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# Neogastropods (Melongenidae, Fasciolariidae, Turridae) from the Cannonball Formation (Paleocene: Thanetian), North Dakota and South Dakota

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NEOGASTROPODS (MELONGENIDAE, FASCIOLARIIDAE, TURRIDAE) FROM  
THE CANNONBALL FORMATION (PALEOCENE: THANETIAN?), NORTH  
DAKOTA AND SOUTH DAKOTA

by  
Brian Edward Silfer

Bachelor of Science with Honors in Geology,  
St. Lawrence University, 1986

A Thesis

Submitted to the Graduate Faculty

of the

University of North Dakota

in partial fulfillment of the requirements

for the degree of

Master of Science

Grand Forks, North Dakota

August  
1990

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This thesis submitted by Brian Edward Silfer in partial fulfillment of the requirements for the Degree of Master of Science from the University of North Dakota has been read by the Faculty Advisory Committee under whom the work has been done, and is hereby approved.

Alan M. Brancara  
(Chairperson)

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This thesis meets the standards for appearance and conforms to the style and format requirements of the Graduate School of the University of North Dakota, and is hereby approved.

Dean of the Graduate School

Permission

Title Neogastropods (Melongenidae, Fasciolaridae, Turridae) from the Cannonball Formation (Paleocene: Thanetian?), North Dakota and

South Dakota

Department Geology and Geological Engineering

Degree Master of Science

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Date 7/13/90

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS.....vi

ACKNOWLEDGMENTS.....viii

ABSTRACT.....x

INTRODUCTION.....1

    General Discussion

    Purpose of Study

    Previous Work

Stratigraphy

Paleontology

    Structural Setting

    Regional Stratigraphy

METHODS OF STUDY.....12

    Field work

    Specimen Preparation and Photography

    Materials

    Approach to Systematic Paleontology

    Subdivision of the Cannonball Formation

    Terminology

RESULTS.....24

    Analysis and Occurrence of Neogastropod Fauna

Taxonomic Analysis

Relative Abundance

Stratigraphic Occurrence of Species

Lithologic Occurrence of Species

INTERPRETATIONS.....32

    Paleoecology of Cannonball Neogastropods

    Cannonball Neogastropods as Paleoenvironmental Indicators

    Comparison with other Neogastropod Faunas

Late Cretaceous Faunas of the Western Interior

            Extinction of Western Interior Neogastropod Taxa

Paleocene Faunas

            Faunal Diversity

            Occurrence of Cannonball Species

    Source of the Cannonball Sea

    Age of the Cannonball Formation

CONCLUSIONS.....61

SYSTEMATIC PALEONTOLOGY.....	65
APPENDIX A . Cannonball Neogastropod Localities and Occurrences in North Dakota and South Dakota.....	181
REFERENCES CITED.....	202

LIST OF ILLUSTRATIONS

Plate

- 1. Neogastropods of the Cannonball Formation.....178
- 2. Neogastropods of the Cannonball Formation.....180

Figure

- 1. Generalized stratigraphic column for Upper Cretaceous and Paleocene strata in North Dakota.....8
- 2. Bedrock geologic map of western North Dakota and northwestern South Dakota showing the Cannonball, underlying undifferentiated Upper Cretaceous formations (Ku), overlying undifferentiated Tertiary formations (Tu) (after Bluemle, 1982; Darton, 1951), and the fossil localities used in this study.....16
- 3. Stratigraphic cross-section showing physical correlation of upper and middle bench-forming sandstones and lower, middle, and upper informal units.....21
- 4. Species diversity of Cannonball neogastropods by informal unit and lithology.....28
- 5. Lithologic occurrence of neogastropod families.....31
- 6. Geologic ranges of neogastropod genera from the Fox Hills (Erickson, 1974), Pierre (Sohl, 1967), and Cannonball Formations.....42
- 7. Camera lucida drawings of growth lines taken from the last whorl of two species of Rhombopsis Gardner and Deussenia Stephenson.....76
- 8. Camera lucida drawing of growth line taken from the posterior slope of the last whorl of Serrifusus dakotaensis (Meek and Hayden), holotype, USNM 256....95
- 9. Camera lucida drawings of growth lines taken from the last whorl of four specimens of Acamptogenotia varicosta n. sp.....114
- 10. Camera lucida drawings of growth lines taken from the last whorl of three species of Alticollarum n. gen.....121

11.	Camera lucida drawing of growth line taken from the penultimate whorl of <u>Orthosurcula longiforma</u> (Aldrich), holotype, USNM 645082.....	123
12.	Camera lucida drawings of growth lines taken from the last whorl of five species of <u>Amuletum</u> .....	135
13.	Camera lucida drawings of growth lines taken from the last whorl of two species of <u>Marshallaria</u> .....	139
14.	Camera lucida drawings of growth lines taken from the last whorl of two species of <u>Obtusicarina</u> n. gen. and one species of <u>Cochlespira</u> Conrad.....	146
15.	Camera lucida drawings of growth lines taken from the last whorl of two species of <u>Vitticoncha</u> n. gen.....	156
16.	Camera lucida drawings of growth lines taken from the penultimate whorl of species assigned to the turrinid genera <u>Coronia</u> De Gregorio and <u>Gemmula</u> Weinkauff.....	167



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## ABSTRACT

The Cannonball Formation of Paleocene age is a shallow-marine, clastic sequence exposed primarily in southwest-central North Dakota and northwestern South Dakota. The formation is characterized by alternating, poorly consolidated, relatively thin sandstone and thick mudstone units. The Cannonball neogastropod families Melongenidae, Fasciolaridae, and Turridae contain 20 species assigned to 15 genera based on 334 individuals from 50 localities. Four genera, Alticollarum, Obtusicarina, Vitticoncha, and Ericksonia are new, whereas Serrifusus, Mesorhytis, Rhombopsis, and Deussenia are first reported occurrences from Tertiary strata. Marshallaria is newly reported from North America and likely from the Northern Hemisphere. Twelve species are additions to the Cannonball fauna; of these, Acamptogenotia varicosta, Serrifusus sohli, Deussenia minuta, and Ericksonia clivilinea are newly described. Mesorhytis dakotensis is the most abundant species; the other species are generally rare.

No stratigraphic zonation of species was observed. The middle informal unit has the most diverse fauna with 16 species, followed by that of the lower with 15 and the upper with 11. The larger number of occurrences is in the sandstone lithology, whereas the greater number of individuals occurs in the mudstone. Cluster analyses indicate little or no correlation between substrate type and

species occurrence and that these neogastropods have no paleoenvironmental significance. These neogastropods are inferred to have been semi-infaunal or shallow infaunal predators.

Comparisons between the neogastropod faunas of the Cannonball and Late Cretaceous Fox Hills and Pierre Formations suggest that 60 percent of the Late Cretaceous genera and all of the species became extinct prior to Cannonball time. Five Cannonball neogastropods occur in the Agatdal Formation of West Greenland, two in the "greensands" of Copenhagen, Denmark, and one in the Aquia Formation of Maryland and Virginia. A northerly or northeasterly source for the Cannonball Sea is inferred as the simplest explanation for the large number of Cannonball species occurring in West Greenland. Furthermore, a connection with the North Atlantic most readily explains the mixture of cool and warmer water gastropod and bivalve genera in the Cannonball fauna, since most of these genera also occur in the West Greenland fauna. Absence of West Greenland "tropical" forms in the Cannonball fauna is attributed to oceanic cooling caused by mixing of North Atlantic and Arctic waters.

Occurrences of Cannonball neogastropods are restricted entirely to other late Paleocene faunas, and, therefore, a late Paleocene (Thanetian) age for the Cannonball Formation is tentatively suggested.

## INTRODUCTION

### General Discussion

The Cannonball Formation (Paleocene: Thanetian?) is a shallow-marine, clastic sequence that records the final phase of marine deposition in the Western Interior of North America. Known bedrock occurrences are restricted to western North Dakota and northwestern South Dakota; however, Canadian occurrences likely exist. Outcrops are scattered and are confined primarily to southwest-central North Dakota in Morton and Grant Counties with the best exposures occurring along the Cannonball and Heart Rivers.

The lithologies of the Cannonball are varied and consist predominantly of poorly consolidated sandstone and mudstone. Depositional environments are complex, consisting of bar, barrier-island beach, shoreface, tidal flat, lagoon, marsh, and estuarine. The vertical repetition of these environments in North Dakota, as reflected by the strata and fossils, suggests periodic transgression and regression of the Cannonball Sea.

Answers to such long-standing questions as the age of the Cannonball Formation, source of the Cannonball Sea, and the similarity between the molluscan faunas of the Cannonball and Late Cretaceous Formations of the Western Interior require detailed faunal comparisons. However, before meaningful comparisons can be made, the taxonomy of

the Cannonball fauna must be re-examined and updated. This study is a small contribution toward this end.

### Purpose of Study

The primary purpose of this study is to revise the taxonomy of part of the Cannonball neogastropods (Turridae, Fasciolaridae, Melongenidae), and to illustrate them fully. Secondary purposes include: (1) to study the paleoecology and paleoenvironmental significance of the Cannonball neogastropods; (2) to compare the Cannonball neogastropod fauna with those of the Upper Cretaceous Fox Hills Formation and Pierre Shale in order to determine the impact of Late Cretaceous extinctions on Western Interior neogastropod taxa; and (3) to gain further insight into the age of the Cannonball Formation and the source of the Cannonball Sea in light of the revised neogastropod taxonomy.

### Previous Work

#### Stratigraphy

Lloyd (1914, p. 247) first called attention to the upper 250 to 300 feet of the "Lance formation" which was ". . . markedly different in lithologic character from the underlying more typical Lance, and has been found at numerous places to contain the remains of a marine fauna, . . ." These strata were mapped separately as the "Cannonball marine member of the Lance formation." Lloyd

(1914) defined the type area as Tps. 132 and 133 N. and R. 88 W. along the Cannonball River where the unit is well exposed. Lloyd and Hares (1915) later added R. 87 W. to the type area. The "Cannonball marine member" was first given formational status by Fox and Ross (1942). A detailed historical summary of Cannonball stratigraphy was given by Cvancara (1965).

A few recent works have dealt with the sedimentology and paleoenvironments of the Cannonball Formation and associated Tertiary nonmarine units in the Cave Hills of Harding County, South Dakota (Goodrum, 1982; Monnens, 1980; Best, 1987). These authors are in general agreement that Cannonball strata in this area represent high-energy, nearshore or beach environments.

In the Cave Hills, the Cannonball is represented primarily by two sandstone sequences (Monnens, 1980; Goodrum, 1983; Best, 1987) which were previously considered to be part of the Tongue River Member of the Fort Union Formation. Pipiringos et al. (1965, p. 10) first alluded to the presence of Cannonball strata in the Cave Hills when they stated that vertebrate fossils collected from the Tongue River Member suggested deposition of the enclosing sediments in a marine or brackish-water environment. This evidence led them to conclude that: "Perhaps the Cannonball shoreline at times extended as far west as the west side of the North Cave Hills where it had a northward trend . . . ."

Jacob (1976) confirmed that these sandstones are within the Cannonball.

The stratigraphic terminology used in this study follows that of the North Dakota Geological Survey (Bluemle, 1983) which recognizes the Cannonball as a formation within the Fort Union Group. The United States Geological Survey, however, considers the Cannonball as a member of the Fort Union Formation.

### Paleontology

The known Cannonball biota consists of bivalves (Cvancara, 1965; 1966; 1970a; 1970b; Van Alstine, 1974); gastropods (Stanton, 1920); scaphopods (Stanton, 1920); nautiloid cephalopods (Feldmann, 1972); lobsters (Feldmann and Holland, 1971); crabs (Holland and Cvancara, 1958); ostracodes (Swain, 1949); foraminiferids (Fox and Ross, 1942; Fox and Olsson, 1969; Fenner, 1974a; 1974b; 1976; Van Alstine, 1974); bryozoans (Cvancara, 1965); scleractinian corals (Vaughan, 1920; Wilson, 1957); sharks, skates, rays, ratfishes, turtles, crocodiles or alligators (Stanton, 1920; Leriche, 1942; Pipiringos et al., 1965; Best, 1987; Cvancara and Hoganson, 1987; Hoganson and Cvancara, 1989); spores and pollen, hystriospherae and dinoflagellates (Stanley, 1965; Robertson, 1975); trace fossils, including Ophiomorpha (Cvancara, 1965; Van Alstine, 1974; Monnens, 1980; Goodrum, 1982; Best, 1987), Arenicolites, Rhizocorallium, Skolithos-



like tubes, and possibly Cylindrichnus (Best, 1987); driftwood (Cvancara, 1965); worms (Brown and Lemke, 1948; Lemke, 1960); and starfish, otoliths, and echinoids (Cvancara, 1988).

### Structural Setting

The occurrences and attitudes of Cretaceous and Tertiary strata in North Dakota are influenced by the intracratonic Williston Basin. The Williston Basin is a structural and sedimentary basin which covers 51,600 square miles (133,644 sq. km) of North Dakota as well as northwestern South Dakota, southern Manitoba and Saskatchewan, and eastern Montana. The sedimentary sequence attains a maximum thickness of 15,128 feet (4611 m) in McKenzie County and ranges in age from Cambrian to Tertiary (Carlson and Anderson, 1965; Carlson, 1982). Major structural features within the basin include the north-south-trending Nesson Anticline in northwestern North Dakota, and the northwest-southeast-trending Cedar Creek Anticline in southeastern Montana and the extreme southwestern portion of North Dakota (Carlson and Anderson, 1965). In addition to these structures, there are numerous smaller anticlines, synclines, joints, and faults (Gerhard et al., 1982; Osterwald and Dean, 1957).

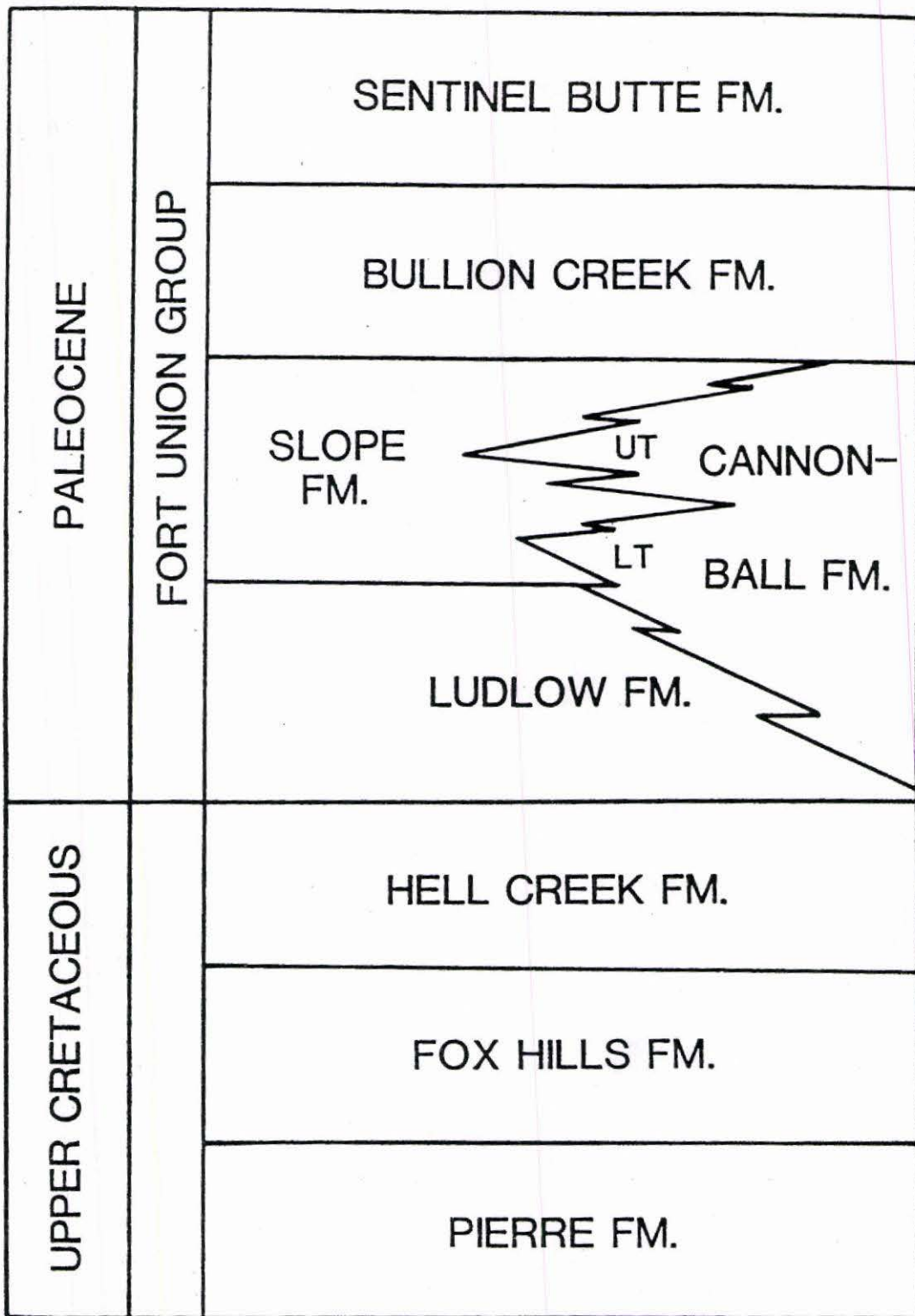
The Cannonball Formation dips gently toward the center of the Williston Basin, which is located approximately 40 miles (64 km) southeast of Williston, North Dakota (Carlson,

1982, p. 4). The magnitude of dip is generally less than one degree, but is greatly increased by local structure (Cvancara, 1976). In southwest-central North Dakota, where Cannonball Formation outcrops are most abundant, the dip direction is towards the northwest (Cvancara, 1976, p. 12). The outcrops in Grant County are positioned on the south or southeast flank of the basin (Carlson, 1982, p. 4). For a more complete structural synthesis, see Cvancara (1976).

### Regional Stratigraphy

The Cannonball Formation is a clastic marine sequence in the lower part of the Paleocene Fort Union Group (Fig. 1). In North Dakota, the major areas of outcrop occur along the Cannonball and Heart Rivers and Cedar Creek in Morton and Grant Counties. The remaining exposures are mainly roadcuts, and, to a lesser extent, hillside slumps and blowouts. North and east of Bismarck, North Dakota, out-crops are scarce due to a thick mantle of glacial drift. The Cannonball has been recognized as far east as northwestern Kidder County, north as far as northeastern Bottineau County, and west as far as western Slope County (Cvancara, 1976, p. 2). In South Dakota, the outcrops occur primarily along the Grand River in Harding, Perkins, and Corson Counties. The type area of the Cannonball Formation is along the Cannonball River in Tps. 132 and 133 N. and Rs. 87 and 88 W. (Lloyd and Hares, 1915).

Figure 1. Generalized stratigraphic column for Upper Cretaceous and Paleocene strata in North Dakota (UT = upper tongue of the Cannonball Formation, LT = lower tongue of the Cannonball Formation).



The Cannonball Formation seems to attain a maximum thickness of 385 feet in the subsurface of southeastern Hettinger County; the thickest exposed section is 282 feet (86 m) in southern Morton County (Cvancara, 1976). The lithologies of the Cannonball Formation are highly variable, but consist primarily of poorly consolidated sandstone and mudstone. Although these lithologies are often well-developed and distinct, they may change vertically through gradual intergradation or by interbedding. Beds in the interbedded part range in thickness from less than an inch to as much as several feet (Cvancara, 1965, p. 26, 27). The contact between these lithologies is most often gradational (Cvancara, 1965, p. 26, 93; Cvancara, 1976, p. 15).

The sandstone occurs in relatively thin units which commonly contains one to five, well-indurated, lenticular or concretionary sandstone beds, which, when present, hold up prominent topographic benches. Benches in about the middle and upper Cannonball can be physically traced (Cvancara, 1980) over much of southwest-central North Dakota. These benches have been used in my study to subdivide the formation into three informal units (see Subdivision of the Cannonball Formation). Cvancara (1965; 1976) stated that macrofossils occur most commonly in the sandstone lithology. However, the greatest number of neogastropod individuals were found in the mudstone.

Over most of the outcrop area of the Cannonball the mudstone lithology dominates the section. The mudstone is generally silty or sandy and commonly contains carbonate-cemented mudstone concretions (Cvancara, 1976, p. 8, 9). The Cannonball Formation can be broadly characterized by its repetitive sequences of relatively thick mudstone overlain by thinner, fairly clean sandstone. Two, or possibly three, such sequences are preserved in North Dakota.

A poorly consolidated, clay-rich, glauconitic sandstone has special importance to this study because of its abundant mollusks. This unit reaches a maximum thickness of about seven feet and is apparently restricted to a half dozen or so localities in the type area along the Cannonball River. However, a unit of similar aspect and stratigraphic position occurs to the north along the Heart River (see measured section 18 of Cvancara, 1965). In this lithology, mollusks are most diverse and occur in greatest abundance. A more complete treatment of Cannonball stratigraphy can be found in Cvancara (1965; 1976).

In western Slope County, the Cannonball strata thin and interfinger with the nonmarine, lignite-bearing deposits of the Ludlow and Slope Formations (Fig. 1). Here, at least two distinct, oyster-bearing, brackish-water tongues occur separated by 150 feet (46 m) (Brown, 1962, p. 10) of strata now assigned to the Slope Formation.

The Ludlow Formation, which also conformably underlies the Cannonball to the east, consists of poorly sorted sand, silt, clay, and minor lignite. The top of the Ludlow Formation is marked by the T-Cross lignite and, where Cannonball strata are absent, it directly underlies the Slope Formation. The Slope Formation overlies the Ludlow in western North Dakota and the Cannonball in central North Dakota (Clayton et al., 1977). The Slope Formation consists of alternating beds of silt, sand, clay, and lignite. The upper contact is placed at the top of the "white marker zone" (Clayton et al., 1977, p. 7). The upper part of the Fort Union group consists of the fluvial and lacustrine deposits of the Bullion Creek and Sentinel Butte Formations.

## METHODS OF STUDY

### Field Work

Field work for this study was accomplished during two one-week periods in the summers of 1988 and 1989. The primary objectives of this work were to gain some familiarity with the lithologies of the Cannonball and their vertical and lateral relationships, to supplement existing gastropod collections, and to record new fossil localities. Cvancara (1965; 1966) described 105 fossil localities in the Cannonball, located primarily southwest of Bismarck, North Dakota in Morton and Grant Counties. In the interest of time and money, only the most fossiliferous localities were revisited for this study.

The Cannonball Formation, as a whole, is relatively unfossiliferous. Therefore, systematic sampling methods such as quadrat, bulk, and line intercept, are inappropriate. Because well-preserved material is scarce, exposures were essentially cleared of all body fossils and recognizable fragments, with the exception of bivalves and the relatively abundant gastropod Drepanochilus perveta (Stanton). The bivalves have been revised by Cvancara (1966), and sizeable collections of D. perveta had already been made.



### Specimen Preparation and Photography

In general, Cannonball gastropods require some preparation before they can be studied. Matrix adhering to the outer shell surface, or filling the aperture, is usually poorly consolidated and can be removed with a fine pick. Broken specimens are also common. When possible, the individuals were repaired using a mixture of clear nail polish and acetone, providing a clear, fast-drying adhesive.

Plate photographs were taken with a Nikon P3 camera equipped with a 55 mm lens. Small specimens were photographed using a Nikon PB-6 bellows attachment with the lens mounted in the normal, rather than in the reversed position. All photographs were taken with Kodak Technical Pan 2415 film.

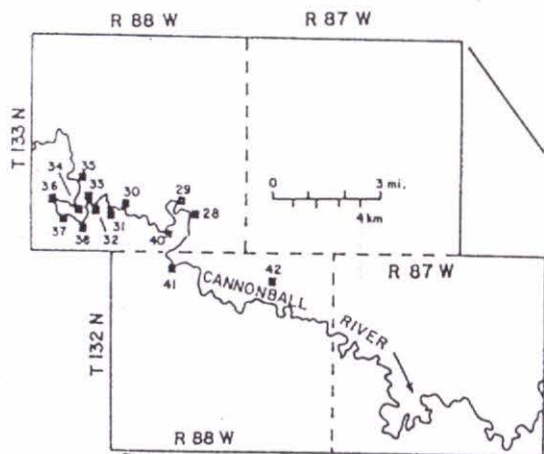
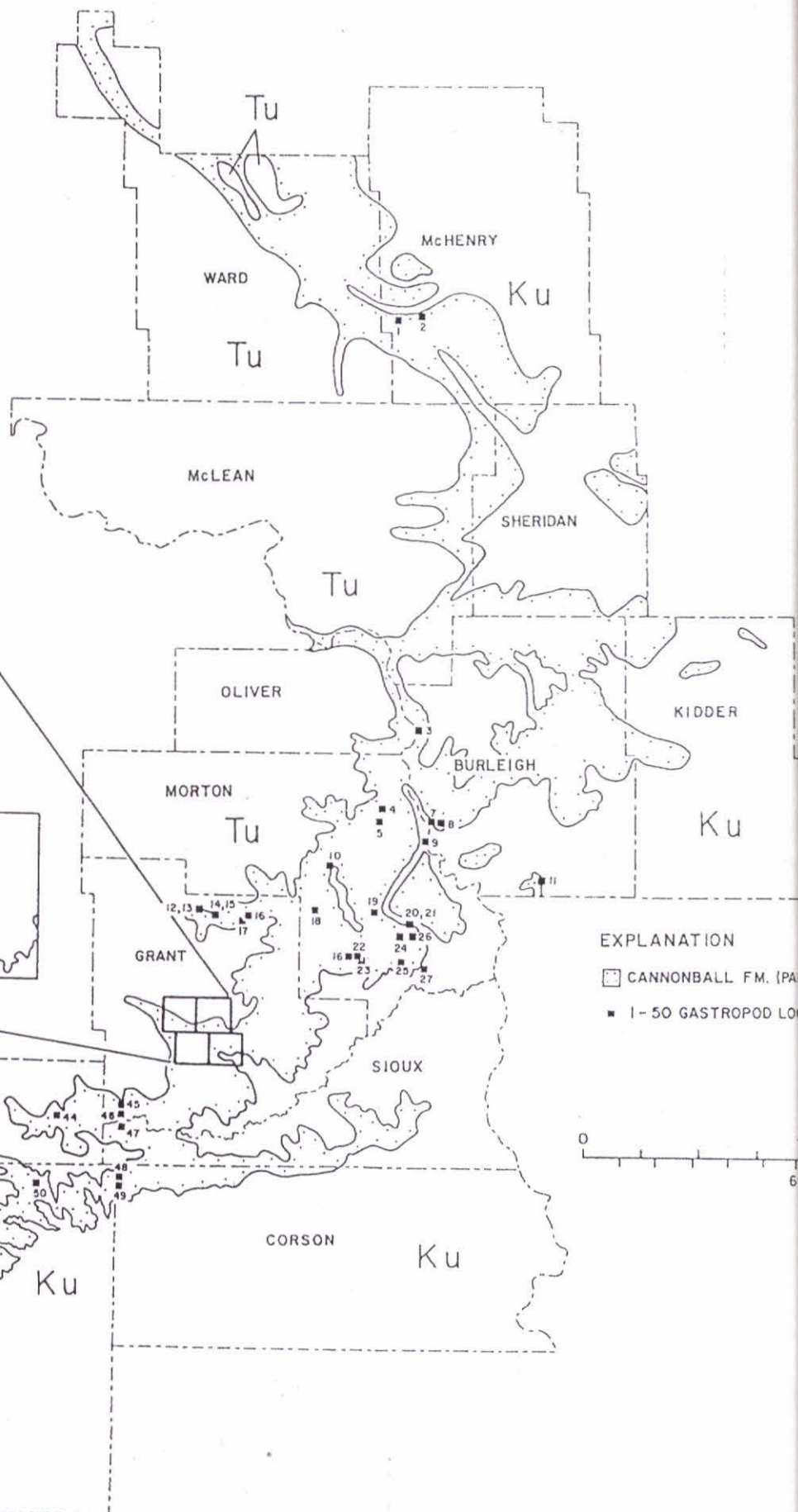
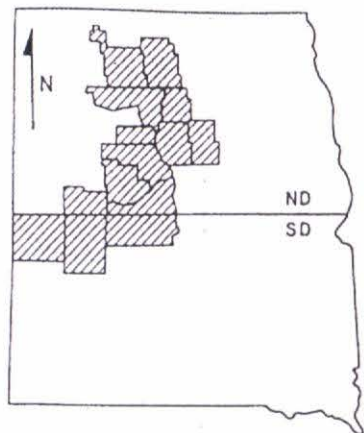
Prior to photographing, specimens were seated in dark, fine-grained sand and lightly coated with ammonium chloride. Specimens were illuminated using three light sources. One desk lamp was positioned on each side of the specimen, at equal distances, to achieve even lighting. A brighter, fiber-optic light, with a variable intensity control, was positioned at the upper left to produce the necessary shadows. In some cases, a white or aluminum foil-covered card was used to reflect light back onto the specimen from the lower right.

Prints were made on Ilford Multigrade Deluxe paper. Proper contrast was achieved using Ilfo-speed black and white filters.

#### Materials

Neogastropods have been collected from 50 localities primarily in southwestern North Dakota and northwestern South Dakota (Fig. 2). This material is contained in the University of Michigan (UMMP), University of North Dakota (UND), and the United States National Museum (USNM) collections. The University of Michigan material was collected by Dr. A. M. Cvanara during 1961 and 1962 while conducting field work for his dissertation on the Cannonball bivalves. Dr. Cvanara later arranged for the loan of this material for further study at the University of North Dakota. The Michigan material can be identified by the fractional accession number consisting of year of collecting and an occurrence number: for example, 1962/Tpa-1. The material in the UND collections was collected primarily by me, with fewer specimens contributed by many individuals. The more notable collectors include C. I. Frye, F. D. Holland, Jr., R. M. Lindholm, and A. M. Cvanara. The UND material bears accession numbers of the form A2675. Material from the USNM collections bear a United States Geological Survey (USGS) accession number consisting of a four digit number.

Figure 2. Bedrock geologic map of western North Dakota and northwestern South Dakota showing the Cannonball, underlying undifferentiated Upper Cretaceous formations (Ku), overlying undifferentiated Tertiary formations (Tu) (after Bluemle, 1982; Darton, 1951), and the fossil localities used in this study. Type area of Cannonball Formation enlarged at left. All localities occur within the Cannonball Formation, although some of those in North Dakota lie outside the formational contacts as placed by Bluemle (1982).



EXPLANATION

- CANNONBALL FM. (PAL)
- 1-50 GASTROPOD LOC



The majority of Stanton's (1920) types were received on loan to be photographed and studied. Exceptions include those specimens that are badly damaged or were adequately figured by Stanton (1920). In addition, important species from the Aquia Formation of Maryland and Virginia and the Midway Group of Texas were also received on loan from the USNM for study and photographing.

### Approach to Systematic Paleontology

The purpose of this section is to acquaint the reader with my approach to systematic paleontology in hopes of promoting efficient use of my work.

Many long standing generic names, such as Turricula, Fusus, Turris, and Fasciolaria have received broad application in the fossil record. Because our knowledge of the gastropods has increased significantly in recent years, as has our knowledge of their taxonomic characters, it has become necessary to re-evaluate these and other genera in light of modern taxonomic concepts. As a result of the present re-examination, five new genera have been proposed. In most cases, the material upon which these genera are based is not well-preserved. Yet, their salient generic features are preserved well enough to document their uniqueness and to allow the potential for additional species to be referred to them. I have taken a less conservative approach here for two reasons; first, it seems needless to

delay recognition of marked differences, for exquisitely-preserved material may never be recovered from the Cannonball, and, secondly, it would be a disservice to science to perpetuate the overly broad use of the above-mentioned genera.

