locality was first reported to be beds of the Dakota Group but were later (Meek, 1878, p. 207) demonstrated to be Fox Hills equivalents. (Meek and Hayden, 1876, p. 271)

Description of material.—Shell large for genus, thin, ovoid, moderately inflated; anterior margin smoothly and tightly rounded; posterior margin unknown; ventral margin gently curving; dorsal margin slopes away from the beaks in a nearly straight line posteriorly and a slightly concave line anteriorly; beaks nearly central, elevated, inturned, prosogyral; hinge of left valve well developed on a relatively
thin hinge plate; one large triangular cardinal tooth just anteriorad from a triangular resilifer which has upturned margins; the anterior one of which is separated from the cardinal tooth by a shallow groove; a similar shallow groove is developed just posteriorad from the resilifer; external ligament groove occupies a position just posterior to the beak and is completely separated from the resilifer; lateral teeth well developed; the anterior lateral is relatively short and stout, the posterior lateral is long and thin; a shallow socket extends from the anterior end of the anterior lateral tooth to the dorsal termination of the cardinal tooth; muscle scars and pallial line unknown; prosopon consists of concentric growth ridges which are regularly spaced only on the lunule and escutcheon; lunule is well defined by a shallow groove; escutcheon is defined by a relatively low, broad ridge.

Remarks.—This species is represented by a single broken left valve which, fortunately shows all the features of the hinge. There is little questions that the generic assignment is correct but the trivial designation is somewhat tenous. Meek (1876, p. 207) indicated that the shell is somewhat compressed but the specimen here referred to the species is moderately inflated. In general size and outline, however, the specimen closely fits the original description.
The most distinguishing feature of the species is the large size and the manner in which the lunule and escutcheon are outlined. The escutcheon in *M. formosa* is defined by a broad, low ridge whereas in *M. warrerana* both the lunule and escutcheon are defined by shallow grooves.

This species seems to be most closely related to *Cymbothorax inflata*, which Stephenson (1941, p. 232) referred to *Cymbothora* although the hinge elements were not preserved. This poor state of preservation also makes the discussion of affinities difficult; however, general size, shape, and convexity are similar in both organisms and it, therefore, seems likely that they are related. The size and shape of all other members of the two genera that were studied are quite different from *M. formosa* so that it is a rather distinctive species.

**Measurements.**—The single left valve of this species has a height of 42.3 mm and a thickness of 15.6 mm. The long axis of the shell is broken and was not measured.

**Types.**—Hypotype, University of North Dakota Cat. No. 9354.

**Locality and stratigraphic position.**—The single specimen was collected from the Timber Lake Member of the Fox Hills Formation at locality 130-80-10.
Superfamily: **TELLINGIDEA**

Family: **TELLINIDAE**

Genus: **Tellina** Linnaeus

**Type reference.**—Linnaeus, 1758, Systema naturae, ed. 10, v. 1, p. 674-678.

**Type species.**—*Tellina radiata* Linnaeus, by subsequent designation of Children (1822).

**Description.**—Shell thin to very thin, to about 60 mm long, subequivalve, inequilateral, ovate to ovato-triagonal in outline (height is 35 to 65 percent of length), moderately inflated (width is 13 to 23 percent of height). Umbones slightly to greatly posterior (at 0.52 to 0.70 of length of valve), low, and opisthogyrate. Anterior end produced, well to broadly rounded. Posterior end acuminate, rostrate, or truncate; rostrum defined by a ridge or by a change in direction of the growth lines; at rostrum the valve commissure is flexed slightly sigmoidally, resulting during growth in a groove and ridge on both valves; groove and ridge are hardly noticeable in some species, and slightly emarginate near rostrum. Lunule long and narrow.

Dentition of right valve consists of a slender oblique anterior cardinal tooth, a bifid triangular posterior cardinal tooth, and distinct anterior and posterior lateral teeth; that of the left valve consists of a deeply bifid triangular anterior cardinal tooth, a slender oblique posterior cardinal tooth, and well-developed or obsolete anterior and posterior lateral teeth. Ligamental groove external, long, narrow, and deep. Nymphe rather prominent in most species. Posterior adductor muscle imprints rounded and varying in size; anterior ones generally longer and slightly narrower. Pallial line approximately parallel to ventral margin of valve. Pallial sinus extremely deep and variable, its apex asymmetrically U-shaped; confluent ventrally with pallial line in some species, separate in others; almost touches anterior adductor muscle imprint.
Sculpture consists of regular concentric incremental lines or raised threads and in some species of obscure very fine radial striae; radial ornamentation suggested in some species by color pattern; exterior porcelaneously smooth in some species. (Stenzel, Krause, and Twining, 1957, p. 120)

Remarks.—Although the Tellinidae have been studied by several workers (Dall, 1900; Salisbury, 1934, and Hertlein and Strong, 1949) and generic and subgeneric placement of individual species remains difficult. The genus-groups are based on characteristics of the hinge and pallial line. The elements of the hinge are weak in almost all species and, in many, the lateral elements are either very weakly developed or absent. The pallial line and pallial sinus are likewise indistinct, although characteristic. The above definition of the genus *Tellina* seems to encompass most of the variations observable in the genus whereas the definition by Olsson and Harbison (1953, p. 212), for example, is perhaps too restrictive.

Some question has also arisen concerning the designation of the type species. Dall (1900, p. 239) considered *T. virgata* Linnaeus the type species as subsequently designated by Lamarck in 1799. His work, *Prodrome d'une nouvelle classification de Coquilles*, has been rejected by Salisbury (1934, p. 80), however, because Lamarck had no intention of designating a type but was merely discussing *T. virgata* as a representative tellinid. In 1861, Lamarck used *T. radiata* in
a similar sense (Salisbury, 1934, p. 60). In 1812, Schmidt (p. 51 and 177) listed several species of Tellina which he considered representative. Among these was T. radiata, which Stenzel, Krause, and Twining (1957, p. 120) considered the type by Schmidt's designation. Salisbury, however, was of the opinion that Children (1823) was the first person to correctly cite T. radiata as the type species. His opinion was upheld by Olsson and Harbison (1953, p. 121) and is cited here.

Kertlein and Strong (1943, p. 64) have summarized the subgeneric characteristics of Tellina in a key which is very useful in studying the genus. It is reproduced below.

Key to the subgenera of Tellina

A. Posterior area with simple concentric lamellae or smooth
   a. Surface obliquely grooved . . . . . Scissulina
      aa. Surface not obliquely grooved
         b. Beaks anteriorly directed . . . . Macaliopsis
            bb. Beaks not anteriorly directed
               c. Right anterior lateral distant from the beak
                  d. Smooth, polished . . . . Tellina s.s.
                     dd. Strong concentric sculpture . Tellinella
                        cc. Right anterior lateral extends close beneath or near beak
                           e. Shell usually exceeding 25 mm. in length
                              f. Resilium external; shell elongate
                                 g. Thick; right posterior lateral strong . . . . . . Eurytellina
                                    gg. Thin; right posterior lateral weak; fine reticulate sculpture . Tellinidella
                                       ff. Resilium internal; shell thin, high . . . . . . . Scrobiculina
                                          ee. Shell not exceeding 25 mm. in length (usually not exceeding 20 mm.)
B. Posterior area with plate-like foliations or posterior end with strong radial sculpture
   a. Pallial sinus free or confluent with pallial line for not more than one-third its length
   b. Posterior area with plate-like foliations
      bb. Posterior end of shell with strong radial sculpture; very small
         Elliptotrechina
   aa. Pallial sinus confluent with pallial line for entire length
      Phylloodella

Subgenus: Eurytellina Fischer

Type reference.—Fischer, Paul, 1887, Manuel de conchyliologie et de paléontologie conchyliologique; p. 1147.

Type species.—Tellina punicea Born, by monotypy.

Diagnosis.—Shell nearly equilateral and nearly equi-valve; umbones elevated, slightly posterior (at 0.52 to 0.54 of greatest length of valve). Anterior end well rounded; posterior end acuminate; ventral margins broadly rounded; umbones and dorsal margins describe an angle of 130 to 145 degrees.

Lateral hinge teeth placed at unequal distances from the umbo; the anterior one half as far from umbo as the posterior one. Lateral hinge teeth of left valve weak but distinct; those of the right valve strong.

Sculpture consists of fine impressed concentric lines restricted to region anterior of the rostral area; rostral area covered with growth lines and raised concentric striae. (Stenzel, Krause, and Twining, 1937, p. 120)
Remarks.—The shells here referred to this subgenus conform closely to the description given above. Hertlein and Strong (1949, p. 64), however, stated that Tellina (Eurytellina) is thick-shelled whereas the Fox Hills specimens are thin-shelled. In this respect they are similar to T. (Tellinidella) Hertlein and Strong, 1949. The latter subgenus is similar to T. (Eurytellina) but differs from it in having a weakly developed right posterior lateral tooth, thin shell and reticulate sculpture (Hertlein and Strong, 1949, p. 80).
The known range of T. (Eurytellina) is Eocene to Recent, whereas T. (Tellinidella) is known only from the Recent. It is very possible that T. (Eurytellina) scitula, or closely related species, were primitive members of the subgenus who gave rise to the subgenus T. (Tellinidella) by thinning of the shell, diminution of the right posterior lateral, and development of reticulate sculpture.

Tellina (Eurytellina) scitula Meek and Hayden
Pl. 6, Figs. 9 & 10


Tellina (Peronacea?) scitula Meek and Hayden. Meek, 1876, U. S. Geol. Survey Terr., v. 9, p. 197-198, pl. 30, fig. 1.
Original description.—Shell elliptical, small, thin, much compressed, curved so as to be convex on the left, and slightly concave on the right sides; extremities narrowly rounded, the anterior end being wider than the posterior; beaks small, nearly central; base forming a regular elliptic curve; surface polished, and marked with distinct lines of growth. Length .50 inch; breadth .13 inch; height .30 inch.

