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Foraminiferids of the Cannonball Formation (Paleocene, Danian) in western North Dakota

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FORAMINIFERIDS OF THE CANNONBALL FORMATION (PALEOCENE, DANIAN) IN WESTERN NORTH DAKOTA

by

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Master of Science, University of North Dakota, 1974

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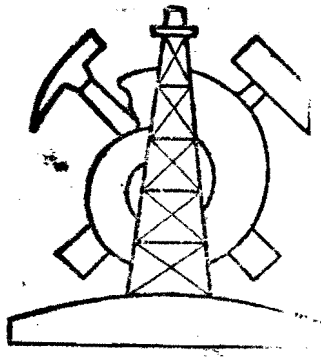

This dissertation submitted by William E. Fenner in partial fulfillment of the requirements for the Degree of Doctor of Philosophy from the University of North Dakota is hereby approved by the Faculty Advisory Committee under whom the work has been done.

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ABSTRACT

In 1974 and 1975 about 2800 samples (of which 265 contained foraminiferids) of the Cannonball Formation were collected from 60 water test wells and two oil wells in Adams, Bowman, Burleigh, Divide, Dunn, Grant, Mercer, Morton, Oliver, Sioux, and Ward Counties in western North Dakota. Fifty species of benthonic foraminiferids and four species of planktonic foraminiferids were identified including eight textulariines, two miliolines and 44 rotaliines. Taxa reported for the first time from the Cannonball include: Reophax sp. (2 species), Ammobaculites expansus Plummer, Spiroplectammina wilcoxensis Cushman and Ponton, Quinqueloculina plummerae Cushman and Todd, Dentalina eocenica Cushman, Lenticulina alabamensis (Cushman), L. arkansasana (Cushman and Todd), L. turbinata (Plummer), Lingulina sp., Spirobolivina emmendorferi (Jennings), Rosalina sp., Pararotalia perclara (Loeblich and Tappan), Fursenkoina sp., Caucasina marylandica (Nogan), Nonion graniferum (Terquem), Pullenia quinqueloba (Reuss), and Anomalinoides umboniferus Schwager. A total of 93 species, including those I collected, has been reported from the Cannonball. The foraminiferid fauna occurs commonly in the mudstone lithofacies and rarely in the sandstone lithofacies in the lower to lower upper Cannonball.

Two foraminiferid assemblages are recognized from R-mode cluster analysis, the Caucasina-Bulimina and Cibicidoides-Ceratobulimina assemblages. Little lateral and vertical continuity in the assemblages suggests strong environmental control and mixing during well drilling.

The presence of Globorotalia pseudobulloides and Globoconusa duabjergensis in my samples suggests that the Cannonball is Danian (earliest Paleocene).

The shallow-water affinities of the foraminiferid assemblages and small size and scarcity of planktonic foraminiferids suggest deposition in water depths of 100 m or less. The dominance of textulariines, including Ammobaculites, in western Adams and eastern Bowman Counties, indicates brackish-water environments in that area. A large, shallow, protected lagoon west of a north-trending barrier island chain is envisioned as a possible complex of depositional environments for the Cannonball. Brackish-water environments are thought to have occurred on the landward side of the lagoon with normal marine environments near the seaward side of the lagoon.

INTRODUCTION

General

Purposes.--The primary purpose of this study is to describe and illustrate a major part of the foraminiferid fauna of the Cannonball Formation. Secondary purposes include the determination of the foraminiferal biostratigraphy and paleoecology, and the determination of the sedimentary environments and age of the Cannonball.

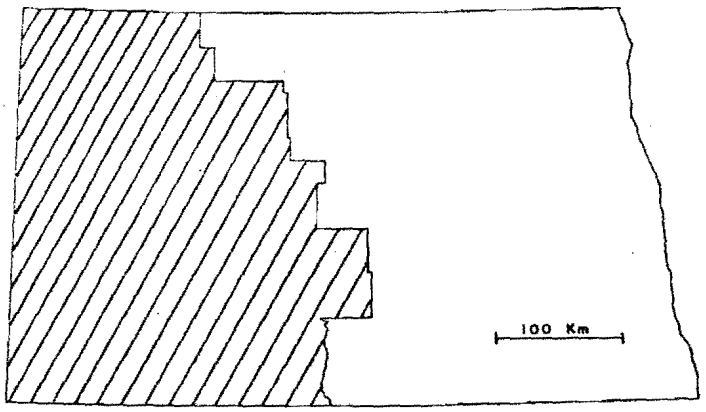
Study area.--Cuttings from 60 water test wells drilled by the North Dakota State Water Commission and two oil wells were used in this study (fig. 1). The wells are mainly southwest of the Missouri River in Adams, Bowman, Dunn, Grant, Mercer, Morton, Oliver and Sioux Counties. Additional wells are in Burleigh, Divide and Ward Counties.

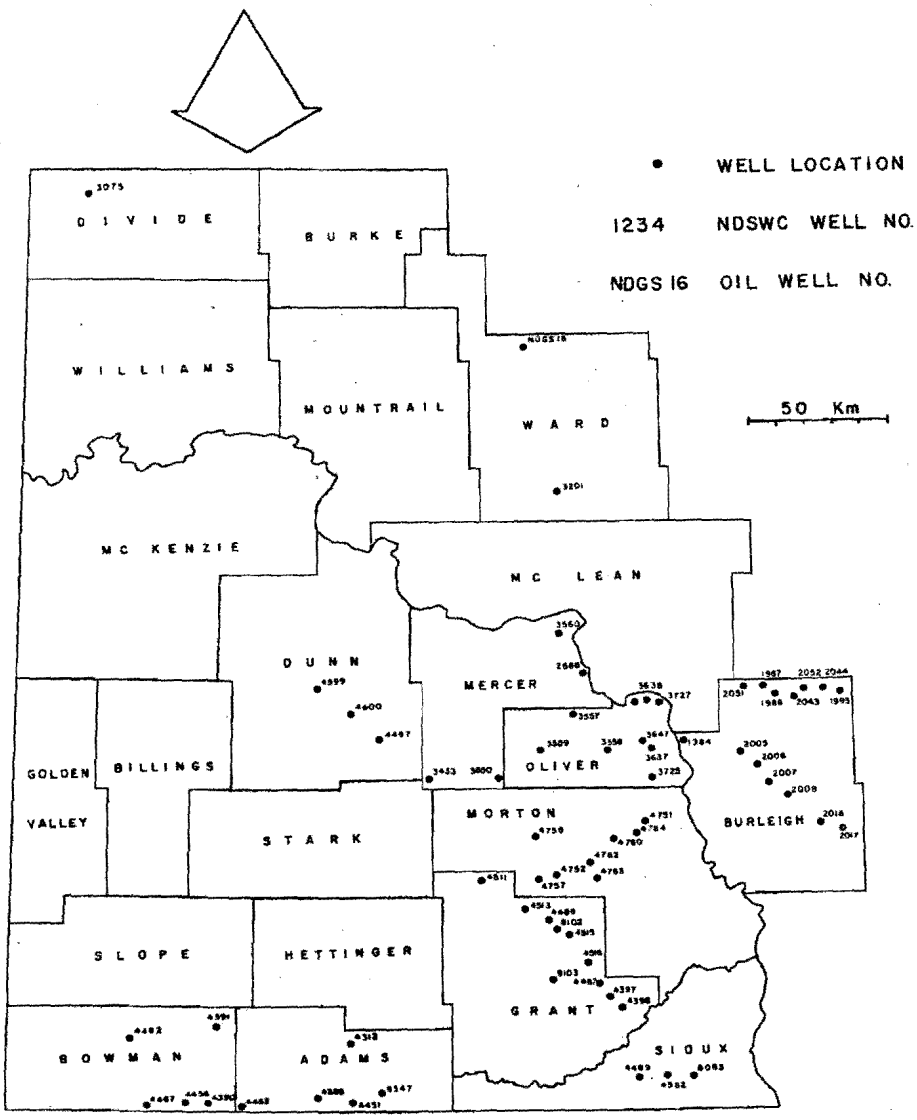
Previous Work

Stratigraphy.--Lloyd named the Cannonball in 1914. His designation was the Cannonball marine member (upper 250-300 ft) of the Lance Formation. The name was derived from the Cannonball River where many of the exposures occur as cutbanks in the type area of the Cannonball Formation (Ts. 132 and 133 N., Rs. 87 and 88 W.).

Prior to the work of Lloyd, most workers, including Meek and Hayden (1856) and Hayden (1857), confused the Cannonball Formation with the Late Cretaceous Fox Hills Formation, which was then known as "Formation No. 5." Ludlow (1875) also erroneously considered a

Fig. 1. Detailed map of western North Dakota showing the locations of wells. Well numbers correspond to those used in figs. 4-12 and Appendix C. Detailed locations for all wells are given in Appendix C.


N
100 Km


WELL LOCATION
1234 NDSWC WELL NO.
NDGS 16 OIL WELL NO.
50 Km
DIVIDE
BURKE
WILLIAMS
MOUNTRAIL
WARD
MC KENZIE
MC LEAN
DUNN
MERCER
OLIVER
GOLDEN VALLEY
BILLINGS
STARK
MORTON
BURLEIGH
SLOPE
HETTINGER
GRANT
SIOUX
BOWMAN
ADAMS

measured section in the Cannonball as part of the Cretaceous "Fox Hills Group."

Leonard (1908) included what is now known to be the Cannonball in the Fort Union Formation. He placed all rocks that occurred above the Cretaceous Pierre and Fox Hills Formations in the Fort Union Formation, but did not distinguish any members. Calvert and others (1914) further restricted the occurrence of the Fort Union by stating that it was underlain by the fresh-water sediments of the Lance Formation, which, in turn, was underlain by the Montana Group.

Lloyd and Hares (1915) first designated the lignitic, nonmarine beds below the Cannonball the "Ludlow lignitic member of the Lance Formation" and suggested that the Ludlow was the nonmarine, stratigraphic equivalent of the Cannonball. They also suggested that the Cannonball occurred as far west as the western part of Slope County, along the Little Missouri River near the town of Yule (no longer extant). The Hell Creek, which at that time was included in the Lance Formation, remained an unnamed member.

Winchester and others (1916) indicated that the Cannonball extended into northwestern South Dakota where they recognized interfingering of the Ludlow and the Cannonball.

Campbell (1916) and Leonard (1919) independently suggested that the Cannonball occurred east of the Missouri River. Campbell indicated that Cannonball was present north of and including part of Bismarck, and southeast of Bismarck in the vicinity of the town of Apple Creek (no longer extant). Leonard (1919, p. 14) suggested that the Cannonball was possibly present below the glacial drift east of the Missouri

River; however, no Cannonball was indicated there on his geologic map (fig. 2). The Hell Creek, as yet, remained unnamed and Leonard referred to it as the "lower member" of the Lance Formation.

Thom and Dobbin (1924a, b) placed the Cannonball in the Fort Union and said the Upper Cannonball and Ludlow were equivalent to the Lebo Member of the Fort Union of eastern Montana. They also indicated that the lower, previously unnamed member of the Lance was equivalent to the Hell Creek of eastern Montana.

Fox and Ross (1942) thought that the Cannonball was probably Paleocene because of the Midway affinities of the Cannonball foraminiferid fauna. They also suggested the elevation of the Cannonball to formational status. The formational status of the Cannonball was first adopted by the North Dakota Geological Survey in 1942 (Laird and Mitchell, 1942). (For a more complete discussion of the history of the stratigraphic study of the Cannonball see Cvancara, 1965, 1976).

Paleontology.--Meek and Hayden (1857, 1858 and 1860) did the first paleontological work in the Cannonball from which they described five new species of mollusks. The Cannonball, at that time, was confused with "Formation No. 5" (Fox Hills Formation).

Leonard (1908) identified two species of oysters from the yet-to-be-named Cannonball in northwestern Slope county along the Little Missouri River.

Stanton, in Lloyd and Hares (1915, p. 537) identified 41 species of fossils including one species of foraminiferid (Nodosaria sp.). The remainder of the forms were mainly mollusks. Stanton indicated that the fauna was a "modified Fox Hills fauna." He, in Winchester and others (1916, p. 25), identified 16 species of mollusks and a fragment

of a crustacean claw.

Stanton (1920) did the first comprehensive study of the Cannonball invertebrate fauna. He listed 2 species of foraminiferids, 63 species of mollusks and 2 species of sharks. Vaughan (1920), in an accompanying paper, listed 6 species of corals. Stanton also amplified his idea that the Cannonball was Cretaceous.

Fox and Ross (1942) identified 64 species of foraminiferids from the Cannonball and, because of the close microfaunal affinities with the Paleocene Midway of the Gulf Coast, they concluded that the Cannonball was Paleocene. Unfortunately, they listed only the 43 species of Cannonball foraminiferids that occurred in the Gulf Coast. None of the foraminiferids they collected was illustrated or described.

Leriche (1942) described three species of sharks from the Cannonball, two of which were Midway (Paleocene) age.

Brown (1948) noted the occurrence of two species of brackish-water bivalves along the Little Missouri River in northwestern Slope County. He suggested that these bivalves indicated a second brackish-water tongue in this area. The first and higher brackish-water tongue was that which was indicated by the oyster bed discovered by Leonard (1908).

Brown and Lemke (1948) reported 4 species of foraminiferids (identified by J. A. Cushman), 10 species of mollusks, 1 species of worm and 5 species of ostracodes (identified by Swain) from the Cannonball exposed along the Souris River. This report extended the distribution of the Cannonball much farther north than was known previously.

Swain (1949) described the five species of ostracodes he previously identified for Brown and Lemke (1948). He concluded that the

ostracodes were restricted to the Midway or Midway-aged rocks and agreed with the conclusions of others who suggested a Paleocene age for the Cannonball.

Holland and Cvancara (1958) reported two species of crabs from the Cannonball and Wilson (1957) identified six species of corals from the Cannonball including one new species. They also reported the first occurrence of one Cannonball coral genus in North Dakota.

Lemke (1960) reported 30 species of foraminiferids (identified by S. K. Fox, Jr.), eight of which were new. He also reported 10 species of worm and 1 species of shark. He suggested (p. 31) that the Cannonball may extend into Canada north of Burke County on the northern flank of the Turtle Mountains.

Cvancara (1965, 1966) identified 30 species of bivalves from the Cannonball. Four species were new and eight of Stanton's (1920) species were placed into synonymy (Cvancara, 1965, p. 87). He also reported a bryozoan; Halymenites (=Ophiomorpha), the burrow of a presumed decapod crustacean; sharks, skates, rays, turtles and crocodiles or alligators. Among the bivalves was one species of boring bivalve discussed by him in later papers (1970a, 1970b).

Stanley (1965) reported dinoflagellates, hystrichosphaerids, spores and pollen and Cvancara (1970b) reported two or three species of driftwood.

Fox and Olsson (1969) identified seven species of planktonic foraminiferids from the Cannonball at Garrison Dam, North Dakota. They concluded that the Cannonball was Danian because it could be assigned to either the Globigerina edita zone of Hillebrandt or the Globorotalia pseudobulloides zone of Bolli, both of which are indicators of the

Danian. They suggested also that because planktonic foraminiferids were relatively scarce and were associated with a shallow-water benthonic foraminiferid assemblage, the Cannonball represented "shallow neritic depths." The small size of the planktonic foraminiferids were also thought to indicate deposition in shallow water.

Feldman and Holland (1971) identified a new species of macrurous decapod from the Cannonball in southern Morton County. Their study represented the first report of Paleocene macrurans from the midcontinent.

Feldman (1972) collected one species of cephalopod from the Cannonball. This represented the first reported occurrence of a cephalopod from the Cannonball.

Holzman (1973) indicated that rhizocorallid burrows were present in the Cannonball.

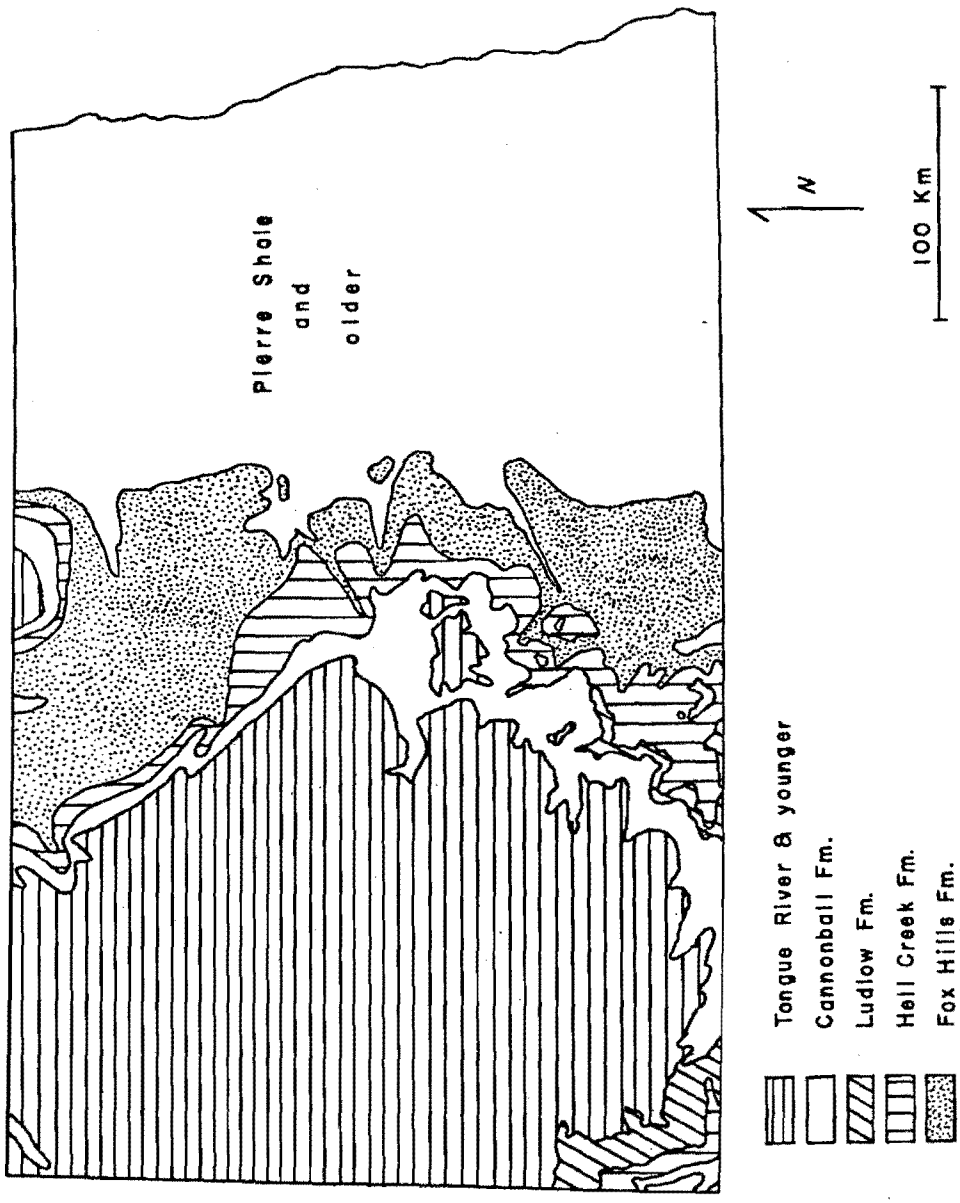
Fenner (1974) reported 26 species of foraminiferids from the Cannonball in outcrops from Grant, Morton and Oliver Counties. Van Alstine (1974) identified two species of foraminiferids, three species of bivalves and Ophiomorpha, the presumed burrow of a decapod crustacean.

Robertson (1975) reported hystrichosphaerids, spores and pollen from the Cannonball.

Geologic Setting

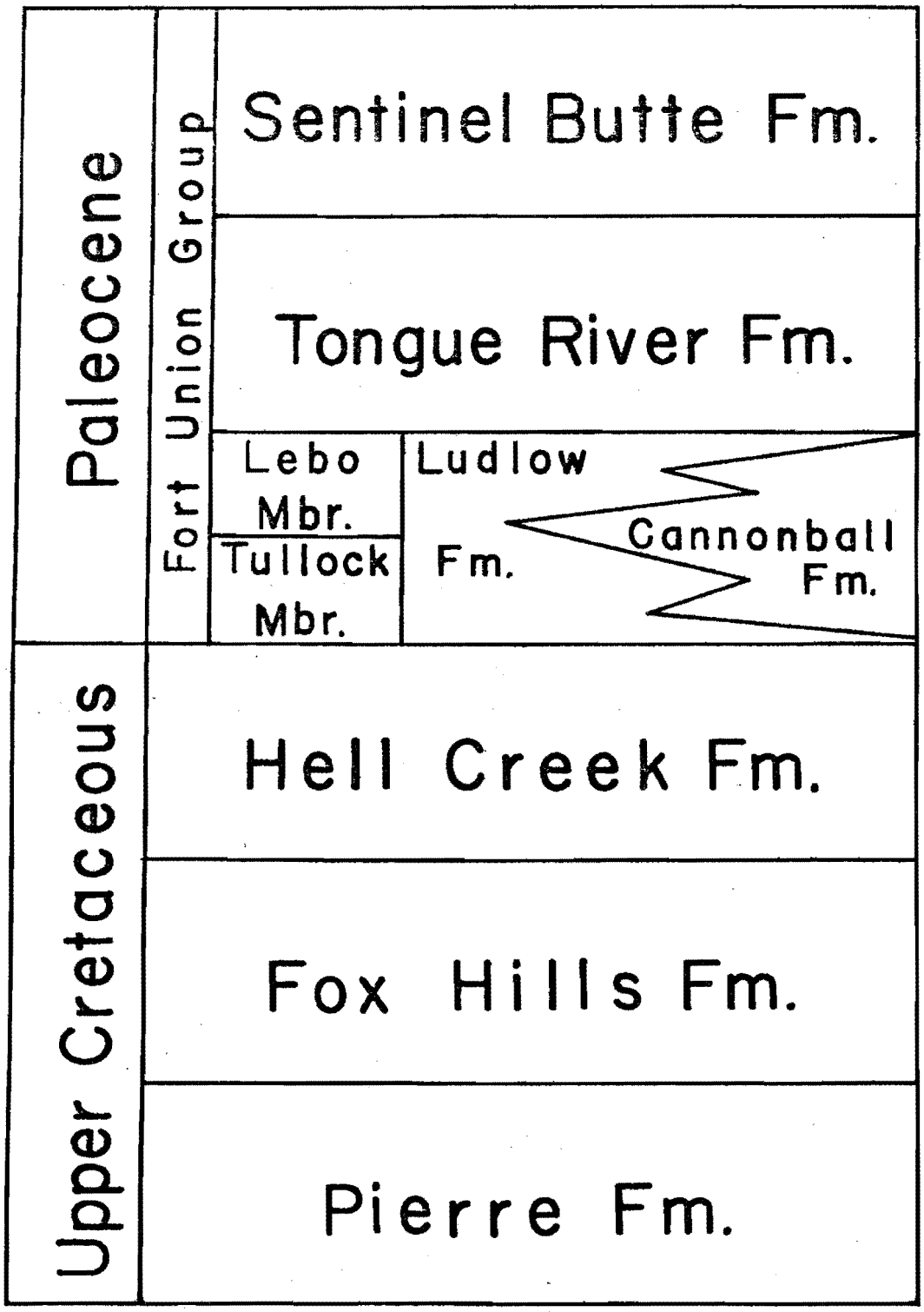
Regional stratigraphy.---Cretaceous and Tertiary rocks underlie most of the state of North Dakota with the main outcrop areas in the southwestern part of the state. Late Cretaceous and Tertiary rocks also crop out along the Souris River and in the Turtle Mountain area in north-central North Dakota (fig. 2).

Fig. 2. Geologic map of North Dakota showing Cannonball Formation and adjacent rock units (modified from Carlson 1973a).


Pierre Shale
and
older
N
100 Km
Tongue River & younger
Cannonball Fm.
Ludlow Fm.
Hell Creek Fm.
Fox Hills Fm.

The Cannonball Formation intertongues with and overlies the nonmarine Ludlow Formation (fig. 3) (Brown, 1948, p. 1271). The Ludlow is composed of interbedded siltstone and claystone, sandstone, lignitic shale and lignite (Moore, 1976). Overlying the Cannonball is the largely fluvial Tongue River Formation, which consists of calcareous sandstone, siltstone, shale and lignite. The Cannonball-Tongue River contact is both conformable and disconformable (Cvancara, 1976, p. 10). Above the Tongue River Formation is the Sentinel Butte Formation, also mainly fluvial, consisting mostly of calcareous sandstone, siltstone, shale and lignite. The Sentinel Butte is distinguished from the Tongue River by its more irregular and steeper slopes, its friable sandstones, its common tabular sand bodies, and its grayish, somber color; the Tongue River most commonly has trough-shaped sand bodies and a yellowish brown color (Jacob, 1975, p. 2). The Ludlow-Sentinel Butte interval is known as the Fort Union Group and comprises the bulk of the Paleocene in North Dakota. The stratigraphic terminology used here is that which has been adopted by the North Dakota Geological Survey. It differs from terminology used by the United States Geological Survey, which recognizes the Ludlow-Sentinel Butte interval as the Fort Union Formation rather than the Fort Union Group. Below the Fort Union lies the Late Cretaceous Hell Creek Formation. The Hell Creek is predominantly nonmarine with possibly two marine tongues, the lower near Bismarck along the Missouri River valley and the upper along the Little Missouri River valley in Slope and Bowman Counties (Frye, 1964). The Hell Creek is composed of sandstone, siltstone, shale, lignite and bentonitic claystone. The Hell Creek is underlain, in descending order, by the marine Fox Hills and Pierre Formations, both of which are late Cretaceous. The Fox

Fig. 3. Generalized stratigraphic column for the Upper Cretaceous and Paleocene in North Dakota (modified from Clayton, 1972, p. 4).


Paleocene
Upper Cretaceous
Fort Union Group
Sentinel Butte Fm.
Tongue River Fm.
Lebo Mbr.
Tullock Mbr.
Ludlow Fm.
Cannonball Fm.
Hell Creek Fm.
Fox Hills Fm.
Pierre Fm.

Hills is predominantly sandstone with smaller amounts of shale and the Pierre is predominantly shale. Overlying the Fort Union Group is the Golden Valley Formation which extends from the uppermost Paleocene into the lower Eocene. It consists of claystone, mudstone, lignite and micaceous sandstone (Hickey, 1972, p. 106-107). Table 1 summarizes the lithologies and depositional environments for the Cannonball and adjacent stratigraphic units.

Structural setting.--The major structural feature that affects the Cretaceous and Tertiary rocks in North Dakota is the Williston Basin. According to Ballard's structure contour map (1942, fig. 2), utilizing the top of the Lower Cretaceous "Dakota Sandstone" as a datum, the center of the basin is about 60 miles southeast of Williston, North Dakota. Benson (1952, p. 228) using the top of the Tertiary as a datum, proposed a basin center east of the one indicated by Ballard. Geophysical well log information from the Cretaceous and Tertiary (Carlson, 1973b) more closely agrees with Benson's suggestion. The regional dip is toward the center of the basin and generally less than 1°, and may vary considerably locally (Cvancara, 1976, p. 12).

Superimposed on the basin are other structures that account, in part, for the local variations in dip value and direction. The northwest-trending Cedar Creek anticline in the southwest corner of the state and the north-trending Nesson anticline just east of Williston, North Dakota are the two most prominent structural features superimposed on the Williston basin. Dips on the flanks of these two structures generally exceed the average dip for the basin (Cvancara, 1976, p. 12). Dip values may also vary depending upon where stratigraphically and

TABLE 1

SUMMARY OF LITHOLOGIES AND DEPOSITIONAL ENVIRONMENTS FOR THE CANNONBALL AND ADJACENT STRATIGRAPHIC UNITS

Formation	Dominant Lithologies	Depositional Environments
Sentinel Butte	Calcareous sandstone, siltstone, shale, lignite	Mainly fluvial
Tongue River	Calcareous sandstone, siltstone, shale, lignite	Mainly fluvial, possibly deltaic in part
Cannonball	Mudstone, sandstone	Marine, brackish-water
Ludlow	Siltstone, claystone, sandstone, lignitic shale, lignite	Fluvial
Hell Creek	Sandstone, siltstone, shale, lignite, bentonitic claystone	Fluvial, brackish-water, minor marine
Fox Hills	Sandstone, siltstone, shale	Marine
Pierre	Shale	Marine

geographically the dip is being measured. Cvancara (1976, p. 12-13) summarized the known values of regional dip in the Williston Basin.

Material and Methods

The material used in this study was from cuttings from 60 water test wells drilled by the North Dakota State Water Commission and two oil wells. The Cannonball-Ludlow interval, as picked by the well site geologist plus an additional 20 m of samples above and below the interval contacts was used in the initial selection of samples. Commonly this chosen interval did not include the entire Cannonball-Ludlow interval and it became necessary to prepare another 20 m of samples from either above or below the chosen interval. This process was repeated until I was certain I had samples for the entire Cannonball-Ludlow interval. Samples at the well site were generally taken at 1.52-m (5.0 ft) intervals. Since the samples were taken at such wide spacings, every sample in the interval was used. Subsamples of 4.0 cc were prepared for the study of microfossils. All samples were obtained from the North Dakota Geological Survey Core and Sample Library in Grand Forks, North Dakota.

Sample preparation for microfossils.--Each 4.0-cc subsample for microfaunal analysis was placed into a small baby food jar to which was added a 5% Calgon (sodium hexa-meta-phosphate) solution. The jars were sealed to prevent contamination. The original covers were used for this purpose because they provided an excellent, water-tight seal. Generally, a few hours were sufficient to disaggregate the clays in most samples. Additional time, up to about 24 hours, was required for a few samples. Samples requiring agitation were agitated gently to avoid breaking

delicate microfossils. After soaking, the samples were wet sieved through a 62μ sieve. Care was taken not to run a large volume of water through the sieve in order to avoid breaking microfossils. The residue from the sieve was washed into a 100 mm watch glass and dried in an oven at 70° to 80° C.

The dried samples were not dry sieved because the small size of the prepared samples made further handling unnecessary. Also, additional sieving would have increased the probability of microfossil breakage.

The prepared samples were picked under an American Optical series 25 microscope at 36 and 72 power and all microfossils were removed and placed onto storage slides that had been previously coated with gum tragacanth. The entire sample was picked.

Statistical methods.--Computerized Q- and R-mode cluster analyses were performed on the Cannonball microfauna using the Dice correlation coefficient. There are a large number of binary (presence-absence) correlation coefficients available (Cheatham and Hazel, 1969). Simpson's index, according to Hazel (1970, p. 3239-3240), emphasizes similarities and in some cases is not suitable for biostratigraphic work. Mello and Buzas (1968, p. 749) indicated that Simpson's index was too insensitive to sample diversity. Hazel (1970, p. 3240) stated that the simple matching coefficient gave erratic results and Mello and Buzas (1968, p. 749) felt that the simple matching coefficient was too insensitive to inadequate sampling. Hall (1969) disliked the Jaccard's coefficient because the mismatches were given equal weight with the matches. He preferred the Dice coefficient because the mismatches were given about half the weight of the matches (Hall, 1969, p. 320, 322). According to Hazel (1970, p. 3239), the Otsuka and Dice coefficients give very similar

results. The Dice coefficient was chosen for both Q- and R-mode for this study because it places more emphasis on similarities rather than differences and is "intermediate in characteristics" (Hazel, 1970, p. 3240). The simple presence-absence method was chosen because it is less sensitive to environmental control than the other coefficients (Hazel, 1970, p. 3240). The Dice coefficient is:

$$\frac{2C}{N_1 + N_2}$$

where, in Q-mode, C is the number of species in common between the two samples being compared, N_1 is the total number of species in sample 1 and N_2 is the total number of species in sample 2. In R-mode, C is the total number of mutual occurrences of the two species being compared, N_1 is the total number of occurrences of species 1 and N_2 is the total number of occurrences of species 2.

Clustering of correlation coefficients can be accomplished by two methods, the weighted pair group method (WPGM) or the unweighted pair group method (UPGM). Hazel (1970, p. 3239) found the UPGM to be more faithful to the original matrix of coefficients and Sokal and Rohlf (1962) found less distortion in the UPGM. Therefore, the UPGM was used in this study.

The correlation coefficients were computed and dendrograms were constructed using the Simqual and Taxon programs of the NTSYS computer system of multivariate statistical programs.

Photographic methods.--Photographs of the foraminiferids (Plates 1-5) are scanning electron photomicrographs made on Kodak commercial film 4127 (Estar thick-base) using a Cambridge Stereoscan S-4 scanning

electron microscope at magnifications of 50X, 100X, 200X or 500X. The specimens were coated in an omnidirectional shadower with an undercoating of carbon and an overcoating of gold-palladium. The specimens were mounted on the SEM stubs using double stick tape.

LITHOSTRATIGRAPHY

General

Thickness.--The thickest reported Cannonball is 120 m in the subsurface at Garrison Dam, North Dakota (Fox and Olsson, 1969). Cvancara (1976, p. 12), however, questioned this value and suggested that the thickest Cannonball occurs in northeastern Adams, southeastern Hettinger and western Grant Counties; he recognized a maximum of 385 ft (about 117 m) in NDSWC well 3527 (134-91-32 CCC) in southeastern Hettinger County. I have interpreted a slightly thicker sequence of 118 m (388 ft) of Cannonball in NDSWC well 4312 (131-94-20 CBC) in north-central Adams County. From this thick area, the Cannonball generally thins to the south, west, and north with a slight thickening in Dunn County (Cvancara, 1976, p. 12). In the westernmost outcrop area of the Cannonball along the Little Missouri River in northwestern Slope County, the Cannonball is represented by two, brackish-water tongues. Van Alstine (1974) reported a combined thickness of the tongues as about 9 m.

The thickest reported, noncomposite outcrop section (Cvancara, 1965, p. 34; Fenner, 1974, p. 16) is on the Heart River west of Mandan, North Dakota. At this locality Cvancara measured 88 m of Cannonball and Fenner measured 98 m of Cannonball; however, Cvancara (1976, p. 12) reported that the lower 76.2 ft (23.2 m) may be Ludlow. Laird and Mitchell (1942, p. 36-37) measured a composite section of Cannonball

with an aggregate thickness of 307 ft (93.3 m), but Cvancara (1976, p. 12) considered the lowest 25 ft (7.6 m) to be in the Ludlow.

Lithology.--The Cannonball Formation is composed primarily of alternating sandstones and mudstones. Minor lithologic types include claystone and shale. The term "shale" has been used by certain workers in reference to Cannonball mudstone; however, since it generally lacks fissility, I have chosen the term mudstone. According to Spock (1962, p. 209), shale is fissle and mudstone is massive, thick-bedded and non-fissle. The term "blocky" has been used to describe the mudstone structure (e.g. Cvancara, 1976, p. 8). Both the sandstone and mudstone are poorly indurated with the exception of mainly carbonate-cemented concretionary zones of varying composition, morphology and size.

The Cannonball sandstones are fine- to very fine-grained with angular to subangular particles. The color of the sandstones varies from yellowish gray to light greenish gray where fresh and both appear brownish yellow where weathered. The composition varies but constituents common to all Cannonball sandstones are quartz, mica (biotite, chlorite, and muscovite) and appreciable to negligible clay. Both Cvancara (1965, p. 25) and Fenner (1974, p. 16) reported clay from all Cannonball sandstones at surface exposures. Small lignitic particles have been observed from most surface and subsurface samples and glauconite is rare to common. Secondary components of the Cannonball sandstones include rare gypsum aggregates and crystals and rare to common marcasite nodules. In subsurface samples, the marcasite nodules occur as commonly as they do in surface samples, but gypsum occurs much more rarely. Marcasite or pyrite also commonly occur as foraminiferid or ostracode infillings.

The clay fraction of five Cannonball mudstone samples (Fenner, 1974, p. 17) is predominantly montmorillonite and illite with traces of kaolinite and possibly chlorite. The mudstones are silty and often sandy, and the coarser grained material consists mainly of abundant quartz, common mica (biotite, chlorite and muscovite) and common lignitic particles. Fenner (1974, p. 17) reported common to rare gypsum aggregates and crystals from the Cannonball outcrops, but in the subsurface, gypsum is rarely, if ever, present. Marcasite nodules and either marcasite or pyrite foraminiferid and ostracode infillings are common. Glauconite pellets are present in most and abundant in few Cannonball mudstones.

Lindberg (1944) indicated that green amphibole was the dominant heavy mineral in 16 samples from Cannonball mudstones and sandstones. Later, Lindberg (in Lemke, 1960, p. 32) identified 13 nonopaque heavy minerals. The nonopaque heavy minerals, in decreasing order of abundance, were garnet, zircon, epidote, sphene, tourmaline, zoisite, rutile, chloritoid, and kyanite with traces of hornblende, biotite, staurolite and glaucophane. Although they comprised over half of the heavy minerals, the opaque heavy minerals were not identified. It seems likely that the opaque heavy minerals were mainly pyrite or marcasite because one or possibly both of these minerals is present and commonly abundant in most Cannonball samples.

Sedimentary structures.--Concretions in the Cannonball are known mainly from the surface. I have not seen any cuttings that could be interpreted as being derived from concretions; however, rarely, sample logs include thin (about 30 cm) limestone or indurated sandstone beds. It is probable that these limestone and indurated sandstone beds

reported from the subsurface are actually concretionary zones. Since the concretions are not as common in the subsurface as they are in exposures, it is possible that the occurrence of concretions is mainly a near-surface phenomenon. Groenewold (1976) largely discounted this possibility because concretions occur at depth in strip mines. He indicated that a more probable explanation for the limited occurrence of concretions in drill holes is that the concretionary zones are discontinuous and the boreholes, therefore, rarely penetrate any actual concretions. If the drill bit were to strike a concretion, it could easily be deflected into the poorly consolidated surrounding rock.

Cannonball concretions are of three types, mudstone, sandstone and limestone (Cvancara, 1965, p. 36-37). The mudstone concretions occur only in the mudstone lithofacies, are well indurated with calcareous cement, are lenticular to subspherical, and are usually elongate parallel to the bedding. They are light to medium gray to bluish gray on fresh surfaces and light gray to brownish yellow on weathered surfaces.

Limestone concretions occur exclusively in the mudstone lithofacies. They are 15-70 cm thick and are dark bluish gray to black on fresh surfaces and light or medium brownish yellow on weathered surfaces.

The concretions in the sandstones are of two types. The smaller type (mean diameter 6-7 cm) is subspherical to elongate and phosphatic; they are light yellowish gray on fresh surfaces and light grayish brownish yellow on weathered surfaces. The larger type (mean diameter 70 cm) is medium gray to medium blue-greenish gray on fresh surfaces and light grayish, brownish yellow on weathered surfaces. The larger concretions

occur as linear zones that are parallel to the bedding and occasionally grade into more massive, continuous, lenticular, sandstone beds.

In addition to concretions, Cvancara (1965, p. 35) reported cross stratification, ripple marks, cone-in-cone structure and questionable clastic dikes and sills. Cross stratification is common in the Cannonball (Cvancara, 1965, figs. 2 and 5 and pl. 1, fig. 1; Fenner, 1974, figs. 3, 4 and 8). Cvancara (1972b) also observed large-scale cross-stratification on the Heart River west of Mandan, North Dakota (NW¼ sec. 13, T. 138 N., R. 83 W.). According to Cvancara (1965, p. 39), cross stratification "is almost entirely restricted to poorly consolidated sandstone with minor amounts of clay."

Ripple marks occur less commonly than cross stratification. Cvancara (1965, p. 39-40) reported ripple marks from three Cannonball localities. At two localities, oscillation ripples were observed and at the third locality, interference current ripples were observed. The orientations of the ripple marks were generally north with the exception of a second subdued cross set at the third locality; its orientation was approximately east-southeast. Ripple marks were also observed by Cvancara (1972b) in the lower-middle Cannonball along the Heart River, west of Mandan, North Dakota (on the line common to secs. 19 and 24, T. 139 N., Rs. 81 and 82 W.).

Cvancara (1965, p. 40) reported cone-in-cone structure at one Cannonball locality. The cone-in-cone structure was noted as a one inch-thick, peripheral layer, surrounding a few sandstone concretions.

Cvancara (1965, p. 40-41) also noted questionable clastic dikes and sills at one locality. The dikes and sills were composed of

sandstone and were located in a silty mudstone. The presumed clastic dikes and sills were similar in composition to the beds overlying the silty mudstone.

Grain-Size Distributions

Because well cuttings are subject to contamination, no grain-size analyses were performed for this study. Fenner (1974, fig. 9) performed grain-size analyses on thirty-three Cannonball outcrop samples distributed among both sandstones and mudstones. The mean grain sizes of sandstone and mudstone samples ranged from 2.4 ϕ to 8.4 ϕ. The mean grain sizes of the sandstone samples ranged from 2.4 ϕ to 3.0 ϕ and those for the mudstone samples ranged from 5.8 ϕ to 8.4 ϕ. The greater grain-size variation was attributed to highly variable amounts of silt (Fenner, 1974, p. 18).

Foraminiferids are concentrated mainly in the mudstone lithofacies. They are most abundant in samples in which less than 5% of the total volume is larger than 4 ϕ.

MICROFAUNAL ANALYSIS

The well cuttings utilized in this study yielded 50 species of benthonic and 4 species of planktonic foraminiferids. The benthonic foraminiferids represent 32 genera in 19 families. The planktonic fauna represents 4 genera in 3 families. By suborder, the fauna consists of 8 textulariines, 2 miliolines and 44 rotaliines. The textulariines account for 15.1% of the species and 17.5% of the individuals, the miliolines comprise 5.7% of the species and 0.1% of the individuals, and the rotaliines represent 81.1% of the species and 82.4% of the individuals.

The rotaliines dominate in terms of numbers of individuals in all wells except NDSWC wells 4453 and 4456 in western Adams and east-central Bowman Counties where the textulariines predominate. The miliolines are represented by only three individuals that occurred in NDSWC well 3647 in eastern Oliver County.

Fox and Ross (1942) indicated that they collected 64 species of foraminiferids from the Cannonball. They, however listed only the 43 species that occurred in the Gulf Coast. Since they did not list all of the species they collected, valid comparisons cannot be made. Of the species they reported, eight were definitely found in this study:

Ammodiscus incertus

Cyclogyra involvens (=Cornuspira involvens)

Nodosaria affinis

Globulina gibba

Globorotalia pseudobulloides

Cibicidoides alleni (=Cibicides alleni)

Gyroidinoides aequilateralis (=Gyroidina aequilateralis)

Ceratobulimina perplexa.

Eight of Fox and Ross' species are similar in appearance to forms collected in this study. Since their specimens were not illustrated, it is not possible to determine whether the species from the two studies that are morphologically similar are the same. The species that are morphologically similar with the names assigned in this study given first are:

Dentalina colei = D. gardnerae

Chrysalogonium sp. = C. granti

Lenticulina midwayensis = L. degolyeri

L. turbinata = L. pseudomammillegera

Bulimina rosenkrantzi = B. quadrata

Allomorphina paleocenica = A. n. sp.

Anomalinoides umboniferus = Valvulineria midwayensis

Alabamina midwayensis = A. exigua

Of the planktonic foraminiferids, one, Globorotalia pseudobulloides was found during both studies.

Twenty-six species reported by Fox and Ross (1942) that I did not collect are:

Spiroplectammina laevis

Eggerella? sp.

Nodosaria longiscata

N. radicula

Dentalina communis

D. mucronata

D. pauperata

D. plummerae

Lagena apiculata

L. substriata

Lenticulina orbicularis

L. rotulata

Marginulina tumida

Palmula budensis

Vaginulina midwayana

V. plumoides

Globulina communis

G. lactea

G. ovata

Guttulina cf. G. wilcoxensis

Stilostomella plummerae (=Nodogenerina plummerae)

Epistominella elegans

Valvulineria allomorphinoides

Siphonina prima

Subbotina triloculinoides (=Globigerina triloculinoide

The following 33 species that I collected were not listed by Fox and Ross (1942):

Reophax sp. (2 species)

Haplophragmoides sp. (2 species

Ammobaculites expansus

Spiroplectammina wilcoxensis

Trochammina sp.

Quinqueloculina plummerae

Dentalina eocenica

D. pseudo-obliquestriata

D. sp.

Lenticulina alabamensis

L. arkansasana

Lingulina sp.

Globulina sp. (2 species)

Pyrulina cylindroides

Spirobolivina emmendorferi

Bulimina sp.

Epistominella minuta

Rosalina sp.

Pararotalia perclara

Chiloguembelina midwayensis

Globoconusa daubjergensis

Cibicides (2 species)

Fursenkoina sp.

Caucasina marylandica

Nonion graniferum

Pullenia quinqueloba

Gyroidinoides sp.

Anomalinoides midwayensis

A. sp.

Cibicidoides vulgaris

Lemke (1960, p. 30-31) reported 30 species of foraminiferids from the Cannonball of which 10 are in common with this study:

Ammodiscus incertus

Nodosaria affinis

Lenticulina midwayensis (=Robulus midwayensis)

Pyrulina cylindroides

Bulimina rosenkrantzi

Globorotalia pseudobulloides (=Globigerina pseudobulloides)

Cibicidoides alleni (=Cibicides alleni)

Ceratobulimina perplexa.

Lemke (1960) reported both Anomalina midwayensis and Anomalinoides midwayensis. Berggren and Aubert (1975, p. 149-150), in their synonymy for Anomalinoides midwayensis, indicated that Anomalina midwayensis is a synonym of Anomalinoides midwayensis.

Lemke did not illustrate any of his specimens, but seven are similar in appearance or were not identified to species and might be in common. The names used in this report are given first:

Dentalina colei = D. gardnerae

Dentalina sp. = Dentalina sp.

Lenticulina midwayensis = L. degolyeri

Bulimina sp. = B. sp.

Haplophragmoides sp. A or B = H. sp. (2 n. sp.)

Lenticulina midwayensis = L. wilcoxensis.

Nogan (1964) noted that Lenticulina wilcoxensis and L. degolyeri are uncoiled varieties of L. midwayensis.

Lemke (1960, p. 30-31) reported 30 species of foraminiferids from the Cannonball of which 10 are in common with this study:

Ammodiscus incertus

Nodosaria affinis

Lenticulina midwayensis (=Robulus midwayensis)

Pyrulina cylindroides

Bulimina rosenkrantzi

Globorotalia pseudobulloides (=Globigerina pseudobulloides)

Cibicidoides alleni (=Cibicides alleni)

Ceratobulimina perplexa.

Lemke (1960) reported both Anomalina midwayensis and Anomalintoide midwayensis. Berggren and Aubert (1975, p. 149-150), in their synonymy for Anomalinoides midwayensis, indicated that Anomalina midwayensis is a synonym of Anomalinoides midwayensis.

