UTAH GEOLOGICAL AND MINERALOGICAL SURVEY

AFFILIATED WITH

THE COLLEGE OF MINES AND MINERAL INDUSTRIES

UNIVERSITY OF UTAH

SALT LAKE CITY, UTAH

MICROFOSSILS OF THE UPPER CRETACEOUS OF NORTHEASTERN UTAH AND SOUTHWESTERN WYOMING

By

REED H. PETERSON, DAVID J. GAUGER
and ROBERT R. LANKFORD

Edited By

DANIEL J. JONES

Bulletin 47 (Contributions in Micropaleontology No. 1) September, 1953

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UTAH GEOLOGICAL AND MINERALOGICAL SURVEY

The Utah Geological and Mineralogical Survey was authorized by act of the Utah State Legislature in 1931; however, no funds were made available for its establishment until 1941 when the State Government was reorganized and the Utah Geological and Mineralogical Survey was placed within the new State Departement of Publicity and Industrial Development where the Survey functioned until July 1, 1949. Effective as of that date, the Survey was transferred by law to the College of Mines and Mineral Industries, University of Utah.

The *Utah Code Annotated 1943, Vol. 2, Title 34,* as amended by *chapter 46 Laws of Utah 1949,* provides that the Utah Geological and Mineralogical Survey "shall have for its objects":

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The Utah Geological and Mineralogical Survey has published maps, circulars, and bulletins as well as articles in popular and scientific magazines. For a partial list of such publications see the inside back cover of this publication and the preceding pages. For other information concerning the geological and mineralogical resources of Utah address:

ARTHUR L. CRAWFORD, *Director*

UTAH GEOLOGICAL AND MINERALOGICAL SURVEY

College of Mines and Mineral Industries

University of Utah

Salt Lake City, Utah

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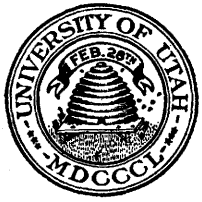

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Plates I to XVI, (pages 112 to 149), show retouched drawings of the microfossils discussed in the text.

FOREWORD

The Utah Geological and Mineralogical Survey has one primary function. It should make available to the citizens of this state and to science and industry generally the geologic background and mineral resource opportunities available in Utah. Its success in performing this function at a minimum of expense has been due largely to the whole-hearted cooperation of other state, federal, and private agencies. The present bulletin, No. 47, is a typical example.

It is an outgrowth of graduate research in the Department of Geology, University of Utah. It was printed with the aid of a loan from the University of Utah Research Fund. The loan will be repaid from the proceeds from the sale of this bulletin by the Utah Geological and Mineralogical Survey.

Bulletin 47 is the first in a series of contributions to the micropaleontology of the stratigraphic section in Utah and bordering areas of the intermountain west. Systematic study of the microfaunas and microfloras of both marine and non-marine strata in the area is just beginning, and preliminary studies indicate abundant microfossils in many formations of the Paleozoic, Mesozoic and Cenozoic.

These micropaleontological contributions are under the direction of Daniel J. Jones, Professor of Sedimentation and Micropaleontology at the University of Utah, and will represent the results of his research and that of graduate students under his supervision.

The faunas thus far discovered are representative of a wide variety of sedimentary environments, both marine and non-marine. Particular attention will be given to the study of faunas in such non-marine units as lakes, stream flood plains, and glaciofluviatile deposits.

It is hoped that micropaleontological evidence may shed some light on the age and correlation of many problematical and controversial time-rock units in Utah and nearby states.

Arthur L. Crawford, Director
Utah Geological and Mineralogical Survey

MICROFOSSILS OF THE UPPER CRETACEOUS
OF NORTHEASTERN UTAH AND SOUTHWESTERN WYOMING

BY

REED H. PETERSON, DAVID J. GAUGER
AND ROBERT R. LANKFORD

EDITED BY

DANIEL J. JONES

ABSTRACT

Microfossils obtained from three upper Cretaceous formations in northeastern Utah and southwestern Wyoming indicate both marine and non-marine facies within the units. The formations studied include the Frontier formation, the Hilliard, and the "Wanship" (Henefer of Eardley). Evidence from the microfaunas and microfloras suggests that the Hilliard and Frontier are dominantly marine where sampled, and that the Wanship fossiliferous zones are dominantly non-marine, or marginal to marine facies.

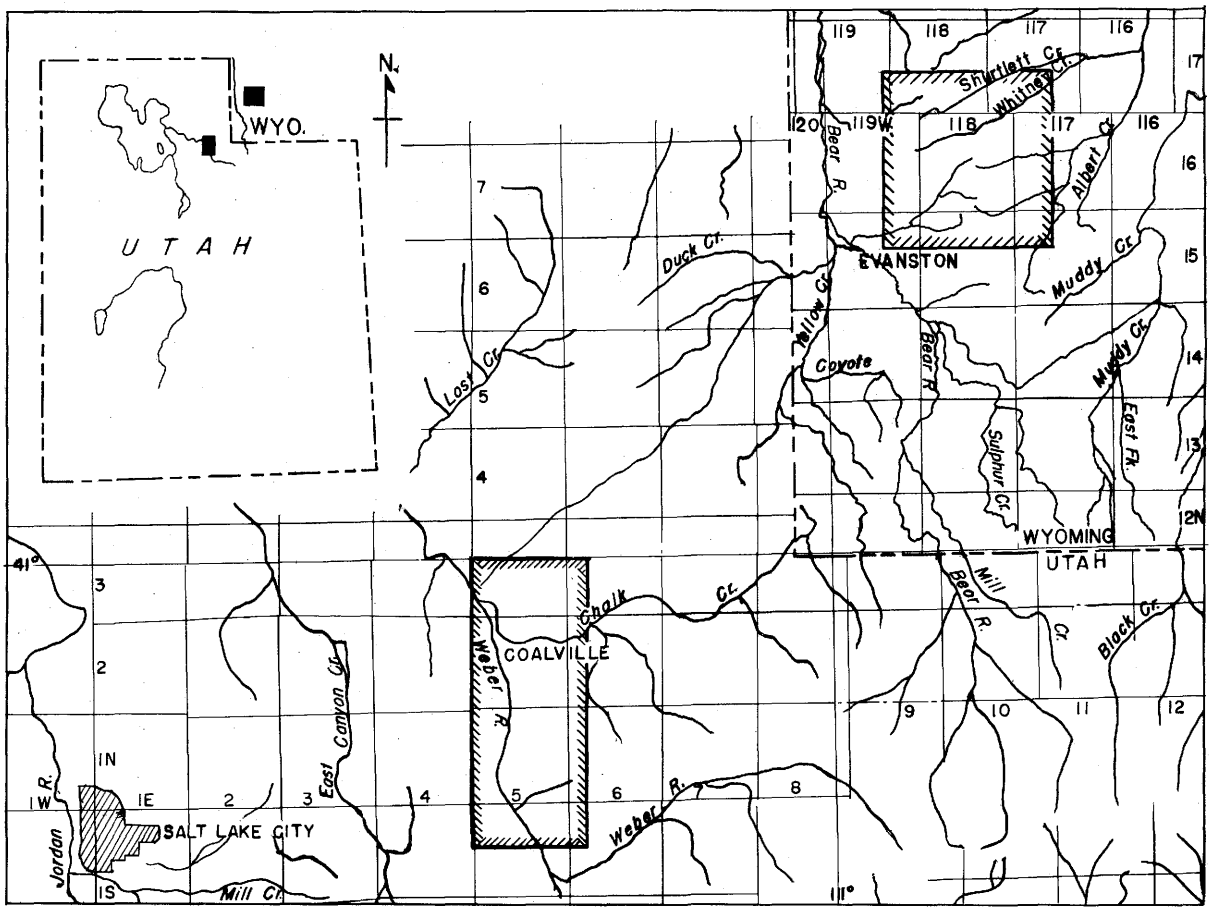
On the basis of the present studies, the following conclusions are drawn concerning the ages of the three formations:

1. In general, the marine fossils bear a closer affinity to upper Cretaceous forms of the Gulf Coast than to other formations of similar age in the Rocky Mountain region.

2. The foraminifera and ostracoda of the Frontier formation in the Coalville, Utah, region suggest that it is in part equivalent to the Upper Eagle Ford-Lower Austin (Turonian-Senonian) of the Texas Gulf Coast Section.

3. The abundant foraminifera and ostracoda of the Hilliard correlate in general with the Taylor of the Gulf Coast, although there are many species of Austin age. This suggests that the Colorado-Montana (Austin-Taylor) boundary lies within the lower portion of the Hilliard.

4. The microfauna and microflora of the "Wanship" formation, dominantly non-marine, are similar to non-marine Upper Cretaceous forms of other areas. However, marine species found in the formation have been described elsewhere from the Paleocene and Eocene.



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INDEX MAP OF NORTHEASTERN UTAH AND SOUTHWESTERN WYOMING

FIGURE 1

INTRODUCTION

It is the purpose of the present report to describe and illustrate the microfossils obtained from three formations of Upper Cretaceous age in northeastern Utah and southwestern Wyoming, and to discuss their significance in age determination and the correlation of Upper Cretaceous formations in which they occur.

The three papers which have been integrated into this bulletin represent the first systematic micropaleontological study of the Upper Cretaceous section in the area, and they mark the beginning of an intensive and long-term program of research on the micropaleontology of the sedimentary column in Utah and bordering regions. Other work in this program includes studies of the microfossils of the Tertiary Salt Lake Group, the Pleistocene faunas of the Lake Bonneville sediments, the nonmarine Cretaceous strata of south-central Utah, the Pennsylvanian and Mississippian of the Confusion Range in west-central Utah, and the microfaunas of the Evanston and Adaville formations in extreme southwestern Wyoming.

The Upper Cretaceous section of northeastern Utah and southwestern Wyoming is situated both geologically and geographically in a critical area. Geographically, the strata are in a zone of rapidly interfingering and intergrading marine and nonmarine facies, and stratigraphically the section contains two critical boundaries: (1) the Colorado-Montana boundary and (2) the Upper Cretaceous—Paleocene boundary.

The main body of this report consists of the following reports, completed as graduate theses in the Department of Geology, University of Utah:

1. "The Microfossils and Correlation of Part of the Frontier Formation, Coalville, Utah," by Reed H. Peterson. (1950)

2. "Microfauna of the Hilliard Formation near Evanston, Wyoming," by David J. Gauger. (1952)

3. "Micropaleontology of the Cretaceous-Paleocene (?) in Northeastern Utah," by Robert R. Lankford. (1952)

It is hoped that the information presented herein will serve to shed some additional light on the two boundary problems referred to above, and also that additional information will be brought to bear on the problem of the complex environmental conditions of deposition of Upper Cretaceous sediments in the area of northeastern Utah and southwestern Wyoming.

The writers and the editor express their sincere appreciation to Professors A. J. Eardley, Wm. Lee Stokes, R. E. Marsell, and Norman C. Williams, all of the Department of Geology of the University of Utah, for their invaluable assistance in various phases of the studies, and for critically reading portions of the manuscript. To Arthur L. Crawford, State Geologist and Director of the Utah Geological and Mineralogical Survey, special appreciation is expressed for his assistance in many problems in preparation of the bulletin. Grateful acknowledgement is also made of a loan from the University of Utah Research Fund which made this publication possible.

Daniel J. Jones

P A R T I

CRETACEOUS STRATIGRAPHY OF NORTHEASTERN UTAH AND SOUTHWESTERN WYOMING

Daniel J. Jones

GENERAL CONSIDERATIONS

The Upper Cretaceous formations of northeastern Utah and southwestern Wyoming have been the subject of many geological investigations, and have received considerable attention for two reasons: (1) they are important economically because of their coal strata, and (2) because two important boundary problems are involved: the Colorado-Montana boundary within the upper Cretaceous, and the long-disputed Cretaceous - Tertiary boundary in the Rocky Mountain region.

The interfingering of marine and non-marine strata also presents a number of facies correlation problems, common to marginal areas of deposition. One of the main purposes of the present investigation is to attempt to bridge the gap in correlation between the Cretaceous section of Wyoming and the northern Rocky Mountains and the section in the Central Rocky Mountain region. (see Figs. 1 and 2.)

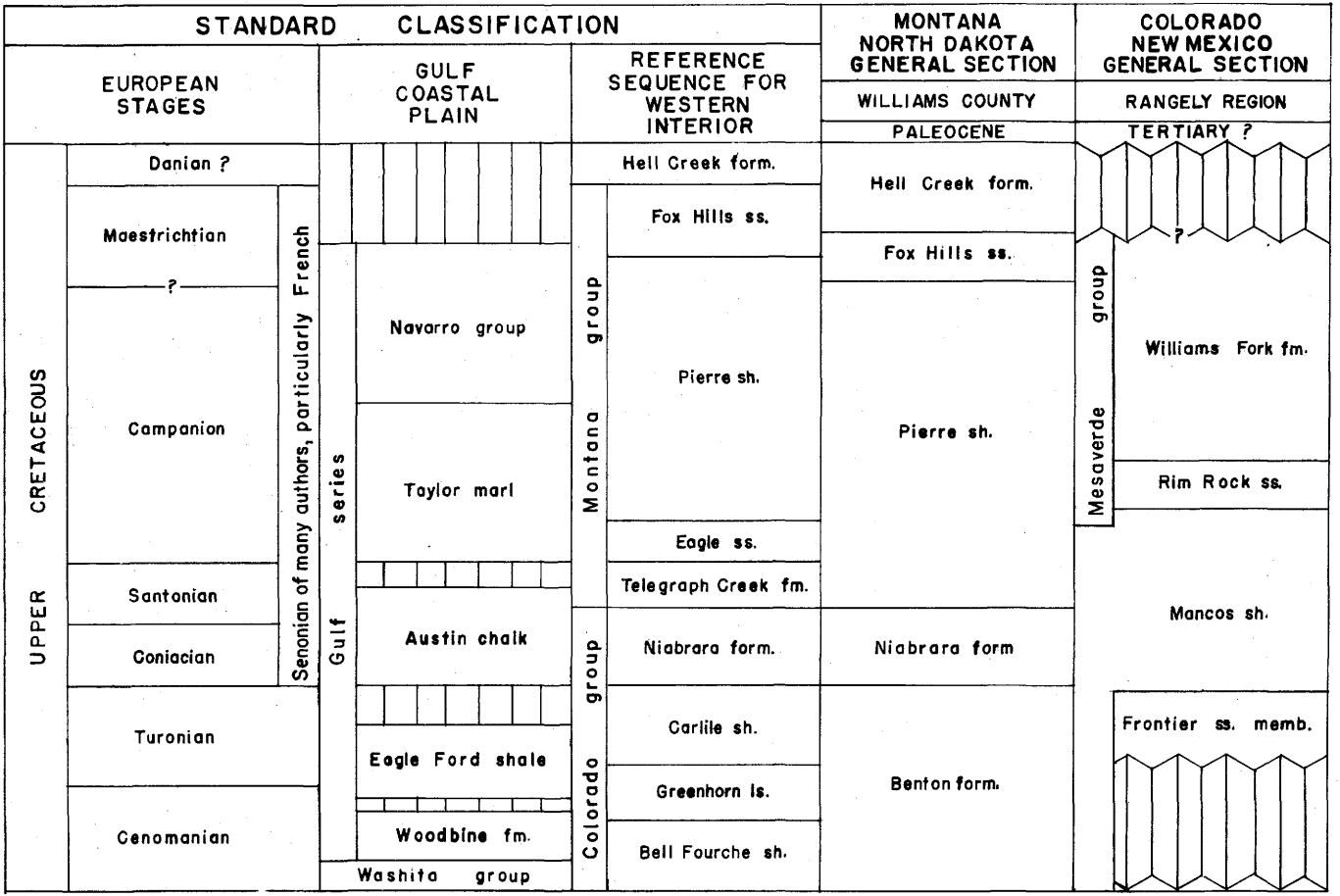
The Upper Cretaceous sections considered in this report are in two areas; the section near Evanston, Wyoming, and the section of the Coalville area, Utah. These will be considered separately. Summaries of previous work in each area are presented in order to provide a background for discussion of the age relationships and correlations.

A. THE CRETACEOUS SECTION NEAR COALVILLE, UTAH

In the past 90 years, the strata of the Coalville and Wanship areas have been studied and reported on by many geologists. A brief review of the literature pertaining to the area under study is presented here and serves to emphasize the purpose of this report.

Beds in the vicinity of Coalville were first referred to the Cretaceous system by Meek and Englemann (1860). F. V. Hayden (1869) and Leo Lesquereux (1873) included the strata in the Lignitic formation of the Tertiary. Lesquereux based his conclusions on evidence furnished by fossil plant remains. In light of the fact that molluscan fossils of established Cretaceous age were found above the leaf-bearing horizons, he suggested that the botanical evidence outweighed the faunal evidence and concluded that the coal measures belonged to the "Lower American Eocene." An extensive collection of the invertebrate fauna was made by Meek (1872) near Coalville. He commented briefly on the unique faunal assemblage and assigned a definite Cretaceous age to the lower units and postulated a Tertiary age for the upper part of the section. Members of the 40th Parallel Survey party (King and Emmons - 1877) assigned the exposed formations both in Coalville and Wanship to the Colorado, Fox Hills and Laramie groups of the Cretaceous. C. A. White (1877) visited the area and reported that "there could be no doubt as to the Cretaceous age of the Strata." His report notes the absence of diagnostic cephalopod, pelecypod, and gastropod genera, characteristic of the then standard upper Missouri Cretaceous sections. White further pointed out that the Cretaceous fauna bore a strong resemblance to that of Texas which also possessed little in common with the upper Missouri. He assigned the lower part of the Coalville section to the Colorado group and the upper to the Fox Hills group. On the basis of molluscan fossils, T. W. Stanton (1893) designated the lower strata of Coalville as Coloradan in age and separated the upper beds into the Montana and Laramie groups. Fossil leaves collected by F. H. Knowlton (1900) from the upper section were first identified as Laramie and later as of Montana age.