Locality and position.—Noreau River, No. 5 of series. (Neek and Hayden, 1856, p. 82)

Diagnosis.—Shell small to medium-sized for genus, nearly equi-valve and nearly equilateral, ovate-elongate, compressed, thin, anterior margin regularly rounded; posterior margin slightly truncate so that it forms an angle of about 120° with the ventral margin, narrow gape; ventral margin very gently curved; the ventral commissure is slightly warped so that the posterior part of the commissure curves gently to the left; dorsal margin formed of two straight elements which slope away from the beaks; beaks very small, slightly incurved, opisthogyral, located just posteriorad from the midline; hinge relatively weak, right valve with two cardinal and two lateral teeth, the anterior cardinal is thin, the posterior one thickened and bilobed; anterior lateral a short protuberance located near the cardinal teeth; posterior lateral about the same size as the anterior lateral but located about half way between the beaks and the posterior margin; left valve with a thin, simple, posterior cardinal tooth and a thickened, bilobed, anterior cardinal tooth; left lateral teeth occur in
a position similar to those of the right valve and fit into
sockets dorsad from the lateral teeth of the right valve;
ligament groove short, narrow, shallow, external, extending
posteriorad from the beaks; adductor muscle scars weakly
developed, the anterior one ovoid, located very near the
interior margin; posterior scar ovoid, located beneath the
posterior lateral tooth; pallial line smooth, moderately
impressed; pallial sinus large, extending two-thirds the way
from the posterior muscle scar to the adductor muscle scar,
narrowing anteriorly and confluent with the pallial line for
a distance of about one-fifth its length; exterior of the
shell divided into two parts by a weak angulation extending
from the beaks to the postero-ventral corner of the shell;
prosocyon anteriorad from the umbonal ridge of regular, impres-
sed growth striae crossed by extremely fine radial striae;
posteriorad from the ridge the growth increments become weakly
lamellose and are crossed by radial striae similar to those
on the rest of the shell.

Remarks.--This common Fox Hills tellinid is readily
recognized on the basis of its compressed form, weak hinge-
ment, ovate shape and large pallial sinus. Most of the
material referred to this species is poorly preserved and
represents only molds of the interior; however, one of the
specimens, UNF Nos. 9350, is well enough preserved that not
only the shell material is intact but also the original color patterns are preserved. These color patterns occur in two general areas. The largest area extends from the beaks about two-thirds of the way to the ventral margin and is predominantly dark yellowish brown (10YR 4/2) with a few concentric traces of moderate yellowish brown (10YR 5/4). The second area, near the periphery, consists primarily of the lighter colored pigment with thin concentric bands of the dark colored pigment. Although these colors probably do not represent the true color of the living animal, they do seem to indicate a reasonable color pattern. Articles dealing with preservation of color patterns in fossils (Foerste, 1930; Stokes and Stifel, 1964) record only 23 species of pelecypods showing color patterns, making this an extremely unusual find.

Specimen 9350 also shows the hinge elements in both valves. They clearly show two lateral teeth in both valves as described and, therefore, significantly modify the description of Meek and Hayden (1856, p. 82) and Meek (1878, p. 197-198) which was apparently based on material that did not completely show the interiors. This observation changes the subgeneric placement which is, in part, based on the nature of the lateral teeth.
Measures.--Four parameters were measured on all specimens that were well enough preserved to show at least three of the parameters.

<table>
<thead>
<tr>
<th>Height</th>
<th>Length</th>
<th>Distance from anterior border to beak</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.5</td>
<td>19.3</td>
<td>10.4</td>
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<tr>
<td>n=11</td>
<td>n=11</td>
<td>n=11</td>
<td>n=3</td>
</tr>
</tbody>
</table>

As the position of the beak is significant in the generic and subgeneric classification of tellinids, this figure was computed by dividing the distance from the anterior margin to the beaks by the total length. This computation yielded a figure of 53.8%, which is consistent with the description given.

Types.--Hypotypes, University of North Dakota Cat. Nos. 9244 and 9350.

Localities and stratigraphic position.--Specimens were collected from the Timber Lake Member of the Fox Hills Formation at localities 129-78-6, 130-78-7, 130-80-10, 130-80-11, 131-78-2, 131-78-3, 131-78-4, 131-80-4, 132-76-10, 133-77-2, 134-71-1, and 134-80-3.

Tellina (Eurytellina?) cheyennensis Meek and Hayden

Pl. 6, Fig. 3

Tellina? cheyensis [lapsus pro Tellina? cheyennensis] Meek
v. 8, p. 82.

Tellina (Arctocaria?) cheyennesis Meek and Hayden. Meek,
1876, U. S. Geol. Survey Terr., v. 9, p. 687, pl. 17,
fig. 16.

Original description.--Shell, ovate, compressed, very thin; posterior extremity rounded; posterior end subtruncated or rounded from above, and very obtusely angular below; base forming an elliptic curve; beaks somewhat elevated, placed a little in advance of the middle, surface ornamented with fine lines of growth and numerous small regular concentric wrinkles, becoming mere lines on the beaks and on the extremities. Length .83 inch; breadth .36 inch; height .87 inch.

We have only seen the outside of this specimen.

Locality and position.--Forks of Cheyenne River,
No. 4 of the series. (Meek and Hayden, 1856, p. 82)

Description of material.--Shell medium-sized for genus, subtriangular, thin, moderately compressed; anterior margin smoothly and evenly rounded; posterior margin more tightly rounded, subtruncated; ventral margin smoothly and gently rounded; dorsal margin forms a smooth, convex curve anteriorad from the beaks and a compound curve posteriorad from the beaks with a slight concave re-entrant just behind the beaks; beaks opisthogyral, located just a little posteriorad from the midline, elevated, inturned; a distinct umbonal ridge extends from the beaks to the posterior-ventral margin, slightly more prominent on the left valve; interior unknown; prosopon
consists of concentric growth undulations, which are more prominent on the ventral margin than on the other parts of the shell, and by minute radial striae which cover the entire shell; ventral commissure twisted so that the anterior portion of the commissure is curved to the left and the posterior part is curved to the right.

Remarks.—Only two specimens of this rare tellinid have been found in the Fox Hills Formation in North Dakota. As with the type material of the species, the interior of the valves is obscured and, therefore, nothing is known of the hinge line or pallial markings. External shape, however, leaves little doubt that the species is correctly assigned on the generic level.

There is, however, considerable doubt concerning the subgeneric placement. Meek (1876, p. 607) questionably referred the species to the subgenus Acropagia on the basis of its "form and general appearance." Although the specimens in the present study offer little other evidence, it would appear that the species might better be referred to the subgenus Eurytellina. The taxonomic position of Acropagia is presently in such a state of flux that it will be almost impossible to use it until the family is reviewed in detail. Dall (1901, p. 290) considered it a subgenus of Tellina whereas Salisbury (1934, p. 80) and Franc (1906, p. 2112)
considered it as a distinct genus. Hartlein and Strong (1949) did not consider the taxon at all.

The only feature which *T. cheyennensis* has in common with other species of *Buryellina* is prosopon. *T. cheyennensis* is characterized by both concentric growth lines and extremely fine radial striae. No other subgeneric features are visible on the exterior of tellinids.

There is also some question on the species assignment in that the above description does not perfectly describe the external shape. Apparently no subsequent description has been published. In profile, the present specimen conforms to the description; but if viewed ventrally the commissure is quite distinctive. The line of junction of the two valves, rather than being straight, is a very gentle curve. There is no indication of deformation of the specimen. The specimen illustrated by Week (1876, pl. 17, fig. 16) shows the left 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.**—Three parameters were measured on both specimens.

<table>
<thead>
<tr>
<th>Height</th>
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<tr>
<td>16.9</td>
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<tr>
<td>( n=2 )</td>
<td>( n=2 )</td>
<td>( n=2 )</td>
</tr>
</tbody>
</table>
Locality and stratigraphic position.--Specimens were collected from the Timber Lake Member of the Fox Hills Formation at localities 129-76-3 and 134-63-1.

_Tellina equilateralis_? Meek and Hayden

_Pl. 6, Figs. 1 & 2_

_Tellina equilateralis_ Meek and Hayden, 1856, Acad. Nat. Sci. Philadelphia, Proc., v. 6, p. 82

_Tellina (Paronaia?) equilateralis_ Meek and Hayden. Meek, 1876, U. S. Geol. Survey Terr., v. 9, p. 196-197, pl. 35, fig. 5.

**Description.**--Shell elliptical, compressed, moderately thick, extremities rounded; anterior end slightly broader than the posterior; beaks small, not elevated, located a little in advance of the middle; surface marked with fine regular concentric lines. Length of right valve 1.15 inches; breadth .12 inch; height .17 inch.

**Locality and position.**--Same as preceding. Mouth of the Judith, in a sandstone supposed to be the same as No. 1 of the series. (Meek and Hayden, 1856, p. 82)

**Remarks.**--The two specimens here referred to this species are so poorly preserved that they cannot be used to supplement the original description. Meek (1876, p. 197), however, assigned "a few internal casts" to the species which gave some indication of the nature of the pallial line which
was typically tellinid and extended just beyond the midpoint of the shell. The specimens found in North Dakota, and referred to this species, are both molds of the interior. One of these is so poorly preserved that the pallial markings are not visible whereas the other specimen shows only very faint indications of the very deep pallial sinus. The poor preservation, therefore, prevents more precise subgeneric classification.

It should be pointed out that the stratigraphic position cited above is in error and was corrected by Meek (1876, p. 197) to place the specimens in the Fox Hills Formation.

**Measurements.**—Three parameters were measured on both specimens.

<table>
<thead>
<tr>
<th>Height</th>
<th>Length</th>
<th>Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>23.5</td>
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<td>13.2</td>
</tr>
<tr>
<td>n=2</td>
<td>n=2</td>
<td>n=2</td>
</tr>
</tbody>
</table>

**Locality.**—Hypotype, University of North Dakota Cat. No. 9352.

**Localities and stratigraphic position.**—Specimens were collected from the Timber Lake Member of the Fox Hills Formation at localities 129-78-6 and 132-79-1.
Family: TANCREDIDAE

Genus: Tancredia Lycett


Type species.--Tancredia donaciformis Lycett, by original designation.

Diagnosis.--Shell inequilaterial, anterior region longer than the posterior which is slightly gaping; right valve with two cardinals and two posterior laterals, left valve with a cardinal and a posterior lateral, ligament external and short; two adductors, pallial sinus entire or with a weak sinus. (translated from Dechaseaux, 1952, p. 294)

Remarks.--The above diagnosis differs slightly from that given by Meek (1876, p. 140) who stated that only one cardinal tooth may be present in each valve and that a second, smaller cardinal may, or may not, be present in the right valve.

The description of Dechaseaux is followed here because it seems to better fit the specimens under consideration.

There has been considerable controversy concerning the taxonomic placement of the family. Dechaseaux (1952, p. 294) and Ternier and Ternier (1960, p. 228) placed the genus in the suborder Schizodonta whereas Dall (1913, p. 484) referred it to the suborder Heterodonta and the superfamily Lucinoidea.
Vokes (1934, p. 70) placed Tancredia in the superfamily Tellinoidea. Thielle (1935) did not consider the family.

It appears that the characteristics of the hinge most closely resemble those of the Tellinoidea so that the classification of Vokes (1934) is followed here.

**Tancredia americana** (Meek and Hayden)

*Pl. 7, Figs. 7-10*


**Tancredia americana** (Meek and Hayden). Meek, 1876, U. S. Geol. Survey Terr., v. 9, p. 142, pl. 38, fig. 1; Shimer and Shrock, 1944, p. 423; pl. 168, fig. 20.