Lemke did not illustrate any of his specimens, but seven are similar in appearance or were not identified to species and might be in common. The names used in this report are given first:

Dentalina colei = D. gardnerae

Dentalina sp. = Dentalina sp.

Lenticulina midwayensis = L. degolyeri

Bulimina sp. = B. sp.

Haplophragmoides sp. A or B = H. sp. (2 n. sp.)

Lenticulina midwayensis = L. wilcoxensis.

Nogan (1964) noted that Lenticulina wilcoxensis and L. degolyeri are uncoiled varieties of L. midwayensis.

Seven species listed by Lemke (1960) that were not collected in this study include:

Epistominella n. sp. (*Pulvinulinella* n. sp.)

Lenticulina inornata (=*Robulus inornatus*)

Lagena substriata

Discorbis n. sp.

Epistominella elegans

Loxostoma sp.

Eggerina n. sp.

Fox and Olsson (1969) reported seven species of planktonic foraminiferids from the Cannonball. Three species in common between their study and this report are:

Globorotalia pseudobulloides

Globoconusa daubjergensis

Chiloguembelina midwayensis.

Species that Fox and Olsson (1969) reported that were not collected in this report include:

Globigerina edita

Subbotina triloculinoides

S. varianta

Chiloguembelina morsei.

The one planktonic species from this report that was not identified by Fox and Olsson (1969) is *Pararotalia perclara*.

I (Fenner, 1974) reported 26 species of benthonic foraminiferids from the Cannonball in outcrop. The following 14 species are in common between my two studies. Where terminology has been changed, the terminology used in this report is given first.

Ammodiscus incertus

Haplophragmoides sp. A = H. excavata

Spiroplectammina wilcoxensis = ?S. sp.

Cyclogyra involvens

Nodosaria affinis

Dentalina colei

D. pseudo-obliquestriata = D. sp.

Lenticulina alabamensis = L. rotulata

L. midwayensis = L. sp. A

Globulina gibba

G. sp. A

Anomalinoides umboniferus = Valvulineria wilcoxensis

Allomorphina paleocenica = A. sp.

Ceratobulimina perplexa.

Twelve species that I (Fenner, 1974) identified from outcrops were not collected for this report:

Bathysiphon eocenicus

Haplophragmoides glabra

Trochammina sp. (not the same as T. sp. in this report)

Peneroplis sp.

Nodosaria latejugata

?Chrysalogonium sp. (not the same as C. sp. in this report)

Dentalina mucronata

?Lagena sp.

Globulina sp. B

Lenticulina sp. B

Marginulina sp.

Cibicides sp. (not the same as any of this genus in this report)

Thirty-nine species identified in this report that I did not identify from outcrops include:

Reophax (2 species)

Haplophragmoides sp. B

Ammobaculites expansus

Trochammina sp.

Quinqueloculina plummerae

Nodosariidae

?Chrysalogonium sp.

Nodosaria sp.

Dentalina eocenica

?D. sp.

Lenticulina arkansasana

L. turbinata

?Lingulina sp.

Globulina sp. B

Pyrulina cylindroides

Spirobolivina emmendorferi

Bulimina rosenkrantzi

B. sp.

Discorbacea

Epistominella minuta

Rosalina sp.

Pararotalia perclara

Chiloguembelina midwayensis

Globoconusa daubjergensis

Cibicides sp.

?*Cibicides* sp.

Fursenkoina sp.

Caucasina marylandica

Nonion graniferum

Nonionella robusta

Pullenia quinqueloba

Alabamina midwayensis

Gyroidinoides aequilateralis

G. sp.

Anomalinoides midwayensis

A. sp.

Cibicidoides alleni

C. vulgaris.

From all studies of the Cannonball, accounting for all possible synonymies, I believe there are at least 93 known species in the Cannonball. The fauna includes eight textulariines, three miliolines and 82 rotaliines. The following faunal list is derived from Fenner (1974), Fox and Ross (1942), Fox and Olsson (1969) and Lemke (1960) in addition to new species from this report:

Bathysiphon eocenicus

Ammodiscus incertus

?Reophax sp. (2 species)

Haplophragmoides glabra

H. sp. (2 species)

Ammobaculites expansus

Spiroplectammina laevis

S. wilcoxensis

Trochammina sp. (2 species)

Eggerella sp.

Eggerina sp.

Cyclogyra involvens

Quinqueloculina plummerae

Peneroplis sp.

Chrysalogonium sp. (2 species)

Nodosaria affinis

N. latejugata

N. longiscata

N. radicula

N. sp.

Dentalina communis

D. eocenica

D. mucronata

D. pauperata

D. plummerae

D. pseudo-obliquestriata

D. sp.

Lagena apiculata

L. substriata

L. sp.

Lenticulina alabamensis

L. arkansasana

Lenticulina inornata

L. midwayensis

L. orbicularis

L. rotulata

L. turbinata

Marginulina tumida

M. sp.

Palmula budensis

Vaginulina midwayana

V. plumoides

Lingulina sp.

Globulina communis

G. gibba

G. lactea

G. ovata

G. sp. (2 species)

Guttulina cf. G. wilcoxensis

Pyrulina cylindroides

Spirobolivina emmendorferi

Stilostominella plummerae

Bulimina rosenkrantzi

B. sp.

Discorbis n. sp.

Epistominella elegans

E. minuta

E. n. sp.

Rosalina sp.

Valvulineria allomorphinoides

Siphonina prima

Pararotalia perclara

Chiloguembelina midwayensis

C. morsei

Globigerina edita

Globorotalia pseudobulloides

Globoconusa daubjergensis

Subbotina triloculinoides

S. varianta

Cibicides sp. (3 species)

Fursenkoina sp.

Caucasina marylandica

Loxostomum sp.

Allomorphina paleocenica

Nonion graniferum

Nonionella robusta

Pullenia quinqueloba

Cibicidoides alleni

C. vulgaris

Alabamina midwayensis

Gyroidinoides aequilateralis

G. sp.

Anomalinoides midwayensis

A. umboniferus

A. sp.

Ceratobulimina perplexa

Samples of a uniform volume of 4 cc collected in this study that contained foraminiferids yielded from a minimum of one to a maximum of 234 individuals (58 individuals/cc). The most productive samples were from NDSWC wells 4388 and 8347. Well 4388 produced a sample which contained 234 individuals. One sample from well 8347 produced 82 individuals. All other samples contained considerably fewer individuals.

In all wells where appreciable foraminiferid-bearing samples are available, the most dense concentration of foraminiferids is in samples from the middle of the foraminiferid-bearing interval. Few foraminiferids are present near the top or bottom of the foraminiferid-bearing interval.

FORAMINIFERAL BIOSTRATIGRAPHY

Foraminiferal Assemblages

Two foraminiferal assemblages are recognized in the Cannonball. The R-mode dendrogram for all wells (Appendix B) shows at least six distinct major clusters; however, only two are probably valid. Four of the major clusters are not significant because the species represented in these clusters are represented by few individuals. The two valid assemblages correspond to the uppermost two major clusters on the dendrogram.

One of the Cannonball assemblages, uppermost on the dendrogram, is the Caucasina-Bulimina assemblage. It is named for Caucasina marylandica and Bulimina rosenkrantzi, which usually dominate samples in which this assemblage occurs. Either one or both of these two species is usually abundant in samples where members of this assemblage occur. Other species in the assemblage include: Haplophragmoides sp. A, Alabamina midwayensis, Gyroidinoides aequilateralis and, less commonly, Ammodiscus incertus and Trochammina sp. The Caucasina-Bulimina assemblage occurs in all wells where more than one species is present. It occurs throughout the study area and is the dominant assemblage in most wells in the western half of the area. In samples where individuals from more than one assemblage are present, the Caucasina-Bulimina assemblage is dominant in terms of number of species, generally in the western half of the study area. The Caucasina-Bulimina assemblage occurs throughout the foraminiferid-bearing interval in the Cannonball Formation.

A second foraminiferid assemblage, the Cibicidoides-Ceratobulimin assemblage is represented by the second major cluster on the R-mode dendr gram for all wells (Appendix B). It is dominated by Cibicidoides alleni and Ceratobulimina perplexa and additionally includes Spirobolivina emmendorferi, Anomalinoides umboniferus, A. midwayensis, and, less commonly, Nodosaria affinis and Lenticulina midwayensis. It may or may not be associated with the Caucasina-Bulimina assemblage. The Cibicidoides-Ceratobulimina assemblage is less clearly defined than the Caucasina-Bulimina assemblage because the species are represented by fewer individuals. Where a mixed fauna composed of elements of both major assemblages occurs, the Cibicidoides-Ceratobulimina assemblage dominates in terms of numbers of species in wells located in the eastern one-third of the study area. The Cibicidoides-Ceratobulimina assemblage occurs throughout the foraminiferid-bearing interval in the Cannonball.

Both assemblages are most commonly represented by four or less of their species. Although both assemblages occur predominantly in the mudstone lithofacies, grainsize may have a subtle effect on their distribution. From the amount of residue remaining after wet sieving, it appears that the Cibicidoides-Ceratobulimina assemblage occurs in slightly sandier lithologies.

Biostratigraphic Correlations

The foraminiferal assemblages were correlated; however, they are of questionable utility. In addition to the two dominant assemblages, the Caucasina-Bulimina and the Cibicidoides-Ceratobulimina assemblages, samples containing elements of both assemblages were plotted as a mixed assemblage (figs. 4-12). Other possible assemblages were not used

Fig. 4. East-west cross section across northern Bowman and Adams Counties with wells arranged according to elevation. Numbers of wells correspond to those on the index map, those on fig. 1, and those on Appendix C. Detailed locations are given in Appendix C. Line patterns indicate foraminiferid assemblages as given in the explanation.

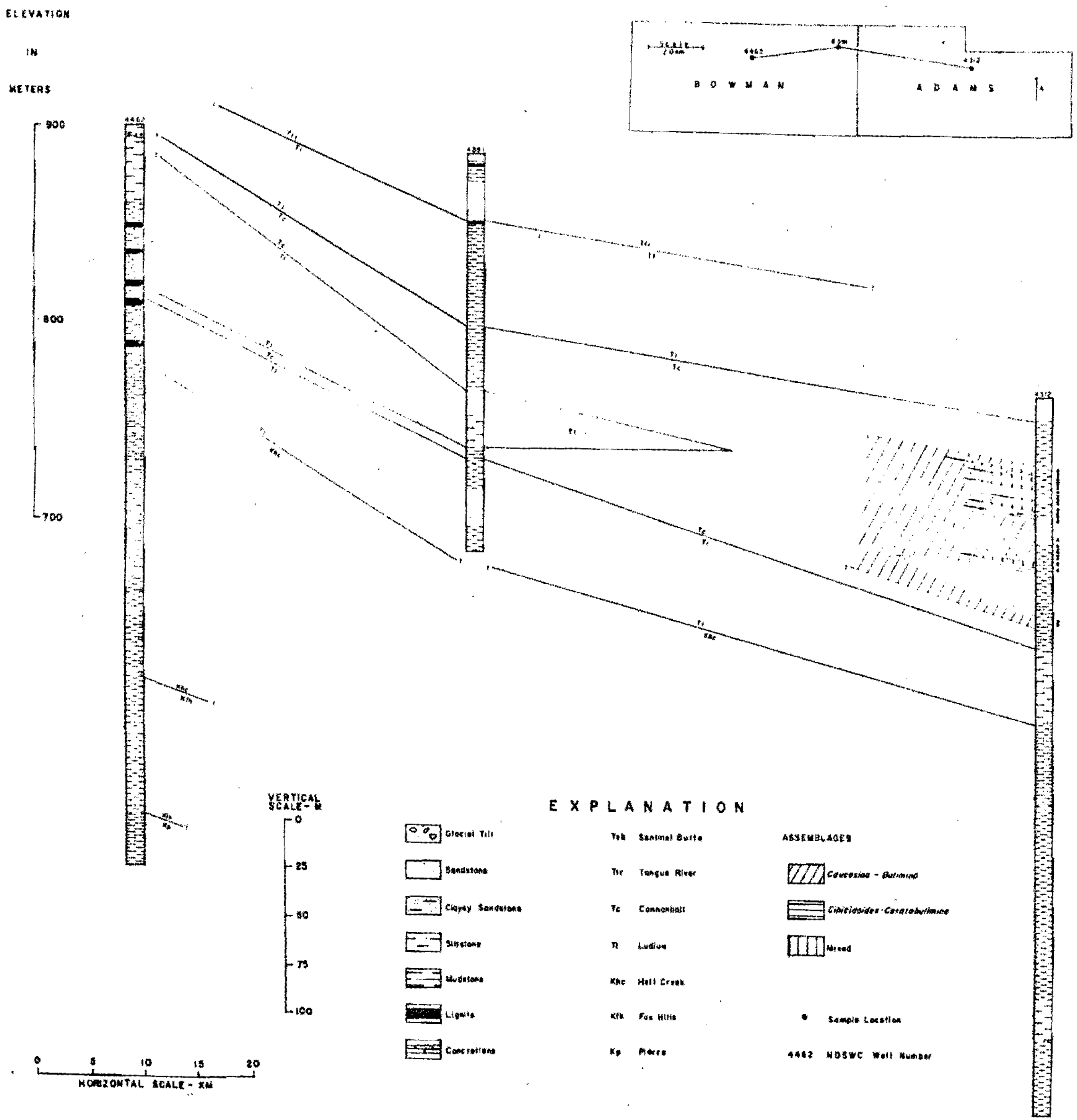

ELEVATION
IN
METERS
900
800
700
4462
4351
4312
BOWMAN
ADAMS
Scale
20km
EXPLANATION
Glacial Till
Sandstone
Clayey Sandstone
Siltstone
Mudstone
Lignite
Concretions
Tsb Sentinel Butte
Ttr Tongue River
Tc Cannonball
Tl Ludlow
Khc Hell Creek
Kfh Fox Hills
Kp Pierre
ASSEMBLAGES
Caucasina - Buliminid
Cibicidoides - Ceratobulimina
Mixed
Sample Location
4462 NDSWC Well Number
VERTICAL SCALE - M
0
25
50
75
100
0
5
10
15
20
HORIZONTAL SCALE - KM

Fig. 5. East-west cross section across southern Bowman and Adams Counties with wells arranged according to elevation. Numbers of wells correspond to those on the index map, those on fig. 1 and those in Appendix C. Detailed locations are given in Appendix C. Explanation of the symbols is given on Fig. 4.

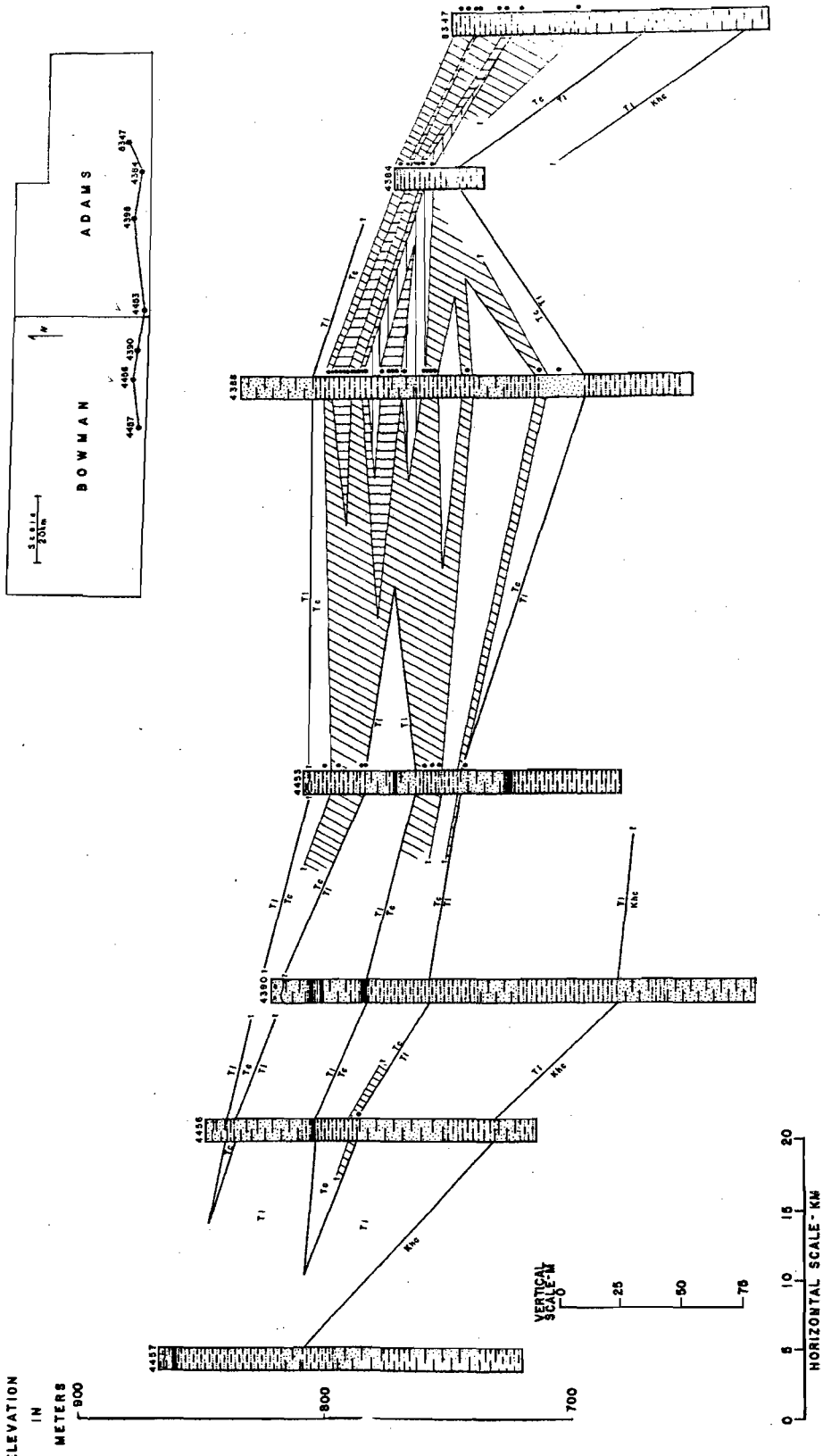

ADAMS
BOWMAN
8347
4384
4388
4453
4390
4456
4457
Tc
Tl
Kkc
ELEVATION IN METERS
800
700
VERTICAL SCALE
0
25
50
75
HORIZONTAL SCALE - KM
0
5
10
15
20

Fig. 6. Southwest-northeast cross section across Grant and Morton Counties with wells arranged according to elevation. Numbers of wells correspond to those on the index map, those on fig. 1 and those in Appendix C. Detailed locations are given in Appendix C. Explanation of the symbols is given on fig. 4.

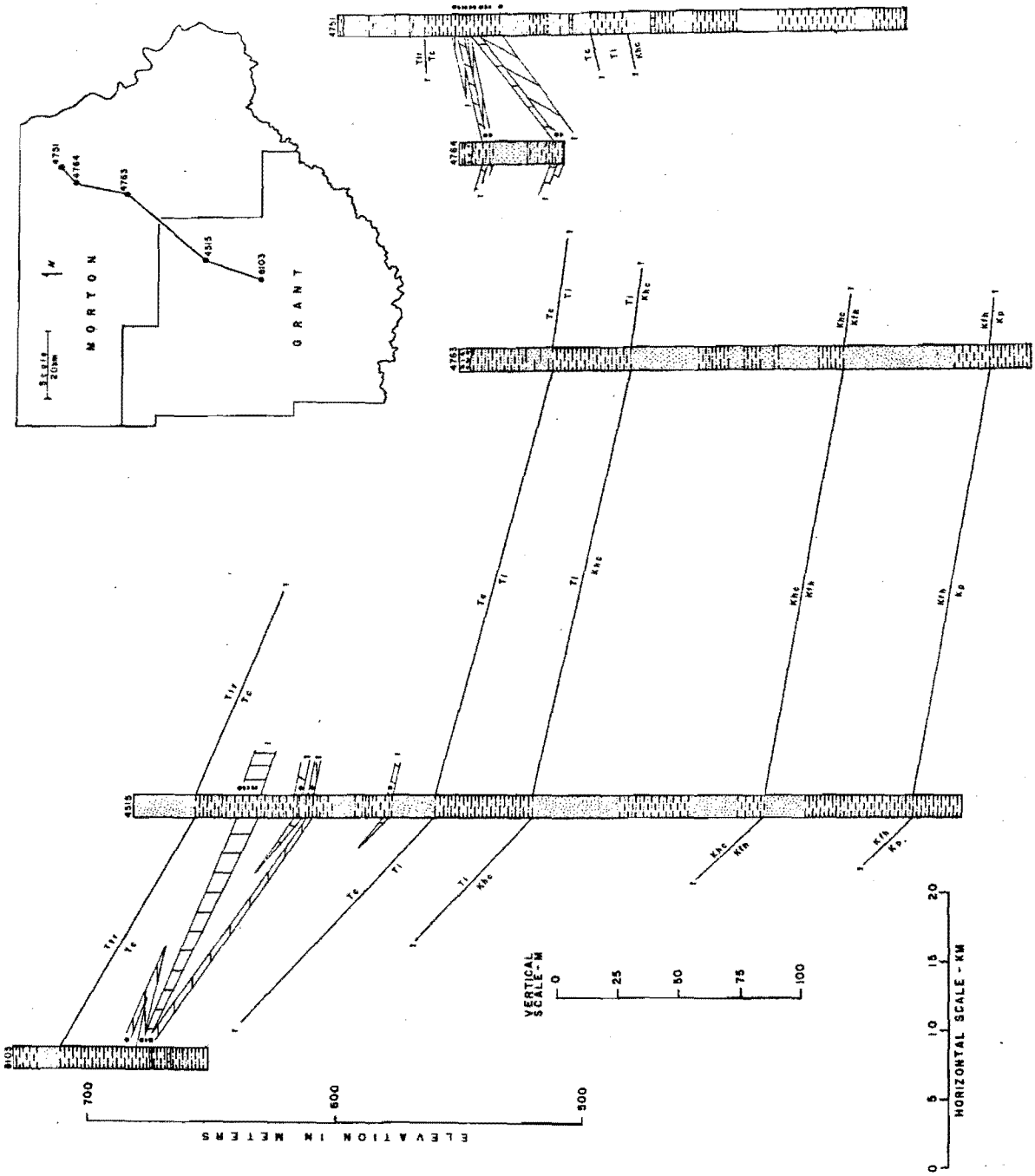

MORTON
GRANT
4731
4784
4763
4515
6103
Scale
20km
N
Tll
Tc
Tl
Khc
Kfh
Kp
VERTICAL SCALE-M
0
25
50
75
100
HORIZONTAL SCALE - KM
0
5
10
15
20
ELEVATION IN METERS
700
600
500

Fig. 7. Northwest-southeast cross section across Grant Cou
with wells arranged according to elevation. Numbers of wells corr
spond to those on the index map, those on fig. 1, and those in App
dix C. Detailed locations are given in Appendix C. Explanation o
the symbols is given on fig. 4.

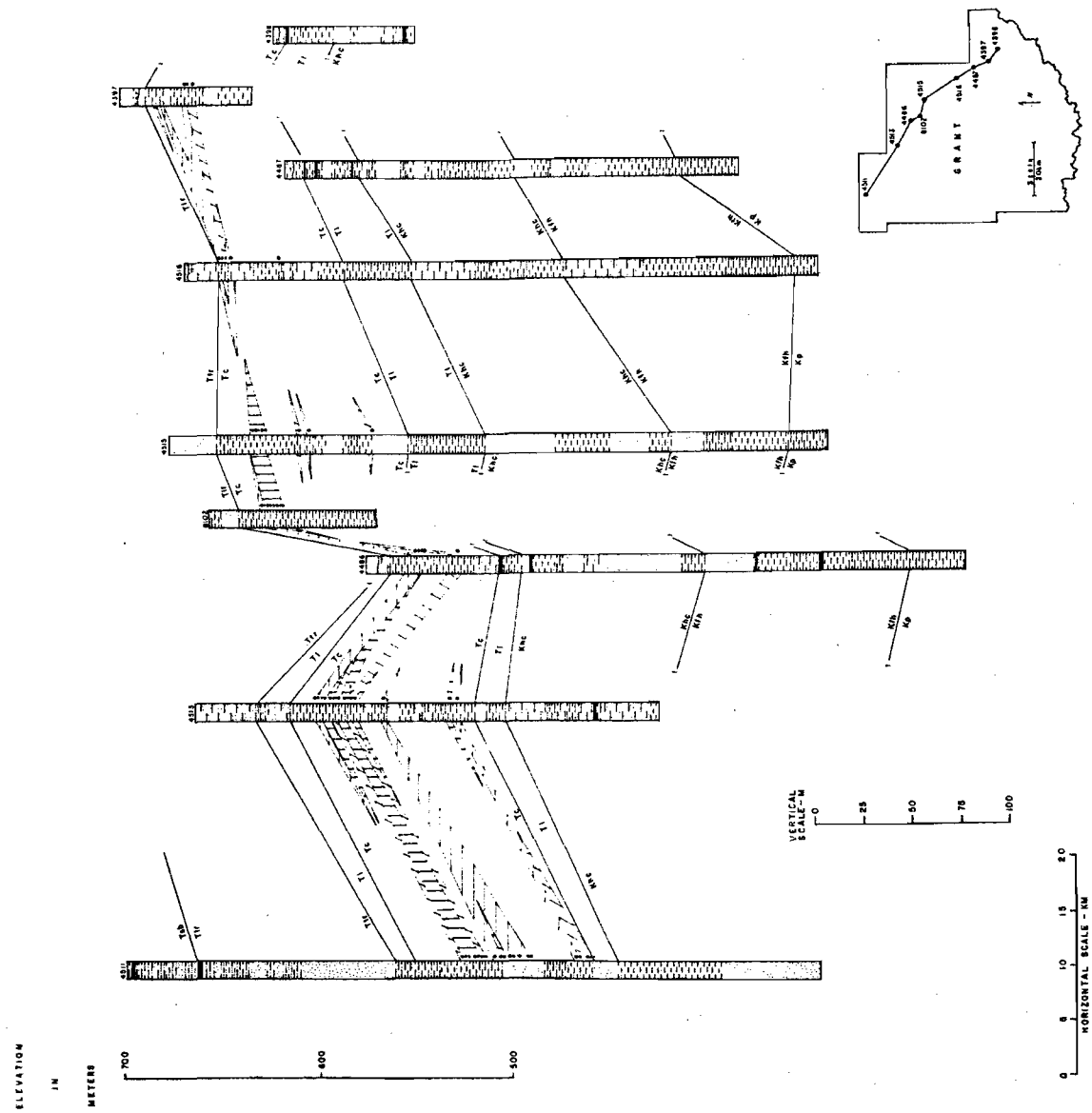

GRANT
ELEVATION IN METERS
700
600
500
VERTICAL SCALE-M
0
25
50
75
100
HORIZONTAL SCALE - KM
0
5
10
15
20

Fig. 8. East-west cross section across Grant and Morton Counties with wells arranged according to elevation. Numbers of wells correspond to those on the index map, those on fig. 1, and those in Appendix C. Detailed locations are given in Appendix C. Explanation of the symbols is given on fig. 4.

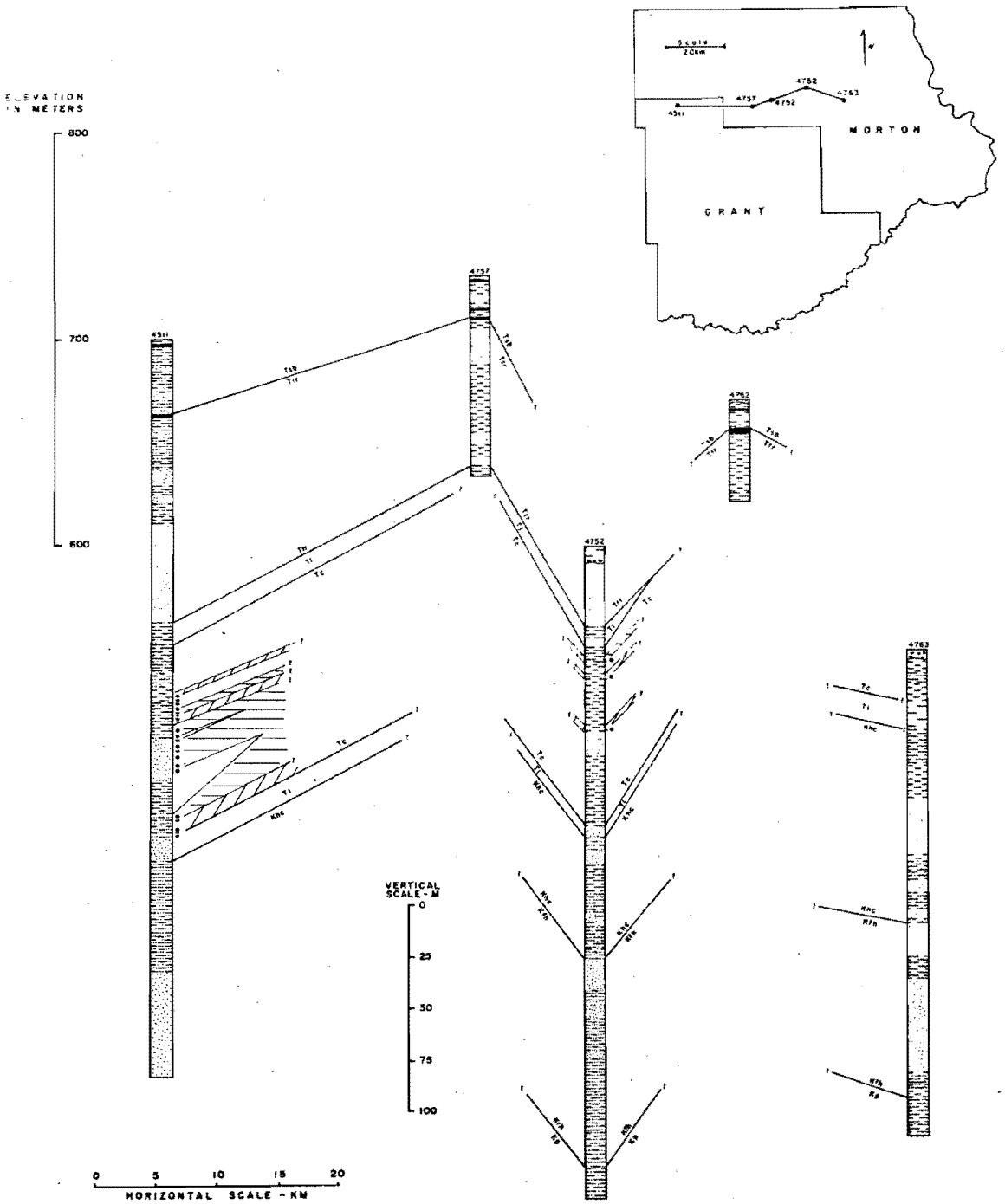

ELEVATION IN METERS
800
700
600
MORTON
GRANT
4511
4757
4752
4753
VERTICAL SCALE - M
0
25
50
75
100
0 5 10 15 20
HORIZONTAL SCALE - KM

Fig. 9. Northwest-southeast cross section across Dunn, Merc
and Oliver Counties with wells arranged according to elevation. Nu
bers of wells correspond to those on the index map, those on fig. 1
and those in Appendix C. Detailed well locations are given in Appe
dix C. Explanation of the symbols is given on fig. 4.

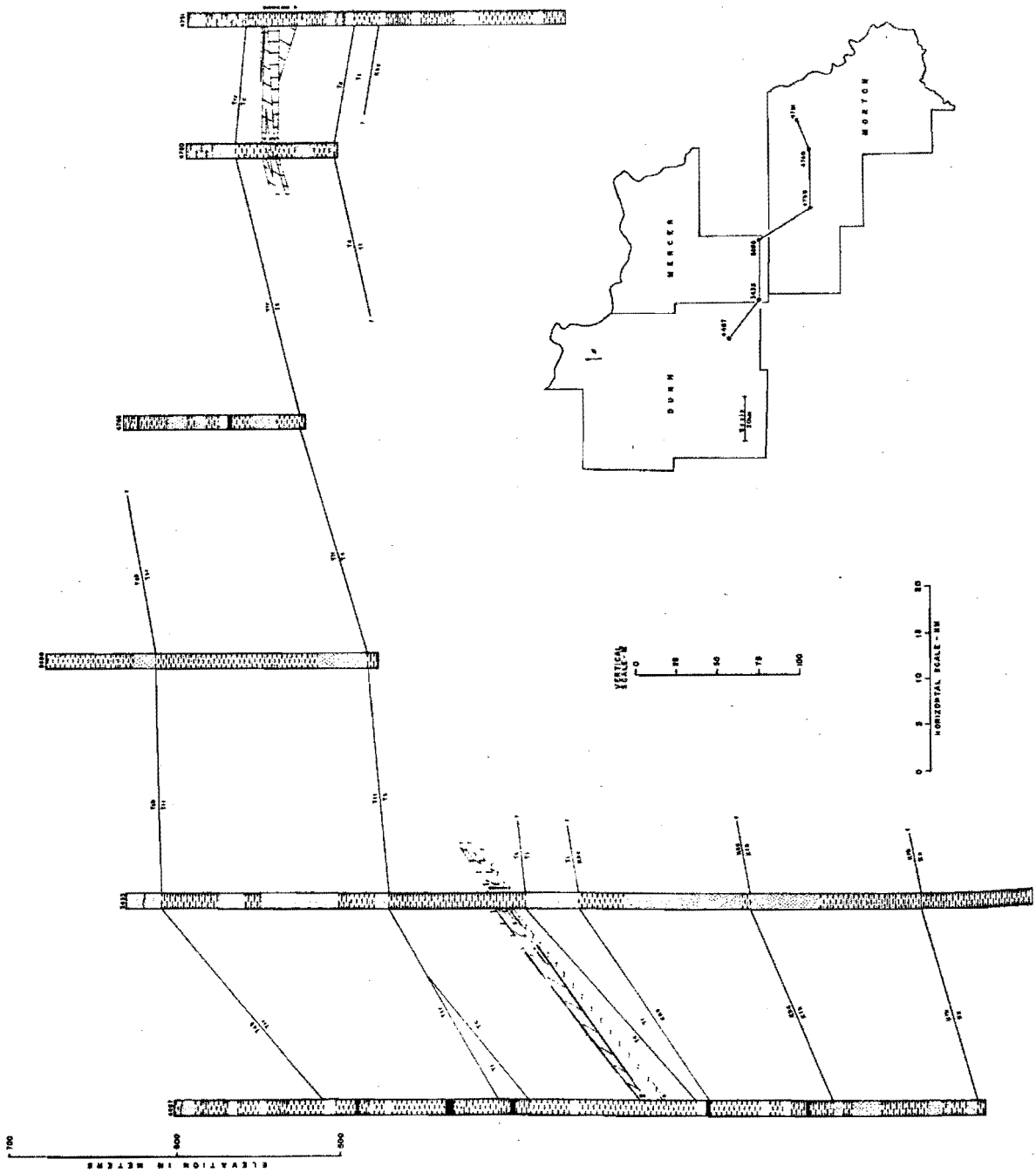

MERCER
MORTON
BURKE
VERTICAL SCALE - FEET
0
25
50
75
100
HORIZONTAL SCALE - MILES
0
5
10
15
20
700
600
500
ELEVATION IN METERS

Fig. 10. Northwest-southeast cross section across Mercer, Oliver and Morton Counties with wells arranged according to elevation. Numbers of wells correspond to those on the index map, thos on fig. 1, and those in Appendix C. Detailed well locations are given in Appendix C. Explanation of the symbols is given on fig.

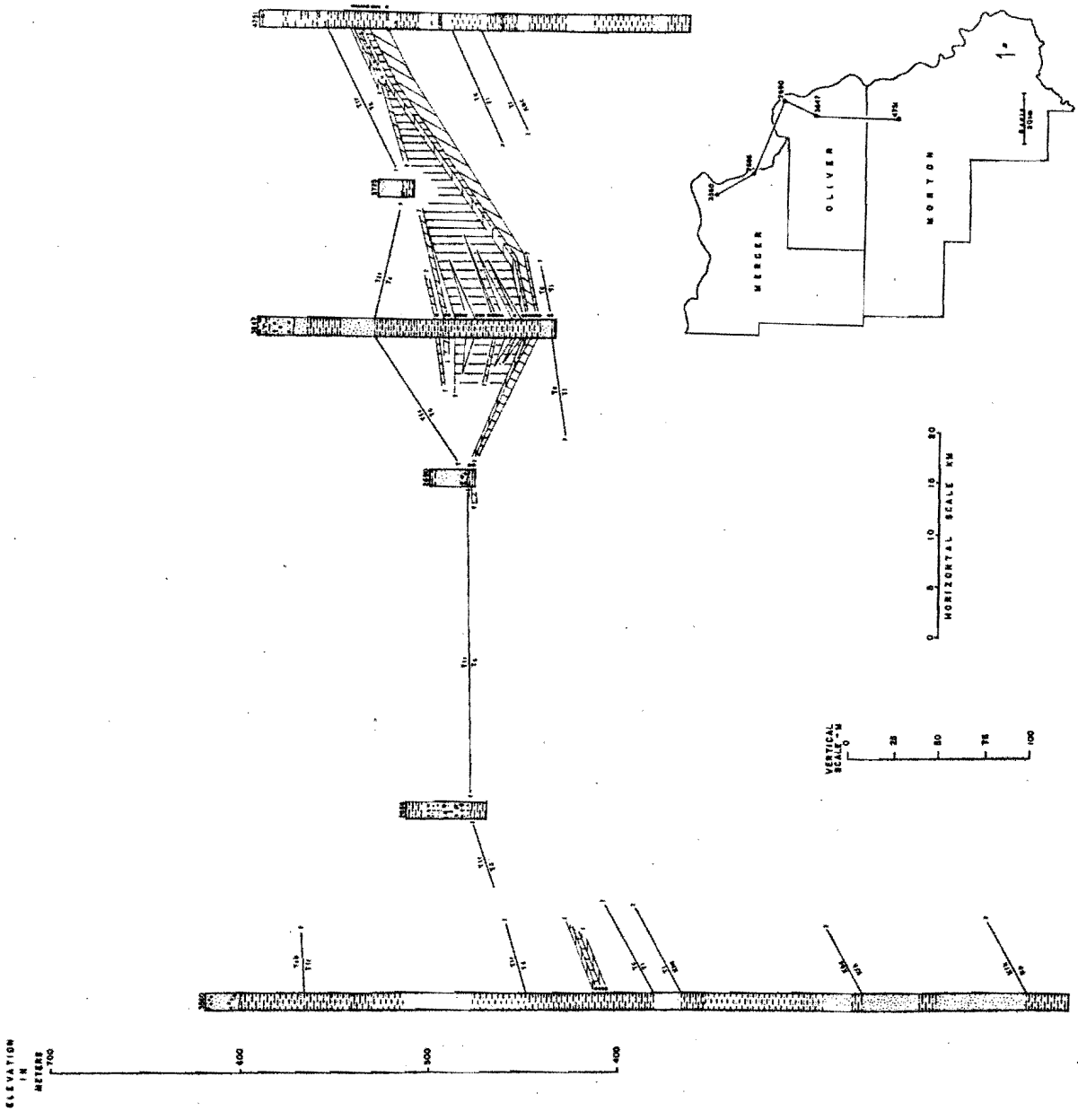

MERCER
OLIVER
MORTON
HORIZONTAL SCALE KM
VERTICAL SCALE - M
ELEVATION IN METERS

Fig. 11. Northwest-southeast cross section across Oliver a
Burleigh Counties with wells arranged according to elevation. Num-
bers of wells correspond to those on the index map, those on fig.
and those in Appendix C. Detailed well locations are given in App
dix C. Explanation of the symbols is given on fig. 4.

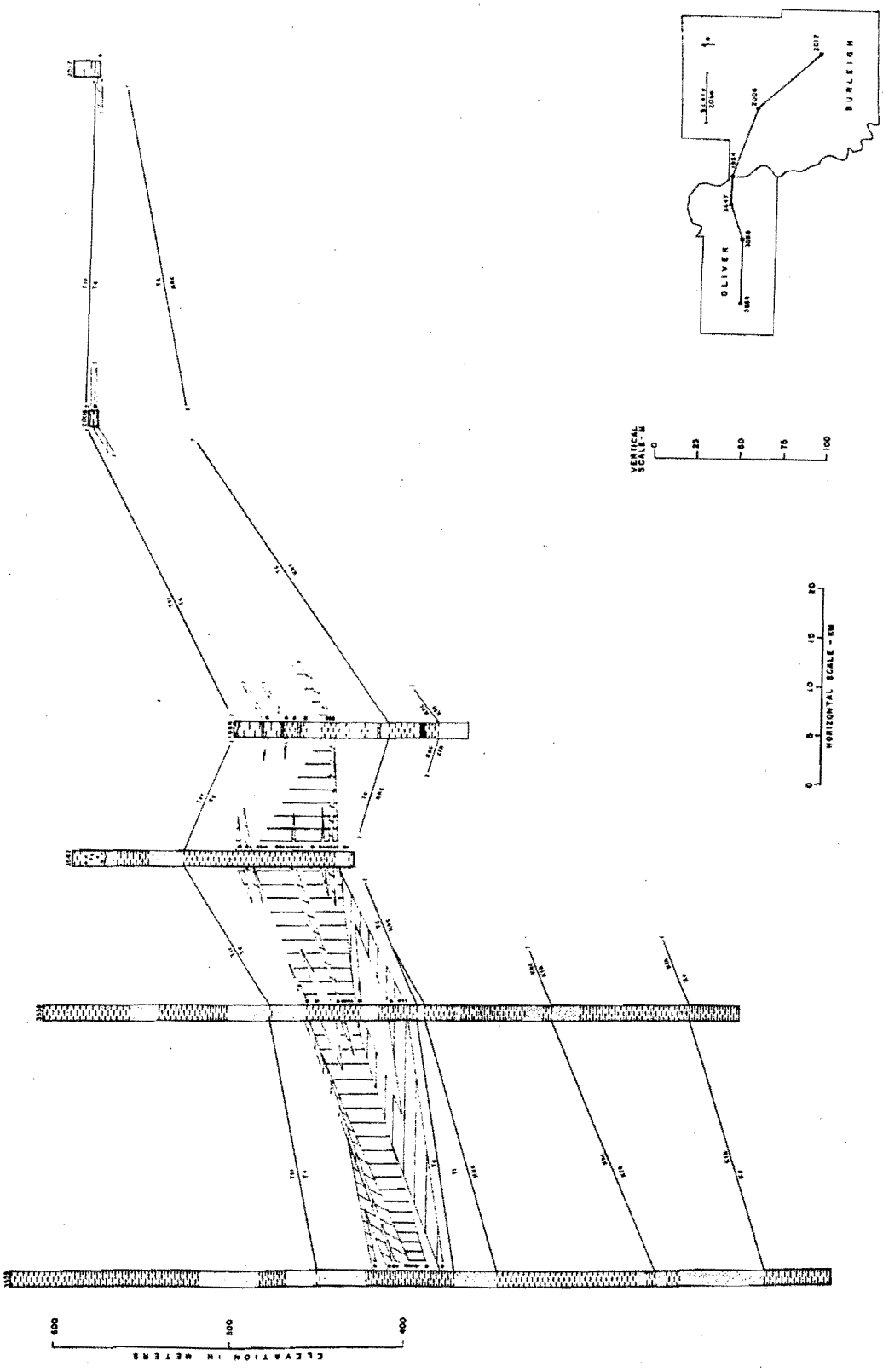
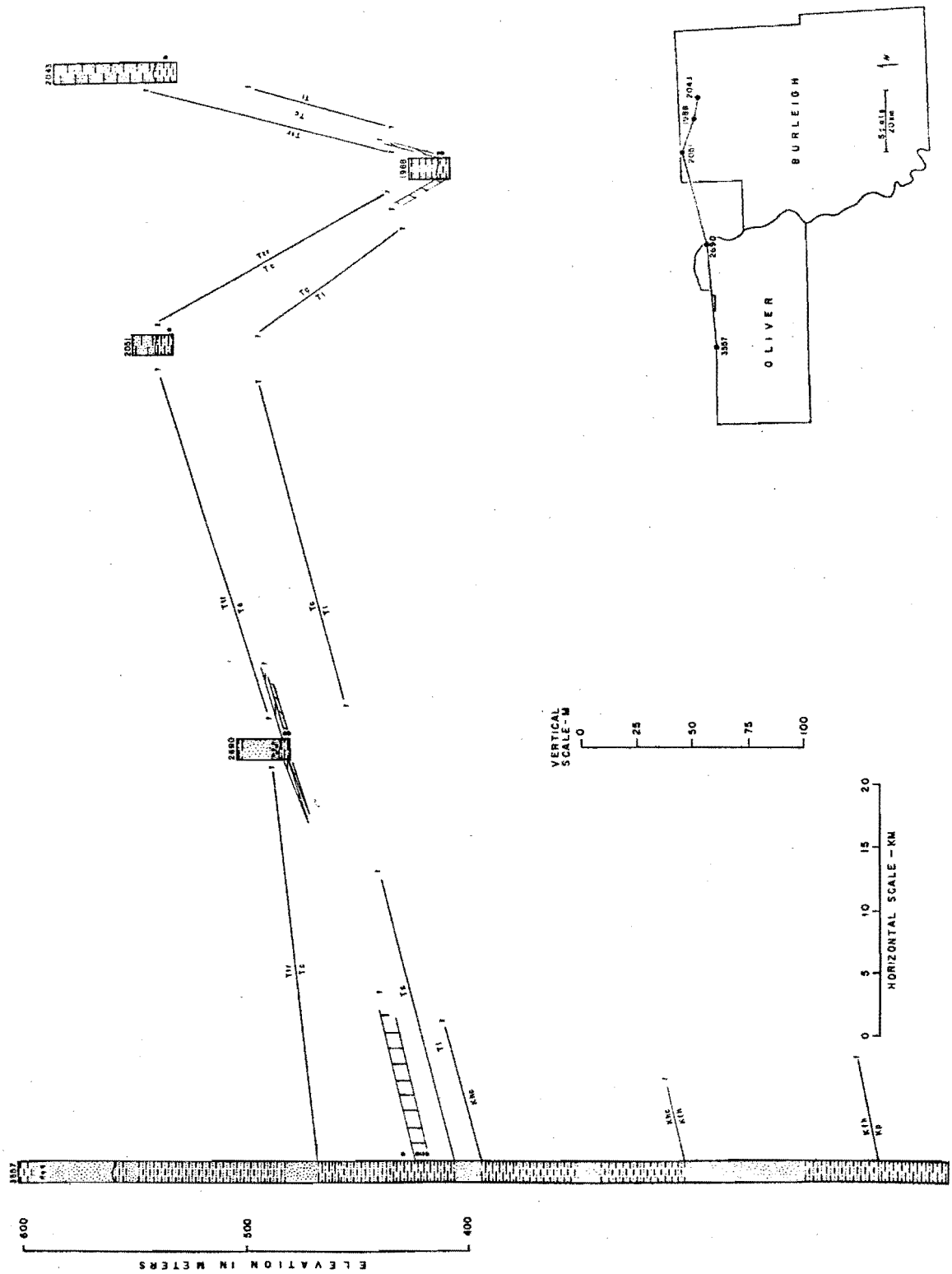

BURLEIGH
OLIVER
VERTICAL SCALE M
0
25
50
75
100
HORIZONTAL SCALE - KM
0
5
10
15
20
ELEVATION IN METERS
600
500
400

Fig. 12. East-west cross section across Oliver and Burl
Counties with wells arranged according to elevation. Numbers o
wells correspond to those on the index map, those on fig. 1, an
those in Appendix C. Detailed locations are given in Appendix
Explanation of the symbols is given on fig. 4.


