Foraminifera from outcrops of the Pierre Shale (Upper Cretaceous) of North Dakota

Everett E. Wilson
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FORAMINIFERA FROM OUTCROPS OF THE PIERRE SHALE
(UPPER CRETACEOUS) OF NORTH DAKOTA

by

Everett E. Wilson

B.S. in Geology, University of North Dakota, 1956

A Thesis
Submitted to the Faculty
of the
Graduate School
of the
University of North Dakota
in partial fulfillment of the requirements
for the degree of
Master of Science

Grand Forks, North Dakota
June
1956
This thesis, submitted by Everett E. Wilson in partial fulfillment of the requirements for the Degree of Master of Science in the University of North Dakota, is hereby approved by the Committee under whom the work has been done.

[Signature]
Chairman

[Signature]
Helen M. Laird

[Signature]
J. R. Bengston

Dean of the Graduate School
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ABSTRACT

FORAMINIFERA FROM OUTCROPS OF THE PIERRE SHALE
(UPPER CRETACEOUS) OF NORTH DAKOTA

Everett E. Wilson, Master of Science

Exposures of the Pierre shale, Upper Cretaceous, in North Dakota are grouped into seven outcrop sectors for purposes of discussion. They are the Bowman County, Emmons County, Stutsman County, southern Sheyenne River, northern Sheyenne River, Cavalier County, and Grand Forks County sectors.

The strata which crop out in the southern Sheyenne River sector have been assigned previously to the Niobrara Formation by two writers and the Pierre shale by one writer. The other exposures discussed in this paper are considered to be definitely Pierre shale. Three lithologic units can be recognized in the lower beds of the Pierre in the Cavalier County sector. The lowest unit is probably lithologically equivalent to the Sharon Springs member of the Pierre shale of South Dakota and the Pembina member of the Verillion River formation of Manitoba and Saskatchewan.

Stratigraphically higher is a unit which may be equivalent to the strata of the southern Sheyenne River sector. The highest unit resembles the "Odanah" beds of Manitoba. The beds of the northern Sheyenne River and Stutsman County
sectors may possibly be equated to the Verendrye and DeGrey members, respectively, of the Pierre shale of South Dakota. An equivalent of the Elk Butte member of the Pierre of South Dakota extends into the Emmons County sector in North Dakota. The strata exposed in the Bowman County sector, although lithologically similar to those of the Emmons County sector, are probably older, and may be equivalent to the Mobridge member of the Pierre of South Dakota.

Microsamples containing Foraminifera were collected from six of the seven outcrop sectors. Seventeen of the samples were obtained from the known Pierre shale and nineteen of the samples were collected from the strata of the southern Sheyenne River sector.

The microfauna indicates that the lower Pierre shale was deposited under conditions which may have been alien to calcareous genera and species. Deposition of the upper Pierre was probably in deep water of normal salinity. The strata of the southern Sheyenne River sector was probably slowly deposited in relatively deep water, away from shore, where dilution by terrestrial rivers was at a minimum.

The Foraminifera described consist of seventy-six species arranged in thirty-nine genera. Two species are new. Faunal analyses indicate that the Pierre of North Dakota is equivalent in age to the Taylor and Navarro groups, in part, of the Gulf Coast states, but does not give a clear age indication of the strata of the southern Sheyenne River sector.
ACKNOWLEDGMENTS

The writer is indebted to Mr. F. C. Holland, Jr., his advisor, for initially pointing out the value of a study of this type. Mr. Holland aided immeasurably by offering his interest, assistance and advice during all phases of the study.

Dr. Wilson M. Laird, State Geologist and Head of the Geology Department of the University of North Dakota, suggested the problem, provided the facilities used in studying and photographing the Foraminifera and afforded the writer the opportunity to have been employed by the North Dakota State Geological Survey during the summers of 1956 and 1957.

While employed by the North Dakota State Geological Survey in 1957 the writer assisted Dr. John R. Bergstrom in a field party whose purpose it was to make a preliminary study of the Pierre shale of North Dakota. During this time the writer had the opportunity to collect a number of samples for his own problem, and a personal knowledge of the location of the outcrops of the Pierre shale in North Dakota was gained. Dr. Bergstrom cleared many perplexing problems of the probable stratigraphy of the Pierre shale of North Dakota for which the writer wishes to express his gratitude.

The writer thanks his wife, Lorraine, for assisting him in the field in September of 1956 when most of the
samples for this study were collected. She also helped with many little things and typed the paper.
INTRODUCTION

Purpose of the Study

In North Dakota the Pierre shale was deposited in all portions of the State except the southeastern corner, where it was either never deposited or removed by pre-Pleistocene erosion. In the western part of North Dakota the Pierre is overlain by later Cretaceous and Tertiary sediments, but to the east of the Missouri River, where it forms the bedrock, it is mantled by glacial drift. However, numerous exposures of the Pierre are present, generally in road cuts and river valleys of the southwestern and north-eastern corners of the State. More scattered outcrops occur along Beaver Creek and the Missouri River near Linton, Emmens County, and the valleys of the James River near Jamestown, Stutsman County and the Sheyenne River in Benson, Eddy, Nelson, Griggs, Steele, Barnes, and Ransom Counties. A single, isolated outcrop is located in the valley of the North Branch of the Turtle River near Niagara, Grand Forks County.

Most of the outcrops of the State are generally isolated and represent stratigraphic sequences less than 100 feet. These strata, of apparently uniform lithology, are difficult to correlate from one outcrop to another. Consequently, little has been done to separate the Pierre of
North Dakota into lithologic units. Examination of the various outcrops has, however, disclosed that different lithologic units of the Pierre shale can be recognised. This is more fully treated in the section on stratigraphy.

Megafossils of the Pierre shale of North Dakota are moderately abundant in localised areas, particularly in limestone "concretions" in the upper part of the Pierre of Bowman (Leonard, 1906, p. 72 and Hare, 1928, p. 15) and Emmons Counties (Fisher, 1952 and Cynarc, 1956). Single specimens, usually Inoceramus sp., have been found by the writer in strata near the base of the Pierre in Cavalier County. The writer knows of no attempt to zone the Pierre shale of North Dakota based on megafossils.

Microfossils are considerably more abundant than megafossils in the Pierre shale of North Dakota. Here, the types of microfossils, known to the writer, include Foraminifera, Radiolaria, sponge spicules and Ostracoda. It was hoped that a study of the Foraminifera would provide a basis for a successful zonation of the Pierre shale of North Dakota and illustrate the affinity to the Pierre of calcareous, buff colored strata that crop out in the valley of the Sheyenne River, from North Valley City, Barnes County and extend south to Fort Ransom, Ransom County. In the past these beds near North Valley City have been assigned to either the Niobrara formation (Leonard, 1906, p. 69 and Kresl, 1956) or the Pierre shale (Klines, 1942, p. 352), both Upper Cretaceous in age, whereas similar beds near Fort Ransom have
been designated as part of the Niobrara formation (Kline, 1942, p. 352).

**Previous Investigations**

Foraminifera of the Pierre shale and its equivalents have been studied in the past, but no known single reference may act as a standard for the identification of these fossils. Particularly is there an absence of literature to which one may refer for a discussion of the Foraminifera of the Pierre shale of North Dakota. Probably the most inclusive, single reference for the Foraminifera of the Upper Cretaceous of western North America is that of Cushman (1946).

In the papers of Carman (1929), Morrow (1934), Loetterle (1937), Bolin (1952), and Grunseth (1955) many species of Foraminifera of the Niobrara formation are described. These references are cited because a number of the same species also occur in the Pierre shale of Nebraska (Dietrich, 1951), South Dakota (Searight, 1937, 1938), and North Dakota.

Several papers on the Foraminifera of the Upper Cretaceous of Manitoba, Saskatchewan, and Alberta, Canada have been published. The reader is referred to Tyrrell (1890), Cushman (1927), and Wickenden (1932A, 1932B and 1941) for the results of earliest investigations in this field. In 1945 Wickenden (p. 49) thought the Hiding Mountain formation of Saskatchewan and Manitoba, from which he listed four species, was a correlative of the Pierre shale.
of the United States. More recently Nauss (1947) described and figured sixteen new species and one new variety of Foraminifera from the Upper Cretaceous of Alberta.

The first list of Foraminifera from the Pierre formation of the northern United States was made by Applin in 1933. Then, Loetterle (1937, p. 56-64) described and figured twelve species from the "lower chalky zone" of the Pierre in eastern South Dakota and northern Nebraska. In 1937 Searight made a lithologic subdivision of the Pierre shale of the Missouri River Valley in South Dakota and listed some Foraminifera of the various members. In 1938 he further listed and partially delimited the occurrence of the Foraminifera of the Sully member of the Pierre in South Dakota and Nebraska.

The writer knows of no previous descriptions of Foraminifera from the Pierre shale of North Dakota. Listings are also lacking. However, Laird (1946, p. 15) noted that Foraminifera are rare above the Niobrara formation, but include "the Ammonia and Anomalina (?) types."
LOCATION OF THE OUTCROPS AND SAMPLES

Location of the Outcrops

As stated previously the Pierre shale of North Dakota crops out, usually in the valleys of rivers, in several regions of the State. More specifically, North Dakota may be divided into seven sectors that include all the exposures of Pierre shale. Below are the locality descriptions of these sectors:

1. Bowman County sector.—In the southwestern corner of North Dakota fairly extensive outcrops of the Pierre occur within Bowman County. This occurrence, hereafter referred to as the Bowman County sector, is bounded on the west by the North Dakota-Montana border, although outcrops of Pierre may be traced into Montana. The other limits of the Pierre outcrops in this sector are formed by the northern edge of T. 132 N., the southern edge of T. 129 N., and the eastern edge of R. 106 W. More specifically the area is bounded on the north by Little Beaver Creek, along which several outcrops occur in T. 132 N., R. 107 W. Between Little Beaver Creek and the northern boundary of T. 130 N. outcrops are scarce. The writer knows of few within this area. However, the surface rocks of the northeastern one-
quarter of T. 130 N., R. 107 W. and the western one-third of T. 130 N., R. 106 W. are nearly all of Pierre shale that weathers into gumbo flats. Extensions of these gumbo flats occur east of the main body as far as the Little Missouri River, and south into secs. 3, 4, 5, 6, and 10, T. 129 N., R. 106 W. The practical boundaries of most of the Pierre outcrops in the Bowman County sector may be given as the Montana boundary on the west, North Dakota Highway 16 on the east, the South Dakota boundary on the south, and the northern boundary of Bowman County on the north.

2. **Emmons County sector.**—In Emmons County one very good section of the Upper Pierre is located on Beaver Creek, in Seaman Park, SE\(\frac{1}{4}\), SE\(\frac{1}{4}\), sec. 17, T. 132 N., R. 76 W., about one mile southwest of Linton. Minor outcrops in Emmons County are located in road cuts on the south side of North Dakota Highway 13, sec. 16, T. 132 N., R. 76 W., about two miles southeast of Linton and in the valley of the Missouri River, sec. 11, T. 129 N., R. 79 W., about five miles north of the South Dakota border.

3. **Stutsman County sector.**—Outcrops of the Pierre shale in Stutsman County are limited to the valleys of the James River and Pipestem Creek. The writer has never observed these of Pipestem Creek, but they have been reported by Kessel (1956). North of Jamestown sever-
al outcrops can be found in the valley of the James, north from Jamestown Dam to sec. 36, T. 144 N., R. 55 W. A fairly abundant concentration of outcrops occurs in a square of four sections of which sec. 36, T. 142 N., R. 63 W. is the northeasternmost section.

4. **Southern Sheyenne River sector**—From a point about one mile north of Valley City, Barnes County, south to Fort Ransom, Ransom County, abundant outcrops of shale occur in the valley of the Sheyenne River and in some road cuts on either side of the main valley. The northernmost group of outcrops in this southern Sheyenne River sector is located in sec. 9, T. 140 N., R. 58 W. From Valley City, south to Kathryn, Barnes County, the outcrops are most abundant on the western side of the Sheyenne Valley, but between Kathryn and Fort Ransom most occurrences are on the eastern side of the valley. The most southern exposure of shale is located in a road cut on the north side of a county road, 321, sec. 12, T. 135 N., R. 58 W., about .25 mile east of Fort Ransom. The writer knows of no shale outcrops south of this exposure.

5. **Northern Sheyenne River sector**—The Baldhill Reservoir separates the southern Sheyenne sector from the northern Sheyenne sector. North of the Baldhill Reservoir outcrops are fairly common in the valley of
the Sheyenne River and extend from sec. 25, T. 146 N., R. 58 W., about six miles east of Cooperstown, Griggs County, north to sec. 19, T. 150 N., R. 60 W., about two miles west-northwest of Pekin, Nelson County. Within this area of outcrops the Sheyenne River swings into the western part of Steele County to expose some shale in secs. 30 and 31, T. 147 N., R. 57 W. To the west of Pekin the occurrences of shale become more remote, but good exposures occur within the Fort Totten Indian Reservation in T. 150 N., R. 36 W. and T. 150 N., R. 65 W., Eddy County. Other exposures included in the northern Sheyenne River sector are road cuts on the east side of United States Highway 281, SW¼, sec. 4, T. 150 N., R. 66 W. and a county road, SW¼, sec. 8, T. 150 N., R. 57 W., Eddy County. Farther west, a single exposure on the Sheyenne River occurs in sec. 14, T. 151 N., R. 70 W., Benson County. An isolated outcrop included in the northern Sheyenne sector, is a single exposure observable from North Dakota Highway 1, SW¼, NW¼, sec. 26, T. 151 N., R. 60 W., Nelson County.

Cavalier County sector.—In the northeastern corner of North Dakota outcrops of the Pierre are abundant in Cavalier County. A number of exposures also exist in Walsh County. This sector, the Cavalier County sector, is similar to the others in that the shale
crops out in the valleys of rivers and in roadcuts that enter these valleys. The rivers along which the Pierre shale is exposed are: the Little North Pembina River, the Pembina River, the Little South Pembina River, the Tongue River, the North Branch of the Park River, the Middle Branch of the Park River, and the South Branch of the Park River. The exposures are most abundant where these rivers and some intermittent streams flow easterly over the edge of the Pembina Escarpment (a north-south ridge of Cretaceous rocks rising above the Lake Agassiz lake plain on the east). Shale crops out in these areas mostly in T. 156 N., R. 57 W.; T. 159 N., R. 57 W. and R. 58 W.; T. 163 N., R. 57 W.; and T. 164 N., R. 58 W.

7. Grand Forks County sector.—This isolated outcrop sector is represented by a few good exposures of Pierre shale in the banks of the North Branch of the Turtle River in sec. 6, T. 152 N., R. 56 W., Grand Forks County.

Location of the Samples

The samples which have proved to contain Foraminifera are distributed among six of the outcrop sectors described above. These are the Bowman County, Sargent County, Stutsman County, southern Sheyenne River, northern Sheyenne River, and Cavalier County sectors.

The localities of the fossiliferous samples are
given below:

A. Twenty-three feet above Little Beaver Creek, cut bank exposure, south bank of Little Beaver Creek, NE influenced by north bank of Menago Creek, sec. 24, T. 132 N., R. 107 W., Bowman County, North Dakota, about 5.5 miles southwest of Harsmouth, Slope County, North Dakota.

B. Twenty-six feet above Little Beaver Creek, otherwise the same as locality A.

C. One-half foot above the center of the road, in a road cut, south side of the road, about three miles west of North Dakota Highway 20, NE influenced by north bank of Menago Creek, sec. 2, T. 141 N., R. 54 W., Stutsman County, North Dakota.

D. Five feet above the center of the road, otherwise the same as locality C.

E. Sixteen feet above the center of the road, otherwise the same as locality C.

F. Five and one-half feet above the east eastern rail of the railroad tracks about fifty yards west of the outcrop, road cut on the east side of the road, SW1/4, sec. 9, T. 140 N., R. 58 W., .75 mile northwest of North Valley City, Barnes County, North Dakota.

G. Nine feet above the railroad tracks, otherwise the same as locality F.

H. Fourteen feet above the railroad tracks, otherwise the same as locality F.

I. Eighteen feet above the railroad tracks, otherwise the same as locality F.
J. Twenty-five feet above the railroad tracks, otherwise the same as locality F.

K. Twenty-nine feet above the railroad tracks, otherwise the same as locality F.

L. Thirty-four feet above the railroad tracks, otherwise the same as locality F.

M. Thirty-eight feet above the railroad tracks, otherwise the same as locality F.

N. Interval of exposure of 0 to 5 feet, road cut, west side of road, SW1/4, SE1/4, sec. 9, T. 140 N., R. 58 W., about .75 mile northwest of North Valley City, Barnes County, North Dakota.

O. Interval of exposure of 5 to 10 feet, otherwise the same as locality M.

P. Interval of exposure of 10 to 15 feet, otherwise the same as locality M.

Q. Interval of exposure of 15 to 20 feet, otherwise the same as locality M.

R. Interval of exposure of 20 to 25 feet, otherwise the same as locality M.

S. Interval of exposure of 25 to 33 feet, otherwise the same as locality M.

T. Interval of exposure of 0 to 5 feet, road cut, southwest side of road, SW1/4, SE1/4, sec. 9, T. 140 N., R. 58 W., about one mile northwest of North Valley City, Barnes County, North Dakota.

U. Interval of exposure of 5 to 10 feet, otherwise the
same as locality T.

V. Interval of exposure of 10 to 15 feet, otherwise the same as locality T.

W. Interval of exposure of 15 to 20 feet, otherwise the same as locality T.

X. Interval of exposure of 20 to 25 feet, otherwise the same as locality T.

Y. Interval of exposure of 25 to 30 feet, otherwise the same as locality T.

Z. Interval of exposure of 0 to 32 feet, road cut, north side of road, NE1, SE4, sec. 12, T. 135 N., R. 58 W., about 0.25 miles east of Fort Ransom, Ransom County, North Dakota.

AA. Core sample, road cut, north side of North Dakota Highway 5, NE1, sec. 24, T. 161 N., R. 57 W., about 1.5 miles west of North Dakota Highway 32, Cavalier County, North Dakota.

BB. Interval of exposure of 5 to 10 feet above the contact (the top of the rusty, oxidized zone) of the Niobrara and Pierre formations, steep cut bank exposure, about 100 yards north of the Tongue River, site of the old Concrete Cement Plant, NE4, sec. 25, T. 161 N., R. 57 W., Cavalier County, North Dakota.