An intensive study of the Coalville coal fields was conducted by Carrol H. Wegemann (1915) who concurred with Stanton's age determinations. J. M. Boutwell (1944) reported that the strata was equivalent to the Colorado group and the Hilliard,



UPPER CRETACEOUS SECTIONS — CENTRAL AND NORTHERN ROCKY MOUNTAINS
FIGURE 2

Adaville and Evanston formations. Eardley (1944, pp. 838-42) in a study of the north-central Wasatch mountains divided the Cretaceous section exposed at Coalville into the Kelvin (?), Aspen, Frontier and Henefer formations. Following Eardley, H. J. Bissell studied the Coalville exposures and proposed time-age units from the Great Plains nomenclature. (1949). For convenience of discussion, the lithologic units of this area as proposed by Wegemann (1915, p. 163) will be used when reference is made to stratigraphic location in the Coalville area, and are shown below.

Table I

Stratigraphic Section at Coalville, Utah

	Feet
1. Top. Conglomerate of Wasatch formation; as exposed in Echo Canyon, over 1,000 feet thick but probably reaching much greater thicknesses in other localities; color, various shades of red; contains boulders 1 foot or less in diameter. Unconformable on all older formations	1,000
2. Soft beds, prevailingly sandy, usually concealed in grassy slopes; fossil leaves and fresh-water shells and thin beds of conglomerate occur at intervals	2,500
3. Beds prevailingly sandy but not well exposed; contain marine shells.	1,650
4. Sandstone, white, coarse, forming the prominent ridge west of the town of Coalville and also north of Dry Hollow	200
5. Shale and thin beds of sandstone; at the base a coal bed, usually in two benches, formerly mined in Dry Hollow and at the Carleton mine.	90
6. Shale	880

	Feet
7. Conglomerate, brown; pebbles principally of limestone and sandstone, the largest 6 inches in diameter	40-100
8. Shale (lacking in some sections, the conglomerate resting directly on the underlying sandstone)	180
9. Sandstone, forming the pronounced cliff just northeast of the town of Coalville, probably equivalent to the Oyster Ridge sandstone member of the Frontier formation of southwestern Wyoming	100-200
10. Shale, pink at base	750
11. Sandstone, in places conglomeratic	30-130
12. Coal bed, locally known as the "Wasatch" bed, mined at Coalville	5-12
13. Sandstone, in some sections very shaly	40-80
14. Shale and sandstone alternating, white and gray, with numerous beds of pink shale, especially toward the base.	750
15. Coal beds, thin, three or four exposed in Spring Canyon, associated with carbonaceous shale .	30
16. Shale, terra cotta in color, with three thin beds of white or gray sandstone	850
	9,250±

1. Kelvin (?) and Aspen Formations. The name Kelvin is applied provisionally to 2,185 feet of coarse terrigenous detritus, dominantly conglomerates, grits, sandstones, and minor components of argillaceous red beds. The Kelvin (?) formation is considered to be early Cretaceous in age because of its stratigraphic position above the Upper Jurassic Morrison formation and beneath the Lower Cretaceous Aspen shale. The formation has its maximum exposure in the area near Rockport, 4 miles south of Wanship. The Kelvin (?) also outcrops in Dry and Crandall Canyons and in the eroded core of the Coalville anticline.

Overlying the Kelvin (?) formation, is the Aspen shale. An early Cretaceous age has recently been established for the formation by Cobban and Reeside (1951) on the basis of ammonites, correlative to genera and species in the Upper Albian of Europe. The Aspen varies in thickness in relatively short distances, but is known to thicken northeastward. For the Weber River Valley, the formation averages from 40 to 60 feet in thickness. The formation consists primarily of blocky, brownish-gray to black bentonitic shale, thin beds of olive to greenish-brown bentonite and grades upward into tan, medium grained, thin bedded sandstone of the Frontier. The Aspen contains abundant cycloid and ctenoid fish scales that are considered diagnostic of the formation. In some localities, the scales are present in the base of the Frontier. The upper boundary of the Aspen is controversial. It is placed either at the lithologic gradation from shale to sandstone, or at the uppermost presence of the fish scales. The lower boundary is a sharp lithologic break with the underlying Kelvin (?) formation. The aspen may be seen to outcrop near Rockport and on the south flank of the Coalville anticline. The Aspen may be missing on the north flank of the anticline.

2. Frontier Formation. The Aspen shale passes gradationally into the overlying Frontier formation which has a maximum exposed thickness of 7554 feet east of Wanship. The thickness of the Frontier on the north flank of the Coalville anticline was computed by the writer to be 4993 feet. This figure was derived from surface measurements and from provisional interpretations by A. J. Fardley of the drilling log and Hassler's (1941) report on the drill core of the J. N. Wilde well (SE 1/4 Sec. 9, T.2.N., R.5.E.).

Lithologically, the Frontier consists of massive, ridge-forming sandstone, separated by soft, gray to dark-colored shale and friable sandstone and siltstone. Thin seams of sub-bituminous coal are occasionally found in the formation east of Wanship. In contrast, the coal in the Coalville

area is more abundant and occurs primarily in the Wasatch coal bed (Unit 12) and in the Spring Hollow beds (Unit 15). These have been described in detail by Wegemann (1915).

The precise age of the Frontier formation in Utah has long been a subject of controversy. The formation was named by W. C. Knight in 1902, and described by A. C. Veatch (1907) near Kemmerer, Wyoming and the fauna was described as being of Colorado age. In his discussion of the strata exposed near Coalville, T. W. Stanton (1893, p. 40) states that the invertebrate fossils collected from strata ranging from a horizon 100 feet below a thick coal bed (Unit 12) to the beds of coarse conglomerate (Unit 7) contain a single fauna of Colorado age. Wegemann suggests that Stanton later came to believe that the 1170 feet (Units 5 and 6) overlying the conglomerate should also be classed as Colorado. Evidence against a Colorado age for the beds above the conglomerate is supported by work completed by F. H. Knowlton (1900, p. 8) on fossil leaves collected from Unit 5; they are believed to be of Montana age. The Colorado-Montana boundary was placed at the base of the conglomerate (Unit 7) by J. M. Boutwell (1937). Beds beneath the conglomerate were indicated as equivalent to the Frontier, and the strata between Unit 7 and the base of the Wasatch (Unit 1) as equivalent to the Hilliard, Adaville, and Evanston formations. Great Plains nomenclature was employed by H. J. Bissell, who suggests the following stratigraphic separation: Units 10 to 16, 2500 feet, pre-Carlile and equivalent to the Aspen and Frontier formations; Units 6 to 9, 1300 feet, Carlile age, equivalent to lower Hilliard; lower part of Unit 3, and Units 4 and 5, 800 feet, Niobrara age, equivalent to middle Hilliard; most of Unit 3, 1000 feet, middle Montana age, equivalent to upper Hilliard; Unit 2, 2500 feet, Fruitland age, and equivalent to the Adaville formation. (1949).

Recent micropaleontological studies in the Coalville and southwestern Wyoming area support Knowlton's conclusions. An evaluation of the Frontier microfauna of the Coalville area indicates

that the Colorado-Montana boundary should be drawn considerably lower in the section than previously supposed, somewhere near the middle of Unit 10. On the basis of Foraminifera and Ostracoda, it is believed that the Colorado-Montana boundary lies in the lower half of the Hilliard. In light of this information, it would appear that the Frontier, as exposed at Coalville, includes a greater time interval than does the type section in Wyoming.

3. Pre-"Wanship" Unconformity. The upper boundary of the Frontier is placed at the base of the conspicuous conglomerate which is unconformable on all underlying sediments in the region studied. The unconformity may be seen along the ridge dividing Cherry and Dry Canyons immediately east of Wanship. Here, the thick basal conglomerate of the "Wanship" formation rests with angular unconformity upon the more steeply dipping beds of the Frontier formation. As the contact is traced southeastward, the relative strikes of the "Wanship" and Frontier formations become increasingly discordant. Finally, the "Wanship" rests unconformably on the Kelvin (?) formation.

From a structural standpoint, the unconformity is in part, related to the Dry Canyon anticline which began to fold in the pre-"Wanship"-post-Frontier interval. The anticline is believed to have been strongly overturned to the south, and deeply eroded, after which deposition of the "Wanship" occurred (N. C. Williams - personal communication - 1952).

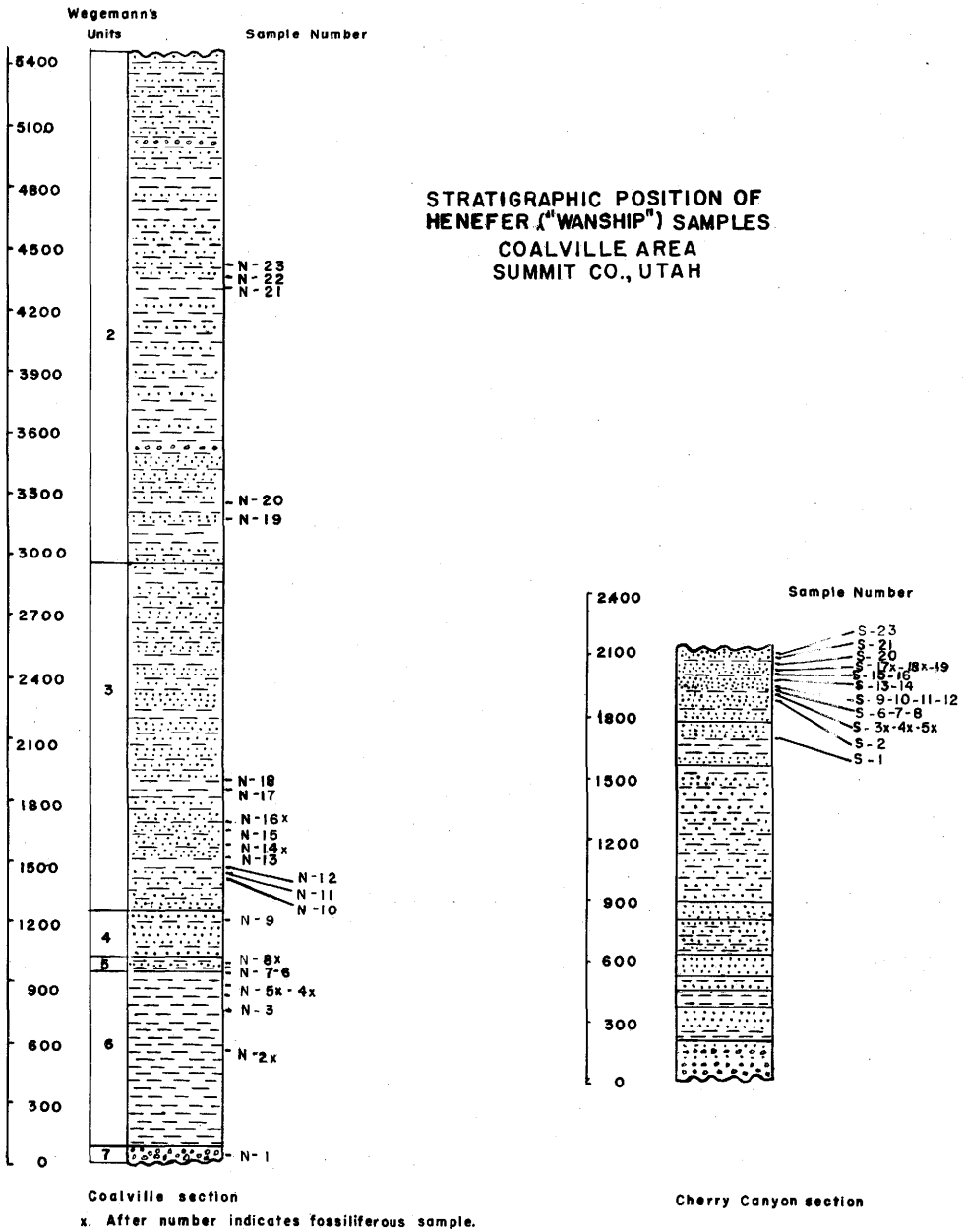
On the north flank of the Coalville anticline, an erosional unconformity has been noted. It occurs in the linear depression of the twin-edged cuesta (Units 7 and 9) which forms the topographic divide between Allen Hollow and Dry Hollow, northeast from the town of Coalville. It may be traced northeastward across Grass Creek and into the slopes forming the Grass Valley-Echo Canyon divide. In general, the two formations have the same strike. The presence or absence of 180 feet of shale (Unit 8) between the basal conglomerate (Unit 7) and a Frontier sandstone ridge (Unit 9) indicates an erosional interval.

The erosional interval, so far as can be determined, does not have a wide distribution, but is restricted to areas of sharp uplift. In the downwarped zones, marginal to eroded structures, nearly continuous sedimentation occurred. The primary evidence indicating crustal unrest is the persistent conglomerate.

4. "Wanship" Formation. The term "Wanship" formation, has been used informally by members of the University of Utah Uinta Field Camp for beds which prior to the summer of 1951, had been referred to as the "Post-Frontier" formation. (Larson, 1951). The present writers use the term primarily as a matter of convenience and do not suggest that it be adopted in the formal nomenclature. "Wanship" was first used in reference to 2117 feet of strata outcropping in Cherry Canyon, east of Wanship, Utah. The rock sequence, as has previously been stated, is bounded by unconformities and is underlain by the Cretaceous Frontier formation, and overlain by the Eocene Wasatch group.

The "Wanship" formation is composed of medium-bedded to massive, ridge-forming sandstone beds separated by soft, friable sandstone and siltstone and soft light-gray to dark-gray shale beds. Intercalated with the shale and friable sandstone are thin, lenticular seams of coal. The basal 170 feet of the formation consists of three thick beds of coarse conglomerate separated by two horizons of medium- to coarse-grained, brown sandstone. Qualitative analyses indicate that a great majority of the lithic units are composed of quartz and impure clays of the montmorillonite group. Minor fractions of limonite, calcite, feldspar, mica and carbon occur as impurities.

In the vicinity of Coalville, Units 2 through 7 are referred to as "Wanship" in age, but it includes a greater time interval than in the area of original reference. Lithologically, the "Wanship" formation in Coalville is similar to the underlying Frontier. Massive sandstone beds outcrop as cuestas and are separated by large thicknesses of friable sandstone,



x. After number indicates fossiliferous sample.

FIGURE 3

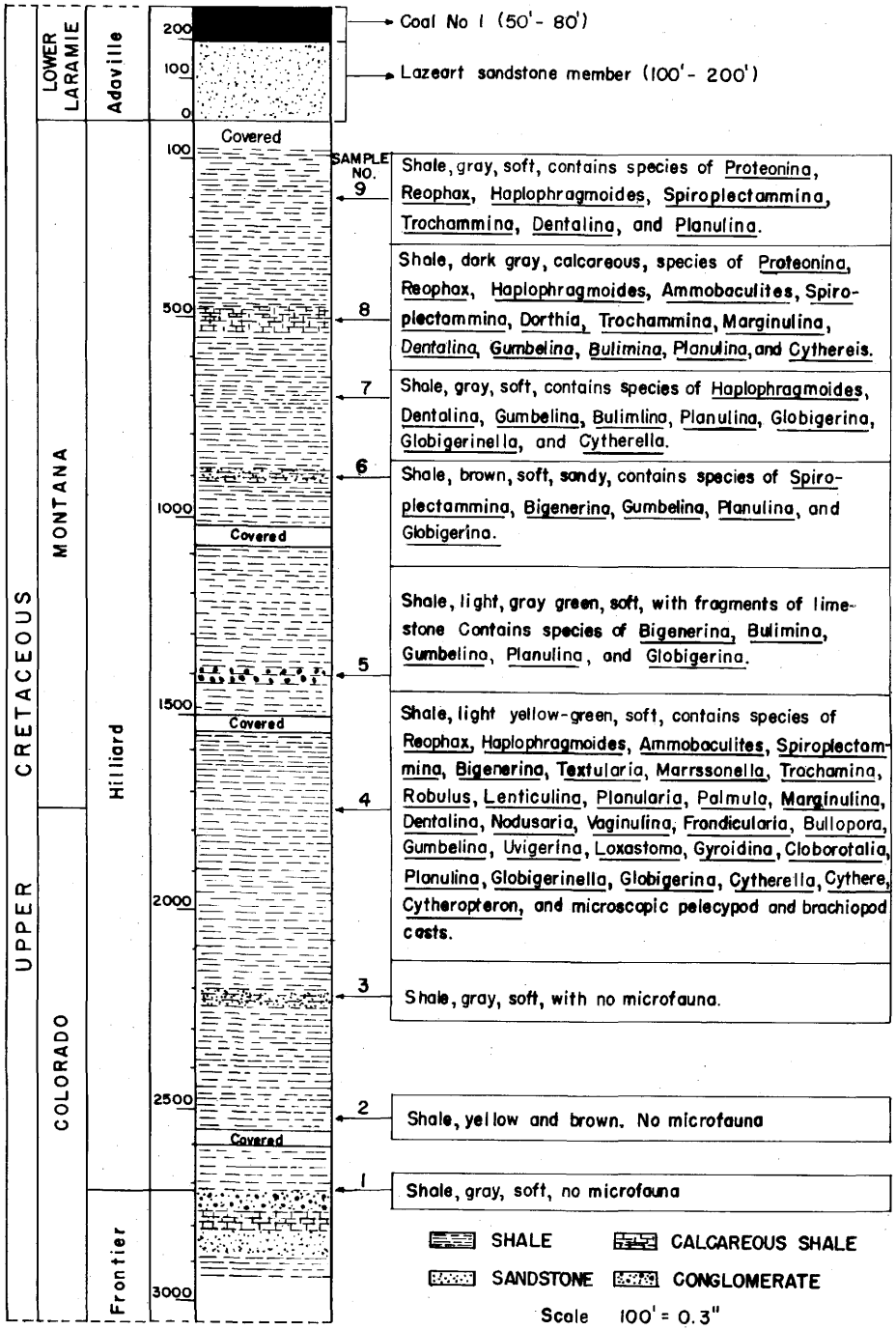
blocky, light-brown to dark-gray and black shales. In contrast to the thinner section in Cherry Canyon, the upper 900 feet of the "Wanship" formation in Coalville (Unit 2) contains abundant lenticular beds of pebble conglomerates which range in thickness from 1 to 22 inches. The conglomerates are separated by beds of nearly pure quartzose sandstone and minor amounts of tan to brown, silty shale. A thick sequence of coarse brown conglomerate beds, 100 feet thick separated by a coarse to fine-grained, limonitic sandstone horizon occurs at the base of the formation. Coal in this area is apparently restricted to one stratigraphic position, the Dry Hollow beds at the base of Unit 5. Highly carbonaceous beds of thin, lenticular black shale occur throughout the lower half of the section, but cannot be classified as coal. (Fig. 3)

B. THE CRETACEOUS SECTION NEAR EVANSTON, WYOMING

The Evanston Cretaceous section is at least 15,700 feet thick and possibly more than 24,000 feet thick. Opinions vary somewhat as to the precise age of the exposed rocks. A. C. Veatch has summarized the opinions prior to 1907 concerning the age of these beds and discusses the Cretaceous problem at length.