BURLEIGH
OLIVER
VERTICAL SCALE-M
0
25
50
75
100
HORIZONTAL SCALE - KM
0
5
10
15
20
ELEVATION IN METERS
600
500
400

because their occurrences are rare and species within the R-mode clusters representing other assemblages usually occur as minor constituents in samples that are dominated by one or both of the two major assemblages.

Where enough information is available, the two assemblages and the mixed assemblage were correlated between wells. Commonly, assemblages were repeated in each well and the Q-mode dendrogram was used to determine which of the assemblages correlated.

The mixed assemblage occurs in more samples than either the Caucasina-Bulimina assemblage or the Cibicidoides-Ceratobulimina assemblage. The Caucasina-Bulimina and Cibicidoides-Ceratobulimina assemblages occur in about equal numbers.

The maximum lateral extent for either of the assemblages or the mixed fauna is four wells (about 32 km). The mixed assemblage is more continuous than either of the assemblages. The type of available information is, in part, the cause for the lack of continuity of the assemblages. Few of the available wells contained the entire Cannonball interval. Wells that were completed below or in the lower part of the Cannonball are usually adjacent to wells that were completed in the upper part of the Cannonball. The correlation of assemblages in the lower part of the formation, therefore, becomes uncertain because no information for that interval is available in adjacent wells. The repetition of the assemblages throughout the Cannonball also makes correlations uncertain.

The biostratigraphic correlations (figs. 4-12) are characterized by much interfingering and many of the assemblages pinch out between wells. This is probably due, in part, to the strong environmental control (salinity and substrate) over foraminiferid distribution.

It is also due, in part, to mixing of the samples as a well is being drilled.

The Caucasina-Bulimina assemblage or a mixed assemblage dominated by elements of the Caucasina-Bulimina assemblage are found stratigraphically lowest in most wells. The lowest stratigraphic occurrences of this assemblage is usually thicker than subsequent, higher occurrences. The mixed assemblage occurs most commonly in the middle part and less commonly in the upper part of the foraminiferid-bearing interval. The Cibicidoides-Ceratobulimina assemblage usually covers a larger stratigraphic interval in the lower part of the foraminiferid-bearing interval than it does in the middle or upper part of the interval. It is also somewhat more continuous in the lower part of the interval.

Biofacies

Q-mode analyses cluster fossil localities or samples into groups with similar faunas (biofacies) (Valentine, 1971, p. 89). Foraminiferal biofacies in the Cannonball are indicated by the major clusters on the Q-mode dendrograms (Appendix A). Since no continuous, long ranging biofacies are recognized, it appears that the foraminiferid distribution and the species within each sample are largely environmentally controlled. Although the exact controlling factors are uncertain, salinity and substrate are probably most important. Because of the lack of continuity in biofacies, no attempt was made to name or correlate them.

AGE OF CANNONBALL FORMATION

Lloyd (1914, p. 248), in naming the "Cannonball marine member of the Lance Formation," questionably assigned the Cannonball to the Tertiary

Stanton (1920) indicated that the Cannonball molluscan fauna was a "modified Fox Hills fauna" and suggested that the Cannonball was late Cretaceous.

The findings of Thom and Dobbin (1924a, 1924b) suggested that the Cannonball was Paleocene. Their mammalian evidence was derived from the Lebo of eastern Montana, which they indicated was equivalent to the upper part of the Cannonball and Ludlow. They said that the mammal remains suggested a Torrejonian (middle Paleocene) mammalian age for the Lebo.

A Cretaceous age for the Cannonball was, however, widely accepted until Dorf (1940) offered substantial, indirect paleobotanical evidence for a Paleocene age for the Cannonball. He said that the plants of the Ludlow indicated a Paleocene age; therefore, since the Cannonball interfingers with and is underlain by the Ludlow, it, too, must be Paleocene.

Jepsen (1940, p. 242-248), using indirect mammalian evidence, suggested that the Cannonball was Paleocene.

Fox and Ross (1940, 1942) presented the first strong direct evidence for a Paleocene age for the Cannonball. Of the 64 species of foraminiferids they identified, 38 species also occurred in the Gulf Coast. Of the 38 Gulf Coast species, the majority occurred in the Paleocene Midway.

Swain (1949) identified five species of ostracodes from the Cannonball. He said that the strong affinities between his small Cannonball ostracode fauna and that of the Paleocene Midway suggested a Paleocene age for the Cannonball.

Brown (1962) presented indirect paleobotanical evidence for a Paleocene age for the Cannonball and he further stated (1962, p. 9) "as early as 1931, I had become convinced of the Paleocene age of the Cannonball member and its correlative nonmarine equivalent . . ."

Jeletzky (1960) stated that the planktonic foraminiferids, specifically Globorotalia pseudobulloides, indicated a largely Danian (=Montian) or more likely earliest Landenian age. He (1962, p. 1006-1007) later revised his age determination to a general Danian age. He indicated that the occurrence of Globigerina triloculinoides and Globorotalia pseudobulloides and the absence of species of Globorotalia of the Globorotalia angulata zone is important in establishing a general Danian age for the Cannonball.

Stanley's (1965) study of the plant microfossils indicated that the Cannonball Formation was Paleocene.

Cvancara (1965, 1966), in revising the Cannonball bivalve fauna, said that through comparisons with the Tertiary faunas of Northern Europe, the closest similarities existed with the Thanetian forms in the London and Paris Basins.

Fox and Olsson (1969) identified seven species of planktonic foraminiferids from the Cannonball near Garrison Dam, North Dakota. They determined that the planktonic foraminiferid fauna of the Cannonball belongs to the Globigerina edita zone of Hillebrandt (1965), which is equivalent to the Globorotalia pseudobulloides zone of Bolli (1966).

The Globigerina edita zone is considered the lowest zone of the Tertiary. This would indicate that the Cannonball is, in part, early Danian.

Sloan (1970, p. 441), in examining mammalian remains from the overlying Tongue River Formation, suggested that the Cannonball Formation encompassed the Puercan and Torrejonian (early to middle Paleocene) mammlian ages. Holzman (1975) suggested that mammalian remains from the basal Tongue River suggested a middle-late Paleocene (middle Tiffanian) age. Fenner (1974), utilizing benthonic foraminiferids, was unable to make an age determination that was any more specific than early Tertiary for the Cannonball.

I have collected two index species of planktonic foraminiferids in this study, Globoconusa daubjergensis and Globorotalia pseudobulloides. Stainforth and others (1975) indicated that Globoconusa daubjergensis extends from the base of the middle early Paleocene to the base of the middle Paleocene, from about 64 m. yr. before present to about 61 m. yr. before present. Globorotalia pseudobulloides ranges from the base of the middle-early Paleocene to the top of the middle-middle Paleocene. The most common occurrences for these two species are from the base of the middle-early Paleocene to the base of the late-early Paleocene for Globoconusa daubjergensis and the base of the middle-early Paleocene to the base of the middle-middle Paleocene for Globorotalia pseudobulloides. The two species are contemporaneous from the base of the middle-early Paleocene to the base of the late-early Paleocene. These species would place the Cannonball into the Globorotalia pseudobulloides zone of Stainforth and others (1975, p. 15). This zone represents the middle-early Paleocene.

Applying my Cannonball data to the zonation of Berggren (1972, p. 202), the Cannonball planktonic foraminiferid fauna would indicate the Globoconusa daubjergensis-Globorotalia pseudobulloides zone of the Danian. This corresponds, in part, to the Globorotalia pseudobulloides zone of Stainforth and others (1975) except that Berggren's zone extends to the base of the Paleocene.

Berggren (1972, p. 202) illustrated the relationships between the ages that have been proposed for the Tertiary. The Puercan and Torrejonian mammlian ages that were proposed for the Cannonball by Sloan (1970, p. 441) are, for the most part, contemporaneous with the Danian age, and the contact between the Puercan and Torrejonian corresponds with about the middle of the Globoconusa daubjergensis-Globorotalia pseudobulloides zone of Stainforth and others (1975).

The planktonic foraminiferids collected in this study suggest an age that agrees with the conclusions of Sloan (1970) indicating a Puercan-Torrejonian age and the conclusions of Fox and Olsson (1969) suggesting a Danian age for the Cannonball. My age determination does not agree with the conclusions of Cvancara (1965, 1966) indicating a Thanetian age; however, since my planktonic foraminiferids were collected mainly from the middle part of the formation, the Danian, more specifically middle-early to early-middle Paleocene age, assignment does not preclude a Thanetian age assignment for the uppermost Cannonball. The uppermost Cannonball could also correspond to the Tiffanian (middle-late Paleocene) as Holzman (1975) suggested.

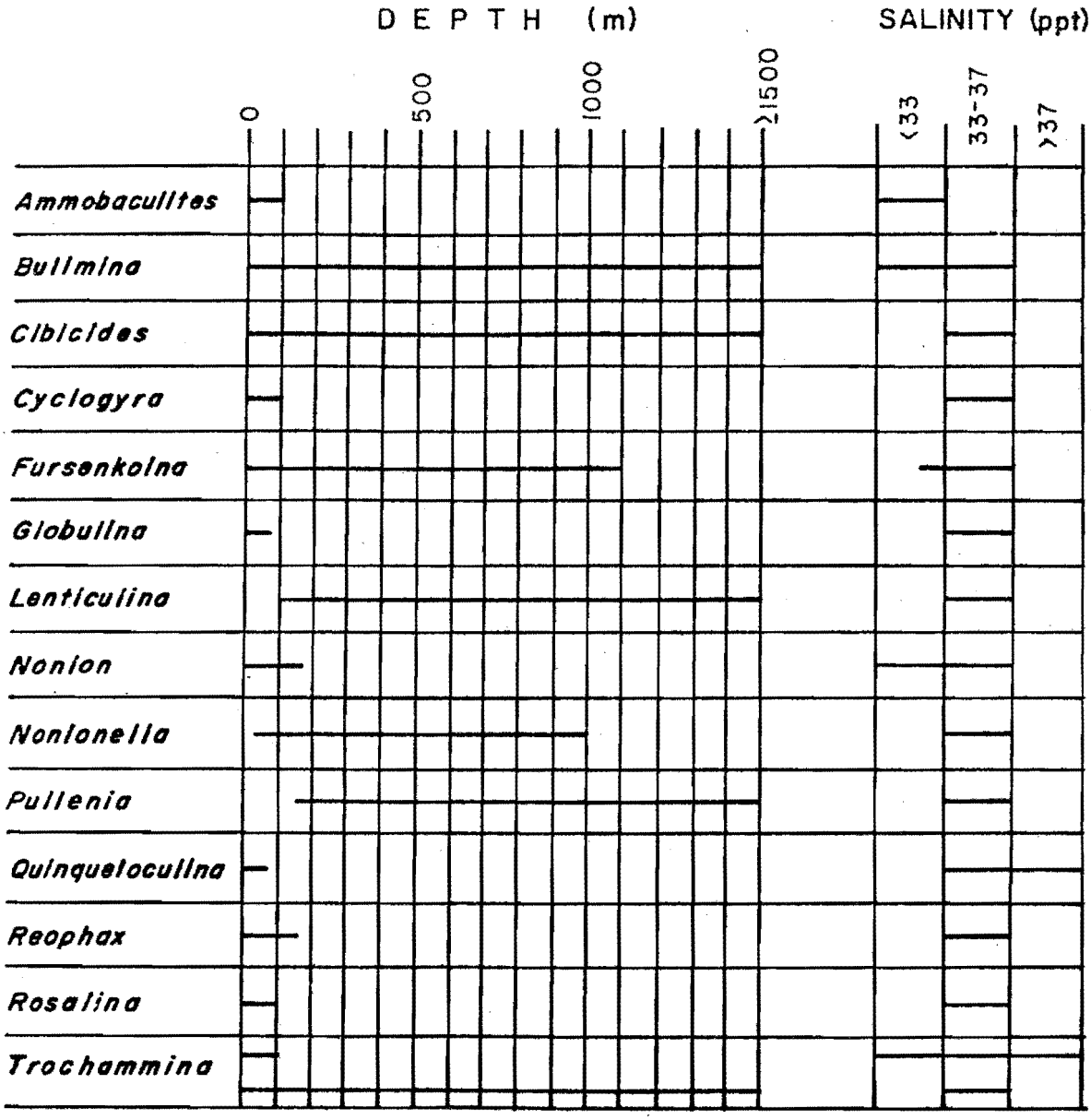
PALEOECOLOGY

The foraminiferid fauna of the Cannonball is generally dominated in terms of numbers of individuals by the rotaliines. Locally, however, the textulariines are dominant. The textulariine-dominant localities occur in the southwestern part of the Williston Basin in NDSWC wells 4453 and 4456 in western Adams and eastern Bowman Counties. NDSWC well 4388 has a mixed fauna with rotaliines dominating in the upper part of the Cannonball (well depth 35-74.7 m) and the textulariines dominating in the lower part of the Cannonball (well depth 74.7-129.5 m).

The textulariine-dominant fauna from the westernmost wells is thought to be indicative of brackish water. The macrofauna collected north of the textulariine-dominant localities in Slope County (Cvancara, 1965; Van Alstine, 1974) is also indicative of brackish water. Anisgard (1970, p. 211-212) indicated that when agglutinated foraminiferids account for greater than 50% of the individuals, the water is persistently shallow, usually turbid and poorly circulated, of below normal salinity and oxygen content, and of extremely high organic content. According to Greiner (1970, p. 83), agglutinated foraminiferids reach their peak in areas of low salinity and low temperatures. Since the foraminiferid fauna to the east is dominated by the rotaliines and the temperature probably did not vary significantly, salinity had to have been the main factor in causing the shift in dominance.

Table 2 summarizes depth and salinity data for Cannonball genera that Murray (1973, Appendix 2) treated in modern environments.

Table 2. Depth and salinity ranges of selected Cannonball foraminiferid genera (modified from Murray, 1973, Appendix 2).


DEPTH (m)
0
500
1000
≥1500
SALINITY (ppt)
<33
33-37
>37
Ammobaculites
Bulimina
Cibicides
Cyclogyra
Fursenkoina
Globulina
Lenticulina
Nonion
Nonionella
Pullenia
Quinqueloculina
Reophax
Rosalina
Trochammina

Ammobaculites, which occurs in the textulariine-dominant localities, is an important environmental indicator. It occurs in shallow water 100 m or less deep, and in water of lower-than-normal marine salinity. Nonion graniferum and Trochammina sp. also occur in the textulariine-dominant areas. Commonly, species within these two genera are tolerant of brackish-water conditions (Table 2). Of the two environmental ranges given for Trochammina, one is restricted to shallow water less than 100 m deep but occurs over a wide salinity range. The other is restricted to normal marine salinities and occurs at depths of less than 100 m to greater than 1500 m deep. The occurrence with Ammobaculites indicates that the Cannonball Trochammina is of the first type, which falls into the lower than normal salinity (brackish-water) range. Nonion, although it occurs in water of lower than normal to normal marine salinity, is thought to be representative of brackish water because of its occurrence with Ammobaculites.

Albritton and others (1954, p. 334-335) recognized two microfaunal "facies" in the Grayson Marl (Cretaceous). One facies was characterized by a predominance in numbers of agglutinated tests with Haplophragmoides and Ammobaculites the predominant genera. This facies was thought to represent a nearshore zone or possibly "weakly brackish waters inside the shoreline." In the textulariine-dominant localities in this study, both Haplophragmoides and Ammobaculites occur.

Lowman (1949, p. 1956) indicated that abundant Haplophragmoides and Trochammina occur in salt marshes along the Gulf Coast. Although these two genera are tolerant of more marine conditions, he suggested that they are most characteristic of a stagnant (quiet, poorly oxygenated) environment. In the westernmost wells of the study area,

Trochammina is abundant and Haplophragmoides is common.

The Fisher α index is a numerical measure of diversity derived from a plot of numbers of species against numbers of individuals (Murray, 1973, p. 8-10). An index of greater than 5 is thought to represent normal marine shelf conditions and an index of less than 5 is thought to represent marginal marine, brackish-water conditions. The Fisher indices for wells in the southwestern part of the study area where 50 or more individuals were present, indicate hyposaline and nearshore shelf seas. When applied to individual samples with 50 or more individuals, the Fisher indices more specifically indicate hyposaline marshes or lagoons in this area. The Fisher α index for NDSWC well 4388 is 4.3 and for NDSWC well 4453 it is 1.0 (there were not enough individuals in NDSWC well 4456 to determine the Fisher α index).

The dominance of agglutinated individuals in NDSWC wells 4453, 4456 and in the lower part of well 4388 (fig. 3) suggests lower than normal marine salinities. The presence of the brackish-water species Ammobaculites expansus and the brackish-water-tolerant genera Nonion, Trochammina and Haplophragmoides support the concept of a brackish-water environment in this area.

At every locality to the east of the brackish-water localities, the foraminiferid fauna is dominated by the rotaliines. The dominance of rotaliines in the eastern and central part of the study area is indicative of marine waters of more normal salinity. The small size and rare occurrence of planktonic foraminiferids suggest that the Cannonball was relatively shallow (Fox and Olsson, 1969, p. 1399-1400). The planktonic foraminiferids collected in this study agree with Fox and Olsson's conclusions regarding size in that they are generally about one-fourth

the size of their respective holotypes. Fox and Olsson (1969) suggested that deeper waters to the east of the present Cannonball outcrop area supported the main planktonic mass.

Lowman (1949, fig. 13) said that planktonic foraminiferids constitute about 20% of the foraminiferid fauna at a depth of 61 m (200 ft). The percentage generally increases into deeper water. The planktonic foraminiferid fauna in the Cannonball does not approach 20% which suggests depths of less than those (61 m or 200 ft) indicated by Lowman.

Ellison (1951) discussed the utility of benthonic foraminiferids in making paleoenvironmental interpretations. He indicated that numbers of calcareous, agglutinated, and planktonic individuals were important, but was uncertain as to how to apply the data. Ellison (1951, fig. 5) reproduced Bannahan's (1950) paleoecological analysis diagram that showed the paleoecological ranges of 17 benthonic foraminiferids and one genus of planktonic foraminiferid from the Marquez Shale (Eocene) of Texas. Of the benthonic genera, nine also occur in the Cannonball: Haplophragmoides, Ammobaculites, Trochammina, Anomalinoides (=Anomalina), Nonion, Quinqueloculina, Ceratobulimina, Lenticulina (=Robulus), and Globulina. Most of the genera occurred over a wide range of environments with Haplophragmoides, Ammobaculites and Trochammina occurring in presumably brackish-water sediments and in sediments transitional between brackish-water and normal marine environments. Anomalinoides and Nonion were reported from brackish-water transitional and normal, shallow, marine sediments. The remainder occurred in normal marine sediments from the "open sea inner neritic" (10-50 m) to "open sea neritic" (0-200 m) depths.

Gernat and Kesling (1966, p. 136-142) discussed several environments including brackish, inner shelf shallow, inner shelf deep, middle shelf, outer shelf, and saline bay. Unfortunately, they placed no depth ranges on the various environments; however, by applying Hedgpeth's (1957, fig. 1) classification of marine environments to Gernat and Kesling's environments, a generalized depth range can be obtained. Gernat and Kesling's shallow inner shelf would correspond to the inner neritic of Hedgpeth and therefore represents a maximum depth of about 50 m. Their outer shelf would correspond to Hedgpeth's outer neritic and would attain a maximum depth of 150-200 m. The genera they collected that also occur in the Cannonball and the environments in which they occurred are Ammobaculites (brackish-water to deep inner shelf), Ammodiscus and Trochammina (brackish water (dominant) to outer shelf (subordinate part of fauna)); Quinqueloculina (saline bay to deep inner shelf), Nonionella, Fursenkoina (shallow inner shelf to middle shelf); Bulimina (shallow inner shelf to middle shelf); Bulimina (shallow inner shelf to outer shelf); Lenticulina, Anomalinoides (=Anomalina), Cibicides, Globulina, Gyroidinoides, Nonion and Spiroplectammina (deep inner shelf to outer shelf). The maximum depth attained by any of these genera is 150-200 m, with most common depth ranges in the 50-200 m range (inner shelf-outer shelf).

The Cannonball calcareous benthonic genera that Murray (1973, Appendix 2) treated (Table 2) predominate in the eastern two-thirds of the study area. Their depth ranges are highly variable. Although most occur over a wide range of depths, five occur only in shallow water to a maximum depth of about 160 m. The wide ranging genera, except Pullenia (represented by one specimen), fall into this depth range.

Combining the depth ranges of the forms restricted to shallow water and the wide-ranging forms, the most likely depth range for the Cannonball calcareous assemblage is about 0-200 m with most forms probably occurring at depths of 100 m or less. Phleger (1960, figs. 14-28) gave the depth distributions of several species of benthonic foraminiferids from the Gulf of Mexico. Combining Phleger's data for each species with composite data for each of the Cannonball genera essentially reproduces Murray's (1973, Appendix 2) results.

Bandy and Arnal (1960) indicated that the diversity of foraminiferids increases offshore. The Fisher α index indicates higher diversity for all wells in the eastern two-thirds of the study area suggesting deeper water and more normal marine conditions in this area.

Combining species diversity and the ecological data for both planktonic and few of the ecologically important benthonic foraminiferids, the indication is that brackish-water conditions occurred west of central Adams County. To the east of central Adams County, more normal marine conditions or conditions transitional between brackish water and more normal marine conditions existed. Ecologically important benthonic genera and the scarcity and small size of planktonic forms indicates a shallow-water marine environment with a maximum water depth of less than 200 m. Most of the area probably represents a water depth of less than 100 m.

DEPOSITIONAL ENVIRONMENTS

The foraminiferids occur commonly in the mudstone lithofacies and rarely in the sandstone lithofacies. Associated with the foraminiferids are abundant lignitic plant remains and rare to common glauconite. The lignitic plant remains appear to be mostly minute woody particles suggesting either aquatic plants or land-derived, peaty material that was lignitized in place.

The presence of rare to abundant lignitic material in the Cannonball rocks is suggestive of shallow water environments. Detling (1946, p. 349) suggested that high carbon content was indicative of shallow water deposition in Lower Tertiary marine rocks in the Coos Bay area of Oregon. Lowman (1949, p. 1956) reported abundant carbonized plant remains associated with shallow-water foraminiferids. Fox and Olsson (1969, p. 1400) noted lignitized plant remains in the Cannonball and concluded that they indicated deposition in "shallow inner neritic depths."

Glauconite is common in most Cannonball samples. The conditions under which glauconite formed also affect the composition of the foraminiferid fauna. Cloud (1955, p. 484) said that glauconite forms in environments with normal marine salinity, slightly reduced conditions and slow sedimentation. He also indicated (p. 490) that glauconite is commonly found in water 5-1000 fathoms deep and suggested that it is most common in the upper part of the 10-400 fathom interval. Sulphide-

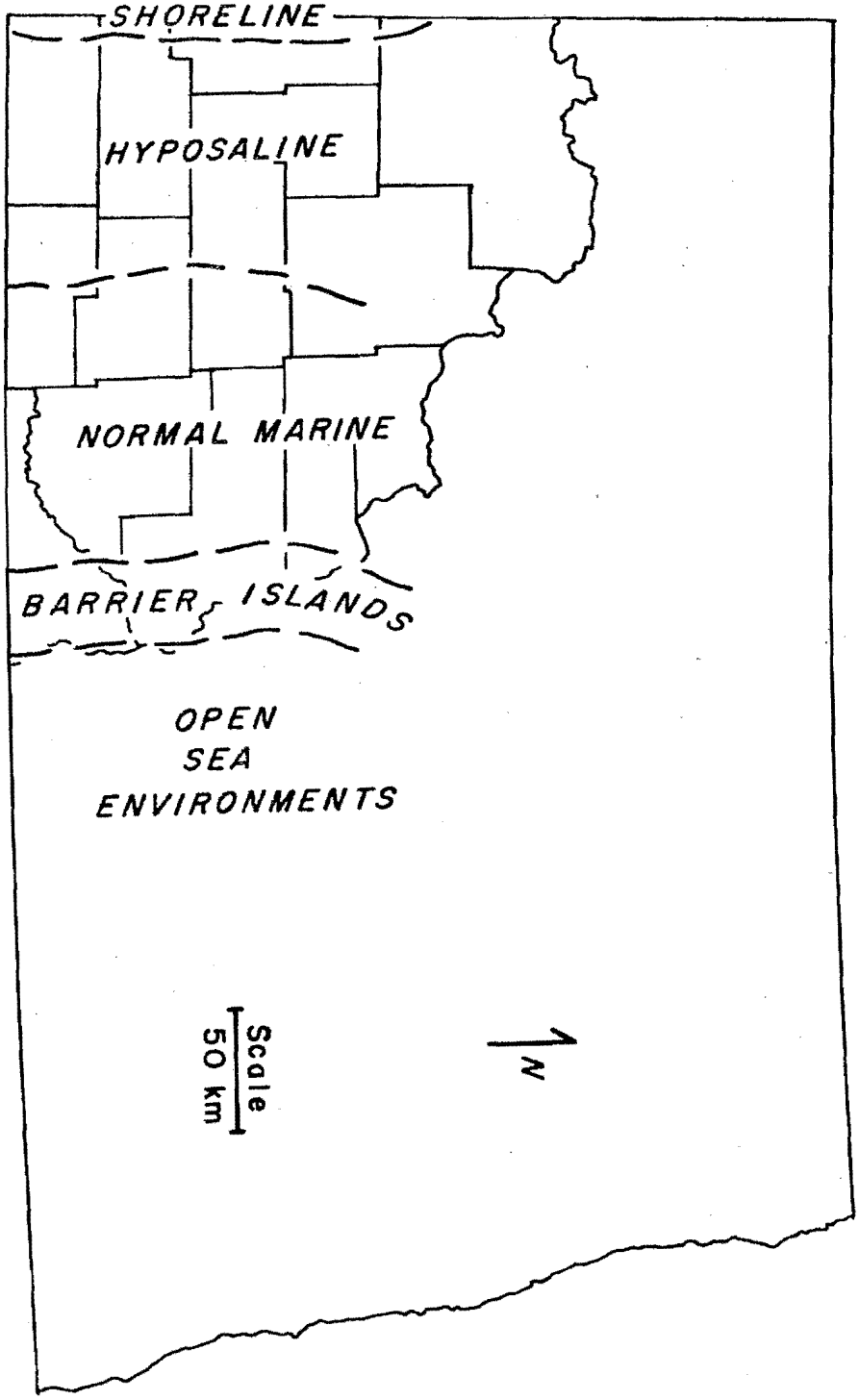
filled foraminiferids and sulphide nodules are common in the Cannonball. If the deposition of the sulphide were primary or if it occurred shortly after the deposition of the sediments, its presence suggests that reducing conditions existed in the Cannonball.

Although it cannot be identified from well cuttings, the trace fossil Ophiomorpha occurs in sandstones of Cannonball exposures (Cvancara 1965; Van Alstine, 1974). Howard (1971) noted that the present-day equivalent of Ophiomorpha is the "deep burrowing crustacean Callianassa major," a shoreface inhabitant. The trace fossil Ophiomorpha was, therefore, assumed to be a shoreface inhabitant. Howard indicated that although Ophiomorpha was not the most abundant shoreface inhabitant, it was the main inhabitant that left a preservable trace. It seems likely, therefore, that many of the Cannonball sandstones represent shoreface environments. The sandstones, however, are usually devoid of foraminiferids (Fenner, 1974). Foraminiferids collected in this study rarely occurred in sandstones, although exact placement of occurrences is uncertain. Phleger (1960, p. 159) indicated that only the larger, more massive foraminiferids could live in the beach environment and the smaller species would probably be transported into deeper, quieter water. Nodosaria affinis, one of the larger, more massive Cannonball foraminiferids, occurs most commonly in the sandstone lithofacies. The occurrence of this species in the presumably shoreface sandstones therefore agrees with Phleger's suggestion. Lowman (1949, p. 1962-1963) indicated that an abundant indigenous foraminiferid fauna inhabits the shoreface and this was probably the case with the Cannonball foraminiferid fauna with the only remnant of the shoreface fauna being the more massive Nodosaria affinis. Cvancara (1965, p. 43) noted that most macrofossils occur in

clayey sandstones transitional between clean sandstones and mudstones. The clayey sandstone is probably transitional between clean sandstones and mudstones and it most likely represents an environment that was transitional between shoreface and deeper water environments (Cvancara, 1976, p. 16). The smaller foraminiferids that occurred with the macrofossils were probably either destroyed or transported to quieter environments. Cvancara (1976, p. 16) indicated that the Ophiomorpha-bearing sandstones were probably barrier island sandstones and that the presence of Ophiomorpha in well sorted sandstones indicated intertidal or shallow subtidal depths, and its presence in poorly sorted sandstone indicated somewhat greater depths. From the thicknesses of sandstones and mudstones in three measured sections, Cvancara (1976, p. 16) suggested that the sandstones, in part, represent depths of up to 40 ft (12.9 m) and the mudstones represent depths in part, of up to and perhaps more than 100 ft (30.5 m).

Cvancara (1972a, p. 73 suggested that the Cannonball represented an environment similar to that which presently occurs along the north coast of Holland and Germany where a barrier island chain (the Frisian Islands) separates a lagoon (the Wadden Sea) from the North Sea. The foraminiferids collected in this study support this analog. Possibly the Cannonball barrier island chain extended northward through central North Dakota, possibly just west of or along the present Missouri River (fig. 13). The deeper water, more open sea environments were to the south and east of the barrier islands, but sediments from these environments have either been destroyed by erosion or covered with glacial drift. Within the Cannonball outcrop area, there is a distinct break

Fig. 13. Hypothetical model of general environments for the Cannonball Formation.


SHORELINE
HYPOSALINE
NORMAL MARINE
BARRIER ISLANDS
OPEN
SEA
ENVIRONMENTS
Scale
50 km
N

in the foraminiferid fauna. To the west of central Adams County, the fauna is dominantly textulariine and it appears to be characteristic of brackish water. To the east of central Adams County, the foraminiferid fauna is dominantly calcareous and is characteristic of more normal marine salinities. These two faunas probably represent subenvironments within the lagoonal environment. The brackish-water fauna is that which would be expected on the landward side of the lagoon. To the north of the brackish-water microfaunal localities, in Slope County, macrofossils have been collected from two brackish-water tongues in the Cannonball (Cvancara, 1965; Van Alstine, 1974).

The more normal marine areas within the Cannonball Formation occur toward the seaward side of the lagoon (fig. 13). The localities that were closer to the barrier island chain, especially a relatively discontinuous one like the Frisian Islands, would be characteristic of more normal marine environments than those closer to the landward side of the lagoon. The small size and scarcity of the planktonic foraminiferids and the composition of the benthonic foraminiferid fauna indicate shallow (100 m or less deep) marine waters over most of the study area. The presence of common to abundant lignitized plant remains in all lithologies supports the idea that although the waters were of more normal marine salinity, they were shallow and possibly restricted.

CONCLUSIONS

Fifty species of bethonic foraminiferids and four species of planktonic foraminiferids were collected from 60 water test wells and two oil wells. The foraminiferid fauna represents 32 genera in 19 families and is dominated in terms of numbers of species and numbers of individuals by the rotaliines. The fauna commonly occurred in the mudstone lithofacies and rarely occurred in the sandstone lithofacies, and was concentrated in the middle part of the formation, with less common occurrences in the lower part of the formation. The densest accumulation of foraminiferids was in south-central Adams County (well 4388) where 58 individuals per cc of sample occur. Elsewhere, the concentration of foraminiferids is considerably less.

All studies of the Cannonball combined yield a total of at least 93 species of foraminiferids, including 8 textularines, 3 miliolines and 82 rotaliines.

Two foraminiferid assemblages are recognized, the Caucasina-Bulimina and Cibicidoides-Ceratobulimina assemblages. The foraminiferid assemblages are laterally discontinuous and recur stratigraphically and sporadically throughout the foraminiferid-bearing interval of the Cannonball suggesting strong environmental control over the foraminiferid distribution. Correlations of assemblages show much interfingering and many pinch outs of assemblages which also indicate strong environmental control and mixing of the assemblages during the well drilling.

Because of little vertical and lateral continuity the biofacies, which are represented by the major clusters on the Q-mode dendrograms, were not utilized.

The shallow-water affinities of the foraminiferid assemblages and the small size and scarcity of the planktonic foraminiferids suggest deposition in shallow-water environments, 100 m or less. The dominance of textulariines, including Ammobaculites, in wells located in eastern Bowman and western Adams Counties suggests local, brackish-water environments. The occurrence of foraminiferids with minute, lignitic particles is indicative of nearshore, protected conditions. A large, shallow, protected lagoon behind a north-trending barrier island chain is envisioned as a possible complex of depositional environments for the Cannonball. Brackish-water environments are thought to have occurred near the landward side of the lagoon with more marine environments near the seaward side of the lagoon.

More detailed microfaunal data over relatively small areas is needed to more precisely determine the biostratigraphic relationships within the Cannonball. Sedimentologic work on surface exposures would be helpful in determining the local depositional environments of the Cannonball. The possibility of using the microflora, particularly the calcareous nannoplankton, should be investigated in order to more precisely determine the age of the Cannonball.

SYSTEMATIC PALEONTOLOGY

The classification for the foraminiferids is that of Loeblich and Tappan (1964). A few genera in their classification have not been generally accepted. In such cases, I have used the accepted genera and have included appropriate comments in a remarks section following the generic diagnosis.

The generic diagnoses are adapted from Loeblich and Tappan (1964) and are, in most cases, rearranged to maintain consistency of order of morphological characteristics. Most of the species diagnoses are adapted from the original diagnoses or descriptions of the species. Where the original diagnoses were unavailable or were written in a foreign language, subsequent adaptations are used.

Generic synonymies are not included. Only the original reference for that genus and the type species are included. Most species synonymies are abbreviated. Rather than giving every citation for a particular name, only the earliest citation is given. Where the earliest citation of a presently accepted name is relatively old, a more recent citation is included. A few of the species that are being reported from the Cannonball for the first time have relatively complete synonymies.

Occurrences are given according to NDSWC or NDGS well number and accession number (fig. 1, Appendix C). The lithologies within which the species occur as well as the general stratigraphic interval over which the species were found are also included.

The discussions include numbers of individuals, the state of preservation and any pertinent information regarding the taxonomy of the foraminiferids.

Phylum PROTOZOA

Subphylum SARCODINA

Order FORAMINIFERIDA

Suborder TEXTULARIINA

Family AMMODISCIDAE Reuss, 1862

Genus AMMODISCUS Reuss, 1862

Original reference.--Reuss, 1862, p. 365.

Type species.--Ammodiscus infimus Bornemann, 1874, p. 725 (by original designation).

Diagnosis.--Test free, discoidal, proloculus followed by undivided planispirally enrolled tubular chamber, which may show transverse growth constrictions but no internal partitions; aperture at open end of tubular chamber; wall agglutinated (adapted from Loeblich and Tappan, 1964, p. C210).

Ammodiscus incertus Brady, 1884

Plate 1, fig. 4

Operculina incertus d'Orbigny, 1839a, p. 71, fl. 6, figs. 16, 17.

Spirillina arenacea Williamson, 1858, p. 93, p. 7, fig. 203.

Trochammina incerta Brady, 1876, p. 71, pl. 2, figs. 10-14.

Ammodiscus incertus Brady, 1884, p. 330, pl. 38, figs. 1-3. Plummer, 1926, p. 63-65, pl. 13, figs. 1a-d.

Diagnosis.--Test slightly biconcave, finely arenaceous (adapted from Plummer, 1926, p. 64).

Measurements.--Maximum diameter of hypotypes 0.2-0.7 mm; minimum diameter of hypotypes 0.7 mm; maximum thickness of hypotypes 0.1 mm.

Hypotypes.--Univ. of N. Dak. Cat. Nos. 13812, 13813.

Occurrence.--This species was collected from NDSWC wells 3559 (A1103, A1108, A1110, A1111), 3433 (A1116, A1119), 3647 (A1141), 4486 (A1167), 4397 (A1169), 8102 (A1178, A1179, A1180), 4453 (A1263), 8347 (A1266), 4388 (A1277, A1279, A1282, A1285, A1288, A1289, A1290), 4384 (A1301, A1303, A1304), 4462 (A1308), 1984 (A1314), 4515 (A1361), 4516 (A1371), 4760 (A1381), 4764 (A1384), 4751 (A1387, A1381, A1392). It occurs throughout the stratigraphic section but is concentrated predominantly in the middle Cannonball most often in the mudstone lithofacies and rarely in the sandstone lithofacies.

Discussion.--The 46 moderately well-preserved individuals that I collected are closely comparable to the individuals of Ammodiscus incertus described and illustrated by Plummer (1926, p. 63065, pl. 13, figs. 1a-d). This species is not abundant in any sample, the maximum number of individuals in any sample being four, but with one or two individuals per sample being most common. Fox and Ross (1942), Lemke (1960) and Fenner (1974) reported this species from the Cannonball.

Family HORMOSINIDAE Haeckel, 1894

Genus REOPHAX Montfort, 1808

Original reference.--Montfort, 1808, p. 331.

Type species.--Reophax scorpiurus Montfort, 1808, p. 331 (by original designation).

Diagnosis.--Test free, elongate, nearly straight or arcuate; chambers few, increasing in size as added; sutures nearly normal to

long axis of test, obscure to moderately constricted; aperture terminal, rounded, at end of distinct tubular neck; wall agglutinated, with comparately little cement, surface rought (adapted from Loeblich and Tappan, 1964, p. C216).

Reophax sp.

Description of material.--Test uniserial; chambers inflated; sutures depressed, wall coarsely arenaceous.

Measurements.--Length of hypotype, 0.6 mm; width of hypotype, 0.2 mm.

Hypotypes.--Univ. of N. Dak. Cat. Nos. 13814, 13815.

Occurrence.--This species was collected from NDSWC wells 8347 (A1272) and 4388 (A1295). It occurs in the middle and upper middle Cannonball in mudstone lithofacies.

Discussion.--This species is represented by two fragments, neither of which has the aboral or apertural extremities preserved. Without an aperture, it is not possible to make a definite generic assignment. This genus has not been reported previously from the Cannonball.

?Reophax sp.

Description of material.--Wall of very fine-grained sand; all specimens flattened; transverse depressions, presumably sutures, extend the width of test.

Measurements.--Length of hypotype, 0.3 mm; width of hypotype, 0.1 mm.

Hypotype.--Univ. of N. Dak. Cat. No. 13816.

Occurrence.--This species occurred in NDSWC wells 3558 (A1091), 3559 (A1106, A1110), 3647 (A1132), 8342 (A1272), 4388 (A1289, A1296, A1297, A1298) and 4384 (A1304). Stratigraphically, this species occurs mainly in the middle Cannonball in the sandstone and mudstone lithofacies.

Discussion.--All of the 26 specimens of this species are poorly preserved and flattened due to compaction. This species was initially assigned to Bathysiphon because of its tube-like test; however, Olsson (1976) indicated that these specimens would be more properly placed in the genus Reophax.

Family LITUOLIDAE de Blainville, 1825

Genus HAPLOPHRAGMOIDES Cushman, 1910

Original reference.--Cushman, 1910, p. 99.

Type species.--Haplophragmoides canariense (d'Orbigny) = Nonionina canariense d'Orbigny, 1839b, p. 128 (by original designation).

Diagnosis.--Test planispirally coiled, involute; aperture an equatorial interiomarginal slit; wall agglutinated (adapted from Loeblich and Tappan, 1964, p. C225).

Haplophragmoides sp. A

Plate 1, fig. 8

Description of material.--Test involute, compressed, umbilicate, thickest part of test adjacent to umbilicus; periphery

subacute; sutures appear raised because of lateral compression; aperture an arched slit at base of last septal face; wall finely arenaceous.

Measurements.--Diameter of hypotype, 0.4 mm; thickness of hypotype, 01. mm.

Hypotypes.--Univ. of N. Dak. Cat. Nos. 13817, 13818.

Occurrence.--This species was collected from NDSWC wells 3560 (A1084), 3558 (A1090-A1094), 3559 (A1104, A1105, A1107-A1113), 3433 (A1114), 3647 (A1141, A1148), 4312 (A1189, A1190, A1194, A1195, A1254), 8347 (A1268, A1269), 4388 (A1277-A1281), 4384 (A1299-A1302, A1304), 4752 (A1376) and 4751 (A1388, A1391, A1394-A1396). It occurs throughout the stratigraphic section but is concentrated mainly in the middle Cannonball. This species occurs in both sandstone and mudstone lithofacies but the majority of occurrences is in the mudstone lithofacies.

Discussion.--The 107 moderately well preserved individuals of this species are somewhat similar in overall appearance to Haplophragmoides gigas var. minor described by Nauss (1947, p. 338-339). The Cannonball forms are more prominantly umbilicate than H. gigas var. minor. In contrast to the other agglutinated species collected in this study, this species is invariable in color; all specimens of this species are white, regardless of the color or composition of the associated sediment. Lemke (1960) reported two new species of Haplophragmoides from the Cannonball, but in the absence of descriptions and illustrations it is not possible to

determine if this is one of them.

Haplophragmoides sp. B

Plate 1, fig. 3

Description of material.--Test broadly umbilicate, slightly evolute with inner portions of inner whorls showing; sutures distinct, depressed and limbate; aperture an interio-marginal slit; wall finely arenaceous.

Measurements.--Diameter of hypotype, 0.4 mm; thickness of hypotype, 0.08 mm.

Hypotype. Univ. of N. Dak. Cat. No. 13819.

Occurrence.--This species is represented by seven individuals collected from NDSWC wells 3559 (A1110), 3433 (A1118), 8102 (A1179), 4312 (A1251) and 4388 (A1287). It is found in the middle Cannonball and occurs most often in the mudstone lithofacies.

Discussion.--This species differs from Haplophragmoides sp. A in that it is less compressed and has a much broader umbilicus. It is also less involute and shows the inner parts of the previous whorl.

Genus AMMOBACULITES Cushman, 1910

Original reference.--Cushman, 1910, p. 114.

Type species.--Ammobaculites agglutinans (d'Orbigny)= Spirolina agglutinans d'Orbigny, 1846, p. 137 (by original designation).

Diagnosis.--Test free, early portion closely coiled, later portion uncoiled and rectilinear, rounded in section; interior simple; aperture terminal, rounded (adapted from Loeblich and Tappan, 1964, p. C239-C240).

Ammobaculites expansus Plummer, 1933

Plate 1, fig. 7

Ammobaculites expansus Plummer, 1933, p. 65.

Diagnosis.--Test coarsely arenaceous, about the first 12 chambers arranged in tight and very strongly compressed and slightly umbilicate coil of two convolutions, final two or three chambers strongly compressed and arranged in rectilinear succession; sutures obscure except last two or three chambers of fully mature test where they are somewhat depressed; aperture narrow, elongate opening at end of final chamber (adapted from Plummer, 1933, p. 65).

Measurements.--Width of type specimen, 0.2 mm; height of type specimen, 0.1 mm.

Hypotype.--Univ. of N. Dak. Cat. No. 13820.

Occurrence.--Four individuals of this species were collected from NDSWC well 4453 (A1264) from the siltstone lithofacies in the upper middle Cannonball.

Discussion.--The individuals of this species are comparable to those of Ammobaculites expansus illustrated by Plummer (1933, p. 65, pl. 5, figs. 4-6). She (1933, p. 65) noted that the Midway forms are, for the most part, dark except for the apertural rim.

The Cannonball forms show a similar characteristic except that the entire lectilinear series of chambers is of lighter color. The Cannonball individuals differ from those of Plummer in that the sutures on the planispiral part of the test are most distinct and this part of the test is less clearly umbilicate. The Cannonball forms are also more finely arenaceous than those illustrated by Plummer. The more finely arenaceous tests may account for the sutures being more distinct on the Cannonball forms. Neither this species nor genus has been previously reported from the Cannonball Formation.

Family TEXTULARIIDAE Eherenberg, 1838

Genus SPIROPLECTAMMINA Cushman, 1927

Original reference.--Cushman, 1927, p. 23.

Type species.--Spiroplectammina biformis (Parker and Jones)= Textularia agglutinans d'Orbigny var. biformis Parker and Jones, 1865, p. 370 (by original designation).

Diagnosis.--Test free, elongate, early portion in planispiral coil of few chambers, later chambers biserially arranged; aperture low arch at inner margin of final chamber; wall agglutinated (adapted from Loeblich and Tappan, 1964, p. C251).

Spiroplectammina wilcoxensis Cushman and Ponton, 1932

Plate 1, fig. 9

Spiroplectammina wilcoxensis Cushman and Ponton, 1932, p. 51.

Diagnosis.--Test broad compressed, periphery subacute, early chambers coiled; chambers distinct, low and broad in the early portion, gradually and rather regularly increasing in height as added, slightly

overlapping, later ones slightly inflated; sutures distinct, slightly depressed especially in the later portion, gently curved making a very slight angle with the horizontal; aperture low curved opening at the base apertural face; wall arenaceous but rather smoothly finished (Cushman and Ponton, 1932, p. 51).

Measurements.--Maximum length of hypotype, 0.3 mm; maximum width of hypotype, 0.2 mm.

Hypotypes.--Univ. of N. Dak. Cat. Nos. 13821, 13822, 13823.

Occurrence.--The ten specimens of this species were collected from NDSWC wells 3560 (A1085), 3559 (A1109, A1111), 8347 (A1268), 4388 (A1284, A1288, A1290) and 4515 (A1362). Stratigraphically, this species occurs in the upper and middle Cannonball, mainly in the mudstone lithofacies and rarely in the sandstone lithofacies.