CC. Interval of exposure of 10 to 15 feet above the contact of the Niobrara and Pierre formations, otherwise the same as locality BB.

DD. Interval of exposure of 15 to 20 feet above the con-
tact of the Niobrara and Pierre formations, otherwise the same as locality BB.

**EB.** Interval of exposure of 20 to 25 feet above the contact of the Niobrara and Pierre formations, otherwise the same as locality BB.

**FP.** Interval of exposure of 25 to 33 feet above the contact of the Niobrara and Pierre formations, otherwise the same as locality BB.

**GG.** Grab sample, along unnamed intermittent stream, a tributary to the Little South Pembina River, 1SW¼, sec. 24, T. 162 N., R. 58 W., about 3.5 miles northwest of Olga, Cavalier County, North Dakota.

**HH.** Interval from 170 to 160 feet below the surface, United States Geological Survey Test Well, 1102, Logan County, North Dakota.

**II.** Interval of exposure of 0 to 17 feet, road cut, east side of United States Highway 281, SW¼, SW¼, sec. 4, T. 150 N., R. 66 W., about 200 yards south of the Sheyenne River, Eddy County, North Dakota.

**JJ.** Interval of exposure of 0 to 85 feet, steep cut bank exposure, south side of Beaver Creek, Seaman Park, sec. 17, T. 132 N., R. 76 W., about .75 mile southeast of Linton, Emmons County, North Dakota.
PROCEDURE

All the samples used in this study, except one, were collected by the writer. At some of the localities the outcrop was trenches to a shallow depth that exposed fresh shale. The samples, usually representing vertical intervals of five feet, were then collected from the trench. In certain instances, when there was an indication that the shale was badly weathered, the samples were obtained by excavating about one foot into the shale. The vertical interval between samples collected in this manner was also about five feet. All measurements were made with a hand level and tape. Each sample weighed approximately five pounds.

The major portion of the samples were collected in the first half of September of 1956. During this time the writer collected samples from the Bowman County sector (localities A and B), Emmons County sector (localities C to E), and a portion of the samples from the southern Sheyenne River sector (localities F to N).

During the summer of 1957, while employed by the North Dakota State Geological Survey in a field party to make a preliminary study of the Pierre shale of North Dakota, time was found to collect additional samples which contained Foraminifera. These were obtained from localities N to Z of the southern Sheyenne River sector; locality II of the north-
ern Sheyenne River sector; and locality GG of the Cavalier County sector.

In October of 1957 the writer returned to the Cavalier County sector and collected samples from localities AA to FF. The remaining sample (locality HH) was obtained from the Geology Department of the University of North Dakota.

In the laboratory the treatment of the samples required methods that varied for individual samples. In all cases one-half of the sample was retained for future reference or investigation. Probably the easiest samples to prepare for examination were those from localities F to Z and GG. These samples were simply soaked in water in porcelain pans overnight, after which they were wet-washed, with a spray, through a 200 mesh sieve to remove the clay. The portion of the sample that did not wash through the sieve was put on paper towels to dry.

Other samples posed a problem as they did not break down easily. The samples from localities A to E, AA to FF, H, and JJ fall into this category. They were first heated in porcelain pans at a temperature of 250 degrees for about one-half hour. To the heated samples was added Stoddard solution (a dry cleaning fluid), in which the samples were allowed to soak for about twelve hours. After the soaking period the Stoddard solution was decanted and water, with either sodium hydroxide or potassium hydroxide pellets, was added. Next, the samples were boiled up to eight hours, or
until it appeared that most of the material had disaggregated. Immediately after, the samples were wet sieved, using the method described above, and the portion retained by the sieve was allowed to dry.

Sieving screens of United States sieve series meshes 20, 35, 60, 80, 100, and pan were used to sieve the dry, disaggregated samples into six size grades for ease of picking. These sieved portions were further split with a microsplitter (Sepor) into an amount that produced a thin covering on the bottom of a 2.25 inch by 3.50 inch paper picking tray. The Foraminifera were removed from the picking tray with a moistened double 0 camel hair brush and transferred to paper slides that had been coated with gum tragacanth solution. To the tragacanth solution had been added a drop of formaldehyde to prevent the formation of mold, and a drop of oil of cloves to mask the odor of the formaldehyde.

The illustrations were prepared by the writer. A photomicrographic attachment (Leitz "Nica") was substituted for the ocular of a monocular microscope to photograph the specimens. An objective with a power of 3.5X was used for most of the specimens, but it was necessary to use an objective with a power of 8.0X for some of the smaller specimens. A microscope illuminator (American Optical Company "Universal") was used to furnish the lighting. The desired relative size of illustration was obtained by enlarging. Prints of individual specimens were then cut out and arranged on paper to form master plates. The master plates were photographed with
a Speed Graphic camera and the negative was enlarged to the dimensions shown in this paper. The actual size of the specimens, given under the descriptions of the species, was determined with an eyepiece micrometer.
STRATIGRAPHY OF THE PIERRé SHALE

It is not the purpose of this paper to divide the Pierre shale of North Dakota into stratigraphic units. However, a brief discussion of the history of subdivision of the Pierre shale and its lithologic equivalents of adjacent areas seems in place, as does an attempt to equate some distinctive lithologic units of the Pierre in North Dakota to lithologic units of nearby areas where applicable.

History of Subdivision of the Pierre Shale in Areas Adjacent to North Dakota

The Pierre shale was named for exposures near Old Fort Pierre in either Stanley or Hughes County, South Dakota, by Meek and Hayden in 1861. (Fide Wilmarth, 1938, p. 1597). No major subdivisions of the Pierre shale were made until 1931 when Elias subdivided the Pierre shale in Wallace County, Kansas, proposing five units from the base up: Sharon Springs member, Wescan member, Lake Creek member, Salt Grass member, and Beecher Island member.

This step seemed to inaugurate an active interest in the stratigraphy of the Pierre shale, for Searight (1937) followed with a five member division of the Pierre shale of central South Dakota naming the Gregory, Sully, Virgin Creek, Mobridge, and Elk Butte members. He differentiated the Gregory and Virgin Creek members into lower and upper units.
and the Sully member into the Agency shale (named by W. J. Russell, 1930, *Cide* Searight, 1937, p. 8), the Oacoma zone, and the Verendrye beds at the top. Searight partially reclassified and redefined the members in 1938 and 1939. In 1938 he (p. 137) adopted a name for the lower unit of the Gregory member using Elias' term Sharon Springs. Searight (1939, *Cide* Gries and Rothrock, 1941, p. 8) later designated lower and upper units of the Sharon Springs member, and supplanted the term Mobridge with the term Interior. In 1941 Gries and Rothrock (p. 8) restored the term Mobridge. They

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<td>Virgin Creek member</td>
</tr>
<tr>
<td>upper</td>
</tr>
<tr>
<td>lower</td>
</tr>
<tr>
<td>Verendrye member</td>
</tr>
<tr>
<td>DeGrey member</td>
</tr>
<tr>
<td>Crow Creek member</td>
</tr>
<tr>
<td>Gregory member</td>
</tr>
<tr>
<td>Sharon Springs member</td>
</tr>
</tbody>
</table>

*Fig. 1.—Units of the Pierre shale of central South Dakota (after Crandell, 1950).*

(1941, p. 9-15) also limited the Sharon Springs member to the lower unit, redefined the Gregory member to include Searight's upper Sharon Springs of 1939 and introduced the term Crow Creek for the old Agency shale of the Sully member. In 1942 Gries (p. 17) combined the terms Agency and Oacoma for the old Oacoma zone.
A lull in reclassification of the Pierre shale of central South Dakota was interrupted in 1950 when Crandell (1950, p. 2341-2343) proposed the DeGrey member for the Agency-Oacoma zone of Gries (1942), and raised the Crow Creek and Verendrye units to member status dropping the term Sully. Since 1950 no redefinition of the terms used in central South Dakota has been made.

All of these same members are not present in western South Dakota, but a lithologic equivalent of the Sharon Springs member of central South Dakota, the Mitten member, is recognized and between the Mitten member and Niobrara formation below, a soft shale, of questionable age, which thickens to the northwest from a few feet near the Nebraska-South Dakota border to 100 feet near the Black Hills, may represent the Gammon member of the Pierre shale of northeastern Wyoming and southeastern Montana (Tourtelot, 1956, p. 56). Tourtelot (1956, p. 66) illustrated the Gammon member as about 800 feet thick in the northern Black Hills, where it is overlain by the Mitten member.

In Colorado the Pierre shale, 5000-8000 feet thick in the foothills of the Front Range (Griffitts, 1949, p. 2015), conformably overlies the Niobrara formation and is conformably overlain by the Fox Hills sandstone (Griffitts, 1949, p. 2011). Four major units of the Pierre shale of Colorado are recognized by Griffitts (1949, p. 2013-2015). They are from the base up: The Sharon Springs member, a very black, fissile, finely laminated shale with many lenses of bentonite,
the whole 400-500 feet thick; the Rusty zone, divided into a lower unit of dark shale and an upper unit of harder, gray shale; the Hygeine zone, subdivided into four units, the Hygeine sandstone, the Terry sandstone, the Rocky Ridge sandstone, and the Richard sandstone; and the Transition zone, a sandy shale. The writer has included this description of the Pierre shale of Colorado to show that the Pierre interval does not only embrace shales, but also sandstones in some areas.

North of the International Border the term Pierre is not used, but Upper Cretaceous strata that crop out in Manitoba and Saskatchewan have been correlated to the Pierre shale of the United States. In 1930 Kirk classified the Cretaceous shales of the Manitoba Escarpment. Since this paper is concerned with the Pierre shale, the following discussion of Kirk's classification will only include the beds that are possibly Pierre or underlying Niobrara formation equivalents.

Kirk (1930, p. 1238-1248) wrote that the Vermilion River beds, dark, carbonaceous shales, of the Riding Mountain area, lithologically resemble the Morden and Pembina beds of the Pembina Mountain area, and that the general aspect of the fossils found in the Vermilion River beds was suggestive of late Pierre age. However, he (p. 130) stated that definite correlation of the Morden beds was not possible at that time. Kirk (1930, p. 129-130B) did not assuredly correlate the intermediate, gray, calcareous Boyne beds of the Pembina Mountain area to the Niobrara for-
nation, but described them as speckled, calcareous shales containing a microfauna that Wickenden thought was indicative of the upper Taylor or Navarro of Texas. The Pembina beds, described by Kirk (1930, p. 1308-1313) as dark non-calcareous shale with thick bands of white, bentonitic clay in the lower part, were considered a Pierre equivalent.

<table>
<thead>
<tr>
<th>Kirk, 1930</th>
<th>Wickenden, 1945</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pembina Mountain Area</td>
<td>Pembina Mountain and Riding Mountain Area</td>
</tr>
<tr>
<td>Odanah beds</td>
<td>Odanah beds</td>
</tr>
<tr>
<td>Riding Mountain beds</td>
<td>Riding Mountain formation</td>
</tr>
<tr>
<td>Pembina beds</td>
<td>Vermilion River formation</td>
</tr>
<tr>
<td>Boyne beds</td>
<td>Boyne member</td>
</tr>
<tr>
<td>Morden beds</td>
<td>Morden member</td>
</tr>
<tr>
<td>Assiniboine beds</td>
<td>Favel formation</td>
</tr>
<tr>
<td>Keld beds</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 2.-Upper Cretaceous units of Manitoba and Saskatchewan as recommended by Kirk (1930) and revised by Wickenden (1945).

Kirk (1930, p. 1248-1253) proposed the term Riding Mountain beds for light gray to greenish gray, non-calcareous shales with abundant nodules and irregular bands of ironstone. The Odanah beds, named by Tyrrell in 1890, were considered by Kirk (1930, p. 1265) to be "consistent in their character." He described the shale as hard, brittle,
slightly siliceous, dark greenish gray when wet and light steel or slightly greenish gray when dry.

In 1945 Wickenden (p. 33) revised Kirk's classification and considered the Morden, Boyne and Pembina beds of the Pembina Mountain area as members of the Vermilion River formation, although the Pembina member was included tentatively. He (p. 42) stated that the Boyne member contained Foraminifera similar to those described by Loetterle from the Niobrara formation of Nebraska, and *Scaphites ventricosus*, whose presence "indicates correlation with the Niobrara of the United States." The Riding Mountain formation was thought by Wickenden (p. 49) to be equivalent to the Pierre shale of the northern United States, and Kirk's (1930) term Odanah was dismissed as a stratigraphic term by Wickenden (1945, p. 48) when he wrote:

... it seems probable that the Odanah is merely a peculiar lithologic phase of the Riding Mountain beds. For this reason the name Riding Mountain is retained in this report for the entire formation and the term Odanah is employed only in referring to the hard type of shale within it.

The Pierre Shale of North Dakota

In North Dakota the Pierre shale overlies the Niobrara formation. Outcrops of the Niobrara formation in northeastern North Dakota, the Cavalier County sector, show it to be a light gray, highly calcareous shale that weathers buff on exposure. At the transition of the Niobrara and Pierre formations is a zone of rusty, oxidized shale about five feet thick at the top of the Niobrara formation. This oxidized transition zone can be observed at the site of the
old Concrto cement plant along the Tongue River, NET, sec. 24, T. 161 N., R. 57 W. The section measured by the writer of the Pierre beds above the oxidized zone of this locality is given below:

<table>
<thead>
<tr>
<th>Pierre shale</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. Shale, light olive gray (5Y 6/1), highly weathered</td>
<td>1</td>
</tr>
<tr>
<td>2. Shale, olive gray (5Y 4/1), non-calcareous, with much yellow ?jarosite along the bedding planes and a few thin (1/4 to 1 inch) cream-colored, waxy, bentonitic, clay layers</td>
<td>24</td>
</tr>
<tr>
<td>1. Shale layers, olive gray (5Y 4/1), non-calcareous, papery thin to nine inches thick, with abundant fish scales and carbonaceous material, the whole interbedded with bentonitic clays, cream-colored, 1/4 to 5.5 inches thick</td>
<td>3</td>
</tr>
<tr>
<td>Total thickness</td>
<td>33</td>
</tr>
</tbody>
</table>

Lithologically, this unfossiliferous shale of the lower Pierre in the Cavalier County sector appears to be equivalent to the Sharon Springs member of South Dakota and the Pembina member of the Vermilion River formation of Manitoba and Saskatchewan.

Above this basal unit of the Pierre shale in the Cavalier County sector thirty-two feet of waxy, greenish, non-calcareous to calcareous shale were observed along an intermittent tributary to the Little South Pembina River, sec. 24, T. 162 N., R. 58 W. The exact relationship of these beds to the lower unit of the Pierre is not known, but it was established by altimeter that these strata lie about forty feet above the base of the Pierre shale in this area. It is
interesting to note that a microsample from these beds (locality 39) yielded species also found at localities P to Y. The evidence is very scanty, but it is suggested that the beds represent a calcareous interval of the lower Pierre shale, which may be equivalent to the calcareous strata that crop out in the southern Sheyenne River sector.

Hard, platy, siliceous shale, with numerous, small, limonitic and hematitic "concretions", is well exposed in the Cavalier County sector in a ditch on the east side of the road in the SW¼, sec. 19, T. 162 N., R. 57 W.; also about fifty yards southwest of the bridge that crosses the North Branch of the Park River, SW¼, sec. 32, T. 160 N., R. 57 W., about half a mile northeast of Milton, Cavalier County; and in the steep cut bank exposure along the South Branch of the Park River, sec. 8, T. 158 N., R. 57 W., Walsh County. These hard, siliceous beds appear to resemble the "Odanah" beds of Manitoba as described by Kirk (1930).

Three distinctive lithologies can be recognized in the Cavalier County sector. Overlying the Niobrara formation is a unit of interbedded, dark, carbonaceous shale and thin, cream-colored, bentonitic, clay layers, overlain by a waxy, greenish, calcareous shale, followed by a hard, platy, siliceous shale.

The exposures of the Pierre shale in the northern Sheyenne River sector will not be discussed in detail, as they do not appear to resemble any other unit of the Pierre shale of North Dakota. However, the microsample from
locality II contained abundant sponge spicules, and because Searight (1938, p. 137) noted that the Verendrye member of the Pierre shale near Oakoma, Brule County, South Dakota contained "skeletal parts of silicispongia." It is suggested that some of the shale in this sector may be a correlative of the Verendrye member of the Pierre shale of South Dakota.

In the Stutsman County sector are good exposures of olive gray, fissile, non-calcareous shale with numerous layers of cream-colored, bentonitic clay. At a few localities in this sector, particularly in the SW\(^1\) sec. 35, T. 142 N., R. 64 W., the shale contains abundant, purplish iron-manganese coated bedding planes and limonitic "concretions." Kreal (1956) described these deposits as "a paper thin metallic deposit of a mineral similar to the manganese mineral manganese." He stated that the "Odanah" beds of Manitoba contained manganiferous "concretions," and opined that the two types of "concretions" were similar. It should be noted that the manganese deposits and "concretions" in the strata of the Stutsman County sector may indicate equivalency of these beds with the DeSmet member of the Pierre shale of South Dakota.

It is generally accepted that the shale cropping out in the Emmons County sector is equal to the Elk Butte member of the Pierre shale of South Dakota. In Emmons County Fisher (1951, p. 8) states that "although a few feet of the Mobridge may occur in the lowest levels along the Missouri River most of the Pierre shale in the county, and most cer-
tainly that around Linton, belongs to the Elk Butte member."
Searight (1937, p. 53) extended the Elk Butte member of the
Pierre shale of central South Dakota into the southern por-
tion of North Dakota, the Bowman County sector.

Gradational contact of the Pierre shale and the
overlying Fox Hills formation, present in South Dakota, may
also be observed at Seaman Park, about three-quarters of a
mile southeast of Linton in the Emmons County sector and
along Little Beaver Creek in the Bowman County sector. Al-
though the shale of these two sectors is lithologically
alike, that of the Bowman County sector may not be equivalent
to the Elk Butte member of the Pierre in South Dakota. Fos-
siliferous limestone "concretions" near the top of the Pierre
along Little Beaver Creek in the Bowman County sector possi-
bly indicate that these beds are lithologically equivalent
to the Mobridge member of the Pierre shale of South Dakota,
in which similar concretions have been found.

