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Macrofossil Biostratigraphy of the Cannonball Formation (Paleocene) in North Dakota

Erik W. Harvey

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MACROFOSSIL BIOSTRATIGRAPHY OF THE CANNONBALL FORMATION
(PALEOCENE) IN NORTH DAKOTA

by

Erik William Harvey

A Thesis
Submitted to the Faculty
of the Department of Geology and Geological Engineering
of the
University of North Dakota
in partial fulfillment of the requirements
for the degree of
Bachelor of Science in Geology
Grand Forks, North Dakota

April
1991
This Thesis submitted by Erik William Harvey in partial fulfillment of the requirements for the degree of Bachelor of Science in Geology from the University of North Dakota has been read by the Faculty Advisor under whom the work has been done, and is hereby approved.

[Signature]

Alan M. Evancara
Permission

Title: Macrofossil Biostratigraphy of the Cannonball Formation (Paleocene) in North Dakota

Department: Geology

Degree: Bachelor of Science in Geology

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Date: 4-29-91
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ACKNOWLEDGMENTS

I would like to thank my advisor, Dr. Alan M. Cvancara, for all of his help and guidance in the preparation of this thesis. I particularly appreciate his meeting with me after his official retirement.

The Chester Fritz Library of the University of North Dakota provided the reference materials so necessary in the research of this thesis.

I would also like to thank my fellow undergraduate students and the faculty and staff of the Department of Geology and Geological Engineering for their support. I especially extend thanks to James Sorensen for his willingness to listen and his understanding.

I would like to sincerely thank my family for their constant encouragement, especially my parents Michael and Margo Harvey. Finally, a special thanks to Kelly Decker, to whom this thesis is dedicated, for her unending support from far away in difficult times. To all--many thanks.
ABSTRACT

The stratigraphy and paleontology of the marine Paleocene Cannonball Formation has been the subject of study since the early 1900s. The formation can be divided into three principal intervals, each consisting of a sandstone/mudstone pair: the upper, middle, and lower intervals.

Paleontological data were studied from those localities for which the stratigraphic position is known. The data from 33 of these localities were analyzed by Q-mode cluster analysis and by sorting.

The cluster analysis produced no definite results. The sorting, however, resulted in the definition of three informal biozones, the Camarocarcinus, Glycymeris, and Dosiniopsis biozones. The Camarocarcinus biozone contains those fossils restricted to the upper and middle intervals. It contains the crab Camarocarcinus arnesoni, the bivalves Cucullaea solenensis and Nucula planimarginata, the sharks Carcharias taurus and Otodus obliquus, and the ratfish group Chimaeriformes. The Glycymeris biozone contains those fossils restricted to the middle interval only. It contains the bivalve Glycymeris subimbricata, the gastropod Exilia sp., and the bony fish Arius? danicus. The Dosiniopsis biozone contains those fossils restricted to the middle and lower intervals. It contains the bivalves Dosiniopsis deweyi and Caestocorbula sinistrirostella, the bony fish Pterothrissus sp., and the gastropods Rhombopsis gracilis, Serrifusus sohli, Fusinus? sp., and Vitoconcha torelli.
INTRODUCTION

General

The Cannonball Formation is a Paleocene marine unit with variable lithology found in the Williston Basin in western North Dakota. The Cannonball crops out primarily in southwestern North Dakota, but probably occurs throughout the western half of the state. The best exposures of the Cannonball occur in the drainage of the Missouri River and three of its western tributaries, the Cannonball and Heart Rivers and Cedar Creek. In most other portions of the state it is concealed by overlying bedrock or glacial sediments. A major exception to this is in the Little Missouri River Valley in southwestern North Dakota. Here, two brackish tongues of the Cannonball are found separated by approximately 30 meters of nonmarine sedimentary rocks of the Slope Formation.

The varied lithology of the Cannonball Formation consists primarily of sandstone and mudstone. Many complex depositional environments are represented by the Cannonball sediments including bar, barrier-island, shoreface, tidal flat, lagoon, marsh, and estuarine. Periodic transgression and regression of the Cannonball Sea is suggested by the vertical repetition of lithologies that represent these environments. Most of these environments occurred in the Cannonball Sea, a large intracratonic sea that covered portions of North America during the Paleocene.

Past studies in biostratigraphy have shown the need for a means of determining stratigraphic position within the Cannonball. Previous attempts, focused on a single fossil group, have met with limited success. This study attempts to produce more
definitive results by broadening the scope to include several fossil groups.

Purpose of Study

The main purpose of this study is to identify biostratigraphic relationships as represented by Cannonball macrofossils. A secondary purpose is the compilation of a database containing information about Cannonball macrofossils in western North Dakota and northwestern South Dakota.

Previous Work

Stratigraphy

The Cannonball was first recognized by Lloyd (1914) as the upper Cannonball member of the Lance Formation. The type area was defined as along the Cannonball River, where the formation is well exposed, in Tps. 132 and 133 N and R. 88 W. Lloyd and Hares (1915) later added R. 87 W. to the type area. The Cannonball retained its status as a member until 1942 when Fox and Ross raised it to the level of formation. A more detailed historical summary is given by Cvancara (1965). A summary of the more recent work on Cannonball stratigraphy is found in Silfer (1990).

The stratigraphic terminology used in this study follows that of the North Dakota Geological Survey (NDGS) (Bluemle, 1982). The NDGS considers the Cannonball as a formation in the Fort Union Group, whereas the USGS considers it as a member of the Fort Union Formation.