**Original description.**—Shell rather thick, ovate or subrhomboidal, compressed; posterior end much broader than the anterior, obliquely subtruncate and gaping; buccal side long, rostrate and closed, very narrowly rounded at the extremity; base forming an elliptical curve, excepting near the anterior end, where it is slightly contracted; dorsal border elevated in the umbonal region, concave in front and convex behind; lateral small, approximate, located a little behind the middle, surface marked with rather faint lines of growth, and sometimes, near the border, with small, obscure concentric wrinkles. Length 2.63 inch; height 1.76 inch; breadth 1.25 inch.

**Locality and position.**—No. 1 Mouth of Judith River. (Meek and Hayden, 1856, p. 274)
Description of material.—Shell medium sized for genus, thick; anterior margin drawn out into narrowly pointed terminus; posterior margin thickened, gaping, truncate; ventral margin a smooth curve from base of posterior truncation to anterior termination; dorsal margin angulate, terminating in prosogyral beaks which are placed slightly posteriorad from the midline; hinge long, thickened; right valve with two thick, poorly defined cardinal teeth, one located beneath the beak and one located near the dorsal edge of the hinge and anteriorad from the beak, separated by a deep, subtriangular socket and a short, weakly developed posterior lateral tooth which is dorsal from a short, shallow socket; left valve with two cardinal teeth which radiate from a point just below the beak and define a deep, subumbonal socket and a thickened, knob-like posterior lateral; dorsal margin anteriorad from the beak of the left valve fits into a shallow groove on the corresponding area of the right valve; ligament external, located in a short, shallow groove behind the beaks; muscle scars distinct; anterior adductor scar elongate parallel to the dorsal margin of the shell, depressed at the posterior extremity; posterior scar elongate dorso-ventrally, less well-defined; pallial line broad and well defined; parallel to ventral margin; pallial sinus a shallow, smooth re-entrant; surface marked by growth lines and faint,
regularly spaced, concentric undulations; growth lines converge abruptly toward beaks in a shallow groove from ventral termination of gape to posterior edge of beaks, separating the posterior portion of shell from the rest of the shell.

Remarks.--The specimens referred to this species closely fit the original description; however, they do not compare closely to the specimen illustrated by Meek (1876), p. 33, fig. 1). This illustration does not show the posterior gape as well developed, as it is described or as it is seen on the specimens here discussed. The original description, and apparently the subsequent work by Meek (1876), was based on fragmentary material which showed neither the total outline nor the characters of the hinge. The internal characteristics in the diagnosis, then, more succinctly define the species and confirm placement of *Tancredia* in the Tellinoidea.

The shape of the specimens was fairly constant in all respects except the orientation of the posterior truncation. In some specimens, the long axis of the truncation is parallel to the dorso-ventral axis of the specimen whereas in others, the axis of the truncation is inclined so that the ventral extremity of the gape is close to the dorso-ventral axis than is the dorsal extremity.
This species is one of the most characteristic of the Fox Hills fauna and has also been reported from the Claggett (Bowen, 1915, p. 115), Horsethief and Two Medicine formations (Stebinger, 1914, p. 62). A closely related, if not synonomous, species, *T. lincoliana* Reeside and Weymouth, is poorly represented in the Aspen Shale of Wyoming (Reeside and Weymouth, 1931, p. 8-9, pl. 1, fig. 6). In the Fox Hills in North Dakota, *T. Americana* is widely distributed and relatively abundant. It often occurs either in otherwise unfossiliferous outcrops or in association with the snail *Lunatia occidentalis*. Rarely, is it abundant where other pelecypods are found in large numbers. The wide posterior gape indicates that the species is a burrowing form. It was found at all four localities with *Panopea occidentalis*, another burrowing form.

**Measurements.**—Three parameters were measured on all specimens that were well enough preserved to display at least two of the dimensions.

<table>
<thead>
<tr>
<th>Height</th>
<th>Length</th>
<th>Width</th>
</tr>
</thead>
<tbody>
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<td>48.0</td>
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</tr>
<tr>
<td>n=39</td>
<td>n=40</td>
<td>n=21</td>
</tr>
</tbody>
</table>

**Types.**—Hypotypes, University of North Dakota Cat. Nos. 9228, 9344, and 9345.

**Localities and stratigraphic position.**—Specimens were collected from the Timber Lake Member of the Fox Hills.

Superfamily: MYOIDEA
Family: HIATELLIDAE
Genus: Panopea Menard, 1807


Type species.--Panopea aldrovandi Menard (=Mya glycimeris Born), by subsequent designation of Children, (1823).

Description.--Shell large, coarse, broadly sub-cylindrical, ventricose, the umbones wide, the valves gaping widely behind. Sculpture is formed mainly by lines of growth and concentric undulations. Hinge with a single cardinal in each valve beneath the umbo. Ligament external, seated on a large rugose nymph. Muscle scars, pallial line and pallial sinus well developed. (Olsson and Harbison, 1953, p. 150)

Remarks.--Two additional characteristics have been mentioned (Keen, 1963) which serve to distinguish Panopea from its nearest relatives. The pallial line in Panopea is broad, conspicuous, and continuous whereas in Panomya and Hiatella the pallial line is a series of disjunct scars.

The suprageneric classification as well as the spelling...
of the genus Panopea have been the subject of much discussion in recent years. Vokes and Cox (1961, p. 185-188) have proposed that the generic name Panopea be considered a valid name and that the generic names Panope, Menard, 1804, Panopaea, Lamarck, 1818, and Glycimeris Lamarck, 1799 and 1801, be considered rejected names. The genus Panopea was originally named by Menard in 1807, and was subsequently misspelled by Menard (Panope, 1807) and incorrectly emended by Lamarck (Panopaea, 1818). The genus Glycimeris was named by Lamarck in 1799 and, although correctly rendered according to the present International Code of Zoological Nomenclature, it has been suggested (Vokes and Cox, 1961, p. 187) as a name to be placed on the Official Index of Rejected and Invalid Generic Names in Zoology. Lamarck did not continue usage of this name and few subsequent authors, with the exception of Meek (1876) and Dall (1898), have used the name Glycimeris in this context. Further, another commonly known and widely distributed clam, Glycymeris Da Costa, bears a name which varies in spelling in only one letter from the genus named by Lamarck. Although this is permissible according to the Code, Vokes and Cox (1961) suggest that this might lead to unnecessary confusion. Their suggestions have been subsequently endorsed by Keen (1961, p. 376) and Dell (1962, p. 50).
Pending a decision by the Commission, the writer will use the generic name Panopea in accordance with the suggestion of Vokes and Cox.

Panopea occidentalis Meek and Hayden

Pl. 7, Figs. 1-4


Glycimeris occidentalis (Meek and Hayden). Meek, 1876, U. S. Geol. Survey Terr., v. 9, p. 250, p. 39, fig. 9.

Original description.—Shell elongate ovate; posterior end broader than the anterior, subtruncated and gaping; buccal end narrowly rounded, almost closed; base straight along the middle, rounding up abruptly behind, and gradually in front; cardinal border nearly parallel with the base behind the beaks, and sloping in front; beaks small, rather depressed, incurved, approximate and located a little in advance of the center; surface ornamented by irregular concentric wrinkles or undulation, most distinct on the upper half.

Locality and position.—Sandstone near mouth of Judith River, probably No. 4 of the section. (Meek and Hayden, 1856, p. 270-271)

Description of material.—Shell large for genus, ovate, truncate posteriorly; anterior margin evenly rounded; posterior margin nearly straight, inclined slightly so that the posterio-ventral terminus is anteriorad of the posterio-dorsal terminus, broadly gaping; ventral margin nearly straight; dorsal margin convex in the region anteriorad from
the beaks and slightly concave posteriorad from the beaks; beaks located along the midline or slightly posteriorly, inturned, opisthogyral; hinge area strongly developed with one vertical, blade-shaped cardinal tooth on the posterior margin of a shallow, triangular resilifer in the left valve; posterior part of hinge greatly thickened, forming a large roll anteriorad from the posterior adductor muscle scar; hinge line of right valve unknown; posterior adductor muscle scar ovoid, elongate dorso-ventrally, strongly depressed below the level of the interior of the shell; anterior adductor muscle scar indistinct; pallial line continuous, reflected as a prominent, narrow ridge; pallial sinus shallow with the deepest part near the ventral end of the sinus; prosopon consists of concentric growth lamellae which are more prominent near the margins than near the beaks.

Remarks.--Specimens of this species were collected from four localities, all near the top of the Timber Lake Member, where they are associated with Tancredia americana and Dosiniopsis deweyi. All specimens consist of single valves which indicates that they had been agitated prior to burial. All specimens were found lying with their convex side up on the bedding planes.

The original description of this species was based on the exterior of one valve of one specimen so that the
internal characteristics were not described. The specimens here referred to the species conform to the description; however, it should be noted that neither Meek and Hayden (1856) nor Meek (1876) mentioned that the beaks were opisthogyral. Their specimen (USNM No. 180) was broken just behind the beaks so that this feature might not have been obvious. This single character readily distinguishes this species from other North American Cretaceous forms.

Measurements.--Four parameters were measured on all specimens which were well enough preserved to display at least three of the parameters.

<table>
<thead>
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<th>Height</th>
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<th>Distance from beak to anterior margin</th>
<th>Valve</th>
</tr>
</thead>
<tbody>
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</tr>
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<td>n=4</td>
<td>n=2</td>
<td>n=4</td>
<td>2 left</td>
</tr>
</tbody>
</table>

Types.--Hypotypes, University of North Dakota Cat. Nos. 9334 and 9335.

Localities and stratigraphic position.--Specimens were collected from the Timber Lake Member of the Fox Hills Formation at localities 130-80-11, 130-80-13, 130-80-15, and 134-80-1.
Superfamily: ANATINOIDEA

Family: PHOLADOMYIDAE

Genus: Goniomya Agassiz


Type species.--Mya angulifera Sowerby by original designation.

Description.--Shell transversely elongate-oval, or oblong, rather convex, or more or less compressed, nearly or quite equivale, generally inequilateral; inner layer pearly, and gaping, the posterior hiatus being larger than the anterior; beaks depressed, contiguous, or approximate, submesial, or more or less in advance of the middle; ligament short, external or marginal; cardinal margin slightly thickened under the beaks, but without teeth; surface minuetly grandular, concentrically striated, and ornamented with costae that are neither radiating nor parallel to the marks of growth, but descend and converge from the dorsal side before and behind the beaks, so as to connect along the flanks in a series of nearly equal angles, or by little short horizontal extensions; muscular scars faintly marked; pallial line unknown. (Meek, 1876, p. 220)

Remarks.--Apparently very little has been done regarding the taxonomic study of this genus. That it is related to Pholadomya has been known since the genus was named. It is distinguished from Pholadomya and other related genera, Procardia and Homoyma, by the presence of distinct chevron-shaped prosopon (Dall, 1913, p. 466).