Discussion.--The individuals of this species are comparable to those of Spiroplectammina wilcoxensis illustrated by Cushman and Ponton (1932, p. 51). This species has not previously been reported from the Cannonball, but Spiroplectammina laevis (Roemer) was reported by Fox and Ross (1942). The forms collected in this study lack the raised sutures and sharply angular periphery diagnostic of S. laevis.

Family TROCHAMMINIDAE Schwager, 1877

Genus TROCHAMMINA Parker and Jones, 1859

Original reference.--Parker and Jones, 1859, p. 347.

Type species.--Trochammina inflatus (Montagu)=Nautilus inflatus Montagu, 1808, p. 81 (by original designation).

Diagnosis.--Test free, trochospiral; globular to ovate chambers increasing gradually in size; aperture low interiomarginal extraumbilical-

umbilical arch may have narrow bordering lip; wall agglutinated (adapted from Loeblich and Tappan, 1964, p. C259).

Trochammina sp.

Plate 1, figs. 5, 6

Description of material.--Test small, compressed, periphery angular to subacute and may be lobate in more flattened specimens; primary whorls obscure, later whorls distinct; spire low and slightly raised above dorsal surface of final whorl; ventral surface flat to slightly concave with small, deep umbilicus; chambers gradually increasing in size, seven to nine on final whorl, chambers appear to be scalloped on ventral side because of compression; sutures radial, appear to be raised because of compression of adjacent chamber walls, spiral suture distinct on some specimens; aperture indistinct but probably umbilical-extraumbilical; wall of fine-grained sand, most specimens stained brown with exception of last chamber that may be white or gray.

Measurements.--Maximum diameter of hypotype, 0.5 mm; maximum thickness of hypotype, 0.2 mm.

Hypotype.--Univ. of N. Dak. Cat. No. 13824.

Occurrence.--This species was collected from NDSWC wells 3558 (A1094), 3559 (A1111), 3557 (A1128), 8102 (A1178), 4312 (A1187, A1195, A1196, A1198, A1250, A1255), 4453 (A1260-A1264), 8347 (A1267, A1268, A1274), 4388 (A1276, A1278-A1280, A1282, A1284, A1289, A1290, A1294-A1297), 4384 (A1300, A1301, A1303, A1304), 4456 (A1306), 1984 (A1313, A1314), 2017 (A1319), 4511 (A1343-A1345), 4513 (A1359), 4515 (A1365, A1366, A1368), 4516 (A1371), 4752 (A1375), 4760 (A1379, A1380), 4764 (A1365), 4751 (A1391) and 3075 (A1402), in the upper-middle and middle

Cannonball, predominantly from the mudstone lithofacies and occasionally from the sandstone lithofacies.

Discussion.--Most of the 235 specimens of this species are compressed, giving the specimens a scalloped appearance. The apertures on all specimens are obscured due to compression. Most specimens are finely arenaceous except for the last whorl that is somewhat coarser. On some specimens, the last chamber is of a somewhat lighter color than the rest of the test. The color difference could be the result of lignite staining of the cement with the last-formed chamber being too recent to completely have taken up the stain. This genus was not reported by Fox and Ross (1942) or Lemke (1960). I (Fenner, 1974) reported a different species of Trochammina from the Cannonball.

Suborder MILIOLINA

Family FISCHERINIDAE Millet, 1898

Genus CYCLOGYRA Wood, 1842

Original reference.--Wood, 1842, p. 458.

Type species.--Cyclogyra multiplex Wood, 1842, p. 458 (by original designation).

Diagnosis.--Test free, discoidal, consisting of globular proloculus and long undivided planispirally wound second chamber, partly or wholly evolute; aperture at open end of the tube; wall calcareous, inperforate, porcellaneous (adapted from Loeblich and Tappan, 1964, p. C438).

Remarks.--According to Loeblich and Tappan (1964, p. C438), the genus Cornuspira should be combined with the genus Cyclogyra.

Cyclogyra involvens (Reuss), 1850

Plate 1, fig. 10

Operculina involvens Reuss, 1850, p. 370, fig. 30.

Cornuspira involvens (Reuss). Reuss, 1863, p. 39, pl. 1, fig. 2.

Diagnosis.--Test strongly concave of numerous (12-19), abruptly increasing, flattened volutions, each of which encloses part of previous volution; innermost volutions narrow, outermost volution wide, occupying 40-60% of diameter; wall smooth (translated and adapted from Reuss, 1850, p. 370).

Measurements.--Diameter of hypotype, 0.2 mm; thickness of hypotype, 0.05 mm.

Hypotype.--Univ. of N. Dak. Cat. No. 13825.

Occurrence.--This species was collected from NDSWC well 3647 (A1152) in the middle Cannonball from the mudstone lithofacies.

Discussion.--The one well-preserved specimen of this species is closely conformable to Reuss' (1850, p. 370, figs. 20a, 20b) description and figures of Cyclogyra involvens (=Operculina involvens) with the exception that the Cannonball form has a more rounded periphery. The Cannonball form is dark amber that is probably due to the infilling by sulphides. Fox and Ross (1942) and Fenner (1974) reported this species from the Cannonball.

Family MILIOLIDAE Ehrenberg, 1839

Genus QUINQUELOCULINA d'Orbigny, 1826

Original reference.--d'Orbigny, 1826, p. 301.

Type species.--Quinqueloculina seminulum (Linné)=Serpula seminulum Linné, 1758, p. 786 (by subsequent designation of Parker and Jones, 1859, pt. 1, p. 480).

Diagnosis.--Test coiled with chambers one-half coil in length and alternating regularly in five planes of coiling 72° apart, but with successive chambers in planes 144° apart, so that three chambers are visible from exterior on one side of test and four visible from opposite side; aperture terminal, rounded, with simple or bifid tooth; wall calcareous porcelaneous, imperforate, with inner pseudchitinous layer, rarely with some agglutinated grains added to exterior (Loeblich and Tappan, 1964, p. C458).

Quinqueloculina plummerae Cushman and Todd, 1942

Plate 1, fig. 13

Quinqueloculina ferussacii d'Orbigny, 1826, p. 301.

Miliola (Quinqueloculina) ferussacii Parker and Jones, 1865, p. 411.

Miliolina ferussacii Sherborn and Chapman, 1886, p. 742.

Quinqueloculina plummerae Cushman and Todd, 1942, p. 25.

Diagnosis.--Test small for genus, nearly as broad as long, in end view about twice as broad as thick, periphery truncate with rounded, carinate edges; chambers distinct, the sides flattened or slightly concave toward the periphery; sutures distinct but little if at all depressed; aperture terminal, without a neck, but with a slightly thickened lip and a short blunt tooth, wall smooth (adapted from Cushman and Todd, 1942, p. 25).

Measurements.--Maximum length of hypotype, 0.2 mm; maximum width of hypotype, 0.1 mm.

Hypotype.--Univ. of N. Dak. Cat. No. 13826.

Occurrence.--This species was collected from NDSWC well 3647 (A1150) from the mudstone lithofacies in the lower-middle Cannonball.

Discussion.--The two Cannonball specimens are slightly more pointed on the aboral extremity and are less distinctly carinate than the Cushman and Todd's (1942, figs. 2a, 2b) figures of the type specimens. This genus has not been previously reported from the Cannonball.

Suborder ROTALIINA

Family NODOSARIIDAE Eherenberg, 1838

Genus NODOSARIA Lamarck, 1812

Original reference.--Lamarck, 1812, p. 121.

Type species.--Nodosaria radicula (Linné)=Nautilus radicula Linné, 1758 (by subsequent designation of Children, 1823, p. 117).

Diagnosis.--Test free, multilocular, rectilinear, rounded in section; sutures distinct and commonly perpendicular to axis of test; surface smooth, costate, striate, hispid or tuberculate; aperture terminal, central, basically radiate, may be produced on neck (adapted from Loeblich and Tappan, 1964, p. C512).

Nodosaria affinis Reuss, 1845

Plate 2, fig. 5

Nodosaria affinis Reuss, 1845, p. 26, pl. 13, fig. 16. Plummer, 1926, p. 89-90, pl. XIV, figs. 2a-d.

Diagnosis.--Test straight, elongate, apiculate; chambers cylindrical or only slightly inflated in earliest portion of test to more strongly globular in later development; sutures transverse, generally slightly constricted in early part of test to deeply constricted above; test ornamented by 9-11 longitudinal costae; aperture protruding, round, mammillate (adapted from Plummer, 1926, p. 90).

Measurements.--Length of hypotype, 1.5 mm; maximum width of hypotype, 0.5 mm.

Hypotype.--Univ. of N. Dak. Cat. No. 13829.

Occurrence.--This species was collected from NDSWC wells 3650 (A1087), 3558 (A1095-A1098), 3559 (A1114), 3433 (A1172), 3557 (A1127, A1128), 3647 (A1134, A1142-A1145, A1152), 8103 (A1161, A1162), 4397 (A1171), 8102 (A1175, A1180, A1182), 4312 (A1195), 4388 (A1287, A1288, A1290, A1291), 4389 (A1301, A1304), 1984 (A1309), 4511 (A1326, A1330, A1331, A1336), 4513 (A1347, A1358), 4514 (A1365, A1367), 4516 (A1369), 4760 (A1381) and 4467 (A1398). It occurred in the middle and lower Cannonball in both the sandstone and mudstone lithofacies.

Discussion.--The 44 specimens of this species are all fragmental. Most individuals are preserved as individual chambers. In each sample, unless the fragments contained at least three chambers, all fragments were collectively called one individual. Of all the specimens, only one aperture was preserved; as a result, the individual apertures could not be counted to determine the numbers of individuals. Only one aboral extremity was found among the fragments and the largest fragment consisted of four chambers. Fox and Ross (1942), Lemke (1960) and Fenner (1974) reported this species from the Cannonball.

Nodosaria sp.

Plate 2, fig. 2

Description of material.--Chambers spherical, highly inflated; sutures highly constricted; surface with 12 longitudinal costae extending length of chambers but not across sutures.

Measurements.--Length of hypotype (1 chamber), 0.5 mm, width of hypotype, 0.5 mm.

Hypotype.--Univ. of N. Dak. Cat. No. 13830.

Occurrence.--This species was collected from NDSWC well 3647 (A1149) in the lower-middle Cannonball from the mudstone lithofacies.

Discussion.--This species differs from Nodosaria affinis in that its sutures are more constricted, and it is much larger.

Genus CHRYSALOGONIUM Schubert, 1907

Original reference.--Schubert, 1907, p. 243.

Type species.--Chrysalogonium polystoma (Schwager)=Nodosaria polystoma Schwager, 1866, p. 217 (by original designation).

Diagnosis.--"Test similar to Nodosaria but with a series of pores taking place of radial apertural slits of Nodosaria" Loeblich and Tappan, 1964, p. C514).

?Chrysalogonium sp.

Plate 2, fig. 1

Description of material.--Test uniserial; chambers elongate, about five times longer than wide; sutures slightly constricted; aperture not preserved; surface unornamented.

Measurements.--Length of hypotype, 0.5 mm; width of hypotype, 0.1 mm.

Hypotype.--Univ. of N. Dak. Cat. No. 13828.

Occurrence.--This species was collected from NDSWC wells 3647 (A1152) and 8102 (A1179) in the middle or lower middle Cannonball from the mudstone lithofacies.

Discussion.--The generic assignment of this form is uncertain because it is represented by only fragments consisting of five separate chambers on which no aperture is preserved. At one locality (A1152), all the chambers appear to be derived from the same individual. When

reconstructing the chambers, they form an arcuate pattern which suggests either the genus Dentalina or the genus Chrysalogonium. This form was tentatively placed into the genus Chrysalogonium because the one species previously collected from the Cannonball that has a chamber shape that most closely conforms to this form is Chrysalogonium granti, reported by Fox and Ross (1942). Olsson (1976) suggested that this form could be placed equally well into either Dentalina or Chrysalogonium.

Genus DENTALINA Risso, 1826

Original reference.--Risso, 1826, p. 16.

Type species.--Dentalina cuvieri (d'Orbigny)=Nodosaria (Dentaline) cuvieri d'Orbigny, 1826, p. 255 (monotypic in Risso, 1826).

Dentalina communis (d'Orbigny)=Nodosaria (Dentaline) communis d'Orbigny, 1826 (designated by Jones, 1883).

Dentalina obliqua (d'Orbigny)=Nodosaria (Dentaline) obliqua d'Orbigny, 1826 (designed by Galloway and Wissler, 1927).

Diagnosis.--"Test elongate, arcuate, uniserial; sutures commonly oblique; aperture radiate, terminal, may be eccentric or nearly central. (Differs from Nodosaria in being asymmetrical.)" (Loeblich and Tappan, 1964, p. C516).

Dentalina colei Cushman and Dusenbury, 1934

Plate 2, fig. 4

Vaginulina legumen (Linné) var. elegans Cole (not d'Orbigny), 1927, p. 21, pl. 3, figs. 10, 11.

Dentalina colei Cushman and Dusenbury, 1934, p. 54, pl. 7, figs. 10, 12.

Diagnosis.--Test elongate, tapering, with the greatest width near the apertural end, slightly curved; chambers distinct, earliest ones slightly compressed, later ones circular in transverse section, increasing very gradually in size and height as added, little if at all inflated; sutures flush with surface, slightly oblique; aperture radiate, toward the inner side of the apertural face; wall smooth (adapted from Cushman, 1951, p. 19).

Measurements.--Length of hypotype, 1.1 mm; maximum width of hypotype, 0.2 mm.

Hypotype.--Univ. of N. Dak. Cat. No. 13831.

Occurrence.--This species was collected from NDSWC wells 3559 (A1106), 3433 (A1122), 8102 (A1182), 2006 (A1318) and 4467 (A1397), in the mudstone lithofacies from the middle and upper-middle Cannonball.

Discussion.--The five fragmental individuals of this species closely resemble the figures of Cushman and Dusenbury (1934, p. 7, figs. 10-12) and the description and figures of Cushman (1951, p. 19, pl. 6, figs. 8-10). Neither Fox and Ross (1942) nor Lemke (1960) reported this species from the Cannonball, but they did report Dentalina gardnerae (Plummer) which is similar to D. colei. It seems unlikely that the present Cannonball forms are D. gardnerae because their boral extremity is too blunt. Cushman's figures (1951, pl. 6, figs. 4-10) clearly illustrate the differences between the two species. The lower one-third of D. gardnerae expands much more abruptly than the upper two-thirds. D. colei does not show such a change. It appears to be increasing gradually and consistently in size from the apex to the aperture.

Dentalina eocenica Cushman, 1944

Plate 2, fig. 6

Dentalina eocenica Cushman, 1944, p. 36, pl. 6, fig. 1.

Diagnosis.--Test small, slender, slightly curved, increasing very slightly in diameter; chambers distinct but only slightly inflated in the later portion, increasing gradually and rather regularly in size as added, the last-formed one in the adult nearly twice as high as broad; sutures distinct, depressed slightly in the later portion, earlier ones slightly oblique, later ones nearly at right angles to the long axis of the test; wall smooth, aperture radiate, terminal, nearly in the center of the terminal face (Cushman, 1944, p. 36.

Measurements.--Length of hypotype (13834), 0.7 mm; maximum width of hypotype, 0.1 mm.

Hypotypes.--University of N. Dak. Cat. Nos. 13832, 13833, 13834.

Occurrence.--This species was collected from NDSWC wells 3559 (A1108), 3557 (A1128), 3647 (A1142) and 4384 (A1301) from the middle Cannonball in the mudstone lithofacies.

Discussion.--This species is represented by three small fragments and one relatively complete specimen (hypotype 13834). This material conforms favorably to Dentalina eocenica Cushman as illustrated by Cushman (1944, pl. 6, fig. 1; 1951, pl. 6, figs. 30-33). Cushman (1944, p. 36) noted that Plummer (1926, p. 79-80) misidentified this species as Nodosaria pauperata (d'Orbigny). Fox and Ross (1942) identified Dentalina pauperata, which may also have been a misidentification of D. eocenica.

Dentalina pseudo-obliquestriata (Plummer) Cushman, 1940

Plate 2, fig. 3

Nodosaria pseudo-obliquestriata Plummer, 1926, p. 87, pl. 4, fig. 18.

Dentalina pseudo-obliquestriata (Plummer) Cushman, 1940, p. 58, pl. 10, fig. 18.

Diagnosis.--Test long, slender, arcuate, tapering toward the aboral extremity; chambers numerous, strongly inflated; sutures strongly constricted; aperture protruding, round, somewhat eccentric; test ornamented by coarse costae that follow the length of test somewhat obliquely (adapted from Cushman, 1951, p. 19).

Measurements.--Maximum length of hypotype, 0.7 mm; maximum width of hypotype, 0.2 mm.

Hypotype.--Univ. of N. Dak. Cat. No. 13835.

Occurrence.--This species was collected from NDSWC wells 3559 (A1108), 3647 (A1138) and 4511 (A1327) in the middle and upper-middle Cannonball from the mudstone and sandstone lithofacies.

Discussion.--The three fragmental individuals that were collected are closely conformable to the description and figures of Cushman (1951, p. 19, pl. 6, figs. 1-3). Cushman (1951, p. 19) noted that this species occurs mostly commonly in the lower part of the Paleocene. This species was not reported by Fox and Ross (1942) or Lemke (1960), but Fenner (1974) reported a single specimen not assigned to a species but which appeared to be D. pseudo-obliquestriata.

?Dentalina sp. A

Plate 2, fig. 7

Description of material.--Test elongate; chambers about twice as long as wide, very slightly inflated; sutures slightly constricted; aperture absent; wall smooth.

Measurements.--Maximum length of hypotype, 0.5 mm; maximum width of hypotype, 0.1 mm.

Hypotype.--Univ. of N. Dak. Cat. No. 13836.

Occurrence.--This species was collected from NDSWC well 2006 (A1318) in the mudstone lithofacies. The location with the stratigraphic section is uncertain.

Discussion.--This species is represented by one fragment consisting of two chambers. Since the sutures appear to be oblique, this form has been questionably assigned to the genus Dentalina. The lack of a larger specimen and the absence of an aperture make a definite generic assignment impossible.

?Dentalina sp. B

Description of material.--Test uniserial; chambers inflated, one and one-half times longer than wide; sutures moderately constricted; aperture possibly radiate, produced on neck; wall smooth.

Measurements.--Length of hypotype, 0.4 mm; width of hypotype, 0.1 mm.

Hypotype.--Univ. of N. Dak. Cat. No. 13827.

Occurrence.--This species was collected from NDSWC well 8102 (A1179) in the middle Cannonball from the mudstone lithofacies.

Discussion.--This species is represented by two badly broken fragments. This is not enough material to make a definite generic assignment. One of the fragments appears to have part of an apertural neck in place, and the aperture may be radiate; however, it is not well enough preserved to be certain. Because the test is arcuate and the chambers are assymetrical, this form has been tentatively assigned to the genus Dentalina.

Genus LENTICULINA Lamarck, 1804

Original reference.--Lamarck, 1804, p. 186.

Type species.--Lenticulina rotulata (Lamarck)=Lenticulites rotulata Lamarck, 1804, p. 187 (by subsequent designation of Children, 1823, p. 153).

Diagnosis.--Test free, planispiral or rarely slightly trochoid, lenticular, biumbonate, periphery angled or keeled; chambers increasing gradually in size, in general or greater breadth than height; sutures radial, straight or curved and depressed, flush or elevated; aperture radial at peripheral angle; surface may be variously ornamented with thickened, elevated sutures, bosses or sutural nodes (adapted from Loeblich and Tappan, 1964, p. C520).

Remarks.--According to Loeblich and Tappan (1964, p. C520), the genus Lenticulina now also includes all species formerly included in the genera Cristellaria and Robulus.

Lenticulina alabamensis? (Cushman) Kellough, 1965

Plate 2, fig. 8

Robulus alabamensis Cushman, 1944, p. 33, pl. 5, fig. 13.

Lenticulina alabamensis (Cushman) Kellough, 1965, p. 105, pl. 4, fig. 11.

Diagnosis.--Test small for the genus, umbonate, closely coiled, periphery with the area of each adult chamber slightly flattened, sharply angled but not carinate; chambers numbrous, 8 to 11 in final coil, distinct, of uniform shape, increasing gradually and regularly in size as added, the apertural angle translucent; sutures distinct, nearly tangential, very slightly curved, not depressed; aperture radiate, with

a slight opening at the upper end of the ventral face; wall smooth, polished (adapted from Cushman, 1944, p. 33).

Measurements.--Maximum diameter of hypotype (13841), 0.3 mm; maximum thickness of hypotype, 0.1 mm.

Hypotypes.--Univ. of N. Dak. Cat. Nos. 13841, 13842, 13843.

Occurrence.--This species was collected from NDSWC wells 3559 (A1111), 3433 (A1116), 3467 (A1141, A1150), 8103 (A1161), 8102 (A1177), 4388 (A1290), 1984 (A1314) and 4751 (A1391) in the middle, upper middle and upper Cannonball from the mudstone lithofacies.

Discussion.--This species is represented by 11 variously preserved specimens that closely resemble Lenticulina alabamensis. The absence of elevated sutures and the lack of distinct umbonal bosses precludes assignment to L. midwayensis, the most common species of Lenticulina in the Cannonball. Olsson (1976) was uncertain of the proper species assignment of this form.

Lenticulina arkansasana (Cushman and Todd) Kellough, 1965

Plate 1, fig. 12

Robulus arkansasanus Cushman and Todd, 1946, p. 48, pl. 7, fig. 14.

Lenticulina arkansasana (Cushman and Todd) Kellough, 1965, p. 105, pl. 4, fig. 12.

Diagnosis.--Test close coiled, strongly umbonate, periphery acute but not keeled, very slightly lobulate; chambers distinct, very slightly inflated, seven or eight in the adult coil, increasing very gradually and uniformly in size as added; sutures distinct, strongly limbate, curved, raised, broadest near umbo where they tend to fuse; aperture at the peripheral angle of the last-formed chamber, slightly

projecting, with distinct median slit extending slightly down the apertural face; wall smooth except for the raised sutures (adapted from Cushman and Todd, 1946, p. 48).

Measurements.--Maximum diameter of hypotype (13837), 1.0 mm; maximum thickness of hypotype, 0.3 mm.

Hypotypes.--Univ. of N. Dak. Cat. Nos. 13837, 13838.

Occurrences.--This species was collected from NDSWC wells 4384 (A1301) and 4513 (A1358) in the upper middle Cannonball from the mudstone lithofacies.

Discussion.--This species is represented by two specimens that compare favorably to the illustration of Kellough (1965, pl. 4, fig. 12). This species is somewhat larger than the other species of this genus. The Cannonball forms differ slightly from that illustrated by Kellough in that they have a small, irregularly developed umbonal boss; however, they are comparable in other characteristics. Olsson (1976) was uncertain as to the proper specific assignment of these forms and indicated a questionable assignment to this species.

Lenticulina midwayensis (Plummer) Plummer, 1933

Plate 1, fig. 11

Cristellaria midwayensis Plummer, 1926, p. 95, pl. 13, fig. 5. Kellough, 1959, fig. 6.

Lenticulina midwayensis (Plummer) Plummer, 1933, p. 54, 61 and 64

Robulus midwayensis (Plummer) Cushman, 1940, p. 54, pl. 9, fig. 12. Toulmin, 1941, p. 579, pl. 78, fig. 23, text fig. 29. Cushman and Todd, 1942, p. 26, pl. 5, figs. 4, 5. Kline, 1943, p. 17, pl. 1, fig. 3. Cushman, 1944, p. 33, pl. 5, fig. 15. Cooper, 1944, p. 351, pl. 5,

figs. 22, 23. Cushman and Todd, 1946, p. 47, pl. 7, fig. 7. Cushman, 1951, p. 13, pl. 3, figs. 14-17. Nogan, 1964, p. 22, pl. 1, figs. 13-16.

Robulus midwayensis (Plummer) var. virginianus Shifflett, 1948, pl. 1, figs. 15-16.

Lenticulina midwayensis (Plummer) Kellough, 1965, p. 106, pl. 3, fig. 8. Berggren, 1974, p. 453. Berggren and Aubert, 1975, p. 81-83, 116, Table VIII, Text fig. 4, pl. I, fig. 2, pl. XII, fig. 14, pl. XVI, fig. 7.

Diagnosis.--Test large, circular, very closely coiled, full bodied, though somewhat compressed; periphery distinctly angular but not flanged in its typical form; chambers 10-12 in adult form; septa elevated, smooth, narrow, gently curved, radiating from a conspicuous central boss and tapering somewhat toward the peripheral margin; aperture at apex of broad septal face (modified from Plummer, 1926, p. 95).

Measurements.--Maximum diameter of hypotype, 0.6 mm; maximum thickness of hypotype, 0.4 mm.

Hypotype.--Univ. of N. Dak. Cat. No. 13839.

Occurrence.--This species was collected from NDSWC wells 3560 (A1083-A1085), 3558 (A1089, A1099), 3559 (A1111, A1112), 3647 (A1144, A1145, A1152), 8102 (A1175, A1182), 4312 (A1184, A1186, A1193, A1197), 8347 (A1268, A1271), 4388 (A1279, A1286, A1288, A1292), 4384 (A1300, A1301, A1304, A1305), 1984 (A1309), 4511 (A1323, A1333, A1334), 4513 (A1347), 4515 (A1364, A1370), 4752 (A1374) and 4751 (A1386, A1389) in the middle Cannonball, predominantly from the mudstone lithofacies and rarely from the sandstone lithofacies.

Discussion.--The 44 specimens of this species closely resemble the illustrations of Lenticulina midwayensis (Plummer) (=Robulus

midwayensis) of Nogan (1964, pl. 1, figs. 13-16) and Kellough (1965, pl. 3, fig. 8). Nogan (1964, p. 22) suggested that Lenticulina midwayensis and L. degolyeri were variants of the same species and included Lenticulina degolyeri in his synonymy. Olsson (1976) said that he treated the two species separately. I have chosen to treat the two species separately and have therefore omitted L. degolyeri from the synonymy.

Lenticulina midwayensis is one of the more cosmopolitan species in the Cannonball. Outside of the Cannonball, it has a worldwide distribution occurring in the Paleocene of the Gulf Coast and Atlantic Coastal Plain in the United States. Occurrences reported from other parts of the world include Nova Scotia, Tunisia, Morocco, Mozambique, South Africa, West Australia, Cameroon, Angola, Saudi Arabia, Libya, and Turkmenia (Berggren and Aubert, 1975; and Berggren, 1974).

This species was reported from the Cannonball by Lemke (1960).

Lenticulina turbinata (Plummer, 1962)?

Plate 2, fig. 10

Cristellaria turbinata Plummer, 1926, p. 93, pl. 7, fig. 4.

Lenticulina turbinata (Plummer) Plummer, 1933, p. 567, 568 (lists).

Robulus turbinatus (Plummer) Cushman, 1940, p. 55, pl. 9, fig. 17.

Lenticulina turbinata (Plummer) Kellough, 1965, p. 106, 107, pl. 3, fig. 9.

Diagnosis.--"Test circular, considerably compressed; peripheral margin sharp and extended into a fragile, white flange that is typically ragged; chambers 8 in final convolution, narrow, smooth; sutures strongly

elevated and of about equal width from large umbonal area to the periphery very strongly curved; aperture at apex of narrow septal face (Plummer, 1926, p. 93)."

Measurements.--Maximum width of hypotype, 0.6 mm; maximum thickness of hypotype, 0.4 mm.

Hypotype.--Univ. of N. Dak. Cat. No. 13840.

Occurrence.--This species was collected from NDSWC well 3647 (A1145) in the lower-middle Cannonball from the mudstone lithofacies.

Discussion.--The exact specific assignment of this form is uncertain because it is represented by only one fragmental individual. The lack of a distinct umbonal boss and strongly curved, elevated sutures suggests assignment to Lenticulina turbinata (Plummer). Although this species has not previously been reported from the Cannonball, Lenticulina pseudo-mamilligera (Plummer) was reported by Fox and Ross (1942). Lenticulina pseudo-mamilligera is similar to L. turbinata; however, L. pseudo-mamilligera lacks the almost circular shape of L. turbinata. This form has tentatively been placed into Lenticulina turbinata because the fragment appeared to have been nearly circular.

Genus LINGULINA d'Orbigny, 1826

Original reference.--d'Orbigny, 1826, p. 256.

Type species.--Lingulina carinata d'Orbigny, 1826, p. 256 (by subsequent designation of Cushman, 1913, p. 61).

Diagnosis.--"Test free, elongate, uniserial and compressed, with succeeding chambers strongly overlapping, as in Pseudonodosaria, aperture an elongate terminal slit in plane of compression" (Loeblich and Tappan, 1964, p. C528).

Lingulina sp.

Plate 2, fig. 15

Description of material.--Test conical chambers uninflated, straight sided; sutures slightly depressed, stand out as white lines against darker chambers; last chamber broadly rounded on oral surface; aperture not preserved; wall unornamented.

Measurements.--Maximum length of hypotype, 0.2 mm; maximum width of hypotype, 0.1 mm.

Occurrence.--This species was collected from NDSWC well 4513 (A1353) in the upper Cannonball from the mudstone lithofacies.

Discussion.--The one fragmental, sulphide-filled specimen of this species lacks an aperture but otherwise appears to belong to the genus Lingulina. A species determination was not possible with the material available. This genus has not previously been reported from the Cannonball.

Family POLYMORPHINIDAE d'Orbigny, 1839

Genus GLOBULINA d'Orbigny, 1839

Original reference.--d'Orbigny in de la Sagra, 1839, p. 134.

Type species.--Globulina gibba (d'Orbigny) = Polymorphina (globuline) gibba d'Orbigny, 1826, p. 266 (by subsequent designation of Cushman, 1927b, p. 189).

Diagnosis.--"Test globular to ovate; chambers strongly overlaping, added in planes of approximately 144° apart; sutures flush, not depressed; aperture radiate but commonly obscured by fistulose growth" (Loeblich and Tappan, 1964, p. C531).

Globulina gibba (d'Orbigny) Cushman, 1927

Plate 2, fig. 13

Polymorphina (Globuline) gibba d'Orbigny, 1826, p. 266.

Polymorphina gibba d'Orbigny. Plummer, 1926, p. 122, pl. 6, fig. 8.

Globulina gibba (d'Orbigny) Cushman 1927b, p. 189.

Diagnosis.--Test broadly oval in lateral view, slightly compressed; chambers few, uninflated; sutures marked by dark lines; aperture produced; wall smooth (adapted from Plummer, 1926, p. 122).

Measurements.--Maximum length of hypotype (13845), 0.5 mm, (13846), 0.4 mm; maximum width of hypotype (13845), 0.4 mm, (13846), 0.2 mm.

Hypotypes.--Univ. of N. Dak. Cat. Nos. 13845, 13846.

Occurrence.--This species was collected from NDSWC wells 3557 (A1127), 8102 (A1175) and 4760 (A1379), in the middle Cannonball from the mudstone lithofacies.

Discussion.--This species is represented by two well-preserved specimens and one sulphide internal mold. It is closely conformable to the illustrations of Globulina gibba (d'Orbigny) of Cushman (1951, p. 9, figs. 26-28). Only the internal mold displays the fistulose apertural growth that frequently occurs in this genus and occasionally occurs in this species. Although the internal mold has a somewhat different shape than the other two specimens, Olsson (1976) placed it in this species. Fox and Ross (1942) and Fenner (1974) reported this species from the Cannonball.

Globulina sp. A

Plate 2, fig. 9

Description of material.--Test elongate, globular, with greatest diameter toward aboral end, tapers toward aperture; sutures indistinct; aperture produced; wall smooth.

Measurements.--Maximum width of hypotype, 0.2 mm; maximum length of hypotype, 0.5 mm.

Hypotype.--Univ. of N. Dak. Cat. No. 13848.

Occurrence.--This species was collected from NDSWC well 4312 (A1251) in the middle Cannonball from the mudstone lithofacies.

Discussion.--Because this form is represented by a single poorly preserved individual; no specific assignment was made.

Globulina sp. B

Plate 2, fig. 14

Description of material.--Test globular, somewhat compressed, aboral extremity formed into slight point; sutures indistinct, slightly depressed; aperture radial; wall smooth.

Measurements.--Length of hypotype, 0.3 mm; maximum width of hypotype, 0.2 mm.

Hypotype.--Univ. of N. Dak. Cat. No. 13847.

Occurrence.--This form was collected from NDSWC well 2051 (A1321) from the mudstone facies. The stratigraphic placement of this species is uncertain.

Discussion.--The slightly depressed sutures and the overall shape with the slight apical point tend to distinguish this form from Globulina gibba (d'Orbigny).

Genus PYRULINA d'Orbigny, 1839

Original reference.--d'Orbigny in de la Sagra, 1839, p. 107.

Type species.--Pyrulina gutta (d'Orbigny) = Polymorphina (Pyruline) gutta d'Orbigny, 1826, p. 267 (by original designation (monotypic)).

Diagnosis.--"Test fusiform; early chambers arranged in spiral series approximately 120° apart, later chambers biserial; sutures flush; aperture radiate" (Loeblich and Tappan, 1964, p. C533).

Pyrulina cylindroides (Roemer) Cushman and Ozawa, 1930

Plate 2, fig. 11

Polymorphina cylindroides Roemer, 1838, p. 385, pl. 3, fig. 26.

Pyrulina cylindroides (Roemer) Cushman and Ozawa, 1930, p. 56, pl. 14, figs. 1-5.

Diagnosis.--Test elongate, subcylindrical, acuminate at both ends, almost circular in transverse section; chambers elongate, each succeeding chamber farther removed from the base; wall smooth, polished (adapted from Toulmin, 1941, p. 594).

Measurements.--Length of hypotype, 0.6 mm; maximum width of hypotype, 0.2 mm.

Hypotype.--Univ. of N. Dak. Cat. No. 13849.

Occurrence.--This species was collected from NDSWC wells 4384 (A1303) and 4515 (A1362) in the upper-middle Cannonball from the mudstone lithofacies.

Discussion.--This species is represented by one well preserved and two poorly preserved specimens. It conforms favorably to the

description of Toulmin (1941, p. 594). Lemke (1960) previously reported this species from the Cannonball.

Family Turrilinidae Cushman, 1927

Genus SPIROBOLIVINA Hofker, 1956

Original reference.--Hofker, 1956, p. 915.

Type species.--Spirobolivina pulchella (Cushman and Stainforth)= Bolivinopsis pulchella Cushman and Stainforth, 1947, p. 78 (by original designation).

Diagnosis.--Test free, elongate with early planispiral stage of about 1.5 volutions, latter biserial, compressed; aperture a loop-shaped opening, with small internal tooth plate similar to Bolivina, tooth plates of successive chambers differing in orientation by 180°; wall thin, calcareous, finely perforate. (Spirobolivina was proposed for calcareous perforate species with internal tooth plate, previously placed erroneously in Bolivinopsis which is an agglutinated form.) (adapted from Loeblich and Tappan, 1964, p. C547).

Spirobolivina emmendorferi (Jennings), 1936

Plate 2, fig. 17

Spiroplectoides emmendorferi Jennings, 1936, p. 26, pl. 3, fig. 8.

Bolivinopsis emmendorferi (Jennings) Olsson, 1960, p. 27, pl. 4, fig. 7. Nogan, 1964, p. 30, pl. 2, fig. 8.

Diagnosis.--Test minute, compressed; early portion coiled, about nine chambers in the coiled portion; later portion biserial with from two to three sets of chambers; aperture terminal (adapted from Jennings, 1936, p. 26).

Measurements.--

Hypotype	Maximum Length	Maximum Width
13850	0.2 mm	0.1 mm
"	0.1 mm	0.1 mm
13851	0.15 mm	0.05 mm

Hypotypes.--Univ. of N. Dak. Cat. Nos. 13850, 13851.

Occurrence.--This species was collected from NDSWC wells 3557 (A1124), 3647 (A1129, A1132-A1135, A1138, A1142, A1144), 2690 (A1157), 8102 (A1175, A1176, A1178-A1181) and 4312 (A1189). It occurred throughout the middle Cannonball in predominantly the mudstone lithofacies and rarely in the sandstone lithofacies.

Discussion.--The 27 individuals of this species that were collected from the Cannonball are, in part, closely conformable to Jennings' (1936, p. 26, pl. 3, fig. 8) description and illustration and Nogan's (1964, pl. 2, fig. 8) illustration. Few of the individuals, however vary from the holotype in that the biserial part of the test is much longer (five or six sets of chambers). Also, these variants are smaller and relatively narrower than those that more closely resemble the holotype. Olsson (1976), however, indicated that all of the variants belong to Spirobolivina emmendorferi. Neither this genus nor this species has been previously reported from the Cannonball. This species does not occur in the Gulf Coast Paleocene, but it has been reported from the Paleocene of the Atlantic Coastal Plain (Olsson, 1960 and Nogan, 1964).

Family BULIMINIDAE Jones, 1875

Genus BULIMINA d'Orbigny, 1826

Original reference.--d'Orbigny, 1826, p. 269.

Type species.--Bulimina marginata d'Orbigny, 1826, p. 269 (by subsequent designation of Cushman, 1911, p. 76).

Diagnosis.--Test triserial in early stage, may tend to reduce to uniserial in later portion; aperture extending up from base of apertual face, with free border that may have elevated rim and fixed border attached to internal tooth plate, which, with fixed shank, is attached to internal chamber wall below aperture, with free shank that may be dentate or smooth, flaring or enrolled and tubular; wall calcareous, finely to coarsely perforate (adapted from Loeblich and Tappan, 1964, p. C559).

Bulimina rosenkrantzi Brotzen, 1948

Plate 2, fig. 12

Bulimina rosenkrantzi Brotzen, 1948, p. 61, pl. 9, fig. 1.

Diagnosis.--Test elongate, about 3 - 3.5 times as long as broad, rounded in transverse section, except a number of specimens which are triangular at the initial end; chambers numerous, 5-6 whorls, the last one forming nearly half the test, only the initial part increasing intensely in breadth, later the breadth is more or less uniform; chambers fairly inflated, sutures distinct, slightly depressed; wall smooth, finely perforated (Brotzen, 1948, p. 61).

Measurements.--

Hypotype	Maximum Length	Maximum Width
13852	0.3 mm	0.2 mm
"	0.25 mm	0.2 mm
13853	0.3 mm	0.1 mm
"	0.2 mm	0.1 mm
13854	0.3 mm	0.2 mm

Hypotypes.--Univ. of N. Dak. Cat. Nos. 13852, 13853, 13854.

Occurrence.--This species was collected from NDSWC wells 3558 (A1092-A1095), 3559 (A1108-A1111), 3433 (A1116-A1119, A1121), 3557 (A1125-A1128), 3647 (A1130, A1134, A1136, A1138-A1140, A11-42-A1145), 2690 (A1158), 8103 (A1161), 8102 (A1178-A1182), 4312 (A1183, A1184, A1187-A1190, A1192-A1196, A1198, A1200, A1250, A1251, A1253-A1255, A1257), 8347 (A1268-A1271), 4388 (A1277-A1282, A1287, A1289, A1290), 4384 (A1300-A1304), 1988 (A1317), 4511 (A1322, A1332), 4513 (A1350, A1351, A1355-A1357), 4515 (A1362, A1363), 4760 (A1379), 4752 (A1391, A1395), 4467 (A1397) throughout the stratigraphic section predominantly from the mudstone lithofacies and occasionally in the sandstone lithofacies.

Discussion.--The 506 well-preserved specimens of this species agree with the description and illustrations of Brotzen (1948, p. 61, pl. 9, fig. 1). In his discussion of this species, Brotzen noted that considerable variation in overall shape exists and similar variation is seen in the Cannonball specimens. Some of the variation is due to microspheric and megalospheric generations but much variation is due to a great variability within the species. In terms of numbers of individuals, this is one of the most abundant species in the Cannonball. Up to 120 individuals were collected in a single sample. This species occurs in 86 samples making it one of the more cosmopolitan species within the Cannonball. Lemke (1960) reported this species from the Cannonball and Fox and Ross (1942) reported the similar-appearing Bulimina quadrata Plummer from the Cannonball. It is likely that the species reported by Fox and Ross is Bulimina rosenkrantzi rather than B. quadrata.

Bulimina sp.

Plate 2, fig. 16

Description of material.--Test elongate, about four times as long as broad, rounded in transverse section, about 6.5 whorls; test very slender and uniformly, gently tapering; chambers slightly inflated; sutures distinct, slightly depressed; aperture, a high, loop-shaped opening; wall smooth, finely perforate.

Measurements.--Length of hypotype, 0.3 mm; maximum width of hypotype, 0.075 mm.

Hypotype.--Univ. of N. Dak. Cat. No. 13855.

Occurrence.--This species was collected from NDSWC wells 3433 (A1119), 4312 (A1194) and 4388 (A1278) in the middle and upper middle Cannonball from the mudstone lithofacies.

Discussion.--This species is represented by four well-preserved specimens. It is similar to Bulimina rosenkrantzi except that the test is narrower and it is tapered much more uniformly and gently toward the aboral extremity. The aboral extremity is gently rounded in this species as opposed to a pointed extremity in Bulimina rosenkrantzi. The aperture appears to be about the same shape and in about the same location as that of B. rosenkrantzi.

Superfamily DISCORBACEA

(no familial or generic designation made)

Plate 2, fig. 18

Description of material.--Test small, biconvex, trochospiral, periphery keeled; all chambers visible on dorsal side, only chambers

of last whorl visible on ventral side; sutures slightly depressed, radial on ventral side; apertures indistinct; wall hyaline, finely perforate.

Measurements.--Maximum width of hypotype, 0.2 mm; maximum thickness of hypotype, 0.05 mm.

Hypotype.--Univ. of N. Dak. Cat. No. 13856.

Occurrence.--This form was collected from NDSWC wells 4312 (A1176?, A1196), 4388 (A1290) and 1984 (A1313?) in the middle or upper-middle Cannonball from the mudstone lithofacies.

Discussion.--This form is represented by two specimens plus two questionable specimens. All specimens are fragmental and all lack an aperture. No identification could be made below the level of superfamily because of the poor preservation of the specimens.

Family DISCORBIDAE Ehrenberg, 1838

Genus EPISTOMINELLA Husezima and Maruhasi, 1944

Original reference.--Husezima and Maruhasi, 1944, p. 397.

Type species.--Epistominella pulchella Husezima and Maruhasi, 1944, p. 397 (by original designation).

Diagnosis.--Test trochospiral; all chambers visible on spiral side, only those of last whorl visible on umbilical side; sutures oblique on spiral side, nearly radial on umbilical side; aperture an elongate vertical slit in face, near and parallel to peripheral keel; wall calcareous, perforate, monolamellid (adapted from Loeblich and Tappan, 1964, p. C578).

Remarks.--This genus includes the genera Pulvinulinella Cushman, 1926, p. 62 (not Eimer and Fickert, 1899) and Pseudoparrella Cushman and Ten Dam, 1948, p. 49 (Loeblich and Tappan, 1964, p. C578).

Epistominella minuta (Olsson), 1960

Plate 3, figs. 2, 3

Pseudoparrella minuta Olsson, 1960, p. 40, pl. 6, figs. 7-9.

Epistominella minuta (Olsson) Nogan, 1964, p. 36, pl. 3, figs. 7, 8.

Diagnosis.--Test minute, biconvex, low trochospiral, compressed, equitorial periphery circular, axial periphery subacute; chambers, seven in final whorl, gradually increasing in size, not inflated; sutures non-limbate, flush with surface, last suture on umbilical side may be somewhat depressed, spiral side oblique, gently curved, umbilical side radial to very slightly curved; aperture interiomarginal-areal, a narrow, somewhat comma-shaped opening, parallel to plane of coiling; wall smooth, finely perforate (adapted from Olsson, 1960, p. 40).

Measurements.--Maximum width of hypotype (13857), 0.25 mm; maximum thickness of hypotype, 0.05 mm.

Hypotypes.--Univ. of N. Dak. Cat. Nos. 13857, 13858.

Occurrence.--This species was collected from NDSWC wells 3647 (A1148, A1154), 8102 (A1180, A1181), 4312 (A1183, A1200), 8347 (A1268), 4388 (A1277-A1280) and 4467 (A1397) in the middle and upper part of the lower Cannonball from the mudstone lithofacies.

Discussion.--This species is represented by 28 specimens that closely resemble the description and illustrations of Pseudoparella minuta Olsson = Epistominella minuta (Olsson) by Olsson (1960, p. 40, pl. 6, figs. 7-9) and the illustrations of Epistominella minuta by Nogan (1964, pl. 3, figs. 7, 8). Epistominella minuta occurs in the Paleocene of the Atlantic Coastal Plain (Olsson, 1960; Nogan, 1964), but has not been reported from the Paleocene of the Gulf Coast. This species

has not previously been reported from the Cannonball, but Lemke (1960, p. 30-31) indicated that a new species of Pulvinulinella was present in the Cannonball. This may have been Epistominella minuta.

Genus ROSALINA d'Orbigny, 1826

Original reference.--d'Orbigny, 1826, p. 271.

Type species.--Rosalina globularis d'Orbigny, 1826, p. 271 (by subsequent designation of Loeblich and Tappan, 1964, p. C584).

Diagnosis.--Test plano-convex, free or attached by flattened umbilical surface, all chambers visible from convex spiral side, only those of final whorl visible around open umbilicus on umbilical side; aperture a low interiomarginal arch at base of final chamber near periphery on umbilical side, with broad chamber flap just beneath aperture extending into open umbilicus, secondary sutural opening opposite side of flap, those of previous chambers also remaining open (Loeblich and Tappan, 1964, p. C584).

Rosalina sp.

Plate 3, fig. 1

Description of material.--Test minute, trochospiral with low spire; periphery gently rounded; spiral side with most chambers visible, last volution overlapping outer part of previous volutions; umbilical side with small, deep umbilicus, adult chamber covers almost half the area of the test; sutures slightly depressed on spiral side, deeply depressed on umbilical side; aperture, umbilical with small aperture flap projecting toward umbilicus; wall finely perforate.

Measurements.--Maximum width of hypotype, 0.35 mm; maximum thickness of hypotype, 0.1 mm.

Hypotype.--Univ. of N. Dak. Cat. No. 13859.

Occurrence.--This species was collected from NDSWC well 4511 (A1339) in the lower middle Cannonball from the sandstone lithofacies.

Discussion.--This form appears similar to Rosalina ystadiensis Brotzen in the appearance of the umbilical side; however it differs in that the umbilicus is narrower and deeper and the periphery is not angular. This form is represented by one well-preserved individual.

Family ROTALIIDAE Ehrenberg, 1839

Genus PARAROTALIA LeCalvez, 1949

Original reference.--LeCalvez, 1949, p. 32.

Type species.--Paraotalia inermis (Terquem) = Rotalia inermis Terquem, 1882, p. 68 (by original designation).