W. C. Knight proposed the name "Hilliard" for the group of dark-colored shales overlying the coal-bearing Frontier formation and underlying the coal-bearing Adaville formation. The Hilliard beds at the type locality were mentioned by J. W. Powell in 1876 as the Sulphur Creek group. He states: "this group of black shales can be well seen in the hills near Hilliard station on the Union Pacific Railroad." It has been considered advisable to use the name Hilliard formation rather than Sulphur Creek group.

The upper and lower limits of the Cretaceous section are not well-defined in the region, as is the case throughout most of the Rocky Mountain area. Veatch states that, "fossils indicate that it (the



DETAILED SECTION OF THE HILLIARD FORMATION NEAR EVANSTON, WYOMING
FIGURE 4

Cretaceous) contains the time equivalents of the Benton, Niobrara, Montana, and Laramie groups of the eastern section, but the natural lithologic subdivisions do not correspond with these faunal subdivisions and do not agree with those east of the Rocky Mountains."

Stanton, in a study of the invertebrate fauna of the "Colorado formation," assigned the beds below the Hilliard to the Colorado. They had earlier been referred to the Fox Hills by most geologists. Veatch's work substantiates Stanton's views on assigning the Frontier to the Colorado group. The occurrence of specimens of Inoceramus exogyroides 3,000 feet above the top of the Frontier in another locality, establishes the Frontier as Benton in age. The Colorado-Montana boundary lies within the Hilliard and will be discussed later.

At Veatch's type section, the Hilliard formation consists of 5,500 to 6,800 feet of gray to black sandy shales and shaly sandstones which weather readily, with low relief, producing broad valleys which afford few good exposures. Thick lenses of white sandstone occur 3,000 to 3,800 feet above the base of the formation. These sandstones contain numerous specimens of large Inoceramus exogyroides, a species characteristic of the basal Niobrara or upper Benton (Colorado) in the Cretaceous east of the Rocky Mountains (See fig. 3).

Underlying the Hilliard is the Frontier formation, which consists of 2,200 to 2,600 feet of alternating beds of yellow and gray sandstone and yellow, gray, and black carbonaceous clays with numerous coal beds. The Frontier forms prominent parallel ridges or hogbacks. It contains distinctive Benton fossils. A prominent upper member, called the "Oyster Ridge" (Hayden, 1872) consists of resistant, ridge-forming beds of coarse sandstone, occasionally conglomeratic, containing numerous large oysters.

Overlying the Hilliard at its type locality is the Adaville formation, which consists of about

4,000 feet of yellow, gray, and black carbonaceous clays with irregularly bedded brown and yellow sandstones and numerous coal beds. South of Hodges Pass tunnel on the Union Pacific Railroad (just west of Kemmerer) there occurs at the base of this formation, immediately overlying the Hilliard, a prominent white sandstone, 100 to 200 feet thick. This is the Lazeart member of the Adaville formation. Its base marks the top of the Hilliard formation, and may be separated from it by an erosional unconformity. Immediately above this sandstone is the Adaville-Lazeart coal (Coal #1) 20 to 84 feet thick, and associated with it are beds containing plants and invertebrate remains older than Laramie. The overlying strata contain leaves of lower Laramie age.

Paleontologically, the Hilliard formation is upper Colorado and middle Montana in age, the lower 950 (?) feet is Benton, the middle 350 (?) feet is Niobrara (?) stratigraphic position), and the upper 2,862 feet is definitely Montana in age. Reeside (1951) has placed the Colorado-Montana boundary in Montana, Utah, Colorado, and New Mexico at the horizon of the first appearance of the cephalopod Desmoscaphites bassleri Reeside. He has found this species in beds of Eagle and Telegraph Creek age and considers it a good time zone fossil of the Montana Group. This cephalopod has not been found to the writers' knowledge in the Hilliard formation.

P A R T II

EVIDENCE FROM THE MICROFOSSILS

Daniel J. Jones

A. ECOLOGICAL SIGNIFICANCE OF THE MICROFOSSILS

Although the present investigations do not allow a detailed ecological interpretation of the faunal assemblages in each of the three formations studied, certain ecological inferences may be drawn on the basis of the faunal characteristics of each formation as observed. The interpretations presented below are of course applicable only to the fossiliferous horizons from which the faunas were obtained.

1. Frontier Microfauna: The Foraminifera found in this formation suggest a neritic to upper bathyal marine environment. The climate may have been temperate to warm-temperate during deposition.

   The occurrences of the pelagic genus Globigerina suggest open sea conditions. This genus is recorded from a wide range of temperatures and depths, but they are most common in waters from 500 fathoms to 3000 fathoms, and they become sparse in regions of cold water.

   Living Frondicularia are found in warm to subtropical climates, ranging in depth from 80 to 600 fathoms.

   Most species of Dentalina are common in waters deeper than 60 fathoms, but rarely occur in water exceeding 3000 fathoms in depth.

   Marginulina also has a rather wide range, but most species are common within a depth range of 50 to 500 fathoms at temperatures between 41° to 70° F.

   Species of the genus Valvulineria are recorded from shallow water down to depths exceeding 1000 fathoms, but are usually found in water shallower than 800 fathoms. The genus is abundant within a temperature range of 38° to 65° E. The comparative scarcity of

Valvulineria in this assemblage reduces the value of the ecological implications of the genus, since such inferences should be based on those occurring in great numbers.

The great number and variety of species in the lower part of the microfossiliferous zone, and the gradual decrease in abundance and variety of forms may be indicative of a gradual cooling of the marine waters. The absence of Globigerina in the upper samples may possibly indicate a closing of the open seaways and restriction of the open circulation of pelagic forms.

2. Hilliard microfauna: The most striking feature of the microfaunal assemblage obtained from the Hilliard formation is the high percentage of arenaceous forms. 60% of the fauna is composed of calcareous- shelled genera of Foraminifera, but the remaining 40% are arenaceous genera. The ratio in the Frontier is more normal for marine assemblages,- 80% to 90% calcareous forms and 10% to 20% arenaceous genera.

Arenaceous assemblages as a rule indicate cool to cold water environments. The water in which the Frontier arenaceous genera lived was probably cool rather than cold.

The calcareous forms of the Hilliard assemblage include the dominant Lagenidae, with a good representation of Rotaliidae and Globigerinidae. No generic representatives of the Miliolidae were found. The Lagenidae, including Nodosaria, Robulus, Lenticulina, Palmula, and Frondicularia are characteristic of the Continental shelf, and between 50 and 500 fathoms are very abundant. The absence of the Miliolids suggests that the waters were not warm and shallow.

As has been suggested previously, the pelagic forms of the Globigerinidae suggest open circulation rather than any significant depth range, and in the Hilliard samples, the upward decrease of species of this group suggest another restriction of open circulation and possible closing of seaways as was noted in the Frontier section.

Thus the faunal assemblage and the uniformly fine-textured sediments of the Hilliard fossiliferous zones suggest rather uniform offshore marine conditions of shallow to intermediate depths in temperate to sub-tropical environments.

3. Wanship Microfossils: The microfauna and microflora suggest that during Wanship time, the deposition was a mixture of marine, brackish, and continental types. As has been mentioned previously, macrofossils found in the section can be referred to nearshore marine and brackish-water forms; the remainder to open marine and fresh-water species.

Ostracoda of the Cytherellid and Cytherid groups are marine and brackish-water types; the Cyprid ostracoda are believed to have lived primarily in fresh water. Charaphyceae are usually considered as restricted to fresh and brackish water; however, they may in some instances have been transported into mixed marine and non-marine environments. The marine and brackish-water ostracoda found in the Wanship samples near Coalville are thick-shelled burrowing forms of the family Cytheridae, adapted to sandy bottoms and somewhat turbulent water. The genus Cytherella is considered generally as a deep-water form. Metacypris, represented in one Coalville sample, is usually found in fresh water. Ecological distribution of the ostracoda of the Wanship shows the following species groupings: marine species 2; marine and brackish species 8; brackish-water species 2; non-marine fresh-water species 11. Three fresh-water species of Charaphyceae are present.

One of the most outstanding characteristics of the Wanship microfauna is the scarcity of foraminifera. Only four species were found, two of which also occur in the Frontier, (Dentalina frontierensis and D. coalvillensis). Wanship specimens of these two forms show some evidence of having been transported and reworked; they are large, thick-shelled speci-

mens and are always fragmentary with rounded edges. The occurrence of these species 2100 feet higher in the Cretaceous section than their first appearance in the Frontier suggests strongly that the disconformity between the Frontier and Wanship may represent a longer period of time than is indicated by field evidence.

The other two species, (Parrella expansa and Quinqueloculina sp.?) were found in association with fresh-water ostracoda, and may also be reworked.

Thus it appears that no diagnostic evidence concerning the ecology of Wanship deposition is furnished from the Foraminifera.

CORRELATION CHART OF UPPER CRETACEOUS AND LOWER TERTIARY FORMATIONS

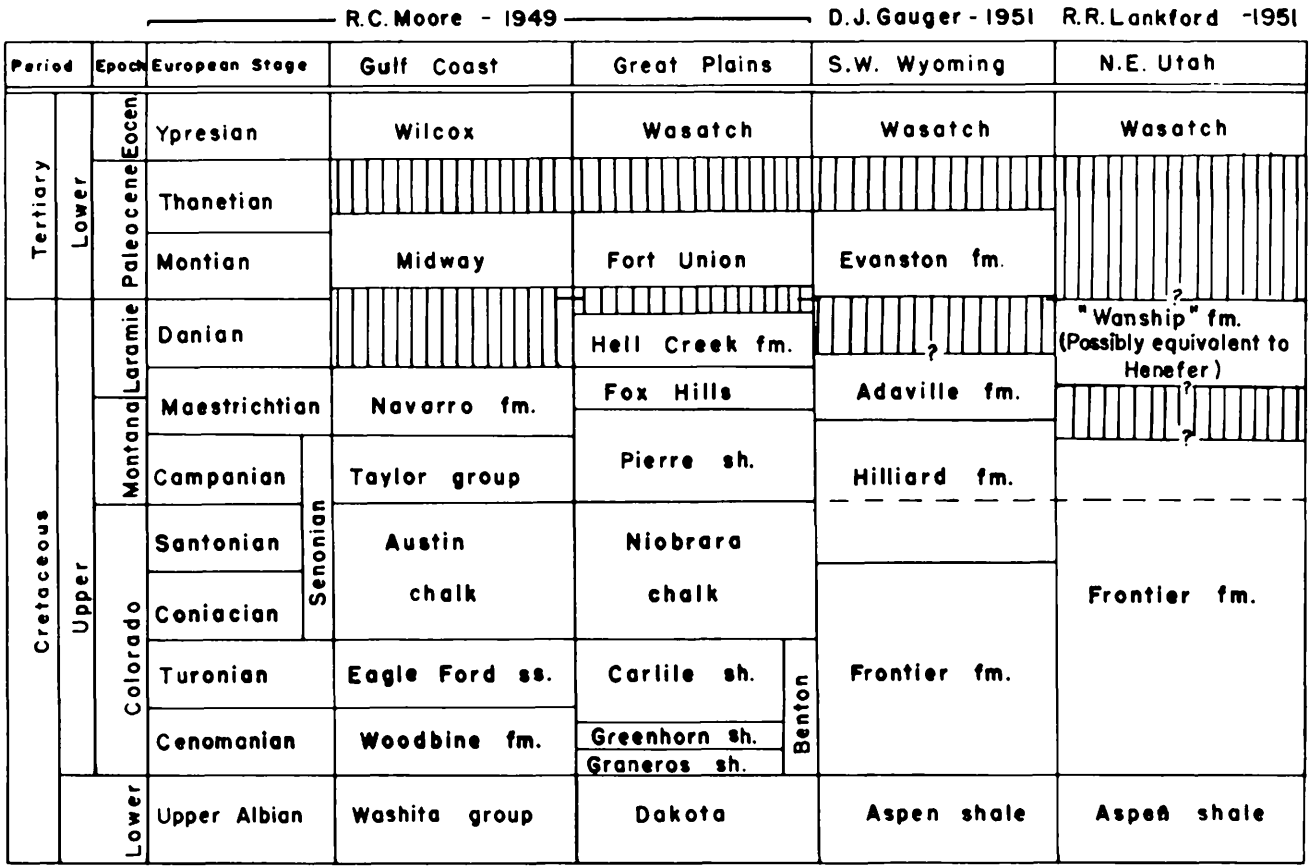


FIGURE 5

B. AGE AND CORRELATION OF UPPER CRETACEOUS STRATA IN THE AREA

The establishment of age relationships and valid correlations of Upper Cretaceous strata in the Rocky Mountains is, in some local areas quite difficult, due primarily to the rapid interfingering of marine and non-marine facies. The area of southwestern Wyoming and northeastern Utah is one of these areas of difficulty in precise dating and correlation. It is felt, however, that the microfossil studies reported herein furnish some additional evidence for strengthening correlations based on megascopic marine fossils, fossil plants, and vertebrate remains.

In suggesting the age relationships shown in figure 4, based on the microfaunal and microfloral evidence, it must be borne in mind that these studies are, in a sense, preliminary, and that much more work must be done to further validate the present results, particularly in the field of non-marine microfossils.

Specifically, the following conclusions are drawn concerning the correlation and ages of the three formations studied:

1. Microfaunal evidence of the age of the Frontier in the Coalville Area, Utah. Table 2 shows there is little or no basis for direct correlation of the portion studied of the Frontier formation with Upper Cretaceous formations of the non-coastal states if microfossils alone are considered.

(a) Correlation of the Hilliard microfauna with those of Gulf Coast (Upper Cretaceous) formations shows somewhat closer faunal affinities. See Fig. 5. Both the Foraminifera and Ostracod faunas have Gulf Coast affinities. The resemblance is even more remarkable when the great distance separating two areas is considered. The Upper

Cretaceous Foraminifera and Ostracoda thus far described from Kansas, Nebraska, Minnesota, Wyoming, North Dakota, etc., and from Canada are quite different from those described in this report. Most of the species described from those areas have been reported from Gulf Coast formations and a great percent of those described in this paper also have been found in Texas and other Gulf Coast states. Differing ecologic conditions may be responsible for the variations and the best explanations for these differences in conditions rest in a knowledge of depths, temperatures and currents of the Upper Cretaceous seaway at the times the organisms lived.

(b) The foraminifera described by present writers from the Frontier and Hilliard formations corroborate the evidence obtained by Fox and Ross (1943), and by Cobban and Reeside (1951) concerning the faunal similarities between the Upper Cretaceous and Paleocene, the central Rocky Mountain region and the Gulf Coast region. In general, the foraminiferal faunas herein described contain a larger number of Gulf Coast Upper Cretaceous species than species previously described from the Upper Cretaceous in the Northern Great Plains, etc. (Applin, 1933) (Wickenden 1932.)

Of the 39 species of Foraminifera reported from the Pierre, Niobrara and Carlile formations by Applin (1933), only Globigerina cretacea and Epistomina caracolla are present in this section of the Frontier formation. Globigerina cretacea was reported from all three of the formations but Epistomina caracolla was found only in the Pierre shale.

Arthur W. Nauss (1947), reported 20 species of Foraminifera from the Lloydminster shale of Alberta, Canada but of these only Globigerina cretacea has been found at Coalville.

Samples collected from formations of the Colorado group by A. L. Morrow (1934), yielded 37 species of Foraminifera and seven species of

Ostracods, most of which were restricted to the middle Greenhorn and basal Niobrara. Of all these species only one, Globigerina cretacea, has been found in the Frontier formation. Globigerina cretacea was reported from the Graneros, Greenhorn, Carlile, and Niobrara formations.

Of the eight species described from the Alberta shale by Wickenden, none were found to be present in this part of the Frontier formation.

As previously mentioned, both the Foraminifera and Ostracod faunas are mixed. For this reason, direct correlation with established units in the Gulf Coast region is difficult. There are two species, Marginulina austinana and Eucythere brownstownensis, which have never been recorded from beds younger than Austin age; and there are four species, Haplophragmoides excavata, Dentalina basiplanata, Epistomina caracolla, and Cythereis thomasi, which have never been recorded from strata older than Taylor age. One species, Frondicularia inversa, although occurring in formations of both Austin age and Taylor age, is considered to be characteristic of Austin formations (see Table II). The fauna, in general, is most indicative of beds of Taylor age, but the fact that common species indicating upper Austin age are present cannot be overlooked.