The genus is abundantly represented in Jurassic rocks but becomes rare and finally extinct in the Upper Cretaceous.
**Goniomya americana** Meek and Hayden

Pl. 7, Figs. 5 & 6

**Goniomya americana** Meek and Hayden, 1856, Acad. Nat. Sci. Philadelphia, Proc., v. 8, p. 81; Meek, 1876, U. S. Geol Survey Terr., v. 9, p. 221, pl. 30, fig. 12;

Morgan and Petsch, S. Dak. Geol. Survey, Rept. of Invest. 49, pl. 5, fig. 4, no. 2.

**Pholadomya americana** (Meek and Hayden). Gabb, 1861, Synopsis Mollusca Cretaceous Fm., p. 164.

Original description. --Our specimens of this interesting shell are too imperfect to give a clear idea of its form, though the direction of the lines of growth indicate an oblong or very narrow oval outline, with a narrowly rounded anterior and subtruncate posterior. Laterally the valves must have been considerably compressed. The beaks are small, not much elevated, and placed in advance of the centre. On the two extremities the costae, which are quite distinct, traverse the shell obliquely backwards from near the hinge to the base, while those originating immediately in front and behind the beaks, converge and meet at various distances down the sides of the shell, so as to form arched or convex angles of from 20° to 30°. Surface ornamented by fine irregular lines of growth, crossed by regular, equidistant, radiating rows of minute transparent granules, placed at regular distances from each other. These granules are so small as to be scarcely visible without the aid of a strong magnifier, under which they look like minute drops of melted amber.

Locality and position. --Moreau Trading Post, No. 5 of the series. (Meek and Hayden, 1856, p. 81-82)

Description of material. --Shell medium to large size for genus, very elongate, rectilinear, slightly compressed,
very thin-shelled; anterior margin subtruncate, curving abruptly into the ventral margin; posterior margin regularly and smoothly rounded, broadly gaping; ventral margin nearly straight; dorsal margin slopes gently away from the beaks in a convex curve in front of the beaks and in a concave curve behind them; beaks small, only slightly elevated above the hinge line, vertical, located about two-fifths the total length from the anterior margin; interior entirely unknown; prosopon consists of weak growth laminae upon which are superimposed crenulations which originate along the hinge line and curve ventrally and toward a line from the beaks to the ventral margin, resulting in a chevron-shaped pattern, the angle of the apex of each chevron is about twenty degrees near the beaks increasing to about thirty degrees near the margin; the undulations are most prominent in the middle of the shell, becoming obsolete near the anterior and posterior margins; the entire surface of the single complete specimen is broadly undulatory which may represent deformation of the thin shell upon burial.

Remarks.--This large and easily recognized species is extremely rare in North Dakota; however, specimens of this species are quite common in the type area of the Timber Lake Member in South Dakota. The elongate, rectilinear outline and chevron-shaped prosopon distinguish this clam from others in the Fox Hills.
KEY TO THE SUBFAMILIES OF THE CORBULIDAE

1. Chondrophore present ............................................ 2
1'. Chondrophore absent ............................................ 4

2. Valves subequal, rostrate, not twisted or distorted ........ 3
2'. Valves subequal, twisted resilium attaches to lateral,
rather than dorsal, part of chondrophore .....................

.............................................................. PACHYDONTINAE

3. Accessory siphonal plate posterior to left valve .........

.............................................................. CAESTOCORBULINAE

3'. No accessory siphonal plate ................................. CARYOCORBULINAE

4. Shell tellinid in external shape, right valve with reduced
hinge plate, cardinal tooth projects from interior of
valve .................................................................. LENTIDIINAE

4'. Shell not tellinid, hinge or right valve well developed

.............................................................. 5

5. Right valve distinctly rostrate, umbonal ridge present

.............................................................. CORBULINAE

5'. Right valve not rostrate, no umbonal ridge .............

.............................................................. CORBULAMELLINAE

Subfamily: CORBULAMELLINAE

Genus: Corbulamella Meek and Hayden

Type reference.—Meek, F. B., and Hayden, F. V., 1857,
Type species.--Corbula? gregaria Meek and Hayden, 1857, by original designation.

Description.--Shell small, inequivalve, subequilateral, trigonoid-subglobose; right valve more convex than the left; hinge of right valve, with a comparatively large cartilage-pit provided with a conical tooth; left valve with a tooth or cartilage-process fitting into, and partly filling the pit of the other valve; interior of each valve with a very prominent, spoon-shaped process, connected with, or bearing the posterior muscular scar; pallial line apparently a little sinuous. (Meek, 1876, p. 246)

Remarks.--Vokes (1945) has assigned this single genus to the subfamily Corbulamellinae so that the generic characteristics are not distinct from those of the subfamily. Corbulamella is readily distinguishable from other members of the Corbulidae by the trigonal outline and absence of posterior rostrum and umbonal ridge.

Corbulamella inornata (Meek and Hayden)

Pl. 6, Figs. 11, 18, 20, 24, 25


Original description.--Shell small, trigonal, very gibbous, anterior side more or less rounded; posterior extremity angular below, base semiovate, the most prominent part being towards the front; hinge sloping from the beaks, which are central; posterior umbonal slopes angular. Right valve more convex than the other, and having its beak more gibbous, elevated and incurved; but the margins of the two valves are equal, nearly or
quite closed, and a little warped. Surface nearly smooth or only marked by very obscure lines of growth, and sometimes a few indistinct concentric wrinkles near the base. Length .27 inch; breadth .29; height of larger valve 23 [sic] inch, of smaller 20 [sic] inch.

Localities and positions.--Long Lake, No. 5, of the general section. (Meek and Hayden, 1958, p. 52)

Description of material.--Shell small, trigonal, gibbous; right valve larger than left one; anterior and posterior margins nearly straight, posterior one slightly more sloping than the anterior; junction of anterior and posterior margins with the ventral margin is angular; ventral margin gently rounded in profile, that of right valve does not overlap left valve; dorsal margin of right valve flattened, that of left valve is more pointed; beaks slightly prosogyral with the beak of the right valve curving over the beak of the right valve; hinge line short, that of the right valve consists of a large cardinal tooth which is curved in a vertical plane so that the convex side faces the dorsal margin; behind the cardinal in the right valve is a deep depression which serves both for the reception of the cardinal tooth of the left valve and for the insertion of the small, internal ligament; hinge of the left valve consists of a similarly curved cardinal tooth posterior to a deep socket; anterior adductor muscle scars ovoid, elongated along the dorso-ventral axis, indistinct; posterior muscle scars subcircular, elevated
above the rest of the shell interior on a concave platform; pallial line indented by a shallow sinus; prosopon of concentric growth lines or growth lines and irregular undulations.

Remarks.--This species has previously been referred to the genus *Corbula* but it appears to be more appropriately referred to the genus *Corbulamella*. By contrast with *Corbula*, as here defined, *Corbulamella inornata* shows no indication of a posterior rostrum on either valve and it does not have a well-defined umbonal ridge. A weak angulation is present on some specimens that might be considered an umbonal ridge; however, it is not nearly as well developed as that on *Corbula*, s. s. Further, that posterior muscle scar is elevated above the interior of the shell, a feature characteristic of *Corbulamella*. When the species was originally named, Meek and Hayden (1858, p. 52) suggested that it might be referable to the genus *Corbulamella* but did not do so because they did not have knowledge of the interior.

This species differs from the type species, *Corbulamella gregaria*, in two conspicuous ways. The ventral margin of the left valve fits into a groove in the right valve. In *C. inornata* the ventral margins are concordant. Also, the umbo of the right valve of *C. inornata* is considerably broader than that of *C. gregaria*. 
Measurements.--Four parameters were measured on all specimens that were preserved well enough to display at least three of the dimensions.

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<td></td>
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</table>

Types.--Hypotypes, University of North Dakota Cat. Nos. 9257, 9259, and 9258.

Localities and stratigraphic position.--Specimens were collected from the Timber Lake Member of the Fox Hills Formation at localities 129-78-6, 130-78-7, 131-78-2, and 132-76-6.

Subfamily: CORBULINAE

Genus: Corbula Lamarck


Type species.--Corbula sulcata Lamarck, by subsequent designation of Schmidt, 1818.

Description.--Shell rather small, inequivalve, inequilateral, discrepantly sculptured even in the juvenile stages; right valve larger, relatively higher and more trigonal in outline, obtusely rostrate posteriorly, concentrically rugose; left valve smaller, transversely elongate, not rostrate posteriorly, with a sparse and irregular radial lineation and a concentric
sculpture restricted largely to the ventral area. (Gardner, 1928, p. 229)

A similarly restricted diagnosis of the genus was given earlier by Gardner (1926, p. 47). Vokes (1945, p. 9-10) has redescribed the type species and has added a number of internal characteristics:

The interior of the right valve is grooved for the reception of the margins of the left. The hinge of the right valve is marked by an anterior socket-like area into which is received the thickened, dentiform, anterior dorsal margin of the left; the right cardinal is moderately heavy, slightly recurved dorsally, the resilial pit is deep, extending dorsad under the top of the umbo, and a small but well-developed posterior lateral tooth is found immediately behind this pit. The hinge of the left valve consists of the thickened anterior dorsal margin, mentioned above; immediately posterior to it there is a deep socket for the reception of the right socket. The ligament is received in a deep resilial pit located posterior to the socket and separated from it by a thin septum; posterior cardinal which is adjacent and fused to the posterior dorsal margin of the valve; the posterior lateral of the right valve is received in a narrow pit on the posterior dorsal margin of the left. The adductor scars are moderately prominent, slightly impressed, the posterior more so than the anterior; the pallial line is obscure, more prominent posteriorly at the broad, shallow, pallial sinus.

Remarks.—The genus *Corbula* has been variously interpreted by zoologists and paleontologists and has included almost all small, rostrate, inequivalve clams. *Corbula*, as here restricted, is referred to the Corbulinae, which is characterized by the absence of a chondrophore in the left valve, presence of a posterior lateral tooth on the right
valve and a posterior cardinal tooth on the left valve. 

*Corbula* is apparently always rostrate and has an angular ridge which extends from the beak to the posterio-ventral margin. *Corbula* is distinguished from *Corbulomima* Vokes, 1945, the only other genus in the Corbuliinae, in that it has a thin septum separating the resilifer from the cardinal socket which is not present in *Corbulomima*. The genus *Caryocorbula* is distinguished from *Corbula* by the presence of a projecting chondrophore in the left valve. Careful study of the illustrations given by Vokes (1945, pl. 1), and Stenzel, Krause, and Twining (1957, p. 166) however, indicates that the structure referred to as a chondrophore extends only slightly, if at all, above the hinge plate. Separation of the two genera can be more readily accomplished by noting the presence or absence of the septum which separates the resilifer from the cardinal socket.