Diagnosis.--Test free, trochospiral, plano-convex to biconvex, umbilicus filled by plug which may be broken out in preservation; chambers rounded to ovate in plan, may have smoothly rounded periphery or develop short, blunt peripheral spine on each chamber, umbilical region of each chamber partially covered by umbilical flap; apertures on umbilical side, interiomarginal and extraumbilical-umbilical with lip; internal "tooth plate" near umbilical and axial chamber wall, intercameral foramen narrow, elongate, comma-shaped or slit-like areal opening, consisting of portion of former aperture, roughly paralleling base of apertural face and restricted by tooth plate of following chamber; wall calcareous, perforate, rotaliid in structure, smooth or variously ornamented with large solid spines or fine scattered spines or nodes (adapted from Loeblich and Tappan, 1964, p. C612).

Remarks.--The genera Neorotalia Bermúdez (1952, p. 75) and Woodella Haque (1956, p. 194) are apparently synonymous with Pararotalia (Loeblich and Tappan, 1964, p. C612).

Pararotalia perclara (Loeblich and Tappan), 1957

Plate 2, figs. 4, 5

Globorotalia perclara Loeblich and Tappan, 1957, p. 191, pl. 40, figs. 7a-c; pl. 41, figs. 8a-c; pl. 42, figs. 4a-c; pl. 45, figs 11a-c; pl. 46, figs. 3a-c; pl. 47, figs. 6a-c; pl. 50, figs. 1a-c; pl. 54, figs. 6a-7c; pl. 57, figs. 3a-4c; pl. 60, figs. 5a-c.

Diagnosis.--Test with flattened sides, small umbilicus, peripheral margin broadly rounded, peripheral outline lobulate; 5 to 6 chambers in the final whorl, increasing gradually in size as added, rounded to ovate in shape, or may somewhat overhang the preceding suture, of somewhat greater breadth than height on the spiral side, and commonly somewhat excavated near the spiral suture, elevated near the periphery; sutures distinct, depressed, curved back at the periphery on the spiral side, radial on the umbilical side; smooth to finely hispid on spiral side (adapted from Loeblich and Tappan, 1957, p. 191).

Measurements.--Maximum width of hypotype, 0.15 mm; maximum thickness of hypotype, 0.05 mm.

Hypotype.--Univ. of N. Dak. Cat. No. 13860.

Occurrence.--This species was collected from NDSWC wells 4312 (A1194), 1988 (A1317), 2043 (A1320) and 3075 (A1403-A1405, A1407) in the middle Cannonball from the mudstone lithofacies.

Discussion.--This species is represented by eight individuals of which seven are fragmental and highly questionable. The one almost complete individual from locality A1320 has been identified as Pararotalia perclara (Loeblich and Tappan) by Olsson (1976). This species has not previously been reported from the Cannonball.

Family HETEROHELICIDAE Cushman, 1927

Genus CHILOGUEMBELINA Loeblich and Tappan, 1956

Original reference.--Loeblich and Tappan, 1956, p. 340.

Type species.--Chiloguembelina midwayensis (Cushman) = Gümbelina midwayensis Cushman, 1940, p. 65 (by original designation).

Diagnosis.--Test free, flaring, inflated chambers biserially arranged, with a tendency to become somewhat twisted; sutures distinct, depressed; aperture a broad low arch bordered by produced necklike extension of chamber, commonly forming more strongly developed flap at one side so that aperture appears to be directed toward one of flat sides of test; wall finely perforate, surface smooth to hispid (adapted from Loeblich and Tappan, 1964, p. C654).

Chiloguembelina midwayensis

subcylindrica Beckmann, 1957

Plate 3, fig. 7

Chiloguembelina midwayensis (Cushman) subsp. subcylindrica Beckmann, 1957, p. 90, pl. 21, figs. 2a-b, 3.

Diagnosis.--Test large for the genus, rapidly increasing in size in the early stages, only slightly increasing in the later portion which may become almost cylindrical; chambers biserially arranged moderately inflated; sutures depressed, slightly slanting; aperture fairly large, about as broad as high, oblique to greatest breadth of test, usually with a narrow transparent collar, sometimes covered by a small end chamber; wall very finely spinose (adopted from Beckmann, 1957, p. 90).

Measurements.--Maximum length of hypotypes (13887), 0.2 mm and (13888), 0.1 mm; maximum width of hypotypes (13887), 0.1 mm and (13888), 0.05 mm.

Hypotypes.--Univ. of N. Dak. Cat. Nos. 13861 (incomplete specimen), 13887, 13888.

Occurrence.--This species was collected from NDSWC wells 3557 (A1127), 3647 (A1151) and 8102 (A1180) in the middle Cannonball from the mudstone lithofacies.

Discussion.--This species is comparable to the figures of Fox and Olsson (1969, p. 169, fig. 3) with the exception that the forms collected in this study have a smoother surface than those of Fox and Olsson. Although this subspecies has not previously been reported fro the Cannonball, this species has been reported by Fox and Olsson (1969 This species also occurs in the Paleocene of the Gulf Coast (Cushman, 1951) and Atlantic Coastal Plain (Nogan, 1964). Beckmann (1957, p. 90 reported this subspecies from the lower Eocene of Trinidad.

Family GLOBIGERINIDAE

Carpenter, Parker and Jones, 1862

Genus GLOBOCONUSA Khalilov, 1956

Original reference.--Khalilov, 1956, p. 249.

Type species.--Globoconusa conusa Khalilov, 1956, p. 249, conspecific with Globoconusa daubjergensis (Brönnimann) = Globigerina daubjergensis Brönnimann, 1953, p. 340 (by original designation).

Diagnosis.--Test small, trochospiral, similar to Globigerina, but commonly with strongly convex spiral side; chambers inflated and globular, increasing rapidly in size; aperture a small rounded umbilical opening, with one or more tiny secondary sutural openings on spiral side against early whorl; wall characteristically spinose (adapted from Loeblich and Tappan, 1964, p. C670).

Globoconusa daubjergensis (Bronnimann)

Plate 3, fig. 6

Globigerina daubjergensis Brönnimann, 1953, p. 340, pl. 1.

Globigerinoides daubjergensis (Brönnimann) Loeblich and Tappan, 1957, p. 184, pl. 40, figs. 1, 8; pl. 41, fig. 9; pl. 42, figs, 6, 7; pl. 43, fig. 1; pl. 44, figs. 7, 8.

Glogoconusa daubjergensis (Brönnimann) Loeblich and Tappan, 1964, p. C670, fig. 538 (1, 2). Fox and Olsson, 1969, p. 1398 (list), pl. 169, figs. 1, 2, 5.

Diagnosis.--Specimens are very small for the genus, outline of trochoid distinctly lobulate; spiral side pointed in initial portion; umbilicus small and shallow; final whorl, the dominant portion of the test, consists of four subglobular chambers, gradually increasing in size; sutures of final whorl strongly incised, those of early test not clearly visible; aperture extremely small, subcircular, opens into shallow umbilical depression; wall thin, finely perforate, covered by minute, irregularly distributed spines (adapted from Brönnimann, 1953, p. 340).

Measurements.--Maximum width of hypotype, 0.1 mm; maximum thickness of hypotype, 0.05 mm.

Hypotype.--Univ. of N. Dak. Cat. No. 13862.

Occurrence.--This species was collected from NDSWC wells 4388 (A1277) and 4384 (A1302) in the upper-middle Cannonball from the mudstone lithofacies.

Discussion.--The two specimens of this species are minute and difficult to work with. This species occurs in the Paleocene of the

Gulf Coast and the Atlantic Coastal Plain (Cushman, 1951; Nogan, 1964). It has been previously reported from the Cannonball by Fox and Olsson (1969).

Family GLOBOROTALIIDAE Cushman, 1927

Genus GLOBOROTALIA Cushman, 1927

Original reference.--Cushman, 1927a, p. 91.

Type species.--Globorotalia menardii (d'Orbigny) var. tumida Brady = Pulvinulina menardii d'Orbigny var. tumida Brady 1877, p. 535 (by original designation).

Diagnosis.--Test free, trochospiral, periphery carinate, chambers angular, rhomboid, or depressed to elevated; aperture interiomarginal an extraumbilical-umbilical arch bordered by lip, varying from narrow rim to broad spatulate or triangular flap; wall finely perforate, but with nonporous keel or peripheral band, surface smooth to cancellate or hispid (adapted from Loeblich and Tappan, 1964, p. C667-C668).

Remarks.--Loeblich and Tappan (1964, p. C668) indicated that the nonkeeled species that were formerly placed into the genus Globorotalia should be placed in the genus Turborotalia. However, when dealing with non-keeled forms, many workers, including Fox and Olsson (1969) and Stainforth and others (1975), have ignored this distinction and have placed nonkeeled forms into the genus Globorotalia. Recent work (Stainforth and others, 1975; Postuma, 1971) places the following species in the genus Globorotalia.

Globorotalia pseudobulloides (Plummer), 1926

Plate 3, figs. 10, 11, 12

Globigerina pseudobulloides Plummer, 1926, p. 33, pl. VIII, fig. 9.

Globorotalia pseudobulloides (Plummer) Bolli, 1957, p. 73, pl. 17, figs. 19-21.

Diagnosis.--Test low trochospiral, spiral side only slightly more compressed than umbilical side, last whorl with generally 5 spherical to ovate chambers which increase rapidly in size; periphery rounded, lobate; sutures depressed, radial on umbilical side, radial to slightly curved on spiral side; umbilicus moderately narrow but open; aperture a low arch, extraumbilical-umbilical with faint lip; wall finely perforate, in early part of test hispid to rugose, in later part almost smooth (adapted from Stainforth and others, 1975, p. 216-217).

Measurements.--Maximum diameter of hypotype (13886), 0.1 mm; maximum thickness of hypotype (13886), 0.05 mm.

Hypotypes.--Univ. of N. Dak. Cat. Nos. 13885, 13886.

Occurrence.--This species was collected from NDSWC well 4388 (A1278, A1279) in the upper-middle Cannonball from the mudstone lithofacies.

Discussion.--This form is represented by two specimens that are comparable to the descriptions and figures of Plummer (1926, p. 33, pl. VIII, fig. 9) and Stainforth and others (1975, p. 216-217, fig. 76(1)). It has been previously reported from the Cannonball by Fox and Ross (1942), Lemke (1960) and Fox and Olsson (1969).

Family CIBICIDIDAE Cushman, 1927

Genus CIBICIDES DeMontfort, 1808

Original reference.--DeMontfort, 1808, p. 122.

Type species.--Cibicides refulgens DeMontfort, 1808, p. 122 (by original designation).

Diagnosis.--Test attached; plano-convex, trochospiral, spiral side flat to excavated, evolute, umbilical side strongly convex, involute, apertural face sharply angled, distinct from umbilical side, periphery angular, with nonporous keel; aperture a low interiomarginal opening with narrow lip, may extend along spiral suture on spiral side; wall calcareous, bilamellar, coarsely perforate on spiral side, large pores of earlier chambers may be closed by lamellar thickening of wall, finely perforate on umbilical side, apertural face nonporous (adapted from Loeblich and Tappan, 1964, p. C688).

Remarks.--Genera synonymous with Cibicides include: Storilus DeMontfort (1808, p. 138), Cymbacides Costa (1839, p. 186), Truncatulina d'Orbigny (1826, p. 278, Lobatula Fleming (1828, p. 232) Soldanina Costa (1856, p. 246), ?Craterella Dons (1942, p. 136) and ?Crateriola Strand (1943, p. 211).

Cibicides sp.

Plate 3, fig. 8

Description of material.--Test trochospiral, planoconvex, umbilical side with clear test material covering narrow umbilicus; periphery subacute, lobulate; chambers moderately inflated on umbilical side, uninflated on spiral side, adult chamber highly inflated on umbilical side; sutures moderately depressed, slightly curved; aperture an interiomargin arched slit, possibly extending along spiral suture; wall coarsely perforate.

Measurements.--Maximum diameter of hypotype, 0.25 mm; maximum thickness of hypotype, 0.15 mm.

Hypotype.--Univ. of N. Dak. Cat. No. 13863.

Occurrence.--This form was collected from NDSWC wells 8102 (A1180) and 4515 (A1362) in the mudstone lithofacies. The stratigraphic placement of this form is uncertain.

Discussion.--This species is represented by three individuals. I have been unable to find a similar form in Gulf Coast or Atlantic Coastal Plain literature. Olsson (1976) did not attempt a species assignment.

?Cibicides sp.

Description of material.--Test trochospiral, plano-convex; periphery smooth, subangular; chambers uninflated; sutures flush with chamber wall; aperture indistinct; wall finely perforate.

Measurements.--Maximum diameter of hypotype, 0.1 mm; maximum thickness of hypotype, 0.05 mm.

Hypotype.--Univ. of N. Dak. Cat. No. 13864.

Occurrence.--This form was collected from NDSWC wells 4312 (A1192) and 4515 (A1362) in the upper middle Cannonball from the mudstone lithofacies.

Discussion.--This form is represented by three fragmental specimens. The generic assignment is highly uncertain because all specimens lack apertures and are highly incomplete. The overall shape of the tests cannot be determined because of the incomplete preservation of the tests.

Family CAUCASINIDAE Bykova, 1959

Genus FURSENKOINA Loeblich and Tappan, 1961

Original reference.--Loeblich and Tappan, 1961, p. 314.

Type species.--Fursenkoina squammosa (d'Orbigny) = Virgulina squammosa d'Orbigny, 1826, p. 267 (by original designation).

Diagnosis.--Test free, narrow, elongate, rounded to ovate in section; chambers inflated, greater in height than breadth, early portion in highly twisted biserial arrangement, later becoming less sigmoid and more typically biserial; sutures distinct, depressed-oblique; aperture narrow, elongate, extending up face of final chamber, lower part may be closed, leaving only suture toward base of chamber, upper part open, resulting in comma-shaped opening, tooth plate attached to closed suture of aperture, with free folded part extending through apertural opening as slight denticulated tooth, opposite end of tooth plate attached to previous apertural foramen; wall calcareous, very finely perforate (adapted from Loeblich and Tappan, 1964, p. C731).

Fursenkoina sp.

Plate 4, figs. 5, 6

Description of material.--Test biserial, plane of biserality twisted up to 90° from apex to adult chamber; chambers moderately inflated; sutures distinct, depressed; aperture a high, loop-shaped slit; wall finely perforate.

Measurements.--Length of hypotypes, 0.2 mm and 0.15 mm; maximum width of hypotypes, 0.05 mm.

Hypotype.--Univ. of N. Dak. Cat. No. 13865 (2 specimens).

Occurrence.--This species was collected from NDSWC well 8102 (A1180-A1182) in the mudstone lithofacies. The stratigraphic placement is uncertain.

Discussion.--This species is represented by four specimens all of which are well preserved. The shape and morphology of the

aperture tends to distinguish this from Chiloguembelina. This genus has not previously been reported from the Cannonball, but it does occur in the Paleocene of the Atlantic Coastal Plain (Nogan, 1964).

Genus CAUCASINA Khalilov, 1951

Original reference.--Khalilov, 1951, p. 58.

Type species.--Caucasina oligocenica Khalilov, 1951, p. 58 (by original designation).

Diagnosis.--Test free, elongate, base bluntly rounded, early portion in low discorbine coil with up to eight chambers per whorl, later whorls becoming high-spired and reduced in number of chambers to three per whorl, early chambers low, later about equal in breadth and height may be inflated, but not extremely high and elongate; sutures distinct, depressed; aperture an elongate loop at inner margin of final chamber, at right angles to sutures with narrow lip at forward margin; wall finely perforate (adapted from Loeblich and Tappan, 1964, p. C734).

Remarks.--According to Loeblich and Tappan (1961 and 1964, p. C735), the genus Aeolostreptis Loeblich and Tappan (1957, p. 227) is a junior synonym of Caucasina.

Caucasina marylandica (Nogan), 1964

Plate 3, fig. 9

Aeolostreptis marylandica Nogan, 1964, p. 31, pl. 2, figs. 16, 17.

Diagnosis.--Test minute, sides almost parallel, tapering gradually to a bluntly rounded initial end; chambers numerous in the early discorbine coil, later becoming triserial, inflated in triserial

portion; sutures depressed in triserial portion; aperture loop shaped, at base of the final chamber; wall smooth (adapted from Nogan, 1964, p. 31).

Measurements.--Length of hypotype, 0.15 mm; maximum width of hypotype, 0.07 mm.

Hypotype. Univ. of N. Dak. Cat. No. 13866.

Occurrence.--This species was collected from NDSWC wells 3558 (A1094, A1095), 3559 (A1103, A1108, A1109, A1111), 3433 (A1117), 3557 (A1126-A1128), 3647 (A1129, A1132-A1135, A1139-A1142, A1145, A1150, A1150, A1152), 4486 (A1165), 8102 (A1176-A1181), 4312 (A1183-A1196, A1198-A1200, A1250, A1252, A1254-A1257), 8347 (A1268, A1269, A1272), 4388 (A1277-A1284, A1287-A1289), 4384 (A1301-A1304), 1988 (A1316), 4511 (A1322-A1325, A1329, A1342), 4513 (A1349, A1350, A1353-A1356) and 4751 (A1361, A1362, A1364, A1371, A1377, A1382, A1390, A1391). Stratigraphically, it occurs in the upper part of the lower Cannonball to the lower part of the upper Cannonball in the mudstone and sandstone lithofacies.

Discussion.--This species is represented by 743 individuals, most of which are well preserved. It agrees favorably with the description and illustrations of Caucasina marylandica (=Aeolostreptis marylandica) of Nogan (1964, p. 31, pl. 2, figs. 16, 17). This species is the most abundant and most cosmopolitan (it occurs in 91 samples) species in the Cannonball. It has not been previously reported from the Cannonball. Elsewhere, it occurs in the Paleocene of the Atlantic Coastal Plain.

Family NONIONIDAE Schulze, 1854

Genus ALLOMORPHINA Reuss, 1849

Original reference.--Reuss in Czjzek, 1849, p. 50.

Type species.--Allomorphina trigona Reuss, 1850, p. 38 (subsequent designation of Reuss, 1850, p. 38, monotypic).

Diagnosis.--Test trochospiral, commonly three chambers to whorl, involute, only final whorl visible externally; aperture an elongate slit, paralleling suture and bordered with slight lip; wall perforate (adapted from Loeblich and Tappan, 1964, p. C743).

Allomorphina paleocenica Cushman, 1948

Plate 4, fig. 1

Allomorphina paleocenica Cushman, 1948, p. 45, pl. 8, fig. 10.

Diagnosis.--Test semi-elliptical in outline, trochoid, one side nearly straight, the other strongly curved, periphery broadly rounded; chambers distinct, slightly inflated, three in a whorl in the adult, increasing very rapidly in size as added; sutures distinct, slightly depressed; aperture an elongate opening on the ventral side at the base of the last-formed chamber with a distinct, overhanging lip; wall smooth (adapted from Cushman, 1948, p. 45).

Measurements.--Maximum diameter of hypotype, 0.4 mm; minimum diameter of hypotype, 0.3 mm; maximum thickness of hypotype, 0.2 mm.

Hypotype.--Univ. of N. Dak. Cat. No. 13874.

Occurrence.--This species was collected from NDSWC well 3558 (A1099) in the lower part of the Cannonball from the mudstone lithofacies.

Discussion.--This species is represented by a single internal mold. It compares favorably with the descriptions of Cushman (1948)

and the figures of Cushman and Todd (1949, pl. 11, fig. 16). I (Fenner, 1974) reported Allomorphina sp. from the Cannonball. This form is probably A. paleocenica.

Genus NONION DeMontfort, 1808

Original reference.--DeMontfort, 1808, p. 210.

Type species.--Nonion incrassatus (Fichtel and Moll) = Nautilus incrassatus Fichtel and Moll, 1798, p. 38 (by original designation).

Diagnosis.--Test free, planispiral and involute, slightly compressed, biumbonate, periphery rounded, peripheral outline lobulate; chambers numerous, increasing gradually in size as added; sutures distinct, depressed, radial, slightly curved; aperture an arched equatorial, interiomarginal slit; wall finely perforate, surface smooth, umbonal region filled with secondarily deposited calcite, either as granules or solid boss (adapted from Loeblich and Tappan, 1964, p. C746).

Nonion graniferum (Terquem), 1882

Plate 4, fig. 2

Nonionina granifera Terquem, 1882, p. 42, figs. 8a-b.

Nonion graniferum (Terquem) Cushman 1939, p. 4, pl. 1, figs. 9-11.

Nonion mauricensis Howe and Ellis in Howe, 1939, p. 57, pl. 8, figs. 1, 2. Olsson, 1960, p. 26, pl. 4, figs. 2, 3. Nogan, 1964, p. 29, pl. 2, figs. 4-5.

Nonion cf. graniferum (Terquem) Brotzen, 1948, p. 69, pl. 8, fig. 1.

Nonion graniferum (Terquem) Pozaryska, 1965, p. 93, pl. 21, figs. 5a-b. Posaryska and Szczechura, 1968, p. 81, pl. 9, figs. 10-12.

Hansen, 1970, p. 97; fig. 34; pl. 11, figs. 1-2; pl. 26, figs. 1-2. Berggren and Aubert, 1975, p. 147.

Diagnosis.--Test with umbilical region somewhat exposed in the last-formed coil and covered with fine papillae of uniform size; periphery occasionally spinose; chambers distinct, about eight in the final coil, inflated, of uniform shape; sutures deep; aperture a low opening at the base of the inner margin of the apertural face; wall smooth except for the papillate umbilical region (adapted from Cushman, 1939, p. 4).

Measurements.--Maximum diameter of hypotypes, 0.15-0.2 mm; maximum thickness of hypotypes, 0.05-0.07 mm.

Hypotypes.--Univ. of N. Dak. Cat. Nos. 13867-13869.

Occurrence.--This species was collected from NDSWC wells 3647 (A1154), 4486 (A1163-A1165), 4453 (A1258) and 4388 (A1293) in the middle, possibly extending from the upper lower Cannonball to the lower upper Cannonball in the mudstone lithofacies.

Discussion.--This form agrees favorably with the illustrations and description of Cushman (1939, p. 4, pl. 1, figs. 9-11). Neither this species nor this genus have previously been reported from the Cannonball. Elsewhere, this species occurs in the Paleocene of the Gulf Coast and Atlantic Coastal Plain as well as the Paleocene of Greenland, and western and eastern Europe. The Cannonball material consists of eight specimens, all generally well preserved.

Genus NONIONELLA Cushman, 1926

Original reference.--Cushman, 1926, p. 64.

Type species.--Nonionella miocenica Cushman, 1926, p. 64 (by original designation).

Diagnosis.--Test free, trochospiral, slightly compressed, periphery rounded, spiral side partially evolute with umbonal boss, opposite side involute with final chamber overhanging umbilical region and may appear to form distinct umbilical flap; chambers relatively numerous, broad, low; aperture interiomarginal, a low arch near periphery extending somewhat onto umbilical side; wall perforate (adapted from Loeblich and Tappan, 1964, p. C748).

Nonionella robusta Plummer, 1931

Plate 4, fig. 3

Nonionella robusta Plummer, 1931, p. 175, pl. 14, fig. 12.

Diagnosis.--Test very small for genus, about equally biconvex but unsymmetrical, periphery narrowly rounded and bluntly angular in maturity, only slightly lobate in later portion of some tests but an even curve on most tests; chambers about eight in final whorl, abruptly lengthening, gently inflated on most specimens; sutures slightly depressed or flush with the contour of the test, somewhat curved; umbilicus on dorsal side, small, narrow, depressed, shallow, showing minute chambers of inner whorl; on ventral side umbilical depression filled with the successive, short extensions of the chambers filling the depression irregularly; aperture a low slit on the periphery at base of final chamber; wall distinctly but not coarsely punctate (adapted from Plummer, 1931, p. 175).

Measurements.--Maximum diameter of hypotype, 0.25 mm, minimum diameter of hypotype, 0.15 mm; maximum thickness of hypotype, 0.05 mm.

Hypotype.--Univ. of N. Dak. Cat. No. 13870.

Occurrence.--This species was collected from NDSWC wells 3647 (A1145, A1152), 4486 (A1163, A1165), 4397 (A1168, A1169), 8102 (A1180),

4384 (A1303), 1984 (A1312), 4511 (A1356) and 4760 (A1379) in the middle Cannonball from the mudstone lithofacies.

Discussion.--All but one of the 14 specimens of this are badly crushed or incomplete. The Cannonball forms appear to be the same as those of Nonionella robusta described and illustrated by Plummer (1931, p. 175, pl. 14, fig. 12). Nonionella cf. robusta was reported from the Cannonball by Fox and Ross (1942).

Genus PULLENIA Parker and Jones, 1862

Original reference.--Parker and Jones in Carpenter, Parker and Jones, 1862, p. 184.

Type species.--Pullenia bulloides (d'Orbigny) = Nonionina bulloides d'Orbigny, 1826, p. 107 = Nonionina sphaeroides d'Orbigny, 1826, p. 293 (original designation (monotopic)).

Diagnosis.--Test free, spheroidal to compressed, planispiral and involute; chambers few, three to six in final whorl; sutures radial; aperture a narrow crescentic interiomarginal slit extending nearly from umbilicus to umbilicus, wall finely perforate (adapted from Loeblich and Tappan, 1964, p. C748).

Pullenia quinqueloba (Reuss), 1851

Plate 4, fig. 4

Nonionina quinqueloba Reuss, 1851, p. 47, pl. 5, fig. 31.

Pullenia quinqueloba (Reuss) Brady, 1884, p. 617, pl. 84, figs. 14, 15. Cushman, 1951, p. 59, pl. 17, fig. 6.

Diagnosis.--Test closely coiled, completely embracing, bilaterally symmetrical; peripheral margin broadly rounded; chambers five in last whorl; sutures faintly depressed between last two chambers (adapted from Plummer, 1926, p. 137).

Measurements.--Maximum diameter of hypotype, 0.27 mm; maximum width of hypotype, 0.15 mm.

Hypotype.--Univ. of N. Dak. Cat. No. 13871.

Occurrence.--This species was collected from NDSWC well 8102 (A1175) in the mudstone lithofacies. The stratigraphic placement is uncertain.

Discussion.--This species is represented by a single, broken specimen. It agrees with Plummer's description (1926, p. 136-137) and with the figures of Cushman (1951, pl. 17, fig. 6). This species has been reported from the Paleocene of the Gulf Coast (Cushman, 1951) and Atlantic Coastal Plain (Nogan, 1964), but has not been reported previously from the Cannonball.

Family ALABAMINIDAE Hofker, 1951

Genus ALABAMINA Toulmin, 1941

Original reference.--Toulmin, 1941, p. 602.

Type species.--Alabamina wilcoxensis Toulmin, 1941, p. 602 (by original designation).

Diagnosis.--Test free, lenticular, trochospiral, periphery subangular, with nonporous margin, all chambers visible on spiral side where curved sutures are strongly oblique, only final whorl visible on opposite side where sutures are nearly radial around umbilical depression, chambers somewhat prolonged into projection at periphery on spiral side, apertural face sharply infolded below this projection; aperture an interiomarginal slit extending from near periphery almost to umbilicus with narrow bordering lip; wall finely perforate with simple monolamellar septa (adapted from Loeblich and Tappan, 1964, p. C748-C750).

Alabamina midwayensis Brotzen, 1948

Plate 4, figs. 7, 8

Pulvinulina exigua Brady, 1884, p. 696, pl. 103, figs. 13, 14. Plummer, 1926, p. 150-151, pl. XI, figs. 3a-c.

Pulvinulina exigua Brady var. obtusa Burrows and Holland, 1897, p. 49, pl. 2, fig. 25. Plummer, 1926, p. 151-152, pl. XI, figs. 2a-c.

Pulvinulinella exigua (Brady) var. obtusa (Burrows and Holland) Cushman and Ponton, 1933, p. 71, pl. 9, fig. 9.

Pulvinulinella obtusa (Burrows and Holland) Cushman and Garrett, 1939, p. 87, pl. 15, figs. 12, 13.

Alabamina midwayensis Brotzen, 1948, p. 99, pl. 16, figs. 1a-c, 2a-c; test figs. 25a-b, 26a-b. Berggren and Aubert, 1975, p. 147, pl. II, fig. 14; pl. X, fig. 2; pl. XII, fig. 2; text fig. 13.

Diagnosis.--Test more or less equally biconvex, peripheral margin bluntly acute, very faintly lobate, 5-6 chambers in the last whorl; sutures transparent, not depressed, almost straight and tangential to the spiral suture on the spiral side; small central filling may be present on the umbilical side; aperture narrow; wall smooth, mostly glossy (adapted from Brotzen, 1948, p. 99).

Measurements.--Maximum diameter of hypotypes, 0.4 and 0.25 mm; maximum thickness of hypotypes, 0.15 and 0.1 mm.

Hypotype.--Univ. of N. Dak. Cat. Nos. 13875 (2 specimens), 13885.

Occurrence.--This species was collected from NDSWC wells 3559 (A1108, A1109), 3433 (A1115, A1116, A1118-A1120), 4397 (A1174), 4312 (A1188-A1190, A1192-A1194, A1198, A1199, A1253, A1254, A1256), 8347 (A1269), 4388 (A1278-A1280, A1284, A1289), 4384 (A1300, A1303, A1304), 4511 (A1322, A1328) and 4513 (A1355-A1357) in the middle Cannonball

from the mudstone lithofacies.

Discussion.--This species appears almost identical to the illustrations of Alabamina midwayensis of Brotzen (1948), Kellough (1965), and Berggren and Aubert (1975). Fox and Ross (1942) reported Alabamina exigua from the Cannonball. It is likely that this form would now be recognized as Alabamina midwayensis. This species occurs in both the Gulf Coast Paleocene and the Atlantic Coastal Plain Paleocene. Elsewhere, it occurs in eastern and western Europe, North Africa, Turkmenia and southwest New Zealand (Berggren and Aubert, 1975).

Genus GYROIDINOIDES Brotzen, 1942

Original reference.--Brotzen, 1942, p. 19.

Type species.--Gyroidinoides nitida (Reuss) = Rotalina nitida Reuss, 1844, p. 214 (by original designation).

Diagnosis.--Test free, trochospiral, spiral side flattened, umbilical side elevated, periphery rounded; chambers rhomboidal in section; sutures radial to curved, flush to depressed; aperture a continuous, low, interiomarginal slit extending from periphery to umbilucus; umbilical portion partially obscured by umbilical flap from each chamber; wall perforate, bilamellar (adapted from Loeblich and Tappan, 1964, p. C753).

Gyroidinoides aequilateralis (Plummer), 1926

Plate 4, figs. 10, 11

Rotalia aequilateralis Plummer, 1926, p. 155, pl. XII, fig. 3.

Gyroidina aequilateralis (Plummer) Cushman, 1944, p. 45, pl. 7, fig. 24.

Gyroidinoides aequilateralis (Plummer) Kellough, 1965, p. 118, pl. 13, fig. 2.

Diagnosis.--Test almost equally biconvex, composed of about two and one-half convolutions that increase very slowly in width; peripheral margin narrowly rounded, faintly lobate in the last-formed portion of the test; chambers compact, numerous, about 10 in final whorl; dorsal sutures distinct, narrow, tapering bands without elevation, strongly curved with a slight angulation, but not oblique, depressed gently between last two or three chambers only; ventral sutures elevated most markedly around the small umbilicus and tapering radially toward the margin; aperture a very narrow slit at base of septal face and bearing a very narrow extended lip; wall finely punctate (adapted from Plummer, 1926, p. 155-156).

Measurements.--

Hypotype	Maximum Length	Maximum Width
13876	0.2 mm	0.07 mm
13877	0.15 mm	0.05 mm
13878	0.3 mm	0.10 mm

Hypotypes.--Univ. of N. Dak. Cat. Nos. 13876, 13877, 13878.

Occurrence--This species was collected from NDSWC wells 3433 (A1117), 4397 (A1173), 8102 (A1177, A1182), 4312 (A1189, A1190, A1195, A1254, A1255), 8347 (A1268, A1269), 4388 (A1278, A1279, A1284), 4384 (A1301, A1392, A1304), 1984 (A1314, A1315), 4511 (A1322, A1328), 4513 (A1356), 4764 (A1382), and 4731 (A1391) in the middle Cannonball from predominantly the mudstone lithofacies.

Discussion.--This species is the same as Gyroidinoides aequilateralis (Plummer) as illustrated by Kellough (1965).

Gyoidinoides aequilateralis was previously reported (as Gyroidina aequilateralis) from the Cannonball by Fox and Ross (1942) and Lemke (1960).

Gyroidinoides sp.

Plate 4, fig. 12

Description of material.--Text minute, trochospiral, planoconvex, periphery gently rounded, spiral side with low spire, umbilical side with narrow, shallow umbilicus; chambers uninflated; sutures indistinct on spiral side, radial on umbilical side, flush with surface; aperture indistinct.

Measurements.--Maximum diameter of hypotype, 0.2 mm; maximum width of hypotype, 0.5 mm.

Hypotype.--Univ. of N. Dak. Cat. No. 13879.

Occurrence.--This form was collected from NDSWC wells 3647 (A1155), 4486 (A1163), 4397 (A1173), 4312 (A1187, A1194), 4388 (A1278), and 1984 (A1311) in the middle and upper middle Cannonball from the mudstone lithofacies.

Discussion.--This form is represented by eight fragmental, poorly preserved specimens. It differs from Gyroidinoides aequilateralis in being more compressed and having a less highly inflated adult chamber. The spiral side has a lower spire and the spiral suture is much less distinct. Also, the final volution appears to have fewer chambers.

Family ANOMALINIDAE Cushman, 1927

Genus ANOMALINOIDES Brotzen, 1942

Original reference.--Brotzen, 1942, p. 23.

Type species.--Anomalinoides plummerae Brotzen, 1942, p. 23 (=Anomalina pinguis Jennings, 1936, p. 195) (by original designation).

Diagnosis.--Test free, nearly planispiral, but asymmetrical, periphery broadly rounded, spiral side partially evolute with umbonal boss, opposite side involute and umbilicate; aperture a low interiomarginal equatorial slit with narrow bordering lip, extending along spiral suture on evolute side under umbilical margin of later chambers; wall coarsely perforate (adapted from Loeblich and Tappan, 1964, p. C775).

Anomalinoides midwayensis (Plummer), 1926

Plate 4, fig. 9

Truncatulina midwayensis Plummer, 1926, p. 141, pl. IX, fig. 7; pl. XV, fig. 3.

Anomalina midwayensis (Plummer) Cushman, 1940, p. 73, pl. 12, fig. 18. Vasilenko and Myatliuk, 1947, p. 211-212, pl. 3, fig. 7. Cushman, 1951, p. 62, pl. 17, figs. 17-19. Harris and Jobe, 1951, p. 52, pl. 10, figs. 4-5. Kellough, 1959, fig. 6.

?Anomalina (pseudo-valvulineria) midwayensis (Plummer) Vasilenko, 1954, p. 100, pl. 13, fig. 4.

Anomalinoides midwayensis (Plummer) Brotzen, 1948, p. 88, pl. 14, fig. 3. Kellough, 1965, p. 117, pl. 15, fig. 7. Berggren and Aubert, 1975, p. 149-150, pl. VI, figs. 1a-f; pl. IX, fig. 3; pl. X, fig. 8, pl. XI, fig. 3; pl. XII, fig. 3; pl. XVI, fig. 2.

Diagnosis.--Test almost equally biconvex, moderately compressed; whorls about two the final one being strongly embracing; chambers usually nine in final whorl, gradually increasing, moderately curving; sutures

broadly elevated on both sides, tapering toward the margin and curved; aperture a slit at base of septal face under a narrow lip that extends to the umbilicus (adapted from Plummer, 1926, p. 141).

Measurements.--Maximum diameter of hypotype (13880), 0.3 mm and (13881) 0.1 mm; maximum thickness of hypotype (13880), 0.15 mm and (13881) 0.05 mm.

Hypotypes.--Univ. of N. Dak. Cat. Nos. 13880, 13881.

Occurrence.--This species was collected from NDSWC wells 3560 (A1083), 3558 (A1094, A1095), 3559 (A1106, A1110), 3433 (A1115), 3557 (A1126-A1128), 3647 (A1133, A1135, A1137-A1139, A1144, A1146, A1148), 2690 (A1157), 8103 (A1159), 4486 (A1163), 4397 (A1172), 4312 (A1193, A1194, A1198, A1199, A1253, A1254, A1256), 8347 (A1271), 4388 (A1287, A1288, A1290), 1984 (A1313, A1314), 2006 (A1318), 4511 (A1324, A1327), 4513 (A1357, A1359), 4515 (A1361), 4516 (A1370), and 4751 (A1390, A1391) in the lower middle to upper middle Cannonball from the mudstone and sandstone lithofacies.

Discussion.--This species agrees with the illustrations of Anomalinoides midwayensis (Plummer) of Berggren and Aubert (1975). Seventy-three generally well-preserved individuals were collected in this study. Lemke (1960) reported both Anomalina midwayensis and Anonalinoides midwayensis from the Cannonball. The synonymy indicates that these are the same species. The reason for his distinction is uncertain. According to Berggren and Aubert (1975, p. 150), this is a common species in the Paleocene of the Gulf Coast and the Paleocene of northern Europe. It also has been reported from the Paleocene of Libya and Mozambique.

Anomalinoides umboniferus (Schwager) 1883

Plate 5, figs. 1, 2

Discorbis umbonifera Schwager, 1883, p. 126, pl. 27, fig. 14.

Anomalina umbonifera (Schwager) Cushman and Potton, 1932, p. 72, pl. 9, fig. 9. Cushman, 1951, p. 72, pl. 17, fig. 16.

Anomalinoides umboniferus (Schwager) Nogan, 1964, p. 42, pl. 6, figs. 16-21; pl. 7, figs. 1-3. Kellough, 1965, p. 117.

Diagnosis.--Test strongly compressed, ventral side completely involute, dorsal side slightly evolute, periphery slightly rounded; chambers distinct, slightly inflated, 7 or 8 chambers making up the adult whorl, increasing gradually and rather uniformly in size as added; sutures distinct, slightly limbate, gently curved; aperture at the base of the last-formed chamber, near the periphery; wall smooth, finely perforate (adapted from Cushman, 1951, p. 62).

Measurements.--Maximum diameter of hypotypes, 0.3 mm, 0.15 mm, 0.2 mm; maximum thickness of hypotypes, 0.2 mm; 0.05 mm, 0.1 mm.

Hypotype.--Univ. of N. Dak. Cat. No. 13882.

Occurrence.--This species was collected from NDSWC wells 3558 (A1083, A1100, A1119), 3433 (A1120, A1123), 3557 (A1125, A1127), 3647 (aa33-A2236, A1142, A1143, A1146, A1147), 8103 (A1161), 4486 (A1164), 4397 (A1172), 8102 (A1175-A1181), 4312 (A1192), 4388 (A1281, A1290), 1984 (A1313, A1314), 4511 (A1325-A1327, A1333, A1338, A1341), 4513 (A1347-A1349, A1352-A1354, A1357, A1358, A1360), 4515 (A1361-A1363), 4516 (A1370, A1372), 4764 (A1383, A1384), and 4751 (A1390, A1391) and NDGS well no. 16 (A1399, A1400) in the lower-middle to the upper Cannonball predominantly from the mudstone lithofacies.

Discussion.--This species is represented by 170 mostly well-preserved specimens that soow the range of morphologic variation of Anomalinoides umboniferous discussed and illustrated by Nogan (1964, p. 42, pl. 6, figs. 16-21; pl. 7, figs. 1-3). This species has not been previously reported from the Cannonball; however, in view of the biometric study of Anomalinoides umboniferus conducted on specimens from the Aquia Formation by Nogan (1964, p. 42-46), it appears that those specimens identified as Valvulineria wilcoxensis by Fenner (1974) are Anomalinoides umboniferus. Nogan indicated that variants of this species from the Aquia were previously misidentified as Valvulineria wilcoxensis. With the number of specimens available in this study it is possible to see the range of variation, including intermediate types, that characterizes this species in the Aquia Formation.

Anomalinoides sp.

Plate 5, fig. 3

Description of material.--Test planoconvex, trochospiral, dorsal side convex with no umbilicus, ventral side planar; periphery lobate, gently rounded; chambers inflated with adult chamber comprising about one-fourth of the test; sutures distinct, depressed; aperture interiomarginal, extending along the spiral suture at base of adult chamber, flaps extend over chamber from base of each chamber; wall finely perforate.

Measurements.--Maximum diameter of hypotype, 0.3 mm; maximum thickness of hypotype, 0.15 mm.

Hypotype.--Univ. of N. Dak. Cat. No. 13883.

Discussion.--This form is represented by two well-preserved specimens that look very similar to what Cushman and Renz (1942, p. 13, pl. 3, fig. 8) called Anomalina sp. According to them, this form is rather variable but is not the same as species already described from the Midway. The Cannonball form has triangular flaps extending from the bases of the chambers along the spiral suture. Cushman and Renz's illustration does not show this feature distinctly; however, in other respects, these forms appear very similar.

Genus CIBICIDOIDES Thalmann, 1939

Original reference.--Thalmann, 1939, p. 448.

Type species.--Cibicidoides muddula (Brady, Parker and Jones) = Truncatulina mundula Brady, Parker and Jones, 1888, p. 228 (by original designation).

Diagnosis.--Test free, trochospiral, biconvex and biumbonate, all chambers visible on spiral side, only those of final whorl visible on umbilical side; aperture a low interiomarginal equatorial arch with slight projecting lip; wall hyaline with series of corase perforations on spiral side, appearing only near previous spiral suture in early portion of test but covering large portion of spiral side of later chambers (adapted from Loeblich and Tappan, 1964, p. C757).

Cibicidoides alleni (Plummer), 1926

Plate 5, figs. 4, 5, 6

Truncatulina alleni Plummer, 1926, p. 144-145, pl. X, figs. 4a-c.

Cibicides alleni (Plummer) Plummer, 1933, p. 54, 61 (lists). Cushman, 1940, p. 73, pl. 12, fig. 19. Fox and Ross, 1942, p. 669, fig. 3 (list). Kline, 1943, p. 61, pl. 6, figs. 21-22. Cooper, 1944,

p. 354, pl. 54, figs. 24, 25. Cushman, 1951, p. 66, pl. 18, figs. 16, 17. Bertels, 1964, p. 174-175, pl. 7, fig. 3. Kellough, 1959, fig. 6. Lemke, 1960, p. 30 (list). Kellough, 1965, p. 120, pl. 15, fig. 3. Mailhe and others, 1967, p. 28, pl. 3, fig. 1. Masiuk, 1967, p. 232, pl. 3, fig. 5. Malumian, 1970, p. 359, pl. 2, fig. 7.

Cibicidoides alleni (Plummer) Berggren and Aubert, 1975, p. 151, pl. V, figs. 1a-d; pl. VII, figs. 1a-3d; pl. IX, fig. 5; pl. X, fig. 1; pl. XI, fig. 2; pl. XII, fig. 11; pl. XVIII, fig. 1; pl. XIX, fig. 5 (see for complete synonymy).

Diagnosis.--Test almost equally biconvex, ventral side of most specimens being more rounded; periphery subacute and bordered by band of clear shell material, faintly lobate in latest development; chambers 10-11 in last whorl, previous whorls concealed by strong elevations of shell matter that follow base of chambers on dorsal face; sutures limbate, on dorsal side marked by conspicuous elevations of transparent shell matter that taper and curve gently toward periphery; sutures on ventral face slightly elevated and curving outward from large, smooth umbilical boss; aperture large arched opening over periphery and extending farther downward on ventral side; wall coarsely punctate (adapted from Plummer, 1926, p. 144-145).

Measurements.--Maximum diameter of hypotype, 0.25 mm; maximum width of hypotype, 0.05 mm.

Hypotype.--Univ. of N. Dak. Cat. No. 13872.

Occurrence.--This species was collected from NDSWC wells 3557 (A1128), 3647 (A1143-A1145), 8102 (A1175-A1181), 8347 (A1271), 4388 (A1285, A1289, A1291), 4384 (A1301, A1304), 4511 (A1339), 4513 (A1349, A1350, A1357), 4515 (A1361-A1363), 4760 (A1380), and 4751 (A1388-A1391)

in the middle Cannonball predominantly from the mudstone lithofacies.

Discussion.--This species is represented by 68 well-preserved specimens. They are the same as the specimens of Cibicides alleni illustrated by Cushman (1951, p. 66, pl. 18, figs. 16, 17) and the specimens of Cibicidoides alleni illustrated by Berggren and Aubert (1975). This species has been previously reported from the Cannonball by Fox and Ross (1942) and Lemke (1960). Several other species of Cibicides and Cibicidoides have been combined into Cibicidoides alleni by Berggren and Aubert (1975, p. 151-153) (not included in my synonymy). They include: Cibicides mortoni (Reuss), Cibicides praecursorius Schwager, Cibicides hilgardi Garrett, Cibicides proprius Brotzen, Cibicides cedarstromi McLean, ?Cibicides breslesensis Rouvillois, ?Cibicidoides hilgardi (Garrett), ?Cibicidoides proprius (Brotzen). They indicated that all of these species recorded from different areas are probably one species (C. alleni) with a relatively high degree of variability.

?Cibicidoides vulgaris (Plummer), 1926

Plate 5, fig. 7

Truncatulina vulgaris Plummer, 1926, p. 145, pl. 10, fig. 3.

Cibicides vulgaris (Plummer) Cushman, 1940, p. 12, fig. 21.

Cibicidoides vulgaris (Plummer) Berggren and Aubert, 1975, p. 154-155, pl. IV, figs. a-k; pl. IX, fig. 6; pl. XI, fig. 6; pl. XII, fig. 1.

Diagnosis.--Test almost equally biconvex, ventral face slightly more elevated; peripheral margin broadly rounded, commonly somewhat lobate; chambers 7-9 in last whorl, last two or three distinctly turgid;

sutures marked by strong elevations of clear shell material curving gently toward periphery from very high ridge of irregular shell matter that follows inner edge of whorl and produces well-developed spiral on both faces; aperture a long, arched slit extending from periphery toward umbilicus under a narrow lip; wall coarsely punctate (adapted from Plummer, 1926, p. 145).

Measurements.--Maximum diameter of hypotype, 0.4 mm; maximum width of hypotype, 0.25 mm.

Hypotype.--Univ. of N. Dak. Cat. No. 13873.

Occurrence.--This species was collected from NDSWC wells 3647 (A1141-A1143), 4388 (A1287), and 4511 (A1328) in the middle or upper-middle Cannonball from the mudstone lithofacies.

Discussion.--This species is represented by six fragments. Olsson (1976) thought the most complete fragment could possibly be a fragment of Cibicidoides vulgaris. The coarsely punctate wall and overall massiveness of the test is reminiscent of Cibicidoides vulgaris. It has, therefore, been questionably placed into this species.