Paleontology

Fossils known from the Cannonball consists of bivalves (Cvancara, 1965; 1966; 1970a; 1970b; Van Alstine, 1974); gastropods (Stanton, 1920; Silfer 1990); scaphopods (Stanton, 1920);
nautiloid cephalopods (Feldmann, 1972); lobsters (Feldmann and Holland, 1971); crabs (Holland and Cvancara, 1958); ostrocodes (Swain, 1949); foraminiferids (Fox and Ross, 1942; Fox and Olson, 1969; Fenner, 1974a; 1974b; 1976; Van Alstine, 1974); bryozoans (Cvancara, 1965); scleractinian corals (Vaughan, 1920; Wilson, 1957); sharks, skates, rays, ratfishes, turtles, crocodiles or alligators (Stanton, 1920; Pipiringos et al., 1965; Best, 1987; Cvancara and Hoganson, 1987; Hoganson and Cvancara, 1989); spores and pollen, hytrichosphaerids and dinoflagellates (Stanley, 1965); trace fossils, including Ophiomorpha (Cvancara, 1965; Van Alstine, 1974; Monnens, 1980; Goodrum, 1983; Best, 1987), Arenicolites, Rhizocorallium, Skolithos-like tubes, and possibly Cylindrichnus (Best, 1987); driftwood (Cvancara, 1965); and worms (Brown and Lemke, 1948; Lemke, 1960).

Fenner (1976) found two foraminiferal assemblages in the Cannonball Formation based on statistical analysis. These assemblages were found to have some biostratigraphic usefulness.

Geologic Setting

Regional Structure

The primary structural influence on Cretaceous and Tertiary strata in North Dakota is the Williston Basin. The Williston Basin is a sedimentary and structural basin covering 51,600 square miles (133,644 square km) in North Dakota, northwestern South Dakota, southern Manitoba and Saskatchewan, and eastern Montana. The basin contains strata ranging from Cambrian to Tertiary in age. It achieves a maximum thickness of 15,126 feet (4611 m) in McKenzie county, North Dakota (Carlson and Anderson, 1965; Carlson 1982). Prominent structural features within the
basin include the north-south trending Nesson anticline in northwestern North Dakota, and the northwest-southeast trending Cedar Creek anticline in southeastern Montana (Carlson and Anderson, 1965).

The general dip of the Cannonball, less than one degree (Cvancara, 1976), is toward the center of the basin, approximately 40 miles (64 km) southeast of Williston, North Dakota (Carlson, 1982, p.4). A more complete structural explanation can be found in Cvancara (1976).

**Regional Stratigraphy**

The Cannonball Formation interfingers with nonmarine sediments of both the Slope and Ludlow Formations (Fig. 1). Along with the Bullion Creek and Sentinel Butte Formations, these units make up the Fort Union Group. The Cannonball is bounded above by the Bullion Creek Formation and below by the Upper Cretaceous Hell Creek Formation.

The interfingering of the Cannonball tongues with the nonmarine sediments of the Slope and Ludlow Formations is further evidence for periodic transgression and regression of the Cannonball Sea.

**Cannonball Stratigraphy**

The Cannonball has been informally divided into three intervals, the upper, middle, and lower intervals (Fig. 2). The divisions used here are based on those of Silfer (1990). Each interval is made up of a sandstone/mudstone pair.
Figure 1. Generalized stratigraphic column for the Upper Cretaceous and Paleocene strata in North Dakota (Modified from Lindholm, 1984).
<table>
<thead>
<tr>
<th>PALEOCENE</th>
<th>FORT UNION GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td>SENTINEL BUTTE FM.</td>
<td></td>
</tr>
<tr>
<td>BULLION CREEK FM.</td>
<td></td>
</tr>
<tr>
<td>SLOPE FM.</td>
<td></td>
</tr>
<tr>
<td>LODLOW FM.</td>
<td></td>
</tr>
<tr>
<td>HELL CREEK FM.</td>
<td></td>
</tr>
<tr>
<td>FOX HILLS FM.</td>
<td></td>
</tr>
<tr>
<td>PIERRE FM.</td>
<td></td>
</tr>
<tr>
<td>CANNONBALL FM.</td>
<td></td>
</tr>
</tbody>
</table>
Figure 2. Stratigraphic cross-section showing physical correlation of upper and middle bench-forming sandstones and lower, middle, and upper informal units (from Silfer, 1990).
EXPLANATION

- COVERED INTERVAL
- SANDSTONE
- MUDSTONE

UBFSS = UPPER BENCH-FORMING SANDSTONE
MBFSS = MIDDLE BENCH-FORMING SANDSTONE

WELL-INDURATED, CONCRETIONARY OR LENTICULAR SANDSTONE

SANDSTONE OR MUDSTONE CONCRETIONS
The Cannonball contains primarily sandstone and mudstone, but the entire range between these two lithologies is present. Unlike other Paleocene formations, the Cannonball does not contain any lignite beds.

The upper and middle sandstone units form topographic benches that have been traced through the use of air photos for tens of miles (Cvancara, 1980). Commonly the sandstone units contain well-indurated concretions. These concretions sometimes contain fossils or fossil impressions.