Specimens here referred to the genus *Corbula* show evidence of a septum as described above. Only the interior of a single right valve is available for study but it does show that the deep indentation on the hinge plate is smooth on the anterior half and rugose on the posterior half. The two areas are separated by a ridge which may be interpreted as the broken remnant of a septum.
The genus *Corbula* was first used by Bruguiere (1797, pl. 230) and he has, therefore often been cited as the author of the genus. He in no way indicated that he was naming a new genus so that his name does not satisfy Articles 12 and 16 of the International Code of Zoological Nomenclature. *Corbula* Bruguiere, 1797, should, therefore, be considered a nomen nudum.

*Corbula monmouthensis* Gardner

Pl. 6, Figs. 3-5, 16, 17, 19, 21


Original description.—Shell rather large for the genus, ovate trigonal in outline, inequilateral and inconspicuously inequivale; umbones subcentral in position, subequal in the two valves, somewhat flattened upon their summits, the apices acute and prosogyrate; right valve more inflated than left in the anterior portion, and with a wider posterior area which is antulated near its dorsal margin and slightly reflected over the left valve; anterior margins of both valves broadly and evenly rounded; posterior dorsal slope more gentle in the right valve than in the left; the lateral margin produced and obtusely angulated in the right, obliquely truncate in the left; base line more strongly arcuate in the larger valve; external sculpture in both valves of very fine, sharp lamellae closely overlapping, the free edges directed toward the umbones, least feeble on the anterior and ventral portions of the disk, very faint in the umbonal region and evanescent near the posterior keel; ligament
internal, supported by a rather inconspicuous lamelliform chondrophore behind the umbones in the left valve; resilial pit in the right valve broad but rather shallow, the solitary tooth subumbonal in position, stout, obtusely conical; receiving socket in left valve also subumbonal, long but not very deep; adductor muscle scars relatively long, rather indistinct; pallial sinus broad, shallow; pallial line rather near the basal margin.

Occurrence.—Monmouth Formation. Brooks estate near Seat Pleasant, Prince George's County. (Gardner, 1916, p. 715-716)

Description of material.—Shell small, moderately thick, ovate, elongate, posteriorly truncate; right valve slightly larger than the left; anterior margin smoothly rounded, commissure straight; posterior margin truncate, the ventral extremity extending farther posteriorad than the dorsal, right valve extends slightly farther posteriorad than the left, both are rostrate and truncate; ventral margin smoothly rounded, margin of left valve fits slightly inside margin of right valve but no groove is developed in the right valve; dorsal margin anterior of the beaks nearly straight, posterior of the beaks it shows a sharp angulation at the dorsal end of the rostrum, commissure slightly undulose with the right valve extending over the left one in the region of the rostrum; beaks central, inturned, very slightly prosogyral; hinge of right valve with a large subumbonal tooth which is slightly flattened and markedly recurved dorsally behind which is a shallow subcircular pit which is divided into two
equal parts by a thin septum, the surface of the anterior part is smooth, that of the posterior part is lamellose; laterals of right valve and entire hinge of left valve unknown; adductor muscle scars ovate, indistinct; pallial line close to the ventral margin, terminated posteriorly by a pallial sinus which extends as a straight vertical line from the pallial line to the posterior adductor muscle scar, not indented; exterior divided into two areas, a posterior triangular area behind a line from the beak to the posterior-ventral extremity of the rostrum which displays only growth lines and the rest of the shell which displays both growth lines and regular, recurved lamellae whose edges are directed dorsally, lamellae become increasingly stronger from the beaks to the ventral margins, slightly more prominent on the right valve than on the left.

Remarks.--The specimens here referred to *C. monmouthensis* conform closely to those described by Gardner (1916, p. 715) except with regard to their overall size. Gardner described them as relatively large corbulids which is not true for those of the Fox Hills. With regard to size, the Fox Hills specimens more closely resemble those described by Wade (1926, p. 97) from the Ripley Formation. The description given by Gardner indicates a "... rather inconspicuous lamelliform chondrophore. ..." in the left valve. Although
the type material has not been seen, it would seem that it is inappropriate to use the term chondrophore in reference to this structure as it is part of the hinge plate and does not seem to extend out from it.

A single specimen, collected from locality 129-78-4, is questionably referred to this species in that the beak of the right valve is considerably more flattened than is that of the rest of the material. In other respects, however, it conforms to the description.

This species is readily recognized on the basis of the nearly equal valves and the prosopon.

Measurements.--Three parameters were measured on all specimens which were well enough preserved to display at least two of the parameters.

<table>
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Types.--Hypotypes, University of North Dakota Cat. Nos. 9338, 9339, and 9340.

Localities and stratigraphic position.--Specimens were collected from the Timber Lake Member of the Fox Hills Formation at localities 129-78-4, 130-78-1, 130-80-11, and 131-78-2.
CONCLUSIONS

Based on the work on the Fox Hills Formation in North Dakota, the following conclusions can be drawn:

1. The Fox Hills Formation crops out in Logan, Emmons, Sioux, Morton, Burleigh, Kidder, Pierce, McHenry, Bottineau, and Bowman counties, but is well exposed only in Emmons, Sioux, and Morton counties in south-central North Dakota.

2. The formations can be subdivided into three members in North Dakota, the Timber Lake, Bullhead, and Colgate members. The lowermost member of the formation in the type area in South Dakota, the Trail City Member, cannot be distinguished on the basis of lithology in North Dakota.

3. Study of the Bivalvia and Cephalopoda of the Fox Hills confirms the Maestrichtian age of the formation in the state. The Fox Hills correlates with the upper portion of the Navarro Group in Texas, the upper part of the Ripley Formation in Mississippi, and the upper part of the Monmouth Group in New Jersey. Cephalopods collected from the Fox Hills in Colorado indicate a somewhat greater age for the unit in that area, probably lowermost Maestrichtian. The formation, therefore, becomes significantly younger to the eastward.
4. The bivalve fauna of the Timber Lake Member probably lived in normal marine water that varied in depth from intertidal to about 80 fathoms. Increase in abundance and magnitude of cross-bedding and presence of extremely shallow-water bivalves and arthropods near the top of the member indicates that the water depth decreased progressively from the base of the member to the top.

5. The Bullhead Member, which normally yields a rather sparse fauna, consists of a sequence of interbedded sandstone and shale. The unit was probably deposited in extremely shallow, brackish water, possible in an estuary or lagoon.

6. The Colgate Member, which locally yields a large oyster assemblage, probably represents a beach deposit separating the predominately marine Fox Hills Formation from the overlying predominately non-marine Hell Creek Formation.

7. The fossils collected from the Fox Hills were, in many cases, taken from concretions which were probably formed at, or very near, their present positions and probably represent calcareous accumulations around organic centers.

8. A volcanic ash bed has been identified in Emmons, Sioux, and Morton counties and, if contemporaneous throughout, indicates that the three members of the formation identified in North Dakota were deposited penecontemporaneously over a lateral distance of about 40 miles. Further petrological and
geochemical work will have to be done before the continuity of the ash can be demonstrated.

9. The paleoecology of the Fox Hills Formation in North Dakota indicates that it represents the littoral and neritic facies of a regressive Upper Cretaceous seaway which retreated to the north and east. The regression probably terminated in the area of Pierce County in central North Dakota by the end of the Cretaceous. A single, minor transgression is suggested by the Breien Member of the Hell Creek Formation. Following the retreat of the Fox Hills sea into central North Dakota, a major advance occurred which resulted in the deposition of the Cannonball Formation of Paleocene age.

10. Forty two species of bivalves assigned to twenty five genera were identified from the Fox Hills Formation in North Dakota. Of this number, three new species, Nucula emmonsensis, Modiolus siouxensis, and ?Astarte hollandi were named. Three other species, Nuculana tarensis, Vetericardia crenalirata, and Corbula monmouthensis, have never before been described from the Upper Cretaceous of the Midcontinent. A single specimen of Tellina scitula was collected that showed color markings and a single specimen of Crenella elegantula showed a small bit of periostracum.
APPENDIX

LIST OF LOCALITIES

The following list of localities includes all areas which have been studied by the writer in North Dakota and which were exposed well enough to allow study. In each case, the first number given will be the locality number. This will be followed by a description of that locality in enough detail to allow relocation of the site. Throughout the text, only the locality numbers are given.

129-78-1: SW¼ sec. 6, T. 129 N., R. 78 W., Emmons County.
129-78-2: NW¼ sec. 5, T. 129 N., R. 78 W., Emmons County.
129-78-3: NW¼, SW¼ sec. 4, T. 129 N., R. 78 W., Emmons County.
129-78-4: SE¼ sec. 9, T. 129 N., R. 78 W., Emmons County.
129-78-5: NW¼ sec. 11, T. 129 N., R. 78 W., Emmons County.
129-78-6: NE¼ sec. 18, T. 129 N., R. 78 W., Emmons County.
129-78-7: SE¼ sec. 7, T. 129 N., R. 78 W., Emmons County.
129-78-8: SE¼ sec. 11, T. 129 N., R. 78 W., Emmons County.
129-79-1: N½ sec. 19, T. 129 N., R. 79 W., Sioux County.
129-79-2: NE cor. sec. 18, T. 129 N., R. 79 W., Sioux County.
129-79-3: NE¼, NW¼ sec. 7, T. 129 N., R. 79 W., Sioux County.
129-7904: NE¼ sec. 14, T. 129 N., R. 79 W., Fox Hills float material on Pierre Formation near the Missouri River, Emmons County.