At the species level, my approach has been much more conservative. Since many species are poorly represented it is often difficult to assess the taxonomic importance of certain shell variations. Therefore, variations in sculpture that could not be shown to intergrade were, in some cases, still regarded as intraspecific variations. This was done with the understanding that additional material may indicate that these differences are constant and significant and, thus, warrant the creation of a new species-level taxon.

#### Subdivision of the Cannonball Formation

The Cannonball Formation contains three laterally persistent sandstone units, one in the lower part of the formation, one near the middle, and another near the top. The middle and upper sandstone units generally contain one to five well-indurated, concretionary or lenticular beds, which, where present, hold up prominent topographic benches. The lower sandstone unit, which is only locally present, forms a poorly developed bench in the Flasher area. The middle and upper benches are best developed near Flasher,

North Dakota, but have been traced over much of southwest-central North Dakota. Cvancara (1980) traced the middle bench approximately 70 miles (113 km) from northeastern Morton County to southwestern Burleigh County, and about 30 miles (48 km) east-west across southern Morton County. He (1980, p. 34) traced the upper bench

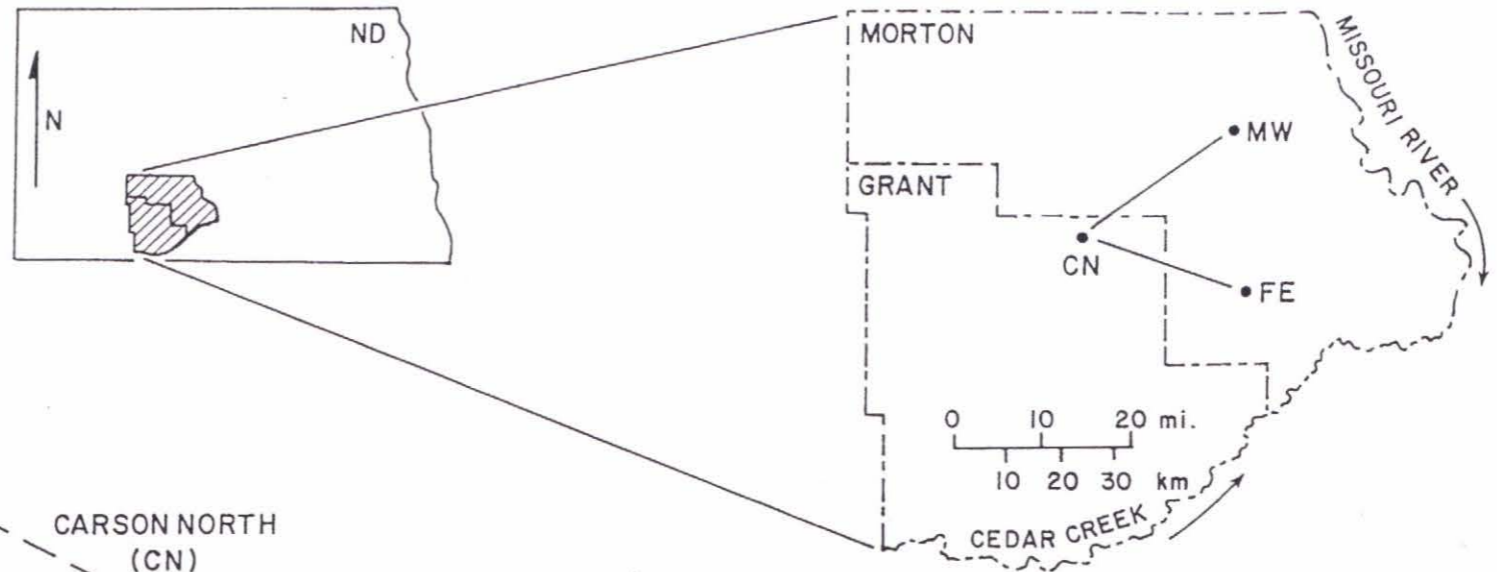
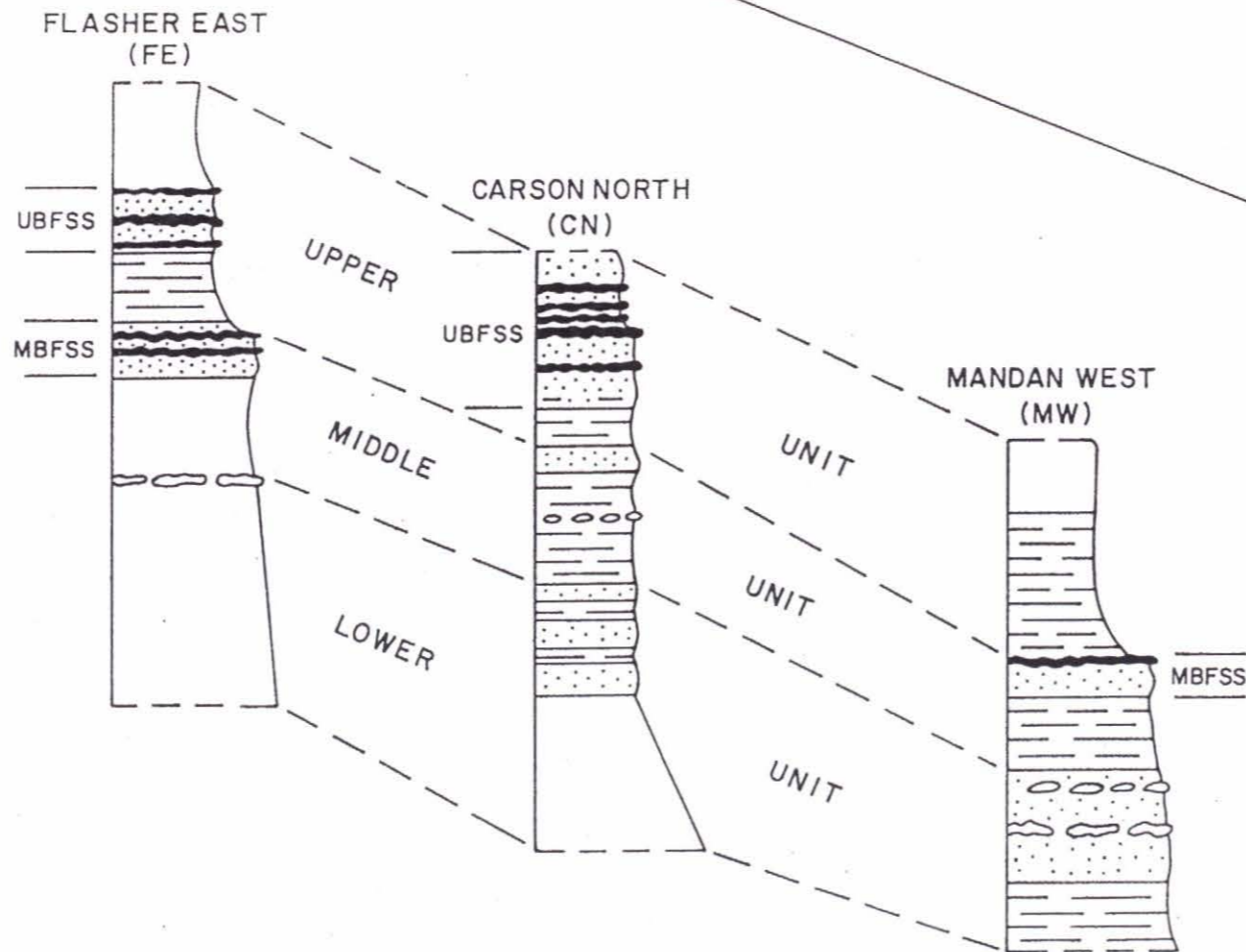
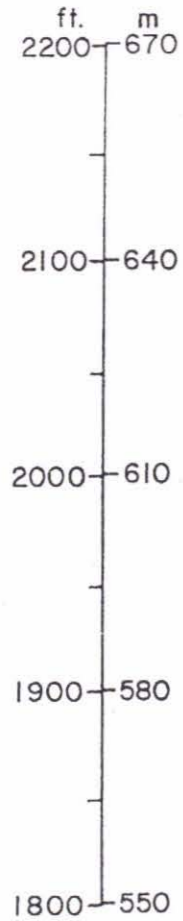
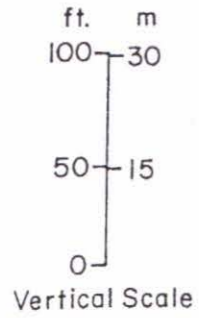
. . . for about 40 miles [64 km] from east-central Morton County to southern Grant County, and about 40 miles [64 km] from northeastern Grant County to east-central Sioux County.

In this study, the middle and upper bench-forming sandstone units, and the third, lower, generally non-bench-forming sandstone unit have been physically (non-chronologically) correlated from southwestern-most Grant County to northeastern Morton County using 24 control sections from Cvancara (1965). Because these sandstone units can be physically correlated over much of the outcrop area of the Cannonball, Cvancara (1989) suggested their use in subdividing the formation into three informal units referred to here as lower, middle, and upper units (Fig. 3). As suggested in figure 3, one or both members of a unit may be locally absent or not exposed.

In theory, each informal unit contains a mudstone and an overlying persistent sandstone. Therefore, each mudstone-sandstone couplet, and, thus, each unit, records a single regressive event. Since the lower and upper parts of the formation are poorly known, and, therefore, may contain

Figure 3. Stratigraphic cross section showing physical correlation of upper and middle bench-forming sandstones and lower, middle, and upper informal units. The Flasher East section is in N1/2SE1/4 sec. 21, T. 135 N., R. 83 W.; the Carson North section is a composite section from E1/2 sec. 21 and SE1/4SW1/4 sec. 17, T. 136 N., R. 86 W.; and the Mandan West section is in SW1/4SE1/4 sec. 10, T. 138 N., R. 83 W. Measured sections are from Cvancara (1965); section names are from Cvancara (1980).





EXPLANATION

- COVERED INTERVAL
- SANDSTONE
- MUDSTONE
- UBFS = UPPER BENCH-FORMING SANDSTONE
- MBFS = MIDDLE BENCH-FORMING SANDSTONE
- WELL-INDURATED, CONCRETIONARY OR LENTICULAR SANDSTONE
- SANDSTONE OR MUDSTONE CONCRETIONS

additional mudstone-sandstone couplets, the lower unit is considered to encompass all strata below the middle unit, whereas the upper unit contains all strata above the middle unit. The sandstone of the upper unit will be referred to as the upper sandstone, whereas the mudstone of the upper unit will be referred to as the upper mudstone. Parallel terminology is used for the middle and lower units.

The informal units proposed here can be readily equated with those defined by Lindholm (1984, fig. 16) on the basis of bivalve associations: the upper sandstone corresponds to the entire upper unit of Lindholm (her Ophiomorpha-crab-driftwood-shark teeth association); the upper mudstone is equivalent to Lindholm's upper-middle unit; the middle sandstone corresponds to the lower-middle unit of Lindholm (her Crassatella-Nucula association); the middle mudstone is contained within Lindholm's lower unit (her modified Crassatella-Nucula and Isognomon associations); and the lower informal unit is contained entirely within the lower unit of Lindholm. A few inconsistencies are apparent when comparing this subdivision to that of Lindholm (1984) because recent thinking has altered the stratigraphic position, and, thus, the correlation of some Cannonball sections. An attempt was made to compare my scheme with that of Hall (1958); however, it was extremely difficult to relate Hall's composite sections to those of Cvanacara (1965).

### Terminology

The term "neogastropod" is not used in its true sense in this study. For the sake of simplicity it is used to refer only to species belonging to the neogastropod families Melongenidae, Fasciolariidae, and Turridae unless otherwise stated.

## RESULTS

### Analysis and Occurrence of Neogastropod Fauna

#### Taxonomic Analysis

The neogastropod fauna contains 20 species assigned to 15 genera within 3 families and 2 suborders. The melongenids include Deussenia minuta n. sp., Deussenia? sp., and Rhombopsis gracilis (Stanton). The fasciolariids include Ericksonia clivilinea n. sp., Exilia sp., Fusinus? sp., Mesorhytis dakotaensis (Stanton), Serrifusus sohli n. sp., and Surculites tormentaria (Stanton). The turrids include Acamptogenotia varicosta n. sp., Alticollarum bacatum (Stanton), Alticollarum janesburgensis (Stanton), Amuletum (Lutema) sp., Marshallaria sp., Obtusicarina tormentaria (Stanton), Vitticoncha torelli (Koenen), Coronia? lloydi (Stanton), Eopleurotoma? danica (Koenen), and two indeterminate species. The number of known Cannonball neogastropods has increased notably from seven (Stanton, 1920) or approximately 300 percent. This value includes five of Stanton's species that were placed in synonymy. Twelve species are here reported for the first time from the Cannonball Formation.

The Turridae is the most diverse family with 11 species, whereas the Fasciolariidae and Melongenidae contain six and three species, respectively. Four genera, Alticollarum, Obtusicarina, Ericksonia, and Vitticoncha are

new, whereas Serrifusus, Rhombopsis, Mesorhytis, and Deussenia are reported for the first time from Tertiary strata. Marshallaria is described for the first time from North America and likely from the Northern Hemisphere.

#### Relative Abundance

Mesorhytis dakotensis is, by far, the most abundant species with 88 individuals representing 28 percent of the total neogastropod material. Other common species include: Acamptogenotia varicosta (12%), Rhombopsis gracilis (9%), Obtusicarina tormentaria (7%), Coronia? lloydi (7%), and Eopleurotoma? danica (7%). The remaining species are relatively rare; seven have relative abundances less than one percent. Species with relative abundance values less than one percent are represented by fewer than four specimens.

#### Stratigraphic Occurrence of Species

It is difficult to determine whether many of the Cannonball neogastropods have biostratigraphic utility since most species are represented by only a few occurrences. Thus, restricted stratigraphic occurrences could be interpreted as real or as an artifact of their low abundance. In general, the stratigraphic distribution of species is rather homogeneous with nine species occurring throughout the section, five present in two informal units,

and six restricted to one unit. Species restricted to a single unit are, in each case, represented by two or fewer specimens.

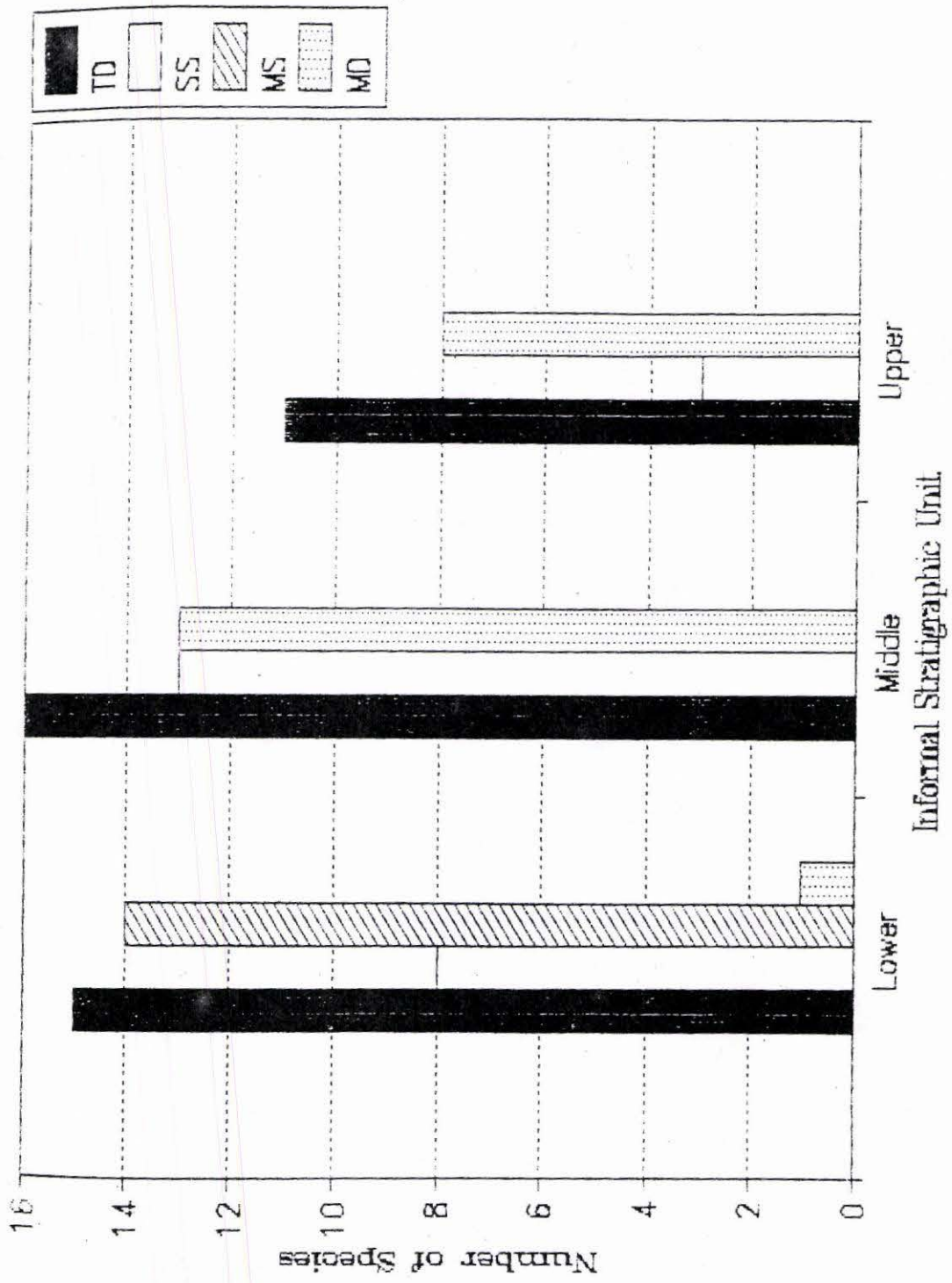
The species diversities of the informal units are also very similar. The middle unit is the most diverse with 16 species, followed by the lower unit with 15, and the upper unit with 11 (Fig. 4). This trend in faunal diversity is mirrored by the number of neogastropod-producing localities in each unit. Therefore, I believe that these diversities are largely controlled by the number and quality of exposures within each unit. There is some indication that the upper unit may actually be the most diverse since 11 species have been collected from only four localities. Sixteen localities expose the middle unit, whereas 14 localities expose the lower unit.

#### Lithologic Occurrence of Species

For the purpose of my study, the lithologies of the Cannonball have been simplified to three basic types, relatively clean sandstone (SS), muddy sandstone (MS), and mudstone (MD). The occurrence and significance of the muddy sandstone is discussed under Stratigraphy.

Overall, the greatest number of neogastropod species occur in the sandstone lithology; however, the greatest number of individuals have been collected from the mudstone. At the family level, the turrids occur most often in muddy

Figure 4. Species diversity of Cannonball neogastropods by informal unit and lithology. Bars represent total number of species occurring in each unit or lithology, not the number of species unique to that unit or lithology. TD = total species diversity of informal unit, SS = sandstone, MS = muddy sandstone, MD = mudstone.

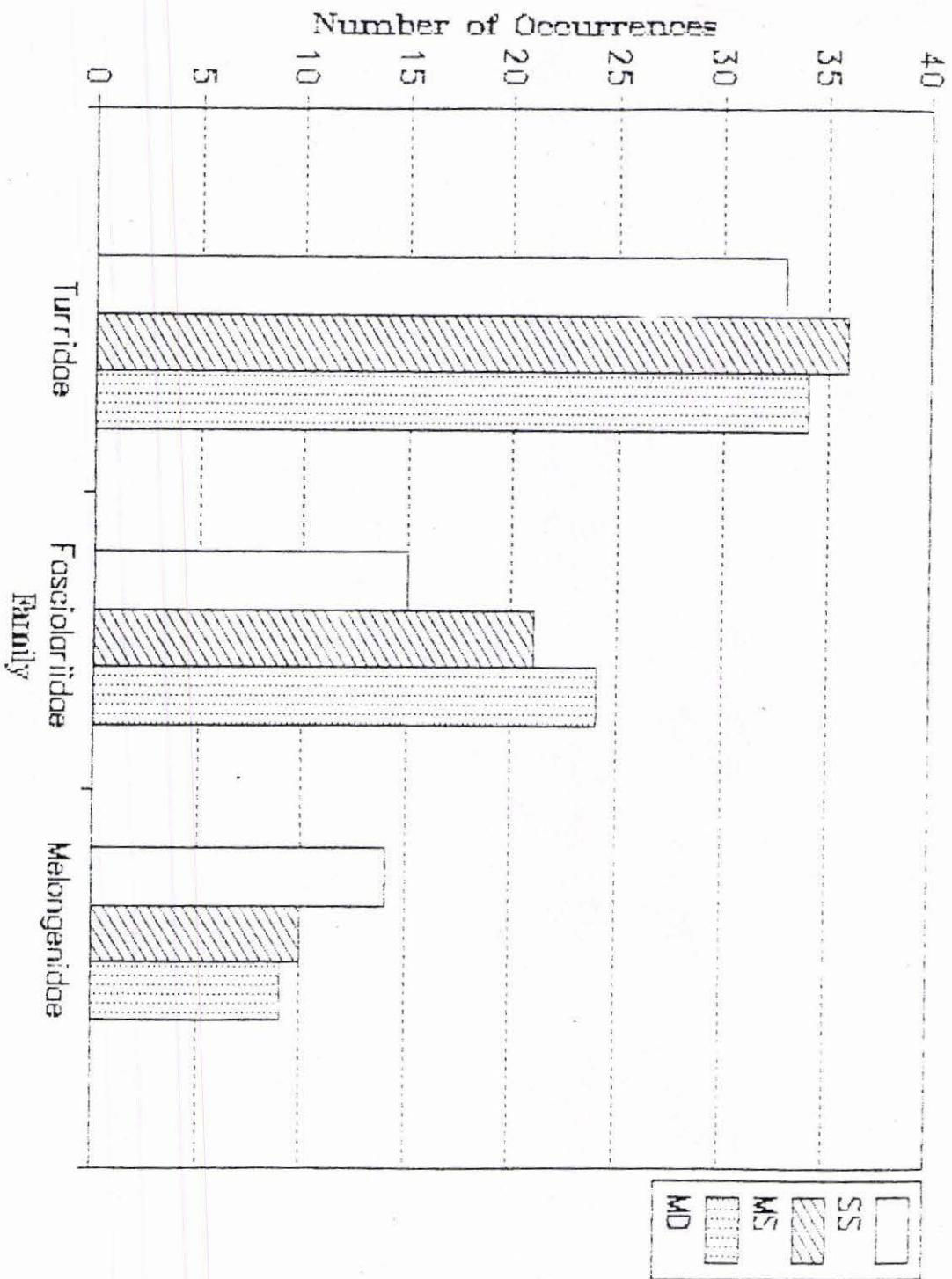




sandstone, the melongenids in sandstone, and the fasciolariiids in mudstone (Fig. 5). The lithologic distribution of species is also rather homogenous with 11 species occurring in all three lithologies, 3 species occurring in two lithologies, and 6 species occurring in only one. Again, species occurring in only one lithology are represented by two or less specimens. Five species occur most often in muddy sandstone, six in mudstone, and two in sandstone. The remaining seven species have equal occurrences in two lithologies.

The break down of each informal unit by lithology, reveals several trends (Fig. 4). In the lower unit, muddy sandstone is, by far, the most diverse. The low diversity of the lower mudstone can likely be attributed to the relatively few localities at which this unit is exposed. The middle mudstone and sandstone lithologies have high diversities of equal magnitude, whereas in the upper unit the mudstone lithology has the highest diversity. All eight species known from the upper mudstone have been collected from locality 11.

Figure 5. Lithologic occurrence of neogastropod families.  
SS = sandstone, MS = muddy sandstone, MD = mudstone.



## INTERPRETATIONS

### Paleoecology of Cannonball Neogastropods

An attempt was made to identify species assemblages and habitats using R-mode and Q-mode analysis, respectively. The R-mode analysis compares the species occurring together at each locality and determines how frequently one species occurs with another. If post-mortem transport and mixing of assemblages can be ruled out, it can be assumed that the species within a given cluster lived in close proximity. This analysis produced three weak clusters that could not be linked to substrate type, suggesting that some other factor, such as depth or salinity, was controlling the occurrence of these species.

The Q-mode analysis determines the degree of similarity between different localities based on the presence or absence of each species. If the localities within a given cluster are predominantly one lithology, then it may be assumed that the species occurring at those localities inhabited the environment indicated by that particular lithology. Resulting clusters dominated by the same lithology contained very different species. Therefore, it was deduced that substrate type was not the most important factor controlling the occurrence of these species. Post-mortem transport does not appear to have been an important factor in the outcome of these analyses, since most shells

show little abrasion, including those recovered from the relatively clean sandstone lithology.

The niches of the Cannonball neogastropods were determined on the basis of their overall shell shape and the feeding habits of their closest living relatives. Since none of the Cannonball neogastropod genera or species is extant, I used the generalized feeding habits of the modern species comprising the families in question.

Modern turrids, melongenids, and fasciolaridiids are dominantly predators. Turrids feed exclusively on polychaete worms, using a venomous injection to immobilize their prey. Modern fasciolaridiids feed predominantly on gastropods, bivalves, and sedentary polychaetes, whereas melongenids prefer gastropods and bivalves. Some melongenids and fasciolaridiids wedge the outer lip between the valves of bivalve prey to allow insertion of the proboscis (Taylor et al., 1980, p. 378, 379; Table 1). I have not found any outer lip damage suggestive of this activity in the Cannonball material.

All of the neogastropods examined in this study have a general fusiform shape. Kohn (1985, p. 176-177) stated that fusiform shells with the anterior extended into a siphonal canal belong to animals that ". . . dwell at least partially buried in sediment." This fact, considered in conjunction with the general feeding habits noted above, suggests that

the Cannonball fusiform neogastropods were semi-infaunal, or shallow infaunal predators.

Shuto (1974) proposed that the morphologic characters of prosobranch gastropod protoconchs could be used to gain insight into larval ecology, that is, whether the larvae were planktotrophic or lecithotrophic (= nonplanktotrophic). The only neogastropod specimen in the UND collections with a complete protoconch is an immature turrid assigned to Eopleurotoma? danica. This protoconch has five volutions, a maximum diameter of 0.9 mm, and a volution to maximum diameter ratio of 0.2. These measurements indicate a planktic life of long to moderate duration (Shuto, 1974, fig. 4). As one might expect, planktotrophic species tend to have wider geographic distributions (Shuto, 1974, p. 254). The data on E? danica agree with this generality, since this species is also present in the Paleocene fauna of Denmark (Koenen, 1885; Ravn, 1939).

One specimen of Amuletum (Lutema) sp. has been bored through the penultimate whorl on the abapertural side (pl. 1 fig. 15). The identification of the predator as a naticid or muricid is complicated by the thin gastropod shell and the slightly worn outer edge of the borehole. According to Carriker and Yochelson (1968, p. B7):

The outer edge of naticid borings is gently countersunk, and the interior surfaces converge toward the center of the inner opening in graceful pronounced parabolic curves, a feature diagnostic

of all holes of species of naticids so far examined . . . .

Muricid boreholes are considerably more variable in vertical section, the shape being controlled, in part, by shell thickness (Carriker and Yochelson, 1968). Muricid borings through thin shells

. . . are difficult to identify as of muricid or naticid origin, except that the inner opening of naticid holes is generally centered and round . . . . (Carriker and Yochelson, 1968, p. B7)

The inner opening on the Cannonball specimen is apparently centered, but is suboval.

In the Cannonball specimen, it appears that predator determination based on borehole shape is inconclusive. However, if one considers the abundance with which naticids occur in the Cannonball, in conjunction with the apparent absence of muricids, it seems safe to assume that a naticid was the predator in this case.

#### Neogastropods as Paleoenvironmental Indicators

Previous authors, working in both North Dakota and South Dakota, have suggested that the Cannonball sediments were deposited adjacent to a broad, low-lying coastal plain (Cvancara, 1965; 1976; Best, 1987). This interpretation is based, in large part, on the fine-grained Cannonball sediments and the Paleocene floras of the northern Great Plains.

In North Dakota, the Cannonball Formation consists primarily of two lithologies, poorly consolidated sandstone and silty or sandy mudstone. The well-sorted, very fine to fine-grained sandstones have been variously interpreted as bar, barrier island beach, near-beach, and shoreface deposits (Cvancara, 1965; 1976). The fair to poorly sorted sandstones are suggestive of deposition on high tidal flats (Cvancara, 1965). The mudstones, which tend to dominate in North Dakota, have been interpreted as tidal flat, lagoon, marsh, estuarine (Cvancara, 1965) and lower shoreface deposits (Cvancara, 1976, p. 13).

The two laterally-persistent, bench-forming sandstones occur throughout much of southwest-central North Dakota and are believed to represent prograding barrier island or shoreface deposits (Cvancara, 1976). Each bench-forming, barrier island sandstone is underlain by a relatively thick shoreface mudstone. Together these lithologies represent one regressive couplet. There appear to be at least two such regressive couplets preserved in the Cannonball section of North Dakota.

In western Slope County, at least two Cannonball tongues (Leonard, 1908; Brown, 1948) interfinger with the continental deposits of the Ludlow and Slope Formations (Fig. 1). These tongues have been interpreted as brackish-water deposits from the presence of abundant oysters. The vertical repetition of marine and brackish-water sediments



in North Dakota suggests at least two periods of transgression and regression. Cvancara (1965) postulated that these episodic transgressions may be related to periods of increased subsidence in the Williston Basin.

In South Dakota, the sandstone lithology predominates. Studies in the Cave Hills of South Dakota generally suggest deposition in high-energy nearshore or beach environments (Monnens, 1980; Goodrum, 1983; Best, 1987).

The lithologic occurrence of the Cannonball neogastropods is quite homogenous with 11 species occurring in all three major lithologies (sandstone, mudstone, and muddy sandstone), 3 species in two lithologies, and the remaining 6 species in only one. Each species known only from a single lithology is represented by two or less specimens.

Cluster analysis is a technique often used to show associations between "observations," in this case species. The Q-mode cluster analysis was used to show the degree of similarity between different localities based on the species recovered from them. Ideally, the localities within a given cluster will be predominantly of one lithology, and, therefore, the species collected from them are assumed to have inhabited the environment represented by that lithology. The results of the Q-mode analysis were inconclusive, suggesting that the neogastropods lack paleoenvironmental significance.

The inability to identify environmentally important neogastropod associations may be due to one or more of the following factors: clustering is controlled by some factor other than substrate type, such as salinity or depth; too few species were clustered; a proportionally large number of species is represented by only one or two occurrences; the lithologic subdivision is too coarse to allow identification of environmentally sensitive species or species assemblages; or post-mortem transport of shells and mixing of assemblages may mask the identification of associations. Three species that may have broad paleoenvironmental significance are Vitticoncha torelli, Deussenia minuta, and Deussenia? sp. Vitticoncha torelli occurs only in sandstone and muddy sandstone, suggesting that its presence may be indicative of higher energy, sandier environments, whereas Deussenia minuta and Deussenia? sp. occur only in muddy sandstone and mudstone suggesting that they are indicative of lower energy, muddier environments.