One problem encountered in dealing with Cannonball stratigraphy is that nowhere is there an outcrop containing the entire Cannonball section. This makes determination of stratigraphic position in isolated outcrops difficult. The regional dip is enough to make use of elevation inaccurate.
METHODS

Data Collection

The data used in this study were collected from four sources: for bivalves, Cvancara (1965) and Lindholm (1984); for gastropods Silfer (1990); and for fishes, Cvancara and Hoganson (1991). Information taken from these sources included location, accession numbers, species present, and other pertinent information. These data were placed into a standard format and stored in a computer database. Although some additional data on Cannonball fossils are present in earlier works, such as Stanton (1920), uncertainty about location and naming of species prohibited their use in this study. Additionally, much of the earlier work has been revised by later workers such as Cvancara (1965) and Silfer (1990).

The compilation resulted in a total of 140 fossil localities with 200 accessions. To produce a useful analysis, only those localities where the stratigraphic position could be definitely determined were used. This selection produced a data set of 40 localities that occur within the Missouri River drainage primarily along the Heart and Cannonball Rivers (Plate 1). An additional seven localities were eliminated due to lack of sufficient species diversity. For the purposes of this study, only localities with three or more species identified were considered. This further reduction resulted in a data set containing 33 localities, with 69 accessions. The final data set contains 40 species including 18 gastropods, 13 bivalves, 9 fishes, and one crab.
Data Processing

Data for this thesis were processed in two ways, a direct statistical approach using cluster analysis and a sorting by species and stratigraphic position. The purpose of both of these methods was to determine if any direct correlation exists between fossil occurrence and stratigraphic position.

Cluster analysis

Cluster analysis is a statistical means for displaying relations among large groups of data. The purpose of cluster analysis is to determine the degree of similarity between units.

Only one mode of analysis was used in this study, Q-mode. Q-mode analysis compares similarities between two samples (for this study, fossil localities).

In cluster analysis, it is first necessary to calculate a matrix containing all similarity combinations between examples. For this study the similarity in species present between fossil localities is compared and similarity coefficients for each pair are calculated. The coefficient used in this study is the Dice Similarity Coefficient (Cheatham and Hazel, 1969):

\[
\frac{2C}{N_1+N_2} \times 100
\]

where \( C \) is the total number of species common to both localities, \( N_1 \) is the number of species at the first locality, and \( N_2 \) is the number of species at the second locality.

Once the matrix has been calculated, the localities with the greatest similarity are combined and their similarities with
remaining localities are averaged. This step is then repeated until all localities are combined to form a single group. This procedure, one of several common clustering methods, is called weighted pair group averaging. The results are then displayed in a dendrogram (Fig. 3) showing the similarity relationships between localities.

**Sorting**

Using the data set established earlier, stratigraphic occurrence was plotted for each species found (Fig. 4). This information was then used to determine which species were restricted stratigraphically. Those species with fewer then three occurrences were ignored as being statistically unimportant. This information was then used in the establishment of informal biosstratigraphic zones.
Figure 3. Q-mode dendrogram based on 18 gastropod, 13 bivalve, 9 fishes, and 1 crab species from 33 localities. Numbers lacking a symbol before them are from the upper interval. Some localities have more than one interval these are differentiated by the presence of a U, M, or L after the number. Numbered localities can be found on Plate 1.
Q-MODE DENDROGRAM

Dice Similarity Coefficient

100 90 80 70 60 50 40 30 20 10 0

4
-31
-32
-72
-74
-140
-2
-9
-10
-8
-88
-102M
*19
*102L
86
-11M
23
-43
*11L
*104
*12
25
30U
-52
-29
*30L
-63
-64
-22
-7
24
-100
-101

-= Middle Interval
*= Lower Interval
Figure 4  Stratigraphic occurrence of Cannonball macrofossils. Numbers in parentheses indicate number of occurrences for species with fewer than three occurrences.
<table>
<thead>
<tr>
<th>SPECIES</th>
<th>LOWER</th>
<th>INTERVAL</th>
<th>UPPER</th>
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</thead>
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<tr>
<td><strong>GASTROPODS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acamptogenotia varicosta</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Alticollarum bacatum</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>A. janesburgensis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amuletum sp.</td>
<td></td>
<td></td>
<td>X(1)</td>
</tr>
<tr>
<td>Coronia? lloydii</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Deussenia minuta</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Eopleurotoma? danica</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Ericksonia clivilinea</td>
<td></td>
<td>X(1)</td>
<td></td>
</tr>
<tr>
<td>Exilia sp.</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Fusinus? sp.</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Marshallaria sp.</td>
<td></td>
<td></td>
<td>X(1)</td>
</tr>
<tr>
<td>Mesorhytis dakotensis</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Obtusicarina tormentaria</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Rhombopsis gracilis</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Serrifusus sohli</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Surculites tormentaria</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Vitticoncha torelli</td>
<td>X</td>
<td>X</td>
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<tr>
<td><strong>BIVALVES</strong></td>
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<td>Adula sp.</td>
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<tr>
<td>Arctica ovata</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Caestocorbula sinistriostella</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Codokia (Claibornites) cedrensis</td>
<td>X(1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crassatella evansi</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Cucullaea solenensis</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Dosiniopsis deweyi</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Glycymeris subimbricata</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neilonella evansi</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Nucula planimarginata</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Periploma sp.</td>
<td>X(2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phenocomya haresi</td>
<td>X(1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teredo (Psiloteredo) globosa</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><strong>FISHES</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arius? danicus</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carcharias taurus</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Chimaeriformes</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Ischyodus dolloi</td>
<td>X(1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Myliobatis? sp.</td>
<td></td>
<td></td>
<td>X(1)</td>
</tr>
<tr>
<td>Notorynchus serratissimus</td>
<td>X(2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Otodus obliquus</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Palaeogaleus vincenti</td>
<td>X(1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palaeohypotodus rutoti</td>
<td>X(2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pterothrissus sp.</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td><strong>CRAB</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Camarocarcinus arnesoni</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>
RESULTS

Cluster Analysis

The dendrogram (Fig. 3) shows only a weak clustering. These clusters provide little or no evidence for a definite stratigraphic relationship among the localities tested. Two clusters (involving localities 31, 32, 72 and 74 and 11L, 104, and 12) can be seen to show the beginnings of more definite clustering, but this is insufficient for any meaningful results. Further testing with localities for which the stratigraphic position was less well defined reduced what little clustering is present.