In North Dakota, then, the strata of the Pierre shale
can be tentatively correlated by lithology to subdivisions of
the Pierre shale of other areas. A probable equivalent of
the Sharon Springs member of the Pierre of South Dakota and
the Pembina member of the Vermilion River formation of
Manitoba and Saskatchewan crops out in the Cavalier County
sector. Also in the Cavalier County sector two other distinc-
tive units of the Pierre shale have been recognized. Above
the basal (Sharon Springs equivalent) in this sector is a
thin, calcareous interval; still higher stratigraphically is
a thick, hard, siliceous shale.

Some of the shale which crops out in the northern Sheyenne River sector may be equivalent to the Verendrye member of the Pierre of South Dakota. Iron-manganese "concretions" in the beds of the Stutsman County sector suggest equivalency of these strata to the DeGrey member of the Pierre shale of South Dakota. Mobridge equivalents may be present in the Bowman County sector of North Dakota. The Elk Butte member of the Pierre shale in South Dakota extends into the Emmons County sector of North Dakota.

All of the above described units are generally accepted as belonging to the Pierre shale of North Dakota. In addition, as mentioned in the introduction, the beds of the southern Sheyenne River sector have been assigned to the Niobrara formation by Leonard (1906, p. 59) and Kress (1956), who considered the beds north of North Valley City as belonging to the Niobrara formation. Kline (1942, p. 352) suggested that the strata exposed north of North Valley City are part of the Pierre shale and that the beds cropping out near the southern end of the sector (near Fort Ransom) are Niobrara.

Along the upper edge of the Sheyenne Valley there are exposed at several localities, especially north of North Valley City, beds which show a sharp change, from the buff-colored beds in question, to strata of gray, non-calcareous shale. A section (measured and described by Dr. John R. Bergstrom) shows this interval at the locality from which microsamples 7 to 1 were collected.
<table>
<thead>
<tr>
<th>Units</th>
<th>Description</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Shale, yellowish gray (5Y7/3 to 5Y7/2), with some ochre-orange zones, calcareous</td>
<td>16</td>
</tr>
<tr>
<td>2.</td>
<td>Shale, slightly darker than yellowish gray (5Y7/2), calcareous</td>
<td>6</td>
</tr>
<tr>
<td>3.</td>
<td>Shale, yellow, darker than below, calcareous</td>
<td>1</td>
</tr>
<tr>
<td>4.</td>
<td>Shale, gray, non-calcareous, with a thin layer of bentonitic clay in the lower part</td>
<td>7</td>
</tr>
<tr>
<td>5.</td>
<td>Shale, olive gray, calcareous</td>
<td>4</td>
</tr>
</tbody>
</table>

Units number 1, 2 and 3 represent the upper part of the strata which Leonard and Krael considered Niobrara, but it is not known if they would include units number 4 and 5. Most likely they would not, but would consider these strata as the basal Pierre of this area. The two upper units, which only show one, thin, bentonitic layer, are decidedly unlike the lower Pierre shale which is exposed at the old Concrete cement plant in the Cavalier County sector. Therefore, the writer does not believe units number 4 and 5 are basal Pierre, because the basal part of the Pierre shale of a wide area is typically a thin interval of interbedded, dark, carbonaceous shale and cream-colored, bentonitic clay.

Lithologically, it is impossible to state with assurance if the calcareous beds below units number 4 and 5 are Niobrara or Pierre, although they do resemble the Niobrara formation. Also, they probably are equal to the strata exposed near Fort Ransom, as cross sections drawn by the writer (from data based on field work of Dr. John R. Bergstrom...
during the summer of 1957) indicate that the same strata are continuous from north of North Valley City, south to Fort Ransom.
PALEOECOLOGY

Most of the species described in this paper are now extinct, so the paleoecologic determinations set forth are based on the inferences derived from the study of living counterparts of the genera occurring in the Pierre shale of North Dakota. The determinations are only an approximation to the actual ecology of the organisms during their time of life partly because the occurrence of Foraminifera in the Pierre of North Dakota may be more abundant than this study shows. The writer realizes that some strata bearing Foraminifera were certainly missed during sampling.

The Foraminifera of this study are chiefly from four stratigraphic intervals in four of the previously described outcrop sectors. The calcareous beds of the southern Sheyenne River sector contained by far the greatest number of species and specimens. Hence it is possible to describe the paleoecology of this sector in more detail than the other sectors. The second greatest number of species were found in the strata of the Bowman County sector. The least number of species, although the species may be locally abundant, occurred in the Cavalier and Stutsman County sectors.

According to Ellison (1951, p. 214) benthonic Foraminifera are better indicators of temperature, depth, amount of light, water composition, and other bottom conditions than
are pelagic Foraminifera. However, pelagic Foraminifera may be utilized to indicate other information. Since Crickmay, et al. (1941, p. 101) stated that they "can occur only in areas relatively free from (1) concomitant clastic sedimentation and (2) abundant benthonic life"; their presence ("Globigerina", Globorotalites, Heterohelix and Planomalina) in association with the benthonic forms in the strata of the southern Sheyenne River sector represents a mixed assemblage. The pelagic forms, sinking to the bottom from the upper levels of the water, comprise a death assemblage mixing with the bottom dwelling living assemblage. However, the number of specimens of the pelagic forms in these beds are considered to represent a normal death rate. Ecologically, their presence is interpreted to mean that clastic sedimentation was slow, and that because pelagic Foraminifera do not live in diluted sea water (Ellison, 1951, p. 219) deposition was at a distance from shore, where dilution by terrestrial rivers was at a minimum. The salinity of the seas during deposition of these strata was of normal content.

Some of the benthonic genera and species from the beds of the southern Sheyenne River sector (localities F to W and Z) are probably good depth indices. Of these Lagenia and Bulimina may be the most useful. Glassner (1947, p. 190) stated that the Lagenidae were generally indicative of deep water, while Phlager (1942, p. 1086), from samples col-
lected off the east coast of the United States, studied an Arctic fauna which showed that *Lagena* was most common at depths less than about 1000 meters but occurred below 2000 meters, and that *Bulimina* was common from approximately 600 to 1600 meters. The abundant occurrence of *Lagena* and *Bulimina* in the beds of the southern Sheyenne River sector, therefore, reflects slow deposition of these strata in relatively deep water.

The common occurrence of arenaceous forms, with the absence of calcareous forms, in the gray shale in the upper levels of the valley of the Sheyenne River in the southern Sheyenne River sector (localities X and Y) and the Pierre shale of the Cavalier and Stutsman County sectors (localities C, D, E, and AA to FF) indicates that these species had the ability to tolerate the conditions of deposition. This does not definitely suggest intolerable conditions, prohibiting the occurrence of calcareous forms during this time interval of deposition. Perhaps volcanic ash, being deposited during this time of the Upper Cretaceous, as attested by the numerous bentonitic layers, may have been the agent responsible for producing an unusual mineral content in the seas.

The salinity of the water, in which the strata of the upper Pierre in the Bowman County sector was deposited, was probably of normal concentration as pelagic Foraminifera are common in these beds. Also, the Lagenidae (only one species of *Lagena*) are common and may indicate deep water.

In summary, the principal paleoecologic factors indi-
cated by the Foraminifera present in this study are salinity and depth of water. The calcareous strata of the southern Shyanne River sector were probably slowly deposited in deep water of normal salinity. Arenaceous forms in the upper strata of the southern Shyanne River sector and the lower Pierre of the Cavalier and Stutsman County sectors may indicate abnormal conditions during deposition of these beds. During upper Pierre sedimentation the seas of the Bowman County sector were deep and of normal salinity.
ANALYSIS OF THE FAUNA

The microfauna described in this paper consists of seventy-six species of Foraminifera, of which two are new, arranged in thirty-nine genera. Their occurrence and abundance are given in Table 1. Twenty-one species occur only in strata identified definitely as Pierre shale; thirty-eight species occur only in the strata of questionable age in the southern Sheyenne River sector; and seventeen species are common to both the Pierre and the beds of the southern Sheyenne River sector.

Of the twenty-one described species from the known Pierre shale, seventeen are assigned to previously identified species. Twelve of these seventeen species have been reported from the Taylor group in the Gulf Coast states and eleven have been reported from the Navarro group. Only four of the species which are common to the Taylor and Navarro groups also occur in the older Austin group of the Gulf Coast states. It appears then, that this portion of the fauna studied indicates that the Pierre shale of North Dakota is probably equal, in age, to the strata of the Taylor and Navarro groups of the Gulf Coast states.

The beds of the southern Sheyenne River sector, principally those located north of North Valley City, will be referred to as the North Valley City beds for ease of dis-
discussion, hereafter. From these strata microsamples F to W were collected.

A comparison of the portion of the fauna which occurs only in the North Valley City beds to faunas previously described from the Niobrara and Pierre formations of other areas and the Austin, Taylor and Navarro groups of the Gulf Coast states does not give a clear age indication. Twenty-five of the thirty-eight species which occur only in the North Valley City beds have been identified to species. Eleven of the species have a long range; five have been recorded exclusively from the Niobrara formation or the Austin or Austin and Taylor groups; and eight have been reported only from the Pierre shale or Taylor or Taylor and Navarro groups by other writers. Even though the age of these beds is not evident from an analysis of the fauna, it is noted that the fauna of the North Valley City beds is essentially unlike that of the known Pierre shale of North Dakota. Of the fifty-five total species occurring in the North Valley City beds, only seventeen are found in the Pierre. It is not known if this faunal difference between the North Valley City beds and the known Pierre is due to lithologic or ecological differences.

Several additional genera and species have been recognized in the North Valley City beds and the strata of the Bowman County and Cavalier County sectors (mostly of the families Rotaliidae and Anomaliniidae), but it was not possible to include these in this paper because of time
limitations. Future study of yet unidentified genera and species may be of use in deciding the affinities of the North Valley City beds.
CONCLUSIONS

Previous study of the Pierre shale of North Dakota has been at a minimum, but earlier workers have described a portion of the megafauna of certain areas. The Pierre shale has not been subdivided, and prior microfaunal studies of the Pierre have not been done.

This paper should be considered an introduction to the problems of the stratigraphy and paleontology, especially micropaleontology, of the Pierre in North Dakota. It has been possible to recognize some lithologic units of the Pierre shale, which seem to be correlatives of subdivisions of the Pierre of other areas. The microfauna seems to indicate that the Pierre of North Dakota is equal in age to part of the Taylor and Navarro groups of the Gulf Coast states. The relationship of the beds of the southern Shyenne River sector to the Niobrara or Pierre formations is not fully understood, since neither lithologically, nor faunally, has the age of the former been demonstrated. The microfauna is inconclusive, but future study of the additional Foraminifera which occur in the strata exposed immediately north of North Valley City may help solve the problem of the age of these beds.
SYSTEMATIC DESCRIPTIONS

All categories above genus are essentially those designated by Cushman in his various textbooks (especially 1948), but the assignment of the genera Bolivinoidae Cushman and Eouvigerina Cushman to the Buliminidae by Glassner (1947), rather than to the Heterohelicidae, is followed (see Gallitelli, 1957, p. 145-146 and 148). The diagnoses are not intended to be complete descriptions of the species, but shortened descriptions of the specimens in the collection.

Phylum PROTOZOA

Class SARCODINA

Order FORAMINIFERA

Family Rhizamminidae

Bathysephon Sars, 1872

Bathysephon vitta Nauss, 1947

Plate 1, figure 6.

Bathysephon vitta Nauss, 1947, Jour. Paleontology, v. 21, p. 234, pl. 48, fig. 4.

Nauss (1947) describes this species as:

Test a compressed tube, open at both ends, with indistinct constrictions at regular intervals; lateral edges broadly rounded; wall 0.07 mm. thick, composed of minute clear grains nearly joined in a white amorphous cement, covered with a black coating.

Measurements.—Length of figured specimen 0.75 mm.;
breadth of figured specimen 0.35 mm.

Discussion.—The specimens assigned to this species are mostly subcylindrical but constricted linearly to give the appearance of two parallel, flattened, fused tubes. All of them have a thin, dark coating that varies in color from gray to black.

This species differs from *Bathyypsilon paraeplplia* Cushman and Gouldoff, from the Upper Cretaceous of California, in being much smaller. Nauss (1947, p. 334) compares *B. vitta*, from the Lea Park shale of Alberta, to *Bathyypsilon scoenica* Cushman and Hanna, and shows *B. scoenica* to be covered with a reddish coating, whereas *B. vitta* is typically coated blackish. *B. vitta* is apparently similar to *Bathyypsilon taurensensis* Sacco and may possibly be the same species.

Hypotype.—Univ. of M. Dak. Cat. No. 1251.

Occurrence.—*B. vitta* is common at localities BB and CC. Additional specimens from locality NE are questionably referred to the species. In shape, size and texture these specimens are like *B. vitta*, but only traces of the dark coating are visible on these questionable specimens.

*Bathyypsilon* n. sp. A

Plate 1, figure 2.

Diagnosis.—Test elongate, compressed, open at both ends; wall whitish, thick, composed of very fine sponge spicules imbedded parallel to the longitudinal axis in an amorphous cement, giving a fibrous appearance to the test.

Measurements.—Length of figured specimen 0.33 mm.
diameter of figured specimen 0.19 mm.

Discussion.—The outstanding characteristic of this species is the fibrous appearance due to the longitudinally arranged sponge spicules. There seems little question that the single specimen in the collection is identical to a form described and illustrated by Dietrich (1951), but since his material has never been published, the species will be referred to as Bathysiphon n. sp. A in this paper.

Hypotype.—Univ. of N. Dak. Cat. No. 1252.

Occurrence.—A single specimen of this species was found at locality AA.

Bathysiphon n. sp. B

Plate 1, figure 1.

Diagnosis.—Test elongate, often compressed along the axial line, with irregularly spaced growth wrinkles or constrictions; wall whitish, thick, composed of very fine, clear sand imbedded in a large amount of cement.

Measurements.—Length of figured specimen 1.76 mm.; breadth of figured specimen 0.19 mm.

Discussion.—Grouped under this designation are white colored specimens that are often compressed longitudinally giving the appearance of parallel, fused tubes as in Bathysiphon vitra Nauta. However, B. vitra is broader than Bathysiphon n. sp. B, and not white in color, but rather, covered with a grayish to black coating.

The wall of the specimens of Bathysiphon n. sp. B is composed of very fine grains with a white amorphous cement
which gives some of the specimens a subhyaline appearance. Because the wall is highly smooth, and growth wrinkles are not abundant, the specimens are different than *Bathyxiphon bronzi* Tappan, even though the two species compare favorably in dimensions.

These specimens superficially resemble the figures of *Bathyxiphon alexanderi* Cushman (Cushman, 1946, pl. 1), but Tappan (1957, p. 202) observes that the types of *B. alexanderi* are not *Foraminifera*, but inorganic, limonitic sticks.

**Hypotype.**—Univ. of N. Dak. Cat. No. 1253.

**Occurrence.**—Bathyxiphon n. sp. B is common at localities J, F, G, I, Y, AA and GG.

**?Bathyxiphon** sp. C

Plate 1, figure 3.

A fairly coarsely arenaceous, tube-like form was found at localities F and G. The specimens do not resemble any other specimens of the collection, nor any other species of *Bathyxiphon*, but they are questionably assigned to that genus. They are considered of little stratigraphic value at this time as their occurrence is so limited.

**Hypotype.**—Univ. of N. Dak. Cat. No. 1254.

**Family** 3accamminidae

**Pelosina** Brady, 1879

**Pelosina complanata** Franke, 1911

Plate 1, figure 5.

**Diagnosis.**—Test free, a single chamber with a short, stout neck; the whole crushed to a lenticular shape with a concave central region; wall whitish, much cement with a few coarsely arenaceous particles.

**Measurements.**—Diameter of figured specimen 0.33 mm.; thickness of figured specimen 0.10 mm.

**Discussion.**—A single specimen is identified as *Pelosina complanata*. This species is not commonly identified in the Pierre shale, but Searight (1937, p. 50 and 1938) does list it. Cushman (1946, p. 15) records it as having been found in the Austin chalk and Taylor marl of Texas.

**Hypotype.**—Univ. of N. Dak. Cat. No. 1255.

**Occurrence.**—The single specimen of this species was found at locality D.

**?Pelosina sp.**

Plate 1, figure 4.

Some specimens of questionable assignment are placed under the genus *Pelosina* Brady. The shape of these specimens is variable, but grades from spherical to flattened lenticular. As the shape is generally lenticular, it is suggested that distortion due to fossilization has altered the original shape from spherical to lenticular. The wall is usually very finely arenaceous with much cement, but some of the specimens (see the 60 mesh size of locality AA) have a slightly coarser texture. Absence of a neck on any
of the specimens throws doubt on their affinity with
Pelosina. Nevertheless, the writer feels they are some
primitive form of Foraminifera, hence, questionably makes
this assignment.

**Hypotype.**—Univ. of N. Dak. Cat. No. 1256.

**Occurrence.**—Occurrences of these doubtful forms were
at localities C, D, J, AA, HH, and II. Similar specimens
were found at locality JJ, but not picked.

**Family Ammodiscidae**

**Ammodiscus** Reuss, 1861

**Ammodiscus cretaceus** (Reuss), 1845

Plate 1, figure 23.

**Ammodiscus cretaceus** (Reuss). Frissell, D. L., 1954, Texas
Univ., Bur. Econ. Geol., Rept. Inv. 22, p. 58, pl.
1, fig. 15.

For further synonymy see Cushman, J. A., 1946, J. S. Geol.

**Diagnosis.**—Test planispiral, both sides slightly
concave; the second chamber increasing very slowly in diam-
eter as added; wall white, very finely arenaceous, with much
cement; aperture the open end of the tube.

**Measurements.**—Diameter of figured specimen 1.10 mm.;
thickness of figured specimen 0.19 mm.

**Discussion.**—This well known species occurs in this
study as a very variable form in both size and shape. The
variance in shape, in most cases, is likely due to dis-
tortion during fossilization.
Hypotype.—Univ. of N. Dak. Cat. No. 1257.

Occurrence.—In North Dakota Amodiscus cretaceus is common in the lower Pierre shale. In this study it was found at localities C, D, E, F, G, H, J, L, M, O, P, W, X, Y, AA and GG.