#### Comparison with Other Neogastropod Faunas

##### Late Cretaceous of the Western Interior

Erickson (1974) reported 36 gastropods from the Maestrichtian Fox Hills Formation, including 17 neogastropods (as used in the normal sense). A comparison of the faunas from the Cannonball and Fox Hills Formations reveals marked differences in family diversity. The Fox

Hills fauna contains 9 fascioliariids, 2 turrids, and 1 melongenid. By contrast, the Cannonball fauna contains 6 fascioliariids, 11 turrids, and 3 melongenids. Most significant is the 33 percent decrease in the number of Cannonball fascioliariids and the 450 percent increase in the number of Cannonball turrids.

Sohl (1967) identified 23 gastropod species from the Pierre Shale at Red Bird, Wyoming. This fauna lacks melongenids and turrids and contains four fascioliariids in a like number of genera. The absence of melongenids and turrids is not understood. Three genera and two species occur in common with the Fox Hills neogastropod fauna reported by Erickson (1974), although Sohl (1967, p. 8) noted an overall dissimilarity.

#### Extinction of Western Interior Neogastropod Taxa

Stanton (1920, p. 12) concluded that 24 species of Cannonball molluscs, including seven gastropods, also occurred in the Upper Cretaceous units of the Western Interior. So substantial was this faunal overlap that Stanton assigned a Late Cretaceous age to the Cannonball. Of the seven Cannonball gastropods assigned to Fox Hills species by Stanton, only Pyrifusus (Neptunella) newberryi (Meek and Hayden, sensu Stanton) and Turricula? contorta (Meek and Hayden, sensu Stanton) were re-examined in my

study. They are considered synonymous and have been reassigned to Acamptogenotia varicosta n. sp.

I have not examined the remainder of Stanton's "Fox Hills" species in enough detail to substantiate his assignments; however, Erickson (1989) stated that Lunatia subcrassa (Meek and Hayden, sensu Stanton) is very close to the Fox Hills representatives. A Cannonball species collected since Stanton's work closely resembles Hercorhyncus (Haplovoluta) hollandi Erickson from the Fox Hills. Erickson's species seems to be misassigned, being more closely related to the buccinid genus Eosiphonalia Ruth. With the possible exception of H. (H.) hollandi, it appears that most, if not all, of the Western Interior neogastropod species became extinct in the Late Cretaceous.

Ten neogastropod genera have been described from the Upper Cretaceous Pierre (Sohl, 1967) and Fox Hills Formations (Erickson, 1974). Four of these genera, Serrifusus, Mesorhytis, Rhombopsis, and Amuletum have ranges extending into Cannonball time (Thanetian?) (Fig. 6). Only Serrifusus occurs in all three formations. The Fox Hills fasciolariid genera belonging to the subfamily Fasciolariinae are completely extinct, whereas only one Fox Hills genus belonging to the subfamily Fusininae, is present in the Cannonball fauna. Mesorhytis, which is present in the Pierre Shale, is unknown from the Fox Hills. From this, it is concluded that 60 percent of the Western Interior Late

Figure 6. Geologic ranges of neogastropod genera from the Fox Hills (Erickson, 1974), Pierre (Sohl, 1967), and Cannonball Formations. Majority of range data modified from Sohl (1964, table 2) to include Cannonball occurrences. Range of Mesorhytis is from Palmer and Brann (1966).

Epoch	Late Cretaceous		Paleocene	
Age	Campanian	Maestrichtian	Danian	Thanetian
Fasciolariidae				
<u>Anomalofusus</u>		████████████████████████████████████████		
* <u>Cryptorhytis</u>	████████████████████████████████████████			
* <u>Graphidula</u>		████████████████████████████████████████		
<u>Hercorhyncus</u>		████████████████████████████████████████		
<u>Mesorhytis</u>	████████████████████████████████████████		████████████████████████████████████████	
<u>Piestochilus</u>		████████████████████████████████████████		
<u>Remera</u>	████████████████████████████████████████			
* <u>Serrifusus</u>	████████████████████████████████████████		████████████████████████████████████████	?
Melongenidae				
<u>Rhombopsis</u>		████████████████████████████████████████	████████████████████████████████████████	?
Turridae				
<u>Amuletum</u> (L.)		████████████████████████████████████████	████████████████████████████████████████	?

\* Genera occurring in both Pierre Shale and Fox Hills Formation.

Cretaceous neogastropod genera became extinct prior to Cannonball time.

### Paleocene faunas

#### **Faunal Diversity**

Stanton (1920) reported 31 gastropod species from the Cannonball Formation. The results of the present study and my experience with the remaining gastropod fauna suggest that only 24 of these species are valid.

The Cannonball gastropod fauna seems to be of relatively low diversity when compared to other Paleocene faunas derived from clastic marine units. The gastropod fauna from Nûggsauq, West Greenland, contains 257 taxa, including 38 archaeogastropods, 103 mesogastropods, and 86 neogastropods (Kollman and Peel, 1983, p. 9). Of the 86 neogastropod (as used in the normal sense) taxa, there is 1 melongenid, 12 fasciolariiids, and 16 turrids. Elements of the Greenland fauna that are noticeably absent from the Cannonball include the patellaceans, cypraeaceans, muricids, harpids, and volutids. Although Stanton (1920) did not describe any Cannonball archaeogastropods, there appear to be at least a few species in the UND collections. However, it is apparent that the Cannonball archaeogastropods comprise a much smaller percentage of the total gastropod fauna than do the Greenland archaeogastropods.

Ravn (1939) and Koenen (1885) reported 100 gastropod taxa from the Paleocene of Denmark. Again, this fauna contains several archaeogastropods, including acmaeids and patellids. The warm-water muricids, volutids, and Pseudoliva are also present. It is difficult to compare family diversities because of somewhat outdated taxonomy. A brief review of Ravn (1939) and Koenen (1885) suggests that there are approximately 5 fasciolariiids, 16 turrids, and, apparently, no melongenids.

The gastropod fauna of the Midway Group of Texas contains 135 taxa; however, 65 of these were treated with open nomenclature (Gardner, 1935). The Midway fauna is in need of taxonomic revision. A cursory review of Gardner's (1935) systematics suggests that there are 9 turrids and no melongenids. The number of valid fasciolariiids is less certain, probably 7. One group that is noticeably more diverse in the Midway fauna are the turritellids, with 17 taxa recognized. Turritellids are very poorly represented in the Cannonball fauna. The presence of Pseudoliva, Ficus, and cypraeids suggests a relatively warm-water fauna in the Midway.

Clark and Martin (1901) described 58 gastropods from the Paleocene Aquia Formation of Maryland and Virginia. Although the Cannonball fauna is still under revision, it is my opinion that its diversity is comparable to the Aquia fauna. The occurrence of muricids, cypraeids, volutids, and



Pseudoliva in the Aquia Formation is suggestive of a relatively warmer oceanic climate. As in the Midway fauna, the turritellids of the Aquia are more diverse and occur in much greater abundance than in the Cannonball Formation. Clark and Martin (1901, p. 64) described limestones in the Aquia Formation that consist almost entirely of Turritella mortoni shells.

The Cannonball neogastropods do not show the similarity with Paris Basin faunas recognized for the bivalves (Cvancara, 1965; 1966). Kollman (1979, p. 85) noted the presence of climatic zones in the Thanetian which were manifested by the presence of several warm-water groups in the Paris Basin that were absent in Denmark. This same latitudinal zonation may explain the marked dissimilarities between the Cannonball and Paris Basin gastropod faunas. Differences in lithology and age are also considered to be important factors. However, this does not explain the similarities in the bivalve faunas. One would have to conclude that the bivalves are less sensitive to climatic changes, possibly because they are largely infaunal.

#### Occurrence of Cannonball Species

Ten of the twenty Cannonball neogastropods, or forms closely resembling them, occur in four other Paleocene faunas: the Midway Group of Texas and Alabama; the Aquia Formation of Maryland and Virginia; the Agatdal Formation of

West Greenland; and the "greensands" of Copenhagen, Denmark. The degree of certainty with which these species from the Cannonball Formation could be identified in other faunas has been a function of one or more of the following factors: quality and accuracy of available plate figures; completeness of species descriptions; quantity and quality of Cannonball material available; and, to some degree, language barriers.

Cannonball species that occur in each of these faunas are given in the left column of the list that follows. In addition, species closely resembling, but not conspecific with, Cannonball species are included. The morphologically similar species is listed in the right column, opposite the Cannonball species it resembles. Cannonball neogastropod species (or similar forms) occurring in other Paleocene Formations are:

**Agatdal Formation, West Greenland (Kollman and Peel, 1983):**

Obtusicarina tormentaria (Stanton)

Alticollarum bacatum (Stanton)

Surculites tormentaria (Stanton)

Deussenia? sp.

Amuletum (Lutema) sp.

Crenaturricula sp. 1

Vitticoncha torelli (Koenen)

Crenaturricula sp. 2

Eopleurotoma? danica (Koenen)

Hemipleurotoma sp.

Ericksonia clivilinea n. sp. cf. Levifusus sp. 2  
Serrifusus sohli n. sp. aff. Tudicla sp.

"Greensands," Denmark (Koenen, 1885; Ravn, 1939):

<u>Eopleurotoma?</u> <u>danica</u> (Koenen)	
<u>Vitticoncha</u> <u>torelli</u> (Koenen)	
<u>Alticollarum</u> <u>janesburgensis</u> (Stanton)	<u>Surcula</u> <u>hauniensis</u> (Koenen)
<u>Eopleurotoma?</u> <u>danica</u> (Koenen)	<u>Pleurotoma</u> ( <u>Eopleurotoma</u> ) <u>seelandica</u> Koenen
<u>Mesorhytis</u> <u>dakotensis</u> (Stanton)	<u>Mitra</u> <u>aequicostata</u> Koenen

Aquia Formation, Maryland and Virginia (Clark and Martin, 1901):

<u>Coronia?</u> <u>lloydi</u> (Stanton)	
<u>Mesorhytis</u> <u>dakotensis</u> (Stanton)	<u>Mitra</u> <u>potomacensis</u> Clark and Martin
<u>Deussenia?</u> sp.	<u>Strepsidura</u> <u>subscalarina</u> Heilprin

Midway Group, Texas and Alabama (Gardner, 1935; Harris, 1896):

<u>Alticollarum</u> <u>bacatum</u> (Stanton)	<u>Orthosurcula</u> <u>adeona</u> (Whitfield)
<u>Vitticoncha</u> <u>torelli</u> (Koenen)	<u>Orthosurcula</u> <u>francescae</u> Gardner
<u>Obtusicarina</u> <u>tormentaria</u> (Stanton)	<u>Orthosurcula</u> <u>phoenicea</u> Gardner

In summary, Cannonball species have been confidently identified only in the higher latitude faunas of Maryland, U. S. A., West Greenland, and Denmark, with the greatest number of Cannonball species occurring in the West Greenland fauna. As the morphologically similar species listed above become better known and additional Cannonball collections are made, these species may be shown to either intergrade with those in the Cannonball or become less similar. Therefore, the relative similarity of these faunas may be altered slightly. However, it is my opinion that when the Cannonball gastropod fauna is completely revised, the similarities with the West Greenland fauna will be greatly magnified.

At the family level, the turrids seem to be the most cosmopolitan with five of the 11 Cannonball turrids

occurring in one of these three faunas. Overall, 70 percent of the species examined were apparently endemic to the Cannonball Sea.

#### Source of the Cannonball Sea

The source of the Cannonball Sea has been a point of interest to all who have worked on the stratigraphy and fauna of the Cannonball Formation. Two avenues have been pursued in an attempt to answer this question: (1) stratigraphic evidence, and (2) the similarity of the Cannonball fauna to other Paleocene faunas. After approximately 80 years of consideration, neither the stratigraphic nor the paleontological data has offered conclusive evidence.

Lloyd and Hares (1915, p. 539, 541) noted the gradual westward thinning of the "Cannonball member," and, therefore, concluded that "The Cannonball sea presumably advanced into western North and South Dakota from the east or northeast, . . . ." Cvanara (1965, p. 98) stated that an east or northeast source was in keeping with the westward and southward thinning of the Cannonball Formation; however, there appeared to be ". . . no evidence, positive or negative, for an easterly source." To a large degree, this lack of stratigraphic evidence results from the thick mantle of glacial till that covers much of the Cannonball Formation north and east of Bismarck, North Dakota. Cvanara (1965,

p. 98-100) went on to cite the absence of correlative marine strata in Canada as evidence against a northern source. The closest contemporaneous marine strata in any direction are the Clayton and Porters Creek Formations in southern Illinois, some 900 miles to the southeast.

Three general interpretations regarding the source of the Cannonball Sea have been inferred based on the Cannonball fauna: from the Arctic or North Atlantic Oceans to the north or northeast (Feldmann, 1972; Erickson, 1978; Lindholm, 1984), from the Gulf of Mexico to the south (Fox and Ross, 1942; Holtzman, 1975; Sloan, 1970), or both (Lemke, 1960; Brown, 1962).

Marincovich et al. (1985) proposed that the Cannonball Formation represented the southernmost deposits of a narrow extension of the Arctic sea. This interpretation was based, in part, on the strong affinities between the bivalve and ostracode faunas of the Price Creek (Ocean Point, Alaska) and Cannonball Formations.

Rosenkrantz (1970, p. 449), in a discussion of Danian paleogeography, said:

A seaway connecting West Greenland with central North America as in Santonian time can not be excluded. There exists a certain, if not very extensive, faunal agreement between the Greenland Danian and the Cannonball Formation of North and South Dakota.

One factor that must be considered when making inferences regarding a source for the Cannonball Sea is its

paleotemperature. An estimation of paleotemperature can be made using the geographic distributions of living relatives of the Cannonball gastropod taxa. Caution must be used when extrapolating these data into the geologic past, since one has to assume that these forms have always inhabited similar oceanic climates. In some cases, this may be a tenuous assumption (Davies, 1975, p. 82).

The Cannonball foraminifers show affinities with both cool and warm water faunas (Lemke, 1960, p. 31), as do the bivalves (Lindholm, 1984, p. 111). The gastropods appear to be no exception. Modern turrids have a world-wide distribution (Powell, 1966, p. 17), whereas modern melongenids (Abbott, 1982, p. 175) and fasciolarids (Abbott, 1982, p. 182) are restricted to the tropics. A brief review of other gastropod groups reveals several additional taxa whose modern counterparts have cool or warmer-water distributions. Those groups with more northern distributions in the modern oceans include the aporrhoids (Davies, 1975, p. 39), Euspira (or Lunatia) (Davies, 1975, p. 39), buccininines (Davies, 1971, p. 355), and Admete (Davies, 1975, p. 39). Groups indicative of warmer oceanic climates include Calyptrophorus (Davies, 1975, p. 103), the cancellariids (Abbott, 1982, p. 225), and the ficids (Abbott, 1982, p. 116).

The mixture of gastropod groups mentioned above seem to indicate a temperate, or possibly warm-temperate

Cannonball Sea. According to Palmer (1974, p. 469), ". . . the climate of the Paleocene and Eocene was universally warm to tropical." This interpretation seems to be consistent with the Paleocene flora of the northern Great Plains which suggest a warm temperate climate (Brown, 1962; Sloan, 1970). The marine and terrestrial faunas of Nûggsauq, West Greenland, and the foraminiferal fauna of the Labrador shelf indicate a temperate climate for that region (Gradstein and Srivastava, 1980, p. 289). It is difficult to compare these paleotemperature estimations without somehow quantifying them.

As noted earlier, the greatest number of Cannonball neogastropods occur in the Paleocene fauna of West Greenland. The Greenland fauna is much more diverse and has a more "tropical" aspect; however, there is also a considerable number of cool water forms. In fact, it appears that each of the cooler and warmer water gastropod genera present in the Cannonball fauna is also present in the West Greenland fauna. Furthermore, the partial list of West Greenland bivalves presented by Rosenkrantz (1970, p. 435-36) contains seven species that are closely related to, or conspecific with, Cannonball species. Included in this list are species belonging to the cooler-water genera Arctica and Nuculana (Davies, 1971, p.) and the warmer-water Isognomon (Davies, 1975, p. 82). Therefore, it seems that a marine connection with the Gulf of Mexico is not necessary



to account for the warm-water groups present in the Cannonball fauna if one infers a northerly or northeasterly source. Conversely, a southern source, alone, would not account for its composition.

According to Gradstein and Srivastava (1980), the north Atlantic and Arctic Oceans were connected by way of the Labrador Sea and Baffin Bay during the Late Cretaceous and Cenozoic. They further speculated that during non-glacial periods, as in the Paleocene, wind-driven ocean currents would have produced a net transport of warmer waters into the Arctic Ocean (Gradstein and Srivastava, 1980, p. 291).

I believe that the northward-flowing, warm Atlantic waters that produced the rich West Greenland fauna would have mixed with Arctic waters and cooled to some extent. This cooling seems to be manifested by the presence of several warm water groups in the Cannonball, but not the more "tropical" groups present in the Greenland fauna, such as the harpids, olivids, muricids, and volutids (Abbott, 1982). This Arctic mixing seems to have effectively filtered out these "tropical" forms, producing the temperate or warm-temperate Cannonball fauna.

The exact geographic orientation of the Cannonball Sea is difficult to determine, but it appears to have been from the north or northeast. Gradstein and Srivastava (1980, p. 288, fig. 6B) indicated that the Labrador, Baffin Island, and Hudson Strait were above sea level during the late

Mesozoic and entire Cenozoic. Therefore, I propose that the Cannonball embayment was located somewhat west of this region. The mixing of Arctic and Atlantic waters proposed here does not complement the restricted Arctic Ocean model proposed by Marincovich et al. (1985) for the Ocean Point fauna.

It is understood that the similarities between the Cannonball, West Greenland, and Denmark faunas may actually reflect a common faunal province, rather than a direct marine connection. However, on the basis of the neogastropods described herein, a marine connection with the Western Interior from the north or northeast is the simplest interpretation that satisfies these data.

#### Age of Cannonball Formation

The term "Thanetian" is used in the broad sense to refer to the entire late Paleocene.

The age of the Cannonball Formation has been a controversial topic since Lloyd (1914) first recognized it as a distinct stratigraphic unit. Stanton (1920) published the first comprehensive paleontological work on the Cannonball fauna. His work revealed a considerable number of mollusks believed to be conspecific with those previously described by Meek and Hayden (1856a; 1856b; 1857) and Meek (1876) from the Upper Cretaceous rocks of the northern mid-continent. Based on these faunal similarities, and its

geographic isolation from other "Eocene" marine strata, Stanton (1920, p. 18) assigned a Late Cretaceous age to the Cannonball. Subsequent workers have attempted to refine this age assignment by analyzing its contained fauna, the floras and faunas of the intimately associated nonmarine units of the Fort Union Group, and the biotas of its correlatives to the west.

Studies on the mammal faunas derived from associated continental units indirectly suggest ages ranging from late early Paleocene (Puercan) to early late Paleocene (early Tiffinian) (Thom and Dobbin, 1924, p. 497; Sloan, 1970, p. 441; Holtzman, 1975, p. 16). Dorf (1940, p. 231) concluded a general Paleocene age for the Cannonball, based on the flora from the Ludlow Formation.

Attempts to use the Cannonball fauna to date the formation have been inconclusive. In general, the foraminiferids have indicated an early Paleocene age, whereas the macro-groups studied thus far show greater similarities with other late Paleocene faunas. A general Paleocene age has been surmised from the Cannonball microflora (Stanley, 1965, p. 208), ostracodes (Swain, 1949, p. 174) and foraminiferids (Fox and Ross, 1942). Later studies on the Cannonball foraminiferids suggested ages ranging from early Danian to largely Landenian (=Thanetian) (Jeletzky, 1960; Jeletzky, 1962, p. 1006-1007; Fox and Olsson, 1969, p. 1400; Fenner, 1976, p. 63). A more

exhaustive treatment of the earlier works can be found in Cvancara (1965), Fenner (1976), and Lindholm (1984).

Cvancara (1965, p. 104) inferred a Thanetian age for the Cannonball on the basis of several morphologically similar bivalves from the Thanetian of the Paris Basin. Thirteen species of Cannonball sharks, bony fishes, and ratfishes also suggest a Thanetian age (Cvancara and Hoganson, 1990).

Lerbekmo and Coulter (1984) indicated that a Cannonball section near Huff, North Dakota, contained magnetic reversals 29 and 28. Judging from the magnetostratigraphic chart of Harland et al. (1982, fig. 5.3), the sampled portion of the "Huff section" is early Danian in age. The "Huff section" is somewhat isolated geographically, and, therefore, its exact stratigraphic position is uncertain but probably in the middle or lower part of the formation (Cvancara, 1990).

Some of the Cannonball neogastropods described herein have been confidently identified only from the Aquia Formation of Maryland and Virginia, the Agatdal Formation of West Greenland, and the "greensands" of Copenhagen, Denmark. According to Hansen (1970, p. 31), the Aquia is of late Paleocene age, because of the appearance of Globorotalia angulata at its base. The age of the Agatdal Formation of Nûggsauq, West Greenland is less certain. Rosenkrantz (1970) considered the age of the Agatdal to be late Danian;

however, he noted similarities between the benthic foraminiferids, mollusks, and fishes of the Agatdal and those from the early Selandian (early late Paleocene) of Denmark. Hansen (1970, p. 23) examined the Agatdal foraminiferids and concurred with this age assignment. Later works have placed the early Paleocene-late Paleocene boundary somewhat lower in the section.

Hansen (cited in Croxton, 1980) placed the upper boundary of the early Paleocene in the lower Kangilia Formation, thus making the overlying Agatdal at least post-Danian in age. Kollman and Peel (1983, p. 8) followed Hansen in assigning the Agatdal to the middle Paleocene. On the basis of these later works, the Agatdal Formation is here considered to be Thanetian in age. The Paleocene fauna from the "greensands" of Copenhagen, Denmark (Koenen, 1885; Ravn, 1939) was considered to be early Selandian (= early Thanetian) by Rosenkrantz (1924) and Thanetian by Kollman (1979, p. 85).

The geologic ranges of the Cannonball neogastropod species, based on their occurrence in these faunas of known age, seem to indicate a Thanetian age for the Cannonball Formation. It must be noted that this interpretation relies heavily on the assumed middle Paleocene age (post-Danian) assignment for the Agatdal Formation. If later workers return the Agatdal to the late Danian, then it may be

reasonably inferred that the Cannonball Formation spans the Danian-Thanetian boundary.

According to Kollman (1979, p. 85), separate warm-water provinces existed on the eastern and western margins of the Atlantic Ocean during the Danian. In the Thanetian, these faunal provinces dissipated and the "transatlantic gene flow" was re-established along with the development of climatic zones (Kollman, 1979, p. 85). The occurrence of two Cannonball species in the early Thanetian of Denmark may indirectly support a Thanetian age assignment for the Cannonball Formation.

There seems to be some foraminiferal evidence against a Thanetian age for the entire Cannonball. According to Hansen (1970, p. 34) the upper boundary of the Danian is marked by the first appearance of Globorotalia angulata. This species has not yet been recovered from the Cannonball. According to Hansen (1970, p. 34), "The Danian stage in the type area coincides with the Globoconusa daubjergensis/Subbotina pseudobulloides zone." Fox and Ross (1942), working in the middle and upper parts of the Cannonball, and Fenner (1976), working in the middle Cannonball, reported these characteristic early Paleocene foraminiferids. According to Blow (1979), Globastica daubjergensis (Bronnimann) s. s. is restricted to the zones P. 1 and P. 2 (Danian), whereas Globorotalia (Turborotalia)

pseudobulloides (Plummer) occurs from the base of zone P. 1, to near the top of zone P. 3 (early Thanetian).

Fox and Ross (1942) described Cannonball foraminifers from five localities, four of which were believed to be in the upper Cannonball and one in the middle. The stratigraphic position of these localities has been re-examined using the detailed Cannonball cross section developed for this study and they appear to be correct. Locality two of Fox and Ross (1942, p. 667), which coincides with measured section six of Cvancara (1965, fig. 3, p. 29), is located primarily in the middle Cannonball, although the base of the exposure is in the lower unit. The exact position of Fenner's (1976) material is somewhat suspect since the foraminiferids were recovered from well cuttings. He believed that his material was from the middle of the formation. In order to suggest that the upper Cannonball is Thanetian in age, one must determine exactly which of Fox and Ross' species came from which locality, particularly those that are characteristic of the early Paleocene.

In summary, the Cannonball neogastropods indicate a late Paleocene age for the formation. However, until it can be demonstrated that Globastica daubjergensis (Bronnimann) occurs in strata younger than Danian, it must be assumed that at least the part of the Cannonball Formation containing this species is Danian in age. The amount of Danian Cannonball depends on the stratigraphic occurrence of

this species which is yet to be accurately determined. If G. daubjergensis is confined to the middle or lower parts of the formation then it may be reasonably assumed that the remainder is of Thanetian or late Paleocene age.



## CONCLUSIONS

The Cannonball neogastropod fauna, which is dominated by turrids, contains 20 species assigned to 15 genera within 3 families. Four genera, Alticollarum, Obtusicarina, Vitticoncha, and Ericksonia are new; and the occurrence of Serrifusus, Mesorhytis, Rhombopsis, and Deussenia in the Cannonball fauna extends the known range of these genera into the Tertiary. Marshallaria is described for the first time from North America and likely from the northern Hemisphere. The number of Cannonball neogastropods has been increased three-fold although five species have been placed in synonymy. Twelve species represent additions to the Cannonball fauna; Acamptogenotia varicosta, Serrifusus sohli, Deussenia minuta, and Ericksonia clivilinea are newly named and described.

Based on their relative abundance, some of the more common species include: Mesorhytis dakotensis (28%), Acamptogenotia varicosta (12%), and Rhombopsis gracilis (9%). The majority of species are rare with seven species represented by three individuals or less.

There is no observable zonation of neogastropod species within the context of the three informal stratigraphic units; however, this may be an artifact of the little material by which many species are represented. The middle unit has the most diverse fauna with 16 species, followed by the lower and upper units with 15 and 11 species,

respectively. The greatest number of neogastropod occurrences is in the sandstone lithology, whereas the greatest number of individuals has been collected from the mudstone.

Cluster analyses indicate that species occurrence is not controlled primarily by lithology, but rather by some other factor such as salinity or depth. The Cannonball neogastropods were determined to be semi-infaunal, or shallow infaunal predators on the basis of their fusiform shape and the feeding habits of the modern representatives of their families. Protoconch measurements from one specimen of Eopleurotoma? danica suggest a larval planktic life of moderate to long duration. The geographic distribution of this species agrees with this interpretation since it is also present in the Paleocene fauna of Denmark.

Q-mode cluster analysis suggests that the Cannonball neogastropods have little or no paleoenvironmental significance. However, Vitticoncha torelli occurs only in sandstone and muddy sandstone, suggesting that it may be indicative of higher-energy, sandier environments, whereas Deussenia minuta and Deussenia? sp. occur only in muddy sandstone and mudstone suggesting that they are indicative of lower-energy, muddier environments.

Comparisons between the Cannonball neogastropods and those of the Western Interior Late Cretaceous neogastropod faunas of the Fox Hills and Pierre Formations indicate that

60 percent of the genera and likely all of the species from these latter formations became extinct prior to Cannonball time.

In general, other Paleocene gastropod faunas derived from clastic marine units are more diverse and seem to represent warmer oceanic climates. The occurrence of Cannonball neogastropods in other faunas is restricted to those from higher latitudes. Five species occur in the Agatdal Formation of West Greenland, two in the "greensands" of Copenhagen, Denmark, and one in the Aquia Formation of Maryland and Virginia. Species that are similar to those in the Cannonball, but apparently not conspecific with them, also occur in these faunas and in the Midway Group of Texas and Alabama.

A northerly or northeasterly source for the Cannonball Sea is suggested based on the strong similarity between the Cannonball, West Greenland, and Denmark faunas, and the relative dissimilarity of the Gulf Coast faunas. Furthermore, most if not all of the boreal and "Tethyan" molluscan genera present in the Cannonball fauna also appear to occur in the West Greenland fauna. By contrast, the Gulf Coast faunas lack the boreal forms and several of the warmer water groups. Therefore, a source to the north or northeast would most readily explain both the generic composition of the Cannonball fauna and the fact that the greatest number of Cannonball species occur in West Greenland. The absence

of the more "tropical" West Greenland forms in the Cannonball fauna is attributed to cooling caused by the mixing of warm, northward-flowing North Atlantic waters and cooler Arctic waters.

The occurrence of Cannonball neogastropods is restricted entirely to other faunas of Thanetian age, and, therefore, a Thanetian age has been interpreted for the Cannonball Formation based solely on the neogastropod data.

## SYSTEMATIC PALEONTOLOGY

The supra-subfamilial classification of the neogastropods used here is that of Taylor and Sohl (1962). The subfamilial classification of the Turridae follows Powell (1966); that of the Fasciolaridae follows Davies (1975). Within each family or subfamily, genera are treated in alphabetical order and indeterminate species are given at the end.

Morphologic terminology follows Cox (1960) with one exception. Cox preferred the term "costa" for gastropod axial sculpture rather than "rib." However, the term costa is rarely, if ever, applied to gastropod shells. For this reason, I have chosen to use rib. Species synonymies are complete, to the best of my knowledge.

All dimensional measurements are in millimeters. In instances where a particular measurement was taken from more than one individual, the range of values is given and the number of shells measured follows in parentheses; for example, H: 12-15 (n=3). Measurement abbreviations are prefixed by the letter "E" (for estimated) where slight allowances have been made for an incomplete shell. The following measurement abbreviations are used:

H = Height  
W = Maximum width  
SH = Spire height  
AW = Aperture width  
PA = Pleural angle (in degrees)

The stratigraphic and geographic occurrence of each species is given in Appendix A. The type locality of each species is given by the appropriate accession number and the corresponding locality number found in Appendix A.

In the Turridae, and to a lesser extent in the Fasciolaridae and Melongenidae, the shape of the growth line has traditionally been given considerable weight in taxonomic distinctions. For this reason, camera lucida drawings of growth lines have been included for most of the Cannonball species, and, where pertinent, for the type species of genera to which Cannonball species have been assigned. These drawings, particularly those of type specimens, should prove valuable in making taxonomic assignments and comparisons.

Three abbreviations used frequently in this section, in reference to collections and catalogued specimens, include: UND=University of North Dakota, Department of Geology and Geological Engineering; UMMP=University of Michigan Museum of Paleontology; and USNM=United States National Museum.

Phylum MOLLUSCA

Class GASTROPODA

Order NEOGASTROPODA

Suborder STENOGLOSSA

Family MELONGENIDAE

Diagnosis.--Shells medium to large; pyriform to subfusiform; spire low to fairly elevated; whorls constricted posteriorly into poorly to well-developed subsutural collar; anterior canal short and indistinct to rather elongate, broadly open to rather narrow, straight to moderately bent; axial sculpture of ribs, nodes, or spines; spiral sculpture of threads and cords; aperture generally broad, sometimes with moderate to deep adapical channel; outer lip internally smooth, lirate, or crenulate; columella smooth, straight or twisted.

Genus DEUSSENIA Stephenson, 1941

Type species.--by original designation; Deussenia cibolensis Stephenson, 1941, p. 332-333, pl. 64, figs. 13, 14.

Diagnosis.--Shells fusiform; whorls constricted posteriorly to moderately broad subsutural collar; spire of moderate height; siphonal canal curved abaperturally; sculpture ornate, consisting of transverse ribs accentuated to nodes at shoulder, dying out anteriorly and posteriorly; strong spiral cords or ribbons on whorl sides and finer spiral threads on collar; growth lines prosocline on collar, strongly sinused at shoulder, and broadly arcuate anteriorly; aperture notched posteriorly; outer lip crenulated internally; columella smooth (modified from Sohl, 1964, p. 199).