Sorting

Sorting of the species by occurrence provided somewhat better results. Several of the taxa were found to have restricted stratigraphic occurrences (Fig. 4). These taxa have been placed in informal biozones named for the most common or distinctive taxon present. Although 12 other species have a limited occurrence, these were disregarded due to lack of sufficient sample size. No species occurring at fewer than three localities within the dataset was considered.
INTERPRETATIONS

The clusters seen in the dendrogram are likely due to either environmental similarity or to complications of sampling such as a locality at which not all fossil types are represented.

As a Result of the sorting performed the following three informal biozones were named. These zones were named for the most common or distinctive species present. The size of the dataset and uncertainty about stratigraphic position prohibit the formal naming of the biozones. Each is defined by the occurrence of one or more of the species included in each group. Each biozone represents a unit or set of units within the Cannonball (Fig. 5).

Camarocarcinus biozone

The Camarocarcinus biozone is named for the crab Camarocarcinus arnesoni, and is restricted to the upper and middle intervals. This group also contains the bivalves Cucullaea solenensis and Nucula planimarginata; the sharks Carcharias taurus and Otodus obliquus; and the ratfish group Chimaeriformes.

Glycymeris biozone

The Glycymeris biozone is named for the bivalve Glycymeris subimbricata, and is restricted to the middle Interval. This group also contains the gastropod Exilia sp. and the bony fish Arius? danicus.
Figure 5. Informal biozones of the Cannonball Formation and species characteristic of them.
Camarocarcinus biozone: upper & middle int.
- Camarocarcinus arnesoni
- Cucullaea solenensis
- Nucula planimarginata
- Carcharias taurus
- Otodus obliquus
- Chimaeriformes

Glycymeris biozone: middle interval
- Glycymeris subimbricata
- Exilia sp.
- Arius? danicus

Dosiniopsis biozone: middle & lower interval
- Dosiniopsis deweyi
- Caestocorbula sinistrirostella
- Fusinus? sp.
- Rhombopsis gracilis
- Serrifusus sohli
- Vitticoncha torelli
- Pterothrissus sp.
Dosiniopsis biozone

The Dosiniopsis biozone is named for the common bivalve Dosiniopsis deweyi, and is restricted to the middle and lower intervals. This group also contains the bivalves Caestocorbula sinistrirostella; the gastropods Fusinius? sp., Rhombopsis gracilis, Serrifusus sohli, and Vittoconcha torelli; and the bony fish Pterothrissus sp.

Each of these biozones can be used as a general indication of stratigraphic position within the Cannonball Formation. The middle interval where, all three groups overlap, is probably best defined. The presence of species from any two groups is a strong indicator of the middle interval.
CONCLUSIONS

Three informal biozones were found and named based on the sorting of the data, the **Camarocarsinus**, **Glycymeris**, and **Dosinopsis** biozones. These zones give an indication of stratigraphic position and should prove useful in future studies of Cannonball stratigraphy.

Further work is needed on the biostratigraphy of the Cannonball Formation. The lack of sufficient localities with definite stratigraphic positions prohibits the naming of formal biozones. A method needs to be found to determine stratigraphic position by means other than fossils. It is possible that another method could be found using sedimentology or geochemistry as a basis. Once this has been found a study of Cannonball biostratigraphy might produce more definitive results.

Further collection of fossil specimens with emphasis on determining stratigraphic position may allow the results of statistical analysis to be applied more positively.
APENDICES
APPENDIX A

SELECTED CANNONBALL MACROFOSSIL LOCALITIES IN NORTH DAKOTA

The localities in this appendix have documented fossil occurrences and were used in this study for both cluster analysis and sorting.

The following example will serve to explain the descriptions in this appendix.

L0007 (Unit 1) M, 132N-88W-5ca, north-facing cutbank exposure, south bank of Cannonball River, 6.5 air miles SSW of Leith, Grant County ND. Lithology: Mudstone; poorly consolidated; very dark gray to nearly black when moist, weathers (when dry) light gray; sandy, in variable amounts.

Accession UND 1004
Carcharias taurus
Accession UND 1028
Arius? danicus
Acamptogenotia varicosta

L0007. The locality number used in this study. These localities are shown on Plate 1 and in Fig. 3 by their corresponding number.

(Unit 1). This is the unit number. The units are numbered from the base of the outcrop.

M This indicates the stratigraphic position of the unit as either the upper, middle or lower interval.

133N-88W-5ca. The legal description of the locality. This numbering system is that used by the North Dakota State Water Commission and is based on the location in the public land classification of the United States Bureau of Land Management. 137 N refers to the township north of the base line; 77 W refers to the range west of the fifth principal meridian; 19 refers to the section number. The letter a, b, c, and d designate, respectively, the northeast, northwest, southwest, and southeast quarter sections, quarter-quarter sections, and quarter-quarter-quarter sections. In this example, 5ca is in the SW1/4NE1/4 of Sec. 5.
This is followed by a description of the locality and distance and direction to the nearest town.