Glomospira Rhesak, 1888

Glomospira charoides var. corona Cushman and Jarvis, 1928

Plate 1, figures 13-14.


Diagnosis.—Test small, consisting of a proloculus and a tubular second chamber that coils about the test in a compressed, helicoid manner, becoming irregular, forming a crown at the end of the test; wall smooth, white, finely arenaceous, with much cement; aperture the open end of the tube.

Measurements.—Height of figured specimen 0.18 mm.; diameter of figured specimen 0.31 mm.

Discussion.—This distinctive species does not seem to have been reported from the Cretaceous of the Gulf Coast states. It has been reported from the Upper Cretaceous of Trinidad and Mexico (Cushman, 1946, p. 19) and the Sully member of the Pierre shale of South Dakota (Jearight, 1937, p. 50 and 1938).

Hypotype.—Univ. of N. Dak. Cat. No. 1258.

Occurrence.—This species is common at localities J and Y. One broken specimen from locality 39 is questionably
assigned to this species.

Family Lituolidae

*Haplophragmoides* Cushman, 1910

*Haplophragmoides* sp.

Plate 1, figure 24.

Numerous arenaceous specimens from several localities are referred to *Haplophragmoides* sp. Distortion due to fossilisation, has left these specimens in poor shape, such that few indicate the number of chambers and the plan of the sutures, which are important characteristics in species discrimination in this genus. The specimens show a gradational texture from those with a finely arenaceous wall to those with a coarser wall with less cement. These were not separated as an attempt to do so would have added little stratigraphic value.

It is likely that most of the specimens in the collection are one of two species commonly reported from the Pierre shale. The size of the arenaceous material of the wall suggests an affinity of some of the specimens with *Haplophragmoides rugosa* Cushman and Water. That species is recorded by Applin (1933, p. 219), Searight (1937, p. 60 and 1938), Dietrich (1951), Cushman (1927, *Side Nauss*, 1947, p. 330), and Wickenden (1941, *Side Nauss*, 1947, p. 330) from the Upper Cretaceous of the northern United States and southern Canada; and by Cushman (1946, p. 20-21) from the Upper Cretaceous Taylor and Navarro of the Gulf Coast.

Because *Haplophragmoides excavata* Cushman and Waters,
a form with a finely arenaceous wall, has been recorded from the Pierre shale by previous workers, including Searight (1937, p. 50 and 1938) and Dietrich (1951), the writer feels many of the specimens at hand may be that species. In the Gulf Coast states Cushman (1946, p. 21) reports H. excavata from strata of both Taylor and Navarro age, and in western Canada from the Upper Cretaceous.

Measurements.—Greatest diameter of figured specimen 1.29 mm.

Hypotype.—Univ. of N. Dak. Cat. No. 1259.

Occurrence.—Hapalophragmoidae sp. was common at localities C, D, E, F, G, H, I, J, K, L, M, AA, BB, EE, FF, and HH and rare at localities P, U, W, and CC.

Family Verneuillinidae

Gaudryina d'Orbigny, 1839

Gaudryina (Gaudryina) rugosa d'Orbigny, 1840

Plate 1, figure 11.

For the entries most frequently included within the synonymies for this species see Loetterle, G. J., 1937, Nebr. Geol. Survey, Bull. 12, p. 19.

For additional, numerous, synonymy entries see Ellis and Massina, 1940, Catalogue of Foraminifera, Aser. Mus. Nat. Hist., under Gaudryina rugosa d'Orbigny, 1840.

Diagnosis.—Test elongate, tapering to a pointed initial end, earliest stages triserial, bluntly angled, forming up to one-half the total length of the test, but usually about one-third; later biserial, sides slightly tapering,
with the widest portion at the apertural end; chambers of
the triserial portion indistinct, about 5 to 3 in the bi-
serial portion, slightly inflated; sutures in biserial
portion depressed, slightly oblique; wall usually finely
arenaceous; aperture an arched opening on the face of the
last chamber.

Measurements.—Length of figured specimen 0.91 mm.;
width of figured specimen 0.29 mm.

Discussion.—This species is highly similar to
Gaudryina rudita Sandidge. Cushman (1946, p. 34) notes that
recordings of G. rudita have been made as G. rugosa. How-
ever, Sandidge (1932A, p. 342) states of G. rudita: "This
species differs from G. rugosa of the Ripley in the greatly
reduced early triserial stage, and in having a much
rougher surface."

As mentioned in the diagnosis the triserial portion
of the specimens of the collection forms one-half to one-
third the total length of the test. None of the specimens
of the collection shows a very rough surface. Most are
rather smoothly finished.

Hypotype.—Univ. of N. Dak. Cat. No. 1260.

Occurrence.—G. rugosa is abundant at locality HH.

Gaudryina (Pseudogaudryina) nebrascensis Loetterle, 1937
Plate 1, figure 7.
For synonymy see Bolin, E. J., 1952, S. Dak. Geol. Survey,
Rept. Inv. 70, p. 16.

Diagnosis.—Test elongate in the adult form, early
portion triserial, short, periphery angled, one keel dividing at the break between the triserial portion and upper biserial portion to form a subquadrate, angled test in transverse view; chambers not distinct, numerous in the biserial portion with short downward projections of the chambers at the periphery; sutures fairly indistinct, oblique in the triserial portion, nearly horizontal in the biserial portion; wall finely arenaceous; aperture a narrow slit in a reentrant of the last chamber.

Measurements.—Length of figured specimen 0.54 mm.; breadth of figured specimen 0.25 mm.

Discussion.—Laudryina nebrasconensis Loetterle seems to bear a resemblance to Laudryina austinae Cushman which is commonly found in beds of Austin age of Texas. However, the latter can be differentiated from the former as it is a much broader form, being about twice as long as broad, whereas L. nebrasconensis is shorter but proportionately more narrow. Also, downward projections of the chambers at the peripheral angles do not seem to be a characteristic of L. austinae.

References to L. nebrasconensis seem to be rare. Loetterle (1937, p. 20) and Bolin (1952, p. 19) feel that the species is restricted to the Fort Hays member of the Niobrara Formation in Nebraska and South Dakota.

Hypotype.—Univ. of N. Dak. Cat. No. 1261.

Occurrence.—In this study L. nebrasconensis was common at locality I and rare at localities J and K.
Clavulinoideae Cushman, 1936

**Clavulinoideae insignis** (Plummer), 1931

Plate 1, figure 10.


**Diagnosis.**—Test large, triangular in transverse view, the edges with a definite, thin flange, the sides of the initial, short, triserial portion sharply tapering, those of the much longer uniserial portion straight, parallel; chambers distinct, rounded and often inflated in the uniserial portion; sutures distinct in the uniserial portion, slightly concave downwards; wall finely arenaceous; aperture rounded, terminal, on the end of a short neck.

**Measurements.**—Length of figured specimen 1.27 mm; breadth of figured specimen 0.39 mm.

**Discussion.**—*Clavulinoideae insignis* (Plummer) is very close to *Clavulinoideae trilatera* variety concava (Cushman), and of this Cushman (1946, p. 40) states:

This species is evidently derived from such forms as *Clavulinoideae trilatera* var. concava of the Taylor. It is a more extreme form with great differences between the microspheric and megaspheric forms and is marked by a very strong development of the keels.

Loetterle (1937, p. 58) gives the following differences be-
The species is very close to *G. trilatara* Cushman as figured from the Cretaceous of Tennessee. The only significant difference seems to be in the aperture, which in *G. insignia* Plummer is at the end of a short, definite neck.

Two characteristics of the specimens of the collection are observed to be distinctive enough for the writer to refer the specimens to *G. insignia* without hesitation. The specimens are definitely keeled and the aperture is protuberant or on the end of a short neck.

*G. insignia* has been reported from the Pierre shale of both Nebraska and South Dakota by Loetterle (1937, p. 53). Cushman (1946, p. 40) gives occurrences of the species in strata of Taylor age in Alabama, Arkansas, Mississippi and Texas.

**Hypotype.** Univ. of N. Dak. Cat. No. 1262.

**Occurrence.** Specimens of *G. insignia* were found to be common at localities V and W. At locality O the species was rare.

**Family Valvulinidae**

**Dorothia** Plummer, 1931

**Dorothia pupoides** (d'Orbigny), 1840

Plate 1, figure 12.


Pseudorivina amyloides d'Orbigny. Sandige, J. R., 1932, Jour. Paleontology, v. 6, p. 268, pl. 41, fig. 1.

**Diagnosis.**—Test subquadrate in transverse view, gently tapering for most of test, near the aperture and rapidly becoming pointed; initially more than three chambers to a short, then triserial, then biserial for more than one-half the length of the test; chambers early indistinct, but more distinct and inflated in the biserial portion; wall finely arenaceous; aperture an arched opening at the base of the last chamber.

**Measurements.**—Length of figured specimen 0.70 mm; width of figured specimen 0.33 mm.

**Discussion.**—After much consideration the specimens were referred to this species. They seem to resemble Dorothyia bullosa (Carsey), but they are not round in end view, rather subquadrate, and they also have a shorter biserial portion.

This species has a wide geographic occurrence having
been reported from the Saratoga chalk of Arkansas by Cushman (1931, p. 301), the Ripley formation of western Alabama by Sandidge (1932b, p. 268), the Dibobrara formation of South Dakota, Nebraska, and Kansas by Loetterle (1937, p. 19), and the Dibobrara formation of South Dakota by Bolin (1952, p. 20).

**Synotype.** Univ. of N. Dak. Cat. No. 1263.

**Occurrence.** *Dorothia putoides* was common in this study at locality 8N.

**Family Miliolidae**

*Quinqueloculina* d'Orbigny, 1826

*Quinqueloculina* cf. *Q. antiqua* var. *augustae*. Franke, 1928

Plate 1, figure 9.

*Quinqueloculina antiqua* (Franke) var. *augustae* (Franke).


**Diagnosis.**—Test small, elongate, about twice as long as broad, greatest breadth near the middle; chambers distinct, slightly inflated; sutures depressed; wall with a glassy appearance; aperture rounded, terminal.

**Measurements.**—Length of figured specimen 0.21 mm.; breadth of figured specimen 0.12 mm.; thickness of figured specimen 0.10 mm.

**Discussion.**—The principal reason for not making a
direct referral of the specimen to \textit{Quinqueloculina antiqua} var. \textit{angusta} is that the apertural end does not protrude. In the description of the variety Cushman (1946, p. 43) states that the apertural end does protrude. In all other respects the specimen is similar to the variety.

\textbf{Hypotype.}—Univ. of N. Dak. Cat. No. 1264.

\textbf{Occurrence.}—The single specimen identified as \textit{Quinqueloculina} cf. \textit{Q. antiqua} var. \textit{angusta} was found at locality \textit{MM}.

\textit{Quinqueloculina} sp.

Plate 1, figure 6.

Single specimens of \textit{Quinqueloculina} sp. were found at localities \textit{N}, \textit{O}, \textit{P}, and \textit{R}. Two poorly preserved specimens were found at locality \textit{T}. In establishing that these specimens had a calcareous wall the specimen from locality \textit{R} was destroyed.

The specimens are quinqueloculina, rounded in side view and have chambers a half-coil in length. The side that shows four chambers (the inner chamber is not clearly distinct) is convex in all of the specimens. The other side of the forms from localities \textit{N}, \textit{R}, and \textit{T} is flat and shows only three chambers. The inner chamber of the forms from localities \textit{O} and \textit{P} is slightly inflated and clearly visible. A single tooth is visible on the specimen from locality \textit{P}, but not on the other specimens.

\textbf{Measurements.}—Length of figured specimen 0.33 mm.

\textbf{Hypotype.}—Univ. of N. Dak. Cat. No. 1265.
Triloculina d'Orbigny, 1826

Triloculina sp.

Plate 1, figure 15.

A specimen of Triloculina sp. was found at locality G. The specimen resembles Triloculina circularis Borneman, but the writer hesitates to make that assignment, based on a single specimen. Cushman (1946, pl. 14, figs. 26 and 27) illustrates a specimen of T. circularis which is slightly different than the specimen of the collection. Cushman's illustration is of a form that apparently has never reached the triloculine stage. It shows quinqueloculine chambers, whereas the specimen in the collection is definitely triloculine and shows only three chambers. The final chambers of the specimen of the collection are nicely rounded and inflated; the aperture is rounded without a tooth, but with a small lip.

Measurements.—Length of figured specimen 0.35 mm.; breadth of figured specimen 0.33 mm.; thickness of figured specimen 0.26 mm.

Hypotype.—Univ. of N. Dak. Cat. No. 1286.

Occurrence.—The single specimen of Triloculina sp. was found at locality G.

Family Lagenidae

Robulus Montfort, 1808

Robulus navarroensis var. navarroensis (Plummer), 1927

Plate 1, figure 17.


For further synonymy see Cushman, J. A., 1946, U. S. Geol. Survey, Prof. Paper 206, p. 51, pl. 16, figs. 6-8.

**Diagnosis.**—Test completely involute, with a small umbo of clear shell material, periphery with a large, flange-like keel; chambers distinct, eight or nine in the last whorl, increasing gradually in size as added; sutures distinct, slightly curved, limbate, flush with the surface; wall smooth, finely perforate; aperture radiate, at the peripheral angle, with an accessory apertural slit below.

**Measurements.**—Diameter of figured specimen 0.77 mm.; thickness of figured specimen 0.31 mm.

**Discussion.**—This form is distinguished from other Upper Cretaceous species of this genus by its large, flange-like keel. Cushman (1946, p. 52) reports Robulus navarroensis var. navarroensis only from strata of Navarro age in the Gulf Coast states, whereas (Frizzell 1954, p. 81) reports it from strata of Taylor and Navarro age. It has also been reported from the Niobrara formation of Kansas, Nebraska, and South Dakota by Loetterle (1937, p. 20-21) and South Dakota by Bolin, (1952, p. 21-22).

**Hypotype.**—Univ. of N. Dak. Cat. No. 1267.

**Occurrence.**—In this study R. navarroensis var. navarroensis was common at locality Y and rare at locality W.
Robulus Montfort, 1808

Robulus taylorensis (Plummer), 1931

Plate 1, figure 18.


Diagnosis.—Test involute, becoming evolute, compressed, umbonate, periphery angled or with a very narrow, thick keel in most specimens; chambers distinct, six to eight in the adult whorl, last two or three inflated; sutures distinct, early flush with the surface, depressed between the last few chambers, curved, limbate near the periphery; wall calcareous, finely perforate; apertural face rounded, triangular; aperture radiate, at the peripheral angle, somewhat protruding.

Measurements.—Length of figured specimen 0.38 mm.; breadth of figured specimen 0.70 mm.; thickness of figured specimen 0.23 mm.

Discussion.—This species is easily recognized. Distinguishing characteristics are the inflated final chambers, the tendency of the test to become involute, and the sutures that are limbate near the periphery. The species seems to resemble Robulus mustari (Boomer), but according to Cushman (1946, p. 53) R. mustari has nine to twelve chambers in the adult coil, while the specimens of the collection rarely have as many as nine chambers.
Cushman (1946, p. 53) reports *A. taylorensis* as being particularly abundant in the lower beds of Taylor age and rare in the upper beds of both Austin and Taylor age. There seems to be no previous references to this species from beds of the Upper Cretaceous in the northern midcontinent.

**Type.**—Univ. of N. Dak. Cat. No. 1268.

**Occurrence.**—This species is abundant at locality HH. It was found at no other locality in this study.

*Aobulus trinitatensis* Cushman and Jarvis, 1932

Plate 1, figure 16.


This species was described by Cushman and Jarvis (1932, p. 22) as:

Test close coiled, compressed, periphery slightly keeled; chambers fairly distinct, 6 to 8 in number in the adult, not inflated; sutures fairly distinct, strongly curved, continuing into the umbilical region, strongly limbate, but not raised; wall ornamented by a series of obliquely curved costae, toward the periphery gradually becoming nearly parallel to the outer edge of the test, and continuous over the chambers; aperture at the peripheral angle, with a supplementary elongate opening in the median line of the ventral face.

**Measurements.**—Length of figured specimen 0.35 mm.; thickness of figured specimen 0.17 mm.

**Discussion.**—This interesting species seems to be rare. It has only been reported from the Upper Cretaceous of Trinidad (Cushman, 1946, p. 54), but according to Cushman (1946, p. 54) "a species very close to this, and perhaps
identical, occurs in the Arkadaphia clay of Texas." If
the Texas form is the same species, R. trinitatensis occurs
in the Navarro group of Texas.

Hypotype.—Univ. of N. Dak. Cat. No. 1269.

Occurrence.—One specimen of this species was found
at locality J.

Rohulus sp.

Six specimens from locality NN are only identified
as Rohulus sp. The apertural characteristics cannot be
determined, and most show no other good, identifying charac-
teristics.

Hypotype.—Univ. of N. Dak. Cat. No. 1270.

Lenticulina Lamarck, 1804

Lenticulina rotulata (Lamarck), 1804

Plate 1, figure 22.

Econ. Geol., Rept. Inv. 22, p. 82.

Diagnosis.—Test large, involute, sides convex,
periphery slightly keeled; about six to nine chambers in the
last whorl of the adult; sutures limbate, slightly curved,
raised, tangential to the periphery, elevated at the center
where they fuse with a slightly raised boss at the center;
wall calcareous, finely perforate; apertural face large,
triangular, flat; aperture radiate, at the peripheral angle.

Measurements.—Greatest diameter of figured specimen
1.66 mm.; thickness of figured specimen 0.48 mm.
Discussion.—Specimens assigned to this species are umboate and keeled; they show a radiate aperture and only slightly raised sutures. In general this species is variable, especially in the height of the sutures and the amount of keel that is preserved.

The specimens of *Lenticulina rotulata* (Lamarck) may be confused with the specimens of *Robulus austeri* (Roemer), but the latter species has a supplementary apertural opening near the periphery and a greater number of chambers in the final whorl (nine to eleven). *L. rotulata* may also be confused with *Robulus navarroensis* (Plummer), but differs in the number of chambers and the height of the sutures, as *R. navarroensis*, according to Cushman (1946, p. 51-52), generally has ten to twelve chambers in the adult whorl, highly raised sutures and an additional apertural opening below its radiate aperture.

Cushman (1946, p. 56-57) gives the occurrence of this species in the Gulf Coast states in beds of Navarro, Taylor and Austin age. To the writer's knowledge the only previous reference to this species from Upper Cretaceous strata of the northern midcontinent was made by Dietrich (1951), who recorded it from the Pierre shale of Nebraska.