Remarks.--As noted by Sohl (1964, p. 199):

. . . Deussenia Stephenson . . . on the basis of growth line, shape, and apertural features, appears to be very closely related to Rhombopsis but differs by having a strongly developed subsutural collar. In Rhombopsis there is a poor development or total lack of such a collar.

Immature specimens of Rhombopsis gracilis (Stanton) occasionally have rather strong collar development (pl. 1 fig. 31), but lack the crenulate outer lip and abaperturally bent canal of Deussenia.

The two Cannonball species assigned to this genus are considerably smaller than the Upper Cretaceous Deussenia from the Gulf Coast and Mississippi Embayment. Furthermore, the Cannonball species have more abruptly constricting last whorls, and more concave, less strongly sinused growth lines, characters more nearly like those displayed by immature specimens of D. ripleyana in the USNM collections.

If the Cannonball species described below are correctly assigned, they represent the first known report of Deussenia from Tertiary strata and an extension of its range into the Paleocene. Presently, I know of no other Paleocene species that appear to be referable to this genus.

Deussenia minuta n. sp.

Pl. 1, Figs. 24, 25.



Diagnosis.--Shell small for genus, height/width ratio 1.8 (n=2); anterior canal somewhat short for genus; 15 axial ribs on last whorl; spiral sculpture of 13 threads on penultimate whorl.

Description of Cannonball material.--Shell of about 6 whorls, subsutural collar well-developed; spire less than half total shell height; last whorl constricting abruptly anteriorly to weakly fascioled canal; suture rather strongly adpressed; protoconch unknown; faint swellings corresponding to axial ribs occasionally visible on subsutural collar; spiral ribbons on whorl sides equal to, or slightly narrower than spaces between, threads on subsutural collar much thinner and proportionally more distantly spaced; inner lip lightly callused, abapertural margin of parietal lip slightly excavated.

Material.--Six specimens, one nearly complete and possibly mature.

Types.--Holotype UND 12878; Paratype UND 12879.

Measurements.--EH: 14.6-15.0 (n=2); EW: 8.0-8.5 (n=2); ESH: 6.4-7.0 (n=2); AW: 3.5-4.5 (n=2); PA: 46-52 (n=2).

Occurrence.--Lower, middle, and upper units of Cannonball Formation.

Type locality.--A2694, locality 14.

Etymology.--This species name is derived from the Latin minutus meaning "minute" in reference to its relatively small size for the genus.

Remarks.-- The small size of the specimens suggests that the available specimens of this species may be immature. If these specimens are mature, they are considerably smaller and have a relatively shorter anterior canal than species from the Upper Cretaceous. Furthermore, the spiral sculpture in the Cannonball specimens is more delicate with a less abrupt change in strength between the whorl sides and posterior slope.

This species differs from Deussenia? sp. in its better developed subsutural collar, unbeaded spiral sculpture, and a more prosocline growth line trace on the posterior slope.

Deussenia? sp.

Pl. 1, Figs. 1, 2.

Diagnosis.--Shell small for genus; subsutural collar poorly developed, posterior slope evenly concave; 15 axial ribs on last whorl; spiral sculpture minutely beaded at intersections with prominent lines of growth.

Description of Cannonball material.--Shell of about 7 whorls; spire somewhat less than half total shell height; last whorl contracting rather abruptly anteriorly to moderately long canal; suture nearly straight, moderately adpressed; protoconch unknown; sculpture on earliest preserved whorl (post-nuclear?) initiated by slightly opisthocline axial ribs extending from suture to suture, spiral threads appearing after about 3/4 whorl, whorls

become constricted posteriorly on second or third teleoconch whorl, constriction of whorls accompanied by appearance of more nodose ribs confined to whorl shoulder; spiral threads equal to, or slightly narrower than spaces between occasionally with intervening finer threads, threads on posterior slope slightly finer, two posterior-most threads on subsutural collar relatively stronger; growth line trace on posterior whorl slope evenly and shallowly opisthocyrt, continuing across shoulder with no change in trend, opisthocline across convex portion of whorl; outer lip unknown; inner lip very lightly callused, threads visible on parietal lip, abapertural margin excavated.

Material.--Two fragmentary specimens.

Types.--Hypotypes UND 12880.

Measurements.--EW: 8.0; EAW: 3.5; PA: 52.

Occurrence.--Lower and upper units of Cannonball Formation.

Remarks.--This poorly known species has a shallow, broadly opisthocyrt growth line trace on the posterior whorl slope, which, at first glance, might appear to be a turrid sinus. According to Sohl (1989), the growth line trace displayed by this species would not preclude its placement in Deussenia.

The strongly shouldered and posteriorly constricted whorls and nodose axial sculpture suggest placement of this species in Deussenia. One specimen is missing part of the

anterior canal, but the preserved part shows the beginning of a slight abapertural bend, further suggesting affinities with Deussenia. Furthermore, the ontogenetic development of the sculpture and whorl shape described above for this species is close to that described by Sohl (1964, p. 200) for D. ripleyana.

Deussenia? sp. differs from Deussenia minuta by its finely beaded spiral sculpture, less well-defined subsutural collar, and more evenly opisthocyrt growth line trace on the posterior slope.

Kollman and Peel (1983, p. 75, fig. 158 a, b) figured a species of Nekewis from the Paleocene of western Greenland similar to Deussenia? sp. in its growth line configuration on the posterior slope and the finely beaded spiral sculpture. The last whorl, at least as figured, appears to be more axially compressed and thus may actually be more closely related to Nekewis Stewart.

Genus RHOMBOPSIS Gardner, 1916

Type species.--by original designation; Fusus newberryi Meek and Hayden, 1857, p. 139.

Diagnosis.--Shells pyriform to subfusiform, of medium size; whorls moderately shouldered, posteriorly constricted to broad subsutural collar or inclined ramp; anterior canal moderately long, rather straight; sculpture of axial ribs or elongate nodes, numerous spiral cords or threads; aperture

sublenticular with shallow posterior notch (modified from Sohl, 1964, p. 198).

Remarks.--Meek (1865, p. 344) proposed Neptunella as a subgenus of Pyrifusus Conrad to accomodate three Upper Cretaceous species from the Western Interior: Fusus newberryi, Fusus subturritus, and Fusus intertextus. Gardner (1916, p. 456) recognized that Neptunella Meek was preoccupied by Neptunella Gray, 1853, and, therefore, proposed the name Rhombopsis to replace it. A more complete summary of Rhombopsis can be found in Sohl (1964, P. 198-199) and Erickson (1974, p. 190-191).

Rhombopsis Gardner bears some resemblance to Pyrifusus Conrad and Deussenia Stephenson, 1941. Pyrifusus differs from Rhombopsis by its lower spire, deeper posterior notch, heavily callused inner lip, and less sinuous growth line (Sohl, 1964, p. 199). Erickson (1974, p. 190) noted in a comparison of the types that Rhombopsis and Pyrifusus are not closely related. I have studied the types of all species assigned to Rhombopsis and Deussenia, and I would agree.

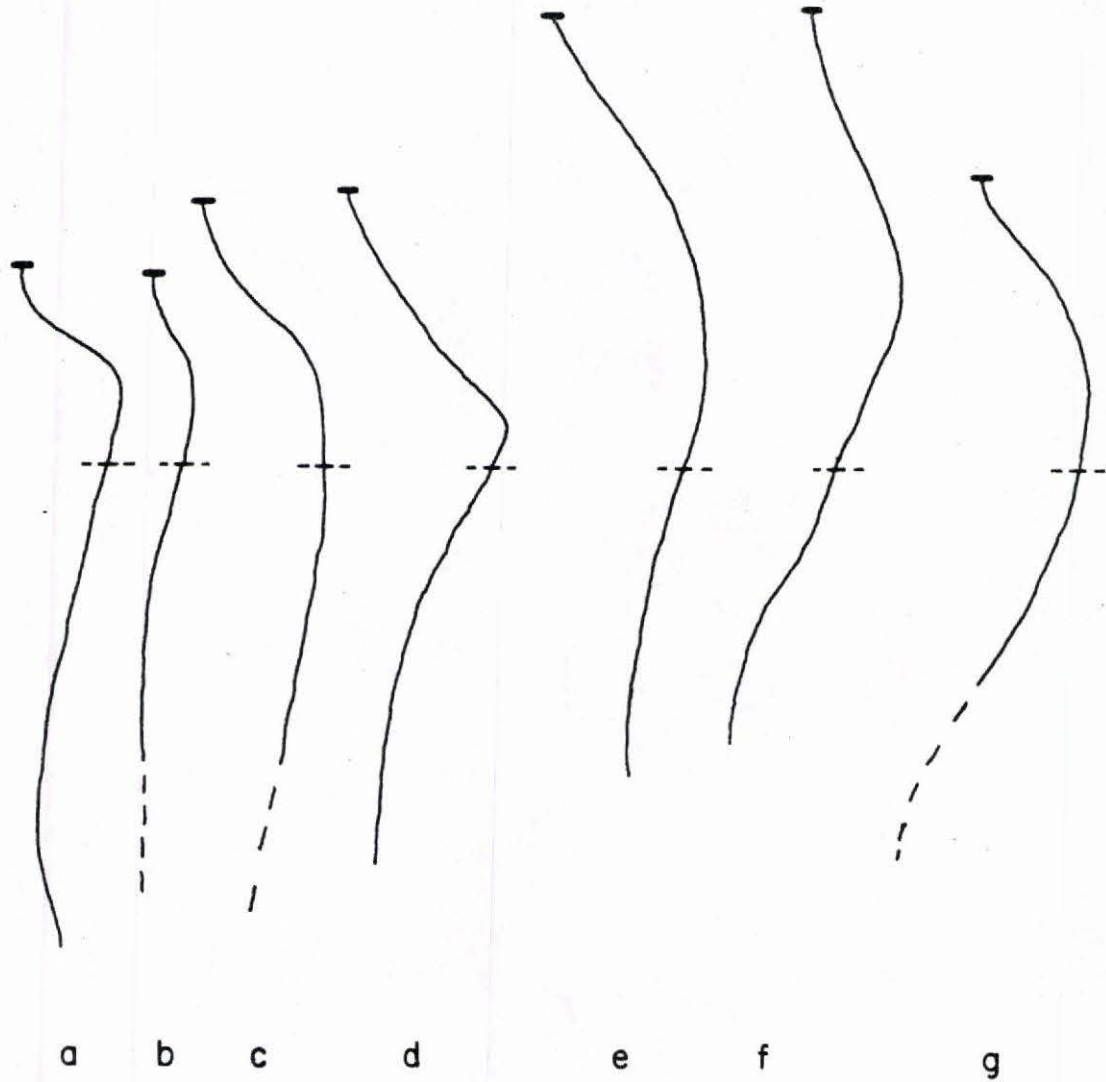
Sohl (1964, p. 199) suggested the possibility of intergradation between Rhombopsis and Deussenia if the concept of Rhombopsis were broadened to include such forms as R. orientalis Wade. Sohl (1964, p. 198) further indicated that although Rhombopsis closely resembles Deussenia in overall shape, growth line, and apertural

features, it can be distinguished from Deussenia by its weak to nearly absent subsutural collar as compared to the strongly developed collar of Deussenia.

Although Deussenia generally has a more strongly developed subsutural collar, some individuals of Rhombopsis gracilis (Stanton), described below, show collar development and growth line trace similar to those of typical Deussenia (Fig. 7). In spite of these similar characters, Rhombopsis may be consistently distinguished from Deussenia by its nearly straight anterior canal and noncrenulate outer lip.

Finlay and Marwick (1937, p. 84) noted some similarity between Rhombopsis and their new turrid genus Marshallaria but distinguished between them with the following statement: "The sinus of the outer lip of Rhombopsis, however, is somewhat different, being broader and not confined to the shoulder, so that the shell has not been regarded as having Turrid affinities." The meaning of this statement is not entirely clear, since the sinus need not be confined to the whorl shoulder to be a turrid. Judging from their accompanying figures, and my knowledge of Rhombopsis, the authors were most likely referring to the fact that the "sinus" of Rhombopsis is not confined to the posterior whorl slope, as it is in Marshallaria.

Figure 7. Camera lucida drawings of growth lines taken from the last whorl of two species of Rhombopsis Gardner and Deussenia Stephenson. Growth lines magnified six times and adjusted to uniform shoulder height. Wide solid line denotes position of posterior suture, dashed line denotes whorl periphery. Arrow points adaperturally. (a) R. gracilis (Stanton), hypotype, U MMP 66062; (b) R. gracilis (Stanton), hypotype, U MMP 66059; (c) D. ripleyana Harbison, hypotype, USNM 130266; (d) D. ripleyana Harbison, hypotype, USNM 130269; (e) Rhombopsis newberryi (Meek and Hayden), holotype, USNM 257; (f) Rhombopsis intertextus (Meek and Hayden), holotype, USNM 253; (g) Rhombopsis subturritus (Meek and Hayden), holotype, USNM 254.





Rhombopsis gracilis (Stanton)

Pl. 1, Figs. 18, 23, 30, 31; text fig. 7a, b.

Pyrifusus (Neptunella) gracilis Stanton, 1920, p. 41, pl. 8,  
figs. 1 a, b.

Diagnosis.--Last whorl slender, tapering gradually anteriorly; height/width ratio 2.2 (n=3); pleural angle about 50 degrees; axial sculpture of 15 prominent ribs per whorl, slightly opisthoclinal to nearly vertical, confined to convex portion of whorl, equal in width to spaces between, tending to become obsolete on last whorl of mature specimens.

Description of Cannonball material.--Species of average size for genus; of about 6 whorls; spire slightly more than one-half total shell height; suture moderately to strongly adpressed; spiral ornament of numerous, rounded spiral bands, equal to, or narrower than spaces between, often with finer lirae inserted between, all becoming finer on posterior slope, subsutural collar, and anterior canal; growth lines sinuous on posterior slope, broadly prosoclyt over convex portion of whorl, orthoclinal on base and anterior canal; outer lip thin; inner lip with moderately thick callus; columella straight.

Material.--Twenty-three specimens of which one is mature.

Types.--Hypotypes UND 12881, UMMP 66059 and 66062.

Measurements.--EW: 18.0; SH: 21.3; EAW: 8.0; PA: 35.

Occurrence.--Lower, middle, and upper units Cannonball Formation.

Type locality.--Accession number torn off label, locality 7.

Remarks.--Rhombopsis gracilis most closely resembles R. intertextus (Meek and Hayden) from the Upper Cretaceous of the Western Interior in its apertural and columellar features. Rhombopsis gracilis differs in having elongate axial ribs and fine, closely spaced spiral threads. Rhombopsis orientalis Wade, from the Upper Cretaceous Ripley Formation of Tennessee, is similar in its overall shape and ornamentation. Rhombopsis gracilis, however, has axial ribs that are longer, more nearly vertical, and more distantly spaced. I have examined the holotypes of R. gracilis and R. orientalis and they appear to be distinct. Rhombopsis orientalis is known only from a single specimen; therefore, additional material may show intergradation. The available specimens of R. gracilis show some variation in the strength of the axial ribs, posterior collar development, and the relative abruptness in which the last whorl tapers anteriorly.

#### Family FASCIOLARIIDAE

Diagnosis.--Shells elongate- to stout-fusiform; anterior canal moderately to extremely produced, straight to

moderately twisted; usually with axial ribs and spiral threads, rarely smooth; outer lip internally lirate or smooth; columella smooth or with plaits.

Subfamily FUSININAE

Diagnosis.--Shells generally elongate-fusiform; anterior canal usually long, straight, or slightly twisted, nearly always without columellar folds or siphonal fasciole (modified from Davies, 1971, p. 368).

Genus ERICKSONIA n. gen.

Type species.--Ericksonia clivilinea n. sp.

Diagnosis.--Shells fusiform; height/width ratio 2.0 (n=1); whorls about 6, rather strongly shouldered, posterior slope concave; spire less than half total shell height; last whorl constricted abruptly anteriorly to long, straight, unfascioled anterior canal; suture slightly adpressed, undulatory; protoconch unknown; axial sculpture of 15 coarse ribs on convex portion of whorl, most prominent at shoulder, decreasing in strength abruptly on anterior and posterior slopes, generally equal to, or slightly broader than spaces between; spiral sculpture of 6 coarse threads on convex portion of whorl, occasionally with finer threads between, three posterior-most coarse threads visible on spire, posterior and anterior slopes of last whorl and anterior canal covered with finer, evenly spaced threads much

narrower than spaces between; growth lines obscured on posterior slope of all whorls, orthocone over base of last whorl and anterior canal; aperture incomplete, sub-ovate; outer lip incomplete, apparently internally non-lirate; inner lip smooth.

Etymology.--This genus is named in honor of Dr. J. Mark Erickson, St. Lawrence University, for introducing me to taxonomy and Paleocene gastropods, and for offering continual guidance, enthusiasm, and critical comments throughout this study. His love for paleontology and involvement with students, as both teacher and friend, make him an asset to the scientific and teaching communities.

Remarks.--Ericksonia shows gross similarities with Levifusus Conrad as conceived of by Palmer (1937), specifically with L. mortoniopsis (Gabb) and L. mortoni (Lea). Ericksonia differs considerably from the more typical Levifusus by its more slender last whorl, absence of axially-compressed peripheral nodes, straighter anterior canal, and a proportionally higher spire. In addition, the outer lip of Ericksonia, although incompletely known, appears to have been internally smooth. Levifusus mortoniopsis and L. mortoni, although similar in overall shape and sculpture, do not seem assignable to Ericksonia because of their more axially-compressed last whorl, more abruptly constricting aperture, and internally lirate outer lip.

Kollman and Peel (1983, p. 83, figs. 183, 184) figured two species which they considered to represent a new, unnamed genus, similar to Levifusus Conrad. Judging from the figures, these forms appear to be referable to Ericksonia. In addition to the Greenland species, they listed L. amplus (Briart and Cornet, sensu Glibert, 1973, pl.8, fig. 7) and Pleurotoma pagoda Heilprin as species related to the new genus. Judging from Glibert's (1973) figure of L. amplus, it appears to be more typical of Levifusus in its axially-compressed peripheral nodes, large last whorl, and strongly bent anterior canal. I have seen the holotype of Pleurotoma pagoda, and it is not referable to Ericksonia; in fact, the assignment of P. pagoda to Levifusus seems questionable based on its more slender last whorl, nearly straight anterior canal, and high clasping whorls. In this last regard, it resembles the Greenland species mentioned above; however, my feeling is that P. pagoda is generically distinct from Ericksonia.

Ericksonia clivilinea n. sp.

Pl. 1, Figs. 26, 27.

Diagnosis.--Same as for genus.

Material.--Single specimen, surface slightly worn, outer lip broken, apex incomplete.

Types.--Holotype UMMP 66060.

Measurements.--(holotype) EH: 43.0; EW: 21.0; ESH 20.0;  
PA: 43.

Occurrence.--Lower unit of Cannonball Formation.

Type locality.--1962/Tpa-3, locality 31.

Etymology.--This species name is derived from the Latin clivus meaning "slope," and linea meaning "thread" in reference to the spiral threads on the posterior slope.

Remarks.--The specific characters of Ericksonia clivilinea are likely the fifteen axial ribs, six coarse threads on the convex part of the last whorl, and fine, distantly spaced threads on the posterior whorl slope. Two specimens figured by Kollman and Peel (1983, p. 83, figs, 183, 184) appear to be closely related; but, based on their figures, these specimens seem to differ in having whorls that clasp slightly higher on the preceding whorl and smooth anterior and posterior slopes on the last whorl. Unless these differences can be refuted, I am reluctant to assign the Greenland forms to this species.

Genus EXILIA Conrad, 1860

Type species.--by monotypy; Exilia pergracilis Conrad, 1860, p. 291.

Diagnosis.--Shells narrow-fusiform; whorls broadly convex, last whorl contracting rather gradually into long, slender, straight canal; spire equal to half total shell height; protoconch of 3 smooth whorls, adult sculpture

initiated abruptly on fourth whorl; axial sculpture of broadly prosocyrte ribs; spiral sculpture of ribbons or threads, covering entire shell surface; aperture narrow; outer lip non-serrate; inner lip smooth; columella without plaits (modified from Bentson, 1941, p. 201).

Remarks.--Much of the following discussion is based on Bentson's (1941, p. 199-237) revision of Exilia. Although some of the species treated in that report have since been reassigned, many of her observations and conclusions are still valid, particularly those regarding the type species of Exilia.

Exilia Conrad has been assigned to several families since its inception. The early familial treatments have been discussed in detail by Bentson (1941, p. 201) and will not be recounted here.

Conrad (1860, p. 291) made no mention of a posterior sinus in the original description of E. pergracilis. Stewart (1927, p. 419) later assigned Exilia to the Turridae after describing a shallow posterior sinus on the holotype. Bentson (1941, p. 210-202) discounted the presence of such a sinus in Exilia with the following statement:

An examination of specimens of E. pergracilis and of other species included in Exilia fails to disclose the presence of even a faint notch, nor are the growth lines of any of the species strongly flexed. There does not appear to be any positive evidence to support the idea that the genus Exilia has an anal sulcus.

Subsequent workers have followed the work of Bentson (1941) in placing Exilia in the Fasciolaridae.

I have not seen the holotype of E. pergracilis; however, E. pergracilis? (Gardner 1935, p. 224, pl. 20, figs. 18, 19) and E. bentsonae Hickman (1980, p. 61, pl. 8, figs. 5-11) have axial ribs that are only broadly curved posteriorly. Therefore, on the basis of the strongly fusiform shape, straight anterior canal, and the lack of a turrid-like sinus, I have opted to follow Bentson (1941) in assigning Exilia to the Fasciolaridae.

Erickson (1974, p. 207) noted that if Exilia were placed among the fasciolarids, Remera Stephenson would become a junior synonym of Exilia. I have examined the holotypes of species assigned to Remera by Sohl (1964, p. 226-227) and Erickson (1976, p. 208), and the two genera do appear to be akin in overall shape and sculpture. Exilia, as I understand it, differs from Sohl's (1964, p. 226) concept of Remera in its more gradually tapered last whorl, spiral sculpture that does not decrease in strength when crossing the axial ribs, more strongly convex whorls, and in its proportionally shorter spire. Bentson (1941, p. 201) described the spire of Exilia as being equal to the aperture in length on unbroken specimens. This character warrants further discussion.

Although the holotype of E. pergracilis has an incomplete anterior canal, one of the hypotypes figured by



Bentson (1941, pl. 1, figs. 12, 13) appears to be complete and has a spire equal to half the total shell height. Many of the species subsequently assigned to Exilia also have incomplete types, yet many of these specimens give the impression that the spire originally exceeded the length of the aperture and canal. I have refrained from emending Bentson's (1941, p. 201) generic diagnosis to include species with proportionally higher spires because most of these species are incompletely known and I have not seen several of the pertinent types. Therefore, I have assumed that the shell proportions displayed by the Cannonball material fall within the range of variation for Exilia.

If it can be shown that Exilia does, in fact, have a spire exceeding half the total shell height, then Exilia and Remera are distinguishable only on the basis of the spiral sculpture and slight variations in whorl shape. In my opinion, these differences warrant no more than subgeneric distinction, but until this problem can be studied in more detail, it seems reasonable to continue their treatment as distinct genera. The Cannonball species has been assigned to Exilia, rather than Remera, on the basis of its broadly convex whorl profile, constant strength of the spiral ribbons, more delicate axial sculpture, and more gradually tapering last whorl. The Cannonball species has a sinuous columella similar to that displayed by many Remera.

The apparent proportionally high spire of many Exilia is similar to that of Graphidula Stephenson. According to Sohl (1964, p. 211), Graphidula has a columella ". . . generally with one moderately strong plait that is not visible at the aperture." One specimen in the UND collections has the columella exposed and it is smooth.

The validity of Zexilia Finlay may also be questionable. Finlay and Marwick (1937, p. 69) stated that although Stewart's (1927) figure of E. microtygma (Gabb) possessed the same curved axials as Zexilia, the columella had several closely spaced ridges or plaits. Powell (1966, p. 143) similarly distinguished Zexilia from Exilia by its lack of columellar folds. The idea that Exilia possesses columellar plaits stems from confusion regarding the type species of Exilia (Bentson 1941, p. 201). Authors have confused E. pergracilis with Fasciolaria pergracilis (Aldrich), a species which does, in fact, display two columellar plaits (Bentson 1941, p. 201). Bentson (1941, p. 201) stated that although E. pergracilis does have spiral lines on the columella, they are by no means true plaits. She further commented on the insignificance of the spiral ridges present on the inner lip of some Exilia:

These lines on the inner lip do not appear to have any morphologic significance and are therefore of no importance as a generic or specific character. They are merely the spiral threads of the ornamentation of the body whorl which show through on specimens having a thin callus covering the inner

lip. They do not become increasingly stronger in the interior of the shell, as do true columellar folds, but rapidly fade out.

I have not seen a figure of Zexilia waihaoensis, the type species of Zexilia; however, I have seen figures of four other Zexilia. Of these, Z. vixcostata and Z. leachi agree rather closely with Exilia in their fusiform shape, sculpture, smooth columella, and growth line trace. Zexilia nodulifera (Finlay and Marwick 1937, pl. 10, figs. 187) is too incomplete for detailed comparisons with American species, yet the axial nodes of Z. nodulifera recall those displayed by E. benstonae Hickman (Hickman 1980, pl. 8, figs. 6, 7) from the Upper Eocene Keasey Formation of Oregon. Therefore, the peripheral nodes displayed by Z. nodulifera would not necessarily preclude its placement in Exilia.

Exilia has been confused with the Recent Eastern Pacific genus Exilioidea Grant and Gale (Hickman 1980, p. 61). Hickman (1980, p. 61) believed Exilioidea to be a neptuneid rather than a fasciolariid on the basis of the well-developed periostracum and large protoconch. Benston (1941, p. 203) further distinguished Exilia from Exilioidea on the basis of a more slender shell, less inflated last whorl, and a proportionally longer, more narrow anterior canal. Vaught's (1989, p. 47) placement of Exilia as a Recent subgenus of the fossil genus Exilioidea is probably a misprint.

According to Bentson (1941, p. 200), the Paleocene distribution of Exilia encompassed Europe and in North America, the Gulf coast region and possibly the Pacific coast. In light of the Cannonball species described here, and the species figured by Kollman and Peel (1983, p. 84, figs. 186 a,b), the North American Western Interior and western Greenland should also be added to its geographic range.

Exilia sp.

Pl. 1, Figs. 9, 10.

Diagnosis.--Shell rather large for genus, height-width ratio 4.3 ( $n=1$ ); probably of 8 to 10 whorls when complete, whorls faintly contracted posteriorly; 22 to 25 axial ribs per whorl; spiral sculpture of about 16 flat-topped ribbons on penultimate whorl; inner lip smooth; columella sinuous in profile.

Description of Cannonball material.--Anterior canal apparently short for genus; suture impressed, straight; width of axial ribs approximately equal to spaces between; spacing of spiral ribbons somewhat variable, generally equal to, or wider than spaces between; growth lines gently opisthocyrte on convex portion of whorl, orthocline on base of last whorl and anterior canal; outer lip broken; inner lip with moderately thick callus, no spiral threads protruding through.

Material.--Four specimens, 3 mature; one nearly complete except for apical whorls, outer lip, and tip of canal.

Types.--Hypotypes UND 1008.

Measurements.--H: 33.0; W: 9.2; SH: 18.5; WA: 3.7; PA: 21.

Occurrence.--Lower and middle units of Cannonball Formation.

Remarks.--The Cannonball species closely resembles E. pergracilis Conrad in terms of the overall shape and sculpture. I have not seen the type of E. pergracilis from the Paleocene of Alabama, and to the best of my knowledge the rather poor description given by Conrad is the only one in existence. Therefore, it is difficult to make any detailed comparisons with the Cannonball species. I have seen the specimen questionably assigned to E. pergracilis by Gardner (1935, pl. 20, figs. 18, 19) from the Midway Group of Texas. It is a smaller, more slender species with more numerous axial and spiral elements.

Specimens of E. crassistria figured by Koenen (1885, pl. 1, fig. 12 a, b) and Ravn (1939, pl. 3, fig. 3 a, b) from the late Paleocene of Copenhagen, Denmark, have more strongly convex whorls and more numerous, narrower axial ribs, giving the sculpture a reticulate appearance. Kollman and Peel (1983, p. 84, figs. 186 a, b) figured an unnamed

species from the late Paleocene of West Greenland, thought to be closely related to E. crassistria Koenen. This species also appears to be smaller than the Cannonball form and has cancellate sculpture resulting from the narrower, more closely spaced axial ribs. Traub (1980, pl. 6, figs. 7 a, b) figured a specimen from the German Paleocene as Exilia cf. crassistria (Koenen) which appears to be quite close to the Cannonball species.

In all likelihood the Cannonball material represents a new species; however, there is not adequate material available, nor have I seen all the types necessary to confirm this.

Genus FUSINUS Rafinesque, 1815

Type species.--by monotypy; Murex colus Linnaeus, 1758.

Remarks.--According to Dall (1909, p. 36) and Woodring (1928, p. 385), Fusinus, rather than Fusus, is the correct name for those species typified by Murex colus Lamarck. Woodring (1928, p. 256) cited Grabau (1904) as stating that the earliest representatives of Fusinus s. s. are from the Eocene deposits of the Paris, London, and Hampshire Basins. This occurrence is entirely possible; however, the term "Eocene," as used by early authors, included strata known today to be Paleocene in age. Detailed summaries of Fusinus, including its complex synonymy, are given by Dall (1909, p. 36-39) and Woodring (1928, p. 256-259).

Fusinus? sp.

Pl. 1, Figs. 3-5.

Description of Cannonball material.--Whorls strongly convex, somewhat flattened posteriorly; anterior canal extremely long, posterior one-half straight, remainder bent slightly abaperturally; suture undulating; protoconch unknown; axial sculpture of strong, broadly rounded ribs, strongest on whorl periphery, dying out on anterior and posterior slopes, broader than spaces between; spiral sculpture of 8 (on last preserved whorl) narrow, widely spaced, elevated ribbons, those on posterior slope and anterior canal slightly weaker, in addition to primary spiral elements, micro-threads form cancellate pattern with fine lines of growth; aperture unknown; outer lip unknown; inner lip smooth, abapertural margin sharply defined and excavated.

Material.--Two fragments of one individual.

Types.--Hypotype UND 12882.

Occurrence.--Middle unit of Cannonball Formation.

Remarks.--This species is known from only two fragments of a single individual, specifically the anterior canal and a portion of three successive whorls joined at the suture. These fragments show several characters that suggest placement in Fusinus, namely its long, slender, anterior canal, convex whorls, and broad axial ribs. Until more

complete material becomes available, this assignment must remain tentative.

Genus SERRIFUSUS Meek, 1876

Type species.--by original designation; Fusus dakotaensis Meek and Hayden, 1856, p. 65.

Diagnosis.--Shell short-fusiform; whorls shouldered anterior to mid-whorl height, posterior slope steeply inclined, nearly flat; spire somewhat less than half total shell height; last whorl large, bicarinate or tricarinate, with carinae nodose to almost spinose, anterior canal bent abaperturally and somewhat twisted; outer lip broadly sinuous in outline between posterior carina and suture (modified from Meek 1876, p. 373).

Remarks.--Serrifusus was previously thought to be confined to the Upper Cretaceous rocks of northern and western North America (Sohl 1967, p. 24; Erickson 1974, p. 204-205). The Cannonball species described below extends the known range of Serrifusus into the Paleocene. Additional comments regarding Serrifusus can be found in Sohl (1967, p. 29) and Erickson (1974, p. 204, 205).