Lithology. This is a description of the lithology of the unit. The more detailed descriptions are from Cvancara (1965).

Accession UND 1004. This designates the accession number of the species that follow. UND is for University of North Dakota, UMi is for the University of Michigan. Specimens are stored in the paleontology collections of the respective schools.
L0002 (Unit 2) M, 130N-90W-9bbd, west-facing cutbank exposure, east bank of Timber Creek, 11.25 air miles N of Thunderhawk, SD, Grant County ND. Lithology: Sandstone; poorly consolidated; medium grayish green when moist, weathers (when dry) medium buff; forms steep exposure face; with small amount of clay; sorting poor to good, grain size very fine to fine.

Accession UMi 1961/Tpa-16, 1962/Tpa-6

- Nucula planimarginata
- Cucullaea solenensis
- Crassatella evansi
- Arctica ovata
- Dosiniopsis deweyi
- Caestocorbula sinistrirostella
- Phenacomya haresi
- Carcharias taurus
- Pterothrissus sp.
- Rhombopsis gracilis
- Exilia sp.
- Acamptogenotia varicosta
- Alticollarum janestburgensis
- Vitticoncha torelli
- Eopleurotoma? danica

Accession UND A2547

- Nucula planimarginata
- Crassatella evansi
- Arctica ovata
- Caestocorbula sinistrirostella
- Carcharias taurus
- Pterothrissus sp.

Accession UND A2548

- Crassatella evansi
- Arctica ovata
- Alticollarum janestburgensis

Accession UND A2561

- Nucula planimarginata

Accession UND A2665

- Acamptogenotia varicosta
Accession UND A2692

*Carcharias taurus*

*Coronia? lloydi*

Accession UND A2693

*Acamptogenotia varicosta*

**L0004 (Unit 2)** U, 132N-87W-9bab, south-facing exposure on south end of small hill, east side of north-south trending "mesa", just north of southern edge, 6.5 air miles SE of Leith, Grant County ND. Lithology: Sandstone; poorly consolidated; light tan olive green when moist, weathers (when dry) light buff; very fine grained; dominantly quartz.

Accession UMi 1962/Tpa-9

*Carcharias taurus*

*Otodus obliguus*

*Myliobatis? sp.*

Accession UND A2646

*Carcharias taurus*

**L0007 (Unit 1)** M, 132N-88W-5ca, north-facing cutbank exposure, south bank of Cannonball River, 6.5 air miles SSW of Leith, Grant County ND. Lithology: Mudstone; poorly consolidated; very dark gray to nearly black when moist, weathers (when dry) light gray; sandy, in variable amounts.

Accession UND 1004

*Carcharias taurus*

Accession UND 1028

*Arius? danicus*

*Acamptogenotia varicosta*
L0008 (Unit 2) M, 133N-88W-34abc, northwest-facing cutbank exposure, east bank of Cannonball River, 6 air miles SW of Leith, Grant County ND. Lithology: Sandstone; poorly consolidated; light grayish green when moist, weathers (when dry) light buff; with appreciable amount of clay sorting poor; sand particles very fine to fine grained, angular to sub-rounded.

Accession UMi 1961/Tpa-6

Nucula planimarginata
Dosiniopsis deweyi
Caestocorbula sinitriostella
Carcharias taurus
Alticollarum bacatum

Accession UND A2672

Mesorhytis dakotensis

L0009 (Unit 5) M, 133N-88W-28ccd, north-facing cutbank exposure, south bank of Cannonball River, 6 air miles SW of Leith, Grant County ND. Lithology: Sandstone; poorly consolidated; dark grayish green when moist, weathers (when dry) light greenish gray; with considerable amounts of clay; sorting fair to poor, sand particles mainly fine grained, angular to sub-rounded.

Accession UMi 1961/Tpa-4, 1962/Tpa-3

Surculites tormentaria
Nucula mansfieldi
Adula sp.
Crassatella evansi
Codokia? (Claibornites) cedrensis
Teredo (Psiloteredo) globosa
Periploma sp.
Carcharias taurus

Deussenia minuta
Rhombopsis gracilis
Ericksonia clivilinea
Exilia sp.
Mesorhytis dakotensis
Acamptogenotia varicosta
Alticollarum janesburgensis
Obtusicarina tormentaris
Indeterminate turrid sp. 1
Accession UND A2553

**Crassatella evansi**

**Arius? danicus**

**Serrifusus sohli**

Accession UND A2554

**Crassatella evansi**

**Alticollarum janestiburgensis**

Accession UND A2668

**Carcharias taurus**

**Deussenia minuta**

**Serrifusus sohli**

**Mesorhytis dakotensis**

**Acamptogenotia varicosta**

**Alticollarum janestiburgensis**

**Obtusicarina tormentaria**

Accession UND A2682

**Serrifusus sohli**

**Mesorhytis dakotensis**

**Acamptogenotia varicosta**

**Alticollarum janestiburgensis**

**Vitticoncha torelli**

LO010 (Unit 3) M, 133N-88W-29dad, north-facing cutbank exposure, south bank Cannonball River, 6.25 air miles SW of Leith, Grant County ND. Lithology: Sandstone; poorly consolidated; dark grayish green when moist, weathers (when dry) light greenish gray; with considerable amounts of clay; sand particles mainly fine grained, dominantly quartz, with glaconite.