312,
129-80-1: SW cor. sec. 25, T. 129 N., R. 80 W., Sioux County.
129-80-2: SW cor. sec. 29, T. 129 N., R. 80 W., Sioux County.
129-81-1: NE$\frac{1}{4}$, NE$\frac{1}{4}$ sec. 1, T. 129 N., R. 81 W., Sioux County.
129-81-2: NE$\frac{1}{4}$, NW$\frac{1}{4}$ sec. 2, T. 129 N., R. 81 W., Sioux County.
129-81-3: NW$\frac{1}{4}$, NE$\frac{1}{4}$ sec. 2, T. 129 N., R. 81 W., Sioux County.
130-78-1: SW$\frac{1}{4}$, NW$\frac{1}{4}$ sec. 33, T. 130 N., R. 78 W., Road cut on east side of road, Emmons County.
130-78-2: SW$\frac{1}{4}$, NW$\frac{1}{4}$ sec. 3, T. 130 N., R. 78 W., road cut on east and west sides of road, Emmons County.
130-78-3: NW cor. sec. 3, T. 130 N., R. 78 W., Emmons County.
130-78-4: NW$\frac{1}{4}$ sec. 3, T. 130 N., R. 78 W., road cut on south side of road, Emmons County.
130-78-5: NW$\frac{1}{4}$ sec. 5, T. 130 N., R. 78 W., Emmons County.
130-78-6: NE$\frac{1}{4}$, NW$\frac{1}{4}$ sec. 3, T. 130 N., R. 78 W., road cut on south side of road, Emmons County.
130-78-7: NW$\frac{1}{4}$ sec. 33, T. 130 N., R. 78 W., Emmons County.
130-79-1: NE$\frac{1}{2}$, NW$\frac{1}{4}$ sec. 1, T. 130 N., R. 79 W., Emmons County.
130-80-1: SE$\frac{1}{4}$ sec. 22, T. 130 N., R. 80 W., Sioux County.
130-80-2: NW$\frac{1}{4}$ sec. 33, T. 130 N., R. 80 W., Sioux County.
130-80-3: SE$\frac{1}{4}$ sec. 28, T. 130 N., R. 80 W., Sioux County.
130-80-4: Sec. 20, T. 130 N., R. 80 W., Sioux County.
130-80-5: NW$\frac{1}{4}$ sec. 34, T. 130 N., R. 80 W., Sioux County.
130-80-6: SW$\frac{1}{4}$, NE$\frac{1}{4}$ sec. 27, T. 130 N., R. 80 W., Sioux County.
130-80-7: SW$\frac{1}{4}$ sec. 27, T. 130 N., R. 80 W., Sioux County.
130-80-8: Center sec. 27, T. 130 N., R. 80 W., Sioux County.

130-80-9: SW$_{34}$ sec. 31, T. 130 N., R. 80 W., Sioux County.

130-80-10: SE$_{34}$ sec. 31, T. 130 N., R. 80 W., road cut on north side of N. Dak. 24, Sioux County.

130-80-11: NW$_{34}$, SW$_{34}$ sec. 32, T. 130 N., R. 80 W., Sioux County.

130-80-12: NW$_{34}$ sec. 27, T. 130 N., R. 80 W., Sioux County.

130-80-13: S$_{32}$ sec. 32, T. 130 N., R. 80 W., Sioux County.

130-80-14: NW$_{34}$ sec. 20, T. 130 N., R. 80 W., Sioux County.

130-80-15: SE$_{34}$, NE$_{34}$ sec. 33, T. 130 N., R. 80 W., Sioux County.

130-81-1: Sec. 36, T. 130 N., R. 81 W., Sioux County.

130-106-1: NW$_{34}$ sec. 11, T. 130 N., R. 106 W., Bowman County.

131-77-1: NE$_{34}$, NW$_{34}$ sec. 7, T. 131 N., R. 77 W., Emmons County.

131-78-1: SW$_{34}$, SE$_{34}$ sec. 33, T. 131 N., R. 78 W., road cut on north side of road, Emmons County.

131-78-2: NE$_{34}$ sec. 12, T. 131 N., R. 78 W., Emmons County.

131-78-3: Center sec. 25, T. 131 N., R. 78 W., Emmons County.

131-78-4: NW$_{34}$ sec. 7, T. 131 N., R. 78 W., south valley wall of Little Beaver Creek, Emmons County.

131-78-5: SE$_{34}$, SW$_{34}$ sec. 34, T. 131 N., R. 78 W., Emmons County.
131-78-6: SE_{1/4} sec. 32, T. 131 N., R. 78 W., road cut on north side of road, Emmons County.

131-79-1: SW_{1/4} sec. 15, T. 131 N., R. 79 W., Emmons County.
131-79-2: SE_{1/4} sec. 12, T. 131 N., R. 79 W., Emmons County.
131-79-3: NE_{1/4} sec. 13, T. 131 N., R. 79 W., road cut on south side of road, Emmons County.

131-80-1: SE cor., SW_{1/4} sec. 27, T. 131 N., R. 80 W., Sioux County.
131-80-2: NW_{1/4} sec. 32, T. 131 N., R. 80 W., Sioux County.
131-80-3: SW_{1/4} sec. 25, T. 131 N., R. 80 W., Sioux County.
131-80-4: NW_{1/4}, SW_{1/4} sec. 29, T. 131 N., R. 80 W., Sioux County.
131-80-5: NE_{1/4}, SW_{1/4} sec. 5, T. 131 N., R. 80 W., Sioux County.
131-80-6: SW_{1/4} sec. 24, T. 131 N., R. 80 W., road cut on west side of N. Dak. 24, Sioux County.

131-81-1: SW_{1/4} sec. 25, T. 131 N., R. 81 W., Sioux County.
131-106-1: SW_{1/4} sec. 4, T. 131 N., R. 106 W., Bowman County.

132-76-1: NW_{1/4} sec. 8, T. 132 N., R. 76 W., Emmons County.
132-76-2: NW_{1/4} sec. 4, T. 132 N., R. 76 W., Emmons County.
132-76-3: NE_{1/4} sec. 4, T. 132 N., R. 76 W., Emmons County.
132-76-4: NW_{1/4} sec. 7, T. 132 N., R. 76 W., Emmons County.
132-76-6: SE_{1/4} sec. 17, T. 132 N., R. 76 W., north facing cutbank along Beaver Creek in Seeman Park, about 1 mile SE from Linton, Emmons County.
132-76-7: SE\textsuperscript{4} sec. 8, T. 132 N., R. 76 W., Emmons County.

132-76-8: SW\textsuperscript{4} sec. 6, T. 132 N., R. 76 W., Emmons County.

132-76-9: NW\textsuperscript{4} sec. 21, T. 132 N., R. 76 W., Emmons County.

132-76-10: SE\textsuperscript{4}, SW\textsuperscript{4} sec. 20, T. 132 N., R. 76 W., Emmons County.

132-76-11: Center sec. 15, T. 132 N., R. 76 W., Emmons County.

132-76-12: NW\textsuperscript{4} sec. 29, T. 132 N., R. 76 W., Emmons County.

132-77-1: NE\textsuperscript{4} sec. 12, T. 132 N., R. 77 W., road cut on north side of road, Emmons County.

132-78-1: SW\textsuperscript{4} sec. 29, T. 132 N., R. 78 W., Emmons County.

132-78-2: SW\textsuperscript{4}, SE\textsuperscript{4} sec. 26, T. 132 N., R. 78 W., Emmons County.

132-78-3: NE\textsuperscript{4} sec. 3, T. 132 N., R. 78 W., south side of road at "T" intersection, Emmons County.

132-78-4: S\textsuperscript{1} sec. 1, T. 132 N., R. 78 W., Emmons County.

132-78-5: NW\textsuperscript{4} sec. 3, T. 132 N., R. 78 W., Emmons County.

132-78-6: NE cor. sec. 24, T. 132 N., R. 78 W., Emmons County.

132-79-1: SE\textsuperscript{4}, NE\textsuperscript{4} sec. 11, T. 132 N., R. 79 W., Emmons County.

132-79-2: SW\textsuperscript{4}, SW\textsuperscript{4} sec. 1, T. 132 N., R. 79 W., road cut on north side of road, Emmons County.

132-79-3: NE\textsuperscript{4} sec. 12, T. 132 N., R. 79 W., Emmons County.


132-79-5: NE\textsuperscript{4}, SW\textsuperscript{4} sec. 26, T. 132 N., R. 79 W., Emmons County.
132-79-6: SW\(\frac{1}{4}\) sec. 25, T. 132 N., R. 79 W., Emmons County.

132-79-7: SE\(\frac{1}{4}\) sec. 23, T. 132 N., R. 79 W., road cut across Beaver Creek, Emmons County.

132-79-8: NE\(\frac{1}{4}\) sec. 11, T. 132 N., R. 79 W., Emmons County.

132-106-1: SW\(\frac{1}{4}\) sec. 20, T. 132 N., R. 106 W., Bowman County.

132-107-1: NE\(\frac{1}{4}\) sec. 24, T. 132 N., R. 107 W., Bowman County.

133-73-1: NW\(\frac{1}{4}\) sec. 26, T. 133 N., R. 73 W., Logan County.

133-75-1: SE\(\frac{1}{4}\) sec. 31, T. 133 N., R. 75 W., Emmons County.

133-75-2: SE\(\frac{1}{2}\) sec. 32, T. 133 N., R. 75 W., Emmons County.

133-75-3: SW\(\frac{1}{2}\) sec. 33, T. 133 N., R. 75 W., Emmons County.

133-76-1: NE\(\frac{1}{4}\), SE\(\frac{1}{4}\) sec. 21, T. 133 N., R. 76 W., Emmons County.

133-76-2: SE\(\frac{1}{2}\) sec. 18, T. 133 N., R. 76 W., Emmons County.

133-76-3: SW\(\frac{1}{2}\) sec. 34, T. 133 N., R. 76 W., Emmons County.

133-76-4: Sec. 33, T. 133 N., R. 76 W., Emmons County.

133-76-5: SW\(\frac{1}{2}\) sec. 27, T. 133 N., R. 76 W., Emmons County.

133-76-6: NE\(\frac{1}{4}\) sec. 21, T. 133 N., R. 76 W., Emmons County.

133-76-7: SE\(\frac{1}{4}\), NE\(\frac{1}{4}\) sec. 33, T. 133 N., R. 76 W., Emmons County.

133-76-8: NE\(\frac{1}{4}\) sec. 32, T. 133 N., R. 76 W., Emmons County.

133-76-9: NW\(\frac{1}{4}\) sec. 29, T. 133 N., R. 76 W., Emmons County.

133-77-1: Center sec. 28, T. 133 N., R. 77 W., bluff on each side of road, Emmons County.