Finlay and Marwick (1937, p. 72) suggested that Taioma may be related to Serrifusus, but it appeared to them to differ from Serrifusus by its more strongly twisted anterior canal and sinuous growth lines on the posterior whorl slope.



The growth line trace from the posterior slope of the holotype of Serrifusus dakotaensis is shown in figure 8.

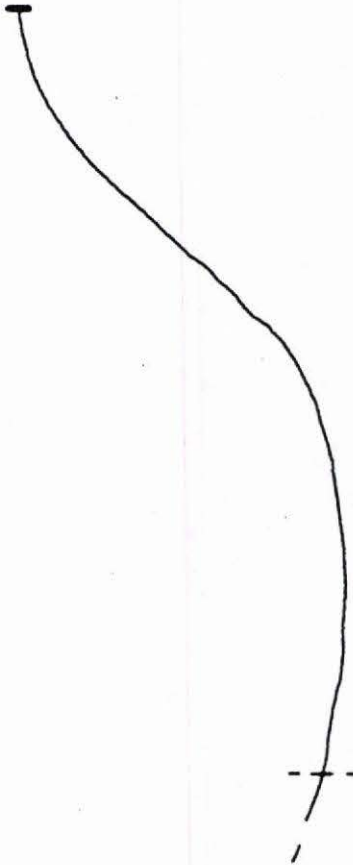
Serrifusus sohli n. sp.

Pl. 1, Figs. 6, 21, 22.

Diagnosis.--Shell small for genus; height/width ratio 1.7 (n=1); last whorl bicarinate, carinae rather continuous; axial sculpture of about 15 broad swellings, accentuated to axially compressed nodes at carinae.

Description of Cannonball material.--Whorls probably 5 or 6, shouldered slightly anterior to mid-whorl height; anterior canal incompletely known, apparently of moderate length; suture more or less scalloped depending on strength of peripheral nodes; protoconchs incomplete and worn, apparently of two or more strongly convex, globose whorls, teleoconch sculpture initiated by single spiral band forming shoulder at about mid-whorl height; axial sculpture extremely variable in strength between individuals, axially compressed nodes appear more pointed on early whorls and, on one specimen, even slightly posteriorly directed, axial swellings absent on posterior slope, or present as broad undulations, absent to moderately well-developed between carinae, fading abruptly on anterior slope of last whorl; spiral sculpture dominated by 2 carinae, posterior carina stronger and with more prominent nodes, secondary spiral

Figure 8. Camera lucida drawing of growth line taken from the posterior slope of the last whorl of Serrifusus dakotaensis (Meek and Hayden), holotype, USNM 256. Growth line magnified six times. Wide solid line denotes posterior suture, dashed line denotes whorl periphery. Arrow points adaperturally.



elements also quite variable in strength and number, of flat ribbons and threads, narrower than spaces between, single relatively stronger ribbon on crest of each carina; aperture subovate to subspherical, with shallow adapical channel, angled at shoulder and anterior carina; outer lip unknown, probably thin; inner lip with moderately thick callus; columella concave with oblique, rather sharp-crested shoulder at posterior margin of anterior canal.

Material.--Twelve specimens, mostly fragments, 1 nearly complete specimen with apex, outer lip and canal slightly damaged, early whorls eroded; 3 immature specimens with apical whorls nearly complete.

Types.--Holotype UND 12883, Paratypes UND 12884 through 12888.

Measurements.--(holotype) EH: 47.0; EW: 28.0; ESH: 23; EAW: 13.0; PA: deformed, 56.

Occurrence.--Lower and middle units of Cannonball Formation.

Type Locality.--A2666, locality 32.

Etymology.--This species is named in honor of Dr. Norman F. Sohl of the United States Geological Survey. His monographs of Late Cretaceous gastropods, service on my Smithsonian Fellowship committee, and helpful comments regarding difficult taxa, have added greatly to the success of this study.

Remarks.--Considerable intraspecific variation is apparent within the available material, mainly in the relative strength of the peripheral nodes and in the number and strength of the secondary spiral elements, particularly on the posterior whorl slope (pl. 1, figs. 6, 22). On some individuals the posterior two-thirds of the posterior slope lacks spiral threads, whereas on others, the entire slope is covered with evenly spaced ribbons of uniform strength.

Serrifusus sohli is considerably smaller than the Upper Cretaceous species. It agrees closely with Meek and Hayden's (1856a, p. 65) type in overall shape and sculpture, and in the characteristics of the aperture and columella. However, it differs in its suppression of the third, anteriormost carina, and in the details of the secondary spiral sculpture. In addition, S. sohli has more continuous carinae than does Serrifusus dakotaensis. The whorl shape of S. sohli most closely resembles a specimen of S. dakotaensis figured by Sohl (1967, pl. 6, fig. 12) from the Fox Hills Formation, and the variety of Serrifusus dakotaensis figured by Meek (1876, pl. 32, fig. 7a). These specimens, however, have tricarinate last whorls and less arcuate columellas.

The oblique shoulder at the posterior margin of the anterior canal, described above, should not be construed as a columellar plait. Less complete specimens with exposed columellas indicate that this shoulder is broadly rounded

throughout the ontogeny of the shell, suggesting that the cresting of this shoulder may be indicative of shell maturity.

Genus SURCULITES Conrad, 1865

Type species.--by original designation; Surcula (Surculites) annosa Conrad, 1865, p. 213.

Diagnosis.--Shells biconic; whorls angulate at mid-height, posterior slope slightly to moderately concave; spire much less than half total shell height; last whorl large, bi- or tricarinate, tapering rather abruptly to moderately long, twisted, fascioled, anterior canal; growth lines broadly arcuate between posterior suture and whorl periphery; outer lip non-lirate internally; inner lip smooth.

Remarks.--Conrad (1865, p.213) based his subgenus Surculites on Surcula (Surculites) annosa, a species known only from internal molds from the Eocene of New Jersey. Like Conrad, later workers have regarded Surculites as a turrid genus. Wrigley (1939, p. 282) argued that the apparent sinus on the posterior slope of Surculites was non-turrid, but rather was controlled by the presence and strength of the peripheral carination. I have examined the holotype of Chrysodomus engonatus (Heilprin) which is surely a Surculites as it is presently understood. The early whorls of this specimen are broadly convex and the growth

lines are nearly straight; yet, as the peripheral carination develops, the growth line on the posterior slope acquires a gentle concavity. Therefore, Wrigley's (1939, p.282) conclusion seem justified.

Possibly of some importance is the observation that the growth line on the posterior slope of the Cannonball specimens tend to remain evenly concave over the majority of the shell, and only on the last one half whorl, or so, does the anterior limb sweep forward producing what some authors have construed as a Clinura-like sinus. This growth line development is also displayed on the Cannonball material and on other specimens of S. engonatus (Heilprin) in the collections of the USNM.

Although Wrigley (1939, p. 281-283) argued against the inclusion of Surculites in the Turridae, he was unable to offer a more suitable placement, stating that ". . . it seems best to place the genus in a not too determinate position between the Fusinidae and the Buccinidae . . . ." Powell (1966, p. 147-147) later followed Wrigley (1939) and considered Surculites likely to be non-turrid. In spite of Wrigley's efforts, subsequent workers have placed Surculites within the Turridae (e.g., Traub, 1980, p. 42; Kollman and Peel 1983, p. 98; Squires 1987, p. 48). Hickman (1976, p. 49, text figure 9, p. 50) placed Surculites within the "Acamptogenotia group" near Nekewis on the basis of its sinus shape and finely granular sculpture.

Without knowledge of the soft parts, it appears doubtful whether the turrid affinities of this genus implied by most authors can be shown with any degree of certainty. Therefore, I have decided to assign Surculites tentatively to the Fasciolaridae with which its shell characters have marked similarities, rather than to the Turridae on the basis of a growth line trace which is not unequivocally turrid.

Surculites resembles Clinura Bellardi in general form and sculpture. I have seen two specimens of C. calliope, the type species of Clinura, from the personal collection of Donald Tippet at the USNM. As also noted by Wrigley (1939, p. 283), the anterior limb of the posterior sinus of Clinura swings adaperturally much farther before crossing the shoulder than in any specimens of Surculites that I examined. Of greater importance in distinguishing these genera is the protoconch sculpture and the presence or absence of a notch on the anterior canal. Clinura shows the typical thatcheriid, diagonally-cancellate protoconch, whereas Heilprin (1880, p. 372) and Wrigley (1939, p. 277) have described the protoconchs of S. engonata and S. errans respectively, as consisting of three, smooth, convex whorls. If one assumes that the protoconchs described by Heilprin and Wrigley are unworn, these genera no doubt belong to different families. In light of these morphologic



comparisons, Traub's (1980, p. 42) use of Clinura as a subgenus of Surculites seems unsatisfactory.

The generic concept of Levifusus Conrad, to which Stanton (1921, p. 41-42) originally assigned the Cannonball species, has been broadened considerably since its inception by the inclusion of distantly related forms (see Palmer 1937, pl. 49-51). Surculites differs from the more typical species in its proportionally higher spire, less inflated last whorl, and non-lirate outer lip.

Serrifusus Meek resembles Surculites in its last whorl shape and ornamentation, although Surculites has a narrower, less steep posterior slope and a growth line that is more deeply concave between the shoulder and the posterior suture. The type material of species belonging to Serrifusus is poorly preserved, with none having a complete anterior canal. If future collections show Serrifusus to have a fascioled anterior canal, of which there is some indication, then these two genera may be very closely related.

Whitfield (1892, p. 218) commented that: "Another of Conrad's genera Cochlespira, cited by Tryon as a synonym of Pleurotoma, is so nearly like this one [Surculites] that it would be difficult to point out differences." If we assume that the species subsequently assigned to Surculites are, in fact, congeneric with the holotype, then distinction between these two groups is rather straight forward. Species

belonging to Cochlespira are more slender, have un-notched anterior canals, and a deeper posterior sinus, which, on some species, is bounded anteriorly by a spiral lamella. Furthermore, the peripheral flange in Cochlespira is ornamented with serrated nodes or upturned spinose processes (Powell, 1966, p. 42). The specimen assigned to Surculites by Kollman and Peel (1983, p. 98, fig. 222) is more likely a Cochlespira.

Surculites tormentaria (Stanton)

Pl. 1, Figs. 16, 17, 19, 20.

Levifusus tormentaria Stanton, 1921, p. 41, pl. 8, figs. 2  
a, b.

Clinura sp. 1 Kollman and Peel, 1983, p. 97, figs. 220c, d.

Diagnosis.--Shell of average size for genus, height/width ratio 1.69 (n=1); last whorl with 2 prominent carinae bearing numerous poorly defined nodes, whorl constricting abruptly anteriorly to anterior-most carina.

Description of Cannonball material.--Shell of about 6 whorls, posterior slope moderately to slightly concave; last whorl moderately concave between carinae; suture slightly channeled; protoconch unknown; axial sculpture confined to carinae, absent on posterior slope, extremely weak between carinae and on anterior slope; entire shell surface covered with moderately strong threads occasionally with finer threads between, spiral sculpture strongest anterior to

anterior-most carinae, slightly weaker between carinae, and intermediate in strength on posterior slope; growth lines between posterior suture and shoulder somewhat variable in shape, generally broadly concave and centered on shoulder slope, but tending to become asymmetrically deeper towards posterior suture in later stages of growth.

Material.--Ten specimens, mostly fragments of immature individuals, 1 worn specimen nearly complete, but flattened, presumed mature.

Types.--Hypotypes UND 12889 and 12890, UMMP 66058.

Measurements.--EH: 39.0; HS: 15.0; PA: 50.

Occurrence.--Lower, middle, and probably upper units of Cannonball Formation; also Paleocene of western Greenland (Kollman and Peel, 1983, p. 97, fig. 220 c, d).

Type locality.--8382, locality 34.

Remarks.--Surculites tormentaria differs from all other Surculites in its two pronounced, coarsely noded carinae, broader and more deeply concave posterior slope, and nonbeaded spiral sculpture. When specimens of S. tormentaria are held side-by-side with specimens of S. engonata, the similarities are striking. On the basis of the available material, these differences appear to be merely specific variations. The presence of nodes on the whorl shoulder may not be unique to S. tormentaria; Whitfield (1892, p. 219) described similar axial sculpture on the holotype of S. annosa as: ". . . transverse striae

of growth also marks the surface, and are sometimes grouped on the angle of the volution so as to produce slight undulations or incipient nodes." It is safe to say that these axial elements present on the holotype, which is an internal mold, were considerably stronger on the original shell.

Clinura sp. 1 (Kollman and Peel, 1983, p. 97, fig. 220 c, d) appears to be conspecific with S. tormentaria. It is doubtful whether that species is a Clinura for reasons mentioned in the above discussion of the genus Surculites.

Stanton (1921, p. 41-42) compared S. tormentaria with a variety of Levifusus trabeatus Conrad (Harris, 1896, pl. 9, fig. 10) from the Midway of the Gulf Coast. I am not at all convinced that Harris' species is a true Levifusus; however, the peripheral spines and lirations on the interior of the outer lip render it generically distinct from the Cannonball species.

The growth line trace on the posterior slope of the Cannonball material is somewhat variable, even on the same specimen. In general, the growth lines on earlier whorls are more evenly concave and symmetrically placed on the posterior slope. However, on the last one quarter turn, or so, the anterior limb of the sinus swings more abaperturally before crossing the shoulder. This forward swing is accompanied by a posterior shift in the apex of the sinus. This growth line ontogeny is identical to that seen on

several specimens of S. engonata. Variability can also be seen in the strength of the nodes.

Subfamily FASCIOLARIINAE

Diagnosis.--Anterior canal more or less inflected, siphonal fasciole present or absent; columella nearly always folded (modified from Davies, 1971, p. 369).

Genus MESORHYTIS Meek, 1876

Type species.--by original designation; Fasciolaria (Mesorhytis) gracilienta Meek, 1876, p. 364, text fig. 45.

Diagnosis.--Shell strongly fusiform; whorls broadly convex; spire produced, about half total shell height; last whorl tapering to long, straight, slightly twisted, fascioled anterior canal; suture impressed; protoconch unknown; sculpture of axial ribs and spiral threads or ribbons; aperture elongate and narrow, with posterior notch; outer lip thin, internally smooth; columella straight, with three plaits located well inside, opposite middle of aperture; inner lip lightly callused.

Remarks.--The familial placement of the genus Mesorhytis can be questioned. Several authors, including Cossmann (1899, p. 172), Termier and Termier (1952, p. 430), Palmer and Brann (1965, p. 764), and Cernohorsky (1970) have placed Mesorhytis in the Mitridae. The Mitridae, however, have been characterized, in part, by their broad,

indistinct, anterior canal (Theile 1931, p. 337; Franc 1968, p. 314). Keen (1971, p. 638) and Davies (1971, p. 381) further characterized the Mitridae as having several columellar plaits which increase in strength posteriorly. Mesorhytis gracilienta, the type species of Mesorhytis, does not display either of these characters. Rather, the plaits are equal in strength and the anterior canal is long and well-defined. Therefore, I submit, that Mesorhytis does not belong in the Mitridae, but rather in the Fasciolariidae as originally proposed by Meek (1876, p. 356).

Meek (1876, p. 356) originally included Mesorhytis Meek as one of five subgenera of Fasciolaria s. l. Meek questioned even a subgeneric placement because of the stronger, less oblique, columellar plaits which are farther posteriorly on the columella than in Fasciolaria s. s. Cossmann (1899, p. 170-171) based his diagnosis of Mesorhytis on badly broken specimens of Fusimitra polita (Gabb) and Mitra cancellata Sowerby. Although I am in complete agreement with Cossmann's (1899) treatment of Mesorhytis as a distinct genus, because Fasciolaria has two plaits low on the columella and a smooth shell surface (Olsson and Harbison, 1953, p. 215), I am not at all convinced that Mitra cancellata Sowerby and Fusimitra polita (Gabb) are congeneric with Mesorhytis gracilienta Meek.

The two specimens of M. cancellata Sowerby figured by Cossmann (1899, pl. 8, figs. 12, 13) are too poorly

preserved to ascertain their generic affinities with any degree of confidence. Furthermore, Sohl (1964, p. 249) considered Fusimitra polita (Gabb) as a representative of that genus, rather than of Mesorhytis. In light of these uncertainties, I have chosen to base the generic diagnosis of Mesorhytis on the type species and Mesorhytis dakotensis from the Cannonball Formation.

Mesorhytis Meek superficially resembles several fasciolariid genera which include Cryptorhytis Meek, Piestochilus Meek, and Graphidula Stephenson. Mesorhytis can be distinguished from these genera by the number and location of the columellar plaits, and by the fact that the plaits of Mesorhytis are visible at the aperture.

Mesorhytis obscura Wade was reassigned to the genus Graphidula by Sohl (1964, p. 211). Mesorhytis? hatchetigbeensis (Aldrich), from the Eocene of the Gulf Coast, has a tuberculate shoulder, concave posterior slope, and an evenly tapered last whorl, features more reminiscent of Vexillum Roding.

Stanton (1920, p. 44) noted that certain species assigned to the genus Mitra Lamarck bear some resemblance to Mesorhytis, specifically, Mitra pomonkensis Clark and Martin (1901, p. 132-133, pl. 21, figs. 10, 10a) and Mitra potomacensis Clark and Martin (1901, p. 133, pl. 21, fig. 11) from the Paleocene and Eocene Aquia and Nanjemoy Formations of the mid-Atlantic Coast. I have examined the

types of Mitra potomacensis, Mitra marylandica Clark (Clark and Martin 1901, p. 132, pl. 21, figs. 9, 9a), and Mitra pomonkensis Clark and Martin (1901, pl. 21, figs. 10a, b). Although M. pomonkensis and M. marylandica are incomplete, all three species appear to belong to Mesorhytis.

In addition to these North American species, Mitra densistria Koenen (1885, pl. 2, figs. 14a, b), Mitra aequicostata Koenen (1885, pl. 2, fig. 13), and Mitra semilaevis Koenen (1885, pl. 2, figs. 15a-c), from the Paleocene of Denmark, may also be assignable to Mesorhytis.

Mesorhytis dakotensis Stanton, 1920

Pl. 1, Figs. 11, 28, 29.

Fasciolaria? (Mesorhytis) dakotensis Stanton, 1920, p. 43, pl. 8, figs. 13 a, 14 b.

Diagnosis.-- Shell large for genus; height/width ratio about 3 (n=1); of about 9 whorls; columella with 3 plaits, posterior plait weaker and slightly closer to central plait; sculpture of 15 prominent axial ribs, numerous spiral ribbons, generally much wider than groove between.

Description of Cannonball material.--Shell large for genus; spire less than half total shell height; suture slightly impressed; protoconch unknown; axial ornament opisthocyrt to orthocline, extending from suture to suture, weak to obsolete on anterior slope of last whorl, width equal to, or slightly wider than spaces between, ribs weak



or absent on last whorl of mature specimens; entire shell surface covered by numerous, inconspicuous spiral bands; growth lines opisthocyrt, becoming prosocline on anterior slope of last whorl; outer lip thin, sinuous in outline, internally smooth; columella straight, bearing 3, oblique plaits opposite middle of aperture, posterior-most plait weaker and closer to central plait.

Material.--Eighty-eight specimens, mostly immature, all mature specimens incomplete.

Types.--Hypotypes UND 12891 through 12894, and UMMP 66061.

Measurements.--EH: 60.0 (n=1); MD: 16.2-19.1 (n=3); ESH: 29.0 (n=1); WA: 8.7 (n=1); PA: 27-32 (n=2).

Occurrence.--Lower, middle, and upper units of Cannonball Formation.

Type locality.--8377, locality 39.

Remarks.--Mesorhytis dakotensis differs from M. gracilienta Meek in its weaker spiral ornament, stronger, less numerous vertical ribs, and in the strength and spacing of the columellar plaits (Stanton 1920, p. 44). I have examined the holotype of Mitra potomacensis Clark and Martin, from the Paleocene Aquia Formation, and it appears to differ from M. dakotensis only in its more distant and uniformly spaced spiral ribbons. Although none of the 88 Cannonball specimens displays such widely spaced ribbons, I have opted to keep these species separate until I can

examine more specimens of M. potomacensis. Furthermore, the Aquia type specimen is an immature individual.

Variability within M. dakotensis lies in the whorl shape. Generally, the whorls of M. dakotensis are evenly convex, yet some immature individuals show slightly flatter whorls with a more noticeable shoulder just anterior to the suture. These variations do not appear to have any stratigraphic or lithologic dependence.

Suborder TOXOGLOSSA

Superfamily CONEACEA

Family TURRIDAE

Diagnosis.--Shells varying considerably in size and shape, generally moderate to large; fusiform, usually with tall spire and long anterior canal, but occasionally truncated anteriorly; sinus generally well-developed, but varying from deep, narrow slit, to shallow, broad concavity, on posterior slope, periphery, or on spiral rib just posterior to periphery.

Subfamily TURRICULINAE

Diagnosis.--Sinus typically deep, rounded to U-shaped, always on posterior slope, often occupying most of it (modified from Powell, 1966, p. 25).

## Genus ACAMPTOGENOTIA Rovereto, 1899

Type species.--by monotypy; Murex (Pleurotoma) intortus Brocchi, 1899, p. 103.

Diagnosis.--Shells moderately large; biconic-fusiform; whorls shouldered at mid-height; last whorl proportionally large, gradually contracted to very short, wide, shallowly notched anterior canal; protoconch of 4 to 4.5 whorls, erect, dome-shaped, tip flattened and planorbid, smooth except for last whorl which bears strong spiral ridges only; axial sculpture of oblique shoulder nodes; spiral sculpture of cords and threads; posterior sinus broad and shallow, occupying most of shoulder slope (modified from Powell, 1966, p. 37).

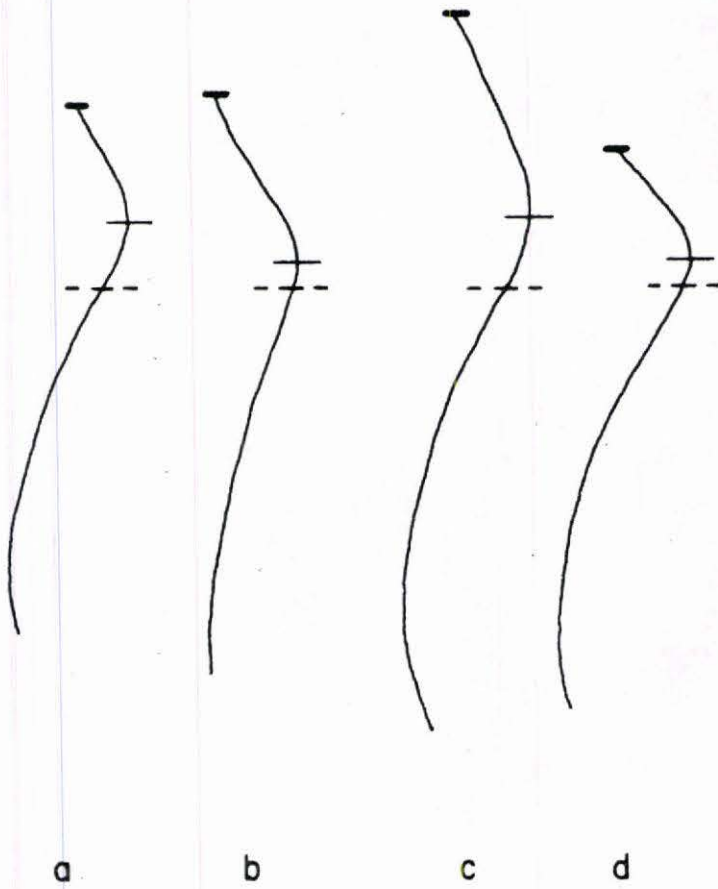
Remarks.--Acamptogenotia belongs to a closely related group of genera which includes Austrotoma Finlay, Megasurcula Casey, and Belophos Cossmann. These genera were treated as subgenera of Acamptogenotia by Hickman (1976). Powell (1966, p. 38) characterized Austrotoma, in part, by the presence of a subsutural marginating fold. Hickman (1976, p. 60) later pointed out that although the presence of a subsutural fold is useful in distinguishing the type species of Austrotoma and Acamptogenotia, some species of Austrotoma lack the subsutural fold, whereas it is present in some species of Acamptogenotia. She further commented that Austrotoma, as well as Megasurcula, could be consistently distinguished from Acamptogenotia by their

deeply notched anterior canal and ridge-margined fasciole (Hickman 1976, p. 60-61).

Following Powell (1966, p. 37-38), Belophos Cossmann differs from Acamptogenotia by its predominant axial sculpture and in the details of the protoconch. Hickman (1976, p. 48) considered Belophos to be a possible synonym of Austrotoma. She further noted (p. 48) that Marshallaria Finlay and Marwick and Marshallena Allan ". . . are related to this group by large size, shallow anal sinus, and tendency to produce similarly ornate sculpture patterns. They differ in having relatively long and unnotched anterior canals." A more complete discussion of these groups can be found in Hickman (1976, p. 47-50, 55-61).

Several specimens in the USNM collections bearing the name Pleurotoma intortus Brocchi, the type species of Acamptogenotia, agree with A. varicosta in their biconic shape and broad, short, slightly twisted anterior canal. Furthermore, the posterior sinus of Pleurotoma intortus, as depicted by Hickman (1976, p. 37, text fig. 11), also resembles that displayed by A. varicosta in that the apex of the sinus is on the anterior half of the posterior whorl slope (Fig. 9). A specimen figured by Kollman and Peel (1983, p. 100, fig. 227) as Pseudotoma sp. appears to belong to Acamptogenotia.

Figure 9. Camera lucida drawings of growth lines taken from the last whorl of four specimens of Acamptogenotia varicosta. Growth lines magnified six times and adjusted to uniform shoulder height. Wide solid line denotes posterior suture, dashed line denotes periphery, narrow solid line denotes apex of sinus. Arrow points adaperturally. (a) A. varicosta, hypotype, USNM 32452; (b) A. varicosta, hypotype, USNM 32452; (c) A. varicosta, paratype, UND 12897; (d) A. varicosta, paratype, UND 12896.



Acamptogenotia varicosta n. sp.

Pl. 2, Figs. 8-10, 16-19, 23; text fig. 9.

Turricula? contorta (Meek and Hayden). Stanton, 1920, p. 47,  
pl. 9, figs. 7, 8.

Pyrifusus (Neptunella) newberryi (Meek and Hayden). Stanton,  
1920, p. 40-41, pl. 7, figs. 8a, b.

Diagnosis.--Species small for genus; height/width ratio 2.1 (n=1); 6 or 7 whorls; suture closely adpressed; axial sculpture variable in strength, of 14 to 18 short ribs or nodes, nearly absent on later whorls of some individuals.

Description of Cannonball material.--Posterior slope concave and constricted to moderately-developed subsutural collar; anterior canal twisted, with moderately strong fasciole; protoconch unknown; spiral threads generally much narrower than spaces between, threads commonly with finer threads between, both becoming slightly finer, and in some cases more distantly spaced on posterior slope and collar, spacing of primary threads tending to increase slightly over anterior slope of last whorl and anterior canal; growth lines defining shallow posterior sinus, apex at about anterior 1/3 of posterior slope; aperture lance-ovate, posteriorly angulate; outer lip thin, smooth internally; inner lip lightly to moderately callused, threads occasionally visible through parietal callus; columella short and straight, slightly to moderately twisted at base.

Material.--Thirty-six specimens, one adult; spire, outer lip, and extremity of anterior canal, partially broken on all specimens.

Types.--Holotype UND 12895, Paratypes UND 12895 through 12899.

Measurements.--(holotype) EH: 40.0; W: 19.0; ESH: 16.0; AW: 9.6; PA: 44.

Occurrence.--Lower, middle, and upper units of Cannonball Formation.

Type locality.--A2703, locality 8.

Etymology.--This species name is derived from the Latin varius meaning "varying" and costa meaning "rib" in reference to the elongate axial nodes which vary considerably in strength and number.

Remarks.--Stanton (1920, p. 47) questionably assigned this species to Turricula Schumacher. Turricula, however, is characterized by large fusiform shells with long, straight or slightly flexed, anterior canals, a tall spire, and a moderate to deep posterior sinus (Powell 1966, p. 231).

Stanton (1920, p. 47) noted that specimens of Turris (Surcula) contorta from the Upper Cretaceous Fox Hills Formation, displayed some variation in the strength of the axial ornamentation, and that those with subdued axial sculpture closely resembled the Cannonball specimens.

Specimens of A. varicosta in the UND collections show a



complete range in the strength of the axial nodes, from well-developed to nearly absent on the last whorl of some specimens. In addition, there is considerable variation in the number of ribs, and, to some degree, shell proportion (compare pl. 2, figs. 10, 19, 23). I have examined the paratypes of Turris (Surcula) contorta in the USNM collections. The Cannonball specimens are, by comparison, considerably larger, have blunter, more oblique nodes, and a better developed subsutural collar (compare pl. 2, figs. 22, 23). I believe that these differences warrant the creation of a new species for the Cannonball form.

One specimen, in particular, displays 23 axial nodes on the last whorl (pl. 2, fig. 10). Since there are no other distinguishing characters, I have opted to include this specimen under A. varicosta until additional material may indicate that it should be recognized as a distinct species.

Acamptogenotia varicosta superficially resembles A. heilprini from the Gulf Coast Eocene (Harris, 1937, pl. 13, figs. 32, 32 a, 32 b); however, Acamptogenotia varicosta is larger, lacks the subsutural band, and has a wider, more concave posterior slope. Stanton (1920, p. 47) compared the Cannonball species with Surcula ostrarupis Harris from the Midway Group (Harris, 1896, p. 191, pl. 7, fig. 13). The rather poor description and figure of the latter make detailed comparison difficult, yet Surcula ostrarupis

appears to be a much smaller shell with a narrower, more elongate anterior canal.

A comparison of A. varicosta (Stanton, 1920, pl. 9, figs. 7, 8) and Pyrifusus (Neptunella) newberryi (sensu Stanton, 1920, pl. 7, figs. 8 a, b) revealed that Stanton's P. (N.) newberryi is actually a portion of a broken A. varicosta (compare pl. 2, figs. 8, 9).

Genus ALTICOLLARUM n. gen.

Type species.--Pleurotoma adeona Whitfield, 1865, p. 262.

Diagnosis.--Shells with whorls constricted posteriorly into well-developed subsutural collar, shoulder close to anterior suture, occasionally partly covered by succeeding whorl; spire approximately equal to one-half total shell height; last whorl large, contracting abruptly anterior to axially-compressed shoulder to form long, slender, anterior canal, inflected abaperturally at tip; suture rather strongly adpressed; protoconch of 3 1/2 smooth whorls followed by 1/2 whorl with axial ribs; posterior sinus deep, centered on posterior slope.

Etymology.--This generic name is derived from the Latin altus meaning "high" and collare meaning "collar" in reference to the high, clasping, subsutural collar and low whorl shoulder.

Remarks.--The following assemblage of characters distinguish Alticollarum from all known turrid genera: a whorl shoulder at, or slightly posterior to, the anterior suture; a high, clasping, subsutural collar; a deep posterior sinus with an apex that is centered on the posterior slope (Fig. 10); strong axial and spiral sculpture; and a long, slender canal, inflected abaperturally at the tip.