Accession UND A2555

**Nucula planimarginata**

**Crassatella evansi**

**Periploma sp.**

**Carcharias taurus**

**Alticollarum janestiburgensis**
Accession UND A2556

Codakia? (Clabbornites) credensis
Crassetella evansi
Caestocorbula sinistrirostella
Periploma sp.

Mesorhytis dakotensis

Accession UND A2666

Arius? danicus

Dussenia minuta
Rhombopsis gracilis
Exilia sp.
Serrifusus sohli
Mesorhytis dakotensis
Acamptogenotia varicosta
Vitticoncha torelli
Eopleurotoma? danica

Accession UND A2681

Mesorhytis dakotensis

L0011 (Unit 2) L, 133N-88W-29dbb, south-southeast-facing cutbank exposure, north bank of Cannonball River, 6.25 air miles SW of Leith, Grant County ND. Lithology: Sandstone; poorly consolidated; dark grayish green when moist, weathers (when dry) light greenish gray; sorting fair to poor, contains considerable amount of clay; sand particles fine grained mainly subangular.

Accession UND A2557

Rhombopsis gracilis

Accession UND A2667

Rhombopsis gracilis
Surculites tormentaria
Mesorhytis dakotensis
Alticollarum janesbugensis

Accession UND A2684

Mesorhytis dakotensis
Acamptogenotia varicosta
Vitticoncha torelli
L0011 (Unit 2)  M, 133N-88W-29dbb, south-southeast-facing cutbank exposure, north bank of Cannonball River, 6.25 air miles SW of Leith, Grant County ND. Lithology: Sandstone; poorly consolidated; dark grayish green when moist, weathers (when dry) light greenish gray; sorting fair to poor, contains considerable amount of clay; sand particles fine grained mainly subangular.

Accession UND A2558

Nucula planimarginata
Crassatella evansi
Acamptogenotia varicosta
Vitticoncha torelli

L0012 (Unit 1)  L, 133N-88W-32?, section (top) begins at top of north-facing bluff on south side of Cannonball River, continues downward to east and terminates at low cutbank exposure on east bank of Cannonball River, 6.75 air miles SW of Leith, Grant County ND. Lithology: Sandstone; poorly consolidated; dark grayish green when moist, weathers (when dry) light grayish green; sorting fair to poor, with considerable amount of clay; sand particles mostly fine grained.

Accession UND A2687

Alticollarum janesburgensis
Vitticoncha torelli
Cornia? lloydi

Accession UND A2688

Surculites tormentaria

Accession UND 8377

Acamptogenotia varicosta
Alticollarum janesburgensis

L0019 (Unit 2)  L, 136N-86W-21bdc, west-facing cutbank exposure, east bank Heart River, about in center of sec. 21 (probably most of exposure in NW sec. 21), 10.5 air miles S of Almont, Grant County ND. Lithology: Sandstone; poorly to moderately consolidated; very dark gray to very dark greenish gray when moist, weathers (when dry) light gray; with considerable amount of clay; sorting poor, sand mainly very fine grained.
Accession UMi 1962/Tpa-28

Neilonella evansi
Adula sp.
Dosiniopsis deweyi
Caestocorbula sinistrirostella
Teredo (Psiloteredo)globosa

Alticollarum bacatum
Obtusicarina tormentaria
Mesorhytis dakotensis
Eopleurotoma? danica
Acamptogenotia varicosta
Serrifusus sohli

**LO022 (Unit 2)** M, 135N-83W-26cb, west-facing roadcut exposure, east side of county road along section line common to secs. 26, 27, 2.5 air miles S of Fallon, Morton County ND. Lithology: Sandstone; poorly consolidated; light greenish gray to medium greenish tan when moist, weathers (when dry) light buff; with small amount of clay; sorting fair, sand mainly fine to very fine, dominantly quartz.

Accession UMi 1961/Tpa-11

Camarocarcinus arnesoni
Nucula planimarginata
Crassatella evansi
Dosiniopsis deweyi
Teredo (Psiloteredo) globosa

Carcharias taurus
Otodus obliquus

Rhomboseps gracilis
Vitticoncha torelli

Accession UND A2633

Carcharia taurus
Palaeohypotodus rutoti
Surculites tormentaria

Accession UND A2648

Otodus obliquus

Accession UND A2664

Carcharias taurus
Ischyodus dolloi
Chimaeriformes

Accession UND A2679
Carcharias taurus
Otodus obliquus
Vitticoncha torelli

L0023 (Unit 3) U, 135N-82W-36aab, northeast-facing exposure in pasture on south side of North Dakota Highway 21, 0.2 miles west of junction of North Dakota Highways 21 and 6, 6.5 air miles N of Brein, Morton County ND. Lithology: Sandstone; poorly consolidated; light greenish gray when moist, weathers (when dry) light greenish buff to light buff; with slight amount of clay, sorting fair to good, sand particles very fine to fine grained.

Accession UMi 1961/Tpa-8, 1962/Tpa-4

Crassatella evansi
Artica ovata

Surculites tormentaria
Acamptogenotia varicosta

L0024 (Unit 1) U, 134N-81W-3aa, south-facing exposure at south end of elongate hill (about on north-south center line of sec. 3), 5 air miles NW of Solen, Morton County ND. Lithology: Sandstone; poorly consolidated; light greenish gray when moist, weathers (when dry) light buff; with small amount of clay; sorting fair to good, sand particles very fine to fine grained, dominantly quartz.