**Hypotype.—** Univ. of N. Dak. Cat. No. 1271.

**Occurrence.**—*L. rotulata* was found to be common at localities A and B, but rare at locality HH.

**Marginulina d'Orbigny, 1826**

**Marginulina austiniana var. austiniana** Cushman, 1937
Plate 1, figure 19.
For synonymy see Frizzell, O. L., 1954, Texas Univ., Bur.
Econ. Geol., Rept. Inv. 22, p. 54.
The description of this species, as given by Cushman
(1937, p. 92) is:
Test elongate, compressed, early portion close
coiled and umbonate, later portion uncoiled, dorsal
side gently curved, ventral side slightly lobulate;
chambers of the early coiled portion indistinct,
later uncoiled ones more distinct, but not inflated;
sutures indistinct except in the later portion where
they are slightly curved, somewhat limbate with a
decided boss-like thickening toward the dorsal side
of the middle; wall smooth except for the sutural
enlargements; aperture radiate, at the outer
peripheral angle.

Measurements.—Length of figured specimen 1.22 mm.;
breadth of figured specimen 0.43 mm.; thickness of figured
specimen 0.28 mm.

Discussion.—This distinctive species is easily sepa-
rated from the other species of this genus by the sutural
characteristics. From Cushman's description it is noted
that the sutures become noticeably limbate on the dorsal side
of the test. The specimens of the collection show this
character very well.

Cushman (1946, p. 59) records this species only from
beds of Austin age in Texas. Apparently it has never been
previously recorded in any other state.

Hypotype.—Univ. of N. Dak. Cat. No. 1272.

Occurrence.—The specimen referred to this species
was found at locality 3, where it is rare.

Marrinolina bullata? Reuss, 1845
Plate 1, figure 26.


Geol. Survey, Rept. Inv. 70, p. 25, fig. 11.


Univ., Bur. Econ. Geol., Rept. Inv. 22, p. 84, pl. 6,

figs. 34-36.

For further synonymy see Cushman, J. A., 1946, U. S. Geol.

Survey, Prof. Paper 206, p. 62.

**Diagnosis.**—Test stout, earliest portion coiled, later uncoiled, subcircular in transverse view; chambers few in number, increasing rapidly in size, last chamber very highly inflated; sutures indistinct, flush with the surface in the earliest stages, the last suture depressed; wall smooth, finely perforate; aperture radiate, protuberant.

**Measurements.**—Length of figured specimen 0.36 mm.; greatest diameter of figured specimen 0.19 mm.

**Discussion.**—The questionable assignment of one specimen to this species was made because of the debatable amount of protuberance of the aperture. Cushman (1946, p. 62) describes the aperture of this species as being on the end of a cylindrical neck. The specimen does have a radiate, protuberant aperture, but there is some doubt that it would be considered to be on the end of a cylindrical neck.

In the Gulf Coast states *Marginulina bullata* Reuss has been reported from strata of Taylor and Navarro age. Bolin (1952) reported it from the Niobrara formation of South Dakota, as did Dietrich (1951) from the Pierre shale of Nebraska.
Hypotype.—Univ. of N. Dak. Cat. No. 1273.

Occurrence.—The specimen assigned to this species was found in the sample from locality A.

Marginalina jensei Reuss, 1862 (1863)

Plate 1, figure 25.


Loetterle (1937, p. 60) described this species as:

Test elongate, in the early portion keeled, closely coiled, later completely uncoiling and becoming uniserial, compressed in the early coiled stage, ornamented by longitudinal costae extending the length of the test; chambers few, indistinct, except final one or two, rounded in section; sutures indistinct, obscured by the ornamentation; aperture terminal, radiate, at the end of a short neck. Length of figured specimen, .55 mm; width, .22 mm.

Measurements.—Length of figured specimen 0.96 mm; greatest diameter of figured specimen 0.27 mm.

Discussion.—Loetterle's illustrations are of a specimen that shows only one distinct, inflated chamber in the uniserial portion of the test. A few specimens of this collection are practically identical to his illustrated specimens in size and the number of distinct, inflated chambers of the uniserial portion. However, the writer found that as this species increases in size there is a comparable increase in the uniserial portion of the test, hence an increase in the number of distinct chambers of the uniserial portion of the test. It is likely that the specimen Loetterle illustrated is an atypical form, and that the typical form shows more
than two distinct, inflated chambers in the uniserial portion of the test.

Of interest is one aberrant specimen. This broken specimen, which shows only the last two chambers, has a double aperture. A normal, radiate aperture is present at the end of the final chamber, and in addition a radiate aperture protrudes out to the side from between the penultimate and final chamber.

This easily recognized species differs from *Marginulina trinitensis* Cushman whose costae fade out on the last chamber giving a banded appearance to the form. Small specimens are somewhat like *Marginulina gatasi* Fappan, but the two species may be differentiated, as *M. gatasi* usually has about twelve costae, while *M. jonasi* usually has more than twelve costae, because as growth proceeds occasional bifurcations of the costae cause the number to increase toward the apertural end, where it may become greater than fifteen. Also the chambers in the uniserial portion of *M. gatasi* are overlapping. *Marginulina radiata* Terqueux differs from *M. jonasi* as the costae of the former cross the sutures obliquely.

The known previous records of this species are mostly from Europe. Nevertheless, both Loetterle (1937) and Dietrich (1957) have reported it from the Pierre shale of Nebraska. Of this Loetterle (1937, p. 60) states: "This species seems to be a good marker for the Pierre shale of Nebraska and South Dakota but the stratigraphic range has not
been fully determined." It seems to the writer that Loescherle's contention holds well to the present, and that H. jonesi may possibly serve as a Pierre index in the northern midcontinent.

*type*.—Univ. of N. Dak. Cat. No. 1274.

*Occurrence.*—This species is common in the 40, 60, and 80 mesh portions of the samples from localities F, G, H, J, K, and G.

**Marginulina navarroana** Cushman, 1937

Plate 1, figure 20.


**Diagnosis.**—Test initially compressed, coiled, then becoming uncoiled and subcircular in top view; chambers numerous, fairly indistinct in the coiled portion, distinct, inflated in the later uncoiled portion of the test; sutures distinct, depressed, oblique in the uniserial portion; wall with medium coarse costae that are slightly twisted and generally not interrupted by the sutures; aperture radiate, protruding.

**Measurements.**—Length of figured specimen 1.20 mm.; maximum diameter of figured specimen 0.43 mm.

**Discussion.**—The single specimen assigned to this species seems identical to specimens of this species illustra-
ted by Cushman (1946, pl. 2, figs. 1-5). Previous refer-
ences to the species have been made from beds of Navarro age
in Alabama and Texas.

**Hypotype.**-Univ. of N. Dak. Cat. No. 1275.

**Occurrence.**-The nicely preserved specimen of *M.
navarroana* was found at locality V.

*Marginalina* sp. A

Plate 1, figure 21.

One many chambered, compressed *Marginalina*, col-
lected at locality W, appears to be closely related to the
specimen Cushman (1946, pl. 22, fig. 24) illustrates as
*Marginalina* sp. B (not to be confused with *Marginalina* sp. B
of this paper). Cushman states that the specimen may be an
abnormal form. The only apparent difference in the specimens
is the absence, in the specimen of the collection, of limbate
sutures, which Cushman's illustrated specimen appears to
possess. For the record, *Marginalina* sp. A is initially,
rather closely coiled, although the initial chambers are in-
distinct. The later portion of the test is uncoiled and
curved; the chambers in this portion of the test are distinct
and become inflated and rounded in top view near the apertural
end. Depressed sutures are present in the later portion of
the test. The wall is smooth throughout, and the aperture
is radiate, only slightly protruding.

**Measurements.**-Length of figured specimen 1.13 mm.;
breadth of figured specimen 0.16 mm.; thickness of figured
specimen 0.12 mm.
**Marginulina** sp. 3

Under this heading are grouped a few specimens from localities A and B that are not further identified due to a shortage of good specimens. Identification is very difficult as the specimens do not have distinctive characteristics. In shape and size they do resemble *Marginulina texascensis* Cushman, which has been reported by Cushman (1946, p. 6) from strata of Taylor and Navarro age in the Gulf Coast states.

**Dentalina** d'Orbigny, 1826

**Dentalina aculeata** d'Orbigny, 1840

*Plate 2, figure 19.*

**Dentalina aculeata** (d'Orbigny)? Frissell, J. L., 1954,

*Texas Univ., Sur. Econ. Geol., Rept. Inv. 22, p. 86,*

*pl. 9, fig. 27.*

For further synonymy see Bolin, E. J., 1952, S. Dak. Geol.


The specimens referred to this species are all incomplete. They do, however, show a generally globular chamber with a neck above and below which probably served to link the chambers together. Spines of varied size abundantly cover the chambers and necks. The specimen from locality 8 and one of the specimens from locality 7 (60 mesh size) are more elongate in side view, and are not definitely spiny, although some evidence for the spines can be seen. These latter men-
tioned forms appear to be more closely related to the specimens illustrated under this species by Cushman (1946, pl. 26, fig. 17) from the Annona chalk of Taylor age, and Bolin (1952, pl. 1, fig. 13) from the Niobrara formation, while the former are more like a specimen from the Cretaceous of Trinidad, as illustrated by Cushman (1946, pl. 26, fig. 18).

**Measurements.**—Diameter of figured specimen 0.17 mm.

**Hypotype.**—Univ. of N. Dak. Cat. No. 1278.

**Occurrence.**—In this study *D. aculeata* was found to be common at locality V and rare at localities A and T.

*Dentalina basiplanata* Cushman, 1938

Plate 2, figure 7.


For further synonymy see Bandy, C. L., 1951, Jour. Paleontol., v. 25, p. 449-500.

**Diagnosis.**—Test elongate, straight to slightly arcuate, initial end broadly rounded; chambers distinct, initially wider than high, then becoming higher than wide and slightly inflated; sutures distinct, only slightly oblique, depressed in the later portion of the test; wall smooth; aperture radiate (not well preserved in the specimens in this collection).

**Measurements.**—Length of figured specimens 0.93 mm.; diameter of figured specimens 0.18 mm.

**Discussion.**—No complete specimens were available for
this identification, but the material on hand shows this species to be distinctive in that the sides only slightly taper and the chambers increase evenly in height as added. The initial chambers are not as high as wide, but the last few attain a height that is given as a ratio of height to diameter of 3:2 by Bandy (1951, p. 500).

In addition to Bandy's reference to this species from the Upper Cretaceous of California, Cushman (1946, p. 68) lists several occurrences from strata of Taylor and Navarro age. Dietrich (1951) recorded the species in the Pierre shale of Nebraska.

**Hypotype.** Univ. of N. Dak. Cat. No. 1279.

**Occurrence.** *Dentalina basiplanata* Cushman was common in the samples from localities A and B and rare in that from locality Q.

*Dentalina cf. D. basitorta* Cushman, 1936

Plate 2, figure 13.

*Dentalina basitorta* Cushman. Frissell, D. L., 1954, Texas Univ., Bur. Econ. Geol., Rept. Inv. 22, p. 67, pl. 9, fig. 34.


**Diagnosis.**—Test medium in size, slightly curved, with a bluntly pointed initial end; chambers somewhat twisted on the axis, few in number, the first two or three broader than high, last two much higher, strongly inflated; sutures distinct, highly oblique, those between the last three chambers
depressed, others less so; wall smooth, finely perforate; aperture radiate, protruding.

Measurements.—Length of figured specimen 0.46 mm.; diameter of figured specimen 0.16 mm.

Discussion.—This identification is left without an unquestioned species designation as only two specimens with the above characteristics are on hand. The specimens differ from *D. basitorta* in the absence of a basal spine. *D. basitorta* may also be more twisted upon its axis than are the specimens of the collection. The specimens are somewhat like *Dentalina leucum* Zeuss as illustrated by Cushman (1946, pl. 23, figs. 1-2), but that species does not appear to have as highly oblique sutures.

Hypotype.—Univ. of N. Dak. Cat. No. 1280.

Occurrence.—Single specimens referred to this species were found at localities A and B.

*Dentalina* cf. *D. consobrina* d'Orbigny, 1846

Plate 2, figure 12.


Diagnosis.—Test large, elongate, gently tapering; chambers elongate, subcylindrical, inflated progressively more with growth; sutures distinct, oblique, slightly depressed; wall smooth, finely perforate; aperture radiate.

Measurements.—Length of figured specimen 1.27 mm.; diameter of figured specimen 0.28 mm.

Discussion.—Only fragments are available for this
identification, and of these only one specimen shows a radiate aperture. Fragments of the lower portion of three specimens show a rounded initial end. Cushman (1946, p. 69) states that this species generally has an initial spine, a characteristic described by d'Orbigny. Because none of the specimens show this characteristic they cannot be definitely assigned to this species.

**Hypotype**.—Univ. of N. Dak. Cat. No. 1281.

**Occurrence**.—This species is rare at locality A. At locality BH it is common.

**Dentalina crinita** Plummer, 1931

**Plate 2, figure 1.**


For further synonymy see Cushman, J. A., 1946, J. S. Geol.

**Jursey**, Prof. Paper 206, p. 69.

**Magnesia**.—Test long, elongate, arcuate, initial end broadly rounded; chambers numerous, wider than high throughout most of the test, but the last few becoming lengthened and inflated; sutures distinct, somewhat thickened, slightly oblique and depressed; wall covered with very fine, parallel, longitudinal costae that mostly do not transgress the sutures; aperture terminal, protruding, radiate.

**Measurements**.—Length of figured specimen 1.42 mm.; diameter of figured specimen 0.26 mm.

**Discussion**.—The fine, longitudinal costae make this...
species easily recognizable. Plummer (1931, p. 155) mentions that specimens of this species are rarely smooth, so it is conceivable that in the future all North Dakota specimens of this species will display the hirsute appearance.

**Synotype.**—Univ. of N. Dak. Cat. No. 1282.

**Occurrence.**—This species is rare; it is represented by only two broken specimens from locality B.

**Dentalina gracilis** (d'Orbigny), 1840

Plate 2, figure 5.

**Dentalina gracilis** (d'Orbigny). Frissell, D. L., 1954,

Texas Univ., Sur. Econ. Geol., Sept. Inv. 22, p. 68, pl. 9, figs. 49–50.


**Diagnosis.**—Test medium for the genus, elongate, slightly to strongly curved, gently tapering to the initial chamber which is broadly rounded; chambers distinct, wider than high at the initial end, becoming higher than wide and inflated toward the apertural end; sutures distinct, somewhat oblique, limbate, depressed; aperture radiate, protruding.

**Measurements.**—Length of figured specimen 1.47 mm.; diameter of figured specimen 0.18 mm.

**Discussion.**—The obliquity of the sutures, protruding aperture and the chambers that become higher than wide and inflated near the apertural end are criteria for the reference of the specimens to this species. Cushman (1946, p. 65,
pl. 23, figs. 3-5) states that this is a variable species and illustrates forms that show this variation. Some of the figures show specimens with a basal spine, whereas others do not. In regard to this matter Sandy (1951, p. 501) feels that forms with a basal spine should be assigned to *Dentalina vimani* Brotzen. The writer agrees with Sandy and has referred those forms with basal spines to *D. vimani*, which also has chambers that are characteristically less inflated than those of *D. gracilis*.

**Hypotype.**—Univ. of S. Dak. Cat. No. 1283.

**Occurrence.**—Specimens of *D. gracilis* were rare at localities 3 and 4.

*Dentalina lorenziana* d'Orbigny, 1840

Plate 2, figure 3.


**Diagnosis.**—Test medium for the genus, slightly curved, elongate, initial and broadly rounded; chambers distinct, inflated near the apertural end, wider than high initially, becoming more elongate near the apertural end; sutures distinct, depressed, oblique; wall smooth, finely perforate; aperture radiate, protruding.
Measurements.—Length of figured specimen 0.68 mm.;
diameter of figured specimen 0.15 mm.

Discussion.—Referred to this species is a specimen
with a rather broadly rounded, initial chamber and later
chambers that increase fairly rapidly in height near the
apertural end. The illustrations of this species given by
Loetterle (1937, pl. 2, fig. 5), Bolin (1952, pl. 2, fig. 1),
and Cushman (1946, pl. 23, figs. 7-11) would indicate that
this must be a variable species. In this study a single
specimen resembles those illustrated as Dentalina lorniana
d'Orbigny by Loetterle and Bolin.

This species occurs in strata of Austin, Taylor, and
Navarro age in the Gulf Coast states. In South Dakota it
occurs in the Niobrara formation (Bolin, 1952, p. 27), and
in Nebraska it occurs in both the Niobrara (Loetterle, 1937,
p. 25) and Pierre (Dietrich, 1951) formations.

Hypotype.—Univ. of N. Dak. Cat. No. 1284.

Occurrence.—One specimen of *D. lorniana* was found
at locality N.

**Dentalina of *D. macalopolitana* Reuss, 1855**

Plate 2, figure 14.

Univ., Bur. Econ. Geol., Rept. Inv. 22, p. 89, pl. 9,
figs. 50-61.

For further synonymy see Cushman, J. A., 1946. U. S. Geol.
Survey, Prof. Paper 206, p. 67.

**Diagnosis.**—Test elongate, tapering, slightly curved,
initial end sharply pointed; chambers numerous, not inflated, of similar shape, wider than high initially, increasing regularly in size as added, becoming higher than wide near the apertural end; sutures oblique, somewhat thickened, flush with the surface; wall smooth, finely perforate; aperture terminal, radiate.

Measurements.—Length of figured specimen 0.51 mm; diameter of figured specimen 0.17 mm.

Discussion.—The main criterion for the assignment of these specimens to this species is their distinctive shape. The specimens flare from an initially pointed end. The fairly oblique character of the suture eliminates an unquestionable, direct assignment to this species. There is also some doubt of the radiate nature of the aperture, as no complete, unbroken specimens have been found. However, the aperture on one of the specimens does appear to be radiate.

Reuss describes this species as beginning with a pointed initial end. Bandy (1951, p. 550) observed that the California forms of Upper Cretaceous age, which he referred to this species, are not apiculate. Also, it appears that those forms from the Selma chalk of Tennessee and the Saratoga chalk of Arkansas are not apiculate (see Cushman, 1946, p. 57, pl. 23, figs. 24-26). Apparently the forms from the Pierre shale are more closely related to the European than to the California, Arkansas and Tennessee forms.