If this fauna is considered to be a transitional fauna, it might be concluded that the shale bed is an age equivalent of upper Austin formations and lower Taylor formations. There is not enough evidence, as yet, for making as refined a correlation as is desired. More collecting at other localities may show that this shale bed is approximately equivalent to the Ozan formation, for example, or even the Gober Tongue of the Austin chalk. For the present, however, the writer believes it best to state that available microfossil evidence indicates an upper Austin and/or lower Taylor age for this portion of the Frontier formation.

2. Microfaunal evidence of the age and correlation of the Hilliard in the Evanston area, Wyoming.

The microfauna of the Hilliard gives some new evidence bearing on the position of the Colorado-Montana boundary in the Upper Cretaceous of the Evanston area.

Stanton (1893), after visiting the Coalville area, placed the Colorado-Montana boundary at the base of the conglomerate (Wegemann's Unit 7). Wegemann (1915) suggested that it be put somewhere in the strata above his Unit 4, but he did not properly evaluate the fossil plant evidence. Veatch (1907) suggested that Stanton had drawn the Colorado-Montana line too low in the section. Bissel (1949) followed Wegemann and stated that the lower part of Unit 3, and Units 4 and 5 are of Niobrara age, placing the Colorado-Montana line somewhere in Unit 3, which has a thickness of over 1,500 feet.

Taylor (Montana) Foraminifera and Ostracoda are present in Unit 10, over 280-380 feet below the conglomerate and 1,490-1,650 feet below Unit 3. If the evidence supplied by the microfossils be considered alone, the Colorado-Montana line must be placed lower in the section than ever suspected before.

3. Microfossil evidence of the age and correlation of the Wanship formation in the Coalville area.

The microfauna and microflora of the Wanship present somewhat confusing and contradictory evidence concerning the geologic age of the beds, since both marine and non-marine assemblages have been found. The importance of this formation in any regional correlation picture lies in the fact that the formation occurs in the vicinity of the Cretaceous-Paleocene boundary.

It is not the purpose of the present paper to reexamine in detail the recently accumulated mass of paleontological evidence from many sources on

the age of the Wanship formation. A systematic review of all fossil evidence bearing on the Wanship correlation problem and the Cretaceous Paleocene boundary will be the subject of a future report.

The marine and non-marine microfossils which have been obtained from the Wanship are shown in Table IV, as well as the known geologic range of each species. It is apparent from this Table that there is a mixture of typical Upper Cretaceous forms and some non-marine forms which have been reported elsewhere from Paleocene and younger horizons. Of 14 previously known species of microfossils found in the Wanship, 6 are restricted to beds of Upper Cretaceous age; 6 range from Paleocene through Eocene; one from Oligocene through middle Pliocene; and one species has been previously reported only from the Pleistocene.

It must be borne in mind that the Wanship microfossils were found below a zone of large Inoceramus, and below an occurrence of a dinosaur ungual bone. This evidence suggests an Upper Cretaceous age for the Wanship, together with the 6 species of microfossils which have been previously observed as confined to Upper Cretaceous beds. On the other hand, the 8 recognizable and previously reported species of Wanship microfossils which occur elsewhere in beds ranging from Paleocene to Pleistocene must not be ignored in considering the age of the Wanship. Future work may resolve this apparent discrepancy in the age relationships of the Wanship formation and its correlation with other Upper Cretaceous strata.

To settle this problem, a great deal of work must be done on the plant fossils, molluscan fossils and microfossils. The plants were studied many years ago and no recent work on the invertebrate fossils has been done. This brief study of the microfossils has yielded far from enough evidence to present a satisfactory solution to the problem. More microfossil collections in all the strata where they are present will play a great part in solving the stratigraphical problems of the Coalville and Evanston Cretaceous sections.

PART III

SYSTEMATIC DESCRIPTIONS OF MICROFOSSILS

A. MICROFAUNA OF THE FRONTIER

Reed H. Peterson

Phylum PROTOZOA
Class Sarcodina Butschli, 1882
Order FORAMINIFERA D'Orbigny, 1826
Family REOPHACIDAE
Subfamily ASCHEMONELLINAE
Genus REOPHAX Montfort, 1808
Reophax sp.
Plate I, figures 1, 2

Test free, elongate, composed of about five undivided chambers in a nearly linear series; wall with a chitinous base and an outer wall of agglutinated material, firmly cemented, sand grains and rarely with a few mica flakes; aperture simple, terminal, with a very distinct neck; chambers distinct and slightly longer than broad. Length of complete specimen 1.1 mm.; width of apertural chamber 0.3 mm.; length of apertural chamber, including apertural neck, 0.48 mm.

This form of Reophax differs from R. inordinatus Young which Young (1951) described from the Frontier of southern Montana, in the number of chambers and the absence of the neck-like spine characterizing R. inordinatus.

This species is common in sample 43 and quite rare in samples 44 and 45. Complete specimens are rare and the large apertural chamber is the portion most commonly found.

Univ. Utah Micropaleo. Coll. No. 300.

Family LITUOLIDAE
Subfamily HAPLOPHRAGMININAE
Genus HAPLOPHRAGMOIDES Cushman, 1910
Haplophragmoides excavata Cushman and Waters
Plate I, figures 3, 4

Haplophragmoides excavata Cushman and Waters, Contr. Cushman Lab. Foram. Research, vol. 2, pt. 4, p. 82, pl. 10, figs. 3a,b, 1927.
Cushman, Royal Soc. Canada Trans., 3rd ser., vol. 21, sec. 4, p. 128, pl. 1, fig. 1, 1927.
Cushman and Jarvis, U. S. Nat. Mus. Proc., vol. 80, art. 41, p. 12, pl. 3, fig. 1, 1932.
Cushman and Hedberg, Contr. Cushman Lab. Foram. Research, vol. 17, p. 82, pl. 21, figs. 1a, b. 1941.
Cushman, Upper Cret. foraminifera of the Gulf Coastal region of the U. S. and adjacent areas, U. S. Geol. Sur. Prof. Paper 206, p. 21, pl. 2, figs. 13-15, 1946.

Haplophragmoides sp. Cushman and Jarvis, Contr. Cushman Lab. Foram. Research, vol. 4, p. 91, pl.12, fig. 16, 1928.

Specimens found are poorly preserved. Only rarely is it possible to observe the nature of the chambers and sutures. The sutures appear to be straight and radial; the wall is finely arenaceous, with a relatively smooth finish. The average diameter of the specimens found is considerably less than that given by Cushman in his descriptions of the species.

This species has a very wide distribution, occurring in Trinidad, Colombia, the Gulf Coastal region of the United States, and western Canada. It has been reported from the Kemp clay, Corsicana marl, Arkadelphia marl, Nacatoch sand, and Neylandville marl of Navarro age and from the Wolfe City sand member of the Taylor marl, the middle part of the Selma chalk, and from the lower part of the Taylor marl. Occurrences from Trinidad, Colombia and Canada are from beds designated as upper Cretaceous in age.

This species was found in samples 43, 44, and 45. Univ. of Utah Micropaleo. Coll. No. 301.

Haplophragmoides kirki Wickenden
Plate I, figures 5a,b

Haplophragmoides kirki Wickenden, Royal Soc. Canada Trans., 3rd ser., sec. 4, p. 85, pl. 1, figs. 1a-c, 1932.
Cushman, Upper Cretaceous Foraminifera of the Gulf Coastal region of the U. S. and adjacent areas, U. S. Geol. Survey Prof. Paper 206, p. 21, 22, pl. 2, fig. 23, 1946.

This species has been found in the Bearpaw shale, Alberta, the Riding Mountain beds, Manitoba, and in well samples from the Lea Park and Pakowki formations in Alberta and Saskatchewan. The Lea Park formation is lower Montana in age and the Bearpaw shale is upper Montana in age. The known range of this species is confined to the Montana group in Canada.

Haplophragmoides kirki has not been reported from the Cretaceous of the Gulf Coastal states of the United States.

Only two broken specimens were found and they were both in sample 43. Univ. of Utah Micropaleo. Coll. No. 302.

Haplophragmoides (?) sp.
Plate I, figures 6a,b

Only one incomplete specimen was found. Seven chambers are visible in the outer whorl; test not completely involute; chambers simple; wall arenaceous, firmly cemented. The aperture was not present. Diameter 0.60 mm.; thickness 0.12 mm.

The single specimen found is from sample 43. Univ. Utah Micropaleo Coll. No. 303.

Family LAGENIDAE
Subfamily NODOSARIINAE
Genus MARGINULINA D'Orbigny, 1826

Uniserial lagenid forms with early chambers coiled have been variously assigned to Marginulina and Marginulopsis. Cushman, in the latest printing of his "Foraminifera" (1950) says, "The relationships of Marginulopsis and Vaginulopsis erected by Silvestri in 1904 still seem to be doubtful. They are possibly synonymous with Marginulina, although some species placed in these genera may belong in Vaginulina." In the present report, therefore, species of this type are retained in Marginulina, although Young (1951) places similar forms from the Frontier of Montana in Marginulopsis.

Marginulina austinana Cushman
Plate I, figures 7,8

Marginulina austinana Cushman, Contr. Cushman Lab. Research, vol. 13, p. 92, pl. 13, figs. 1-4, 1937.
Cushman, Upper Cret. Foraminifera of the Gulf Coastal region of the U. S. and adjacent areas, U. S. Geol. Sur. Prof. Paper 206, p. 59, pl. 20, figs. 5-10, 1946.

Specimens found at Coalville are identical with those described by Cushman from beds of Austin age in Texas. This species has been reported from the Gober tongue of the Austin chalk, the Austin chalk, and the Brownstown marl of Texas.

Marginulina austinana was found only in sample 44 of the Coalville area. One complete specimen was found along with several fragments. Univ. Utah Micropaleo. Coll. No. 304.

Marginulina austinana Cushman var. directa
Cushman, Plate I, figures 9-15

Marginulina austinana Cushman var. directa Cushman, Cushman Lab. Foram. Research Contr., vol. 13, p. 93, pl. 13, figs. 5-8, 1937.

Cushman, Upper Cret. Foraminifera of the Gulf Coastal Region of the U. S. and adjacent areas, U. S. Geol. Sur. Prof. Paper 206, p. 59, pl. 20, figs. 11-16, 1946.

Most specimens found at Coalville are identical with specimens figured and described by Cushman.

This variety has been recorded from the Austin chalk and the lower and middle parts of the Taylor marl in Texas. It has been found in the Wolfe City sand member of the Taylor marl and the lower part of the Taylor marl, and in the Gober Tongue of the Austin chalk, the Austin chalk, and Bonham marl of Texas.

This is the most common species found in the Coalville samples. Nearly every sample contains at least a few fragments and, in most instances, well-preserved and complete specimens were found. Univ. of Utah Micropaleo. Coll. No. 305.

Marginulina austinana Cushman var. wasatchensis Peterson, n. var., Plate I, figures 16-18

Test elongate, compressed, early portion closely coiled and umbonate, later portion uncoiled, ventral side slightly lobulate, dorsal side gently curved; chambers of the early coiled portion may be indistinct, later uncoiled chambers distinct; sutures distinct except rarely in the uncoiled portion, slightly curved, somewhat limbate, and with a decided boss-like thickening toward the dorsal side of the middle; wall smooth except for the sutural enlargements; periphery angled, often slightly nodose; aperture radiate, at outer peripheral angle. Length of complete specimen 0.9 mm.; width 0.3 mm.

This variety differs from Marginulina austinana Cushman in the less compressed test, dorsal side straight or slightly concave, fewer chambers in the coiled portion, and later chambers more inflated. It differs from Marginulina austinana Cushman var.

directa Cushman only in the continuation of the boss-like thickenings of the sutures to the dorsal side to produce the angled periphery. Variety directa and variety wasatchensis seem to grade into each other. The point of distinction is the angled periphery.

Well preserved specimens were found in samples 28, 43 and 44. The species is common only in sample 44, however. Univ. of Utah, Micropaleo. Coll. No.306.

Genus DENTALINA D'Orbigny, 1826
Dentalina sp.?
Plate I, figure 19

Test elongate, slender, slightly curved; chambers distinct, all inflated, slightly overlapping, increasing in size as added, as long as broad; sutures distinct, depressed; wall smooth. Length of incomplete specimen 1.10 mm.; diameter of largest chamber 0.20 mm.

Only one specimen of Dentalina sp? was found. This may or may not be a species new to science. As far as the writer can determine, no species similar to this has been reported from the upper Cretaceous of the United States.

The single specimen found is from sample 43. Univ. of Utah Micropaleo Coll. No. 307.

Dentalina gracilis D'Orbigny
Plate I, figures 20,21

Dentalina gracilis D'Orbigny, Soc., geol. France Mem., 1st ser., vol. 4, p. 14, pl. 1, fig. 5, 1840.
Franke, Preuss, geol. Landesanstalt Abh., new ser., vol. III, p. 29, pl. 2, fig. 22, 1928.
Cushman, Contr. Cushman Lab. Foram. Research, vol. 16, p. 77, pl. 13, figs. 9-11, 1940.
Cushman and Deaderick, idem, vol. 18, p. 57, pl. 11, fig. 4, 1942.

Cushman and Todd, idem, vol. 19, p. 57, pl. 10, fig. 6, 1943.
Cushman, idem, vol. 20, p. 6, pl. 1, fig. 28, 1944; idem, vol. 20, p. 86, pl. 13, fig. 12, 1944.
Cushman, Upper Cretaceous Foraminifera of the Gulf Coastal region of the U. S. and adjacent areas, U. S. Geol. Sur. Prof. Paper 206, pp. 65, 66, pl. 23, figs. 3-6, 1946.

This species seems to be quite variable, but some specimens found at Coalville comply well with the published figures and descriptions of the species. Dentalina gracilis has a relatively long range in the American Cretaceous. The species has been reported from beds of Navarro, Taylor and Austin age, and it is widely distributed in upper Cretaceous strata of Texas, Arkansas, Mississippi, and Alabama.

Specimens referable to this species were found only in samples 42 and 43. Broken fragments from other samples might be of this species but identification from the fragments is very uncertain. Univ. of Utah Micropaleo. Coll. No. 308.

Dentalina basiplanata Cushman
Plate I, figures 22,23

Dentalina annulata Cushman (not Reuss), Tennessee Div. Geology Bull. 41, p. 28, pl. 3, fig. 3, 1931.
Dentalina reussi Plummer (not Neugeboren), Texas University Bull. 3101, p. 151, pl. 11, fig. 5, 1931.
Sandidge, Jour. Paleontology, vol. 6, p. 274, pl. 42, fig. 10, 1932.
Dentalina basiplanata Cushman, Contr. Cushman Lab. Research, vol. 14, p. 38, pl. 6, figs. 6-8, 1938; idem, vol. 16, p. 82, pl.14, figs. 1-6, 1940.
Cushman and Hedberg, idem, vol. 17, p. 88, pl. 21, fig. 23, 1941.
Cushman and Todd, idem, vol. 19, p. 56, pl. 10, fig. 7, 1943.

Cushman and Deaderick, Jour. Paleontology, vol. 18, p. 333, pl. 51, figs. 17,18, 1944.
Cushman, Upper Cretaceous Foraminifera of the Gulf Coastal region of the U. S. and adjacent areas, U. S. Geol. Survey, Prof. Paper 206, p. 68, pl. 24, figs. 1-6, 1946.

This species ranges through beds of Taylor and Navarro age in the Gulf Coastal region of the United States. Cushman (1946) states that the species is very abundant in beds of upper Navarro age and occurs less commonly in the lower beds of Navarro age. Specimens from beds of Taylor age are rare. Dentalina basiplanata has not been reported from beds of Austin age, but the species has been recorded from the lower part of the Taylor marl in Texas.

Some quite complete specimens from samples 43 and 44 belong to this species. This species occurs only frequently in these samples, however. Univ. of Utah Micropaleo. Coll. No. 309.

Dentalina cf. D. angusticostata Cushman
Plate I, figure 24

Specimens found at Coalville are very fragmentary, consisting of only one or two chambers. These specimens compare well with Dentalina angusticostata Cushman. The chambers are distinct, somewhat inflated and fusiform, longer than broad and only slightly overlapping; sutures distinct, depressed and somewhat limbate; wall ornamented with many longitudinal costae that are continuous across the sutures. The figured specimen has approximately 16 costae; one chamber is 0.50 mm. long and 0.30 mm. broad.

Dentalina angusticostata Cushman has been recorded from the Corsicana marl of Texas. The specimens found at Coalville are from samples 43 and 44 where the species is very rare. Univ. of Utah Micropaleo. Coll. No. 310.

Dentalina frontierensis Peterson, n. sp.
Plate I, figures 25, 26

Test elongate, slender, gently curved, initial end with a distinct spine, tapering with greatest width near apertural end; initial chambers quite distinct but not inflated, later chambers greatly inflated, usually as long as broad but may be longer or shorter than broad; sutures distinct, flush with surface on initial portion, depressed in later portion; surface ornamented by distinct longitudinal costae, 8-10 in number, continuous from one chamber to the next, present on all chambers except final chamber, dying out on next to last chamber; aperture terminal, radiate. Length of complete specimen 1.64 mm.; width of largest chamber 0. 2

This species occurs frequently in samples 43 and 44. Fragments from other samples, however, resemble this species. Holotype: Univ. of Utah, Micropaleo. Coll. No. 311.

Dentalina solvata Cushman
Plate I, figure 27.