Accession UMi 1961/Tpa-9

Camarocarcinus arnesoni

Teredo (Psiloteredo) globosa

Acamptogenotia varicosta

L0025 (Unit 11) U, 131N-82W-13cca, east-facing landslide exposure, 8.5 air miles NNE of Selfridge, Sioux County ND. Lithology: Sandstone; poorly consolidated; light grayish green when moist, weathers (when dry) light buff; negligible to moderate amount of clay; sorting fair to good, sand very fine to fine grained, mainly angular.

Accession UMi 1962/Tpa-29

Camarocarcinus arnesoni

Nucula planimarginata
Articia ovata
Teredo (Psiloteredo) globosa

Carcharias taurus
L0029 (Unit 2) M, 138N-81W-13bda, east-facing, steep road cut exposure, west side of asphalt-covered road, 4.25 air miles S of Mandan, Morton County ND. Lithology: Sandstone; poorly consolidated; light grayish green when moist, weathers (when dry) light buff; negligible amount of clay; sorting good, sand particles mainly fine grained, angular to subangular, dominantly quartz.

Accession UMi 1962/Tpa-25

- Nucula planimarginata
- Glycymeris subimbricata
- Arctica ovata
- Dosiniopsis deweyi
- Notorynchus serratissimus
- Carcharias taurus

L0030 (Unit 5) L, 138N-83W-10dda, south-facing cutbank exposure, north bank of Heart River, 12 air miles WSW of Mandan, Morton County ND. Lithology: Sandstone; poorly consolidated; light grayish to greenish tan when moist; weathers (when dry) light grayish buff; with considerable clay; sand particles very fine to fine grained.

Accession UMi 1962/Tpa-10

- Arctica ovata
- Teredo (Psiloteredo) globosa

L0030 (Unit 7) U, 138N-83W-10dda, south-facing cutbank exposure, north bank of Heart River, 12 air miles WSW of Mandan, Morton County ND. Lithology: Sandstone; poorly consolidated; light to medium grayish green when moist, weathers (when dry) light buff; negligible amount of clay; sorting good, mainly fine grained; sand angular to subrounded.

Accession UNDA2563

- Crassatella evansi
- Arctica ovata
- Dosiniopsis deweyi
- Pterothrissus sp.

Accession UMi 1962/Tpa-10

- Arctica ovata
- Teredo (Psiloteredo) globosa
- Carcharias taurus
- Chimaeriformes
L0031 (Unit 1) M, 139N-82W-23dda, south-facing roadcut exposure (slide area), north side of US Highway 10 and northside of Heart River (100 to 200 yards north of river), about on section line common to secs. 23 and 24, 4 air miles WNW of Mandan, Morton County ND. Lithology: Mudstone; poorly consolidated; very dark gray to nearly black when moist, weathers (when dry) light to medium gray; silty to sandy, micaceous.

Accession UMi 1961/Tpa- 22

- Arctica ovata
- Carcharias taurus
- Otodus obliquus

Accession UND A2450

- Carcharias taurus
- Palaeohypotodus rutoti
- Pterothrissus sp.
- Arius? danicus
- Mesorhytis dakotensis

Accession UND A2550

- Arctica ovata
- Carcharias taurus
- Serrifusus sohli

Accession UND A2662

- Obtusicarina tormentaria

Accession UND A2675

- Carcharias taurus
- Fusinus? sp.
- Obtusicarina tormentaria

L0032 (Unit 1) M, 139N-80W-31aab, south-southwest facing man-made exposure, north side of small gully, 2 miles NW of intersection of US Highway 83 and 10 (and about 0.3 miles east of Missouri River), 2 air miles NW of Bismark, Burleigh County ND. Lithology: Sandstone; poorly consolidated; light grayish green when moist, weathers (when dry) light buff; negligible amount of clay; sorting good, fine grained sand particles angular to sub-rounded, dominantly quartz.
Accession UMl 1962/Tpa-18

*Crassatella evensi*
*Arctica ovata*

*Carcharias taurus*
*Otodus obliquus*

*Serrifusus sohli*

**L0043 (Unit 1)** M, 139N-80W-32bba, roadcut exposure on south side of gravel road, 1.6 air miles NW of Junction US 10 and 83, Burleigh County ND. Lithology: Light grayish green, poorly consolidated, fine grained sandstone.

Accession UMl 1962/Tpa-19

*Nucula planimarginata*
*Crassatella evansi*
*Arctica ovata*
*Dosiniopsis deweyi*

*Otodus obliquus*

*Rhombopsis gracilis*
*Serrifusus sohli*
*Surculites tormentaria*
*Vitticoncha torelli*

Accession UND A2703

*Acamptogenotia varicosta*

**L0052 (Unit 1)** M, 139N-82W-34cac, west-facing cutbank exposure, east (right) bank of Heart River, 6.5 air miles WSW of Mandan, Morton County ND. Lithology: very fine to fine grained, poorly consolidated lenticular sandstone.

Accession UMl 1962/Tpa-17

*Arctica ovata*
*Dosiniopsis deweyi*
*Caestocorbula sinistrirostella*
*?Teredo (Psiloteredo) globosa*
*Carcharias taurus*
L0063 (Unit 1) M, 135N-81W-6daa, roadcut exposure on east side of ND Highway 6, 5.5 air miles S of St. Anthony, Morton County ND. Lithology: Sandstone.

Accession UND A2698

Glycymeris subimbricata
Arctica ovata
Dosiniopsis deweyi
Rhombopsis gracilis

L0064 (Unit 1) M, 135N-82W-1aad, small, isolated hill exposure on west side of road, 5.5 air miles of St. Anthony, Morton County ND. Lithology: Sandstone.