Hypotypos.—Univ. of N. Dak. Cat. No. 1265.

Occurrence.—Dentalina cf. D. megalopolitana was
common at localities 4 and 3.

**Dentalina cf. D. niobrarensis** Loetterle, 1937
Plate 2, figure 2.

**Dentalina niobrarensis** Loetterle, 1937, Nebr. Geol. Survey, Bull. 12, p. 24, pl. 2, fig. 3.


**Diagnosis.**—Test large, gently tapering, initial end with a bulbous protoconch whose axis is at an acute angle from the axis of the remaining chambers; chambers distinct, few in number, inflated, subspherical, increasing gradually in size as added; sutures distinct, depressed, gently oblique; wall smooth, finely perforate; aperture radiate, at the inner angle of the terminal face.

**Measurements.**—Length of figured specimen 1.18 mm.; diameter of figured specimen 0.26 mm.

**Discussion.**—The single specimen is somewhat like **D. niobrarensis**, but is larger than that species. Additional specimens would most likely show a variation in size and indicate that **D. niobrarensis** attains a size as large as the specimen in the collection. The absence of a basal spine eliminates an assignment to **Dentalina catusula** Reuss, which is about the same size.

Previous references to this species have been made by Loetterle (1937) and Bolin (1952) from the Niobrara formation. To the writer's knowledge this species has never been reported from the Pierre shale.
Hypotype.—Univ. of N. Dak. Cat. No. 1286.

Occurrence.—Dentalina cf. D. niobrarensis was rare at locality B.

Dentalina wimani Brotzen, 1936

Plate 2, figure 6.

For synonymy see Bandy, O. L., 1951, Jour. Paleontology, v. 25, p. 501.

Diagnosis.—Test elongate, slightly arcuate, gently tapering to the initial chamber which is apiculate; chambers distinct, initially broader than high, later becoming higher than wide and slightly inflated; sutures distinct, oblique, slightly depressed throughout; wall smooth; aperture radiate, protruding.

Measurements.—Length of figured specimen 0.21 mm.; diameter of figured specimen 0.13 mm.

Discussion.—Dentalina wimani Brotzen is a distinctive species that should not be confused with any other. The apiculate initial and separates it from Dentalina gracilis d'Orbigny. Bandy (1951, p. 501) states that specimens with an initial spine that have previously been referred to D. gracilis, should be referred to D. wimani.

Hypotype.—Univ. of N. Dak. Cat. No. 1287.

Occurrence.—D. wimani was common at localities A, B, and K, and rare at L, M, O, Q, and U.

Nodosaria Lamarck, 1812

Nodosaria distans Reuss, 1855
Plate 2, figure 25.


**Diagnosis.**—Test elongate, slender, slightly tapering, with a short, initial spine; chambers inflated; sutures depressed, limbate; wall with about seven to twelve, high, plate-like costae that extend the length of the test; aperture radiate, protruding.

**Measurements.**—Length of figured specimen 2.05 mm.; diameter of figured specimen 0.34 mm.

**Discussion.**—Single specimens with the above characteristics were found at localities G and J. The diagnostic characteristic for this assignment is the shape of the test and the number of costae. Most important, however, is the characteristic of distinct separation between chambers, which the specimens of the collection show very well. The specimens are similar to the specimen from the Upper Cretaceous of Peru illustrated by Frissell (1943, pl. 56, fig. 14) as _Hodosaria_ sp. aff. _H. distans_ Reuss. The specimens differ from _Hodosaria paumercula_ Reuss in having fewer costae.

In the Gulf Coast states _H. distans_ has been reported from strata of Austin age and lower strata of Taylor age. No previous reference to the species from the Pierre or Niobrara formations is known.
Hypotype.—Univ. of W. Dak. Cat. No. 1288.

Occurrence.—The specimens referred to this species were rare at localities G and J.

Nodosaria paupercula Reuss, 1845
Plate 2, figure 10.


Diagnosis.—Test large, elongate, with a short initial spine; chambers sub-globular, highly inflated, all nearly the same size except the initial chamber, which is larger than the later chambers in the megalospheric form; sutures indistinct, depressed; wall with ten to fourteen, coarse costae that extend the length of the test, some bifurcating to form new costae; aperture radiate, protruding.

Measurements.—Length of figured specimen 2.48 mm.; diameter of figured specimen 0.44 mm.

Discussion.—The characteristics that helped distinguish this species from Nodosaria distans Reuss in this study, which it resembles, are the highly inflated, sub-globular form of the chambers, the greater number of costae and the absence of lixibate sutures. The specimens somewhat resemble Dentalina delicatula Cushman, but D. delicatula has more ribs, and none cross the sutures as in N. paupercula. The specimens closely resemble figures of this species from
Trinidad as given by Cushman (1946, pl. 27, figs. 10-12). Cushman states that his illustrated specimens may not be "identical" to the specimens figured by Reuss, but it is the writer's opinion that Cushman's specimens, Reuss's specimens, and the specimens of the collection are probably the same species.

**Hypotype.**—Univ. of N. Dak. Cat. No. 1289.

**Occurrence.**—This species is rare at localities C and K.

**Modosaria proboscidea** Reuss, 1851

Plate 2, figure 26.


**Diagnosis.**—Test short, tapering to the initial end which has a short spine; chambers distinct, few; sutures distinct, depressed, wall ornamented with twelve to fifteen plate-like costae that are not broken at the sutures and run the length of the test; aperture central, at the end of a short neck that may be broken in all the specimens.

**Measurements.**—Length of figured specimen 0.50 mm.; diameter of figured specimen 0.21 mm.

**Discussion.**—**Modosaria proboscidea** Reuss is a form that should not be confused with any other Foraminifera of the Pierre shale in North Dakota. It probably should be
noted that the specimens from the Pierre shale do not seem "identical" to a specimen from the upper part of the Taylor marl of Texas as illustrated by Cushman (1946, pl. 26, fig. 12). Cushman's illustration shows a form with costae that die out near the top of the last chamber, whereas the specimens of the collection are more like the type described by Reuss as having thirteen to fourteen costae that run the length of the test.

**Hypotype.**—Univ. of N. Dak. Cat. No. 1290.

**Occurrence.**—This species is rare at localities D and F.

### Nodosaria zippai Reuss, 1845

**Plate 2, figure 9.**

For synonymy see Bolin E. J., 1952, S. Dak. Geol. Survey, Rept. Inv. 70, p. 29.

**Diagnosis.**—Test large, elongate, sides nearly parallel in the megaspheric form, tapering in the microspheric form, with a short initial spine; chambers numerous, distinct, only slightly inflated, wider than high, nearly the same size throughout; sutures distinct, limbate; wall with seven to ten coarse costae that run the length of the test; aperture (not observed) probably radiate.

**Measurements.**—Length of figured specimen 2.45 mm.; diameter of figured specimen 0.53 mm.

**Discussion.**—Cushman (1946, pl. 25, figs. 8-23) illustrates specimens which he refers to as *Nodosaria affinis* Reuss. They are apparently similar to specimens illustrated
by Sandige (1932b, pl. 42, figs. 13 and 14), Loetterle (1937, pl. 3, fig. 2) and Bolin (1952, pl. 2, figs. 4 and 5) as *Nodosaria zippel* Reuss. The confusion, due to interpretation of Reuss's intent, stems on whether *N. zippel* should be reserved for specimens with seven or more ribs or costae. Sandige (1932b, p. 275-278) discusses the problem fully and concludes that *N. affinis* has few ribs and *N. zippel* has a greater number (seven to fourteen) of ribs.

*N. zippel* (including *N. affinis* Reuss of Cushman, 1946) has often been recorded in strata of Austin, Taylor, and Navarro age in the Gulf Coast states. In Kansas, Nebraska and South Dakota it has been reported from the Niobrara formation. Dietrich (1951) reports *N. affinis* (probably *N. zippel*) from the Pierre shale of Nebraska.

**Hypotype.**—Univ. of N. Dak. Cat. No. 1291.

**Occurrence.**—*N. zippel* is rare at localities B and J.

*Nodosaria sp.*

Plate 2, figure 8.

A single specimen of *Nodosaria sp.* was obtained from the sample at locality J. The specimen resembles *Nodosaria zippel* Reuss in shape and *Nodosaria distans* in the number of costae. Highly limate sutures prohibit referral of the specimen to either of those species, and because only a single, broken specimen is present further identification is unwarranted.

**Measurements.**—Length of figured specimen 0.79 mm.
Hypotype.—Univ. of N. Dak. Cat. No. 1292.

**Chrysalosgonium** Schubert, 1907

**Chrysalosgonium oxium** Cushman, 1938

Plate 2, figure 4.


From locality O a single specimen resembles Chrysalosgonium oxium Cushman. The specimen is broken and does not show if it possesses a sieve plate for an aperture or a spine on the initial end, both characteristics of this species. Clearly shown, however, are the fine costae that ornament the wall, the limbate sutures and the long, straight chambers, characteristics suggesting that the specimen be assigned to this species.

**Measurements.**—Length of figured specimen 1.27 mm.

Hypotype.—Univ. of N. Dak. Cat. No. 1293.

**Chrysalosgonium cf. G. granti** (Plummer), 1927

Plate 2, figure 11.


**Diagnosis.**—Test elongate, slightly arcuate, apiculate; chambers numerous, initial chamber higher than wide,
those immediately above wider than high, increasing rapidly in length until they are about twice as high as wide near the apertural end; last few somewhat inflated; sutures distinct, limbate, only slightly depressed; wall smooth; aperture on the end of a neck.

**Measurements.**—Length of figured specimen 1.20 mm; diameter of figured specimen 0.14 mm.

**Discussion.**—A few specimens are very similar to *Chrysalagoconium granti* (Plummer) and may be that species, although the apertural characteristics are not distinct, and consequently, do not give a good indication of the species. The initial spines of the specimens is of use in distinguishing between this species and *Dentalina* cf. *D. consobrina* d'Orbigny. *Stilostomella exilia* Cushman has chambers which attain a length of three times the diameter, whereas the adult of *Chrysalagoconium* cf. *C. granti* has chambers that are about twice the diameter in length.

Cushman (1946, p. 136) reported this species from strata of Taylor and Navarro age in Texas and strata of only Navarro age in Arkansas and Mississippi. Also Bolin (1952, p. 27) reported the species from the Niobrara formation of South Dakota.

**Hypotype.**—Univ. of N. Dak. Cat. No. 1294.

**Occurrence.**—The specimens referred to *Chrysalagoconium* cf. *C. granti* were common at locality K and rare at locality G.

**Pseudoglandulina** Cushman, 1929
Pseudoglandulina bistegia (Olszewski), 1875
Plate 2, figure 16.

Diagnosis.--Test stout, initial end broadly rounded, apertural end pointed; chambers two in number, inflated, the first nicely rounded, the second pointed; sutures distinct, horizontal, depressed, limbate; wall smooth; aperture central, probably radiate (not clear).

Measurements.--Length of figured specimen 0.80 mm.; greatest diameter of figured specimen 0.35 mm.

Discussion.--Neither of the specimens referred to this species show the apertural characteristics well, and Cushman (1946, p. 76) observes that specimens of this species from the Upper Cretaceous of Trinidad do not possess well preserved apertural characters. Nevertheless, the specimens in this collection seem identical to the specimens illustrated by Cushman (1946, pl. 27, figs. 31 and 32).

The species has not been reported from either the Niobrara or Pierre formations previously. It seems to be quite rare.

Hypotype.--Univ. of N. Dak. Cat. No. 1295.

Occurrence.--P. bistegia was found at locality ? where it was rare.

Pseudoglandulina sp.
Plate 2, figure 15.

Diagnosis.--Test fusiform, about one-half as broad as
long, bluntly pointed at each end; chambers about five in number, the last making up about one-half the length of the test; sutures distinct, except in the early portion; slightly depressed; aperture probably radiate, at the end of a very short neck.

**Measurements.**—Length of figured specimen 0.25 mm.; greatest diameter of figured specimen 0.15 mm.

**Discussion.**—Only one specimen of this species was available, so the identification was left at the generic level. The condition of the aperture was such that a clear description of it cannot be given. Additional specimens may disclose this species to be *Pseudoglandulina lagenaoides* (Olsson), but the evidence for that identification is insufficient at this time.

**Hypotype.**—Univ. of N. Dak. Cat. No. 1296.

**Occurrence.**—A single specimen assigned to the genus *Pseudoglandulina* was present in the sample that was taken from locality B.

*Citharina* d'Orbigny, 1839

*Citharina multicostata* (Cushman), 1930

Plate 2, figure 24.


**Diagnosis.**—Test elongate, highly compressed, dorsal edge straight, ventral edge convex, pointed at both ends;
chambers numerous, oblique, slightly curved, increasing regularly in breadth as added; sutures distinct, oblique, lixivate, curved, sub-parallel to the ventral edge; wall with fine costae parallel to the dorsal edge, usually not transgressing the sutures; aperture on an extension of the dorsal edge, radiate.

**Measurements.**—Length of figured specimen 1.08 mm.; breadth of figured specimen 0.18 mm.; thickness of figured specimen 0.08 mm.

**Discussion.**—*Citharina multicostata* (Cushman) is a distinctive species. Although it is like *Citharina suturalis* (Cushman) the two may be distinguished by the costae, which, in *C. suturalis*, are limited to the sutures.

A discrepancy exists in the literature as to whether this species should be assigned to the genus *Citharina* or *Planularia*. In 1951 Sandy (p. 495) assigned it to *Planularia* on the basis of "the flat subtriangular test with chambers increasing rapidly in breadth as added." Then in 1954 Frizzell listed the species under the genus *Citharina*. According to descriptions of the two genera it appears that *Planularia* should include only those specimens with coiled initial chambers, and *Citharina* should be used for those species whose initial chambers are elongate and as oblique as the later chambers of the test.

Cushman (1946, p. 79) gives *C. multicostata* as common in strata of Navarro age in Texas, Arkansas, Mississippi, Alabama, and Tennessee. He states that specimens recorded
from beds below the Navarro are often rare and non-typical.

Hypotype.—Univ. of N. Dak. Cat. No. 1297.

Occurrence.—This species was found at localities P, G, I, J, and K. It is considered rare at localities P, G, and I and common at the other localities. The species is found chiefly in the 60 and 80 mesh portions of the samples.

*Frondicularia* DeFrance, 1826

*Frondicularia goldfussii* Reuss, 1860

Plate 2, figure 21.


For further synonymy see Bandy, O. L., 1951, Jour of Paleontology, v. 25, p. 497.

Only one specimen in the collection is referred to

*Frondicularia goldfussii* Reuss, but it fits the description of the species very well. The species is similar to *Pseudo-frondicularia extensa* (Morrow) from the Niobrara formation of Kansas, but the latter is smaller than *F. goldfussii* and tends, according to Morrow (1934, p. 193) to possess a broadly rounded periphery in edge view, rather than a flat, even slightly concave periphery as the specimens assigned to this species.

Measurements.—Length of figured specimen 2.53 mm.; width of figured specimen 1.03 mm.; thickness of figured specimen 0.12 mm.

Hypotype.—Univ. of N. Dak. Cat. No. 1298.

Occurrence.—This species, which is not known to have
been previously reported from the Pierre shale, was found only at locality V.

_Pseudofrondicularia_ Wedekind, 1937

_Pseudofrondicularia_ sp. A

Plate 2, figure 23.

A single specimen is assigned to _Pseudofrondicularia_ sp. A. The proloculus and chambers immediately above have been broken away, but the upper, remaining portion of the specimen shows the test to be elongate, narrow, with nearly parallel, straight sides that are truncated and visibly concave and thick in edge view. The chambers appear to be about six or seven in a reconstructed, complete individual; the raised sutures are sigmoid and nearly tangential to the sides of the test; the aperture is radiate, on the end of a short neck.

The specimen differs from _Pseudofrondicularia linearis_ (Franke), which has depressed sutures. _Pseudofrondicularia archiaciana_ (d'Orbigny) appears to be wider than the specimen at hand.

_Measurements._--Length of figured specimen 1.48 mm.; width of figured specimen 0.25 mm.; thickness of figured specimen 0.14 mm.

_Hypotype._--Univ. of N. Dak. Cat. No. 1290.

_Occurrence._--_Pseudofrondicularia_ sp. A is rare in this study being represented by a single specimen from locality W.
Plate 2, figure 22.

Two broken specimens from locality V are not assigned to a particular species as only the upper portion of the tests is preserved for identification. The specimens are similar to *Pseudofrondicularia verneuiliana* (d'Orbigny) in shape, but unlike it in possessing slightly costate sutures near the aperture. The specimens also resemble *Frondicularia inverse* Reuss and *Pseudofrondicularia intermittens* (Reuss) in certain characteristics, but both of these species have a rounded periphery in edge view, whereas *Pseudofrondicularia* sp. 3 has a truncated, flat periphery.

**Measurements.**—Length of figured specimen 2.08 mm.; width of figured specimen 0.85 mm.; thickness of figured specimen 0.20 mm.

**Hypotype.**—Univ. of M. Dak. Cat. No. 1300.

**Occurrence.**—*Pseudofrondicularia* sp. 3 was rare at locality 7.

*Lagenia* Walker and Jacob, 1798

*Lagenia hauteriviana* subsp. *hauteriviana*  
Bartenstein and Brand, 1951

Plate 2, figure 20.

For synonymy see Ellis and Messina, 1953, Catalogue of Foraminifera, Amer. Mus. Nat. Hist., under *Lagenia*  
*hauteriviana* Bartenstein and Brand subsp. *hauteriviana* Bartenstein and Brand, 1951.

**Diagnosis.**—Test ovoid in side view, circular in end view, with a short, narrow, initial spine and a thicker, long-
er, apertural neck; wall smooth, hyaline.

Measurements.—Length of figured specimen 0.19 mm.; diameter of figured specimen 0.09 mm.

Discussion.—The specimens referred to this species do not resemble any other specimens of the collection. They differ from *Lagena laevia* var. *stavensis*? Bandy in shape, being more elongate, and in possessing a basal spine. The smooth wall separates them from *Lagena* sp. B.

Hypotype.—Univ. of N. Dak. Cat. No. 1301.