Family CERATOBULIMINIDAE Cushman, 1927

Genus CERATOBULIMINA Toula, 1915

Original reference.--Toula, 1915, p. 654.

Type species.--Ceratobulimina contraria (Reuss) = Rotalina contraria Reuss, 1851, p. 76 (by original designation (monotypic)).

Diagnosis.--Test trochospiral, deeply umbilicate, chambers enlarging abruptly, whorls few, coiling dextral; aperture umbilical, consisting of elongate slit extending in groove up face of final chamber on umbilical side; internally incomplete, marginally serrate

partition attached to posterior side of vertical apertural slit at interior of umbilical side, bends around aperture and extends across and is attached to spiral wall for short distance; wall laminated, polished (adapted from Loeblich and Tappan, 1964, p. C766).

Ceratobulimina perplexa (Plummer), 1926

Plate 5, figs. 8, 9

Rotalia perplexa Plummer, 1926, p. 156, pl. 12, fig. 2.

Ceratobulimina perplexa (Plummer) Cushman and Harris, 1927, p. 173, pl. 29, fig. 2. Kellough, 1965, p. 118, pl. 14, figs. 8, 9.

Diagnosis.--Test oval, about equally biconvex, considerably compressed; peripheral margin broadly rounded, somewhat lobate; chambers gently curving, 6 to the final whorl; dorsal sutures marked by thick, smooth or very slightly elevated, tapering bands that become distinctly angular at their broadest points; ventral sutures depressed radiate from a sunken umbilicus; aperture a conspicuous round opening at the base of the septal face and protected by an arched flap that is directed into the umbilicus; wall smooth, glistening, finely punctate (adapted from Plummer, 1926, p. 156-157).

Measurements.--Maximum diameter of hypotype, 0.35 mm; maximum width of hypotype, 0.15 mm.

Hypotype.--Univ. of N. Dak. Cat. No. 13884.

Occurrence.--This species was collected from NDSWC wells 3558 (A1090), 3557 (A1128), 3647 (A1132, A1133, A1135, A1140, A1142), 8103 (A1160), 8102 (A1175-A1179, A1181), 4388 (A1289), 4513 (A1347, A1349, A1357), 4515 (A1362), and 4751 (A1388, A1389, A1391) in the middle Cannonball predominantly from the mudstone lithofacies.

Discussion.--This species is represented by 45 well-preserved specimens that are identical with Plummer's (1926, pl. 12, fig. 2) and Nogan's (1964, pl. 3, figs. 12, 13) figures. Within the Cannonball, this species shows little morphologic variation. Since figures of other workers are identical with the Cannonball material, it seems that the variation within the species is slight. This species was previously reported from the Cannonball by Fox and Ross (1942), Lemke (1960), and Fenner (1974).

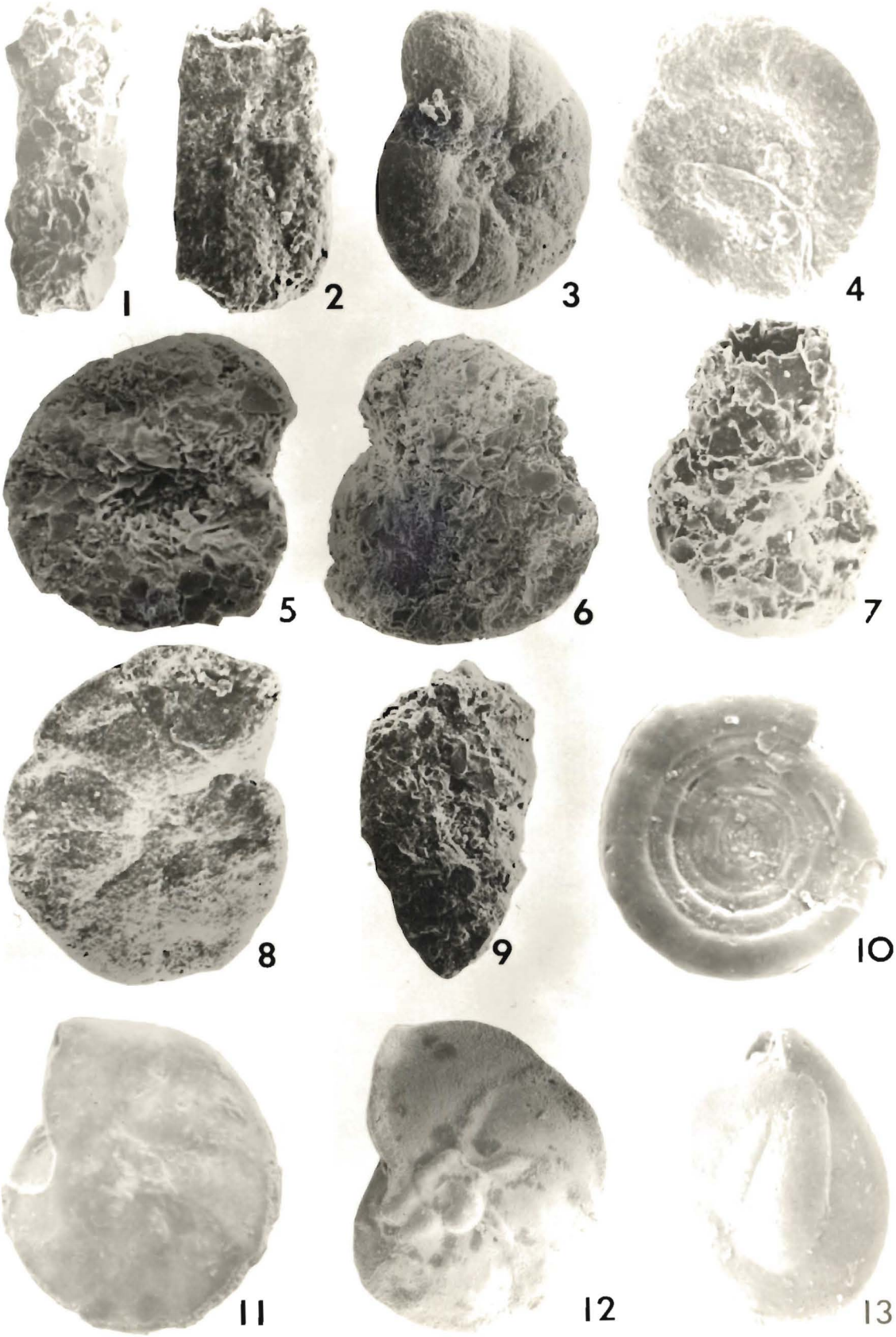
PLATES

Accession numbers correspond to those in Appendix C.

Explanation of Plate 1

Figure

1. Reophax sp., X160, side view. Accession number A1272, Univ. of N. Dak. Cat. No. 13814.
2. ?Reophax sp., X190, side view. Accession number A1091, Univ. of N. Dak. Cat. No. 13816.
3. Haplophragmoides sp. B, X260, oblique view. Accession number A1110, Univ. of N. Dak. Cat. No. 13819.
4. Ammodiscus incertus Brady, X270, side view. Accession number A1111, Univ. of N. Dak. Cat. No. 13812.
5. Trochammina sp., X150, ventral view. Accession number A1261, Univ. of N. Dak. Cat. No. 13824.
6. Trochammina sp., X130, dorsal view. Accession number A1261, Univ. of N. Dak. Cat. No. 13824.
7. Ammobaculites expansus Plummer, X170, side view. Accession number A1264, Univ. of N. Dak. Cat. No. 13820.
8. Haplophragmoides sp. A, X430, side view. Accession number A111 Univ. of N. Dak. Cat. No. 13818.
9. Spiroplectammina wilcoxensis Cushman and Ponton, X130, side vie Accession number A1284, Univ. of N. Dak. Cat. No. 13823.
10. Cyclogyra involvens (Reuss), X250, side view. Accession number A1152, Univ. of N. Dak. Cat. No. 13825.
11. Lenticulina midwayensis (Plummer), X90, side view. Accession number A1193, Univ. of N. Dak. Cat. No. 13839.
12. Lenticulina arkansasana (Cushm an and Todd), X60, side view. Accession number A1358, Univ. of N. Dak. Cat. No. 13838.
13. Quinqueloculina plummerae Cushman and Todd, X280, side view. Accession number A1150, Univ. of N. Dak. Cat. No. 13826.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13. Globulina gibba (d'Orbigny), X150, side view. Accession number A1175, Univ. of N. Dak. Cat. No. 13845.

14. Globulina sp. B, X260, side view. Accession number A1321, Univ. of N. Dak. Cat. No. 13847.

15. Lingulina sp., X230, side view. Accession number A1353, Univ. of N. Dak. Cat. No. 13844.

16. Bulimina sp., X90, side view. Accession number A1194, Univ. of N. Dak. Cat. No. 13855.

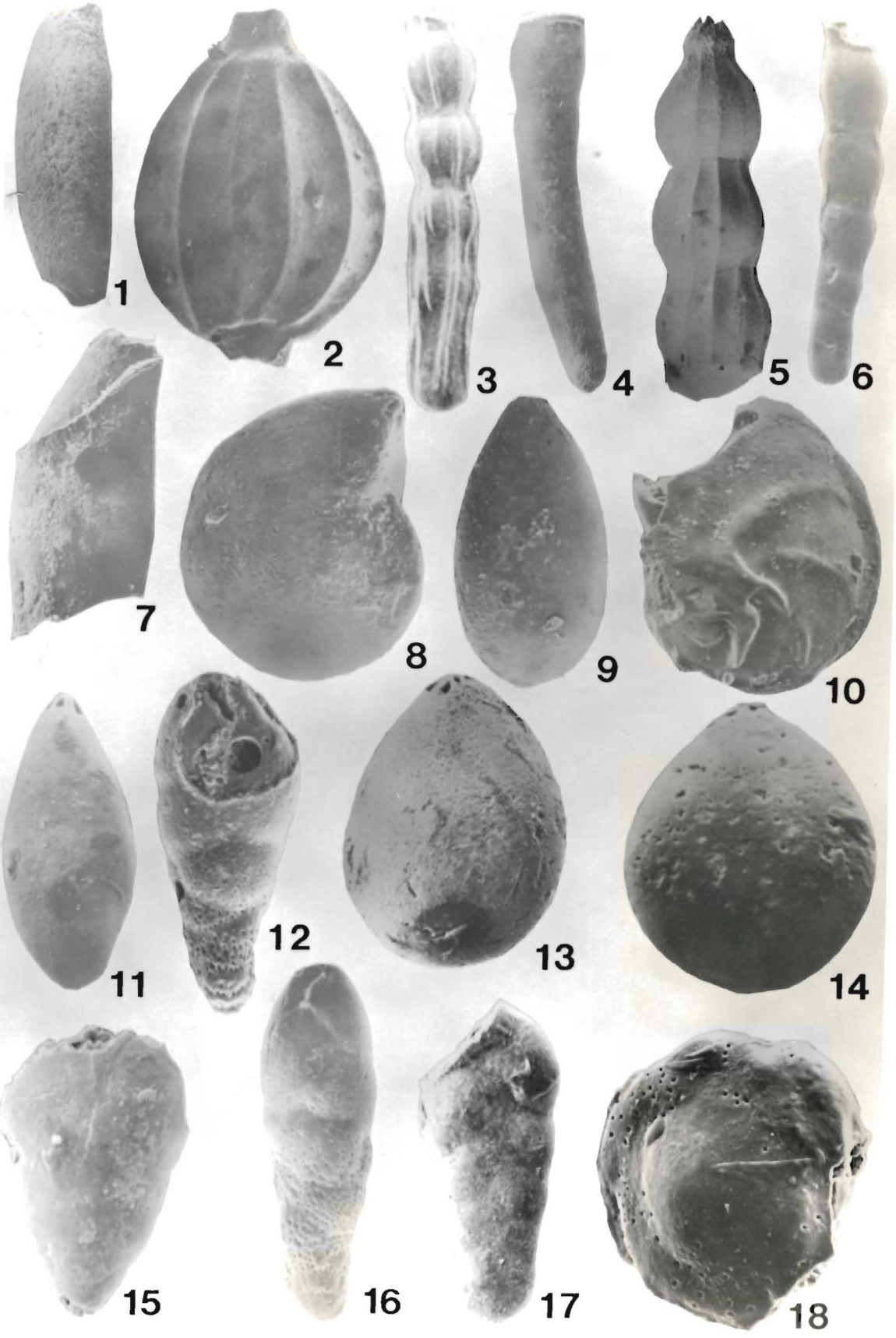
17. Spirobolivina emmendorferi (Jennings), X190, side view. Accession number A1175, Univ. of N. Dak. Cat. No. 13850.

18. Discorbacea, X300, dorsal view. Accession number A1290, Univ. of N. Dak. Cat. No. 13856.

Explanation of Plate 2

Figure

1. ?Chrysalogonium sp., X110, side view. Accession number A1152, Univ. of N. Dak. Cat. No. 13828.
2. Nodosaria sp., X80, side view. Accession number A1149, Univ. of N. Dak. Cat. No. 13829.
3. Dentalina pseudo-obliquestriata (Plummer), X100, side view. Accession number A1138, Univ. of N. Dak. Cat. No. 13835.
4. Dentalina colei Cushman and Dusenbury, X50, side view. Accession number A1106, Univ. of N. Dak. Cat. No. 13831.
5. Nodosaria affinis Reuss, X40, side view. Accession number A130 Univ. of N. Dak. Cat. No. 13829.
6. Dentalina eocenica Cushman, X90, side view. Accession number A1301, Univ. of N. Dak. Cat. No. 13834.
7. Dentalina sp. A, X140, side view. Accession number A1318, Univ of N. Dak. Cat. No. 13836.
8. Lenticulina alabamensis (Cushman and Todd), X120, side view. Accession number A1111, Univ. of N. Dak. Cat. No. 13841.
9. Globulina sp. A, X90, side view. Accession number A1346, Univ. of N. Dak. Cat. No. 13848.
10. Lenticulina turbinata (Plummer)?, X70, side view. Accession number A1145, Univ. of N. Dak. Cat. No. 13840.
11. Pyrulina cylindroides (Roemer), X80, side view. Accession number A1362, Univ. of N. Dak. Cat. No. 13849.
12. Bulimina rosenkrantzi Brotzen, X170, side view. Accession number A1182, Univ. of N. Dak. Cat. No. 13852.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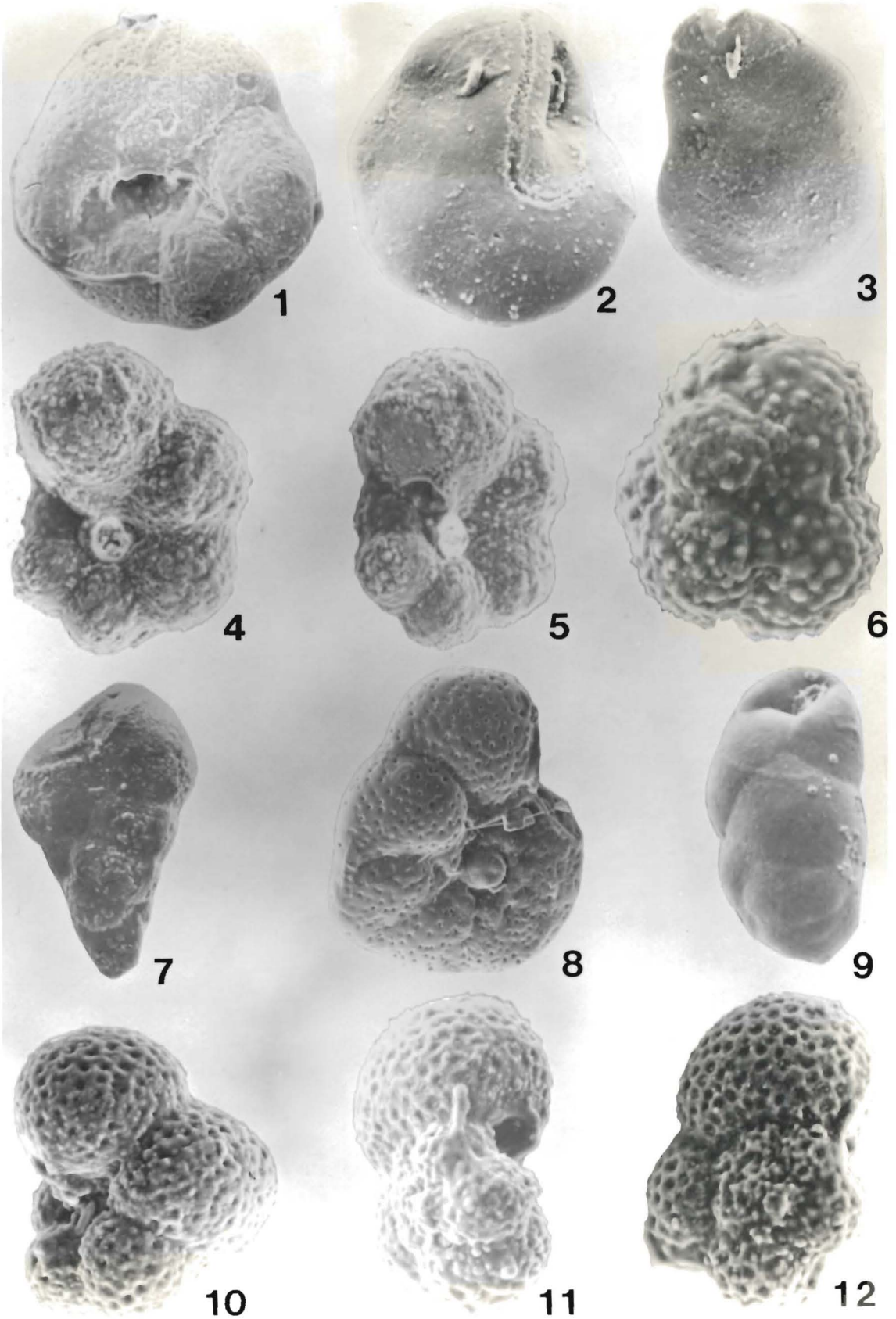
Explanation of Plate 3

Figure

1. Rosalina sp., X170, ventral view. Accession number A1339, Univ. of N. Dak. Cat. No. 13859.
2. Epistominella minuta (Olsson), X350, ventral view. Accession number A1278, Univ. of N. Dak. Cat. No. 13857.
3. Epistominella minuta (Olsson), X320, dorsal view. Accession number A1278, Univ. of N. Dak. Cat. No. 13857.
4. Pararotalia perclara (Loeblich and Tappan), X220, ventral view. Accession number A1194, Univ. of N. Dak. Cat. No. 13860.
5. Pararotalia perclara (Loeblich and Tappan), X220, oblique apertural view. Accession number A1194, Univ. of N. Dak. Cat. No. 13860.
6. Globoconusa daubjergensis (Bronnimann), X480, dorsal view. Accession number A1277, Univ. of N. Dak. Cat. No. 13862.
7. Chiloguembelina midwayensis subcylindrica Beckmann, X320, side view. Accession number A1180, Univ. of N. Dak. Cat. No. 1388
8. Cibicides sp., X120, ventral view. Accession number A1180, Univ. of N. Dak. Cat. No. 13863.
9. Caucasina marylandica (Nogan), X240, side view. Accession number A1183, Univ. of N. Dak. Cat. No. 13866.
10. Globorotalia pseudobulloides (Plummer), X410, ventral view. Accession number A1278, Univ. of N. Dak. Cat. No. 13885.
11. Globorotalia pseudobulloides (Plummer), X360, apertural view. Accession number A1279, Univ. of N. Dak. Cat. No. 13886.
12. Globorotalia pseudobulloides (Plummer), X360, dorsal view. Accession number A1279, Univ. of N. Dak. Cat. No. 13886.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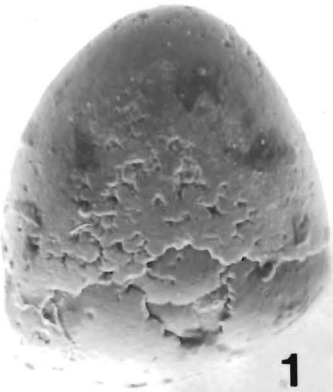
Explanation of Plate 4

Figure

1. Allomorphina paleocenica Cushman, X120, dorsal view. Accession number A1099, Univ. of N. Dak. Cat. No. 13874.
2. Nonion graniferum (Terquem), X250, side view. Accession number A1154, Univ. of N. Dak. Cat. No. 13868.
3. Nonionella robusta Plummer, X200, ventral view. Accession numbe A1356, Univ. of N. Dak. Cat. No. 13870.
4. Pullenia quinqueloba (Reuss), X160, side view. Accession number A1175, Univ. of N. Dak. Cat. No. 13871.
5. Fursenkoina sp., X230, side view. Accession number A1182, Univ. of N. Dak. Cat. No. 13865.
6. Fursenkoina sp., X490, apertural view. Accession number A1182, Univ. of N. Dak. Cat. No. 13865.
7. Alabamina midwayensis Brotzen, X240, ventral view. Accession number A1278, Univ. of N. Dak. Cat. No. 13875.
8. Alabamina midwayensis Brotzen, X300, dorsal view. Accession number A1116, Univ. of N. Dak. Cat. No. 13885.
9. Anomalinoides midwayensis (Plummer), X200, ventral view. Accession number A1135, Univ. of N. Dak. Cat. No. 13880.
10. Gyroidinoides aequilateralis (Plummer), X200, ventral view. Accession number A1328, Univ. of N. Dak. Cat. No. 13878.
11. Gyroidinoides aequilateralis (Plummer), X400, dorsal view. Accession number A1188, Univ. of N. Dak. Cat. No. 13877.
12. Gyroidinoides sp., X310, dorsal view. Accession number A1311, Univ. of N. Dak. Cat. No. 13879.



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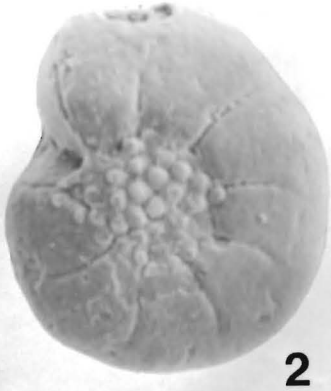

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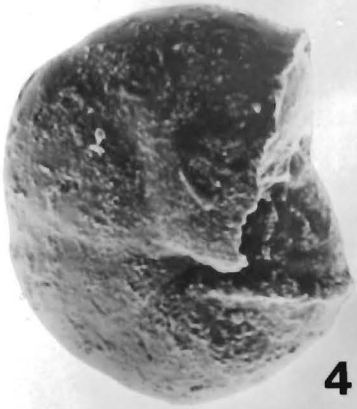

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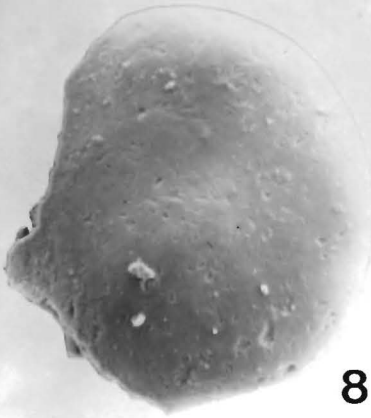

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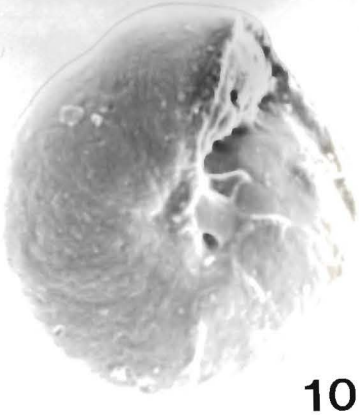

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Explanation of Plate 5

Figure

1. Anomalinoides umboniferus (Schwager), X200, dorsal view. Accession number A1175, Univ. of N. Dak. Cat. No. 13882.
2. Anomalinoides umboniferus (Schwager), X160, ventral view. Accession number A1175, Univ. of N. Dak. Cat. No. 13882.
3. Anomalinoides sp., X130, ventral view. Accession number A1157, Univ. of N. Dak. Cat. No. 13883.
4. Cibicidoides alleni (Plummer), X200, ventral view. Accession number A1181, Univ. of N. Dak. Cat. No. 13872.
5. Cibicidoides alleni (Plummer), X200, apertural view. Accession number A1181, Univ. of N. Dak. Cat. No. 13872.
6. Cibicidoides alleni (Plummer), X280, dorsal view. Accession number A1181, Univ. of N. Dak. Cat. No. 13872.
7. ?Cibicidoides vulgaris (Plummer), X170, dorsal view. Accession number A1328, Univ. of N. Dak. Cat. No. 13873.
8. Ceratobulimina perplexa (Plummer), X170, dorsal view. Accession number A1135, Univ. of N. Dak. Cat. No. 13884.
9. Ceratobulimina perplexa (Plummer), X200, ventral view. Accession number A1135, Univ. of N. Dak. Cat. No. 13884.

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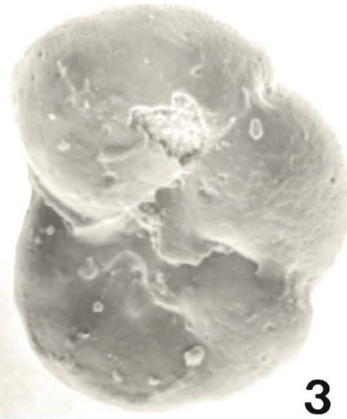

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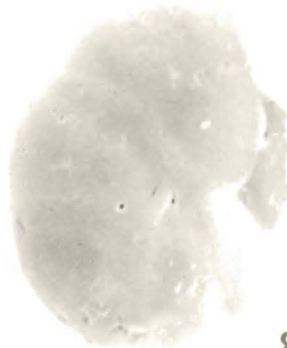

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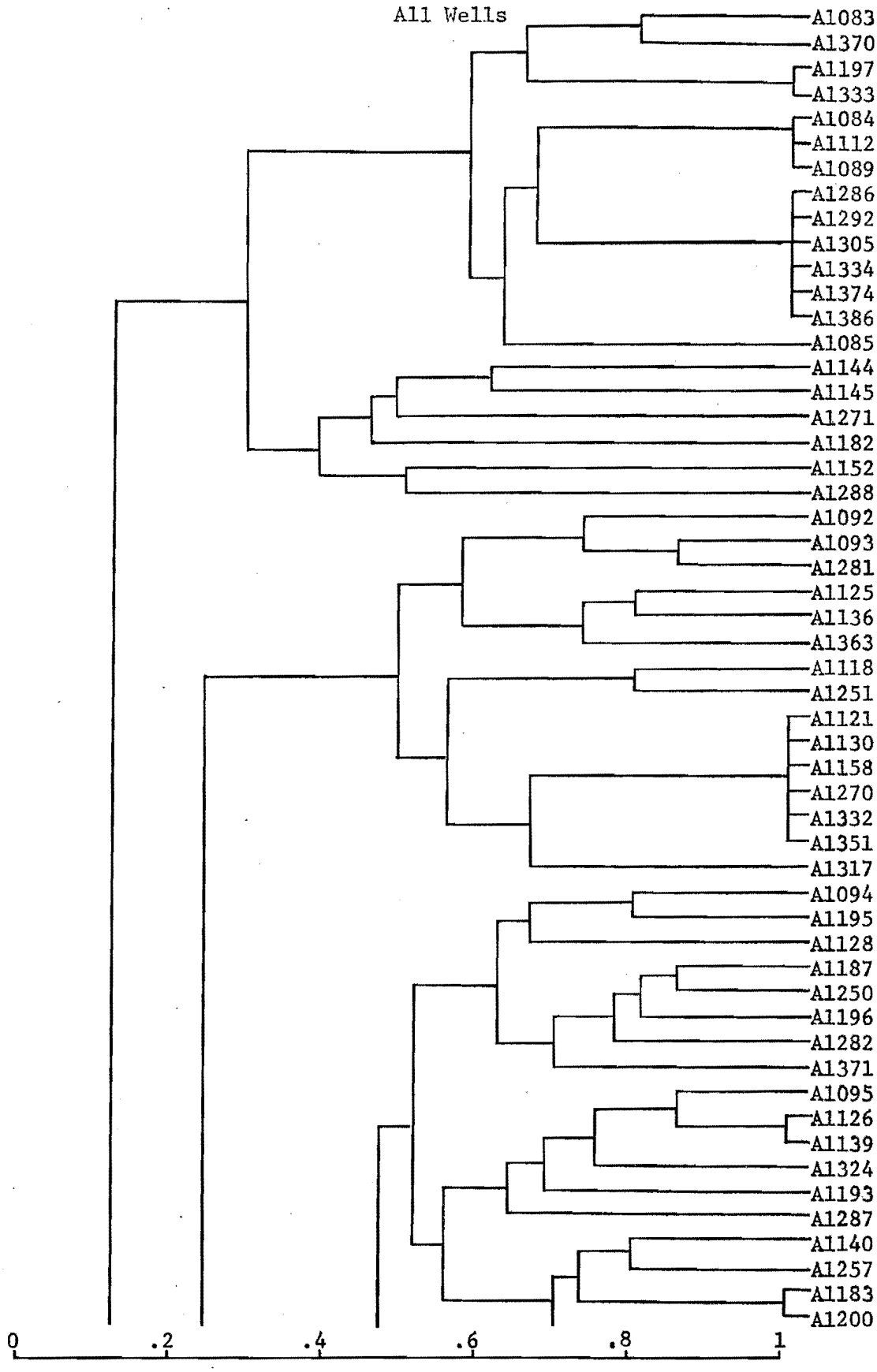
APPENDIX A

Q-Mode dendrograms of foraminiferid-bearing samples.

Numbers preceded by an A are accession numbers of the department of Geology, University of North Dakota. Numbers heading dendrograms are NDSWC well numbers. Scales across bottoms of dendrograms show levels of association.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A1112
A1089
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A1292
A1305
A1334
A1374
A1386
A1085
A1144
A1145
A1271
A1182
A1152
A1288
A1092
A1093
A1281
A1125
A1136
A1363
A1118
A1251
A1121
A1130
A1158
A1270
A1332
A1351
A1317
A1094
A1195
A1128
A1187
A1250
A1196
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A1371
A1095
A1126
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A1324
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A1140
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A1200
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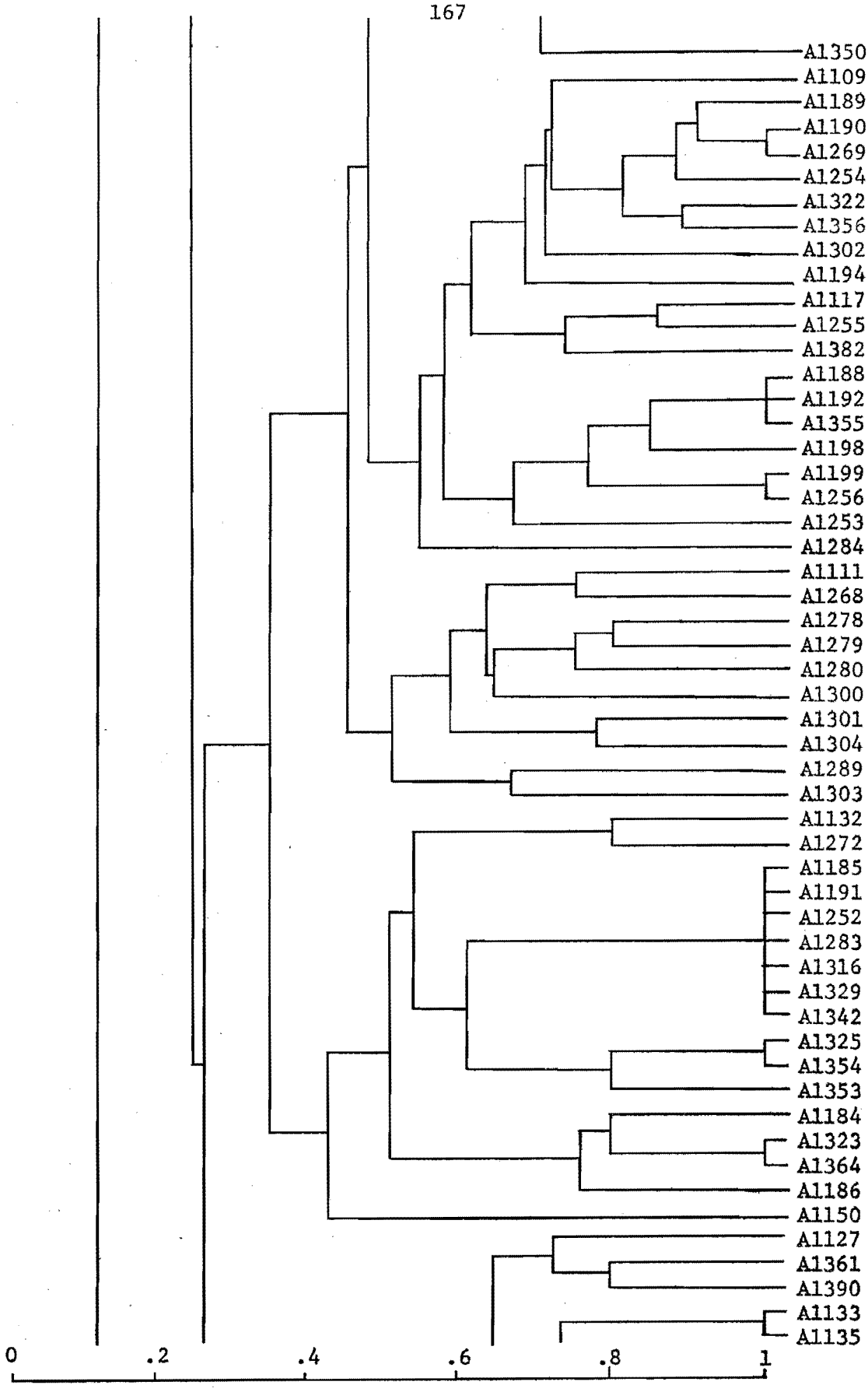
1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A1269
A1254
A1322
A1356
A1302
A1194
A1117
A1255
A1382
A1188
A1192
A1355
A1198
A1199
A1256
A1253
A1284
A1111
A1268
A1278
A1279
A1280
A1300
A1301
A1304
A1289
A1303
A1132
A1272
A1185
A1191
A1252
A1283
A1316
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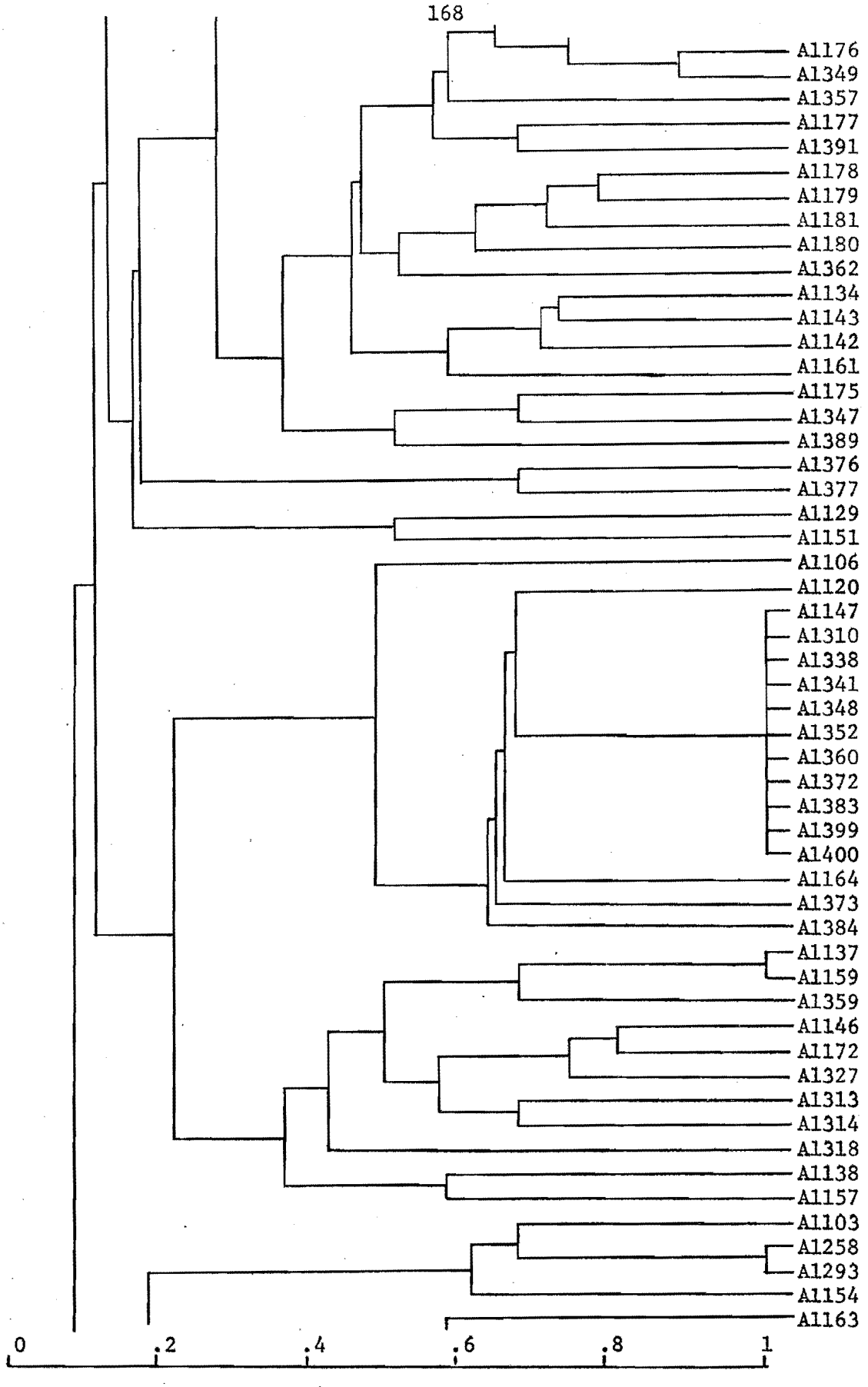
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A1181
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A1362
A1134
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A1142
A1161
A1175
A1347
A1389
A1376
A1377
A1129
A1151
A1106
A1120
A1147
A1310
A1338
A1341
A1348
A1352
A1360
A1372
A1383
A1399
A1400
A1164
A1373
A1384
A1137
A1159
A1359
A1146
A1172
A1327
A1313
A1314
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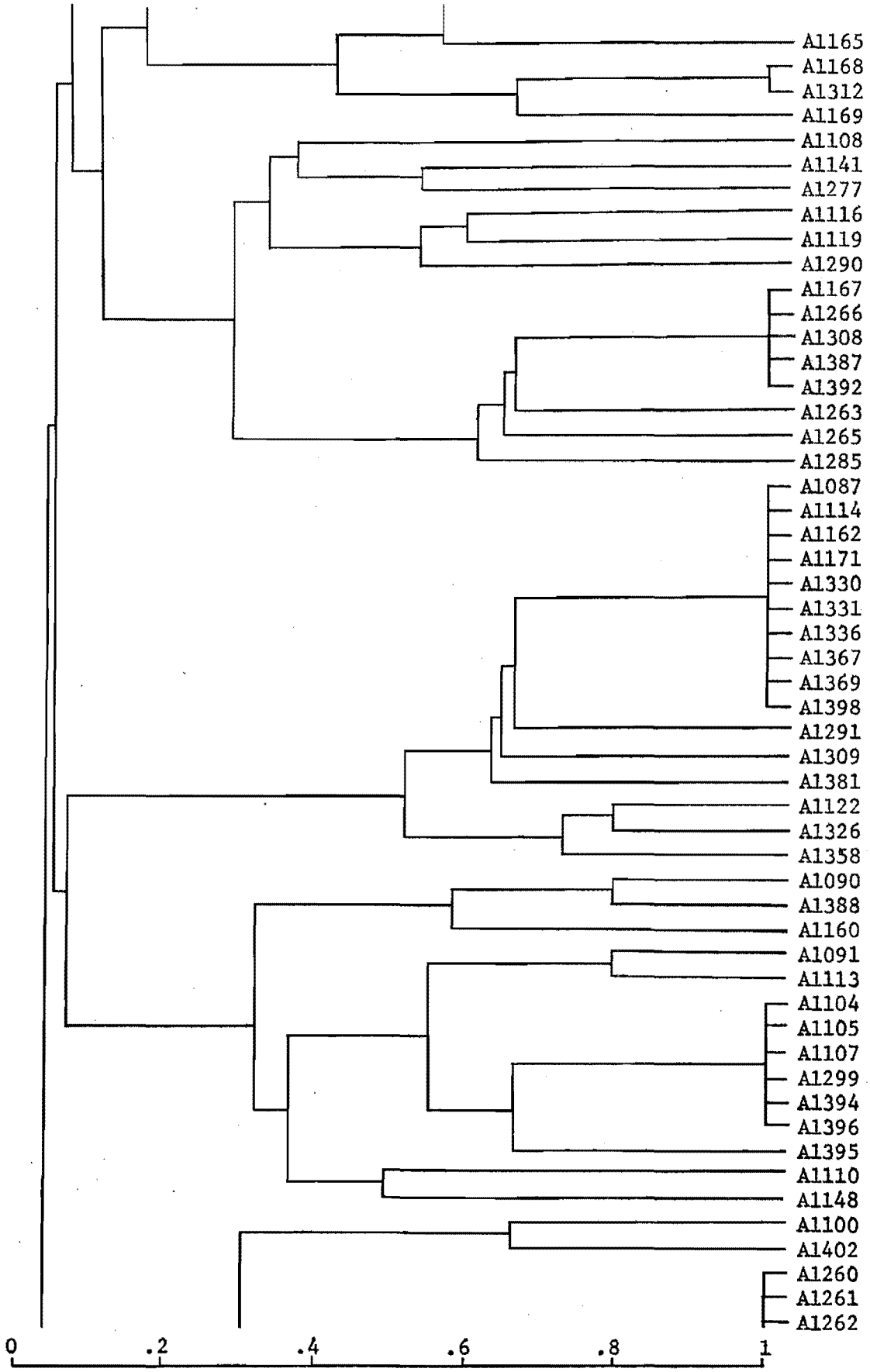
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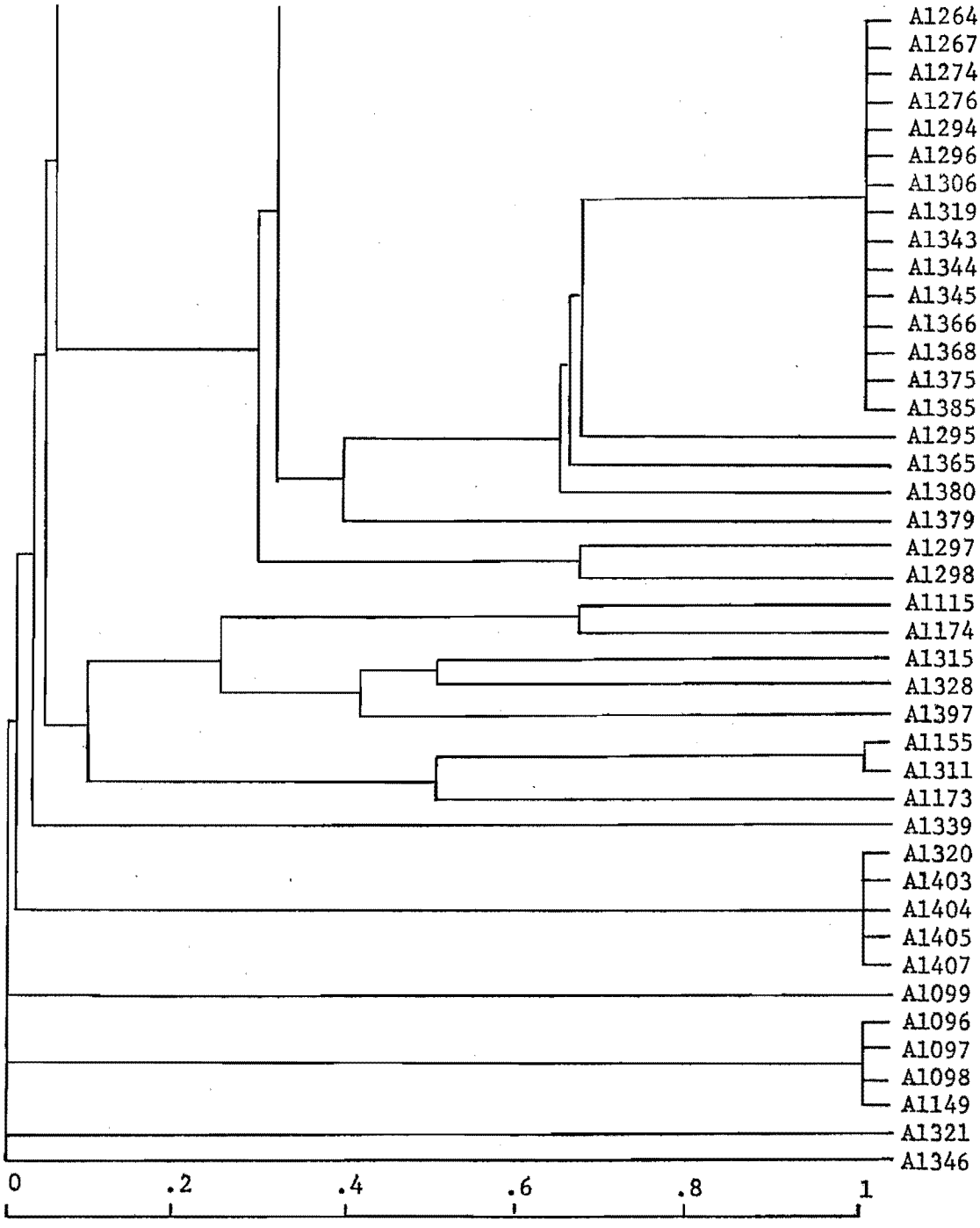
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A1297
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A1174
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A1311
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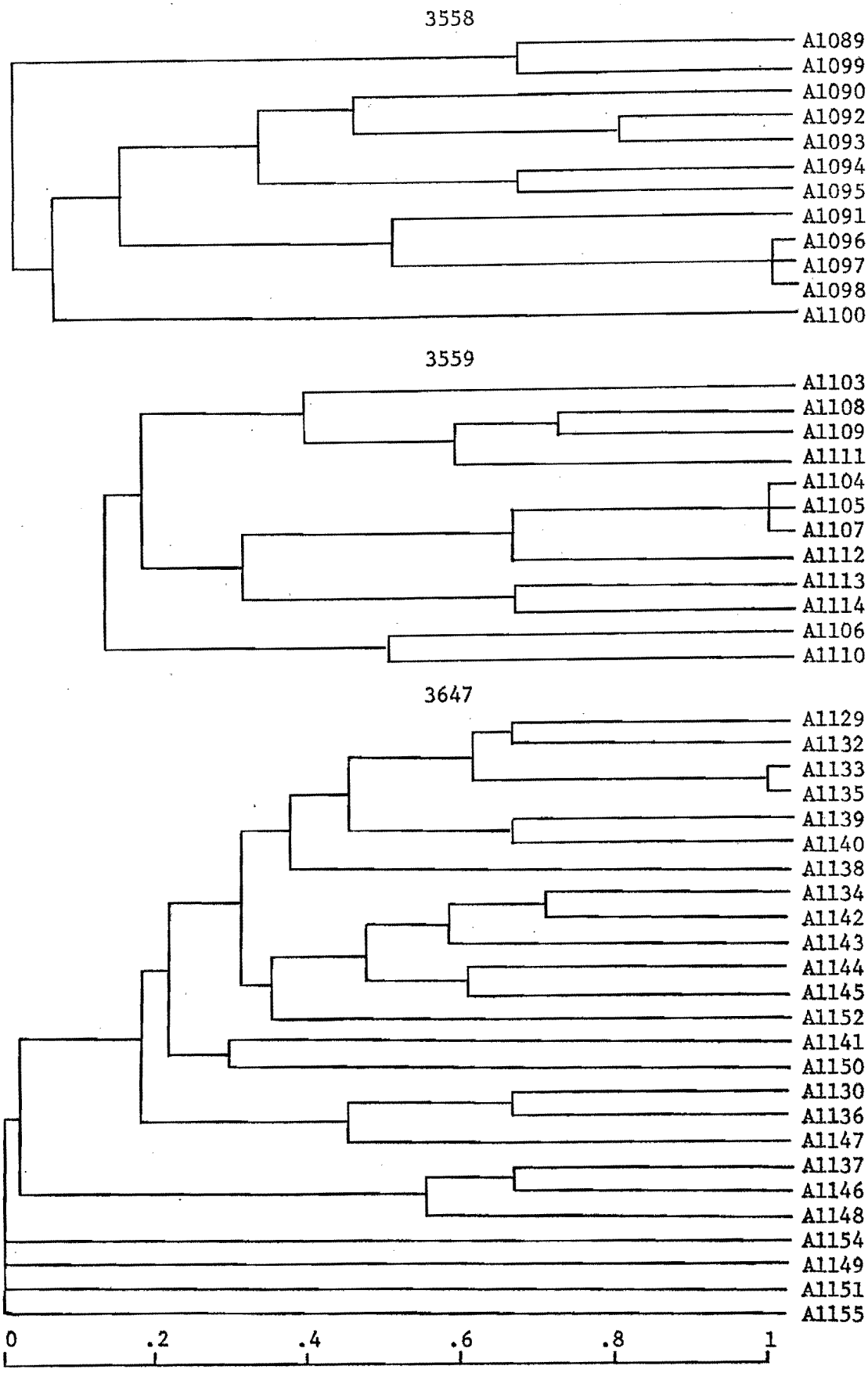
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A1111
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A1106
A1110
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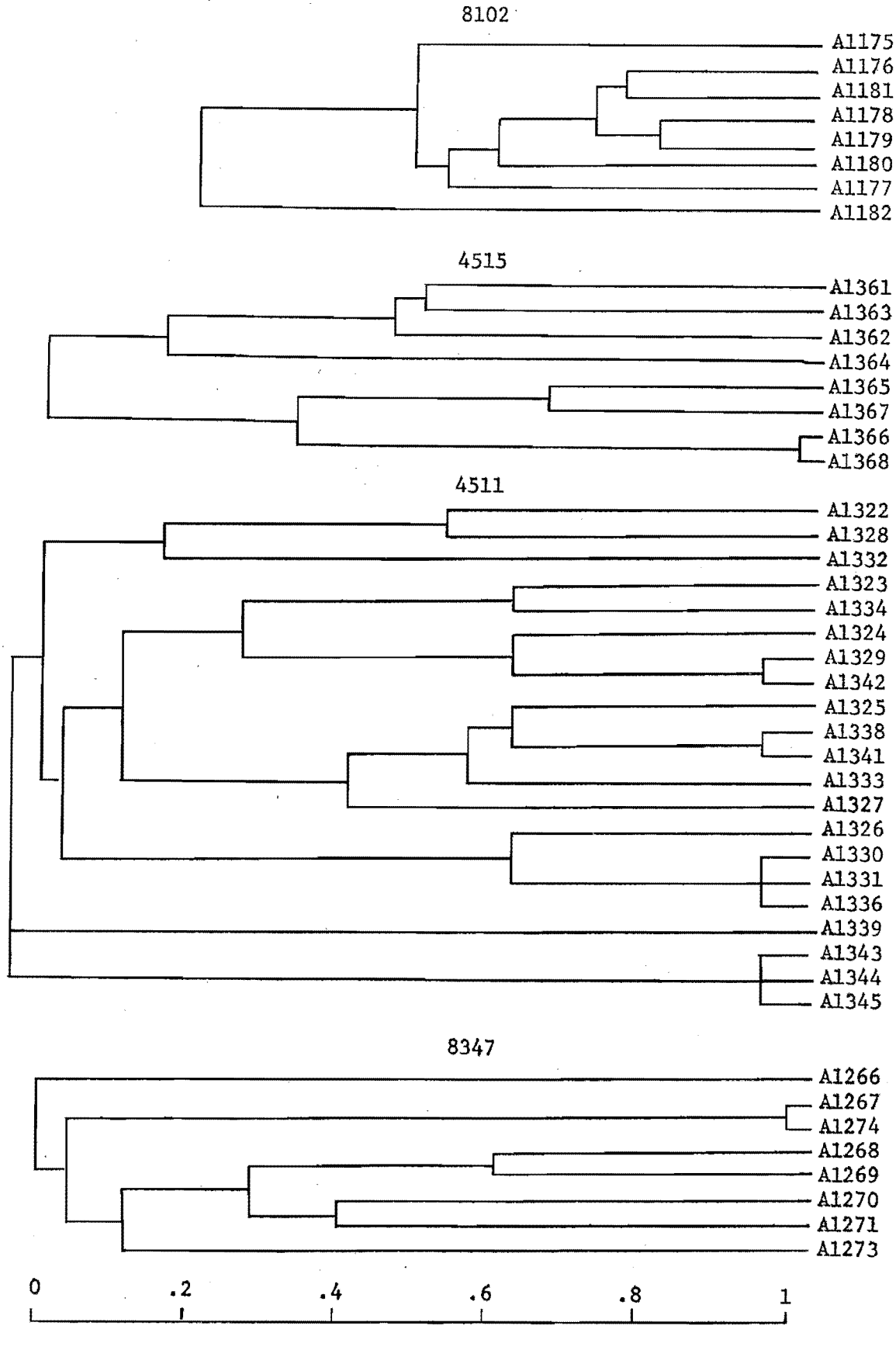
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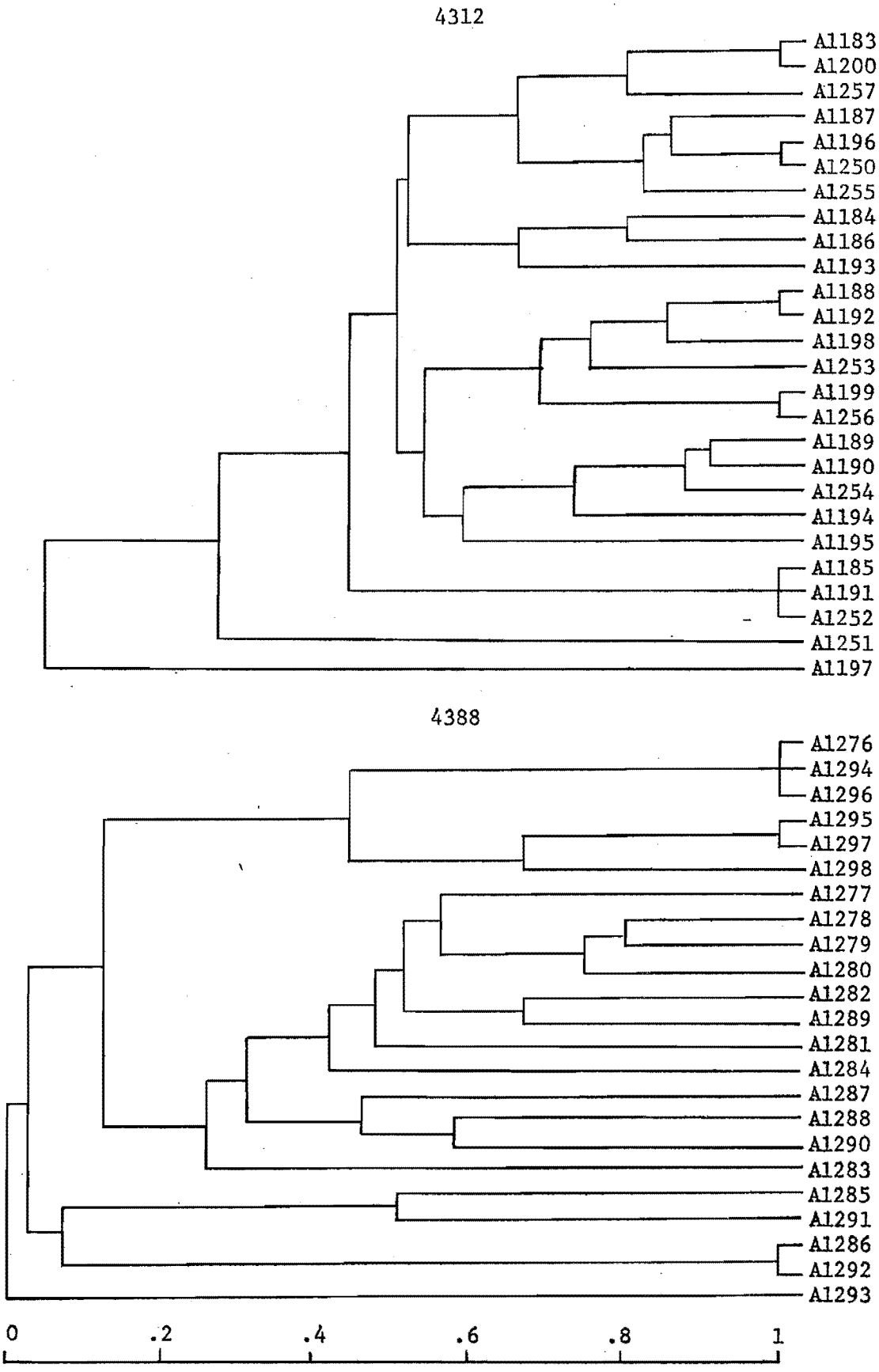
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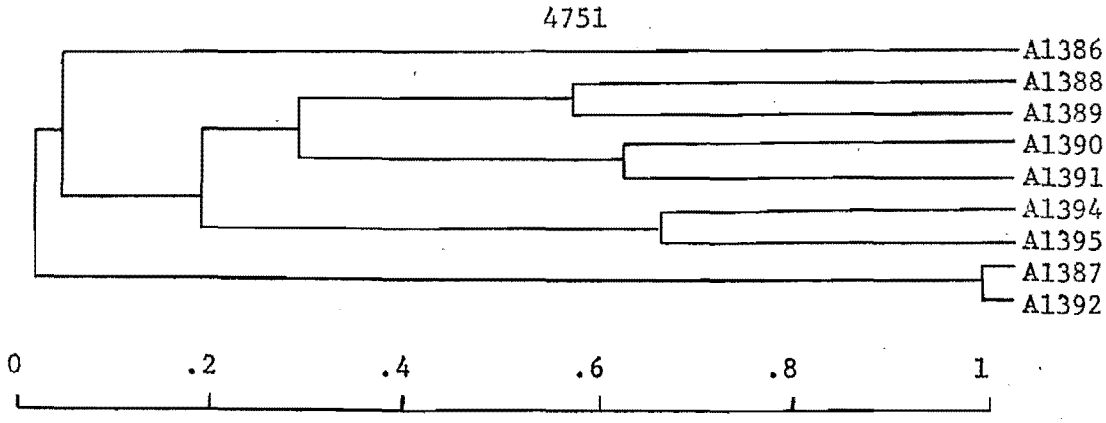
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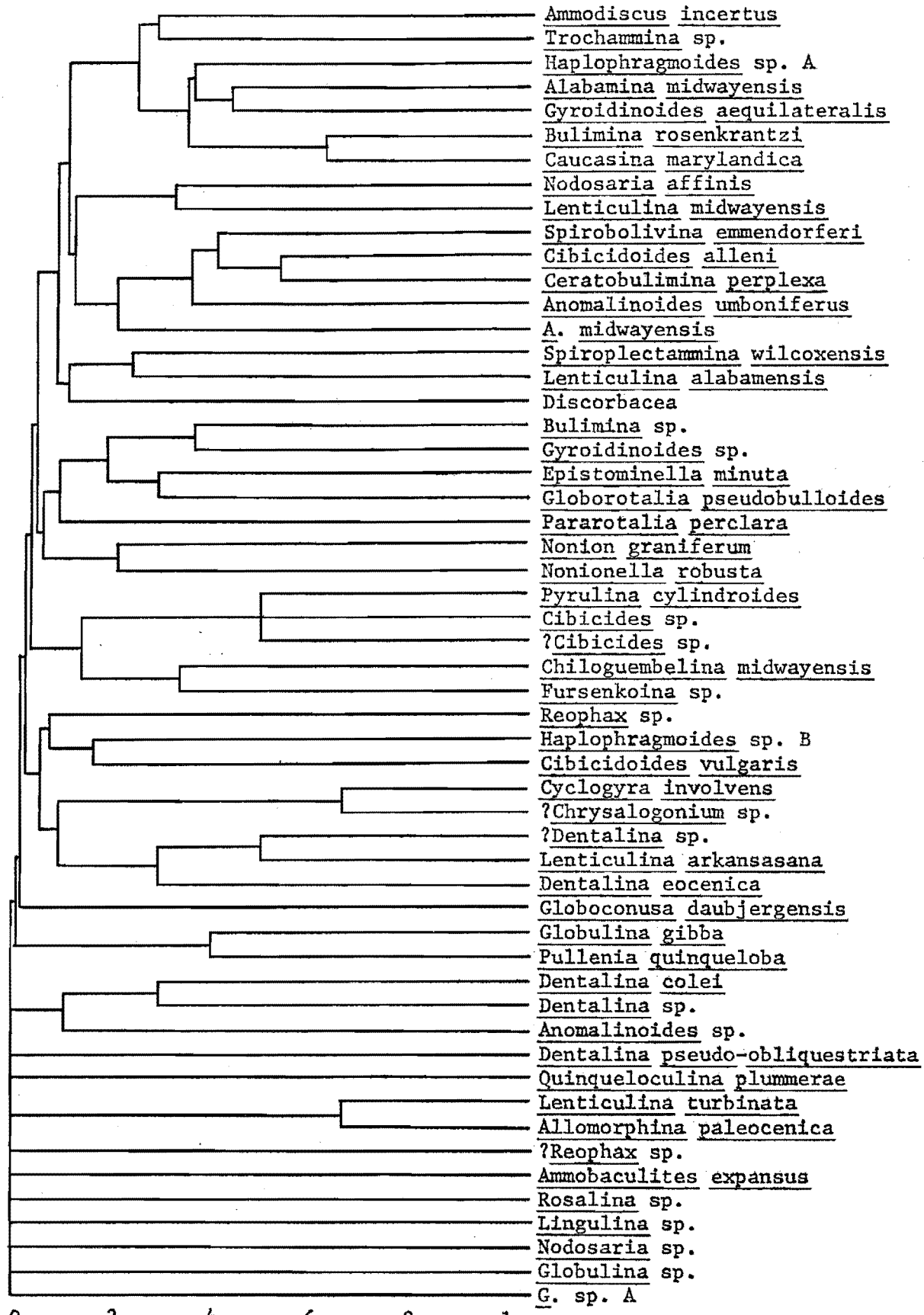
APPENDIX B