Specimens are fragmentary in nature and very rare. Only a few fragments were found in all the samples checked. The figured specimen does not have the chambers connected by stolonlike portions and the chambers are not smooth as is characteristic for the mature portions of Dentalina solvata Cushman. The costae are more prominent over the sutures and the chambers appear to resemble those of the younger portions of the species. No specimen shows the characteristics of the initial or apertural ends. The walls of the specimen found are ornamented by 8-10 longitudinal costae and the diameter of the largest chamber is 0.20 mm.

Dentalina solvata Cushman has been reported from beds of Navarro and Taylor age and from the Gober Tongue of the Austin chalk.

Specimens were found only in samples 44 where the species is very rare. Univ. of Utah Micropaleo. Coll. No. 312.

Dentalina coalvillensis Peterson, n. sp.
Plate II, figures 1, 2.

Test elongate, slightly tapering, slightly curved, initial end usually with a distinct spine; early chambers indistinct, not inflated, strongly overlapping, later chambers distinct, inflated, slightly longer than broad; sutures on later portion distinct, depressed, slightly oblique; wall smooth; aperture terminal, radiate. Length of complete specimen 1.25 mm.; diameter of largest chamber 0.18 mm.

This species is rare when found and occurs only in sample 44. Holotype: Univ. of Utah Micropaleo. Coll. No. 313.

Dentalina utahensis Peterson, n. sp.
Plate II, figures 3, 4

Test elongate, slightly tapering, slightly curved, initial end often with distinct spine; early chambers indistinct, strongly overlapping, later chambers distinct, slightly overlapping, about as long as broad; sutures on initial portion indistinct, flush with surface, sutures on later portion distinct, depressed; surface smooth except for a light roughening in the early portions of some specimens, no distinct costae. In many specimens there seems to be a slight decrease in the size of the chambers in the portion immediately following the initial part of the test. This decrease in size is followed by an increase in size to make the broadest portions of the test near the apertural end and at a distance of about one-third the length of the test from the initial end. Length of average-sized specimen more than 4.50 mm.; diameter of chamber 0.50 mm.

This is one of the most common species found in the samples studied. Nearly every sample contained at least a few broken specimens. Holotype: Univ. of Utah Micropaleo. Coll. No. 314.

Dentalina summitensis Peterson, n. sp.
Plate II, figures 5, 6.

Test elongate, slender, gently curved, initial end with distinct spine, tapering with greatest width near apertural end; initial chambers indistinct, later chambers distinct, slightly overlapping, as long as broad; sutures on initial portion indistinct, flush with surface, sutures on later portion distinct, depressed, slightly oblique; surface ornamented by numerous longitudinal costae, continuous from chamber to chamber, usually 16-18 in number, costae somewhat oblique; aperture terminal, radiate. Length up to 3.50 mm.; diameter 0.45 mm.

Dentalina summitensis is very common in many of the samples. Only samples 20, 21, 25, 27, 40, and 44 failed to yield identifiable specimens. Holotype: Univ. of Utah Micropaleo. Coll. No. 315.

Genus FRONDICULARIA Defrance, 1826
Frondicularia inversa Reuss
Plate II, figures 7-9

Frondicularia inversa Reuss, Geogostische Skizzen Bohmen, vol. 2, pt. 1, p. 211, 1844; Verstein Bohm, Kreide-formation, pt. 1, p. 31, pl. 8, figs. 15-19, pl. 13, fig. 42, 1845; Paleontolographica, vol. 20, pt. 2, 1872-75, p. 94, pl. 2 (21), figs. 5-7, 11, (1874).
Perner, Foram. Ceskeho Cenomau (Resume), p. 59, pl. 7, fig. 9, 1892.
Franke, Greifswald Univ., Geol.-palaeont. Inst., Abh., vol. 6, p. 48, pl. 4, fig. 1, 1925.
Cushman, Contr. Cushman Lab. Foram. Research, vol. 12, p. 16, pl. 3, figs. 23, 24, 1936.
Cushman, Upper Cretaceous Foraminifera of the Gulf Coastal region of the U. S. and adjacent areas, U. S. Geol. Sur. Prof. Paper 206, p. 86, pl. 33, figs. 11-18, 1946.

Cushman (1946) reports that the recorded range of this species is from the lower Cretaceous to the top of the upper Cretaceous. He states that in the United States, however, the species is characteristic and should be referred to other species.

Frondicularia inversa was found in samples 42, 43, 44, and 45 where its occurrence is quite frequent. Univ. of Utah Micropaleo. Coll. No.316.

Family POLYMORPHINIDAE
Subfamily RAMULININAE
Genus RAMULINA Rupert Jones, 1875
Ramulina arkadelphiana Cushman
Plate II, figures 10, 11

Ramulina arkadelphiana Cushman, Contr. Cushman Lab. Foram. Research, vol. 14, p. 43, pl. 7, figs. 12-14, 1938.
Cushman, Upper Cretaceous Foraminifera of the Gulf Coastal region of the U. S. and adjacent areas, U. S. Geol. Survey Prof. Paper 206, p. 99, pl. 43, figs. 3-8, 1946.

The specimens from the Frontier formation seem to have all the characteristics of Ramulina arkadelphiana Cushman. They are not similar to any other species reported from the Cretaceous of the United States. Cushman (1946) states that this species occurs very abundantly in the Arkadelphia marl, the Prairie Bluff chalk, and the Kemp clay.

The finding of Ramulina arkadelphiana Cushman at Coalville extends the known range of this species.

Specimens referrable to this species were found only in samples 43 and 44 where they are quite rare. Univ. of Utah Micropaleo. Coll. No. 316.

Family ROTALIIDAE
Subfamily DISCORBINAE
Genus VALVULINERIA Cushman, 1926
Valvulineria infrequens Morrow
Plate II, figures 12a-c

Valvulineria infrequens Morrow, Jour. Paleon. vol. 8, p. 197, pl. 30, figs. 3 a-c, 1934.
Cushman and Deaderick, Contr. Cushman Lab. Foram. Research, vol. 18, p. 64, pl.15, figs. 17-19, 1942.
Cushman, idem, vol. 20, p. 95, pl. 14, fig. 22, 1944.
Cushman, Upper Cretaceous Foraminifera of the Gulf Coastal region of the U. S. and adjacent areas, U. S. Geol. Sur. Prof. Paper 206, p. 138, pl. 57, fig. 5, 1946.

This species was first described by Morrow from the basal Niobrara chalk, Ellis County, Kansas. Since then it has been found in beds of Austin and lower Taylor age in the Gulf Coastal region of the United States.

Only one nearly complete specimen was found in sample 43.

Genus GYROIDINA D'Orbigny, 1826
Gyroidina (?) sp.
Plate II, figures 13 a, b

The one specimen found at Coalville which might be referred to this genus is too poorly preserved to permit accurate identification. It seems to have characteristics of Gyroidina sp., but better preserved specimens may show that it belongs to another genus.

Sample 43 yielded the only specimen found.

Subfamily SIPHONININAE
Genus Epistomina Terquem, 1883
Epistomina caracolla (Roemer)
Plate II, figures 14a, b

Gyroidina caracolla Roemer, Verstein. norddeutschen Kreidegebirges, p. 97, pl. 15, fig. 22, 1840-41.
Rotalia caracolla Reuss, Sitz. Ber. Akad. Wiss. Wien., vol. 46, p. 84, pl. 10, fig. 6, 1862.
Discorbis ripleyensis W. Berry (in Berry and Kelly), U. S. Nat. Mus. Proc., vol. 76, art. 19, p. 11, pl. 3, figs. 16-18, 1929.
Epistomina caracolla (Roemer) Franke, Greifswald Univ., Geol.- paleont. Inst., Abh., vol. 6, p. 88, pl. 8, figs. 10a-c, 1925.
Cushman and Church, California Acad. Sci. Proc., 4th ser., vol. 18, p. 517, pl. 40, figs. 10(?), 11-13, 1926.
Cushman, Tennessee Div. Geology Bull. 41, p. 55, pl. 10, figs. 1a-c, 1931.
Loetterle, Nebraska Geol. Survey Bull, 2nd ser., Bull. 12, p. 62, pl. 11, figs. 2a-c, 1937.
Cushman and Todd, idem, vol. 19, p. 69, pl. 12, fig. 5, 1943.
Cushman, Upper Cretaceous Foraminifera of the Gulf Coastal region of the U. S. and adjacent areas, U. S. Geol. Sur. Prof. Paper 206, pp. 142-143, pl. 59, figs. 1, 2, 1946.
Dam, A. Ten, Foraminifera from the middle Neocomian of the Netherlands, Jour. Paleontology, vol. 22, no.2, pp. 187, 188, pl. 32, figs. 17, 20, 21, 1948.

Most of the specimens found at Coalville are poorly preserved. They are worn and do not have all the characteristics of a well-preserved specimen. Epistomina caracolla is very distinctive therefore, even poorly preserved specimens can be identified with little doubt.

This species is widely distributed in the Upper Cretaceous of Europe and America. It has been recorded from California, the Gulf Coastal

Plain, South Dakota (Pierre shale), and Nebraska (Pierre shale) in the United States, and from the Colon shale of Colombia.

Cushman (1946) records the species from formations of Navarro age and Taylor age. It is found in beds of lower Taylor age but there is no report of this species in beds of Austin age in the Gulf Coastal region.

A. W. Nauss (1947) described a species of Epistomina (Epistomina fax Nauss) which differs from Epistomina caracolla by being flatter on the dorsal side, having a less pronounced keel, and lacking an umbo. No specimens could be found which agree well with this description. It is probable that, if better preserved specimens could be found, Epistomina fax Nauss could be recorded from this locality. Epistomina fax is restricted to the lower 200 to 300 feet of the Lea Park shale of the Canadian plains.

A. Ten Dam records Epistomina caracolla from the middle Neocomian of England and Germany and from the middle Neocomian at Glanerbrug, Netherlands. He states that occurrences of the species in beds other than the lower Cretaceous are based on misidentifications.

Cobban and Reeside (1952) list E. caracolla from three zones in the late Greenhorn and early Carlile portion of the Frontier in the Cumberland Gap section, southwest Wyoming.

Only samples 29 and 42 failed to yield specimens of this species. There is a noticeable abundance of the species in the samples higher up in the section with a marked decrease downward. In some of the higher samples this was often almost the only species present. Univ. of Utah Micropaleo. Coll. No. 317.

Family GLOBIGERINIDAE
Subfamily GLOBIGERININAE
Genus GLOBIGERINA D'Orbigny, 1826
Globigerina cretacea D'Orbigny
Plate II, figures 15a,b

Globigerina cretacea D'Orbigny, Mem. Soc. Geol. France, Ser. 1, vol. 4, p. 34, pl. III, figs. 12, 13, 14, 1840. (This species has been recorded in so many papers dealing with Upper Cretaceous foraminifera in the United States that its synonymy is too extensive for reproduction.)

Globigerina cretacea D'Orbigny ranges through the Upper Cretaceous and has been reported from younger formations as well. It is widely distributed in North America and elsewhere.

K. W. Carman described four varieties of Globigerina cretacea. The specimens found at Coalville are most like her Variety 2, which was found in both the Benton and Niobrara formations of Wyoming.

Cobban and Reeside (1952) report the occurrence of G. cretacea from two shale horizons in the late Greenhorn-Early Carlile portion of the Frontier section at Cumberland Gap, Wyoming.

In spite of the fact that Globigerina cretacea is the most abundant and widespread of Upper Cretaceous foraminifera, the species was found only in five samples and was common only in samples 43 and 44. Univ. of Utah Micropaleo. Coll. No. 318.

Phylum ARTHROPODA
Class CRUSTACEA
Order OSTRACODA Latrielle
Family CYTHERELLIDAE
Genus CYTHERELLA Jones, 1849
Cytherella parallela (Reuss)
Plate III, figures 1a,b,c

Cytherina parallela Reuss, Verstein, Bohm. Kreidef., pt. 1, p. 16, pl. 5, fig. 33, 1845.
Cythere truncata Bosquet, Mem. Soc. Roy. Sci. Liege, vol. 4, p. 357, pl. 1, figs. 2a-3, 1847.
Cytherella truncata Jones, Monogr. Entom. Cret. Eng., Paleontogr. Soc. London, p. 30, pl. 7, figs. 25a-e, 1849.
Cytherella parallela (Reuss), Denkschr. K. Akad. Wiss. Wein., vol. 7, p. 40, 1854.
Alexander, Univ. Texas Bull. 2907, p. 50, pl. 1, figs. 13, 16, 1929.
Loetterle, G. J., The micropaleontology of the Niobrara formation in Kansas, Nebraska, and South Dakota, Nebraska Geol. Sur., Bull. 12, Second Ser., pp. 49-50, pl. VIII, figs. 3a,b, 1937.

Specimens found at Coalville are rare. This species is reported by Alexander from the Taylor marl and upper Austin chalk of Texas. It is common in the Taylor marl above and below but not in the Wolfe City sand member, and occurs rarely in the upper part of the Austin chalk. Loetterle reported the species from the Fort Hays limestone member of the Niobrara formation where, with one exception, it is quite rare.

At Coalville, Cytherella parallela was found in samples 43 and 45 where it is quite rare. One specimen found in sample 46 might be referred to this species but, because of its broken condition, identification is doubtful. Univ. of Utah Micropaleo. Coll. No. 319.

Cytherella bullata Alexander
Plate III, figures 2a,b,c

Cytherella obesa Alexander (not C. obesa Jones, Kirkby and Brady, 1884), Univ. Texas Bull. 2907, p. 51, pl. 1, figs. 3, 6, 1929.
Cytherella austinensis Alexander, Univ. Texas. Bull. 2907, p. 51, pl. 2, figs. 4, 6, 1929.
Cytherella bullata Alexander, Jour. Paleontology, p. 101, 1932; Am. Mid. Nat., vol. 13, p. 305, pl. 28, figs. 3, 4, 1932.
Loetterle, G. J., The micropaleontology of the Niobrara formation in Kansas, Nebraska, and South Dakota, Nebraska Geol. Sur., Bull. 12, Second Ser., pp. 50, 51, pl. VIII, figs. 4a,b, 1937.

This species was described by Alexander in strata from the upper Austin chalk to the Pecan gap member of the Taylor marl. It is said to be common in the Austin chalk and rare in the Taylor marl and completely absent from the Wolfe City sand member of the Taylor marl. In the Niobrara formation its range is confined to the Fort Hays limestone member, where it is rare at most localities.

This species is quite common in samples 43, 44, and 45 from Coalville. One specimen in sample 46 might be referred to this species but the broken character of the specimen prevented accurate identification. Univ. of Utah Micropaleo. Coll.No.320.

Family CYPRIDAE
Genus PARACYPRIS G. O. Sars, 1865
Paracypris cf. P. tenuicula Alexander
Plate III, figures 3a,b,c

Paracypris tenuicula Alexander, Univ. Texas, Bull. 2907, p. 66, pl. 4, figs. 2, 8, 1929.
Loetterle, G. J., The micropaleontology of the Niobrara formation in Kansas, Nebraska, and South Dakota, Nebraska Geol. Sur., Bull. 12, Second Series, pp. 49-50, pl. VIII, figs. 7a, b, pp. 52, 53, 1937.

Carapace in side view elongate, attenuate, highest anterior to the middle; anterior end narrow, posterior end produced, acute; dorsal margin strongly arched, ventral margin concave; left valve overlapping the right around entire margin; carapace in dorsal view, elongate, lanceolate, widest at the middle, anterior and posterior ends acute; surface smooth. Length of specimen 0.8 mm.; height 0.35 mm.; width 0.25 mm.

Specimens found at Coalville differ from those described by Alexander and Loetterle in having a less accuminate posterior end when viewed from the side, and the dorsal margin is not regularly arched. The outline has a depression in the anterior one-third.

Loetterle reports Paracypris tenuicula from the Fort Hays limestone and Alexander found the species only in the upper part of the Austin chalk where it is said to be rare.

Paracypris cf. P. tenuicula was found only in sample 44, where it is extremely rare. Only a few poorly preserved specimens were found. Univ. of Utah Micropaleo. Coll. No. 321.

Family CYTHERIDAE
Genus EUCYTHERE Brady, 1866

Eucythere brownstownensis Alexander
Plate III, figures 4a,b,c

Eucythere brownstownensis Alexander, Journ. Pal., vol. 10, no. 8, p. 690, pl. 93, fig. 4, December, 1936.
Shimer and Shrock, Index Fossils of North America, p. 689, pl. 291, fig. 14, 1947.

This species has been reported from the Brownstown clays of upper Austin age in Texas. Coalville specimens which are referrable to this species are found only in sample 43 where they are quite rare. Univ. of Utah Micropaleo. Coll. No. 322.

Genus CYTHEREIS Jones, 1849
Cythereis thomasi (Israelsky) Alexander
Plate III, figures 5, 6, 7, 8, 9

Cytheropteron ponderosana Israelsky, Ark. Geol. Survey, Bull. 2, p. 9, pl. 2A, figs. 1a-c, 1929.
Cythereis thomasi (Israelsky) Alexander, Jour. Paleontology, vol. 7, no. 2, pp. 211, 212, pl. 27, fig. 17, June, 1933.

Israelsky recorded this species from the Ozan formation, Annona chalk, and Marlbrook marl of Arkansas. Alexander says that it appears only in the Annona chalk of northwestern Texas.

Specimens found at Coalville are well preserved and are quite common in samples 43, 44, and 45. Univ. of Utah Micropaleo. Coll. No. 323.