Occurrence.—The specimens assigned to this species occurred at localities H, J, N, O, and J, where they were rare.

*Lagena laevia* var. *stavensis*? Bandy, 1949

Plate 2, figure 17.

For synonymy see Bandy, O. L., 1951, Jour. Paleontology, v. 25, p. 503.

Bandy (1951, p. 503) describes *Lagena laevia* var. *stavensis* Bandy as:

Test globular, ovoid, widest just below the middle, circular in cross-section; base rounded, smooth, neck short, round, tapering about one-seventh the length of the body; wall smooth, finely perforate; aperture round, without lip, at the end of the short, tapering neck.

Measurements.—Diameter of figured specimen 0.09 mm.

Discussion.—This assignment is somewhat doubtful, but the specimens are more like the variety described by Bandy than any other form. On only a few of the specimens is the neck complete. The wall is smooth, generally hyaline, and
the base is without a spine. This latter character may be
used to differentiate this form from *Lacuna hemeroviana*
Bartenstein and Brand.

**Hypotype.**-Univ. of N. Dak. Cat. No. 1302.

**Occurrence.**-The specimens assigned to this variety
were abundant at localities C, H, I, J, M, R, and T; common
at localities F, E, L, N, S, and MM; and rare at localities
O, U, and V.

*Lacuna* sp. A

Plate 3, figure 14.

**Diagnosis.**-Test medium for the genus, pyriform, with
eleven plate-like costae that appear to extend over the
length of the test; aperture radiate, small, on the end of a
short neck.

**Measurements.**-Length of figured specimen 0.69 mm.;
greatest diameter of figured specimen 0.44 mm.

**Discussion.**-The assignment of a single specimen to
*Lacuna* sp. A is doubtfully made even though the specimen ap-
ppears to be a single chamber. Weathering has removed the
prominent costae from the lower one-third of the test so that
they are obscure except over the upper two-thirds of the test.

This species differs from *Lacuna acuticosta* Reuss
in shape, as *Lacuna* sp. A is as broad near the top of the test
as near the base. *Lacuna sulcata* (Walker and Jacob) is
larger than this species. One other species that *Lacuna* sp. A
resembles is *Lacuna substriata* Williamson, but the latter
species has costae that are finer and more abundant than those
of Lagena sp. A.

Hypotype.—Univ. of N. Dak. Cat. No. 1303.

Occurrence.—The single specimen doubtfully assigned to Lagena sp. A was found at locality B.

Lagena sp. B

Plate 2, figure 18.

Three specimens are only identified to genus at this time. The specimens are all single, spine-covered chambers, rounded in both side and top views, with a short apertural neck. The small size and absence of a basal neck eliminates a referral of the specimens to Denticina aculeata d'Orbigny, although they do resemble that species. They are too round and do not have a long neck as does Lagena hispida Reuss.

Measurements.—Diameter of figured specimen 0.41 mm.;

Hypotype.—Univ. of N. Dak. Cat. No. 1304.

Occurrence.—Lagena sp. B is rare at localities F and G.

Family Heterohelicidae

Heterohelix Ehrenberg, 1841


The following diagnosis of the genus Heterohelix is
taken from Gallitelli (1957, p. 137):

Test calcareous, biserial or planispiral in the early stages. Chambers generally inflated, globular to reniform. Wall calcareous, perforate, surface smooth or striate. Aperture basal, relatively large, with simple margin.

According to Gallitelli's diagnosis, *Heterohelix* may or may not be initially planispiral.

*Guembelina* was described by Cushman (1927, p. 59, side Gallitelli, 1957, p. 137) as usually coiled in the early portion of the test in the microspheric form, but frequently completely biserial in the megalospheric form. Gallitelli recognised the similarity of the two genera (*Heterohelix* and *Guembelina*) and examined over 3000 specimens of species that had been assigned to *Guembelina*. She concluded that since both genera included forms that were either completely biserial or early coiled, the two were synonymous, and suppressed *Guembelina* as a junior synonym of *Heterohelix*. The writer accepts Gallitelli's suppression of *Guembelina* and refers the reader to her paper for a more complete discussion of this problem.

*Heterohelix pseudotessera* (Cushman), 1938

Plate 3, figure 5.


*Guembelina pseudotessera* Cushman, Frissell, B. L., 1954, Texas Univ., Bur. Econ. Geol., Rept. Inv. 22, p. 109, pl. 15, figs. 33-34.

For further synonymy see Cushman, J. L., 1946, U. S. Geol.
Diagnosis.--Test biserial throughout, or with a short planispiral, initial stage, tapering, compressed; chambers distinct, usually wider than high, last few inflated; sutures distinct, depressed, slightly curved, concave downward; wall finely perforate, finely striate; aperture large, at the base of the last chamber.

Measurements.--Length of figured specimen 0.31 mm.; breadth of figured specimen 0.21 mm.; thickness of figured specimen 0.09 mm.

Discussion.--It is not difficult to separate this species from other Upper Cretaceous species of Heterohelix. The characteristically wide chambers with sutures that are slightly curved, concave downward, are diagnostic features of this species.

Cushman (1945, p. 106) records the species from strata of Taylor and Navarro age in the Gulf Coast states as does Belin (1952, p. 40) from the Niobrara formation of South Dakota and Dietrich (1951) from the Pierre shale of Nebraska.

Hypotype.--Univ. of N. Dak. Cat. No. 1305.

Occurrence.--H. pseudotessara was common at localities P, Q, I, L, M, N, O, R, S, T, U, V, W, and Z.

Heterohelix striata (Ehrenberg), 1838
Plate 3, figure 5.

For further synonymy see Bandy, O. L., 1951, Jour. Paleontology, v. 25, p. 510.

**Diagnosis.**—Test biserial throughout, or initially with a very short planispiral stage; chambers distinct, generally globular; sutures distinct, straight, depressed, horizontal to slightly oblique; wall with fine striations; aperture large, at the base of the last chamber.

**Measurements.**—Length of figured specimen 0.25 mm.; breadth of figured specimen 0.16 mm.; thickness of figured specimen 0.10 mm.

**Discussion.**—The specimens assigned to this species are all striate, some prominently, others poorly. With a magnification of 150X it was possible to observe the striations, or at least the alignment of perforations, on all of the specimens. Previous writers have usually considered the presence of striations as characteristic of this species. Cushman (1946, p. 105) notes that it is possible to differentiate *Heterohelix striata* (Ehrenberg) from *Heterohelix globulosa* (Ehrenberg) by the surface characters. He described *H. globulosa* as having a smooth wall and states that the "fine perforations show little or no tendency to form elongate lines." Bandy (1951, p. 510) commented upon the surface character of *H. striata* as varying from an almost smooth wall to a strongly striate wall, and wrote that forms with obscure striae are easily mistaken for *H. globulosa*. Since the specimens of the collection are striate the writer does not hesitate to assign all of them to *H. striata*. 
\textit{H. striata} is a commonly occurring species having been recorded from strata of Austin, Taylor and Navarro age in the Gulf Coast states (Cushman, 1945, p. 105), the Upper Cretaceous of California (Bandy, 1951, p. 510) and the Pierre shale of Nebraska (Dietrich, 1951). Moreover, some specimens identified as \textit{H. globosa} from the Moberara formation of Nebraska and South Dakota may be \textit{H. striata}.

\textbf{Type.}—Univ. of N. Dak. Cat. No. 1306.

\textbf{Occurrence.}—This species was abundant at localities C, I, M, N, O, Z, and T and common at localities B, F, H, J, K, L, P, Q, S, U, V, W, Z, and GG.

\textbf{Bolivinopsis} Yakovlev, 1891

\textbf{Bolivinopsis rosula} (Ehrenberg), 1854

Plate 3, figure 9.


The following description is given by Cushman (1946, p. 102) of \textit{Bolivinopsis rosula} (Ehrenberg):

Test very elongate, slender, compressed, the early portion closely coiled, planispiral with a single coil, later chambers biserial, of uniform size and shape, the sides of the test parallel; chambers numerous in the adult, often higher than broad; sutures distinct, extending obliquely backward; wall smooth and polished, calcareous, finely perforate.

\textbf{Measurements.}—Length of figured specimen 0.62 mm.
breadth of figured specimen 0.12 mm.

**Discussion.**—The specimens of the collection show well the characteristic of chambers that are higher than wide. That character certainly eliminates confusion with another common Upper Cretaceous *Bolivinopsis, B. papillata* (Cushman), of which Cushman (1946, p. 102) states has broader chambers than *B. rosula*.

In the Gulf Coast states *B. rosula* is very common in strata of Austin, Taylor and Navarro age. The species has not been reported from the Niobrara formation, but Dietrich (1951) found it in abundance in the lower part of the Pierre shale of Nebraska.

**Hypotype.**—Univ. of N. Dak. Cat. No. 1307.

**Occurrence.**—In this study *B. rosula* was not abundant, but portions of the test were found to be common in the samples from localities N, J, L, M, K, O, Q, K, S, T, and W.

Family *Buliminidae*

*Bulimina* d'Orbigny, 1826

*Bulimina aspera* Cushman and Parker, 1840

Plate 3, figure 1.


For further synonymy see Bandy, O. L., 1951, Jour. Paleontology, v. 25, p. 511.

**Diagnosis.**—Test elongate, broad, only slightly tapering in the megaspheric form, rapidly tapering in the micro-
spheric form, often with one or more initial spines; chambers distinct, inflated in the later portion of the test; sutures distinct, depressed; wall finely perforate, in the initial portion often roughened; aperture elongate, with a slight lip, nearly at the apex of the test.

Measurements.—Length of figured specimen 0.71 mm.; diameter of figured specimen 0.31 mm.

Discussion.—Many of the specimens assigned to this species have an apiculate initial end, with some having more than one spine. A number of these specimens, plus some others, show an initial roughened test, while several more specimens are without either the initial spines or roughened surface, but show alignment of the perforations of the wall in the initial portion of the test.

All of these characteristics are typical of this species as given by Cushman (1946, p. 121). A few additional specimens are without any of these characteristics, but they so highly resemble the specimens of Bulimina aspera Cushman and Parker in shape, size and number and inflation of the chambers that they are grouped under this species. It is possible that the initial spine has been broken away. Since these latter specimens are smooth-walled they resemble Bulimina kirkampensis Cole, a similar, but larger, smooth-wall form.

B. aspera has been reported from strata of Taylor and Navarro age in the Gulf Coast states. It also occurs in the Upper Cretaceous of California (Bandy, 1951, p. 511–512) and
in the Pierre shale of Nebraska (Dietrich, 1951).

**Hypotype.**—Univ. of N. Dak. Cat. No. 1308.

**Occurrence.**—*E. aspera* was abundant at localities F, G, H, I, J, K, L, N, P, Q, R, T, U, and HH.

**Entosolania Ehrenberg, 1846**

**Entosolania orbignyana** (Seguana)

Plate 3, figure 7.

A single Foraminifera from locality U is referred to **Entosolania orbignyana** (Seguana). The specimen consists of a single, globular chamber with a clear flange and two additional flanges of lesser diameter on either side of the larger central flange, all surrounding the chamber. Treating the specimen with glycerin failed to disclose an entosolenian tube, but the specimen appears to be identical to specimens illustrated by Cushman (1946, pl. 52, fig. 17) from the Ripley formation of Tennessee. He states (1946, p. 126) that "well-preserved specimens in some of the Cretaceous samples show an entosolenian tube and display much variation in the general shape and relative strength of the flanges." This species has not been previously recorded from either the Niobrara or Pierre Formations.

**Measurements.**—Length of figured specimen 0.30 mm.

**Hypotype.**—Univ. of N. Dak. Cat. No. 1309.

**Vimulina d'Orbigny, 1826**

**Vimulina tegulata** Reuss, 1845

Plate 3, figure 3.


For additional synonymy see Bandy, O. L., 1951, Jour. Paleontology, v. 25, p. 512.

**Diagnosis.**—Test elongate, gently tapering, somewhat compressed, initial end broadly rounded; chambers in the earliest stages indistinct, later distinct, oblique, slightly inflated in the adult; sutures oblique, slightly depressed; wall smooth; aperture elongate, narrow, extending from the base of the last chamber to the apex.

**Measurements.**—Length of figured specimen 0.47 mm.; breadth of figured specimen 0.14 mm.; thickness of figured specimen 0.10 mm.

**Discussion.**—As it is impossible to determine clearly with magnifications of 160X if the early stage in these specimens is coiled, it is with some question that this assignment is made. The specimens resemble *Loxostomum platinum* (Carsey), a completely biserial form, in shape and size. However, the latter species becomes loosely biserial in the late stages and seems to be more elongate than *T. tegulata*. Other writers, including Cushman (1946, p. 130) and Bandy (1951, p. 511) give a length to breadth ratio for *L. platinum* of 5:1 or 6:1. The specimens of *T. tegulata* in this collection have a length to breadth ratio less than that given for
L. plattii

L. taculata is a rather common species. It has been reported from strata of Austin, Taylor and Navarro age in the Gulf Coast states (Cushman, 1946, p. 126), the Upper Cretaceous of California (Bandy, 1951, p. 512) and the Niobrara Formation of Nebraska (Loetterle, 1937, p. 40) and South Dakota (Bolin, 1952, p. 46).

**Hypotype.**—Univ. of N. Dak. Cat. No. 1310.

**Occurrence.**—This species was rare at localities L and U.

**Bolivinoidae** Cushman, 1927

**Bolivinoidae decoratus** var. **lattigus** (Carsey), 1926

Plate 3, figure 15.

For synonymy see Frissell, P. L., 1934, Texas Univ., Bur. Econ. Geol., Rept. Inv. 22, p. 112.

**Diagnosis.**—Test biserial, cuneiform, periphery angled, apertural and becoming rounded, smooth; chambers numerous, not distinct, covered by thick, raised costae that die out at the middle of the last two chambers, costae are sub-parallel to the sides of the test, at right angles to and interrupted by the sutures; early sutures indistinct, later sutures distinct; wall calcareous; aperture at the base of the last chamber, narrowly loop-shaped.

**Measurements.**—Length of figured specimen 0.37 mm; breadth of figured specimen 0.26 mm.

**Discussion.**—In a revision of the family Hetero-
helicidae Gallitelli (1957, p. 136) removed the genus Bolivinae from the Heterohelicidae and placed it, with Bolivinita Cushman and Tappania Montanaro Gallitelli, in the subfamily Bolivinitidae of the family Buliminidae. She (p. 135) established that Bolivinae has "a continuous tube arising from the first chamber" and is "constantly and clearly biserial". Using 162X (the highest available) the writer is not convinced that the test of Bolivinae decoratus var. latticosa (Carsey) is not initially coiled, but accepts Gallitelli's completely biserial characteristic for Bolivinae as she used 216X. In addition, Cushman (1946, p. 133) described this variety as "mainly biserial".

The variety differs from the typical form of the species chiefly in the ornamentation. The costae of the variety are confined to the chambers, being broken by the sutures, which are at right angles to the costae, whereas the costae of the typical form of the species are unbroken in transgressing the sutures.

Cushman (1946, p. 113) gives the occurrence of the variety in strata of Taylor and Navarro age in the Gulf Coast states. Occurrences in either the Niobrara or Pierre formations have not been reported.

_Hypotype._-Univ. of S. Dak. Cat. No. 1311.

_Occurrence._-B. decoratus var. latticosa is common at localities O, S, V, and W. At localities N and GG it is rare.

_Eouvierina_ Cushman, 1926

_Eouvierina gracilis_ Cushman, 1926
Plate 3, figure 4.


**Diagnosis.**—Test biserial throughout, initially strongly biserial, becoming loosely biserial near the apertural end, often twisted upon its axis; chambers distinct, later chambers slightly inflated; sutures distinct, depressed, oblique, straight; wall ornamented with numerous, short, fine spines; aperture on the end of a neck, with a phialine lip.

**Measurements.**—Length of figured specimen 0.30 mm.; breadth of figured specimen 0.13 mm.; thickness of figured specimen 0.10 mm.

**Discussion.**—_souvigerina gracilis_ Cushman has some distinguishing characteristics that can be easily recognized. The spines that cover the surface serve to be important in separating it from similar Upper Cretaceous species such as _E. americana_ Cushman and _E. austinana_ Cushman. Another spiny _souvigerina, E. hispida_ Cushman, is especially like young _E. gracilis_ but the former species possesses a basal spine.

_E. gracilis_ has only been reported from strata of Taylor age (Cushman, 1946, p. 115) in the Gulf Coast states.

**Hypotype.**—Univ. of N. Dak. Cat. No. 1312.

**Occurrence.**—This species is common at localities G, H, I, J, K, O, T, U, and V.
**Loxostomum Ehrenberg, 1854**

*Loxostomum plaitum* var. *plaitum* (Carsey), 1926

Plate 3, figure 2.


**Diagnosis.**—Test elongate, initial end broadly rounded, gently tapering, biserial throughout; chambers distinct, oblique, wider than high, sometimes slightly concave downward; sutures distinct, oblique, slightly depressed; wall smooth; aperture subterminal, narrowly ovate.

**Measurements.**—Length of figured specimen 0.31 mm.; breadth of figured specimen 0.11 mm.

**Discussion.**—*Loxostomum plaitum* var. *plaitum* (Carsey) tends to become uniserial in the adult. This characteristic helps to distinguish it from *Virgulina tegulata* Reuss with which it may be confused.

*L. plaitum* var. *plaitum* has been recorded in strata of Austin, Taylor and Navarro age in the Gulf Coast states (Cushman, 1946, p. 130-131) and the Upper Cretaceous of California (Bandy, 1951, p. 511). Loetterle (1937, p. 62) found it in the Pierre shale of Nebraska.

**Hypotype.**—Univ. of N. Dak. Cat. No. 1313.
Occurrence.—L. plaitum var. plaitum is rare at localities M, O, T, and W, but at locality R it is common.

Family Ellipsocidinidae

Pleurostomella Reuss, 1860

Pleurostomella austini Tana Cushman, 1933

Plate 3, figure 8.

For synonymy see Frissell, D. L., 1954, Texas Univ., Bur. Econ. Geol., Rept. Inv. 22, p. 120.

The apertural characteristics of the single specimen referred to this species cannot be fully determined. The last chamber has been distorted causing the aperture to be compressed. Consequently, the aperture appears to be a narrow, elliptical opening with the long axis normal to the axis of the test, at the apex.