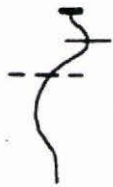
Gardner (1935, p. 216) referred the type species of Alticollarum to Orthosurcula Casey. Alticollarum differs from Orthosurcula by its prominent spiral and axial sculpture, more compressed whorl shoulder closer to the anterior suture, and a posterior sinus with a concave upwards posterior limb. In Orthosurcula, the posterior limb of the posterior sinus is straight-prosocline, beginning at the posterior suture (Fig. 11). In spite of these differences, Alticollarum resembles Orthosurcula in the position of the posterior sinus in relation to the whorl shoulder and in the protoconch sculpture. Alticollarum resembles Hesperiturris Gardner (1945, p. 237) in the position of the whorl shoulder; however, Alticollarum has a proportionally longer anterior canal and lacks the noded subsutural collar.

Kollman and Peel (1983, p. 99) compared a congeneric specimen from the Paleocene of West Greenland with Leucosyrinx Dall. Alticollarum can be distinguished from

Figure 10. Camera lucida drawings of growth lines taken from the last whorl of three species of Alticollarum. Growth lines adjusted to uniform shoulder height. Wide solid line denotes posterior suture, dashed line denotes whorl periphery, narrow solid line denotes apex of sinus. Arrow points adaperturally. (a) A. janesburgensis (Stanton), holotype, USNM 32447 (X1.5); (b) A. janesburgensis (= Turricula textilis Stanton, "holotype", USNM 32448) (X2); (c) A. bacatum (Stanton), hypotype, UMMP 66063 (X1); (d) Orthosurcula adeona (sensu Gardner, 1935, p. 216, pl. 20, fig. 20), hypotype (X6).



a



b

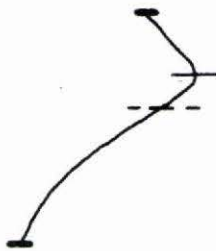


c



d

Figure 11. Camera lucida drawing of growth line taken from the penultimate whorl of Orthosurcula longiforma (Aldrich), holotype, USNM 645082. Growth lines magnified six times. Wide solid line denote posterior and anterior sutures, dashed line denotes top of whorl shoulder, narrow solid line denotes apex of sinus. Arrow points adaperturally.



Leucosyrinx by its more anteriorly located whorl shoulder, deeper posterior sinus, the anterior limb of which does not sweep as far adaperturally, and a larger, axially costate protoconch. Species assigned to Leucosyrinx (Sabogasyrinx) Powell (1969, p. 343-344), resemble Alticollarum in the position of the whorl shoulder; however, they display the typical posterior sinus and protoconch of Leucosyrinx.

In addition to the Cannonball species described below, the following species are referable to Alticollarum:

Pleurotoma (Surcula) adeona Whitfield (Harris, 1896, p. 76, pl. 17, figs. 9, 10) from the Paleocene of Alabama;

Pleurotoma (Surcula) persa Whitfield (Harris, 1896, p. 77, pl. 17, fig. 11) from the Paleocene of Alabama; and possibly

Clinura sp. 2 from the Paleocene of West Greenland (Kollman and Peel, 1983, p. 98, fig. 221).

Alticollarum bacatum (Stanton)

Pl. 2, Figs. 2-4; text fig. 10c.

Turricula bacata Stanton, 1920, p. 46, pl. 9, fig. 4, 5.

cf. Leucosyrinx sp. Kollman and Peel, 1983, p. 98, figs.

223c, d.

Diagnosis.--Shells of average size for genus; height/width ratio 2.4 (n=1); of about 7 or 8 whorls; spire about 10 percent less than 1/2 total shell height; axial sculpture of 17 oblique peripheral nodes, partially covered by succeeding whorls on spire.



Description of Cannonball material.--Last whorl with narrowly rounded, prominent shoulder, subsutural collar nearly vertical; suture gently scalloped by underlying nodes; protoconch unknown; axial nodes dying out abruptly posterior to shoulder, drawn out anteriorly across periphery and onto basal slope of last whorl; spiral sculpture poorly preserved, of threads and finer lirae, threads coarsest on whorl periphery, equal to, or slightly narrower than spaces between, becoming finer and more closely spaced on anterior slope of last whorl and anterior canal, sculpture on posterior slope and subsutural collar poorly preserved, apparently somewhat weaker than threads on periphery, with finer lirae between, 2 or 3 slightly stronger threads directly anterior to posterior suture; anterior limb of posterior sinus opisthocline-prosoclyrt across convex portion of last whorl, defining broad lobe in outer lip, growth lines nearly orthocline on anterior canal; aperture lance-oval, with strong posterior angulation; outer lip unknown; inner lip eroded, apparently thinly callused; columella straight.

Material.--Three specimens, 1 nearly complete except for broken outer lip and eroded spire, remaining specimens badly broken.

Types.--Hypotypes UMMP 66063.

Measurements.--EH: 36.0; W: 15.0; ESH: 14.5; EAW: 6.0; PA: 35.

Occurrence.--Lower unit of Cannonball Formation, Paleocene Agatdal Formation of West Greenland (Kollman and Peel, 1983, p. 99, figs. 223c, d).

Type locality.--7964, locality 37.

Remarks.--The holotype of Alticollarum bacatum (Stanton) is flattened and badly broken, with only a small portion of the ornament preserved (pl. 2, fig. 2). Although A. bacatum is poorly known, two specimens in the UND collections agree closely enough with the type in their whorl shape and ornamentation to warrant their assignment to this species and, thus, further expanding its concept.

Alticollarum bacatum can be distinguished from A. janesburgensis by its smaller spire angle, more axially compressed last whorl, and flattened peripheral nodes that are often partially covered by the succeeding whorl. Orthosurcula adeona (sensu Gardner, 1935, pl. 20, fig. 20) is quite similar in its overall shape and proportions, but has nodes that are more pointed and rest on the anterior suture. A specimen figured by Kollman and Peel (1983, p. 99, fig. 223c, d) as cf. Leucosyrinx is here referred to this species.

Alticollarum janesburgensis (Stanton)

Pl. 2, Figs. 6, 7, 26, 27, 32, 33; text fig. 10a, b.  
Turricula janesburgensis Stanton, 1920, p. 45-46, pl. 9,  
figs. 2 a, b.

Turricula textilis Stanton, 1920, p. 46, pl. 9, figs. 3 a,  
b.

Diagnosis.--Shell average size for genus; height/width ratio about 2.9 (n=1); of 7 or 8 whorls, shoulder positioned at, or slightly posterior to anterior suture; axial sculpture of 15 to 17 peripheral nodes.

Description of Cannonball material.--Posterior whorl slope slightly concave to nearly vertical; suture slightly undulating; spire apparently equal to one-half total shell height; protoconch unknown; axial nodes fading abruptly anterior and posterior to shoulder, showing a slight tendency to be axially compressed; spiral sculpture of moderately strong threads with one or two finer threads between, threads slightly weaker on posterior slope, 2 slightly stronger and more closely spaced threads directly anterior to posterior suture, spiral sculpture somewhat granulose at intersections with growth lines; anterior limb of posterior sinus sweeping across shoulder at rather steep angle, becoming orthocline on base of last whorl and anterior canal; outer lip broadly lobate anterior to shoulder; inner lip with moderately thick callus; columella nearly straight to somewhat sinuous.

Material.--Twenty-two specimens, generally poorly preserved, none complete.

Types.--Hypotypes UND 12900 and 12901, UMMP 66069.

Measurements.--EH: 42.0; EW: 14.5-15.0 (n=2); SH: 22.0;  
EAW: 5.0-5.5 (n=2); PA: 32-33 (n=2).

Occurrence.--Lower, middle, and upper units of  
Cannonball Formation.

Type locality.--8478, locality 43.

Remarks.--Stanton (1920, p. 46) said the following  
regarding T. textilis:

Shell resembling T. janesburgensis  
in general form and coarser sculpture,  
but it has a relatively shorter canal,  
the upper slope of its whorls is more  
deeply concave, the carina is nearer to  
the suture, and the spiral sculpture is  
much finer, with more nearly equal and  
more closely crowded irregular lines.  
These differences are believed to  
justify specific separation, though it  
is possible that future collections may  
show enough intermediate forms to prove  
that the differences are only of  
varietal value.

The respective holotypes of Turricula? janesburgensis  
and T. textilis are, in fact, distinguishable by these  
characters; however, specimens collected since Stanton's  
work indicate some overlap. The relative concavity of the  
posterior whorl slope seems to be controlled, at least in  
part, by the strength of the peripheral nodes; that is,  
specimens with weaker nodding tend to have a flatter, more  
nearly vertical subsutural collar (compare pl. 2, figs. 26,  
27). Among the specimens in the UND collections, there  
appears to be no correlation between the concavity of the  
posterior slope and the details of the spiral sculpture as  
originally proposed by Stanton (1920, p. 46). The position

of the peripheral nodes in relation to the anterior suture appears to be somewhat variable both between specimens and on the same specimen. In general, the nodes are directly posterior to the anterior suture; however, specimens with weaker peripheral nodes, flatter posterior slopes, and fine, closely-spaced, uniform threads, also have nodes directly posterior to the suture of the succeeding whorl (pl. 2, fig. 27). Stanton's (1920, p. 46) claim regarding the relative length of the aperture and canal cannot be justified as both holotypes are missing the anterior and posterior extremities. Examination of the holotypes suggests that the original lengths of the aperture and canal may have been about half the total shell height. Unfortunately, the UND specimens are also incomplete.

Due to the overlap in these characters, there is no consistent basis by which the holotypes of A. janesburgensis and "T. textilis" can be distinguished; therefore, I have placed these species in synonymy, retaining the trivial name janesburgensis by priority of pagination.

Species variability is primarily in the concavity of the posterior whorl slope and in the position of the nodes in relation to the anterior suture. As mentioned above, the nodes are generally located directly posterior to the suture.

Orthosurcula adeona sensu Gardner (1935, p. 214, pl. 20, fig. 20) is similar to C. janesburgensis, but is

smaller, has a lower spire angle, and fewer peripheral nodes.

Genus AMULETUM Stephenson, 1941

Type species.--by original designation; Turricula macnairyensis Wade, 1926, p. 113, pl. 36, figs. 8, 9.

Diagnosis.--Small, rather slender shells; whorls rounded, slightly constricted posteriorly to sloping subsutural collar; siphonal canal elongate, slender, and curved somewhat; protoconch proportionally large, consisting of 3 to 4 smooth whorls; transverse and spiral sculpture sometimes nodose; posterior sinus shallow; columella lacks plications and narrows to thin edge at anterior extremity (modified from Sohl, 1964, p. 274).

Remarks.--According to Sohl (1964, p. 274), Amuletum Stephenson and Remnita Stephenson are closely related. Amuletum, however, has teleoconch sculpture initiated by axial ribs, a columellar lip that narrows anteriorly to a knife-like edge, better developed transverse sculpture, and a posterior sinus located more posteriorly on the shoulder slope.

Amuletum appears to have been reported mainly in Gulf Coast and Mississippi Embayment Late Cretaceous faunas, although Erickson (1974, p. 221-223) reported two species of Amuletum from the Western Interior Fox Hills Formation, and noted Amuletum-like species from the Upper Cretaceous rocks

of Vancouver and Sucia Islands, British Columbia. If my assignment is correct, it is the first known report of Amuletum from Paleocene rocks.

Erickson (1974, p. 221) referred three species from the Cannonball Formation to Amuletum: Turris cordensis Stanton, Turris lloydi Stanton, and Turricula cincta Stanton. Based on Stanton's (1920) figures, these reassignments seem justified; however, the figures do not accurately portray the position and shape of the posterior sinus. After examination of the type material, Turris cordensis and Turris lloydi have been placed in synonymy and referred to Coronia De Gregorio, whereas Turricula cincta has been placed in synonymy with Turris? tormentaria and assigned to the new genus Obtusicarina.

Additional comments regarding both Amuletum and Lutema can be found in Sohl (1964, p. 274-275; 278) and Erickson (1974, p. 221-223).

Subgenus LUTEMA Stephenson, 1941

Type species.--by original designation; Lutema simpsonensis Stephenson, 1941, p. 373, pl. 71, figs. 22, 23.

Diagnosis.--Medium-sized Amuletum; whorls tending to be more strongly shouldered than in Amuletum s. s.; ornament subdued, transverse sculpture suppressed or accentuated to nodes at shoulder (modified from Sohl 1964, p. 278).

Amuletum (Lutema) sp.

Pl. 1, Figs. 14, 15; text fig. 12a.

Diagnosis.--Species of average size for subgenus; of about 5 moderately shouldered whorls; axial sculpture of oblique nodes on shoulder, strongest on early whorls, becoming weak or absent on later whorls; 2 pronounced subsutural cords; posterior sinus broadly rounded, confined posteriorly by subsutural cords, apex of sinus centered on posterior slope.

Description of Cannonball material.--Anterior canal fascioled; suture impressed, to almost channeled; protoconch unknown; spiral ornament between shoulder and anterior suture of about 4 faint bands separated by narrow groove, spiral ornament on posterior slope poorly preserved, but apparently more variable in strength, and, at least on earlier whorls, more distantly spaced, 2 posterior-most spirals considerably stronger, forming subsutural cord, on anterior slope of last whorl and anterior canal, spiral sculpture strengthening slightly and alternating in size, finer threads nearly filling gap between wider bands; posterior sinus broadly rounded, somewhat axially compressed by subsutural cord, apex centered on posterior slope; aperture ovate, posteriorly angulate; outer lip unknown; abapertural margin of inner lip well-defined and excavated.

Material.--Two specimens, most complete specimen likely immature, missing tip of spire and outer lip, early whorls



decorticated, bore-hole in penultimate whorl; second larger specimen slightly worn, missing tip of canal and outer lip.

Types.--Hypotypes UND 12902 and 12903.

Measurements.--EW: 4.0; SH: 6.0; EAW: 1.5; PA: 29.

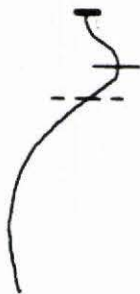
Occurrence.--Upper unit of Cannonball Formation and possibly Paleocene Sonja Lens Member of the Agatdal Formation, West Greenland (Kollman and Peel, 1983, p. 96, fig. 216).

Remarks.--I have examined the types of all species previously assigned to Amuletum (Lutema). The Cannonball species resembles two Upper Cretaceous species in particular: Amuletum (Lutema) sp. (Sohl, 1964, pl. 46, figs. 5, 6) from the Ripley Formation and Amuletum (Lutema) sp. (Erickson, 1974, pl. 20, figs. 7, 8) from the Fox Hills Formation. The Cannonball species is unique, however, in its strong subsutural cord and compressed, broadly rounded posterior sinus which is centered on the posterior slope (Fig. 12).

Genus MARSHALLARIA Finlay and Marwick, 1937

Type species.--by original designation; Verconella spiralis Allan, 1926, p. 340, pl. 76, fig. 9.

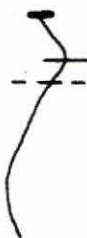
Figure 12. Camera lucida drawings of growth lines taken from the last whorl of five species of Amuletum. Growth lines magnified six times and adjusted to uniform shoulder height. Wide solid line denotes posterior suture, dashed line denotes whorl periphery, narrow solid line denotes apex of sinus. Arrow points adaperturally. (a) Amuletum (Lutema) sp., hypotype, UND 12902; (b) A. (Lutema) simpsonensis (Stephenson), holotype, USNM 77154; (c) A. (Amuletum) fasciolatum (Wade), holotype, USNM 32849; (d) A. (Amuletum) dumasensis Sohl, holotype, USNM 130519; (e) A. (Amuletum) macnairyensis (Wade), holotype, USNM 130516.



a



b



c



d



e

Diagnosis.--Shells of moderate size, fusiform; whorls shouldered at mid-height, posterior slope concave; spire  $2/3$  apertural height; last whorl contracting gradually anteriorly to fairly long, wide, twisted, slightly fascioled anterior canal; protoconch multi-spiral, conic, smooth, with a small nucleus; axial sculpture of short, low, axial ribs bluntly tubercled at shoulder; spiral sculpture of regular spiral threads; aperture channeled posteriorly, gradually contracting anteriorly; outer lip thin, broadly and evenly sinused across shoulder, sweeping forward anterior to shoulder angle; inner lip thinly callused, columella smooth, twisted gently at posterior margin of canal (modified from Finlay and Marwick, 1937, p. 83).

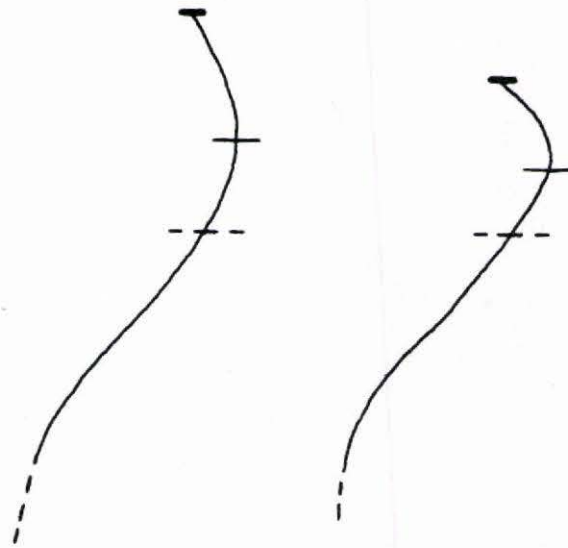
Remarks.--I have decided to follow the generic diagnosis of Finlay and Marwick (1937), rather than that of Powell (1966, p. 27), because of its greater reliance on hard-part characters. Powell's (1966) diagnosis, however, contains a more detailed description of the protoconch and posterior sinus.

Powell (1966, p. 27) stated that Marshallaria ranges from the Paleocene through the upper Oligocene of New Zealand. To the best of my knowledge, the Cannonball Formation occurrence is only the second report of this genus outside New Zealand, the other from the Paleocene of Antarctica (Zinsmeister, Feldmann, Woodburne, and Elliot, 1989).

Marshallaria is similar to Marshallena Allan but differs in the characters of the protoconch and posterior sinus. According to Powell (1942, p. 80), "Marshallaria has a regularly concave sinus throughout the post-nuclear whorls, whereas Marshallena (quoted as Marshallia in error, Finlay and Marwick, 1937, p. 84) has a very shallow one. The protoconch in Marshallaria is somewhat dome-shaped and has strong spiral cords on the last whorl: that of Marshallena is more regularly conic and appears practically smooth." Hickman (1976, p. 48) stated that Marshallaria differs from Acamptogenotia and related genera by its relatively longer, un-notched anterior canal.

I have compared the Cannonball specimen with one specimen in the collections of the USNM that bears the name Marshallaria formosa Allan in the handwriting of A. W. B. Powell (Tippet, 1989). The Cannonball specimen agrees well with this specimen of M. formosa in all of its generic characters, particularly the last whorl shape, posterior sinus (Fig. 13), and apertural features. Although these specimens are definitely congeneric, both the USNM and Cannonball specimens seem to have last whorls that contract more gradually, and a shorter, less well-defined anterior canal as compared to types of the species referred to Marshallaria. In spite of these apparent differences, I have placed considerable weight on Powell's assignment of

Figure 13. Camera lucida drawings of growth lines taken from the last whorl of two species of Marshallaria. Growth lines magnified six times and adjusted to uniform shoulder height. Wide solid line denotes posterior suture, dashed line denotes whorl periphery, narrow solid line denotes apex of sinus. Arrow points adaperturally. (a) Marshallaria sp., hypotype, UMMP 66056; (b) M. formosa (Allan), USNM 24390.



a

b

the USNM specimen to Marshallaria in making the generic assignment of the Cannonball species.

Both the USNM and Cannonball specimens also have internally crenulate outer lips. I have been unable to find the interior of the outer lip described for the other species referred to this genus by Finlay and Marwick (1937, p. 84) and Powell (1942, p. 81); however, if it is found to be a consistent feature, the generic diagnosis should be emended accordingly.

Marshallaria sp.

Pl. 1, figs. 7, 8, 13; text fig. 13a.

Diagnosis.--Shell of average size for genus; about 6 whorls; height/width ratio 2.0 (n=1); axial sculpture of 15 short, oblique, peripheral nodes; spiral sculpture of about 26 fine, closely spaced threads on penultimate whorl; outer lip internally crenulate.

Description of Cannonball material.--Whorls with deeply and evenly concave posterior slope; suture rather closely adpressed; protoconch unknown; axial nodes disappearing abruptly on posterior slope, barely reaching anterior suture; spiral threads equal to, or slightly narrower than spaces between on most convex portion of whorl, threads becoming stronger and more distantly spaced across anterior slope of last whorl and anterior canal, often with finer threads between, threads somewhat weaker and more distantly



spaced on posterior slope; prominent growth lines forming beads at intersections with spiral threads; aperture broadly ovate, rather deeply channeled posteriorly; outer lip with broad, forward sweeping lobe anterior to shoulder.

Material.--Single specimen, early whorls worn, anterior canal partially broken, outer lip nearly complete.

Types.--Hypotype UMMP 66056.

Measurements.--EH: 25.0; W: 12.6; ESH: 11.5; AW: 5.0; PA: 44.

Occurrence.--Lower unit of Cannonball Formation.

Remarks.--Marshallaria sp. most closely resembles Marshallaria senta Powell, from the Miocene of New Zealand, in its peripheral nodes. Marshallaria sp. differs in being much smaller and having a different spiral sculpture. Powell (1942, p. 81) described the spiral sculpture on the last whorl as consisting of ". . . about 30 primary cords with from 2-4 intermediates . . . ." Although Powell (1966, p. 81) did not describe the outer lip, the plate figure does not portray a crenulated internal margin.

I have noted in the generic discussion that a specimen from the USNM collections bearing the name Marshallaria formosa (Allan) is quite similar to Marshallaria sp., but differs in its peripheral nodes and larger spire angle.

Genus OBTUSICARINA n. gen.

Type species.--Turris? tormentaria Stanton, 1920. p. 45, pl. 9, figs. 1 a, b.

Diagnosis.--Small- to medium-sized shells; elongate-fusiform; whorls with bluntly-rounded medial carina, posterior slope concave; spire about half total shell height; last whorl constricted rather abruptly to moderately long, straight, anterior canal; sutures weakly adpressed; protoconch not entirely known, apparently of about 2 1/2 smooth whorls; posterior sinus moderately deep, broadly rounded, apex positioned at, or slightly anterior to mid-shoulder slope; axial sculpture of short, prosocline ribs forming subsutural band, and short opisthocline ribs on peripheral carina, ribs fading anterior to carina; columella twisted at anterior margin of aperture.

Etymology.--This generic name is derived from the Latin word obtusus meaning "blunt" and carina meaning "keel" in reference to the bluntly rounded peripheral keel.

Remarks.--The pronounced medial carina, elongate-fusiform shape, and axial sculpture suggest a systematic placement of Obtusicarina close to Cochlespira Conrad and its allies. Obtusicarina is characterized by a low, bluntly rounded carina crenulated by short, opisthocline ribs. Cochlespira has an axially compressed, flange-like keel that bears pointed, serrated nodes or is coronated by upcurved, spinose processes (Powell, 1966, p. 42). Tahusyrix Powell,

from the Upper Eocene of New Zealand, resembles Obtusicarina in general form and sculpture; however, the peripheral keel in Tahusyrix is more axially compressed and serrate, whereas the protoconch is ". . . small, broadly conical of four whorls, first two smooth and rounded, the remaining ones carinated towards the suture, and distantly axially ribbed." (Powell, 1966, p. 407).

In addition to Turris tormentaria of Stanton (1920), Clinura sp. 1 from the Paleocene of West Greenland (Kollman and Peel 1983, p. 98, fig. 22) and Orthosurcula phoenicea Gardner from the Paleocene of Texas are referable to this genus. Clinura sp. 2 from the Paleocene of West Greenland (Kollman and Peel 1983, p. 97, fig. 220 a, b only) and Surcula (Cochlespira) boggildi (Ravn 1939, p. 93, pl. 4, fig. 9 a, b) from the Paleocene of Denmark may also be congeneric. The western Greenland specimens assigned to Clinura by Kollman and Peel (1983) do not, at least as figured, display the typical thatcheriid sinus and protoconch of Clinura.

Orthosurcula phoenicea Gardner (1935, p. 219, pl. 20, fig. 11, 12) is not an Orthosurcula, as noted previously by Vokes (1939, p. 116) and MacNeil and Dockery (1984, p. 179). Orthosurcula is, in general, much larger, nearly smooth, with a lower whorl periphery and a deeper posterior sinus just posterior to the whorl shoulder. The protoconch characters of Obtusicarina are based entirely on the

holotype of O. phoenicea (Gardner, 1935, p. 219-220, pl. 20, figs. 11, 12) which has the most complete apex available. The protoconch of O. phoenicea is slightly broken, but appears to have originally consisted of two to two and one-half smooth whorls, similar to that of Cochlespira (Powell, 1966, p. 42). Gardner (1935, p. 219) originally assigned this species to Orthosurcula because she considered the axially and spirally sculptured whorls, directly following the initial smooth whorls, to be part of the protoconch. I have shown the holotype of O. phoenicea to M. G. Harasewych at the USNM, and it was his opinion that these sculptured whorls are post-embryonic.

Due to the similarity in the protoconchs of Obtusicarina and Cochlespira, and the fact that O. phoenicea has lightly beaded spiral sculpture (pl. 2, fig. 12), it is conceivable that when related species become better known this genus may be treated as a subgenus of Cochlespira. Obtusicarina and Cochlespira are also quite similar in their posterior sinus configurations (Fig. 14).

Obtusicarina tormentaria (Stanton)

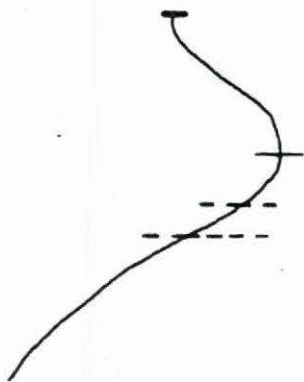
Pl. 2, Figs. 11, 13, 14; text fig. 14a, b.

Turris? tormentaria Stanton, 1921, p. 45, pl. 9, figs. 1 a,  
b.

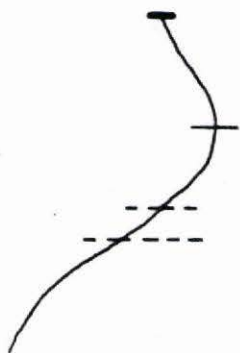
Turricula cincta Stanton, 1921, p. 46, pl. 9, figs. 6 a, b.

Clinura sp. Kollman and Peel, 1983, p. 97, figs, 220a, b.

Figure 14. Camera lucida drawings of growth lines taken from the last whorl of two species of Obtusicarina n. gen. and one species of Cochlespira Conrad. Growth lines adjusted to uniform shoulder height. Wide solid line denotes posterior suture, dashed lines denote anterior and posterior margins of peripheral carina, narrow solid line denotes apex of sinus. Arrow points adaperturally. (a) Obtusicarina tormentaria (Stanton), hypotype, UND 12905 (12X); (b) O. tormentaria (= Turricula cincta Stanton, "holotype", USNM 32451) (12X); (c) Obtusicarina phoenicea (Gardner), holotype, USNM 373058, (25X); (d) Cochlespira terebralis (Lamarck) (6X).



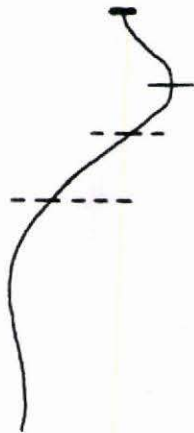
a



b



c



d

Diagnosis.--Shell of about 8 to 10 whorls; height/width ratio 3.0 (n=1); axial sculpture of about 23 ribs per whorl, dying out abruptly anterior to carina; 4 to 6 threads on carina, 3 or 4 cords between carina and anterior suture on spire whorls.

Description of Cannonball material.--Threads on carina equal to, or slightly narrower than spaces between, about 8 to 10 weaker threads on posterior slope, somewhat variable in strength, but always relatively weak, spacing of spiral cords anterior to carina variable, occasionally with finer threads between, cords decreasing in strength on anterior slope of last whorl and anterior canal; posterior sinus initially rather shallow, becoming progressively deeper on later whorls; aperture subovate, posteriorly angulate, flattened between carina and posterior suture; outer lip incompletely known; inner lip lightly callused, abapertural margin distinct and excavated, threads protruding through parietal callus.

Material.--Twenty-three specimens, 3 mature, none complete.

Types.--Hypotypes UND 12904 and 12905.

Measurements.--EH: 32.0; EW: 11.0; ESH: 15.0; EAW: 4.0; PA: 28-30 (n=3).

Occurrence.--Lower, middle, and upper units of Cannonball Formation and the Paleocene Sonja Lens Member of

the Agatdal Formation, West Greenland (Kollman and Peel, 1983, p. 97, figs. 220a, b)

Type locality.--8459, locality 18.

Remarks.--The holotype of Obtusicarina tormentaria is badly worn. All traces of growth lines and the majority of the sculpture have been removed, except for a few spiral threads adjacent to the parietal lip. Recent collections have produced specimens that agree so closely with the holotype in general shape that they undoubtedly represent the same species. Stanton (1920, p. 45) questionably assigned this species to Turris Roding. The modern concept of Turris, however, is confined to shells with a narrow posterior sinus restricted to a spiral rib directly posterior to the whorl periphery (Powell 1966, p. 51).

Turricula cincta Stanton (1920, p. 46, pl. 9, figs. 6 a, b) is placed in synonymy with O. tormentaria, the latter specific name being kept by priority of pagination. Stanton (1921, p. 47) considered the impressed band or sulcus anterior to the carination on the last whorl to be diagnostic of Turricula cincta. The available specimens suggest, however, that this feature is related to immaturity, and thus, does not have any taxonomic importance.

Variability within O. tormentaria is primarily in the strength, number, and spacing of spiral threads between the peripheral carina and the anterior suture on the spire



whorls, and in the strength of the spiral threads on the posterior slope.

Orthosurcula phoenicea Gardner is a closely related species and is probably based on an immature specimen, as it displays the same sulcus on the last whorl. Obtusicarina tormentaria differs from O. phoenicea in its more pronounced peripheral carina, less strongly beaded spiral sculpture, and stronger and fewer axial ribs (compare pl. 2, figs. 11, 12). Orthosurcula phoenicea is known only from the holotype from the Kincaid Formation; therefore, the collection of additional material may show that these are only subspecific differences.

Genus VITTICONCHA n. gen.

Type species.--Pleurotoma torelli Koenen, 1885, p. 32, pl. 2, fig. 2.

Diagnosis.--Shells elongate, fusiform; whorls bluntly angular at mid-whorl, posterior slope concave; spire about half total shell height; last whorl tapering rather abruptly to long, slightly curved, anterior canal; sculpture of spiral bands or threads and oblique peripheral ribs or nodes, often granulose on posterior slope; outer lip smooth internally; protoconch incompletely known; sinus broadly open, shallow, apex nearer to periphery than to posterior suture.

Etymology.--This generic name is derived from the Latin vitta meaning "ribbon" and concha meaning "shell" in reference to the dominant spiral sculpture.

Remarks.--Vitticoncha most closely resembles Apiotoma Cossmann in its small, smooth protoconch, and in certain aspects of its sculpture, particularly the poorly developed axial elements that become obsolete on later whorls.

Apiotoma palmerae Dockery, like Vitticoncha torelli, has granulose sculpture on the posterior slope and a relatively stronger band of subsutural nodes. Vitticoncha differs from Apiotoma by having a proportionally higher spire, whorls that are shouldered at mid-height, and a last whorl that contracts more abruptly anteriorly. Zemacies Finlay, apparently a close relative of Apiotoma, was described by Powell (1966, p. 36) as having a very deep posterior sinus and an outer lip with a ". . . weak broad insinuation below, approximating a stromboid notch." Zemacies also appears to have a more gradually tapering last whorl than Vitticoncha.