R-Mode dendrograms of foraminiferid species.

Scale along bottom shows levels of association, and numbers at the top of each diagram are NDSWC well numbers.

All Wells


Ammodiscus incertus
Trochammina sp.
Haplophragmoides sp. A
Alabamina midwayensis
Gyroidinoides aequilateralis
Bulimina rosenkrantzi
Caucasina marylandica
Nodosaria affinis
Lenticulina midwayensis
Spirobolivina emmendorferi
Cibicidoides alleni
Ceratobulimina perplexa
Anomalinoides umboniferus
A. midwayensis
Spiroplectammina wilcoxensis
Lenticulina alabamensis
Discorbacea
Bulimina sp.
Gyroidinoides sp.
Epistominella minuta
Globorotalia pseudobulloides
Pararotalia perclara
Nonion graniferum
Nonionella robusta
Pyrulina cylindroides
Cibicides sp.
?Cibicides sp.
Chiloguembelina midwayensis
Fursenkoina sp.
Reophax sp.
Haplophragmoides sp. B
Cibicidoides vulgaris
Cyclogyra involvens
?Chrysalogonium sp.
?Dentalina sp.
Lenticulina arkansasana
Dentalina eocenica
Globoconusa daubjergensis
Globulina gibba
Pullenia quinqueloba
Dentalina colei
Dentalina sp.
Anomalinoides sp.
Dentalina pseudo-obliquestriata
Quinqueloculina plummerae
Lenticulina turbinata
Allomorphina paleocenica
?Reophax sp.
Ammobaculites expansus
Rosalina sp.
Lingulina sp.
Nodosaria sp.
Globulina sp.
G. sp. A
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.6
.8
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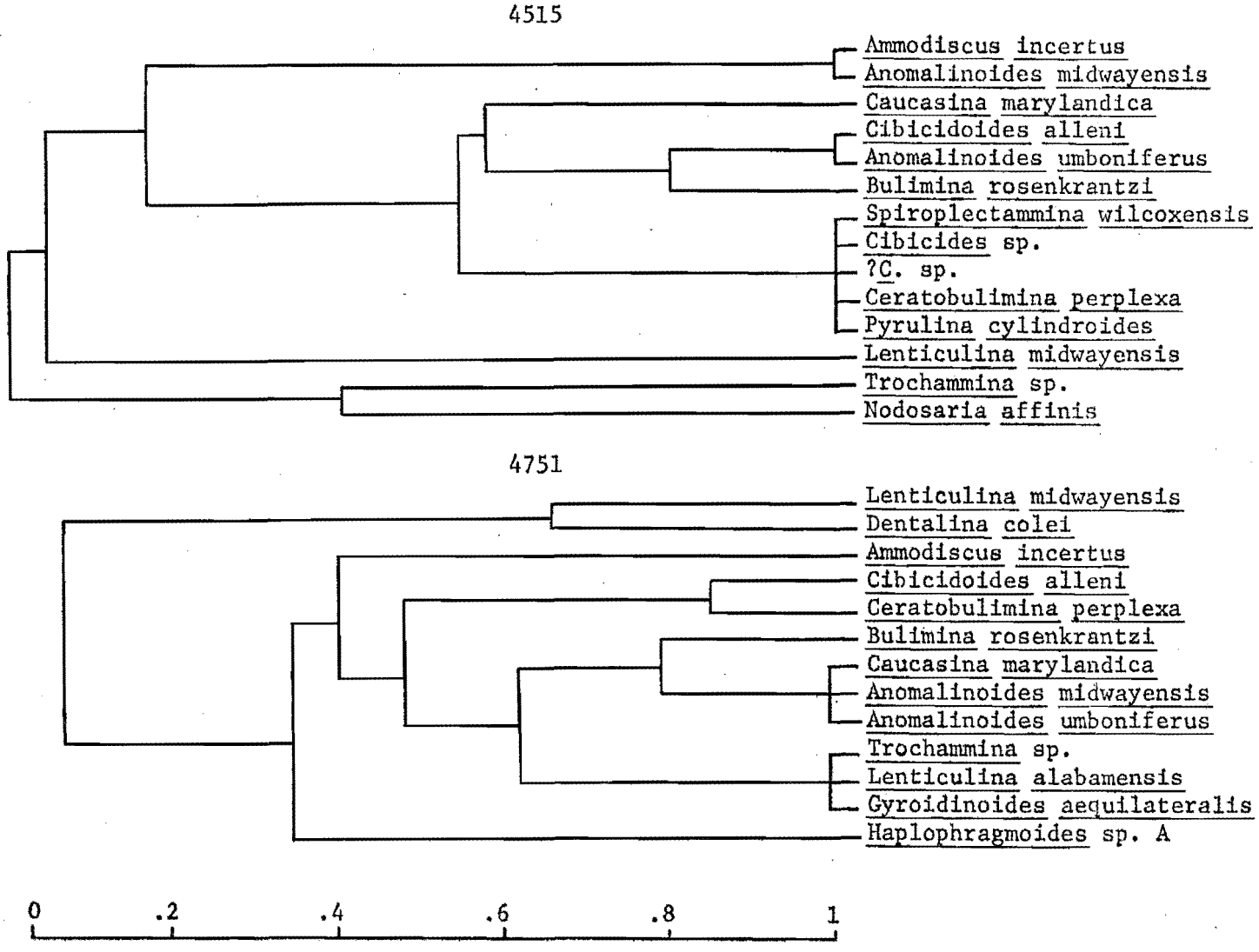
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Anomalinoides midwayensis
Caucasina marylandica
Cibicidoides alleni
Anomalinoides umboniferus
Bulimina rosenkrantzi
Spiroplectammina wilcoxensis
Cibicides sp.
?C. sp.
Ceratobulimina perplexa
Pyrulina cylindroides
Lenticulina midwayensis
Trochammina sp.
Nodosaria affinis
4751
Lenticulina midwayensis
Dentalina colei
Ammodiscus incertus
Cibicidoides alleni
Ceratobulimina perplexa
Bulimina rosenkrantzi
Caucasina marylandica
Anomalinoides midwayensis
Anomalinoides umboniferus
Trochammina sp.
Lenticulina alabamensis
Gyroidinoides aequilateralis
Haplophragmoides sp. A
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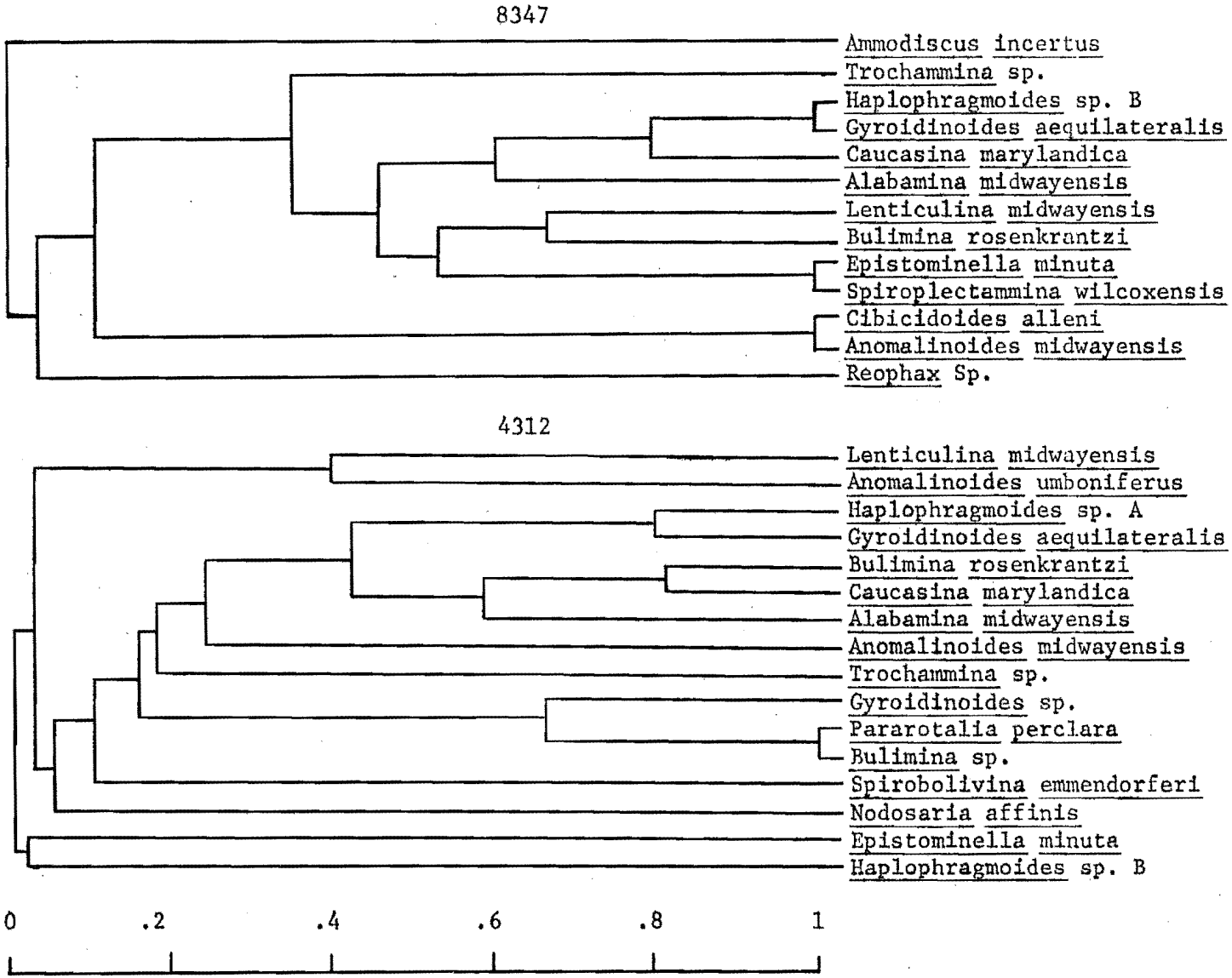
.4
.6
.8
1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Ammodiscus incertus
Trochammina sp.
Haplophragmoides sp. B
Gyroidinoides aequilateralis
Caucasina marylandica
Alabamina midwayensis
Lenticulina midwayensis
Bulimina rosenkrantzi
Epistominella minuta
Spiroplectammina wilcoxensis
Cibicidoides alleni
Anomalinoides midwayensis
Reophax Sp.
4312
Lenticulina midwayensis
Anomalinoides umboniferus
Haplophragmoides sp. A
Gyroidinoides aequilateralis
Bulimina rosenkrantzi
Caucasina marylandica
Alabamina midwayensis
Anomalinoides midwayensis
Trochammina sp.
Gyroidinoides sp.
Pararotalia perclara
Bulimina sp.
Spirobolivina emmendorferi
Nodosaria affinis
Epistominella minuta
Haplophragmoides sp. B
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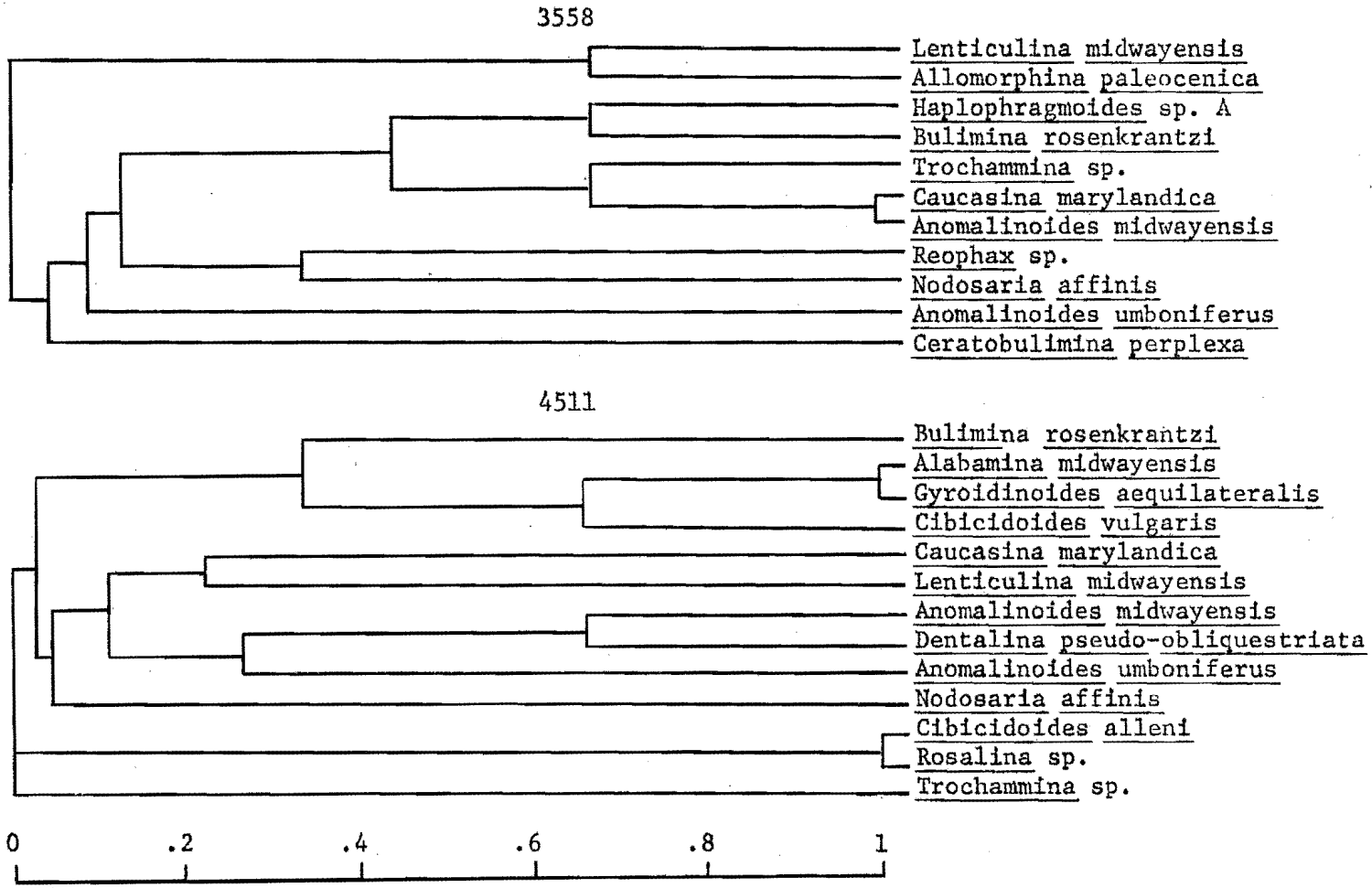
.8
1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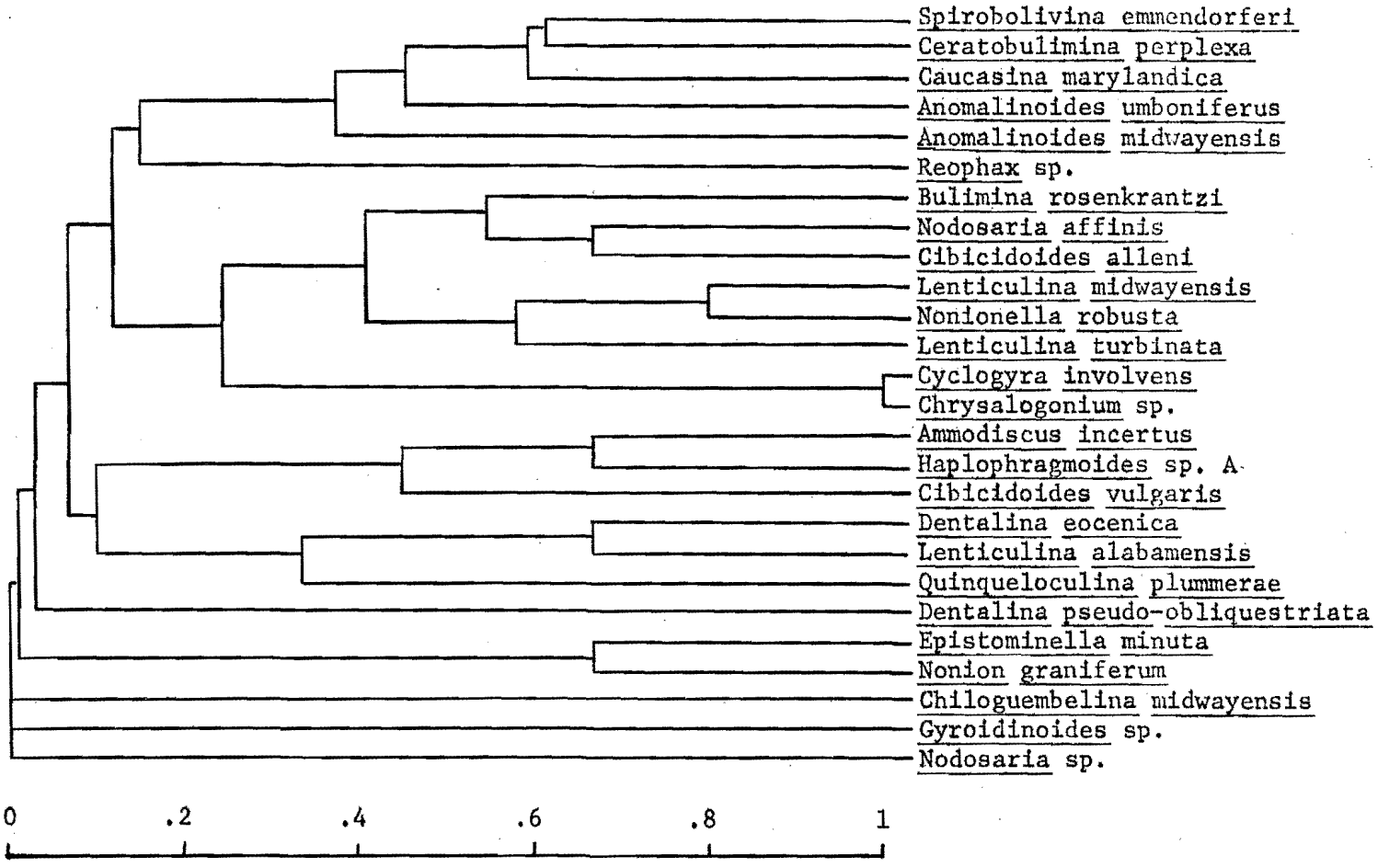
Lenticulina midwayensis
Allomorphina paleocenica
Haplophragmoides sp. A
Bulimina rosenkrantzi
Trochammina sp.
Caucasina marylandica
Anomalinoides midwayensis
Reophax sp.
Nodosaria affinis
Anomalinoides umboniferus
Ceratobulimina perplexa
4511
Bulimina rosenkrantzi
Alabamina midwayensis
Gyroidinoides aequilateralis
Cibicidoides vulgaris
Caucasina marylandica
Lenticulina midwayensis
Anomalinoides midwayensis
Dentalina pseudo-obliquestriata
Anomalinoides umboniferus
Nodosaria affinis
Cibicidoides alleni
Rosalina sp.
Trochammina sp.
0
.2
.4
.6
.8
1


Spirobolivina emmendorferi
Ceratobulimina perplexa
Caucasina marylandica
Anomalinoides umboniferus
Anomalinoides midwayensis
Reophax sp.
Bulimina rosenkrantzi
Nodosaria affinis
Cibicidoides alleni
Lenticulina midwayensis
Nonionella robusta
Lenticulina turbinata
Cyclogyra involvens
Chrysalogonium sp.
Ammodiscus incertus
Haplophragmoides sp. A
Cibicidoides vulgaris
Dentalina eocenica
Lenticulina alabamensis
Quinqueloculina plummerae
Dentalina pseudo-obliquestriata
Epistominella minuta
Nonion graniferum
Chiloguembelina midwayensis
Gyroidinoides sp.
Nodosaria sp.
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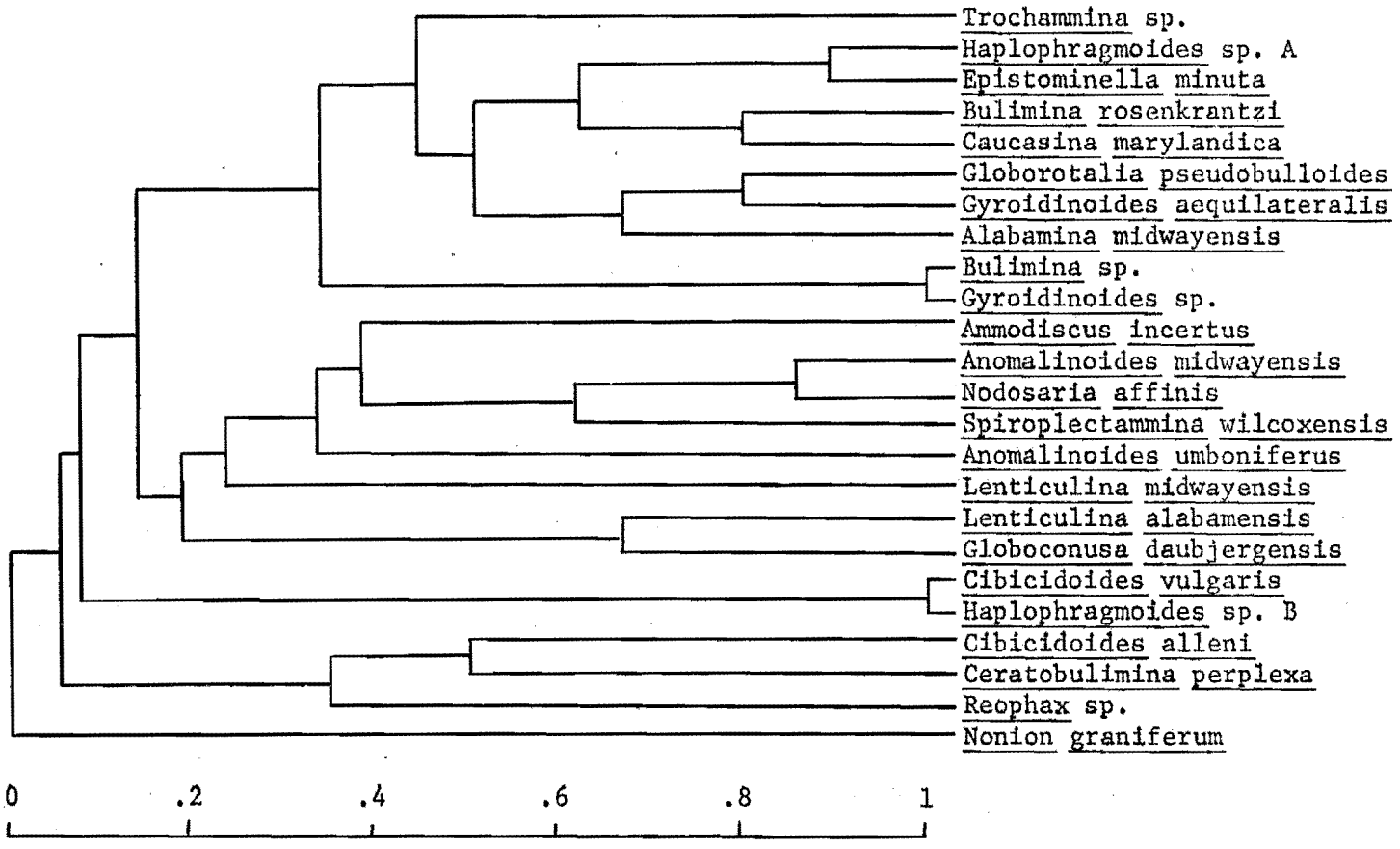
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Haplophragmoides sp. A
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Caucasina marylandica
Globorotalia pseudobulloides
Gyroidinoides aequilateralis
Alabamina midwayensis
Bulimina sp.
Gyroidinoides sp.
Ammodiscus incertus
Anomalinoides midwayensis
Nodosaria affinis
Spiroplectammina wilcoxensis
Anomalinoides umboniferus
Lenticulina midwayensis
Lenticulina alabamensis
Globoconusa daubjergensis
Cibicidoides vulgaris
Haplophragmoides sp. B
Cibicidoides alleni
Ceratobulimina perplexa
Reophax sp.
Nonion graniferum
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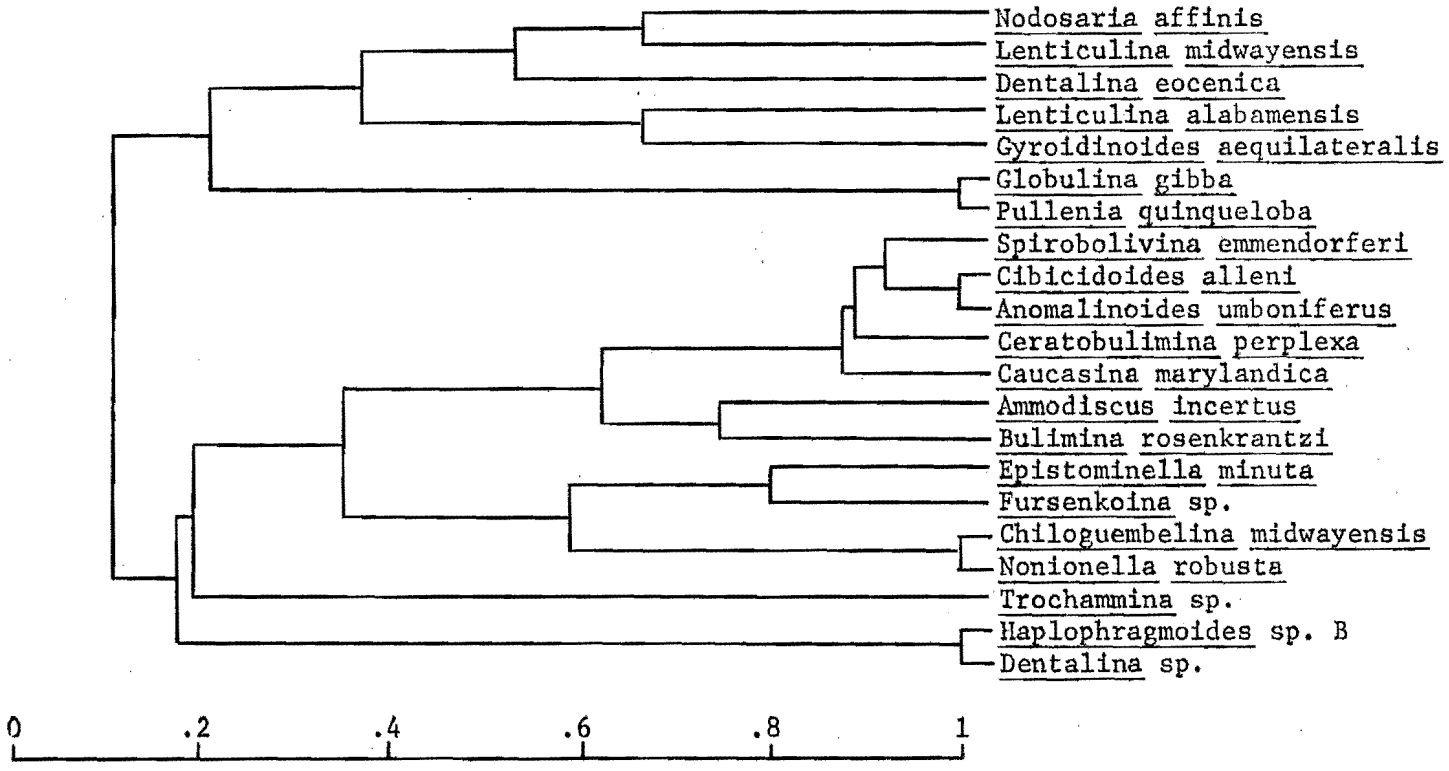
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Spirobolivina emmendorferi
Cibicidoides alleni
Anomalinoides umboniferus
Ceratobulimina perplexa
Caucasina marylandica
Ammodiscus incertus
Bulimina rosenkrantzi
Epistominella minuta
Fursenkoina sp.
Chiloguembelina midwayensis
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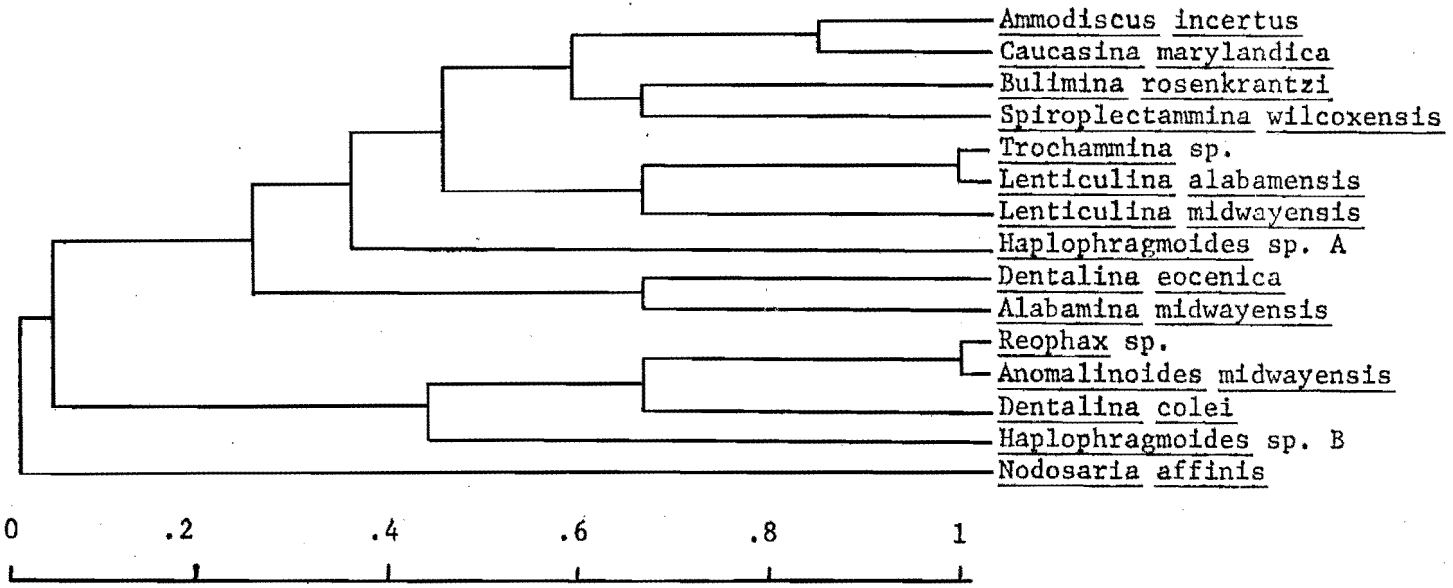
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Haplophragmoides sp. A
Dentalina eocenica
Alabamina midwayensis
Reophax sp.
Anomalinoides midwayensis
Dentalina colei
Haplophragmoides sp. B
Nodosaria affinis
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APPENDIX C

Well Information for the Cannonball Formation

Elevations, depth to the top of the Cannonball, thickness of the Cannonball, and foraminiferid intervals are given in meters.