133-77-2: SE\(\frac{1}{4}\) sec. 27, T. 133 N., R. 77 W., Emmons County.
133-77-3: NE¼ sec. 2, T. 133 N., R. 77 W., Emmons County.
133-77-4: SW¼ sec. 26, T. 133 N., R. 77 W., Emmons County.
133-77-5: NE¼ sec. 35, T. 133 N., R. 77 W., Emmons County.
133-77-6: NW¼, SW¼ sec. 27, T. 133 N., R. 77 W., Emmons County.
133-77-7: SW¼ sec. 28, T. 133 N., R. 77 W., Emmons County.
133-77-8: SW¼ sec. 20, T. 133 N., R. 77 W., Emmons County.
133-77-9: NW¼, NE¼ sec. 28, T. 133 N., R. 77 W., Emmons County.
133-77-10: NW¼ sec. 11, T. 133 N., R. 77 W., Emmons County.
133-78-1: Center sec. 1, T. 133 N., R. 78 W., Emmons County.
133-78-2: NW¼, SW¼ sec. 1, T. 133 N., R. 78 W., Emmons County.
133-78-3: NW¼ sec. 28, T. 133 N., R. 78 W., Emmons County.
133-78-4: NE¼ sec. 5, T. 133 N., R. 78 W., Emmons County.
133-78-5: SW¼ sec. 28, T. 133 N., R. 78 W., Emmons County.
134-71-1: Center sec. 26, T. 134 N., R. 71 W., Logan County.
134-71-2: NE¼, NE¼ sec. 19, T. 134 N., R. 71 W., Logan County.
134-72-1: SW¼, NW¼ sec. 27, T. 134 N., R. 72 W., Logan County.
134-74-1: SW¼ sec. 5, T. 134 N., R. 74 W., Emmons County.
134-75-1: NE¼ sec. 12, T. 134 N., R. 75 W., Emmons County.
134-77-1: SE¼ sec. 35, T. 134 N., R. 77 W., Emmons County.
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134-77-2: SW¼ sec. 36, T. 134 N., R. 77 W., Emmons County.
134-77-3: SW¼ sec. 14, T. 134 N., R. 77 W., Emmons County.
134-77-4: SE¼, SW¼ sec. 35, T. 134 N., R. 77 W., Emmons County.

134-77-5: SE¼ sec. 34, T. 134 N., R. 77 W., Emmons County.
134-78-1: NW¼ sec. 23, T. 134 N., R. 78 W., Emmons County.
134-78-2: S½, S½ sec. 6, T. 134 N., R. 78 W., Emmons County.
134-78-3: SW¼ sec. 18, T. 134 N., R. 78 W., Emmons County.
134-79-1: NE¼ sec. 24, T. 134 N., R. 79 W., Emmons County.
134-79-2: SW¼ sec. 12, T. 134 N., R. 79 W., Emmons County.
134-79-3: NW¼ sec. 12, T. 134 N., R. 79 W., Emmons County.
134-79-4: SW¼ sec. 1, T. 134 N., R. 79 W., Emmons County.
134-79-5: NW¼ sec. 21, T. 134 N., R. 79 W., Sioux County.
134-79-6: SW¼ sec. 16, T. 134 N., R. 79 W., Morton County.
134-80-1: SW¼ sec. 26, T. 134 N., R. 80 W., cut bank on the Cannonball River, Sioux County.
134-80-2: SW¼ sec. 21, T. 134 N., R. 80 W., Morton County.
134-80-3: Sec. 21, T. 134 N., R. 80 W., Morton County.
134-80-4: SE¼ sec. 21, T. 134 N., R. 80 W., Morton County.
134-80-5: NW¼ sec. 24, T. 134 N., R. 80 W., Morton County.
134-80-6: SW¼ sec. 24, T. 134 N., R. 80 W., Morton County.
134-80-7: SW¼ sec. 21, T. 134 N., R. 80 W., Morton County.
134-81-1: NE¼ sec. 36, T. 134 N., R. 81 W., Sioux County.
135-78-1: SW¼ sec. 6, T. 135 N., R. 78 W., Emmons County.
135-79-1: NW¼ sec. 36, T. 135 N., R. 79 W., Emmons County.
136-78-1: SW½ sec. 28, T. 136 N., R. 78 W., Emmons County.
136-78-2: SW¼ sec. 29, T. 136 N., R. 78 W., Emmons County.
136-78-3: NE¼ sec. 31, T. 136 N., R. 78 W., Emmons County.
137-76-1: SW¼ sec. 11, T. 137 N., R. 76 W., Burleigh County.
138-74-1: SW¼ sec. 16, T. 138 N., R. 74 W., Kidder County.
141-73-1: NE¼ sec. 36, T. 141 N., R. 73 W., S. side of Sibley Buttes, Kidder County.
151-74-1: SW¼ sec. 13, T. 151 N., R. 74 W., railroad cut, Pierce County.
154-78-1: SW¼ sec. 30, T. 154 N., R. 78 W., McHenry County.
163-76-1: SW¼ sec. 8, T. 163 N., R. 76 W., Bottineau County.
163-76-2: SE cor. sec. 6, T. 163 N., R. 76 W., Bottineau County.
REFERENCES

Allen, R. S., 1948, Geological correlation and paleoecology:


North Dakota: N. Dak. Geol. Survey First Biennial
Rept., 103 p.

Bartram, J. G., 1937, Upper Cretaceous of Rocky Mountain area:

Am. Assoc. Petroleum Geologists Bull., v. 21, no. 7,
p. 899-913.

of Agriculture, Yearbook, p. 1045-1054.

Boucot, A. J., 1953, Life and death assemblages among fossils:


Bowen, C. F., 1915, The stratigraphy of the Montana Group

with special reference to the position and age of the

Judith River Formation in north-central Montana: U. S.


Butler, P. A., 1954, Summary of our knowledge of the oyster

in the Gulf of Mexico: U. S. Bureau of Fisheries Bull.,
v. 89, p. 479-489.

Calvert, W. R., 1912, Geology of certain lignite fields in

eastern Montana: U. S. Geol. Survey Bull., v. 471,
p. 187-201.


Cox, L. R., 1929, Notes on the Mesozoic family Tancrediidae, with descriptions of several British Upper Jurassic species, and of a new genus Eodonax: Annals and Mag. of Nat. Hist., ser. 10, v. 3, no. 18, p. 569-594, pls. XIII and XIV.


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---, 1857, On some new species of fossils from the Cretaceous formation of Nebraska Territory: St. Louis Acad. Sci. Trans., v. 1, p. 38-42.


Foerste, A. F., 1930, The color patterns of fossil cephalopods and brachiopods, with notes on gastropods and pelecypods: Univ. of Michigan, Mus. of Paleontology Contr., v. 3, no. 6, p. 109-150, 5 pls.


---, 1926a, The nomenclature of the superspecific groups of *Corbula* in the lower Miocene of Florida: Nautilus, v. 40, p. 41-47.


---, 1933, The Midway Group of Texas Univ. Texas, Pub. 3301, 403 p., 28 pls.


Hall, James, and Meek, F. B., 1854, Description of new species of fossils from the Cretaceous formations of Nebraska, with observation upon Baculites ovatus and Baculites...

Hansen, G. A., 1929, Vertical range of the more common species of the Upper Cretaceous in the Western Interior: Jour. Paleontology, v. 3, p. 86.


____, 1908, On the genera of Veneridae represented in the Cretaceous and older Tertiary deposits: Malacological Soc. London Proc., v. 8, p. 148-177, pl. VI.


McDermott, J. F., (editor and annotater), 1951, Up the Missouri with Audubon; the journal of Edward Harris: Norman, Oklahoma, Univ. Oklahoma Press.


Meek, F. B., 1864, Checklist of the invertebrate fossils of North America; Cretaceous and Jurassic: Smithsonian Misc. Coll., v. 7, no. 177, 40 p.


, 1839, Description of some new species of organic remains of the Cretaceous Group of the United States:


Rau, J. L., and others, 1962, Geology and ground water
resources of Kidder County, North Dakota; Part 1 -
des Nucules: Inst royal des Sciences naturelles de
Prime, Temple, 1865, Monograph of American Corbiculidae:
Rau, J. L., and others, 1962, Geology and ground water
resources of Kidder County, North Dakota; Part 1 -
Reeside, J. B., Jr., 1928, New Cretaceous mollusks from
11, p. 306-313, 2 pls.
Reeside, J. B., Jr., and Weymouth, A. A., 1931, Mollusks from
the Aspen Shale (Cretaceous) of southwestern Wyoming:
Reinhart, P. W., 1935, Classification of the pelecypod
family Arcidae: Musee royal d'Histoire naturelle de
Belgique Bull., v. 11, no. 13, p. 1-68.
Rennie, J. V. L., 1929, Cretaceous fossils from Angola:
Ann. of South African Mus., v. 28, p. 1-54, pls. I-V.
____, 1929, New Lamellibranchia and Gastropoda from the
Upper Cretaceous of Pondoland: Ann. South African Mus.,
v. 28, p. 159-260, pls. XVI-XXXI.


—, 1939, Revised nomenclature for some nuculid pelecypods: Jour. Paleontology, v. 13, p. 21-41.


Simpson, G. G., Roe, Anne, and Lewontin, R. C., 1960, 

Sinclair, R. M., and Isom, B. G., 1963, Further studies on 
the introduced Asiatic clam (Corbicula) in Tennessee: 
Nashville, Tennessee, Tennessee Dept. of Public Health, 
78 p., 14 pls.

Skogstrom, H. C., Jr., 1959, The paleoecological significance 
of Tancredia americana: S. Dak. Acad. Sci. Proc., v. 37, 
p. 139-141.

oysters from the Gulf Coast and Caribbean: U. S. Geol. 
Survey Prof. Paper 483H, 22 p., 5 pls.

Stanton, T. W., 1910, For Hills Sandstone and Lance Formation 
("Ceratops beds") in South Dakota, North Dakota, and 
eastern Wyoming: Am. Jour. Sci., 4th ser., v. 30, 
p. 172-188.

---, 1917, A Cretaceous volcanic ash bed on the Great Plains 
in North Dakota: Washington Acad. Sci. Jour., v. 7, 
p. 80-81.

---, 1920, The fauna of the Cannonball marine member of the 
Lance Formation: U. S. Geol. Survey Prof. Paper 128, 
61 p.

Stebinger, Eugene, 1914, The Montana Group of northwestern 


Whitfield, R. P., 1886, Brachiopoda and Lamellibranchiata of the Raritan clays and Greensand marls of New Jersey:
U. S. Geol. Survey Mon. 9, 338 p., 35 pls.

Wilder, F. A., 1902, Geologic report on the lignite area:
PLATES
Fig. 1. Topographic bench formed on the top of the Timber Lake Member. One of the resistant units can be seen just below the surface in the foreground. View looking west from the top of Red Horse Butte, sec. 36, T. 130 N., R. 80 W., Sioux County, North Dakota.

Fig. 2. Timber Lake Member in a roadcut, NW\text{\kern-.1667em}/sec. 20, T. 130 N., R. 106 W., Bowman County, North Dakota.

Fig. 3. Pierre-Fox Hills contact SW\text{\kern-.1667em}/sec. 20, T. 130 N., R. 106 W., Bowman County, North Dakota.

Fig. 4. Pierre-Fox Hills contact exposed on a north-facing cutbank of Beaver Creek, in Seeman Park, SE\text{\kern-.1667em}/sec. 17, T. 132 N., R. 76 W., Emmons County, North Dakota.
Fig. 1. Oyster bed near the top of the Timber Lake Member, NE\textsubscript{4} sec. 11, T. 132 N., R. 79 W., Emmons County, North Dakota.