Genus ORTHONOTACYTHERE Alexander, 1933

Orthonotacythere sp.
Plate III, figures 10a,b

Carapace broadly ovate, highest near anterior end; dorsal margin long, straight; ventral margin convex, anterior end broadly and obliquely rounded, no teeth apparent, a low ridge near anterior margin parallel to the margin; ventral margin swings sharply upward near posterior end to the short, blunt, compressed, caudal process, projecting ventrally from the central, posterior margin. A shallow, obscure, vertical sulcus divides the carapace into two nearly equal lobes; the posterior lobe appears to be slightly larger than the anterior; surface rough, bearing six distinct, rounded tubercles. Two tubercles near the dorsal margin are the most prominent (one of these is broken in the specimen illustrated), one is near the dorsal-posterior margin of the carapace and the other, which seems to be the most prominent of all the tubercles, is near the central-dorsal margin; near the ventral-posterior edge of the "large" tubercle is a very small tubercle; near the dorsal anterior margin is another small tubercle; the other tubercles are short, blunt, and rounded and occur in a posterior-anterior line, near the center of the carapace. Length 0.65 mm.; height 0.41 mm.; width 0.47 mm.

This species is very rare in the Coalville samples. One almost complete specimen was found in sample 45. Other small fragments which appear to belong to this species were found. Univ. of Utah Micropaleo. Coll. No. 324.

B. MICROFAUNA OF THE HILLIARD

David J. Gauger

Phylum PROTOZOA
Class SARCODINA Batschli 1882
Order FORAMINIFERA D'Orbigny 1826
Family REOPHACIDAE
Sub-family ASCHEMONELLINAE
Genus REOPHAX Montfort 1808

Reophax constrictus (Reuss) Cushman,
Plate 4, figs. 5 and 5a

Haplostiche constricta Reuss, in Geinitz, Palaeontographica, vol. 20, pt. 2, 1872-75, p. 121, pl. 24, figs. 9-12, 1874.

Perner, K. Bohm. Gesell. Wiss. Prag sitzungsber., p. 38, 1893.

Matouschek, Lotos, vol. 43, p. 125, 1895.

Franke, Naturh. Ver. preuss. Rheinlande u. Westfalens Verh., 69 Jahrg., vol. 59, 1912, p. 260 (1913): Greifswald Univ., Geol. - palaeont. Inst., Abh., vol. 6, p. 8, pl. 1, fig. 7, 1925; Preuss. Geol. Landesanstalt Abh., new ser., vol. 111, p. 20, pl. 2, fig. 5, 1928.

Brotzen, Zeitschr. Deutschen Palastina-Vereins, Jahrg. 1934, p. 32, 1934.

Reophax constrictus (Reuss) Cushman, Contr. Cushman Lab. Foram. Research, vol. 20, p. 1, pl. 1, fig. 1, 1944.

Cushman, Upper Cretaceous Foraminifera of the Gulf Coastal region of the U. S. and adjacent areas, U. S. Geol. Survey Prof. Paper 206, p. 16, pl. 1, figs. 21-22, 1946.

Test composed of (a few) usually 2 or 3, subglobular chambers, increasing very little if at all in diameter; chambers distinct, the later ones becoming constricted so that the sutures are much depressed; wall coarsely arenaceous, roughly finished; apertural end when perfect terminating in a definite neck. Length 0.75 mm., breadth 0.25 mm.

This species occurred only in Sample 4 of the Hilliard formation. It occurs throughout the Taylor marl and into the lower Navarro formation. Univ. of Utah Micropaleo. Coll. No. 1.

Genus PROTEONINA Williamson, 1858
Proteonina difflugiformis, Plate 4, figs. 1-4

Proteonina difflugiformis (H. B. Brady) Rhumbler, Plate 4, figs. 1-4

Reophax difflugiformis H. B. Brady, Quart. Jour. Micr. Sci., new ser., vol. 19, p. 51, pl. 4, figs. 3a,b, 1879; Challenger Rept., Zoology, vol. 9, p. 289, pl. 30, figs. 2-4 (not 1, 5), 1884.

Proteonina difflugiformis Rhumbler, Archiv. Protistenkunde, book (vol.) 3, p. 245, text figs. 80a,b, 1903.

Cushman. U. S. Nat. Mus. Bull. 71, pt. 1, p. 42, text figs. 40, 41, 1910.

Cushman and Waters, Cushman Lab. Foram. Research Contr., vol. 2, pt. 4, p. 82, pl. 10, fig. 1, 1927.

Cushman, idem, vol. 5, p. 78, pl. 12, fig. 2, 1929; Tennessee Div. Geology Bull. 41, p. 17, pl. 1, figs. 1, 2, 1931.

Cushman, Upper Cretaceous Foraminifera of the Gulf Coastal Region of the United States and adjacent areas, U. S. Geol. Survey Prof. Paper 206, p. 15, pl. 1, figs. 7, 8, 1946.

Test a single elongate ovaloid or pyriform chamber with a more or less distinct tubular neck, usually tapering gradually from the body of the chamber, undivided; wall fairly thick, of sand grains of variable size, firmly cemented; aperture circular, simple, terminal. Height 0.50 mm., diameter 0.40 mm.

This species was found in Samples 8 and 9 of the Hilliard formation. It is characteristic of beds of Navarro age in the Gulf Coast. Univ. of Utah Micropaleo. Coll. No. 2.

Genus HAPLOPHRAGMOIDES Cushman, 1910
Haplophragmoides rugosa Gauger, n. sp.
Plate 4, fig. 6

Test large, tending to become evolute, slightly inflated, umbilicate; periphery broadly rounded; chambers triangular in outline, distinct, eight or nine in last whorl; sutures commonly indistinct, but marked by depressions between the slightly inflated chambers; wall arenaceous, neatly joined abundant grains 0.01 mm. in diameter embedded in a small amount of cement; aperture a low-arched slit at base of septal face of last-formed chamber. Greatest diameter 1.3 mm., least diameter 1.0 mm., thickness 0.4 to 0.5 mm. Samples 4 and 8. Holotype: Univ. of Utah Micropaleo. Coll. No. 3.

Haplophragmoides calcula Cushman and Waters
Plate 4, figs. 7, 8, 9, 13

Haplophragmoides calcula Cushman and Waters, Contr. Cushman Lab. Foram. Research, vol. 2, pt. 4, p. 83, pl. 10, figs. 5a,b, 1927.
Cushman, Royal Soc. Canada Trans., 3rd ser., vol. 21, sec. 4, p. 129, pl. 1, fig. 3, 1927.
Cushman, Upper Cretaceous Foraminifera of the Gulf Coastal Region of the United States and adjacent areas, U. S. Geol. Survey Prof. Paper 206, p. 19-20, pl. 2, figs. 11, 12, 1946.

Test closely coiled, planispiral, very strongly compressed, periphery sometimes slightly lobulate; chambers and sutures usually indistinct; wall very coarsely arenaceous, roughly finished on the exterior in spite of the considerable amount of cement; color usually greenish-black or gray with darker grains of sand on the surface. Length up to 1 mm., thickness 0.25 mm. This species was found in samples 4, 7, and 8 of the Hilliard formation. Univ. of Utah Micropaleo. Coll. No. 4.

Haplophragmoides excavata Cushman and Waters
Plate 4, fig. 10

Haplophragmoides excavata Cushman and Waters, Contr. Cushman Lab. Foram. Research, vol. 2, pt. 4, p. 82, pl. 10, figs. 3a,b, 1927.
Cushman, Royal Soc. Canada Trans., 3d ser., vol. 21, sec. 4, p. 128, pl. 1, fig. 1, 1927.
Cushman and Jarvis, U. S. Nat. Mus. Proc., vol. 80, art. 14, p. 12, pl. 3, fig. 1, 1932.
Cushman and Hedberg, Contr. Cushman Lab. Foram. Research, vol. 17, p. 82, pl. 21, figs. 1a,b, 1941.
Cushman, U. S. Geol. Survey Prof. Paper 206, p. 21, pl. 2, figs. 13-17, 1946.
Haplophragmoides sp. Cushman and Jarvis, Contr. Cushman Lab. Foram. Research, vol. 4, pl. 12, p. 91, fig. 16, 1928.

Test closely coiled planispiral, compressed, periphery subacute; chambers distinct, 10 in the last formed coil in the adult, the borders of each chamber distinctly thickened, central portion depressed; sutures straight, a relatively small amount of cement, smoothly finished; color usually light gray. Diameter usually about 1.0 mm., thickness 0.20 mm. to 0.40 mm. Very widely distributed species, being found in the Taylor, Navarro, in Trinidad, Columbia, Arkansas, Mississippi, and western Canada. Found in sample 8 and also in sample 9 of the Hilliard formation. Univ. of Utah Micropaleo. Coll.No.5

Haplophragmoides inflata Gauger n. sp.
Plate 4, figs. 11, a, 12

Test planispiral, umbilicate, not completely involute; periphery rounded but rather narrow; chambers distinct, inflated, 9 to 10 in the last-formed coil; sutures slightly curved, nearly radial, depressed; wall composed of a few rather fine, angular grains of arenaceous material and much cement, smooth; aperture a low arch a little to one side of the plane of coiling at the base of the apertural face of the last-formed chamber, which is usually

compressed; color gray; diameter about 0.3 mm., thickness 0.13 mm.

Found in Sample 8 of the Hilliard formation, This is a good index market, being a distinctive microfossil. Holotype: Univ. of Utah Micropaleo. Coll. No. 6.

Genus AMMOBACULITES Cushman, 1910

Ammobaculites coprolithiformis (Schwager) Cushman, Plate 5, figs. 1-8

Haplophragmium coprolithiformi Schwager, Benecke's Geogn. -paleont. Beitrage, vol. 1, p. 654, p. 34, fig. 3, 1868.

Ammobaculites coprolithiforme Cushman, Royal Soc. Canada Trans. 3rd ser., vol. 21, sec.4, p. 130, pl. 1, figs. 6, 7, 1927.

Cushman and Jarvis, U. S. Nat. Mus. Proc., vol. 80, art. 14, p. 13, pl. 3, figs. 4, 5, 1932.

Wickenden, Jour. Paleontology, vol. 6, pt. 2, p. 204, pl. 29, fig. 2, 1932.

Cushman, Cushman Lab. Foram. Research Special Pb. 5, pl. 5, fig. 10, 1933.

Cushman and Deaderick, Contr. Cushman Lab. Foram. Research vol. 18, p. 51, pl. 9, fig. 9, 1942; Jour. Paleontology, vol. 18, p. 328, pl. 50, fig. 2, 1944.

Ammobaculites coprolithiformis (Schwager) Cushman, U. S. Geol. Survey Prof. Paper 206, p. 22, pl. 3, figs. 7-9, 1946.

Test elongate, early portion closely coiled, later chambers rectilinear, of uniform width, generally circular in section; sutures distinct, depressed; wall arenaceous but smoothly finished; aperture circular, terminal; length 1.5 mm. breadth 0.6 mm. Univ. of Utah Micropaleo Coll. No. 7.

Ammobaculites stephensoni Cushman
Plate 5, figs. 9, 10

Ammobaculites stephensoni Cushman, Contr. Cushman Lab. Foram. Research, vol. 9, p. 49, pl. 5, figs. 2a, b, 1933; idem, vol. 20, p. 2, pl. 1, fig. 3, 1944.
Cushman and Deaderick, Jour. Paleontology, vol. 18, p. 329, pl. 50, fig. 3, 1944.
Cushman, U. S. Geol. Survey Prof. Paper 206, p. 24, pl. 3, fig. 17, 1946.

Test very much compressed, the earlier portion closely coiled and somewhat involute, later portion uncoiled, periphery rounded; chambers rather indistinct, comparatively few, 4 or 5 in a coil; sutures indistinct, nearly straight; wall rather coarsely arenaceous but with a large proportion of cement and with fairly smooth finish. Length 0.80 mm., breadth 0.50 mm., thickness 0.20 mm.

This species ranges from Eagle Ford through Austin and Taylor marl. It was recovered from Sample 4 of the Hilliard formation. Univ. of Utah Micropaleo. Coll. No. 8.

Ammobaculites fragmentarius Cushman
Plate 5, figs. 11-18

Ammobaculites fragmentaria Cushman, Royal Soc. Canada Trans., 3d ser., vol. 21, sec. 4, p. 130, pl. 1, fig. 8, 1927: Tennessee Div. Geology Bull. 41, p. 18, pl. 1, figs. 4a, b, 1931.
Cushman and Deaderick, Jour. Paleontology, vol. 18, p. 329, pl. 50, fig. 4, 1944.
Ammobaculites fragmentarius Cushman, U. S. Geol. Survey Prof. Paper 206, p. 23, pl. 3, figs. 10-16, 1946.

Test large, compressed, early portion planispiral, later and larger portion uniserial, rectilinear, with the sides tapering; chambers distinct, gradually increasing in size as added, greatest width of the

test made by the last-formed chamber; sutures distinct, depressed; wall of coarse sand, in flat flakes, rather neatly cemented; aperture elliptical, terminal. Length up to 1.50 mm. Austin, Taylor and lower Navarro. Found in Sample 4 of the Hilliard formation. Univ. of Utah Micropaleo. Coll.No.9.

Ammobaculites texanus Cushman
Plate 5, fig. 19

Ammobaculites texana Cushman, Contr. Cushman Lab. Foram. Research, vol. 9, p. 50, pl. 5, fig. 3, 1933.
Cushman, U. S. Geol. Survey Prof. Paper 206, p. 23, pl. 3, figs. 22-23, 1946.

Test large, compressed, periphery lobulate and rounded, the umbilical region somewhat excavated and the test becoming somewhat evolute in the adult; chambers fairly distinct, especially in the adult, usually 5 or 6 in the coil in the younger stages, slightly more in the adult before uncoiling takes place, slightly inflated, especially in the later development; sutures indistinct, very slightly depressed; wall very coarsely arenaceous, compressed, of rather large fragments with a considerable proportion of cement, somewhat roughly finished in the young stages, becoming smoother in the adult. Up to 2.0 mm. in diameter, thickness 0.60 mm. in the adult. Found in Sample 4 of the Hilliard formation. All localities in the Navarro. Univ. of Utah Micropaleo. Coll. No. 10.

Family TEXTULARIIDAE
Genus Spiroplectammina Cushman, 1927

Spiroplectammina navarroana Cushman
Plate 5, figs. 20-24

Spiroplectammina navarroana Cushman, Contr. Cushman Lab. Foram. Research, vol. 8, p. 96, pl. 11, figs. 14a, b, 1932.
Cushman and Deaderick, Jour. Paleontology, vol. 18, p. 329, pl. 50, fig. 5, 1944.
Cushman, U. S. Geol. Survey Prof. Paper 206, p. 27, pl. 5, fig. 13, 14, 1946.

Test elongate, very slightly if at all tapering in the adult portion; chambers nearly as high as broad, rounded at the periphery, somewhat inflated; sutures distinct, slightly depressed, nearly at right angles to the periphery; wall rather coarsely arenaceous, with large fragments but with fairly smooth finish; aperture somewhat oblique, consisting of a narrow arched opening at the inner margin of the apertural face. Length 0.75 mm., breadth 0.20 mm., thickness 0.10 mm. Taylor and Navarro. Samples No. 8 and 10 yielded these specimens. Univ. of Utah Micropaleo. Coll. No. 11.

Spiroplectammina lalickeri Albritton and Phleger
Plate 5, figs. 25-27

Spiroplectammina lalickeri Albritton and Phleger, Jour. Paleontology, vol. 11, p. 353, text figs. 2, 3, 1937.
Cushman, U. S. Geol. Survey Prof. Paper 206, p. 29, pl. 6, figs. 28-29, 1946.

Test small, slender, elongate, slightly bent with sides converging toward an evenly rounded initial end; periphery narrowly rounded, initially smooth, lobulate in later portion of the test; chambers numerous, first few in a planispiral coil, succeeding ones biserial, increasing gradually in height as added; sutures fairly distinct, limbate, slightly raised in initial half of test, thereafter

slightly depressed; sutures oblique, forming an angle of 20° to 45° with the horizontal; wall arenaceous, smoothly finished, with a considerable amount of cement; aperture a low subrectangular opening at the flattened base of the last-formed chamber; color gray. Length 0.50-0.60 mm., breadth 0.22-0.25 mm., thickness 0.08 mm. Definitely a Taylor age microfossil, with only one occurrence in beds of Austin age. Found in Sample 4 of the Hilliard. Univ. of Utah Micropaleo. Coll. No. 12a.

Spiroplectammina dentata (Alth) Cushman and Jarvis var. tenuisa Gauger n. var.
Plate 6, figs. 1, 1a, 2

Test much compressed, about 1 1/2 times as long as broad, periphery subacute, the ends of the chambers extended into short spinose processes; chambers distinct, low and broad, numerous, increasing very slightly in height but increasing rapidly in breadth as added; sutures distinct, limbate, wall finely arenaceous, with much cement, and smoothly finished. The specimen is much thinner than S. dentata, the chambers are extremely compressed, the sutures very limbate. Found in Sample 4 of the Hilliard formation, and is an Upper Cretaceous form found in Europe and in Trinidad. This is the first record of this species in the United States. Univ. of Utah Micropaleo. Coll. No. 12b.

Genus BIGENERINA D'Orbigny, 1826

Bigenerina elongata Gauger n. sp.
Plate 6, figs. 3a, 3, 4-6

Test elongate, strongly compressed, the early biserial portion tapering, later uniserial portion with the sides nearly straight, often slightly reduced in diameter toward the apertural end; chambers numerous, rather indistinct; sutures fairly distinct, very slightly if at all depressed; wall arenaceous, with a large proportion of light-gray cement with fine angular mineral fragments of about

the same color, surface rough in the upper part, but the biserial portion is usually quite smooth; aperture terminal, elliptical, sometimes slightly protruding. Length 1.00 mm., breadth 0.25 mm., thickness 0.10 to 0.20 mm. Found in Samples 4 and 6 of the Hilliard formation. This species differs from B. hastata Cushman in being more strongly compressed and in being composed of larger arenaceous fragments. Holotype: Univ. of Utah Micropaleo. Coll. No. 13.