In addition to Vitticoncha torelli, the following Paleocene species are referable to this genus: Orthosurcula francescae Gardner (1935, p. 218-219, pl. 20, figs. 11, 12) from the Paleocene Midway group of Texas, U. S. A.; Crenaturricula sp. 2 (Kollman and Peel, 1983, p. 96, fig. 217) from the Paleocene Agatdal Formation of West Greenland; and possibly Crenaturricula sp. 1 (Kollman and Peel, 1983,

p. 96, fig. 216), also from the Agatdal Formation of West Greenland.

As noted previously by MacNeil and Dockery (1984, p. 179), Orthosurcula francescae does not belong to that genus. Orthosurcula is, generally, much larger, nearly smooth, with a more anteriorly located whorl periphery, and a different protoconch than that displayed by O. francescae. The specimens referred to Crenaturricula by Kollman and Peel (1983) also appear to be misassigned.

Vokes (1939, p. 114) originally proposed Crenaturricula for a group of Eocene species that resembled Fusiturricula, but are ". . . in general larger and stouter than in the later species of this genus [Fusiturricula], the anal sinus somewhat shallower and the outer lip does not project as far forward." Vokes (1939, p. 114) referred three species to his new subgenus: Fusiturricula (Crenaturricula) crenatospira, the type species of Crenaturricula; F. (C.) domengenica; and Pleurotoma dentata Lamarck.

I have seen examples of several species in the USNM collections that Glibert (1960) later referred to Crenaturricula, including: Pleurotoma crassicosta Edwards, 1856; Pleurotoma dentata Lamarck, 1804; Pleurotoma exorta Solander, 1766; and Pleurotoma macilienta Solander, 1766. These species appear to be closely related to each other and to the type species.

In general, these species of Crenaturricula are characterized by a stout-biconic profile; sharply angulate whorls; axial swellings that are vertically compressed at the shoulder, giving the periphery a scalloped appearance, and continuing anteriorly to the suture as broad swellings; spiral sculpture of relatively coarse, widely spaced cords on the whorl sides with secondary and often tertiary threads between, fine threads on the posterior slope, and generally one to three stronger subsutural threads or bands; a minute, smooth, protoconch of about two whorls; and an anterior canal that is moderately to strongly fascioled. This summary is based on specimens in the USNM collections. Since the identifications were accepted at face value, there may be some inaccuracies. Consultation of Edwards (1860), however, indicated that these names were reasonable. Vitticoncha differs from Crenaturricula by its more slender outline, bluntly rounded shoulder, non-axially compressed nodes, non-serrate whorl periphery, and, generally, a shallower posterior sinus, the apex of which is positioned closer to the periphery.

Vitticoncha torelli (Koenen)

Pl. 2, Figs. 30, 31; text fig. 15a, b.

Pleurotoma torelli Koenen, 1885, p. 32, pl. 2, fig. 2;

Gronwall, 1897. p. 66.

Pleurotoma (Eopleurotoma) torelli Koenen, Cossmann, 1896, p.

81.

Diagnosis.--Shells of about 8 whorls; height/width ratio 3.0 (n=1); axial sculpture of faint ribs accentuated into oblique nodes at periphery, becoming weak or absent on later whorls, forming nodes on posterior slope at intersections with spiral bands, band directly anterior to posterior suture most strongly noded; spiral sculpture dominated by low, flat bands, about 6 on whorl sides, generally wider than spaces between, about 5 on posterior slope, ranging from wider, to narrower than spaces between.

Description of Cannonball material.--Axial sculpture initially of nearly vertical axial ribs extending from suture to suture, reduced to peripheral nodes after about three-quarter whorl, nodes dying out mid-way between periphery and anterior suture, continuing across posterior slope as narrow collabral swellings, axial sculpture reduced to accentuated growth lines on adult whorls; spiral sculpture variable in strength and spacing, threads commonly alternating in strength over last whorl and anterior canal; posterior sinus somewhat variable in shape, generally as described in generic diagnosis, occasionally very broadly rounded with poorly defined apex occupying majority of posterior slope; aperture lance-oval; inner lip lightly callused, spirals showing through on parietal lip of some specimens; columella straight.

Material.--Fifteen specimens, generally fragmented, mostly immatures, one specimen nearly complete except for protoconch and outer lip, others missing various amounts of spire, anterior canal, or both.

Types.--Hypotypes UND 12906, UMMP 66070.

Measurements.--EH: 14.0; W: 4.4; SH: 6.8; AW: 1.5; PA: 31.

Occurrence.--Lower, middle, and upper units of Cannonball Formation, Paleocene of Denmark (Ravn, 1939, p. 91, pl. 4, figs. 6 a, b, 13), and possibly the Paleocene Agatdal Formation, West Greenland (Kollman and Peel, 1983, p. 96, fig. 217).

Remarks.--Vitticoncha torelli resembles O. francescae Gardner from the Paleocene Midway Group of Texas (Gardner, 1935, p. 218-219) in its overall shape, ornament, and posterior sinus shape (Fig. 15). Obtusicarina torelli differs from O. francescae in its less strongly elevated spiral bands, the absence of two spiral bands on the whorl periphery, and whorls that are less contracted anteriorly. Since O. francescae is known only from the type, it is my opinion that these species should remain separate until, and unless, intergradation can be documented. Variability within the species characters is primarily in the strength and spacing of the spiral sculpture, node development on the posterior slope, and sinus shape.

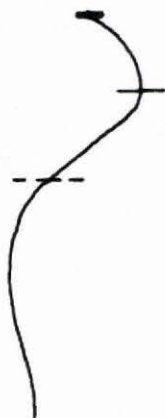
Figure 15. Camera lucida drawings of growth lines taken from the last whorl of two species of Vitticoncha n. gen. Growth lines magnified six times and adjusted to uniform shoulder height. Wide solid line denotes posterior suture, dashed line denotes whorl periphery, narrow solid line denotes apex of sinus. Arrow points adaperturally. (a) V. torelli (Koenen), hypotype, UMMP 66070; (b) V. torelli (Koenen), hypotype, UND 12906; (c) V. francescae (Gardner), holotype, USNM 373057.



a



b



c



Kollman and Peel (1983, p. 96) suggested that Crenaturricula sp. 2 (Kollman and Peel, 1983, p. 96, fig. 217), from the Paleocene of West Greenland, is related to O. torelli Koenen and Pleurotoma hauniensis Koenen. It seems possible that O. torelli is conspecific with their Crenaturricula sp. 2; however, the pencil drawing and brief remarks are not adequate to establish this relationship. It is doubtful whether Pleurotoma hauniensis (Koenen, 1885, p. 28-29, pl. 1, figs. 19 a, b; Ravn, 1939, p. 90, pl. 4, figs. 3 a, b, 4, 5 a, b) is congeneric with O. torelli due to its more anteriorly-located whorl shoulder and noded periphery.

Indeterminate turrid sp. 1

Pl. 1, Fig. 12.

Description of Cannonball material.--Shell fusiform; whorls 8 or 9; shouldered at mid-whorl, posterior slope evenly concave; last whorl constricting rather abruptly anteriorly, anterior canal missing; suture slightly impressed, straight; protoconch unknown; axial sculpture of about 16 short oblique nodes confined to shoulder region; spiral sculpture anterior to whorl shoulder of low, flat-topped, ribbons slightly wider than spaces between, often intercalated with fine spiral threads, sculpture on posterior slope of thin, widely spaced threads, occasionally intercalated with finer threads, about 6 on posterior slope of last whorl; growth lines indicating moderately-deep,

axially-compressed sinus centered on posterior slope, anterior limb of sinus not sweeping adaperturally appreciably, posterior limb approaching orthocline anterior to suture; aperture incomplete, angulate posteriorly, outer lip unknown; inner lip smooth; columella incomplete, apparently straight.

Material.--Single flattened specimen, anterior portion of shell missing, early whorls worn.

Types.--Hypotype UMMP 66057.

Occurrence.--Lower unit of Cannonball Formation.

Remarks.--The only available specimen of this species is too incomplete to allow confident generic or specific assignment, being badly flattened, missing the anterior portion of the shell, and having the protoconch and early whorls obscured. The shape and depth of the posterior sinus, as given above, may not be entirely correct as the flattening has undoubtedly caused some distortion.

Although I have refrained from making a specific or generic determination, its salient features suggest that it may belong to Vitticoncha. This specimen differs from Vitticoncha torelli (Koenen) by its larger size, lack of granulose ornament on the posterior slope, and its seemingly more compressed posterior sinus.

## Subfamily TURRINAE

Diagnosis.--Anterior of shell sometimes truncated; sinus on peripheral carina or on spiral rib just posterior to periphery, varies from deep, narrow slit to broadly open V-shape (modified from Powell, 1966, p. 44).

## Genus CORONIA de Gregorio, 1890

Type Species.--by subsequent designation; Pleurotoma childreni Lea, 1833, p. 173.61

Remarks.--Cossmann (1896, p. 78) placed Coronia in synonymy with Hemipleurotoma Cossmann, a poorly known genus from the Miocene of Italy that has generally been regarded as a synonym of Gemmula Weinkauff (Olsson 1964, p. 92; Glibert 1960, p. 4; Hickman 1976, p. 82). Gardner (1935, p. 214) pointed out that the published figure of Pleurotoma archimedis, the type species of Hemipleurotoma, appeared to differ from the Eocene Coronia of the Gulf Coast by its more constricted posterior sinus. She further commented that although the spire of the type specimen was broken, other Italian species that closely resemble the type, have a smaller, more obtuse protoconch. Therefore, Gardner (1935, p. 214) reinstated the name Coronia to hold this group of Gulf Eocene turrids characterized by:

. . . the rather large, conic, multi-spiral protoconch in which the earlier whorls are smooth, the later costate; by the slender fusiod conch, with both the axial and spiral sculpture strongest upon the periphery, and by a siphonal notch, broad

and not remarkably deep, following the periphery of the whorl as in true Pleurotoma.

Powell (1966, p. 281) questioned the validity of Coronia, commenting that some recent Indo-Pacific species of Gemmula also have, to some degree, smooth initial whorls, and that such slight differences in the protoconch have little importance.

Coronia belongs to a complex group of closely related turrid genera that differ primarily in the shape and location of the posterior sinus and the size and sculpture of the protoconch. This group, in part, includes Eopleurotoma Cossmann, Epalxis Cossmann, Hesperiturris Gardner, and Gemmula Weinkauff. Eopleurotoma and Epalxis differ from Coronia by their more broadly rounded posterior sinus which is not confined to the whorl periphery, but rather extends posteriorly onto the whorl slope (Powell 1966, p. 45,46). Hesperiturris can be distinguished from Coronia by the protoconch and lower, strongly noded peripheral carina (Powell 1966, p. 46). Hesperiturris has a protoconch consisting of five to five and one-half whorls, the first three to three and one-half smooth, followed by a single whorl bearing axial ribs (Gardner 1945, p. 237; Powell 1966, p. 46).

Since the reinstatement of Coronia, it has been treated as a synonym of Gemmula by Harris (1937, p. 10), a subgenus of Gemmula by Harris and Palmer (1947, p. 418), and as a separate genus by Gardner (1945, p. 240), MacNeil and

Dockery (1984, p. 173), and Dockery (1977; 1984). MacNeil and Dockery (1984, p. 174) erected Coroniopsis as a new subgenus of Coronia. This Oligocene subgenus differs from Coronia s. s. by a protoconch with one whorl or less bearing axial ribs and a low whorl periphery with strong, non-bicarinate axial ribs.

Although the material available to me is incomplete, the shallower posterior sinus and protoconch differences described by Gardner (1935, p. 214) would seem to warrant giving Coronia full generic status, since recent workers have regarded these as useful features for distinguishing turrid genera (Hickman 1976, p. 25; Powell 1966, p. 6).

Gemmula most closely resembles Coronia in terms of location of the posterior sinus and general ornamentation; however, Gemmula is characterized by a deep, slit-like sinus (Olsson 1964, p. 92; Gardner 1945, p. 240); a well-developed, generally double, peripheral keel that bears vertical pairs of gemmules; a proportionally longer canal; and a small, turbinate protoconch consisting of three smooth whorls followed by half a whorl with axial ornament (Olsson 1964, p. 92).

Coronia? lloydi (Stanton)

Pl. 2, Figs. 5, 21, 28, 29; text fig. 16a.

Pleurotoma (Hemipleurotoma) childreni Lea, Clark and Martin, 1901, p. 127, pl. 20, figs. 10, 11.

Turris lloydi Stanton, 1920, p. 45, pl. 8, fig. 16.

Turris cordensis Stanton, 1920, p. 45, pl. 8, fig. 12.

Diagnosis.--Shells of about 8 to 10 whorls; height/width ratio likely variable, for one incomplete, 2.0; spire approximately half total shell height; axial sculpture of 19 to 23 short, crescentic peripheral ribs; spiral threads generally much narrower than spaces between, 10 to 12 spiral threads per whorl, about 5 overriding peripheral ribs.

Description of Cannonball material.--Whorls posteriorly constricted, with pronounced, rounded carina at, or slightly anterior to mid-whorl; last whorl contracting abruptly anteriorly to moderately long, twisted, fascioled anterior canal, tip inflected; suture moderately adpressed, weakly channeled; protoconch unknown; axial sculpture variable in strength, ribs sub-rounded to moderately sharp crested, most prominent on whorl periphery, decreasing abruptly in strength anteriorly and posteriorly, showing some tendency to become shorter and more node-like on later whorls of some specimens; spiral sculpture of threads and cords somewhat variable in strength and spacing, threads on posterior slope beaded by growth lines, occasionally on last whorl, 3 or 4 closely spaced threads directly anterior to periphery, about 14 cords spread over anterior slope of last whorl and anterior canal, becoming smaller and more closely spaced anteriorly, often with fine threads between, 1 or 2

posterior-most cords visible on spire; growth lines prominent, defining moderately deep sinus confined to periphery; aperture lance-oval; outer lip smooth internally; inner lip thin, adapertural margin distinct and excavated; columella short, twisted anteriorly.

Material.--Nineteen specimens, 2 specimens with anterior canal and outer lip largely intact.

Types.--Hypotypes UMMP 66064, 66066, and 66068.

Measurements.--EH: 12.0; EW: 6.0; ESH: 7.5; EAW: 2.5; PA: 32-35 (n=2).

Occurrence.--Lower, middle and upper Cannonball Formation and Paleocene Aquia Formation, Maryland and Virginia, U. S. A. (Clark and Martin, 1901, p. 127, pl. 20, figs. 10, 11).

Type locality.--7963, locality 42.

Remarks.--I question the placement of this species in Coronia because of the proportionally long anterior canal and the somewhat atypical shape and ornamentation of the adult whorls. A secure generic assignment for this species is nearly impossible due to the poor preservation of the protoconchs on the UND and USNM material. The relatively broad posterior sinus, crescentic axial ribs, and absence of the double peripheral carinae and gemmules suggest, to me, a closer affinity with Coronia than to Gemmula s. s.

I have examined most of the types of species assigned to Gemmula by Harris (1937) and later to Coronia by Harris

and Palmer (1947) and Palmer and Brann (1966). Of these species, none rivals C.? lloydi in terms of its pronounced whorl carina and well-developed, elongate axial ribs. Furthermore, the curved axials are traversed by three to five spiral threads rather than the double spiral bands typical of species placed in Coronia and more so in those assigned to Gemmula. The strong subsutural cord found on most early Tertiary species assigned to Gemmula and Coronia from the Gulf Coast is essentially absent on C.? lloydi.

The holotype of C.? lloydi and one specimen in the UND collections have the transitional sculpture between the protoconch and teleoconch preserved. This sculpture consists of axial ribs that extend from suture to suture and three or four widely spaced spiral threads. The beginning of adult sculpture is marked by the reduction of the axial ribs to crescentic peripheral nodes. This transitional sculpture appears to have some significance as it is also seen on Pleurotoma mediavia Harris and Gemmula cretacea Sohl. Both of these species, like C.? lloydi, are characterized by poor development of the subsutural cord and double peripheral bands and a pronounced whorl shoulder. Conversely, Gulf Coast species typically have strong subsutural cords, well-developed double peripheral spirals, more flat-sided whorls, and protoconchs that show an abrupt initiation of teleoconch sculpture.

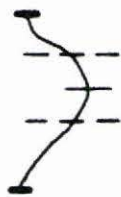


Coronia? lloydi agrees well with Coronia childreni (Lea), the type species of Coronia, in the shape and location of the posterior sinus. However, C.? lloydi differs in having more numerous spiral threads, a more pronounced whorl shoulder, and stronger, more arcuate axial ribs. Pleurotoma mediavia (Harris) closely resembles C.? lloydi in these characters and in the shape of the posterior sinus (Fig. 16); however, P. mediavia has more numerous axial riblets and as many as three transverse swellings on the interior of the outer lip, deep within the aperture.

A specimen from the Aquia Formation figured by Clark and Martin (1901, pl. 20, fig. 10, 11) as Pleurotoma (Hemipleurotoma) childreni (Lea) appears to be conspecific with C.? lloydi. The only observable differences are the more sharply convex shoulder, shorter and more closely spaced ribs, and two slightly stronger threads on the periphery.

Stanton (1920, p. 45, pl. 8, fig. 12, 16) originally assigned this species to Turris Roding; however, Turris is characterized by a deep, narrow posterior sinus on a rib directly posterior to the peripheral carina (Powell 1966, p. 51; Powell 1969, p. 327).

Figure 16. Camera lucida drawings of growth lines taken from the penultimate whorl of species assigned to the turrid genera Coronia De Gregorio and Gemmula Weinkauff. Growth lines magnified twelve times and adjusted to a uniform posterior suture height. Wide solid line denotes posterior and anterior sutures, dashed lines denote posterior and anterior margins of peripheral carina, narrow solid line denotes apex of sinus. Arrow points adaperturally. (a) Coronia? lloydi (Stanton), holotype, USNM 32445; (b) Coronia mediavia (Harris); (c) Gemmula cretacea Sohl, holotype, USNM 130533.



a



b



c

Erickson (1974, p. 221) said that Coronia? lloydi was likely referable to Amuletum Stephenson; however, Amuletum has a posterior sinus on the posterior whorl slope.

Turris cordensis Stanton is known only from a single, badly-worn specimen. I have examined the holotype and most, if not all, of the specific characters are lost, making assignment of material to this species nearly impossible. The shell is similar to worn specimens of C.? lloydi in the UND collections, and, therefore, I have placed it in synonymy with Coronia? lloydi.

Genus EOPLEUROTOMA Cossmann, 1889

Type species.--by original designation; Pleurotoma multicostata Deshayes, 1834, p. 269.

Remarks.--I have examined most of the Eocene species from the North American Gulf Coast that were considered by Powell (1966, p. 45) to be typical representatives of Eopleurotoma. In general, the whorls are strongly shouldered, and the axial ribs are separated into two distinct parts, an opisthocline, somewhat crescentic node on the whorl sides, and a moderate to well-developed subsutural node. On the intervening posterior slope, the axial element is weak to virtually absent. Cossmann (1896, p. 80) (translated by Harris, 1937, p. 27) characterized the axial sculpture of Eopleurotoma in the following manner:

. . . costules obliquely bent, sub-nodulose  
for a third the height of each whorl, interrupted

or decreased in the posterior depression, reappearing again near the suture, along which is formed a beaded band . . . .

Many of the Cannonball specimens show axial sculpture that agrees with that described above by Cossmann. These specimens have a pronounced, double, subsutural band; whorls that are somewhat constricted posteriorly; and axial sculpture that shows a slight to moderate decrease in strength across the posterior slope. Furthermore, these same specimens have fine, rudimentary nodes where the axial ribs intersect the two raised, subsutural bands (pl. 2, figs. 20, 25).

According to Powell (1966, p. 45), the posterior sinus of Eopleurotoma is ". . . broadly V-shaped, its apex extending a little above the peripheral nodules." The Cannonball representatives of E.? danica display a similar posterior sinus. The apex of the sinus is broadly rounded and not confined to the periphery, but rather extends onto the posterior slope (pl. 2, fig. 20).

Powell (1966, p. 45) described the protoconch of Eopleurotoma as ". . . small, smooth and paucispiral." The Cannonball material has a protoconch consisting of four smooth, rather flat-sided whorls, followed by three-quarters of a whorl of fine, closely spaced (breplic) axial ribs. Several of the Gulf Coast Eocene species, considered by Powell (1966, p. 45) to be characteristic species of Eopleurotoma, were described by Harris (1937, p. 27-39) as

having protoconchs consisting of up to three smooth whorls. Eopleurotoma plumbella is said to have a protoconch of four smooth whorls (Harris, 1937, p. 28). Furthermore, several of these species are described as having one or more whorls ornamented with nearly vertical axial ribs.

If the closely spaced (brephic) axial ribs displayed by the Cannonball species, are, in fact, part of the protoconch, then the protoconch sculpture agrees with Oxyacrum Cossmann, which was treated as a subgenus of Eopleurotoma by Powell (1966, p. 45). He (1966, p. 45) made the following comments regarding Oxyacrum: "Members of this subgenus are very similar to Eopleurotoma but have a tall narrowly conical protoconch of four and one-half smooth whorls, plus a whorl of brephic axials. It occurs in the Eocene of Europe and England."

The Cannonball specimens assigned to Eopleurotoma have quite variable axial sculpture, whorl shape, and subsutural cord strength. In spite of this variability, I know of no other species of Eopleurotoma that has such weakly shouldered whorls and axial sculpture that is so continuous across the posterior slope. One possible exception is E. cainei (Harris) from the Lower Claiborne (Harris, 1937, pl. 4, fig. 7-9). In spite of the atypical whorl shape and axial sculpture, the Cannonball representatives of E. ? danica have several noteworthy similarities with the more typical species of Eopleurotoma, and, therefore, the

creation of a new generic grouping to hold them may be unwarranted. My reluctance regarding this generic assignment stems, in large part, from several individuals that have very weak subsutural cords, nearly convex whorls, and axial ribs that decrease evenly in both directions away from the periphery and do not reappear as a subsutural node (pl. 2, fig. 15). Admittedly, the sculpture of these shells does not closely resemble Eopleurotoma.

Eopleurotoma seems to be poorly represented in the Paleocene. Pleurotoma seelandica Koenen, to the best of my knowledge, is the only Paleocene species still referred to this genus (Cossmann, 1896, p. 81; Harris, 1937, p. 27; Powell, 1937, p. 45). Cossmann (1896, p. 81) also referred Pleurotoma infraeocaenica Cossmann and Pleurotoma torelli Koenen to Eopleurotoma; however, Powell (1966, p. 45) placed P. infraeocaenica in Fusiturris Thiele; and P. torelli is here referred to the new genus Vitticoncha.

Eopleurotoma? danica (Koenen)

Pl. 2, Figs. 15, 20, 24, 25.

Pleurotoma danica Koenen, 1885, p. 26-27; Gronwall, 1897, p.

66.

Pleurotoma (Hemipleurotoma) danica Koenen, Ravn, 1939, p.

89, pl. 4, fig. 1 a, b.

Diagnosis.--Height/width ratio 2.9 (n=1); shells of about 7 posteriorly-constricted whorls; axial sculpture of

about 17 curved axial ribs; spiral sculpture of broad, low bands separated by fine, incised grooves, approximately 12 on penultimate whorl, subsutural band poorly to moderately well-developed.

Description of Cannonball material.--Whorl profile broadly convex to moderately constricted posteriorly; height of spire exceeds 1/2 total shell height by approximately 20 percent; last whorl constricting rather abruptly anteriorly to short, slightly twisted, weakly fascioled anterior canal; suture simple, straight; protoconch proportionally large, of about 3.5 smooth, broadly convex whorls; teleoconch sculpture initiated by narrow, nearly vertical, variably spaced axial ribs extending from suture to suture, after about 1/2 whorl, faint spiral bands appear separated by fine incised grooves, subsutural cord appearing concurrently with spiral sculpture; axial sculpture following shape of posterior sinus, quite variable in strength, often subdued on first few teleoconch whorls, ribs thickened at periphery, dying out abruptly anterior to periphery, decreasing in strength slightly across posterior slope, forming faint node at intersection with subsutural cord; strength and spacing of spiral bands increasing across anterior slope of last whorl, becoming somewhat finer and more closely spaced again on anterior canal; growth lines defining broadly rounded posterior sinus, apex extending onto posterior slope, lines not sweeping adaperturally appreciably anterior to



periphery, becoming orthocone on anterior slope of last whorl and anterior canal; aperture elongate-oval; outer lip thin, internally smooth; inner lip lightly callused, abapertural margin excavated, spiral bands occasionally visible on parietal lip; columella short, nearly straight, twisted slightly at anterior margin of aperture.

Material.--Twenty-three specimens, generally poorly preserved, 1 with complete protoconch.

Types.--Hypotypes UND 12907, UMMP 66065 and 66067.

Measurements.--HT: 14.0; EW: 4.6-4.8 (n=2); SH: 9.5; EAW: 1.6; PA: 26-33 (n=3).

Occurrence.--Lower, middle, and upper units of Cannonball Formation, Paleocene of Denmark (Koenen, 1885, p. 26-27; Ravn, 1939, p. 89, pl. 4, figs. 1 a, b), and possibly Paleocene of West Greenland (Kollman and Peel, 1983, p. 100, fig. 225).

Remarks.--The Cannonball representatives of this species show considerable variability in whorl shape and in the strength of the axial and spiral sculpture. Several individuals in the UND collections have subdued axial ribs over the majority of the shell (pl. 2, fig. 15). These shells tend to have a very weak subsutural cord, a broadly convex whorl profile, and axial ribs that decrease in strength both anteriorly and posteriorly from the poorly defined periphery and do not reappear as subsutural nodes. Others develop a moderate shoulder after the second

teleoconch whorl and have well-developed axial ribs and a double subsutural band. Presently, there is no indication that this variation has stratigraphic or environmental significance.

In light of the variation displayed by the Cannonball material, it seems likely that Surcula rosenkrantzi Ravn and Pleurotoma seelandica Koenen are synonyms of E.? danica. A specimen figured by Kollman and Peel (1983, p. 99) as Hemipleurotoma sp. appears to have coarser spiral threads than E.? danica, but is no doubt a closely related species. A single broken specimen, with a slightly larger pleural angle and more widely-spaced spiral bands, has been tentatively assigned to E.? danica (pl. 2, fig. 20). If additional material indicates that these are consistent differences, it should then be recognized as a distinct species.

Ravn (1939, p. 89) placed E. danica in Hemipleurotoma, which he considered to be a subgenus of Pleurotoma. Bellardi's figure (1877, pl. 29, fig. 18) of Pleurotoma archimedis, the type species of Hemipleurotoma, is quite similar to Gemmula having a strong peripheral keel that bears vertical pairs of gemmules and a deep, narrow, posterior sinus. Therefore, it appears that the relationship between E.? danica and the type of Hemipleurotoma is at the subfamilial level.

## Indeterminate turrid sp. 2

Pl. 2, Fig. 1.

Description of Cannonball Material.--Whorls incomplete, but apparently shouldered above mid-whorl, periphery unkeeled, posterior slope concave, constricted to well-developed subsutural collar; suture closely adpressed; axial sculpture of variably spaced, slightly thickened growth lines; spiral sculpture strongest anterior to shoulder, of widely spaced cords, occasionally with fine threads between, 6 finer, more closely spaced threads positioned on shoulder, threads becoming stronger and more distantly spaced on posterior slope and subsutural collar; posterior sinus rather deep, narrow, positioned squarely on shoulder.

Material.--Portion of two whorls joined at suture.

Types.--Hypotype UND 12908.

Occurrence.--Middle unit of Cannonball Formation.

Remarks.--This species differs from the Cannonball species assigned to Coronia DeGregorio primarily in the non-keeled whorl periphery, and, therefore, is believed to be generically distinct. The rather deep posterior sinus on the rounded, non-keeled periphery is somewhat reminiscent of Fusiturris Thiele.

**PLATES**

EXPLANATION OF PLATE 1  
(Locality numbers are given in Appendix A)

- Figs. 1, 2. Deussenia? sp.  
Apertural and abapertural views of incomplete individual; hypotype, UND 12880; X3; locality 14 (A2674).
- Figs. 3-5. Fusinus? sp.  
3. Fragment of three successive whorls; hypotype, UND 12882; X1.5; locality 30 (A2683). 4, 5. Apertural and abapertural views of anterior portion of hypotype, UND 12882; X1.5.
- Figs. 6, 21, 22. Serrifusus sohli n. sp.  
6. Fragment illustrating strong spiral ribbons over entire posterior slope of whorl; paratype, UND 12886; X1; locality 36 (A2691). 21, 22. Apertural and abapertural views of nearly complete individual; holotype, UND 12883; X1; locality 32 (A2666).
- Figs. 7, 8, 13. Marshallaria sp.  
7, 8. Apertural and abapertural views of nearly complete individual; hypotype, UMMP 66056; X1.5; locality 30 (1962/Tpa-15). 13. Oblique apertural view of UMMP 66056 illuminated from upper right to illustrate anterior fasciole and crenulations on interior of outer lip; hypotype, UMMP 66056; X1.5.
- Figs. 9, 10. Exilia sp.  
Apertural and abapertural views of hypotype, UND 1008; X1.5; locality 4 (A2675).
- Figs. 11, 28, 29. Mesorhytis dakotensis (Stanton).  
11. Incomplete, immature individual illustrating three columellar plaits; hypotype; UND 12893; X1; locality 31 (A2668). 28. Poorly preserved, mature individual illustrating aperture shape and long, well-defined anterior canal; hypotype, UND 12894; X1; locality 34 (A2685). 29. Abapertural view of another mature, poorly-preserved individual; hypotype, UMMP 66061; X1; locality 33 (1961/Tpa-1).
- Fig. 12. Indeterminate turrid sp. 1.  
Abapertural view of flattened, incomplete individual; hypotype, UMMP 66057; X1.5; locality 31 (1961/Tpa-4).
- Figs. 14, 15. Amuletum (Lutema) sp.  
Apertural and abapertural views of immature hypotype with borehole (naticid?) in penultimate whorl, UND 12902; X5; locality 14 (A2674).
- Figs. 16, 17, 19, 20. Surculites tormentaria (Stanton).  
16, 17. Apertural and abapertural views of slightly dorso-ventrally flattened individual; hypotype, UMMP 66058; X1; locality 8 (1962/Tpa-19). 19, 20. Apertural and abapertural views of another individual illustrating strong, noded carinations on last whorl and well-preserved spiral sculpture; hypotype, UND 12889; X1; locality 30 (A2683).
- Figs. 18, 23, 30, 31. Rhombopsis gracilis (Stanton).  
18. Abapertural view of immature individual illustrating more axially compressed last whorl; hypotype, UMMP 66059; X1.5; locality 28 (1961/Tpa-32). 23. Abapertural view of incomplete adult individual lacking axial sculpture on last whorl; hypotype, UND 12881; X1; locality 20 (A2699). 30, 31. Apertural and abapertural views of immature individual illustrating well-preserved axial and spiral sculpture; hypotype, UMMP 66062; X1.5; locality 35 (191/Tpa-2).
- Figs. 24, 25. Deussenia minuta n. sp.  
Apertural and abapertural views of nearly complete individual; holotype, UND 12878; X3; locality 14 (A2694).
- Figs. 26, 27. Ericksonia clivilinea n. sp.  
Apertural and abapertural views of holotype, UMMP 66060; X1; locality 31 (1962/Tpa-3).