Fig. 2. *Ophiomorpha major* burrows exposed along a west facing cutbank of the Cannonball River, SW\textsubscript{4} sec. 26, T. 134 N., R. 80 W., Sioux County, North Dakota.

Fig. 3. Surface of a bedding plane near the top of the Timber Lake Member, exposed along a small creek, SE\textsubscript{4} sec. 29, T. 130 N., R. 80 W., Sioux County, North Dakota. The fossils exposed include *Tancredia americana* and *Panopea occidentalis*.

Fig. 4. Exposure of the Timber Lake Member, NE\textsubscript{4} sec. 3, T. 132 N., R. 73 W., Emmons County, North Dakota.
PLATE 3

Fig. 1. Bullhead Member exposed in small stream valley, NW ¼ sec. 33, T. 130 N., R. 78 W., Emmons County, North Dakota.

Fig. 2. Channel eroded in the Colgate Member, NE ¼ sec. 7, T. 134 N., R. 78 W., Emmons County, North Dakota.

Fig. 3. Bullhead-Colgate contact, NW ¼ sec. 7, T. 134 N., R. 78 W., Emmons County, North Dakota.

Fig. 4. Colgate Member exposed in a railroad cut, SW ¼ sec. 13, T. 151 N., R. 74 W., Pierce County, North Dakota.
Figs. 1-4. *Nemodon sulcatinus* (Evans and Shumard)

1. Mold of the interior of the right valve of UND specimen 9201, X2, showing a portion of shell.
2. Mold of the interior of the left valve of UND specimen 9200, X2, showing dorso-ventral sulcus.
3. Dorsal view of UND specimen 9200, X2.

Figs. 5, 6, 9, 10. *Crenella elegantula* Meek and Hayden

5. Dorsal view of UND specimen 9218, X1.

Figs. 7&8, 11-15. *Modiolus galpinianus* (Evans and Shumard)

7. Mold of the interior of the left valve of UND specimen 9214, X1.
8. Mold of the interior of the right valve of UND specimen 9214, X1.
12. Interior of left valve of UND specimen 9346, X1.
14. Mold of the interior of the left valve of UND specimen 9347, X1, showing a bit of shell material.
15. Mold of the interior of the right valve of UND specimen 9215, X1.

Fig. 16. *Modiolus siouxensis* sp. nov.

16. Mold of the interior of the left valve of UND specimen 9361 (holotype), X1.

Fig. 17. Nuculana sp.

17. Mold of the interior of the right valve of UND specimen 9374, X2.

Figs. 18&19. *Nuculana tarensis* (Gardner)

18. Exterior of left valve of UND specimen 9372, X2.

19. Interior of left valve of UND specimen 9372, X2.

Figs. 20-22. *Nuculana evansi* (Meek and Hayden)

20. Mold of the interior of the left valve of UND specimen 9371, X2.


22. Mold of the dorsum of UND specimen 9371, X2.

Figs. 23&24. *Nuculana bisulcata* (Meek and Hayden)

23. Mold of the interior of the left valve of UND specimen 9212, X2.

24. Mold of the interior of the left valve of UND specimen 9268, X2.

Figs. 25-28. *Nuculana scitula* (Meek and Hayden)

25. Mold of dorsum of UND specimen 9207, X2.
26. Mold of the interior of the right valve of UND specimen 9207, X2.

27. Exterior of right valve of UND specimen 9206, X2.


Figs. 29, 30. *Nucula emmonsensis* sp. nov.

29. Mold of the interior of the right valve of UND specimen 9366 (holotype), X2.

30. Mold of dorsum of UND specimen 9366 (holotype), X2.

Fig. 31&32. *Nucula obsoleta striata* Meek and Hayden

31. Interior of the left valve of UND specimen 9365, X2.

32. Exterior of the left valve of UND specimen 9365, X2.

Figs. 33-35, 41&42. *Nucula planomarginata* Meek and Hayden

33. Exterior of right valve of UND specimen 9202, X2, showing gastropod boring in the umbonal area.

34. Interior of right valve of UND specimen 9202, X1.


41. Interior of left valve of UND specimen 9363, X2.

42. Exterior of left valve of UND specimen 9363, X1½.

Figs. 36-38. *Nucula cancellata* Meek and Hayden

36. Mold of the interior of the left valve of UND specimen 9203, X1.

37. Mold of dorsum of UND specimen 9204, X1½.

38. Mold of the interior of the right valve of UND specimen 9204, X1½, showing a bit of shell material.
Figs. 39 & 40. **Nucula subplana** Meek and Hayden


40. Exterior of right valve of UND specimen 9364, X1½, showing gastropod boring.

Fig. 43. **Limopsis striatopunctatus** Evans and Shumard

43. Exterior of left valve of UND specimen 9213, X2.

Figs. 44-47. **Cucullaea shumardi** Meek and Hayden

44. Dorsal view of UND specimen 9359, X1.

45. Interior of left valve of UND specimen 9358, X1.

46. Exterior of left valve of UND specimen 9358, X1.

47. Mold of the interior of the left valve of UND specimen 9209, X1.
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PLATE 5

Figs. 1-6. **Crassostrea glabra** (Meek and Hayden)

1. Interior of left valve of UND specimen 9330, X4.
2. Exterior of right valve of UND specimen 9308, X1.
3. Interior of right valve of UND specimen 9308, X1.
4. Interior of left valve of UND specimen 9329, X2.
5. Exterior of left valve of UND specimen 9307, X1.
6. Interior of left valve of UND specimen 9307, X1.

Fig. 7. **Crassostrea subtrigonalis** (Evans and Shumard)

7. Interior of left valve of UND specimen 9329, X2.

Figs. 8&9. **Protocardia subquadrata** (Evans and Shumard)

8. Mold of the interior of the left valve of UND specimen 9230, X1½.
9. Mold of the interior of the right valve of UND specimen 9230, X1½.
11. Interior of the left valve of UND specimen 9377, X4.

Figs. 10&12. **Limopsis striatopunctatus** Evans and Shumard

10. Mold of the interior of the left valve of UND specimen 9375, X2.
12. Mold of the interior of the right valve of UND specimen 9376, X1.

Figs. 13&14. **Anomia micronema** Meek

14. Interior of left valve of UND specimen 9336, X1, unwhitened, showing central muscle area and three indistinct muscle scars.

Figs. 15-17. *Crassostrea pellucida* (Meek and Hayden)

15. Exterior of left valve of UND specimen 9331, X1.
16. Interior of left valve of UND specimen 9332, X1.
17. Exterior of left valve of UND specimen 9332, X1.

Figs. 18&19. *Gervillia recta* Meek and Hayden

18. Mold of the interior of the right valve of UND specimen 9312, X1.
19. Mold of the interior of the left valve of UND specimen 9313, X1.

Fig. 20. *Corbicula moreauensis* (Meek and Hayden)


Figs. 21&22. *Cardium whitei* Dall

22. Interior of the left valve of UND specimen 9356, X4.

Figs. 23&24. *Corbicula cytheriformis* (Meek and Hayden)

23. Interior of the right valve of UND specimen 9333, X1.

Fig. 25. *Pteria nebrascana* (Evans and Shumard)

25. Exterior of the left valve of UND specimen 9343, X2.

Figs. 26-28. *Pteria linguaeformis* (Evans and Shumard)

27. Exterior of the right valve of UND specimen 9223, Xl.

28. Mold of the interior of the left valve of UND specimen 9286, Xl.
Figs. 1&2. *Tellina equilateralis?* Meek and Hayden

1. Mold of the interior of the left valve of UND specimen 9352, Xl.
2. Mold of the interior of the right valve of UND specimen 9352, Xl.

Figs. 3-5, 16, 17, 19, 21. *Corbula monmouthensis* Gardner

5. Interior of the right valve of UND specimen 9340, X2.
17. Mold of the dorsal interior of UND specimen 9338, X4.
19. Mold of the interior of the left valve of UND specimen 9338, X4.

Figs. 6&7. *Vetericardia crenalirata* (Conrad)

6. Interior of the right valve of UND specimen 9355, X4.

Fig. 8. *Tellina cheyennensis* Meek and Hayden

8. Exterior of the left valve of UND specimen 9254, Xl.

Figs. 9&10. *Tellina scitula* Meek and Hayden

9. Exterior, exfoliated, of the right valve of UND specimen 9244, Xl.
10. Mold of the interior of the left valve of UND specimen 9244, X1.

Figs. 11, 18, 20, 24&25. Corbulamella inornata (Meek and Hayden)


24. Mold of the interior of the left valve of UND specimen 9258, X4.

25. Mold of the dorsal interior of UND specimen 9258, X4.

Figs. 12, 26, 31-35. Mactra warrenana Meek and Hayden

12. Exterior of the right valve of UND specimen 9241, X1, unwhitened to show preservation of color pattern.


32. Mold of the interior of the right valve of UND specimen 9232, X1.

33. Dorsal exterior of UND specimen 9234, X1.

34. Anterior view of UND specimen 9234, X1.

35. Exterior of the right valve of UND specimen 9234, X1.

Fig. 13. Dosiniopsis deweyi (Meek and Hayden)

13. Interior of left valve of UND specimen 9357, X1.

Figs. 14&15. Mactra formosa Meek and Hayden

15. Exterior of the left valve of UND specimen 9354, X1.

Fig. 23. *Limopsis striatopunctatus* Evans and Shumard

23. Mold of the dorsal interior of UND specimen 9376, X2.

Figs. 22, 27-30. *Gervillia subtortuosa* Meek and Hayden

22. Exterior of the left valve of UND specimen 9311, X1.

27. Exterior of right valve of UND specimen 9227, X1.

28. Mold of the interior of the left valve of UND specimen 9227, X1, with some of the shell present.

29. Exterior of the right valve of UND specimen 9226, X1.

30. Interior of the right valve of UND specimen 9226, X1.
PLATE 7

Figs. 1-4. *Panopea occidentalis* (Meek and Hayden)

1. Interior of left valve of UND specimen 9334, X1.
2. Exterior of left valve of UND specimen 9334, X1.
   Note the depressed area near the ventral margin probably resulting from damage of the mantle during growth.
3. Interior of left valve of UND specimen 9335, X1.

Figs. 5&6. *Goniomya americana* Meek and Hayden

5. Exterior of left valve of UND specimen 9360, X1.

Figs. 7-10. *Tancredia americana* (Meek and Hayden)

7. Interior of right valve of UND specimen 9344, X1.
Figs. 1, 2. *Pecten (Syncyclonema) halli* Gabb

1. Exterior of left valve of UND specimen 9378, X4.
2. Interior of left valve of UND specimen 9378, unwhitened, X4.

Figs. 3, 4. *?Astarte hollandi* sp. nov

3. Exterior of right valve of UND specimen 9379, holotype, X1.
4. Interior of right valve of UND specimen 9379, holotype, X1.