Accession UMi 1961/Tpa-25

Glycymeris subimbricata
Arctica ovata
Dosiniopsis deweyi
Caestocorbula sinistrirostella
Eopleurotoma? danica

L0072 (Unit 1) M, 135N-83W-34cbd, two roadcut exposures, south side of ND Highway 21, 6 air miles E of Flasher, Morton County ND. Lithology: Light grayish green, poorly consolidated, fine grained sandstone.

Accession UMi 1961/Tpa-20

Arctica ovata

Carcharias taurus
Palaeogaleus vincenti
Otodus obliquus
Chimaeriformes

Accession UND A2647

Carcharias taurus

L0074 (Unit 1) M, 135N-83W-22aad, roadcut exposure on west side of gravel road, (0.2 miles south of northeast corner sec. 22, about 7.25 miles east-northeast of Flasher, ND), 1.2 air miles S of Fallon, Morton County ND. Lithology: Light greenish gray, poorly consolidated very fine to fine grained sandstone.
Accession UMi 1961/Tpa-12, 1962/Tpa-5

Nucula sp.
Cucullaea solenensis
Arctica ovata
Dosiniopsis deweyi

Carcharias taurus
Palaeogaleus vincenti
Otodus obliquus

L0086 (Unit 1) U, 136N-87W-21cab, south facing cutbank exposure, north (left) bank of Heart River, A.A. Stegmeier farm center of sec. 21, 11.5 air miles NNW of Carson, Grant County ND. Lithology: Dark gray, poorly consolidated, sandy mudstone.

Accession UMi 1961/Tpa-31

Nucula planimarginata
Cucullaea solenensis

Carcharias taurus
Otodus obliquus

Deussenia minuta
Mesorhytis dakotensis
Obtusicarnia tormentaria

Accession UND A2694

Deussenia minuta
Mesorhytis dakotensis
Alticollarum janesburgensis
Amuletum (Lutema) sp.
Obtusicarina tormentaria
Coronia? lloydii
Eopleurotoma? danica

Accession UND A2695

Eopleurotoma? danica

L0088 (Unit 1) M, 136N-88W-24cca, southwest facing cutbank exposure along the Heart River, 19 air miles SW of Almont, Grant County ND. Lithology: ?.

Accession UND A8464, UMi 1962/Tpa-24

Nucula planimarginata
?Caestocorbula sinistrirostella

Surculites tormentaria
Mesorhytis dakotensis
Coronia? lloydii
Eopleurotoma? danica
L0100 (Unit 1) M, 133N-88W-26dcc, west-facing cutbank exposure, east (left) bank of Cannonball River, 5.25 air miles SW of Leith, Grant County ND. Lithology: Light grayish green, poorly consolidated, fine-grained sandstone.

Accession UMi 1961/Tpa-32

Nucula planimarginata

Rhombopsis gracilis
Obtusicarina tormentaria

L0101 (Unit 1) M, 133N-88W-26cbb, west-facing cutbank exposure, east (left) bank of Cannonball River, 5.25 air miles SW of Leith, Grant County ND. Lithology: Light grayish green, poorly consolidated, fine-grained sandstone and it's contained indurated lenticular sandstone.

Accession UMi 1961/Tpa-7

Arctica ovata
Teredo (Psiloteredo) globosa

Obtusicarina tormentaria

L0102 (Unit 1) L, 133N-88W-28dbd, south and southwest-facing cutbank exposure, north (left) bank of Cannonball River, 6.5 air miles SW of Leith, Grant County ND. Lithology: Medium to dark greenish gray, poorly consolidated, clayey sandstone.

Accession UND A2669

Rhombopsis gracilis
Serrifusus sohli
Mesorhytis dakotensis
Acamptogenotia varicosta

Accession UND A2683

Deussenia minuta
Fusinus? sp.

Surculites tormentaria
Mesorhytis dakotensis
Acamptogenotia varicosta
Obtusicarina tormentaria
Eopleurotoma? danica
L0102 (Unit 3) M, 133N-88W-28dd, south and southwest-facing cutbank exposure, north (left) bank of Cannonball River, 6.5 air miles SW of Leith, Grant County ND. Lithology: Medium to dark greenish gray, poorly consolidated, clayey sandstone.

Accession UMi 1961/Tpa-15

Nucula planimarginata
Neilonella evansi?
Crassatella evansi
Arctica ovata
Dosiniopsis deweyi
Caestocorbula sinistrirostella
Teredo (Psiloteredo) globosa

Carcharias taurus

Surculites tormentaria
Mesorhytis dakotensis
Acamptogenotia varicosta
Marshallaria sp.
Coronia? lloydii

L0104 (Unit 1) L, 133N-88W-29c, about 6 miles south of former Kayser, 7.75 air miles SW of Leith, Grant County ND. Lithology: Muddy sandstone.

Accession UND A2671

Serrifusus sohli
Surculites tormentaria
Acamptogenotia varicosta

Accession UND A2683

Serrifusus sohli
Mesrhytis dakotensis
Alticollarum janesburgensis

L0140 (Unit 1) M, 137N-77W-19dd, east and west-facing roadcut exposures, Burleigh county, ND. Lithology: Sandstone.

Accession UND A2640

Carcharias taurus

Accession UND A2680

Notorynchus serratissimus
Chimaeriformes
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Cannonball Formation (Paleocene)

PLATE 1

(Harvey, 1991)