Cushman (1946, p. 131-132) reports this species from the Austin group of Texas. Loetterle (1937, p. 49) and Solin (1952, p. 49-50) have recorded the species from the Miobrara formation of Nebraska and South Dakota respectively.

Measurements.—Length of figured specimen 0.72 mm.; greatest diameter of figured specimen 0.15 mm.

Hypotype.—Univ. of N. Dak. Cat. No. 1314.

Occurrence.—The specimen referred to P. austini Tana was found in the sample from locality U.

Pleurostomella subnodosa Reuss, 1860

Plate 3, figure 10.

18, fig. 6.


One specimen was assigned to this species. The specimen shows a loose biserial arrangement of chambers throughout, and is slightly twisted upon its axis. The aperture is subterminal, broadly semi-ovate, with a slight, overhanging lip. What appears to be a basal tooth may be clearly seen on one side of the aperture base.

The arrangement of the chambers distinguishes this species from Pleurostromella nitida Morrow, which is more tightly biserial. Pleurostromella austiniana Cushman is more slender and has an aperture which is broader above than below.

P. subnodosae is greatly restricted in range in Texas, where it has been found in strata of Taylor age. However, the species has also been recorded in the upper part of the Cretaceous of Europe, the Selma chalk of Florida, and the Mendes shale, Cretaceous, of Mexico (Cushman, 1946, p. 132).

Measurements.—Length of figured specimen 0.55 mm.; diameter of figured specimen 0.14 mm.

Hypotype.—Univ. of N. Dak. Cat. No. 1315.

Occurrence.—P. subnodosae was found at locality T.

Ellipsoidella Heron-Allen and Earland, 1910

Ellipsoidella gracillima (Cushman), 1933

Plate 3, figure 11.

fig. 13.

*Nodosarella gracillima* Cushman. Frizzell, J. B., 1954, Texas Univ., Bur. Econ. Geol., Rept. Inv. 22, p. 120, pl. 13, fig. 11.


**Diagnosis.**—Test elongate, initially biserial, uniserial for most of the length; chambers distinct, increasing uniformly in length, final chambers up to twice as wide as high; sutures distinct, depressed; wall smooth; aperture semi-elliptical, on the upper side of the last chamber.

**Measurements.**—Length of figured specimen 0.57 mm.; diameter of figured specimen 0.11 mm.

**Discussion.**—Placement of this species in the genus *Ellipsoidella* is accepted and briefly discussed by Frizzell (1954, p. 151). The writer also accepts the assignment and refers the reader to Stainforth (1952a, p. 6) who discusses the validity of rejecting the use of the genus *Nodosarella* for forms that are initially biserial like *Ellipsoidella gracillima* (Cushman).

This species differs from *Nodosarella texana* Cushman in biseriality of the initial chambers, overall shape and the length of the final chambers. *N. texana* has a height to width ratio of the last chamber of 3:1 to 4:1 (Cushman, 1946, p. 133), whereas the same ratio for *N. gracillima* is less than 2:1. Characteristically, *N. texana* is very slender, slightly curved and larger than *N. gracillima*.

References to this species from strata of Austin and
Taylor age in the Gulf Coast states and the Niobrara formation of Kansas have been made. In South Dakota the species has been reported from the Niobrara formation by Bolin (1952, p. 50-51).

*Hypotype.*—Univ. of N. Dak. Cat. No. 1316.

*Occurrence.*—This species was rare at localities V and W.

**Stileostomella Cuppy, 1894**


In 1952 Stainbrook (1952A, p. 6-14) thoroughly discussed the reasons for referring to *Siphonodosaria* many Upper Cretaceous species that had previously been referred to *Ellipsospondosaria*. At that time Stainbrook was not aware of a paper by Finlay (1947), in which it was recommended that the valid name *Stileostomella Cuppy* replace *Siphonodosaria*, a synonym of *Stileostomella*. Stainforth later (1952B, p. 9) called attention to Finlay’s paper and stated “the almost forgotten name *Stileostomella Cuppy*, 1894, is valid and should replace both *Siphonodosaria* and *Hodeoparina*.”

**Stileostomella exilia (Cushman), 1936**

Plate 3, figure 28.


**Diagnosis.**—Test very elongate, apiculate; chambers distinct, higher than wide throughout, becoming several times as high as wide near the apertural end; sutures distinct, very slightly depressed, liiabate; wall smooth; aperture not preserved in any of the specimens.

**Measurements.**—Length of figured specimen 1.50 mm.; diameter of figured specimen 0.09 mm.

**Discussion.**—The specimens assigned to *Stilostomella exilis* Cushman are not complete; only one shows the basal spine. The chambers are very elongate, which serves to distinguish the species from *Chryselogonium granti* (Plummer), and the presence of a basal spine eliminates confusion with *Dentalina cf. D. consobrina* of this collection.

In the Gulf Coast states *S. exilis* seems to be restricted to strata of Taylor age. It probably is not a commonly occurring species in the Niobrara and Pierre formations as it has not been previously reported from those formations in the northern midcontinent.

**Hypotype.**—Univ. of N. Dak. Cat. No. 1317.

**Occurrence.**—*S. exilis* was found at localities N, P, S, and V. It is rare.

*Stilostomella stephensoni* var. *speciosa* (Cushman), 1938

Plate 3, figure 12.

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Plate 3, figure 13.

**Diagnosis.**—Test short, fusiform, initial end pointed, with a short spine, apertural end bluntly pointed; chambers few visible, about five, last chamber making up about one-half the length of the test; sutures flush with the surface; wall smooth; aperture probably an elliptical opening with a small hood.

**Measurements.**—Length of figured specimen 0.26 mm.; diameter of figured specimen 0.15 mm.

**Discussion.**—One specimen identified as *Ellipso-
glandulina* sp. is not well preserved, especially near the apertural end. The aperture appears to be an elliptical opening, so the specimen is questionably referred to the genus *Ellipso-glandulina*.

It is probable that the specimen should be referred to *Ellipso-glandulina velascoensis* Cushman, which species *Ellipso-glandulina* sp. resembles in shape and size. Yet, the writer feels such an assignment would be unsafe if based on a single, weathered specimen.

**Hypotype.**—Univ. of N. Dak. Cat. No. 1319.

**Occurrence.**—*Ellipso-glandulina* sp. was found at locality 3.

**Family Botaliidae**

*Gyroidina* d'Orbigny, 1826

*Gyroidina girardiana* (Reuss), 1851

Plate 3, figures 24, 29-30.


Cushman (1946, p. 140) described this species as follows:

Test trochoid, planoconvex, dorsal side flattened or even slightly concave, ventral side subconical with the umbilical region open, periphery with a distinct angle at the dorsal edge; chambers fairly distinct, of rather uniform shape, increasing very slowly in size as added, usually about $\delta$ in the adult whorl, inflated very slightly if at all; sutures fairly distinct, slightly depressed, nearly radial on both ventral and dorsal sides; wall smooth; aperture between the periphery and umbilicus on the ventral side, low.

**Measurements.**—Diameter of figured specimen 0.29 mm.; height of figured specimen 0.23 mm.

**Discussion.**—The specimens of this species in this collection are very amply described above. However, the specimens of this collection do not appear to be as deeply umbilicate as the specimens of the species figured by Cushman (1946, pl. 58, fig. 9). The dorsal edge of the specimens of the collection is distinctly angled, and that characteristic was used to advantage in separating specimens of this species from those of *Gyroidina globosa* (Hagenow).

No record of this species is known from beds of the Upper Cretaceous in the northern midcontinent. In the Gulf Coast states the species has been recorded from beds of Austin, Taylor, and Navarro ages.

**Hypotype.**—Univ. of N. Dak. Cat. No. 1320.
Occurrence.—The species is common at localities A and B.

**Gyroidina globosa** (Hagenow), 1842

Plate 3, figures 25-27.


Diagnosis.—Test trochoid, biconvex, ventral side highly convex with a small, deep umbilicus, dorsal side less convex; periphery broadly rounded, lobulate; chambers usually six in the adult whorl, inflated; sutures depressed, on the ventral side radial, gently curved, on the dorsal side somewhat tangential to the spiral suture on the inner whorls and the periphery on the outer whorl; wall usually smooth, finely perforate; aperture elongate, at the base of the last chamber on the ventral side, with a slight lip.

Measurements.—Diameter of figured specimen 0.26 mm.; thickness of figured specimen 0.22 mm.

Discussion.—**Gyroidina globosa** (Hagenow) is similar to **Gyroidina nitida** (Reuss), which has been recorded from the Niobrara formation by Morrow (1934, p. 197), Leetterle (1937, p. 42), and Bolin (1952, p. 53). Characteristics of the two species and geologic occurrence show them to be distinguishable, however. The specimens of **G. globosa** in this collection are larger than **G. nitida** and are fairly consistent
in the number of chambers of the last whorl with six, whereas Morrow, Loetterle and Bolin give the number of chambers of the last whorl of *G. nitida* as four to six. Also, Cushman (1946, p. 140) notes that the last whorl of *G. globosa* varies in position relative to the inner whorls. The specimens of the collection show this variation causing some specimens to appear ventrally more convex and umbilicate than others.

*G. globosa* has not been reported from the Niobrara formation, but Morrow, Loetterle and Bolin have found *G. nitida* to be fairly well restricted to the Fort Hays member of the Niobrara formation. In the Pierre shale of Nebraska both *G. globosa* and *G. nitida* have been found by Dietrich (1951), but from the states of the Gulf Coast Cushman (1946, p. 140) shows *G. globosa* to be characteristic of the strata of Taylor age, and less so of the beds of late Austin age and early Navarro age.

**Hypotype.**—Univ. of N. Dak. Cat. No. 1321.

**Occurrence.**—In this study *G. globosa* was found to be abundant at localities A and B.

_Stenosina_ Brotzen, 1936

_Stenosina americana_ Cushman and Dorsey, 1940

_Plate 3, figures 21-23._


Diagnosis.—Test planoconvex, dorsal side flattened to slightly concave, ventral side convex, with an umbo of coarsely perforate shell material, periphery sometimes slightly lobulate, with a small, flange-like, dorsally directed keel; chambers indistinct dorsally in the inner whorls, distinct ventrally, about nine in the final whorl; sutures on the dorsal side indistinct, except those of the last whorl which are slightly curved, raised, tangential, those of the ventral side somewhat limbate, of clear shell material, nearly radial; wall coarsely perforate; aperture elongate, at the base of the final chamber, on the ventral side.

Measurements.—Diameter of figured specimen 0.38 mm.; thickness of figured specimen 0.20 mm.

Discussion.—This species is smaller than *Stensiolina excolata* (Cushman). *Stensiolina americana* Cushman and Dorsey possesses an umbilical area of clear shell material, whereas *S. excolata* has a smooth umbilical area.

*S. americana* has been recorded (Cushman, 1946, p. 142) in strata of Taylor and Navarro age in the Gulf Coast states. The writer knows of no references to it from the Upper Cretaceous of the northern midcontinent.

Hypotype.—Univ. of N. Dak. Cat. No. 1322.

Occurrence.—*S. americana* was common at localities N, O, T, U, V, and W. At localities Q and R it was rare.

*Epistomina Terquem, 1883*

*Epistomina supracretacea* ten Dam, 1948
Plate 3, figures 18-19.

**Hoglundina supracrateracea** (ten Dam). Bandy, O. L., 1951,
Jour. Paleontology, v. 25, p. 507, pl. 74, fig. 3.
For further synonymy see Frizzell, B. L., 1954, Texas Univ.,

**Diagnosis.**—Test nearly circular, biconvex, ventral side more convex than dorsal; periphery slightly lobulate with a thickened keel; chambers distinct, increasing gradually in size as added; sutures distinct, liabate, flush with the surface on both ventral and dorsal sides; radiate, straight, fusing with the umbo on the ventral side; oblique, slightly curved on the dorsal side; wall hyaline, finely perforate; aperture a narrow slit along the base of the last formed chamber on the ventral side; accessory apertures as slits along the peripheral margin of the chambers on the ventral side.

**Measurements.**—Diameter of figured specimen 0.35 mm.; thickness of figured specimen 0.17 mm.

**Discussion.**—In 1948 Brotzen erected the genus **Hoglundina** for species which he thought possessed different apertural characteristics than the genotype of **Epistomina**. Ten Dam (1949, p. 232) felt that Brotzen acted prematurely in erecting the genus **Hoglundina** as "Macfaden (1935) who examined the Terquem collection at Lille, France, concluded that the apertures were badly figured" and "until Terquem's types, and particularly that of **Epistomina regularis** are carefully restudied, it seems hazardous to erect a new genus".
Epistominae supracretacea ten Dam has been reported from the Pierre shale of Nebraska by Loetterle (1937, p. 52). Cushman (1946, p. 143) gives numerous occurrences in beds of Taylor and Navarro age in the Gulf Coast states.

_Hypotype._-Univ. of N. Dak. Cat. No. 1323.

_Occurrence._-In this study specimens of the species were found to be rare at localities A and B and abundant and fairly well preserved at locality HH.

Family Chilostomellidae

_Pullenia_ Parker and Jones, 1862

_Pullenia americana_ Cushman, 1936

Plate 3, figures 16-17.


_Diagnosis._-Test planispiral, involute, slightly umbilicate; periphery slightly lobulate; chambers distinct, slightly inflated, about five to seven in the adult whorl; sutures distinct, depressed, somewhat curved; wall smooth, finely perforate, aperture a low arched opening at the base of the last chamber, extending toward the umbilicus on either side.

_Measurements._-Diameter of figured specimen 0.25 mm.; thickness of figured specimen 0.18 mm.

_Discussion._-P. americana was reported from the Pierre
shale of Nebraska by Dietrich (1951). A species, with which it may possibly be confused, is *Pullenia corvelli* White, which has been recorded from the Pierre shale of Nebraska and South Dakota by Loetterle (1937, p. 63). *P. corvelli* is much more globular than *P. americana*, however. *Pullenia cretacea* Cushman, a species more closely resembling *P. americana* than even *P. corvelli*, differs from *P. americana* in having fewer and less inflated chambers, a lesser lobulate periphery, and only slightly depressed sutures. *P. cretacea* is also much broader in peripheral view than is *P. americana* (Cushman, 1946, p. 147).

Cushman (1946, p. 146) records *P. americana* from beds of Taylor and Navarro age in Texas, Tennessee, and Arkansas; Taylor age in Mississippi; and Navarro age in Alabama.

**Hypotype.**—Univ. of N. Dak. Cat. No. 1324.

**Occurrence.**—In this study *P. americana* was found in samples from seven localities, being common in occurrence at locality B and rare at localities A (a single specimen was found and subsequently lost), L, O, Q, V, and W.

Family Hantkeninidae

*Planomalina* Loeblich and Tappan, 1946

*Planomalina aspera* (Ehrenberg), 1854

Plate 3, figure 20.


fig. 2.
For further synonymy see Bandy, O. L., 1951, Jour. Paleontology, v. 25, p. 508.

**Diagnosis.**—Test planispirally coiled in the adult, bimamillate, adult tending to become slightly evolute; chambers globular, increasing gradually in size as added, typically six in the final whorl of the adult; sutures distinct, depressed, straight, radial; wall hispid; aperture a large, arched opening at the base of the final chamber, extending back the length of the final chamber on both sides, with a distinct lip.

**Measurements.**—Diameter of figured specimen 0.20 mm.; thickness of figured specimen 0.13 mm.

**Discussion.**—This species, previously referred to *Globigerinella* by most workers, should be referred to *Planomalina*. Bolli *et al.* (1957, p. 29) consider *Globigerinella* a junior synonym of *Hastigerina*, which is only known from the Tertiary. The apertural characteristics plainly show that this well known species should be included in the genus *Planomalina*.

*Planomalina aspera* (Ehrenberg) has been frequently reported from Upper Cretaceous strata of the northern mid-continent. Some recent references to it from this area include Bolin (1952, p. 55) from the Niobrara formation of South Dakota; Loetterle (1937, p. 45) from the Niobrara formation of Kansas, Nebraska, and South Dakota; Dietrich (1951) from the Pierre shale of Nebraska; and Nause (1947, p.
331 and 337) from the Lea Park shale of Alberta, Canada. In addition Sandy (1951, p. 508-509) reported it from the Upper Cretaceous of California.

**Hypotype.**-Univ. of N. Dak. Cat. No. 1325.

**Occurrence.**-This species was abundant at localities G, H, and 0 and common at localities F, H, I, J, K, L, M, P, Q, R, S, T, U, V, W, Z, OG, and RH.

**Family Globorotaliidae**

**Globorotalites** Brotzen, 1942

**Globorotalites micheliniana** (d'Orbigny), 1840

Plate 3, figures 30-32.


**Diagnosis.**-Test planoconvex, dorsal side flat, ventral side convex, with an umbilicus, periphery slightly lobulate, with a thin keel; chambers distinct, six or seven in the last whorl; sutures distinct, flush with the surface, slightly limbate, slightly curved, dorsally tangential; wall smooth, finely perforate; aperture elongate, at the base of the final chamber on the ventral side.
Measurements.—Diameter of figured specimen 0.51 mm.;
thickness of figured specimen 0.35 mm.

Discussion.—Globorotalites micheliniana (d’Orbigny)
may be distinguished from Globorotalites umbilicatus
(Loetterle) by the number of chambers of the final whorl. G.
micheliniana usually has about six or seven, while G.
umbilicatus has about eight or nine according to Loetterle
(1937, p. 43).

G. micheliniana has been reported from strata of
Austen and Taylor age in the Gulf Coast states. Bolin (1952,
p. 59) reported it from the Niobrara formation of South
Dakota. Dietrich (1951) reported it from the lower Pierre
shale of Nebraska.

Hypotype.—Univ. of N. Dak. Cat. No. 1326.

Occurrence.—This species was common at localities Q,
V, and W, and rare at localities P, S, and U.
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<td>C. C. C. C. C. C. C.</td>
<td>4.6, 3.5, 3.5, 3.5</td>
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PLATE I

Figures 15-26
All specimens are hypotypes in the coll. of the Univ. of North Dakota.

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PLATE 1
Figures 1-14

All specimens are hypotypes in the coll. of the Univ. of North Dakota.

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Plate 3

Figures 1-13

All specimens are hypotypes in the coll. of the Univ. of North Dakota.

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