Textularia washitaensis Carsey
Plate 6, figs. 7-11

Textularia washitensis Carsey, Univ. of Texas Bull. No. 2612, p. 24, pl. 7, fig. 6, March, 1926.

Test elongate, attenuate, moderately narrow, somewhat flattened, often curved, bent or slightly twisted; chambers quite numerous, biserially arranged, very gradually enlarging, full but not noticeably inflated; giving a rather straight appearance to the sides of the shell; sutures slightly depressed, usually not clear-cut but almost always discernible; apical end often truncate; apertural end rather broadly truncate; shell agglutinate, slightly rough. Length up to 1 mm. Univ. of Utah Micropaleo. Coll. No. 14.

The specimens were found in Sample 4 of the Hilliard formation, but they are not common. Cushman, (1946) lists but four species of the genus, none of which correspond to the specimens which are found at this locality.

Textularia inflata Gauger n. sp.
Plate 6, figs. 12, 13, 13a

This form is definitely a new species of Upper Cretaceous Textularia. A diligent search was made of the literature and this species was not previously described.

Test elongate, attenuate, narrow, inflated, often curved, bent, or slightly twisted; chambers quite numerous, biserially arranged, enlarging slowly, noticeably inflated; giving an undulating appearance to the sides of the shell; sutures clear-cut, deeply depressed; apical end bluntly pointed; apertural end rather broadly rounded; aperture a low opening in the median portion of the inner margin of the last-formed chamber with an elongate lobe at each side. Length up to 0.60 mm., breadth 0.3 mm., thickness 0.15 mm. Holotype: Univ. of Utah Micropaleo. Coll. No. 15.

This species was found in Sample 4 of the Hilliard samples, where it is quite rare.

Family VALVULINIDAE
Subfamily VALVULININAE
Genus MARRSONELLA

Marrsonella conica Gauger n. sp.
Plate 6, figs. 14, a, 15, 16

Test in front view generally triangular with a flaring apertural end and a blunt initial end; roughly conical, somewhat circular in transverse section, test tilted with respect to plane of final chamber; 2 or 3 chambers to whorl, adult whorl 1 or 2 chambers to whorl; trochoid throughout; chambers numerous, not too distinct; sutures for most part distinct, almost flush with the surface, in some specimens slightly depressed, meeting in a zig-zag pattern; wall arenaceous, much cement, smoothly finished except for last two whorls, which are rather coarsely arenaceous; aperture large, semi-circular or horseshoe-shaped opening at the base of inner margin of last-formed chamber, no tooth was noted. Length up to 1.6 mm., diameter 1.5 mm., height about equal to breadth.

These specimens were found in Sample 4 of the Hilliard formation and would make good index fossils for this horizon, but they are not abundant enough to be sure of recovery when drilling through the formation. Most specimens are in good condition with slight evidence of compression or distortion, but their rather coarsely arenaceous final chambers with their rim thickened by additions of coarse sand grains make apertural determinations difficult. Range is not known, but found in Sample 4. Holotype: Univ. of Utah Micropaleo. Coll. No.16.

Genus Dorothia Plummer, 1931

Dorothia bulletta (Carsey) Plummer
Plate 6, figs. 17-19

Gaydryina indentata Cushman and Jarvis, Contr. Cushman Lab. Foram. Research, vol. 4, p. 92, pl. 13, fig. 7, 1928.

Verneuilina conica White, Jour. Paleontology, vol. 2, p. 310, pl. 42, fig. 4, 1928.

Dorothia bulletta Plummer, Texas Univ. Bull. 3101, p. 132, pl. 8, figs. 13-17, 1931.

Sandidge, Jour. Paleontology, vol. 6, p. 271, pl. 41, figs. 9, 10, 1932.

Cushman, Cushman Lab. Foram. Research Special Pub. 4, pl. 12, figs. 8a, b, 1933, idem. Special Pub. 5, pl. 8, figs. 10a, b, 1933; Geol. Soc. America Bull., vol. 47, p. 416, pl. 11, figs. 2a, b, 1936; Cushman Lab. Foram. Research Pub. 8, p. 84, pl. 9, figs. 4-9, 1937.

Jennings, Bull. Am. Paleontology, vol. 23, No. 78, p. 14, pl. 1, fig. 12, 1936.

Loetterle, Nebraska Geol. Survey Bull., 2nd ser., Bull. 12, p. 58, pl. 10, figs. 6a, b, 1937.

Cushman and Hedberg, Contr. Cushman Lab. Foram. Research, vol. 17, p. 85, pl. 21, fig. 12, 1941.

Cushman and Todd, idem., vol. 19, p. 53, pl. 9, fig. 10, 1943.

Cushman and Deaderick, Jour. Paleontology, vol. 18, p. 330, pl. 50, fig. 22, 1944.

Cushman, U. S. Geol. Survey Prof. Paper 206, p. 46, pl. 12, figs. 21-26, 1946.

Test generally cylindrical, the base somewhat tapering or rounded, sides nearly parallel for most of their length, transverse section rounded or slightly compressed; earliest whorl with 4 or 5 chambers, later triserial, and in the adult biserial; chambers distinct, very slightly inflated, increasing very little in size as added, somewhat overlapping; sutures distinct, slightly depressed in the adult portion; wall distinctly arenaceous, but with much cement and smoothly finished; aperture a low, broad opening at the inner margin of the last-formed chamber, often with a slight lip. Length up to 0.1 cm., diameter 0.35 mm. Abundant in the Navarro, present in the Taylor and Austin. This specimen was found in Sample 8, where it is very rare. Univ. of Utah Micropaleo. Coll. No. 17.

Family TROCHAMMINIDAE
Genus TROCHAMMINA Parker and Jones, 1859

Trochammina diagonis (Carsey) Cushman and Waters
Plate 6, fig. 20

Haplophragmoides diagonis Carsey, Texas Univ. Bull. 2612, p. 3, fig. 1, 1928.
Trochammina diagonis (Carsey) Cushman and Waters, Contr. Cushman Lab. Foram. Research, Vol. 2, pt. 4, p. 84, pl. 10, figs. 7a, c, 1927.
Cushman, Royal Soc. Canada Trans., 3d ser. vol. 21, sec. 4, p. 132, 1927; Cushman Lab. Foram. Research Special Pub. 5, pl. 18, figs. 2a, c, 1933.
Plummer, Texas Univ. Bull. 3101, p. 140, 1931.
Cushman and Deaderick, Contr. Cushman Lab. Foram. Research, vol. 18, p. 55, pl. 10, figs. 8, 9, 1942; Jour. Paleontology, vol. 18, p. 331, pl. 50, fig. 23, 1944.
Cushman and Todd, Contr. Cushman Lab. Foram. Research, vol. 19, p. 54, pl. 9, fig. 13, 1943.
Cushman, U. S. Geol. Survey Prof. Paper 206, p. 49, pl. 15, figs. 1-3, 1946

Test trochoid, somewhat compressed, periphery lobulated; chambers distinct, 6 or 7 in the last-formed coil, increasing rather uniformly in size as added, the general shape being rather constant; sutures distinct, depressed, on the dorsal side slightly curved, on the ventral side nearly radial; wall arenaceous, with much cement; aperture a narrow opening on the ventral side at the inner margin of the last-formed chamber. Diameter 0.65 to 0.80 mm. Univ. of Utah Micropaleo Coll. No. 18.

This species is common to the Austin, Taylor and Navarro. Found in Samples 4 and 8 of the Hilliard section.

Trochammina taylorana Cushman
Plate 6, figs. 21, 22

Trochammina taylorana Cushman, Contr. Cushman Lab. Foram. Research, vol. 13, p. 101, pl. 15, fig. 4, 1937.

Cushman, U. S. Geol. Survey Prof. Paper 206, pl. 15, fig. 13, 1946.

Test small, compressed, periphery acute, lobulate, the last whorl somewhat open on both dorsal and ventral sides; chambers distinct, slightly inflated, 5 or 6 in the last-formed whorl, increasing rapidly in size as added; sutures distinct, slightly depressed, very slightly curved, nearly radial; wall distinctly arenaceous, of rather uniform sand grains with a few larger ones, firmly cemented; aperture ventral, at the inner margin of the last-formed chamber. Length 0.30 mm., breadth 0.25 mm., thickness 0.075 mm. The types are from the Taylor marl. This is a distinct scale-like species that occurs in considerable numbers at the horizon of Sample 8 of the Hilliard section. It differs from T. diagonis (Carsey) Cushman and Waters in its smaller size, flatter test, and more evolute ventral side. Univ. of Utah Micropaleo. Coll. No. 19.

Trochammina excavata Gauger n. sp.
Plate 6, fig. 23

Test small, compressed, periphery acute, lobulate, the last whorl somewhat open on both dorsal and ventral sides; chambers distinct, slightly inflated, the last two being compressed and edged by a low rim, 9 to 10 chambers to last-formed whorl, increasing rather regularly in size as added except for the final chamber, which is larger; sutures distinct, slightly indented, very slightly curved, nearly radial; wall distinctly arenaceous, firmly cemented; aperture ventral, at the inner margin of the last-formed chamber. Length 0.25 mm., breadth 0.2 mm., thickness 0.07 mm.

These specimens were found only in Sample 4 of the Hilliard formation. They differ from T. diagonis (Carsey) Cushman in the number of chambers, smaller size, and compressed final chamber with the thickened rim. Holotype: Univ. of Utah Micropaleo Coll. No. 20.

Family LAGENIDAE
Genus ROBULUS Montfort, 1808

Robulus munsteri (Roemer) Cushman
Plate 7, figs. 1, 2

Robulina munsteri Roemer, Verstein. norddeutschen Oolithengebirges, Nachtrag., p. 48, pl. 22, fig. 29, 1839; Verstein. norddeutschen Kreidegebirges, p. 98, pl. 15, fig. 30, 1840-41.
Robulus munsteri Cushman, Jour. Paleontology, vol. 6, p. 334, pl. 50, figs. 2a, b, 1932, Contr. Cushman Lab. Foram. Research, vol. 17, p. 58, pl. 15, fig. 6, 1941.
Cushman and Hedberg, idem., vol. 17, p. 86, pl. 21, figs. 14a, b, 1941.
Cushman and Deaderick, idem., vol. 18, p. 56, pl. 10, figs. 10-13, 1942: Jour. Paleontology, vol. 18, p. 331, pl. 50, fig. 28, 1944.
Cushman, Contr. Cushman Lab. Foram. Research vol. 20, p. 85, pl. 13, fig. 7, 1944.
Cushman, U. S. Geol. Survey Prof. Paper 206, p. 53, pl. 17, figs. 3-9, 1946.

Test involute except for the last portion in the adult, which may tend to become slightly evolute and show the preceding coil, compressed, umbonate, periphery sharply keeled; chambers distinct, of uniform shape and increasing very gradually in size, not inflated, 9 to 12 in the adult coil; sutures distinct, slightly limbate, tangential, slightly curved; wall smooth; aperture radiate, at the outer peripheral angle. Diameter up to 1.50 mm., thickness 0.40 to 0.60 mm.

Occurs in the Navarro, Taylor, and Austin. The Hilliard specimens came out of Sample 4. Considerable variation is shown in this species. Univ. of Utah Micropaleo. Coll. No. 21.

Genus LENTICULINA Lamarck, 1804

The principal difference between this genus and Robulus is in the aperture. This is not always easily determined in poorly preserved fossil material, and, therefore, the generic position of many species is difficult to determine. There are so many species already named in the European Cretaceous that a study of these is necessary before applying names to most of our American Cretaceous forms.

Lenticulina rotulata Lamarck
Plate 7, figs. 3-5

Lenticulina rotulata Lamarck, in Cushman, U. S. Geol. Survey Prof. Paper 206, pp. 56-57, pl. 18, fig. 19, pl. 19, figs. 1-7, 1946.

Very many forms have been referred to Lamarck's species. Test involute, tending to become evolute in some specimens; with a distinct umbo, slightly curved tangential sutures, and usually a distinct keel; Diameter up to 1.75 mm., thickness at umbones 0.75 mm.

Found in basal Navarro, Taylor and Austin. The specimens figured here were found in Sample 4 of the Hilliard formation. Univ. of Utah Micropaleo. Coll. No. 22.

Genus PLANULARIA Defrance, 1824

Planularia inflata Gauger n. sp.
Plate 7, figs. 11-13a.

Test very strongly compressed, thickest across the center of the last-formed chamber, early portion coiled, later portion uncoiling; periphery variable, with a thin keel in the earliest portion, largely disappearing in uncoiled specimens; chambers distinct, increasing very rapidly in size, becoming elongate in the adult, strongly inflated in the later portion in the uncoiled forms, variable in

number; sutures distinct, strongly limbate, depressed strongly in later portion, earlier sutures more strongly curved than later ones; wall usually smooth, aperture radiate, at the peripheral angle, slightly protruding. Length 0.80 mm., breadth 0.40 mm., thickness 0.30 mm.

This specimen was found in Sample 4 of the Hilliard and would make a good marker for this horizon. Holotype: Univ. of Utah Micropaleo. Coll. No. 23.

Genus MARGINULINA D'Orbigny, 1826

Marginulina cretacea Cushman
Plate 8, fig. 1

Marginulina cretacea Cushman, Contr., Cushman Lab. Foram. Research, vol. 13, p. 94, pl. 13, figs. 12-15, 1937; idem. vol. 20, p. 5, pl. 1, fig. 18, 1944.
Cushman and Deaderick, Jour. Paleontology, vol. 18, p. 332, pl. 51, fig. 5, 1944.
Cushman, U. S. Geol. Survey Prof. Paper 206, p. 61, pl. 21, figs. 16-20, 39.
Marginulina intermedia Cushman (not Philippi), Jour. Paleontology, vol. 6, p. 334, pl. 50, figs. 4a, b, 1932.

Test much compressed; early portion coiled, especially in the microspheric form, later portion uncoiled; dorsal periphery strongly convex, not lobulate, ventral periphery concave; dorsal margin acute, ventral margin slightly rounded; chambers distinct, increasing gradually in size as added, not inflated; sutures distinct, radiate at the outer peripheral angle. Length 1.30 mm., breadth 0.45 mm.

Found in the Taylor and lower Navarro formations on the Gulf Coast. Found in Sample 8 in the Hilliard formation. Univ. of Utah Micropaleo. Coll. No. 24.

Marginulina texasensis Cushman
Plate 8, fig. 2

Marginulina texasensis Cushman, Contr. Cushman Lab. Foram. Research, vol. 14, p. 95, 1938.
Frizzel, Jour. Paleontology, vol. 17, p.342, pl. 56, fig. 4, 1943.
Cushman and Deaderick, idem., vol. 18, p. 332, pl. 51, figs. 6, 7, 1944.
Cushman, Contr., Cushman Lab. Foram. Research vol. 20, p. 86, pl. 13, fig. 8, 1944.
Cushman, U. S. Geol. Survey Prof. Paper 206, p. 61, pl. 21, figs. 21-29, 38, 40, 1946.
Marginulina texana Cushman, Contr. Cushman Lab. Foram. Research, vol. 13, p. 95, pl. 14, figs. 1-4, 1937.
Cushman and Hedberg, idem, vol. 17, p. 88, pl. 21, fig. 21, 1941.
Marginulina elongata Cushman (not D'Orbigny), Jour. Paleontology, vol. 5, p. 304, pl. 35,figs. 6a, b, 1932.
Marginulina modesta Cushman and Jarvis (not Reuss), U. S. Nat. Mus. Proc., vol. 80, art 14, p. 26, pl. 8, figs. 6a, b, 1932.

Test elongate, slender; early portion coiled, rapidly becoming uncoiled, with rather uniform diameter throughout; ventral margin in the adult convex, lobulated, dorsal margin concave; nearly circular in diameter; chambers distinct, strongly inflated in the later portion, increasing gradually in height toward the apertural end; sutures distinct, depressed in the later portion; wall smooth; aperture radiate, protuberant, at the dorsal peripheral angle. Length up to 1.50 mm., diameter 0.25 mm.

Occurs in the Taylor and lower Navarro formations in the Gulf Coast. Found in Sample 4 of the Hilliard formation. Univ. of Utah Micropaleo.Coll. No. 25.

Genus DENTALINA D'Orbigny 1826

Dentalina gracilis D'Orbigny
Plate 8, figs. 3-6

Dentalina gracilis D'Orbigny, Soc. Geol. France Mem., 1st ser., vol. 4, p. 14, pl. 1, fig. 5, 1840.
Franke, Preuss, Geol. Landesanstalt Abh., new ser., vol. 111, p. 29, pl. 2, fig. 22, 1928.
Cushman, Contr., Cushman Lab. Foram. Research vol. 16, p. 77, pl. 13, figs. 9-11, 1940.
Cushman and Deaderick, idem., vol. 18, p. 57, pl. 11, fig. 4, 1942.
Cushman and Todd, idem, vol. 19, p. 57, pl. 10, fig. 6, 1943.
Cushman, idem., vol. 20, p. 6, pl. 1, fig. 28, 1944; idem., vol. 20, p. 86, pl. 13, fig. 12, 1944.
Cushman, U. S. Geol. Survey Prof. Paper 206, p. 65, plate 23, fig. 3-6, 1946.

Test elongate, gently curved, slightly tapering; chambers few, 8 to 10 in most specimens, increasing slowly in size as added, inflated, initial chamber on some specimens roundly inflated and bulbous, greater in diameter than those immediately following; sutures distinct, depressed, somewhat limbate, slightly oblique; aperture small, radiate, terminal at the end of a thin neck in some specimens. Length 0.60 to 0.80 mm.

Found in the Gulf Coast in the Austin, Taylor, and Navarro formations. In this paper in Samples 4, 7, 8, and 10. Univ. of Utah Micropaleo. Coll. No. 26.