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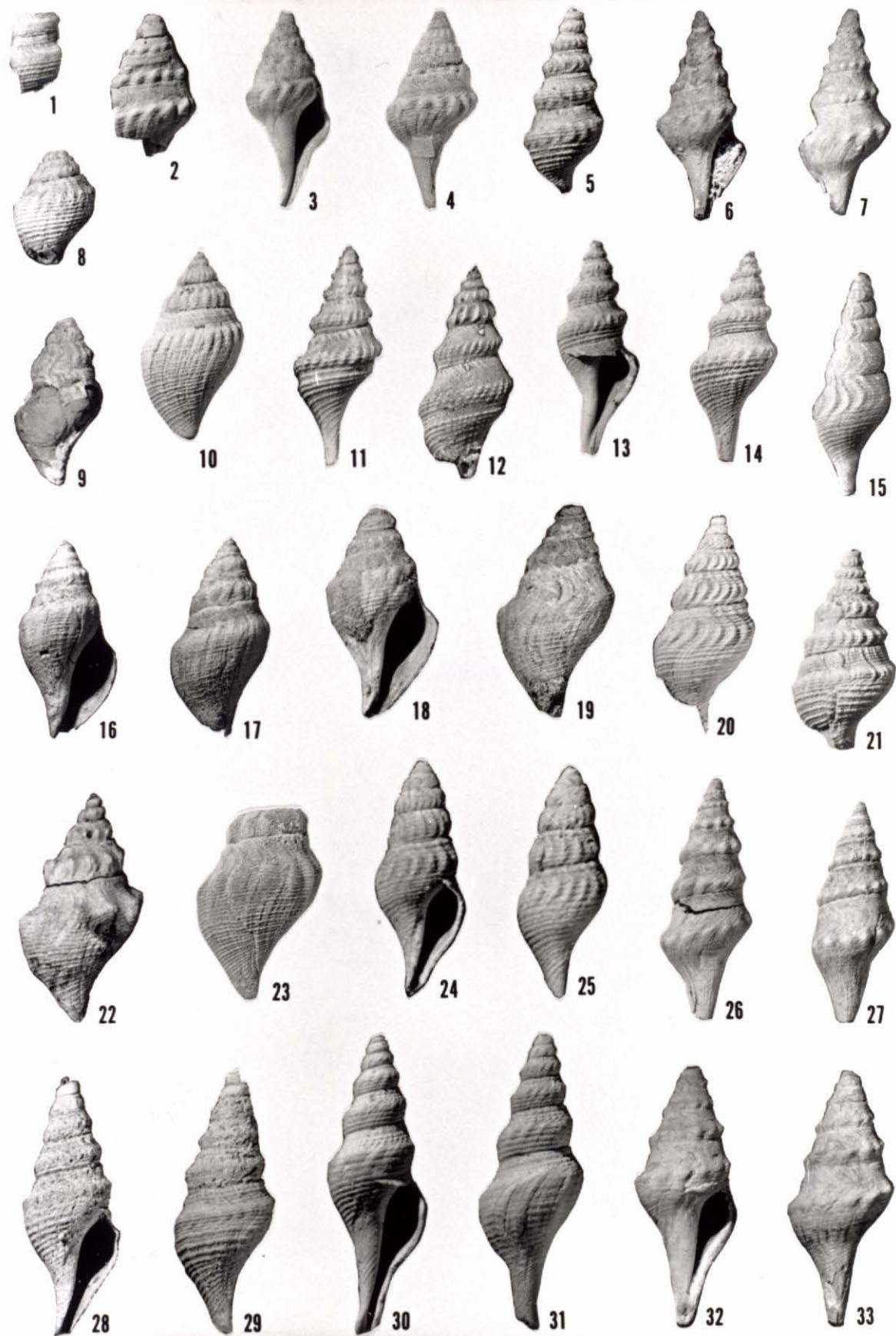
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31

EXPLANATION OF PLATE 2  
(Locality numbers are given in Appendix A)

- Fig 1. Indeterminate turrid sp. 2.  
Fragment of two successive whorls; hypotype, UND 12908; X2; locality 19 (A2552).
- Figs. 2-4. Alticollarum bacatum (Stanton).  
2. Flattened, fragmented individual; holotype, USNM 32449; X1; locality 37 (7964). 3, 4. Apertural and abapertural views of nearly complete individual; hypotype, UMMP 66063; X1; locality 33 (1961/Tpa-1).
- Figs. 5, 21, 28, 29. Coronia? lloydi (Stanton).  
5. Abapertural view of incomplete individual; hypotype, UMMP 66064; X4; locality 31 (1962/Tpa-3). 21. Abapertural view of incomplete individual with larger spire angle; hypotype, UMMP 66066; X3; locality 31 (1962/Tpa-3). 28, 29. Apertural and abapertural views of immature, nearly complete individual; hypotype, UMMP 66068; X4; locality 31 (1962/Tpa-3).
- Figs. 6, 7, 26, 27, 32, 33. Alticollarum janesburgensis (Stanton).  
6, 7. Apertural and abapertural views of individual figured by Stanton (1920) as Turricula textilis; hypotype, USNM 32448; X1.5; locality 39 (7377). 26. Abapertural view of individual illustrating strong peripheral nodes and concave posterior whorl slope; hypotype, UMMP 66069; X1; locality 31 (1961/Tpa-4). 27. Abapertural view of individual illustrating weak peripheral nodes, nearly vertical posterior slope, and fine spiral sculpture; hypotype, UND 12900; X1; locality 31 (A2554). 32, 33. Apertural and abapertural views of individual; holotype, USNM 32447; X1.5; locality 43 (8478).
- Figs. 8-10, 16-19, 23. Acamptogenotia varicosta n. sp.  
8. Abapertural view of individual figured by Stanton (1920) as Pyrifusus (Neptunella) newberryi (Meek and Hayden); hypotype, USNM 32431; X1; locality 10 (9141). 9. Abapertural view of individual figured by Stanton (1920) as Turricula? contorta (Meek and Hayden); hypotype, USNM 32452; X1; locality 18 (8451). 10. Abapertural view of immature individual with 23 axial ribs; paratype, UND 12896; X1.5; locality 33 (A2558). 16, 17. Apertural and abapertural views of immature individual illustrating poorly-developed axial sculpture on last whorl; paratype, UND 12899; X1; locality 31 (A2668). 18, 19. Apertural and abapertural views of mature individual with nearly complete aperture and anterior canal; holotype, UND 12895; X1; locality 8 (A2703). 23. Abapertural view of individual showing well-developed, elongate axial nodes; paratype, UND 12898; X1.5; locality 33 (A2684).
- Figs. 11, 13, 14. Obtusicarina tormentaria (Stanton).  
11. Abapertural view of immature individual illustrating sulcus anterior to whorl periphery on last whorl; hypotype, UND 12904; X3; locality 14 (A2694). 13, 14. Oblique-apertural, and abapertural views of immature individual; hypotype, UND 12905; X1.5; locality 14 (A2694).
- Fig. 12. Obtusicarina phoenicea (Gardner).  
Abapertural view of immature(?) individual from Midway Group, Texas; holotype, USNM 373058; X5; USGS 11696.
- Figs. 15, 20, 24, 25. Eopleurotoma? danica (Koenen).  
15. Abapertural view of individual with nearly convex whorls, weak subsutural bands, and axial ribs that decrease gradually in strength away from the periphery and do not reappear as subsutural nodes; hypotype, UMMP 66065; X4; locality 45 (1962/Tpa-6). 20. Abapertural view of individual with lower spire angle and more widely spaced spiral ribbons; hypotype, UND 12907; X4; locality 15. 24, 25. Apertural and abapertural views of immature individual; hypotype, UMMP 66067; X10; locality 24 (1961/Tpa-25).
- Fig. 22. Turris (Surcula?) contorta Meek and Hayden.  
Abapertural view of individual; paratype, USNM 271; X1.5; USGS accession number unknown.
- Figs. 30, 31. Vitticoncha torelli (Koenen).  
Apertural and abapertural views of mature individual; hypotype, UMMP 66070; X4; locality 45 (1961/Tpa-16).





**APPENDIX A**

Cannonball Neogastropod Localities and Occurrences  
in North Dakota and South Dakota

Localities in this appendix, with the exception of 6 and 43, are shown in figure 2 by their corresponding locality number. For the purpose of this appendix, an "occurrence" is considered to be a collection made at a unique geographic location and stratigraphic position, whereas a locality number refers only to a unique geographic position. Therefore, separate occurrences from the same locality (different collecting date, lithology, or horizon) will bear the same locality number, but a different accession number. Each occurrence is represented by a separate column, and the species collected are indicated opposite the name by the number of individuals.

The legal description of fossil localities follows the format used by the North Dakota State Water Commission (NDSWC). In North Dakota, the first number of the description is the township north of the baseline, the second number is the range west of the fifth principal meridian, and the third number is the section in which the locality occurs. In South Dakota, the second number is the range east of the Black Hills meridian. The letters A, B, C, and D designate, respectively, the northeast, northwest, southwest, and southeast quarter section, quarter-quarter section, and quarter-quarter-quarter section. For example, 133-88-22-ABCD is in the SE1/4, SW1/4, NW1/4, NE1/4 section

22, Township 133 North, Range 88 West. Therefore, in the NDSWC format, subdivisions of a section proceed from the most inclusive to the least inclusive. For this appendix, half-sections are indicated in the following manner: A-B=north half-section, C-D=south half-section, A-D=east half-section, and B-C=west half-section. North Dakota localities have townships ranging from 130 to 153, whereas in South Dakota they are either in 22 or 23.

The accesssion number schemes (ACC) and informal stratigraphic units (STRAT) used in this appendix are explained under Methods of Study. The three primary lithologies (SS, MS, MD) are discussed under Lithologic Occurrence of Species.

#### Explanation of Symbols

1. LOC = Locality number
2. TWP = Township
3. RNG = Range
4. SEC = Section
5. QTR = Quarter. A=NE1/4, B=NW1/4, C=SW1/4,  
D=SE1/4
6. ACC = Accession number
7. YEAR = Year of collecting
8. EXP = Exposure

CBS = Cutbank, south-facing  
BOnw = Blowout, northwest-facing  
HSsw = Hill slope, southwest-facing  
RCe = Roadcut, east side of road

9. LITH = Lithology  
SS = sandstone  
MD = mudstone  
MS = muddy sandstone
10. STRAT = Informal stratigraphic unit  
L = Lower  
M = Middle  
U = Upper
11. SPEC = Species
12. UNK = Unknown

LOC	1	2	2
TWP	153	153	153
RNG	80	79	79
SEC	21	18	18
QTR	DAB	CDB	CDB
ACC	Tpa-31	Tpa-32	A2704
YEAR	1962	1962	1987
EXP	RCnw	RCse	RCse
LITH	MD	SS	SS
STRAT	UNK	UNK	UNK
SPEC			
1. <i>Deussenia minuta</i>	0	0	0
2. <i>Deussenia? sp.</i>	0	0	0
3. <i>Rhombopsis gracilis</i>	0	0	0
4. <i>Ericksonia clivilinea</i>	0	0	0
5. <i>Exilia sp.</i>	0	0	0
6. <i>Fusinus? sp.</i>	0	0	0
7. <i>Serrifusus sohli</i>	0	0	0
8. <i>Surculites tormentaria</i>	0	0	0
9. <i>Mesorhytis dakotensis</i>	0	1	1
10. <i>Acamptogenotia varicosta</i>	0	0	0
11. <i>Alticollarum bacatum</i>	0	0	0
12. <i>Alticollarum janesburgensis</i>	0	0	0
13. <i>Amuletum (Lutema) sp.</i>	0	0	0
14. <i>Marshallaria sp.</i>	0	0	0
15. <i>Obtusicarina tormentaria</i>	0	0	0
16. <i>Vitticoncha torelli</i>	0	0	0
17. Indeterminate turrid sp. 1	0	0	0
18. <i>Coronia? lloydi</i>	0	1	0
19. <i>Eopleurotoma? danica</i>	1	1	0
20. Indeterminate turrid sp.2	0	0	0

LOC	3	4	4	4	4	4
TWP	141	139	139	139	139	139
RNG	81	82	82	82	82	82
SEC	12	23	23	23	23	23
QTR	DD	DDA	DDA	DDA	DDA	DDA
ACC	Tpa-20	A2675	A2450	Tpa-22	A2550	A2662
YEAR	1962	1956	1961	1961	1982	1988
EXP	CBw	RCn	RCn	RCn	RCn	RCn
LITH	SS	SS/MD	SS/MD	SS/MD	SS/MD	SS/MD
STRA	M	M	M	M	M	M
SPEC						
1.	0	0	0	0	0	0
2.	0	0	0	0	0	0
3.	0	0	0	2	0	0
4.	0	0	0	0	0	0
5.	0	1	0	0	0	0
6.	0	0	0	0	0	0
7.	0	0	0	0	1	0
8.	0	0	0	0	0	0
9.	2	0	2	1	0	0
10.	2	0	0	0	0	0
11.	0	0	0	0	0	0
12.	0	0	0	0	0	0
13.	0	0	0	0	0	0
14.	0	0	0	0	0	0
15.	1	1	0	1	0	1
16.	3	0	0	0	0	0
17.	0	0	0	0	0	0
18.	0	0	0	0	0	0
19.	0	0	0	0	0	0
20.	0	0	0	0	0	0

LOC	5	6	7	8	8	9
TWP	139	139	139	139	139	138
RNG	82	81	80	80	80	81
SEC	34	UNK	31	32	32	13
QTR	DA	UNK	AAC	BAC	BAC	BA
ACC	Tpa-16	UNK	Tpa-18	Tpa-19	A2703	A2543
YEAR	1962	UNK	1962	1962	1966	1982
EXP	BOs	UNK	HSsww	RCs	RCs	RCw
LITH	SS	UNK	SS	SS	SS	SS
STRA	M	M?	M	M	M	M
SPEC						
1.	0	0	0	0	0	0
2.	0	0	0	0	0	0
3.	0	1	0	1	0	0
4.	0	0	0	0	0	0
5.	0	0	0	0	0	0
6.	0	0	0	0	0	0
7.	0	0	3	3	0	1
8.	0	0	0	2	0	0
9.	1	0	0	0	0	0
10.	0	0	0	0	1	1
11.	0	0	0	0	0	0
12.	0	0	0	0	0	0
13.	0	0	0	0	0	0
14.	0	0	0	0	0	0
15.	0	0	0	0	0	0
16.	0	0	0	1	0	0
17.	0	0	0	0	0	0
18.	0	0	0	0	0	0
19.	0	0	0	0	0	0
20.	0	0	0	0	0	0

LOC	10	11	12	13	14	14
TWP	137	137	136	136	136	136
RNG	83	77	88	88	87	87
SEC	6	20	24	24	21	21
QTR	CC	DAC	DAA	C	DBD	DBD
ACC	9141	Tpa-13	Tpa-24	8464	A2674	Tpa-31
YEAR	1914	1961	1962	1913	1956	1961
EXP	CB	RCe&w	CBsw	CB?	CBs	CBs
LITH	UNK	SS	MD	UNK	MD	MD
STRA	UNK	M	M	U?	U	U
SPEC						
1.	0	0	0	0	1	1
2.	0	0	0	0	1	0
3.	0	0	0	0	0	0
4.	0	0	0	0	0	0
5.	0	0	0	0	0	0
6.	0	0	0	0	0	0
7.	0	0	0	0	0	0
8.	0	0	1	0	0	0
9.	0	3	4	0	17	4
10.	1	0	0	0	0	0
11.	0	0	0	0	0	0
12.	0	0	0	0	1	0
13.	0	0	0	0	1	0
14.	0	0	0	0	0	0
15.	0	0	0	0	0	1
16.	0	0	0	0	0	0
17.	0	0	0	0	0	0
18.	0	0	0	1	1	0
19.	0	0	1	0	0	0
20.	0	0	0	0	0	0



LOC	14	15	16	17	18	19
TWP	136	136	136	136	136	136
RNG	87	87	86	86	84	82
SEC	21	21	21	29	16	18
QTR	DBD	ACC	DB	UNK	C	BBC
ACC	A2694	A2695	Tpa-28	8459	8451	Tpa-19
YEAR	1989	1989	1962	1913	1913	1961
EXP	CBs	CBs	CBw	CBe?	CBe?	RCe
LITH	MD	MD	SS	UNK	UNK	SS
STRA	U	U	L	U?	UNK	M
SPEC						
1.	2	0	0	0	0	0
2.	0	0	0	0	0	0
3.	0	0	0	0	0	3
4.	0	0	0	0	0	0
5.	0	0	0	0	0	0
6.	0	0	0	0	0	0
7.	0	0	1	0	0	0
8.	0	0	0	0	0	0
9.	20	0	2	0	0	0
10.	0	0	1	0	2	0
11.	0	0	1	0	0	0
12.	3	0	0	0	0	0
13.	1	0	0	0	0	0
14.	0	0	0	0	0	0
15.	4	0	3	1	0	0
16.	0	0	0	0	0	0
17.	0	0	0	0	0	0
18.	2	0	0	0	0	0
19.	1	1	1	0	0	0
20.	0	0	0	0	0	0

LOC	19	19	19	19	19	19
TWP	136	136	136	136	136	136
RNG	82	82	82	82	82	82
SEC	18	18	18	18	18	18
QTR	BBC	BBC	BBC	BBC	BBC	BBC
ACC	Tpa-7	A2551	A2545	A2552	A2631	A2663
YEAR	1962	1979	1982	1982	1986	1988
EXP	RCe	RCe	RCe	RCe	RCe	RCe
LITH	SS	SS	SS	SS	SS	SS
STRA	M	M	M	M	M	M
SPEC						
1.	0	0	0	0	0	0
2.	0	0	0	0	0	0
3.	2	1	0	1	1	1
4.	0	0	0	0	0	0
5.	0	0	0	0	0	0
6.	0	0	0	0	0	0
7.	0	0	0	0	0	0
8.	0	0	0	0	0	0
9.	0	0	0	0	0	0
10.	0	0	1	1	0	0
11.	0	0	0	0	0	0
12.	0	0	0	0	0	0
13.	0	0	0	0	0	0
14.	0	0	0	0	0	0
15.	0	0	0	0	0	0
16.	0	0	0	0	0	0
17.	0	0	0	0	0	0
18.	2	0	0	0	0	0
19.	0	0	0	0	0	0
20.	0	0	0	1	0	0

LOC	20	21	22	23	23	24
TWP	136	136	135	135	135	135
RNG	81	81	83	83	83	82
SEC	30	31	26 or 27	26	26	1
QTR	DAD	CC	B-C or A-D	CBD	CBD	AA
ACC	A2699	Tpa-24	Tpa-11	A2633	A2679	Tpa-25
YEAR	1956	1961	1961	1986	1989	1961
EXP	RCw	HSn-nw-w	RCe&w	RCe	RCe	HSe
LITH	SS	SS	SS	SS	SS	SS
STRA	M	M	L	M	M	M
SPEC						
1.	0	0	0	0	0	0
2.	0	0	0	0	0	0
3.	2	1	1	0	0	0
4.	0	0	0	0	0	0
5.	0	0	0	0	0	0
6.	0	0	0	0	0	0
7.	0	0	0	0	0	0
8.	0	0	0	1	0	0
9.	0	0	0	0	0	0
10.	0	0	0	0	0	0
11.	0	0	0	0	0	0
12.	0	0	0	0	0	0
13.	0	0	0	0	0	0
14.	0	0	0	0	0	0
15.	0	0	0	0	0	0
16.	0	0	1	0	1	0
17.	0	0	0	0	0	0
18.	0	0	0	0	0	0
19.	0	0	0	0	0	6
20.	0	0	0	0	0	0

LOC	25	25	26	27	28	29
TWP	135	135	135	134	133	133
RNG	82	82	81	81	88	88
SEC	36	36	5 or 6	3	26	26
QTR	ABB	ABB	B-C or A-D	DB	DCC	CB
ACC	Tpa-8	Tpa-4	A2698	Tpa-9	Tpa-32	Tpa-7
YEAR	1961	1962	UNK	1961	1961	1961
EXP	HSne	HSne	RCe,w	HS	CBw	CBw
LITH	SS	SS	SS	SS	SS	SS/MD
STRA	U	U	M	U	M	M
SPEC						
1.	0	0	0	0	0	0
2.	0	0	0	0	0	0
3.	0	0	1	0	1	0
4.	0	0	0	0	0	0
5.	0	0	0	0	0	0
6.	0	0	0	0	0	0
7.	0	0	0	0	0	0
8.	0	1	0	0	0	0
9.	0	0	0	0	0	0
10.	1	0	0	1	0	0
11.	0	0	0	0	0	0
12.	0	0	0	0	0	0
13.	0	0	0	0	0	0
14.	0	0	0	0	0	0
15.	0	0	0	0	1	1
16.	0	0	0	0	0	0
17.	0	0	0	0	0	0
18.	0	0	0	0	0	0
19.	0	0	0	0	0	0
20.	0	0	0	0	0	0

LOC	30	30	30	31	31	31
TWP	133	133	133	133	133	133
RNG	88	88	88	88	88	88
SEC	28	28	28	28	28	28
QTR	DBB	DBB	DBB	CCD	CCD	CCD
ACC	Tpa-15	A2669	A2683	Tpa-4	Tpa-3	A2553
YEAR	1962	1988	1989	1961	1962	1982
EXP	CBwsw	CBwsw	CBwsw	CBnne	CBnne	CBnne
LITH	MS	MS	MS	MS	MS	MS
STRA	L	L	L	L	L	L
SPEC						
1.	0	0	1	0	1	0
2.	0	0	0	0	0	0
3.	0	1	0	0	1	0
4.	0	0	0	0	1	0
5.	0	0	0	0	1	0
6.	0	0	1	0	0	0
7.	0	1	0	0	0	2
8.	1	0	2	1	0	0
9.	2	2	1	3	1	0
10.	4	2	1	1	0	0
11.	0	0	0	0	0	0
12.	0	0	0	1	1	0
13.	0	0	0	0	0	0
14.	1	0	0	0	0	0
15.	0	0	1	0	3	0
16.	0	0	0	0	0	0
17.	0	0	0	1	0	0
18.	1	0	0	0	8	0
19.	0	0	1	0	0	0
20.	0	0	0	0	0	0

LOC	31	31	31	32	32	32
TWP	133	133	133	133	133	133
RNG	88	88	88	88	88	88
SEC	28	28	28	29	29	29
QTR	CCD	CCD	CCD	DDB	DDB	DDB
ACC	A2554	A2668	A2682	Tpa-3	Tpa-2	A2555
YEAR	1982	1988	1989	1961	1962	1979
EXP	CBnne	CBnne	CBnne	CBn	CBn	CBn
LITH	MS	MS	MS	MS	MS	MS
STRA	L	L	L	L	L	L
SPEC						
1.	0	1	0	0	0	0
2.	0	0	0	1	0	0
3.	0	0	0	1	0	0
4.	0	0	0	0	0	0
5.	0	0	0	0	0	0
6.	0	0	0	0	0	0
7.	0	1	1	0	0	0
8.	0	0	0	0	0	0
9.	0	3	1	0	1	0
10.	0	4	1	0	1	0
11.	0	0	0	0	0	0
12.	1	2	1	0	0	1
13.	0	0	0	0	0	0
14.	0	0	0	0	0	0
15.	0	2	0	0	0	0
16.	0	0	1	0	0	0
17.	0	0	0	0	0	0
18.	0	0	0	0	0	0
19.	1	0	0	0	0	0
20.	0	0	0	0	0	0

LOC	32	32	32	33	33	33
TWP	133	133	133	133	133	133
RNG	88	88	88	88	88	88
SEC	29	29	29	29	29	29
QTR	DDB	DDB	DDB	DB	DB	DB
ACC	A2556	A2666	A2681	Tpa-1	Tpa-1	A2557
YEAR	1982	1988	1989	1961	1962	1979
EXP	CBn	CBn	CBn	CBsse	CBsse	CBsse
LITH	MS	MS	MS	MS	MS	MS
STRA	L	L	L	L	L	L
SPEC						
1.	0	1	0	0	0	0
2.	0	0	0	0	0	0
3.	0	1	0	1	0	1
4.	0	0	0	0	0	0
5.	0	1	0	0	0	0
6.	0	0	0	0	0	0
7.	0	1	0	0	1	0
8.	0	0	0	0	0	0
9.	3	2	1	2	0	0
10.	0	1	0	0	0	0
11.	0	0	0	1	0	0
12.	0	0	0	1	0	0
13.	0	0	0	0	0	0
14.	0	0	0	0	0	0
15.	0	0	0	0	0	0
16.	0	1	0	0	0	0
17.	0	0	0	0	0	0
18.	0	0	0	0	0	0
19.	0	1	0	0	0	0
20.	0	0	0	0	0	0

LOC	33	33	33	34	34	34
TWP	133	133	133	133	133	133
RNG	88	88	88	88	88	88
SEC	29	29	29	29	29	29
QTR	DB	DB	DB	CDB	CDB	CDB
ACC	A2558	A2667	A2684	8382	A2671	A2685
YEAR	1982	1988	1989	1913	1988	1989
EXP	CBsse	CBsse	CBsse	CBnnw	CBnnw	CBnnw
LITH	MS	MS	MS	MS?	MS	MS
STRA	L	L	L	L?	L	L
SPEC						
1.	0	0	0	0	0	0
2.	0	0	0	0	0	0
3.	0	1	0	0	0	0
4.	0	0	0	0	0	0
5.	0	0	0	0	0	0
6.	0	0	0	0	0	0
7.	0	0	0	0	1	2
8.	0	1	0	1	1	0
9.	0	2	2	0	0	2
10.	2	0	3	0	3	1
11.	0	0	0	0	0	0
12.	0	1	0	0	0	1
13.	0	0	0	0	0	0
14.	0	0	0	0	0	0
15.	0	0	0	0	0	0
16.	1	0	1	0	0	0
17.	0	0	0	0	0	0
18.	0	0	0	0	0	0
19.	0	0	0	0	0	0
20.	0	0	0	0	0	0



LOC	35	35	35	36	37	37
TWP	133	133	133	133	133	133
RNG	88	88	88	88	88	88
SEC	29	29	29	30	31	31
QTR	BAA	BAA	BAA	DBA	AAB?	AAB
ACC	Tpa-2	A2670	A2686	A2691	7964	A2689
YEAR	1961	1988	1989	1989	1912	1989
EXP	CBw	CBw	CBw	CBs	CBne?	CBne
LITH	MD	MD	MD	MS	MS?	MS
STRA	M	M	M	L	L?	L
SPEC						
1.	0	0	0	0	0	0
2.	0	0	0	0	0	0
3.	1	0	1	0	0	0
4.	0	0	0	0	0	0
5.	0	0	0	0	0	0
6.	0	0	0	0	0	0
7.	0	0	0	1	0	0
8.	0	0	0	0	0	0
9.	1	3	1	0	0	0
10.	1	1	0	0	0	0
11.	0	0	0	0	1	0
12.	3	0	0	0	0	0
13.	0	0	0	0	0	0
14.	0	0	0	0	0	0
15.	0	0	1	0	0	0
16.	0	0	0	1	0	1
17.	0	0	0	0	0	0
18.	1	1	0	1	0	0
19.	2	0	0	0	0	0
20.	0	0	0	0	0	0

LOC	37	38	38	39	40	40
TWP	133	133	133	133	133	133
RNG	88	88	88	88	88	88
SEC	31	32	32	32?	34	34
QTR	AAB	BDD	BDD	A?	ADD	ADD
ACC	A2690	A2687	A2688	8377	Tpa-6	A2672
YEAR	1989	1989	1989	1913	1961	1988
EXP	CBne	CBn	CBn	CBn?	CBnw	CBnw
LITH	MS	MS	MS	MS?	SS	SS
STRA	L	L	L	L?	M	M
SPEC						
1.	0	0	0	0	0	0
2.	0	0	0	0	0	0
3.	0	0	0	0	0	0
4.	0	0	0	0	0	0
5.	0	0	0	0	0	0
6.	0	0	0	0	0	0
7.	0	0	0	0	0	0
8.	0	0	1	0	0	0
9.	0	0	0	1	0	1
10.	0	0	0	0	0	0
11.	0	0	0	0	1	0
12.	0	1	0	1	0	0
13.	0	0	0	0	0	0
14.	0	0	0	0	0	0
15.	0	0	0	0	0	0
16.	0	1	0	0	0	0
17.	0	0	0	0	0	0
18.	0	1	0	0	0	0
19.	1	0	0	0	0	0
20.	0	0	0	0	0	0

LOC	41	42	43	44	45	45
TWP	132	132	132	130	130	130
RNG	88	88	87	92	90	90
SEC	5	11	18?	22	9	9
QTR	DCB	B	UNK	A	BBD	BBD
ACC	A2701	7963	8478	Tpa-23	Tpa-16	Tpa-6
YEAR	1956	1912	1913	1962	1961	1962
EXP	CBnne	HSs?	CB?	CBs	CBw	CBw
LITH	UNK	UNK	UNK	MD	SS	SS
STRA	UNK	L or M?	UNK	UNK	M	M
SPEC						
1.	0	0	0	0	0	0
2.	0	0	0	0	0	0
3.	0	0	0	0	1	0
4.	0	0	0	0	0	0
5.	0	0	0	0	1	0
6.	0	0	0	0	0	0
7.	0	0	0	0	0	0
8.	0	0	0	0	0	0
9.	0	0	0	0	0	0
10.	1	2	0	0	1	0
11.	0	0	0	0	0	0
12.	0	0	1	1	2	0
13.	0	0	0	0	0	0
14.	0	0	0	0	0	0
15.	0	0	0	1	0	0
16.	0	0	0	0	1	1
17.	0	0	0	0	0	0
18.	0	1	0	1	0	0
19.	0	0	0	0	1	1
20.	0	0	0	0	0	0

LOC	45	45	45	45	46	47
TWP	130	130	130	130	130	130
RNG	90	90	90	90	90	90
SEC	9	9	9	9	21	33
QTR	BBD	BBD	BBD	BBD	BBC	B-C
ACC	A2548	A2665	A2692	A2693	Tpa-15	A2700
YEAR	1982	1988	1989	1989	1961	1962
EXP	CBw	CBw	CBw	CBw	RCe	RCe
LITH	SS	SS	SS	MD	SS	SS
STRA	M	M	M	M	M	M
SPEC						
1.	0	0	0	0	0	0
2.	0	0	0	0	0	0
3.	0	0	0	0	0	0
4.	0	0	0	0	0	0
5.	0	0	0	0	0	0
6.	0	0	0	0	0	0
7.	0	0	0	0	0	1
8.	0	0	0	0	0	0
9.	0	0	0	0	1	0
10.	0	2	0	1	0	0
11.	0	0	0	0	0	0
12.	1	0	0	0	0	0
13.	0	0	0	0	0	0
14.	0	0	0	0	0	0
15.	0	0	0	0	0	0
16.	0	0	0	0	0	0
17.	0	0	0	0	0	0
18.	0	0	1	0	0	0
19.	0	0	0	0	0	1
20.	0	0	0	0	0	0

LOC	48	49	50
TWP	23	22	22
RNG	17	17	15
SEC	34	3	4
QTR	C	BBD	ADC
ACC	8473	A2697	A2644
YEAR	1913	1987	1987
EXP	UNK	RCe	RCwBO
LITH	UNK	MD	SS
STRA	UNK	L?	L
SPEC			
1.	0	0	0
2.	0	0	0
3.	0	0	0
4.	0	0	0
5.	0	0	0
6.	0	0	0
7.	0	1	0
8.	1	0	0
9.	0	0	1
10.	0	0	0
11.	0	0	0
12.	0	0	0
13.	0	0	0
14.	0	0	0
15.	0	0	0
16.	0	0	0
17.	0	0	0
18.	0	0	0
19.	0	0	0
20.	0	0	0

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