Location	County	NDSWC Well No.	Elev.	Depth to Top Tc	Thick-ness TC	Foraminiferid Intervals	UND Acces-sion Nos.	Source
129-93-08 CBB	Adams	8347	749.8	0	76.2	3.0-4.6, 6.0-7.6, 9.1-12.2, 18.3-19.8, 21.3-22.9, 27.4-29.0, 30.5-32.0, 50.3-53.3	A1266-A1275	Croft, 1974, p. 56-57
129-94-28 DA	Adams	4384	771.0	0	25.9	1.5-3.0, 4.6-12.2, 15.2-16.8	A1299-A1305	Croft, 1974, p. 64
129-96-13 AAD	Adams	4388	830.3	30.5	107.9	35.1-51.8, 56.4-57.9, 59.4-64.0, 65.5-67.1, 73.2-79.2, 91.4-98.0, 120.4-121.9, 128-129.5	A1276-A1298	Croft, 1974, p. 86
129-98-32 ABD	Adams	4453	804.7	2.4 48.1	21.9 15.2	7.6-9.1, 13.7-15.2, 22.9-25.9, 47.2-48.8, 50.3-51.8, 52.0-54.9, 64.0-65.5	A1258-A1265	Croft, 1974, p. 109
129-100-25 DAA	Bowman	4390	819.3	? 39.0	? 25.0	None	-----	Croft, 1974, p. 118
129-100-19 AAA	Bowman	4456	847.3	9.1 44.2	3.0 16.8	64.0-65.5	A1306	Croft, 1974, p. 115-116
129-102-27 AAA	Bowman	4457	867.2	No TC	0	None	_____	Croft, 1974, p. 125-126

130-82-36	BBC	Sioux	8083	669.6	No Tc	0	None	-----	Randich, 1975, p. 86-87
130-84-36	ABA	Sioux	4489	654.7	No Tc	0	None	_____	Randich, 1975, p. 92-93
131-94-20	CBC	Adams	4312	762.0	12.2	115.8	35.1-32.0, 54.9-59.4, 61.0-62.5, 70.1-71.6, 73.2-80.8, 82.3-83.8, 85.3-86.9, 111.3-114.3	A1183-A1257	Croft, 1974, p. 200
131-102-07	DDD	Bowman	4462	897.6	0 88.4	1.5 9.3	1.5-3.0, 85.3-86.9	A1307-A1308	Croft, 1974, p. 232
132-84-06	CCC	Grant	4398	624.6	3.0	3.6	None	-----	Randich, 1975, p. 146-147
132-99-32	DDC	Bowman	4391	883.9	86.9 149.4	32.0 6.1	None	-----	Croft, 1974, p. 261
133-84-30	AAA	Grant	4397	702.6	9.1	57.9	16.8-21.3, 32.0-35.1, 36.6-38.1	A1169-A1174	Randich, 1975, p. 180
133-85-12	ADD	Grant	4487	618.4	4.6	5.2	None	-----	Randich, 1975, p. 181-182
133-86-06	BBB	Grant	8103	730.6	19.8	59.4	45.7-47.2, 51.8-56.4	A1159-A1162	Randich, 1975, p. 184-185
134-85-21	BAB	Grant	4516	670.6	2.1	66.1	16.8-21.3, 22.9-24.4, 47.2-48.8	A1369-A1373	Randich, 1975, p. 201-202
135-86-15	DDD	Grant	4515	680.0	30.5	91.4	42.7-50.3, 65.5-67.0, 71.6-73.1, 103.6-105.1	A1361-A1368	Randich, 1975, p. 214-215
135-86-07	DDD	Grant	8102	659.9	13.8	71.6	25.9-36.6	A1175-A1181	Randich, 1975, p. 212-213

136-87-36	ABD	Grant	4486	579.1	5.8	32.6	24.4-30.5, 45.7-47.2	A1163-A1167	Randich, 1975, p. 229-231
136-88-13	AAA	Grant	4513	667.8	48.8	96.0	61.0-64.0, 65.5-74.7, 76.2-82.3, 96.0-97.5, 129.5-131.6, 134.1-135.6	A1346-A1360	Randich, 1975, p. 232-234
137-83-06	CDD	Morton	4763	548.6	4.6	32.0	None	-----	NDSWC Unpublished Data
137-86-03	AAD	Morton	4752	600.5	49.3	82.3	53.3-59.9, 62.5-64.0, 86.9-88.4	A1374-A1376	NDSWC Unpublished Data
137-87-12	CDA	Morton	4757	731.5	93.0	5.2	None	-----	NDSWC Unpublished Data
137-89-09	ABA	Grant	4511	702.6	144.8	93.0	170.7-175.3, 176.8-185.9, 187.4-189.0, 190.5-193.5, 196.6-207.3, 211.8-213.4, 228.6-231.6, 234.7-239.3	A1322-A1345	Randich, 1975, p. 241-243
138-85-26	CDD	Morton	4762	670.6	39.6	9.1	None	-----	NDSWC Unpublished Data
139-76-20	ABB	Burleigh	2017	597.7	12.2	3.0	13.7-15.2	A1319	Randich, 1965, p. 174
139-77-15	CCC	Burleigh	2016	534.3	9.3	4.4	None	-----	Randich, 1965, p. 177-178
139-83-12	DBA	Morton	4751	597.4	35.0	68.6	47.2-56.4, 57.9-62.5, 65.5-67.0	A1386-A1395	NDSWC Unpublished Data

139-83-28	DAD	Morton	4764	548.6	4.6	38.1	9.1-12.2, 38.1-39.6, 41.1-42.7	A1382-A1385	NDSWC Unpublished Data
139-84-27	BBC	Morton	4760	597.4	29.9	26.5	47.2-48.8, 51.8-56.4, 68.6-70.1	A1377-A1381	NDSWC Unpublished Data
139-87-23	BBB	Morton	4756	638.6	106.7	3.0	None	-----	NDSWC Unpublished Data
140-78-14	AAA	Burleigh	2008	539.8	5.9	3.2	None	-----	Randich, 1975, p. 213
141-78-35	BBB	Burleigh	2007	562.7	3.7	.9	None	-----	Randich, 1975, p. 221
141-78-05	DDD	Burleigh	2006	588.3	1.5	3.0	3.0-4.6	A1318	Randich, 1975, p. 221
141-82-22	CDA	Oliver	3725	532.2	11.6	6.7	None	-----	Croft, 1970, p. 57
141-88-23	DDC	Mercer	3650	684.3	195.1	6.1	None	-----	Croft, 1970, p. 66
141-90-19	CCD	Mercer	3433	634.0	158.5	82.3	218.5-230.7, 246.9-248.4	A1115-A1123	Croft, 1970, p. 75
142-79-26	DDD	Burleigh	2005	618.1	12.5	1.2	None	-----	Randich, 1965, p. 227
142-81-04	ADC	Burleigh	1984	507.8	2.4	85.9	16.8-18.3, 29.0-30.5, 33.5-35.1, 39.6-41.1, 51.8-56.4	A1309-A1315	Randich, 1965, p. 230-232
142-82-05	DAA	Oliver	3647	595.9	62.8	96.0	93.0-94.5, 97.5-100.6, 103.6-109.7, 114.3-118.9, 120.4-129.5, 134.1-135.6, 138.7-150.9, 155.4-158.5	A1129-A1155	Croft, 1970, p. 78

142-82-09	DDD	Oliver	3637	624.8	---	---	None	-----	Croft, 1970, p. 79
142-84-24	BBA	Oliver	3558	611.4	128.5	83.5	149.4-150.9, 153.9-155.4, 164.6-167.6, 169.2-175.3, 178.3-179.8, 196.6-198.1, 201.2-205.7, 208.8-211.8	A1088-A1102	Croft, 1970, p. 84-85
142-86-20	BBA	Oliver	3559	628.5	173.7	77.7	205.7-207.3, 213.4-214.5, 222.5-231.6, 234.7-236.2, 243.8-245.4	A1108-A1114	Croft, 1970, p. 89-90
142-92-09	DAB	Dunn	4467	606.6	213.4	100.6	280.4-283.5, 293.4-295.7	A1396-A1398	NDSWC Unpublished Data
143-85-03	DAD	Oliver	3557	605.9	134.1	61.0	170.7-172.2, 176.8-182.9	A1124-A1128	Croft, 1970, p. 106-107
143-93-09	BCB	Dunn	4600	650.1			None	-----	NDSWC Unpublished Data
144-75-15	AAA	Burleigh	1993	614.5	33.5	.6	None	-----	Randich, 1965, p. 241
144-76-12	BBB	Burleigh	2044	594.4	50.3	4.6	None	-----	Randich, 1965, p. 242-243
144-76-07	DAD	Burleigh	2052	588.0	41.1	4.6	None	-----	Randich, 1965, p. 242
144-77-23	CAC	Burleigh	2043	588.3	44.2	9.8	48.8-50.3	A1320	Randich, 1965, p. 245-246
144-77-18	DAA	Burleigh	1988	429.2	12.5	5.5	15.2-18.3	A1316-A1317	Randich, 1965, p. 245

144-79-01	CCB	Burleigh	2051	555.0	10.7	7.6	15.2-16.8	A1321	Randich, 1965, p. 251
144-82-26	BBA	Oliver	2690	508.4	19.8	4.6	19.8-24.4	A1156-A1158	Croft, 1970, p. 133
144-82-28	CBA	Oliver	3638	519.4	-----	-----	None	-----	Croft, 1970, p. 135
144-94-07	DAA	Dunn	4599	692.8			None	-----	NDSWC Unpublished Data
145-84-28	DCC	Mercer	2686	517.5	34.1	8.5	None	-----	Croft, 1970, p. 208
146-85-10	CBB	Mercer	3560	622.1	170.7	68.5	207.3-213.4, 248.4-249.9	A1083-A1087	Croft, 1970, p. 229
152-85-35	DDA	Ward	3201				None	-----	Pettyjohn, 1968, p. 83
157-85-16	D	Ward	NDGS 18	511.8			108.2-111.3, 144.8-146.3	A1399-A1401	Lemke, 1960, p. 11
163-101-35	CBB	Divide	3075	690.4			152.4-158.5, 161.5-164.6, 173.7-176.8, 179.8-185.9	A1402-A1407	Armstrong, 1965, p. 98
160-91-10	CC	Burke	NDGS 2892				None	-----	Armstrong, 1971, p. 21-22

REFERENCES

REFERENCES

Albritton, C. C., W. W. Schell, C. S. Hill, and J. R. Puryear. 1954. Foraminiferal populations in the Grayson Marl. Geol. Soc. Am. Bull. 65:327-336.

Anisgard, H. W. 1970. Causes of dominantly arenaceous foraminiferal assemblages in downdip Wilcox of Louisiana. Gulf Coast Assoc. Geol. Soc., Trans. 20:210-217.

Armstrong, C. A. 1965. Geology and ground water resources of Divide County, North Dakota. N. Dak. Geol. Surv., Bull. 45(II). 112 pp.

_____. 1971. Ground-water resources of Burke and Mountrail Counties. N. Dak. Geol. Surv., Bull. 55(III). 86 pp.

Ballard, N. 1942. Regional geology of Dakota basin. Am. Assoc. Pet. Geol., Bull. 26:1557-1584.

Bandy, O. L., and R. E. Arnal. 1960. Concepts of foraminiferal paleoecology. Am. Assoc. Pet. Geol., Bull. 44(12):1921-1932.

Bannahan, A. 1950. The foraminifera of the Marquez (Middle Eocene) Shale, Bastrup County, Texas. Masters Thesis. Univ. Tex.

Beckmann, J. P. 1957. Chiloguembelina Loeblich and Tappan and related foraminifera from the lower Tertiary of Trinidad, B.W.I. U. S. Nat. Mus., Bull. 215:83-95.

Benson, W. E. 1952. The geology of the Knife River area, North Dakota. U. S. Geol. Surv. Open-file Rep. 323 pp.

Berggren, W. A. 1972. A Cenozoic time-scale-some implications for regional geology and paleobiogeography. Lethaia 5(2):195-215.

_____. 1974. Paleocene benthonic foraminiferal, biogeography and paleoecology of Libya and Mali. Micropaleontology 20(4):449-465.

_____, and J. Aubert. 1975. Paleocene bethonic foraminiferal biostratigraphy, paleobiogeography and paleoecology of Atlantic Tethyan regions: Midway-type fauna. Palaeogeog., Palaeoclimat., Palaeoecol. 18(2):73-192.

Bermudez, P. J. 1952. Estudio sistematico de los Foraminiferos rotaliformes. Venezuela Minist. Minas and Hedrocarb. Bull. Geol. 2(4):1-230.

Bertels, A. 1964. Micropaleontologia del palloceno de General Roca (Prov. de Rio Negro). Rev. Museno La Plata (N. S.) 4(23): 125-184.

Bolli, H. M. 1957. The genera Globigerina and Globorotalia in the Paleocene-lower Eocene Lizard Springs Formation of Trinidad, B.W.I. U. S. Nat. Mus., Bull. 215:61-81.

Bolli, H. M. 1966. Zonation of Cretaceous to Pliocene maring sediments based on planktonic Foraminifera. Asoc. Venez. Geol. Mineria, y Petrol. Bol. Inform. 9:339-341.

Bornemann, L. G. 1874. Ueber die Foraminiferengattung Involuta. Deutche Geol. Gesell., Zeitschr. 26:702-749.

Brady, H. B. 1876. A monograph of the Carboniferous and Permian Foraminifera (the genus Fusulina excepted). The Paleontograph. Soc. London, p. 1-166; pls. 1-12.

_____. 1877. Supplementary note on the Foraminifera of the Chalk (?) of the New Britain Group. Geol. Mag., new. ser., decade 2. 4:534-536.

_____. 1884. Report on the Foraminifera dredged by HMC Challenger during the years 1873-1876. Rep. Scientific Results Explor. Voyage HMC Challenger, Zoology 9:1-814; pls. 1-115.

_____, W. K. Parker, and T. R. Jones. 1888. On some Foraminifera from the Abrohlos Bank. Zool. Soc. London, Trans. 12(7):211-239.

Bronnimann, P. 1953. Note on planktonic Foraminifera from Danian localities of Jutland, Denmark. Eclogae Geol. Helv. 45(2):339-341.

Brotzen, F. 1942. Die Foraminiferengattung Gavelinella nov. gen. and die Systematik der Rotaliiformes. Sver. Geol. Undersok 36(8) (Serv. C, no. 451):1-60.

_____. 1948. The Swedish Paleocene and its foraminiferal fauna. Sver. Geol. Unders., Ser. C, no. 1, 493 (Arsb. 42(2)). 144 pp. 19 pls.

Brown, R. W. 1948. Correlation of Sentinel Butte shale in western North Dakota. Am. Assoc. Pet. Geol., Bull. 32(7):1265-1274.

_____. 1962. Paleocene flora of the Rocky Mountains and Great Plains. U. S. Geol. Surv., Prof. Pap. 375. 119 pp.

_____, and R. W. Lemke. 1948. Newly discovered outcrops of the Cannonball Formation in North Dakota. Science 107:624-625.

Burrows, H. W., and R. Holland. 1897. The Foraminifera of the Thanet Beds of Pegwell Bay. Geol. Assoc., Proc. 15:19-52.

Calvert, W. R., A. L. Beekly, V. H. Barnett, and M. A. Pishel. 1914. Geology of the Standing Rock and Cheyenne River Indian reservations, North and South Dakota. U. S. Geol. Surv., Bull. 575. 59 pp.

Campbell, M. R. 1916. Guidebook of the western United States, pt. 4, The Northern Pacific Route with a side trip to Yellowstone Park. U. S. Geol. Surv., Bull. 611. 218 pp.

Carlson, C. G. 1973a. Generalized bedrock geologic map of North Dakota (revised Nov., 1973). N. Dak. Geol. Surv. Misc. Map 16.

_____. 1973b. Oral communication.

Carpenter, W. B., W. K. Parker, and T. R. Jones. 1862. Introduction to the study of Foraminifera. Roy. Soc. Publs. 319 pp.

Carsey, D. O. 1926. Foraminifera of the Cretaceous of central Texas. Tex., Univ., Bull. 2612:1-56.

Cheatham, A. H., and J. E. Hazel. 1969. Binary (presence-absence) similarity coefficients. J. Paleontol. 43:1130-1136.

Children, J. G. 1823. Lamarck's genera of shells, translated from the French by J. G. Children with plates from original drawings by Miss Anna Children. The Author, London. 177 pp.

Clayton, L. 1972. Roadlog. Pages 2-30 in F. T. C. Ting, ed. Depositional environments of the lignite-bearing strata in western North Dakota. N. Dak. Geol. Surv. Misc. Series 50.

Cloud, P. E., Jr. 1955. Physical limits of glauconite formation. Am. Assoc. Pet. Geol., Bull. 39(4):484-492.

Cole, W. S. 1927. A foraminiferal fauna from the Guaybal Formation in Mexico. Bull. Am. Paleontol. 14:1046; pls. 1-5.

Cooper, C. L. 1944. Smaller foraminifera from the Porter's Creek Formation (Paleocene) of Illinois. J. Paleontol. 18:343-354.

Costa, O. G. 1839. Descrizione di alcune specie nuove di testacei freschi e fossili del regno delle due Sicilie. R. Accad. Sci. Napoli, Cl. Fis. Storia Nat., Atti. 4:175-192.

_____. 1856. Paleontologia del regno di Napoli, Parte II. Accad. Pont. Napoli Atti. 7(2):113-378.

Croft, M. G. 1970. Ground water basic data, Mercer and Oliver Counties, North Dakota. N. Dak. Geol. Surv., Bull. 56(II). 268 pp.

_____. 1974. Ground-water basic data for Adams and Bowman Counties, North Dakota. N. Dak. Geol. Surv., Bull. 65. 294 pp.

Cushman, J. A. 1910. A monograph of the foraminifera of the North Pacific Ocean. U. S. Nat. Mus., Bull. 71(1) Astrorhizidae and Lituolidae. 134 pp.

_____. 1911. A monograph of the foraminifera of the North Pacific Ocean, Pt. 2. Textulariidae. U. S. Nat. Mus., Bull. 71(2). 108 pp.

_____. 1913. A monograph of the foraminifera of the North Pacific Ocean, Pt. 3. Lagenidae. U. S. Nt. Mus., Bull. 71. 125 pp.

_____. 1926. Foraminifera of the typical Monterey of California. Cushman Lab. Foram. Res., Contr. 2(3):53-69.

_____. 1927a. An outline of a re-classification of the foraminifera. Cushman Lab. Foram. Res., Contr. 3(1):1-105.

_____. 1927b. The designation of some genotypes in the foraminifera. Cushman Lab. Foram. Res., Contr. 3(4):188-190.

_____. 1939. A monograph of the foraminiferal family Nonionidae. U. S. Geol. Surv., Prof. Pap. 191. 100 pp.

_____. 1940. Midway foraminifera from Alabama. Cushman Lab. Foram. Res., Contr. 16(3):51-74.

_____. 1944. A Paleocene foraminiferal fauna from the Coal Bluff marl member of the Naheola Formation of Alabama. Cushman Lab. Foram. Res., Contr. 20(2):29-50.

_____. 1948. Additional new foraminifera from the American Paleocene. Cushman Lab. Foram. Res., Contr. 24(2):43-45.

_____. 1951. Paleocene foraminifera of the Gulf Coastal Region. U. S. Geol. Surv., Prof. Paper 232. p. 1-75.

_____, and A. M. Dusenbury Jr. 1934. Eocene foraminifera of the Poway conglomerate of California. Cushman Lab. Foram. Res., Contr. 10(3):54.

_____, and J. B. Garrett. 1939. Eocene Foraminifera of Wilcox age from Woods Bluff, Alabama. Cushman Lab. Foram. Res., Contr. 15(4):77-89.

_____, and Y. Ozawa. 1930. A monograph of the foraminiferal family Polymorphinidae, Recent and fossil. U. S. Nat. Mus., Proc. 77:1-195; pls. 1-40.

_____, and G. M. Ponton. 1932. An Eocene foraminiferal fauna of Wilcox age from Alabama. Cushman Lab. Foram. Res., Contr. 8(3):51-72.

Cushman, J. A., and H. H. Renz. 1942. Eocene, Midway foraminifera from Soldado Rock, Trinidad. Cushman Lab. Foram. Res., Contr. 18(1):1-14.

_____, and R. M. Stainforth. 1947. A new genus and some new species of foraminifera from the upper Eocene of Ecuador. Cushman Lab. Foram. Res., Contr. 23(4):77-80.

_____, and A. ten Dam. 1948. Pseudoparrella a new generic name, and a new species of Parrella. Cushman Lab. Foram. Res., Contr. 24(3):49-50.

_____, and R. Todd. 1942. The foraminifera of the type locality of the Naheola Formation. Cushman Lab. Foram. Res., Contr. 18:25-26.

_____, and_____. 1946. A foraminiferal fauna from the Paleocene of Arkansas. Cushman Lab. Foram. Res., Contr. 22(2):45-65.

_____, and_____. 1949. Species of the genera Allomorphina and Quadrimorphina. Cushman Lab. Foram. Res., Contr. 25(3):59-72.

Cvancara, A. M. 1965. Bivalves and biostratigraphy of the Cannonball Formation (Paleocene) in North Dakota. Ph.D. Dissertation. Univ. Mich. 470 pp.

_____. 1966. Revision of the fauna of the Cannonball Formation (Paleocene) of North and South Dakota, Part I, Bivalvia. Univ. of Mich. Mus. Paleontol., Contr. 20(10):277-374.

_____. 1970a. North Dakota's state fossil. N. Dak. Quart. 32(3): 31-35.

_____. 1970b. Teredinid (Bivalvia) pallets from the Paleocene of North America. Paleontology 13(4):619-622.

_____. 1972a. Summary of the Cannonball Formation (Paleocene) in North Dakota. Pages 69-73 in F. T. C. Ting, ed. Depositional environments of the lignite-bearing strata in western North Dakota. N. Dak. Geol. Surv. Misc. Series 50. 134 pp.

_____. 1972b. Field notes from June 8, 1972.

_____. 1976. Geology of the Cannonball Formation (Paleocene) in the Williston Basin, with reference to uranium potential. N. Dak. Geol. Surv. Rep. of Invest. 57. 22 pp.

Czjzek, J. 1849. Uber zwei neue Arten von Foraminiferen aus dem Tegel von Baden und Mollersdorf. Freunde Naturwiss. Wien, Ber. Mitteil. 5(6):50-51.

Detling, M. R. 1946. Foraminifera of the Coos Bay Lower Tertiary, Coos County, Oregon. J. Paleontol. 20(4):348-361.

Dons, C. 1942. Craterella albescens, n. gen., n. sp., ein neuer Foraminifer. K. Norske Vidensk. Selsk., Forhandl. 14(36):136.

Dorf, E. 1940. Relationship between floras of type Lance and Fort Union Formations. Geol. Soc. Am., Bull. 51:213-236.

Drooger, C. W. 1952. Foraminifera from Cretaceous-Tertiary-Transitional strata of the Hodna Mountains, Algeria. Cushman Found. Foram. Res., Contr. 3(2):89-103.

Eimer, G. H. T. and C. Fickert. 1899. Die Artbildung und Verwandtschaft bei den Foraminiferen, Entwurf einer naturlichen Eintheilung derselben. Zeitschr. Wiss. Zool. 65(4):527-636.

Ellison, S. P., Jr. 1951. Microfossils as environmental indicators in marine shales. J. Sed. Petrol. 21(4):214-225.

Feldman, R. M. 1972. First report of Hercoglossa ulrichi (White, 1882) (Cephalopoda: Nautilida) from the Cannonball Formation (Paleocene) of North Dakota, U.S.A. Malacologia 11(2):407-413.

_____, and F. D. Holland, Jr. 1971. A new species of lobster from the Cannonball Formation (Paleocene) of North Dakota. J. Paleontol. 45(5):838-843.

Fenner, W. E. 1974. The foraminiferids of the Cannonball Formation (Paleocene, Danian) and their paleoecologic significance: Grant, Morton and Oliver Counties, North Dakota. M.S. Thesis, Univ. N. Dak. 135 p.

Fichtel, L. von, and J. P. C. von Moll. 1798. Testacea microscopica aliaque minuta ex generbus Argonauta et Nautilus ad naturam picta et descripta (Microscopishe und andere Klein Schalthiere aus den Geschlechtern Argonaute und Schiffer). Camesina, Wien. 123 pp.

Fleming. J. 1828. A history of British animals, exhibiting the descriptive characters and systematic arrangement of the genera and species of quadrupeds, birds, fishes mollusca and radiata of the United Kingdom. Edinburgh.

Fox, S. K., Jr., and R. K. Olsson. 1969. Danian planktonic foraminifera from the Cannonball Formation in North Dakota. J. Paleontol. 43(6):1397-1404.

Fox, S. K., Jr., and R. J. Ross, Jr. 1940. Foraminiferal evidence for the Midway (Paleocene)age of the Cannonball marine beds in North Dakota. Geol. Soc. Am., Bull. 51:1970. (Abstr.)

_____, and _____. 1942. Foraminiferal evidence for the Midway (Paleocene) age of the Cannonball Formation in North Dakota. J. Paleontol. 16:660-673.

Frye, C. K. 1964. Marine tongues in the Hell Creek Formation, North Dakota. The Compass 41(2):167-171.

Gernat, R. E., and R. V. Kesling. 1966. Foraminiferal paleoecology of the Oligocene middle Frio in Chambers County, Texas. Gulf Coast Assoc. Geol. Soc., Trans. 16:131-158.

Greiner, G. O. G. 1970. Distribution of major benthonic foraminiferal groups on the Gulf of Mexico continental shelf. Micropaleontology 16(1):83-101.

Groenewold, G. 1976. Oral communication.

Haeckel, E. 1894. Systematische phylogenic Entwurf eines naturlichen Systems der Organismen auf Grund ihrer Stammesgesohichte. Theil 1, Systematische Phylogenie der Protisten und Pflanzen. Geor Reimer, Berlin. 400 pp.

Hall, A. V. 1969. Avoiding informational distortion in automatic grouping programs. Syst. Zool. 18(3):318-329.

Hansen, H. J. 1970. Danian foraminifera from Nugssuaq, West Greenland. Meddel. Gronland 193(2). 132 pp.

Haque, A. F. M. 1956. The foraminifera of the Ranekot and Laki of Nammal Gorge, Salt Range. Geol. Surv. Pakistan, Paleontol. Pakistanica 1:1-300.

Harris, R. W., and B. I. Jobe. 1951. Microfauna of basal Midway outcrops near Hope, Arkansas. Transcript Press, Norman, Ok. 113 pp.

Hayden, F. V. 1857. Notes explanitory of a map of the country bordering on the Missouri River from the mouth of the Platte River to Fort Benton, in lat. 47°30' N., long. 110°30' W. Phila. Acad. Nat. Sci., Proc. 9:109-116.

Hazel, J. E. 1970. Binary coefficients and clustering in biostratigraphy. Geol. Soc. Am., Bull. 81(11):3237-3252.

Hedgpeth, J. W. 1957. Classification of marine environments. Pages 17-28 in J. W. Hedgpeth, ed. Treatise on marine ecology and paleoecology. Geol. Soc. Am., Mem. 67.

Hickey, L. J. 1972. Stratigraphic summary of the Golden Valley Formation (Paleocene-Eocene) of western North Dakota. Pages 105-122 in F. T. C. Ting, ed. Depositional environments of the lignite-bearing strata in western North Dakota. N. Dak. Geol. Surv. Misc. Series 50.

Hillebrandt, A. von. 1965. Foraminiferen-Stratigraphie im Altertiar von Zumaya (Provinz Gurpuzcoa, N W Spanien) und ein Vergleich mit anderen Tethys-Gabieten. Bayer. Akad. Wiss. Math.-Naturwiss. Kl. 123:1-62.

Hofker, J. 1956. Tertiary foraminifera of coastal Ecuador, Part II. Additional notes on the Eocene species. J. Paleontol. 30: 891-958.

Holland, F. D., Jr., and A. M. Cvancara. 1958. Crabs from the Cannonball Formation (Paleocene) of North Dakota. J. Paleontol. 32 (3):495-505.

Holzman, R. C. 1973. Letter to A. M. Cvancara dated Dec. 17, 1973.

Holzman, R. C. 1975. Letter to C. G. Carlson, N. Dak. Geol. Surv., dated October 15, 1975.

Howard, J. D. 1971. Comparison of the beach-to-offshore sequence in modern and ancient sediments. Pages 148-183 in Howard, Valentine, and Warme, eds. Recent Advances in paleoecology and Ichnology. Amer. Geol. Inst. Short Course Lecture Notes.

Howe, H. V. 1939. Louisiana Cook Mountain Eocene Foraminifera. La. Geol. Surv., Bull. 14. 122 pp.

Husezima, R., and M. Maruhasi. 1944. A new genus and thirteen new species of foraminifera from the core-sample of Kasiwazaki oilfield, Nigata-ken. Sigenkagaku Kenkyusyo J. 1(3):391-400.

Imbrie, J., and E. G. Purdy. 1962. Classification of modern Bahamian carbonate sediments. Am. Assoc. Pet. Geol., Mem. 1:253-272.

Jacob, A. F. 1975. Criteria for the differentiating the Tongue River and Sentinel Butte Formations (Paleocene), North Dakota. N. Dak. Geol. Surv. Rep. Invest. 53. 55 pp.

Jeletzky, J. A. 1960. Youngest marine rocks in western interior of North America and the age of the Triceratops-beds: with remarks on comparable dinosaur-bearing beds outside North America. Int. Geol. Congr. Rep. XXIst Sess. Norden, Pt. V. The Cretaceous-Tertiary Boundary. Copenhagen. p. 25-40.

_____. 1962. The allegedly Danian dinosaur-bearing rocks of the globe and the problem of the Mesozoic-Cenozoic boundary. J. Paleontol. 36(5):1005-1018.

Jennings, P. H. 1936. A microfauna from the Monmouth and basal Rancocas Groups of New Jersey. Bull. Am. Paleontol. 23(78):161-234.

Jepsen, G. L. 1940. Paleocene faunas of the Polecat Bench Formation, Park County, Wyoming. Am. Philos. Soc., Proc. 83:217-340.

Kellough, G. R. 1959. Biostratigraphic and paleoecologic study of Midway foraminifera along Tehuacana Creek, Limestone County, Texas. Gulf Coast Assoc. Geol. Soc., Trans. 9:146-160.

Kellough, G. R. 1965. Paleoecology of the Foraminiferida of the Wills Point Formation (Midway Group) in northeast Texas. Gulf Coast Assoc. Geol. Soc., Trans. 15:73-153.

Khalilov, D. M. 1951. O faune foraminifer i rasehlenenii oligotsenovykh otlozheniy severovostochnogo predgorya Malogo Kavaga. Akad. Nauk Azerbardzhanskoi SSR, Izvestya 3:43-61.

_____. 1956. O Pelagicheskoy faune foraminifer paleogenovykh otlozheniy Azerbaydzhana. Akad. Nauk Azerbaidzhanskoi SSR, Inst. Geol. 17:234-255.

Kline, V. H. 1943. Clay County fossils: Midway Foraminifera and Ostracoda. Miss. Geol. Surv., Bull. 53:1-98.

Laird, W. M., and R. H. Mitchell. 1942. The geology of the southern part Morton County, North Dakota. N. Dak. Geol. Surv., Bull. 14. 42 pp.

Lamarck. 1804. Suite des mémoires sur les fossiles des environs de Paris. Mus. Nat. Historie Nat. Paris, Ann. 5:179-188.

_____. 1812. Extrait du cours de zoologie du Muséum d'Histoire Naturelle sur les animaux invertébres. Paris. 127 pp.

LeCalvez, Y. 1949. Révision des Foraminiferes Lutétiens du Bassin de Paris. II. Rotaliidae et familles affines. Carte Géol. Détaillee France, Mém. 54 pp.

Lemke. R. W. 1960. Geology of the Souris River Area, North Dakota. U. S. Geol. Surv., Prof. Pap. 325. 138 pp.

Leonard, A. G. 1908. The geology of southwestern North Dakota with special reference to coal. State Geol. Surv. N. Dak. 5th Bienn. Rep. p. 27-114.

_____. 1919. The geology of North Dakota. J. Geol. 27(1):1-27.

Leriche, M. 1942. Contribution a l'étude faunes ichthyalogiques maime des terrains Tertiares de la Plaine Cotiere Atlantique et du centre des États-Unis. Soc. Géol. France, Mem. 45. 20(2-4). 110 pp.

Lindberg, M. L. 1944. Heavy mineral correlation of the Fox Hills, Hell Creek, and Cannonball sediments, Morton and Sioux Counties, North Dakota. J. Sed. Petrol. 14(3):131-143.

Linné, C. 1758. System naturae per regna tria naturae, secundum classes, ordines, genera, species cum characteribus, differentiis, synoymus, locis, 10th ed. G. Engelman, Lipsiae. 1:1-824.

Lloyd, E. R. 1914. The Cannonball River lignite field, Morton, Adams, and Hettinger Counties, North Dakota. U. S. Geol. Surv., Bull. 541:243-291.

_____, and C. J. Hares. 1915. The Cannonball marine member of the Lance Formation of North and South Dakota and its bearing on the Lance-Laramie problem. J. Geol. 23(6):523-547.

Loeblich, A. R., Jr., and H. Tappan. 1956. Chiloguembelina, a new Tertiary genus of the Heterohelicidae (Foraminifera). Wash. Acad. Sci. J. 46(11):340.

_____, and_____. 1957. Planktonic foraminifera of Paleocene and early Eocene age from the Gulf and Atlantic Coastal Plains. U. S. Nat. Mus., Bull. 215:173-197.

_____, and_____. 1961. Suprogeneric classification of the Rhizopodea. J. Paleontol. 35:245-330.

_____, and_____. 1964. Treatise on invertebrate paleontology, Part C, Protista 2, Sarcodina (Foraminiferida). Geol. Soc. Am., Univ. Kan. Press. 900 pp.

Lowman, S. W. 1949. Sedimentary facies in Gulf Coast. Am. Assoc. Petrol. Geol., Bull. 33:1939-1997.

Ludlow, W. 1875. Report of a reconnaissance of the Black Hills of Dakota made in the summer of 1874. Washington Govt. Printing Off., U. S. Engineer Dept., U. S. Army War Dept. 121 pp.

Mailhe, A. R., N. Malumian, and A. C. Riccardi. 1967. Contribucion al concimiento de los Foraminiferos del Rocanense de la Cuenca de Anelo (Provincia de Neuquen). Ameghiniana, Rev. Assoc. Paleont. Argentina 5(1):21-33.

Malumian, N. 1970. Foraminiferos danianos de la Formacian Pedro Luro, Provincia de Buenos Aires, Argentina. Amegheniana 7(4):355-367.

Meek, R. B., and F. V. Hayden. 1856. Descriptions of new species of Gasteropoda from the Cretaceous Formation of Nebraska Territory. Phila. Acad. Nat. Sci., Proc. 8:63-69.

_____, and_____. 1857. Descriptions of new species and genera of fossils collected by Dr. F. V. Hayden in Nebraska Territory, under the direction of Lieut. G. K. Warren, U. S. Topographical Engineer, with some remarks on Tertiary and Cretaceous formations of the north-west, and the parallelism of the latter with those of other portions of the United States and territories. Phila. Acad. Nat. Sci., Proc. 9:117-148.

Meek, F. B., and F. V. Hayden. 1858. Descriptions of new organic remains collected in Nebraska Territory in the year 1857, by Dr. F. V. Hayden, geologist to the exploring expedition under the command of Lieut. G. K. Warren, Top. Engr. U. S. Army, together with some remarks on the geology of the Black Hills and portions of the surrounding country. Phila. Acad. Nat. Sci., Proc. v. 41-59.

_____, and _____. 1860. Descriptions of new organic remains from the Tertiary, Cretaceous and Jurassic rocks of Nebraska. Phila. Acad. Nat. Sci., Proc. (for 1860) p. 175-185.

Mello, J. F., and M. A. Buzas. 1968. An application of cluster analysis as a method of determining biofacies. J. Paleontol. 42 (3):747-758.

Montagu, G. 1808. Testacea Britannica, Supplement. S. Woolmer, Exeter, England. 183 pp.

Montfort, Denys de. 1808. Conchyliologie systematique et classification methodique des coquilles. 1:1-409.

Moore, W. L. 1976. Oral communication.

Murray, J. W. 1973. Distribution and ecology of living benthic foraminiferids. Crane, Russak and Company, New York. 274 pp.

Nauss, A. W. 1947. Cretaceous microfossils of the Vermillion area, Alberta. J. Paleontol. 21(4):329-343.

Nogan, D. S. 1964. Foraminifera, stratigraphy and paleoecology of the Aquia Formation of Maryland and Virginia. Cushman Found. Foram. Res., Spec. Pub. 7. 50 pp.

Olsson, R. K. 1960. Foraminifera of Cretaceous and earliest Tertiary age in the New Jersey Coastal Plain. J. Paleontol. 34(1):1-58.

_____. 1976. Written communication of Feb. 10, 1976.

Orbigny, A. D. d'. 1826. Tableau méthodique de la classe des Céphalopodes. Ann. Sci. Nat. Paris Ser. 1, 7:245-314.

_____. 1839a. Foraminifères. in R. De La Sagra, Histoire physique, politique et. naturelle de lile de Cuba. 224 pp.

_____. 1839b. Foraminifères des Iles Canaries. in Hist. Nat. des Iles Canaries par. MM. P. Barker-Webet Sabin Berthelot. Bethune, Paris, France. tome 2(2):128.

_____. 1846. Foraminifères fossiles du Bassin Tertiare de Vienne (Autriche). Gide et Comp., Paris. 312 pp.

Parker, W. K., and T. R. Jones. 1859-72. On the nomenclature of foraminifera. Pt. 1, On the species enumerated by Linnaeous and Gmelin, ser. 3, 3:474-482 (1859); Pt. 2, On the species enumerated by Walker and Montagu, ser. 3, 4:333-351 (1859); Pt. 3, ser. 3, 5:174-183 (1860); Pt. 4, ser. 3, 6:29-40 (1860); Pt. 8, Textulariia, ser. 3, 11:91-98 (1863); pt. 10, The species enumerated by d'Orbigny in the "Annales des Science Naturelles, v, vii, 1826, ser. 3, 12:429-441 (1863); Pt. 15, The species figured by Ehrenberg, ser. 4, 10:184-200 (1872).

_____, and _____. 1865. On some Foraminifera from the North Atlantic and Arctic Oceans, including Davis Straits and Baffins Bay. Philos. Trans. 155:325-441.

Pettyjohn, W. A. 1968. Geology and ground water resources of Renville and Ward Counties. Pt. 2, Ground water basic data. N. Dak. Geol. Surv., Bull. 50. 302 pp.

Phleger, F. B. 1960. Ecology and distribution of recent foraminifera. The Johns Hopkins Press. 297 pp.

Plummer, H. J. 1926. Foraminifera of the Midway Formation in Texas. Univ. Tex., Bull. 2644:1-206.

_____. 1931. Some Cretaceous foraminifera in Texas. Univ. Tex., Bull. 3101:109-203.

_____. 1933. Foraminiferal evidence of the Midway-Wilcox contact in Texas. Univ. Tex., Bull. 3201:51-68.

Postuma, J. A. 1971. Manual of planktonic foraminifera. Elsevier Pub. Co., Amsterdam. 420 pp.

Pozarsyka, K. 1965. Foraminifera and biostratigraphy of the Danian and Montian in Poland. Paleontol. Pol. 14:156 pp.

_____, and J. Szczechura. 1968. Foraminifera from the Paleocene of Poland, their ecological and biostratigraphical meaning. Paleontol. Pol. 20:107 pp.

Randich, P. G. 1965. Geology and ground water resources of Burleigh County, North Dakota, Part II, Ground water basic data. N. Dak. Geol. Surv., Bull. 42. 273 pp.

_____. 1975. Ground-water basic data for Grant and Sioux Counties, North Dakota. N. Dak. Geol. Surv., Bull. 67. 303 pp.

Reuss, A. E. 1844. Geognostiche Skizzen aus Bohmen 2:304 pp.

_____. 1845. Die Versteinerungen der Bohmischen Kreideformation, Stuttgart, Deutchland. E. Schweizerbart. 1:1-148. (Abstr.)

Reuss, A. E. 1850. Neues Foraminiferen aus der Schichten des Osterreichischen Tertiarbeckens. K. Akad. Wiss. Wien, math.-naturwiss. Cl., Denkschr. 1:365-390.

_____. 1851. Uber die fossilen Foraminiferen und Entomostraceen der Septarienthone der Umgegend von Berlin. Zeit. deutch. Geol. Gesell. 3:49-92.

_____. 1862. Entwurf einer systematischen zusammenstellung der Foraminiferen. K. Akad. Wiss. Wein, math.-naturwiss. Cl., Sitzungber. 44:365.

_____. 1863. Betrage zur kentniss der tertiaren Foraminiferen-fauna (Zweite Folge). K. Akad. Wiss. Wien, math.-naturwiss. Cl., Sitzungsber 48(1):36-71.

Risso, A. 1826. Histoire naturelle des principales productions de l'Europe meridionale et particulierement de celles des environs de Nice et des Alpes maritimes. F-G Levrault, Paris, 4:1-439.

Robertson, E. B. 1975. Pollen and spores as stratigraphic indices to the North Dakota Paleocene. Ph.D. Dissertation. Univ. of Minn. 192 pp.

Roemer, F. A. 1838. Die cephalopoden des norddeutschen tertiaren Meeressandes. Neues Jahr. Mineral. p. 381-394.

Sagra, R. de la. 1839. Foraminiferes. Histoire phys. pol. and nat. de l'isle de Cuba. 224 pp.

Schubert, R. J. 1908. Beitrage zu einer naturlichen Systematik der Foraminiferen. Neues Jahrb. Mineral. Geol. und Paleont. 25:232-260.

Schwager, C. 1866. Fossile Foraminiferen von Kar-Nicobar. Novara-Exped. Geol. 2:187-268.

_____. 1883. Die Foraminiferen aus den Eocaenablagerungen der libyschen Wuste und Aegyptens. in K. A. Von Zittel, ed. Beitrage zur Geologie und Palaontologie der libyschen Wuste und der angrenzenden Gebeite. Palaeontographica 30(1):81-153.

Sherborn, C. D., and F. Chapman. 1886. On some microzoa from the London Clay exposed in the Drainage Works, Picadilly, London. J. Roy. Mic. Soc. p. 737-763.

Shifflett, E. 1948. Eocene stratigraphy and foraminifera of the Aquia Formation. Md. Dept. Geol., Mines and Water Resour., Bull. 3:1-93.

Sloan, R. E. 1970. Cretaceous and Paleocene terrestrial communities of western North America. N. Am. Paleontol. Conv., Chicago, 1969. Proc. E, p. 427-453.

Sokal, R. R., and F. J. Rohlf. 1962. The comparison of dendrograms by objective methods. Taxon 11:33-40.

Spock, L. E. 1962. Guide to the study of rocks, 2nd ed. Harper and Row, New York. 298 pp.

Stainforth, R. M., J. L. Lamb, H. Luterbacher, J. H. Beard, and R. M. Jeffords. 1975. Cenozoic planktonic foraminiferal zonation and characteristics of index forms. Univ. Kan. Paleontol. Contr. Art. 62. 425 pp.

Stand, E. 1943. Miscellanea nomenclatonia zoologica et palaeontologica. Archiv Naturgeschichte 92(A(A8)):30-69.

Stanley, E. A. 1965. Upper Cretaceous and Paleocene plant microfossils and Paleocene Dinoflagellates and Hystrichosphaerids from northwestern South Dakota. Bull. of Am. Paleontol. 49(222):179-384.

Stanton, T. W. 1920. The fauna of the Cannonball marine member of the Lance Formation. U. S. Geol. Surv., Prof. Pap. 128-A:1-66.

Swain, F. M. 1949. Early Tertiary Ostracoda from the western interior United States. J. Paleontol. 23(2):172-181.

Terquem, O. 1882. Les Foraminiferes de 1'Eocene des environs de Paris. Soc. Geol. Grance, Mem. 3. 2:1-193.

Thalmann, H. E. 1939. Bibliography and index to new genera, species and varieties of Foraminifera. (for 1936) J. Paleontol. 13: 425-465.

Thom, W. T. Jr., and C. E. Dobbin. 1924a. Stratigraphy of Cretaceous-Eocene transition beds in eastern Montana and the Dakotas. Geol. Soc. Am., Bull. 35:481-506.

_____, and _____. 1924b. Correlation of the Lebo member of the Fort Union with Cannonball member of the Lance. Wash. Acad. Sci. J. 14(7):165.

Toula, F. 1915. Uber den marinen Tegel von Neudorf an der March (Deveny-Ujfala) in Ungarn und seine Mikrofauna. K. K. Geol. Reichsanst., Jahrb. 64(4):635-674.

Toulmin, L. D. 1941. Eocene smaller Foraminifera from the Salt Mountain Limestone of Alabama. J. Paleontol. 15:567-611.

Valentine, J. W. 1971. The architecture of the present marine biosphere. Pages 81-103 in J. D. Howard, J. W. Valentine, and J. E. Warme, eds. Recent advances in paleoecology and ichnology. A.G.I. Short Course Lecture Notes. 268 pp.

Van Alstine, J. B. 1974. Paleontology of brackish-water faunas in two tongues of the Cannonball Formation (Paleocene, Danian), Slope and Golden Valley Counties, southwestern North Dakota. M.S. Thesis. Univ. N. Dak. 101 pp.

Vasilenko, V. P. 1954. Anomalinidy in iskopaemye foraminifery SSSR. VNIGRI, N.S. 80:282 pp.

_____, and E. V. Myatliuk. 1947. Foraminifery i stratigrafiya verkhnego mela yuzhnoembenskogo raiona. Pages 161-221 in Mikrofauna nefty anykhmestorozhdenii Kavkaza, Emby i Srednei Azii. VNIGRI, Gostopteknizdat, Leningrad-Moskow.

Vaughan, T. W. 1920. Corals from the Cannonball marine member of the Lance Formation. U. S. Geol. Surv., Prof. Paper. 128-A:61-66.

Williamson. 1858. On the Recent Foraminifera of Great Britain. Roy. Soc. Publs. 107 pp.

Wilson, E. E. 1957. An investigation of the corals from the Cannonball Formation (Paleocene) of North Dakota (abs.) N. Dak. Acad. Sci. Proc. 11:15-16.

Winchester, D. E., C. J. Hares, E. R. Lloyd, and E. M. Parks. 1916. The lignite field of northwestern South Dakota. U. S. Geol. Surv., Bull. 627. 169 pp.

Wood, S. V. 1842. A catalogue of shells from the Crag. Ann. and Mag. Nat. Hist. Ser. 1, 9:455-462.