Genus NODOSARIA Lamarck, 1812

Nodosaria affinis Reuss
Plate 8, fig. 8

Nodosaria affinis Reuss, in Cushman, U. S. Geol. Survey Prof. Paper 206, pp. 70, 71, pl. 25, figs. 8-23, 1946.

A fragment consisting of the final two chambers of a specimen which is referred to N. affinis was found in Sample 4 of the Hilliard formation. The form is so obvious that its identification is positive even in individual sections of chambers. Its large size will differentiate it from fragments of Dentalina solvata. Diameter about 0.30 mm., but may be as much as 0.75 mm. Univ. of Utah Micropaleo. Coll. No. 27.

Genus DENTALINA D'Orbigny, 1826

Dentalina solvata Cushman
Plate 8, fig. 7

Dentalina solvata, Cushman, Contr. Cushman Lab. Foram. Research, vol. 14, p. 39, pl. 6, figs. 9-14, 1938; idem, vol. 16, p. 83, pl. 14, figs. 13-17, 1940; idem, vol. 20, p. 7, pl. 1, fig. 29, 1944.
Cushman and Deaderick, Jour. Paleontology, vol. 18, p. 333, pl. 51, figs. 12, 13, 1944.

Test elongate, slender, slightly curved, initial end with a short spine; chambers distinct, early chambers slightly overlapping, gradually increasing in size as added and becoming less overlapping until in the adult they are in a loose series, somewhat longer than broad, connected by narrow, stolonlike portions; sutures distinct, strongly limbate, more and more depressed as growth proceeds; wall in the early portion with 8 to 10 longitudinal costae, costae persisting over the sutures; aperture terminal, radiate. Length up to 3.00 mm., diameter 0.20 to 0.22 mm.

Found in Austin, Taylor, and Navarro of the Gulf Coast, it reaches its maximum development in the Taylor. Found in Sample 4 of the Hilliard formation. Univ. of Utah Micropaleo. Coll. No. 28.

Genus VAGINULINA D'Orbigny, 1826

Vaginulina webbervillensis Carsey
Plate 8, figs. 9-11

Vaginulina webbervillensis Carsey, Texas Univ. Bull. 2612, p. 39, pl. 2, fig. 7, 1926.
Cushman, Contr., Cushman Lab. Foram. Research vol. 6, p. 27, pl. 4, fig. 7, 1926.
Plummer, Texas Univ. Bull. 3101, p. 160, 1931.
Cushman and Todd, Contr., Cushman Lab. Foram. Research, vol. 19, p. 59, pl. 10, figs. 21a, b, 1943.
Todd, Am. Jour. Sci., vol. 242, p. 334, pl. 1, figs. 9-18, 1944.
Cushman, U. S. Geol. Survey Prof. Paper 206, p. 81, pl. 30, figs. 5-10, 1946.

Test very large, much compressed, broadest toward the apertural end, periphery usually bicarinate or tricarinate in the young, usually rounded and smooth in the adult; dorsal edge nearly straight, thickened; ventral edge much convex; initial end typically with a distinct spine; chambers numerous, distinct, low and broad, curved, increasing rapidly in width as added; sutures usually flush with the surface, strongly curved backward toward the initial end, which usually develops a few costae; aperture somewhat protruding, at the dorsal angle, radiate. Length up to 6.00 mm., breadth quite variable.

This species characterizes the upper part of the Navarro formation in the Gulf Coast. It was found in Sample 4 of the Hilliard formation. Univ. of Utah Micropaleo. Coll. No. 29.

Genus FRONDICULAPIA Defrance, 1826

Frondicularia archiaciana D'Orbigny
Plate 8, figs. 14, 16-18

Frondicularia archiaciana D'Orbigny, Soc. Geol. France Mem., 1st ser., vol. 4, p. 20, pl. 1, figs. 34-36, 1840.

Eley, Geology in the garden, p. 197, pl. 4, fig. 19, 1859.
Heron-Allen and Earland, Royal Micr. Soc. Jour., p. 419, pl. 7, figs. 11, 12, 1910.
Franke, Greifswald Univ., Geol.-palaeont. Inst., Abh., vol. 6, p. 52, pl. 4, fig. 18, 1925; Preuss. geol. Landesanstalt Abh., new ser., vol. 111, p. 71, pl. 6, figs. 14, 15, 1928.
Cushman, Contr. Cushman Lab. Foram. Research vol. 6, p. 37, pl. 5, figs. 9-12, 1930; Tennessee Div. Geol. Bull. 41, p. 35, pl. 4, figs. 13a, b, 1931.
Sandidge, Jour. Paleontology, vol. 6, p. 278 pl. 42, figs. 15, 26, 1932.
Cushman, idem, p. 335; Contr. Cushman Lab. Foram. Research, vol. 12, p. 19, pl. 4, figs. 8-10, 1936.
Jennings, Bull. Am. Paleontology, vol. 23, No. 78, p. 22, pl. 2, fig. 18, 1936.
Cushman and Todd, Contr. Cushman Lab. Foram. Research, vol. 19, p. 60, pl. 10, fig. 26. 1943.
Cushman, idem, vol. 20, p. 9, pl. 2, fig. 8, 1944.
Cushman, U. S. Geol. Survey Prof. Paper 206, p. 91, figs. 8-20, pl. 37, 1946.

Test elongate, gently tapering, greatest breadth toward the apertural end, compressed, sides flattened, periphery truncate; chambers distinct, not inflated, gradually increasing in size as added, proloculum rounded; sutures distinct, raised, limbate, slightly sigmoid; wall smooth, except for the raised sutures and the proloculum, which has several longitudinal costae; aperture terminal, radiate. Length up to 2.50 mm., breadth 0.50 to 0.65 mm.

Common in beds of Taylor age, with a few localities in the lower beds of Navarro age. Found in Sample 4 of the Hilliard formation. Univ. Utah Micropaleo. Coll. No. 30.

Frondicularia undulosa Cushman
Plate 8, figs. 13 and 15

Frondicularia undulosa Cushman, Contr. Cushman Lab. Foram. Research, vol. 12, p. 13, figs. 7-11, 1936.
Loetterle, Nebraska Geol. Survey Bull., 2d ser., Bull. 12, p. 29, pl. 3, figs. 8, 9, 1937.
Cushman and Deaderick, Contr. Cushman Lab. Foram. Research, vol. 18, p. 60, pl. 13, figs. 2, 3, 1942.
Cushman, idem, vol. 20, p. 89, 1944.
Cushman, U. S. Geol. Survey Prof. Paper 206, p. 87, pl. 34, figs. 9-13, 1946.

Test typically elongate, with the sides nearly parallel or gently tapering, but in some specimens somewhat broader and flaring; periphery truncately rounded, undulate; broader sides flattened; whole test thin; chambers distinct, increasing gradually in size as added, the basal portion rounded to form the lobular periphery; apertural end narrow, extended; sutures distinct, strongly oblique, nearly straight or slightly concave toward the outer side; wall smooth except for the proloculum in the megalospheric form, which has a single, raised, longitudinal costa, the base with a short, stout spine; aperture small, at the end of a somewhat slender neck. Length up to 2.50 mm., breadth 0.50 to 0.75 mm., thickness 0.15 mm., but the forms figured in this report are much smaller.

Characteristic of the Austin, but occurs rarely in the Taylor marl. The forms figured here occur in Sample 4 of the Hilliard formation. Univ. of Utah Micropaleo. Coll. No. 31.

Frondicularia clarki Bagg
Plate 8, fig. 12

Frondicularia clarki Bagg, U. S. Geol. Survey Bull. 88, p. 48, pl. 3, fig. 4, 1898.
Weller, New Jersey Geol. Survey, Paleontology, vol. 4, p. 227, pl. 2, fig. 23, 1907.

Cushman, Contr., Cushman Lab. Foram. Research vol. 6, p. 34, pl. 5, figs. 1, 2, 1930.
Plummer (part), Texas Univ. Bull. 3101, p. 171, pl. 9, fig. 17 (not fig. 16), 1931.
Cushman, Contr., Cushman Lab. Foram. Research vol. 12, p. 12, pl. 3, figs. 4-6, 1936.
Jennings, Bull. Am. Paleontology, vol. 23, No. 78, p. 22, pl. 2, fig. 21, 1936.
Cole, Florida Dept. Cons. Geol. Bull. 16, p. 34 (list), pl. 2, fig. 11, 1938.
Cushman, and Todd, Contr., Cushman Lab. Foram. Research, vol. 19, p. 61, pl. 10, fig. 25,1943.
Cushman, U. S. Geol. Survey Prof. Paper 206, p. 92, figs. 1-5, pl. 38, 1946.

The test in the microspheric form has a shape near the base somewhat different from that of the megalospheric form. The surface is smooth, but the sutures are usually distinct and peculiarly curved, giving an almost elliptical shape to the test, especially in the adult megalospheric form. The whole test is very flat and thin. The initial proloculum may have a few longitudinal costae.

In the Texas Cretaceous, it has been found to be common and characteristic of the upper Navarro. It was found in Sample 4 of the Hilliard formation. Univ. of Utah Micropaleo. Coll. No. 32.

Genus PALMULA Lea, 1833

Palmula pilulata Cushman
Plate 7, figs. 6-10, 14-16

Palmula pilulata Cushman, Contr. Cushman Lab. Foram. Research, vol. 14, p. 37, pl. 6, fig. 2, 1938.
Cushman, U. S. Geol. Survey Prof. Paper 206, p. 84, plate 32, figs. 18-21, 1946.

Test much compressed; periphery truncate except about initial portion which is carinate, with a thin transparent flange; early portion coiled; chambers distinct, comparatively few, early coiled chambers of rather uniform shape, increasing very gradually

in size; adult chambers chevron-shaped, extending backward at the sides but not including much of the early coiled chambers; sutures limbate, very slightly raised, each of the earlier sutures ending at the inner end in a raised bead, slightly elongate; wall smooth except for the raised sutures; aperture in the adult terminal, radiate, very slightly projecting. Length up to 3.00 mm., breadth 2.00 mm.

Typical of the Austin (Bonham marl) in the Texas Cretaceous. Found in Sample 4 of the Hilliard formation. Univ. of Utah Micropaleo. Coll. No. 33.

Genus BULLOPORA Quenstedt, 1856

Bullopora tuberculata (Sollas) Cushman
Plate 9, figs. 1, 1a, 2

Webbina tuberculata Sollas, Geol. Mag., Dec. 2, vol. 4, p. 104, pl. 6, figs. 4-7, 9, 1877.
Vitrewebbina tuberculata Chapman, Annals and Mag. Nat. History, ser. 6, vol. 18, p. 332, text fig. 4, 1896; Royal Micr. Soc. Jour., pp. 586, 587, pl. 13, fig. 3, 1896: Annals and Mag. Nat. History, ser. 7, vol. 3, p. 315, text fig. 3, 1899.
Franke, Greifswald Univ., Geol.-palaeont. Inst. Abh., vol. 111, new ser., p. 125, pl. 11, fig. 22, 1928.
Bullopora tuberculata (Sollas) Cushman, Cushman, U. S. Geol. Survey Prof. Paper 206, p. 99, pl. 42, figs. 5-7, 1946.

Test attached, consisting of a Globulina-like stage followed by a series of globular, oval, fusiform, or irregularly shaped chambers, generally in a single series joined by stolonlike connections, or branching into two or more series, wall hispid or finely tuberculate. Specimens are not as common as is the smooth species B. laevis. All localities are in the upper part of the Taylor marl in the Gulf Coast. Found in Sample 4 of the Hilliard formation, and is a very good index species. Univ. Utah Micropaleo. Coll. No. 34.

Genus GUMBELINA Egger, 1899

Gumbelina globulosa (Ehrenberg) Egger
Plate 9, figs. 3-14

Textularia globulosa Ehrenberg, K. Preuss. Akad. Wiss. Berlin, Abh., p. 135, pl. 4, fig. 4 beta, 1834: Mikrogeologie, pl. 21, fig. 87, etc., 1854.

Gumbelina globulosa Egger, K. Bayer, Akad. Wiss., Math.-naturh. Abt., Abh., Kl. 2, vol. 21, pt. 1, p. 32, pl. 14, fig. 43, 1899. (This species has been recorded in so many papers dealing with upper Cretaceous foraminifera in the United States that its synonymy is too extensive for reproduction.)

Cushman, U. S. Geol. Survey Prof. Paper 206, p. 105, pl. 45, figs. 9-15, 1946.

Test rapidly tapering, greatest breadth toward the apertural end, initial end subacute, 1 1/2 times as long as broad in side view, with the chambers regularly enlarging to the greatest width at the last-formed chamber. Periphery distinctly indented throughout; chambers inflated throughout; increasing in size rather more rapidly toward the apertural end, nearly spherical; sutures distinct, depressed throughout; wall smooth, finely perforate; aperture broad, low, with a slightly thickened rim above. Length 0.30 to 0.50 mm., breadth 0.20 to 0.25 mm., thickness 0.18 to 0.25 mm.

Found in Taylor and Navarro age formations in the Gulf Coast. Recovered from Samples 4, 5, 6, 7, and 8 of the Hilliard formation. Univ. Utah Micropaleo. Coll. No. 35.

Genus EOUVIGERINA Cushman, 1926

Eouvigerina inflata Gauger n. sp.
Plate 9, fig. 15

Test fusiform, elongate, slightly tapering, periphery rounded, of medium size, greatest breadth

above the middle; chambers distinct, inflated, increasing rapidly in height as added, mostly triserial, earlier portion biserial; sutures distinct, depressed; wall thin, finely perforated, opaque, lower portion of test crossed by very fine costae, almost indiscernible under highest powers. Length 0.5 mm., diameter 0.35 mm. Found in Sample 4 of the Hilliard formation.

Another specimen was found in the Hilliard (Sample 4) which had well developed costae over the lower portion of the test, otherwise identical with the above named species. The specimen was misplaced and it would be impossible to describe it from memory and guess at its measurements. Holotype: Univ. of Utah Micropaleo. Coll. No. 36.

Family BULIMINIDAE
Subfamily BULIMININAE
Genus BULIMINA D'Orbigny, 1826

Bulimina kickapooensis Cole
Plate 9, fig. 16

Bulimina kickapooensis Cole, Florida Dept. Cons. Geol. Bull. 16, p. 45, pl. 3, fig. 5, 1938.
Cushman, U. S. Geol. Survey Prof. Paper 206, p. 123, pl. 51, fig. 11, 12, 14; pl. 66, fig. 12, 1946.

Test about 2 1/2 times as long as broad, megalospheric form tapering very slightly, microspheric rapidly, consisting of 5 or 6 whorls; chambers numerous, distinct, slightly inflated, sharply angled; sutures distinct, slightly depressed; wall smooth, perforate; aperture loop-shaped at apex of test, with a thin, plate-like tooth. Length 0.72 mm., diameter 0.28 mm.

Found in Samples 4, 5, 6, 7, and 8 of the Hilliard formation, this species ranges from Austin through Navarro age formations, with its greatest development in the Taylor age formations. Univ. of Utah Micropaleo. Coll. No. 37.

Genus LOXOSTOMA Ehrenberg, 1854

Loxostoma plaitum (Carsey) Cushman
Plate 9, fig. 17-20

Bolivina plaitum Carsey, Texas Univ. Bull. 2612, p. 26, pl. 4, fig. 2, 1926.
Loxostoma plaitum Cushman, Tennessee Div. Geology Bull. 41, p. 51, pl. 8, fig. 9, 1931.
Loxostoma plaitum Plummer, Univ. of Texas Bull. 3101, p. 182, pl. 10, fig. 5-7, 1931.
Loxostoma plaitum (Carsey) Cushman, U. S. Geol. Survey Prof. Paper 206, p. 130, pl. 54, fig. 10-14, 1946.

Test 4 times as long as broad in the adult, elongate, slender, slightly tapering, greatest breadth toward the apertural end, slightly twisted, compressed, tending to become somewhat uniserial in the adult, periphery rounded; chambers numerous, distinct, increasing rather rapidly in height toward the apertural end; earlier chambers biserial, inflated slightly if at all, later chambers strongly inflated and failing to completely reach across the test; sutures distinct, slightly depressed, often somewhat limbate, earlier sutures strongly oblique, slightly curved, later sutures strongly curved; wall smooth, finely perforate; aperture tending to become terminal in the adult, narrowly ovate. Length 0.50 mm., breadth 0.12 mm., thickness 0.08 to 0.10 mm.

The species ranges from Austin through Taylor and Navarro age formations. It tends to become broader in the lower Navarro and tends less strongly toward the uniserial condition. There is much variation in this species.

Found in Sample 4 of the Hilliard formation, Univ. Utah Micropaleo.Coll. No. 38.

Genus GYROIDINA D'Orbigny, 1826

Gyroidina depressa (Alth) Cushman and Church
Plate 9, figs. 21-26

Rotalina depressa Alth, Haidinger's Naturw. Abh., vol. 3, p. 266, pl. 13, fig. 21, 1850.
Rotalia cretacea Carsey, Texas Univ. Bull. 2612, p. 48, pl. 5, figs. 7a, b, 1926.
Rotalia beccarii (Linne) D'Orbigny var. ripleyensis W. Berry in Berry and Kelley, U. S. Nat. Mus. Proc., vol. 76, art. 19, p. 15, pl. 3, figs. 10-12, 1929.
Gyroidina depressa Cushman and Church, California Acad. Sci. Proc., 4th ser., vol. 18, p. 515, pl. 41, figs. 4-6, 1929.
Gyroidina depressa (Alth) Cushman and Church, Cushman, U. S. Geol. Survey Prof. Paper 206, p. 139, pl. 58, figs. 1-4, 1946.

Test much compressed, trochoid, biconvex, the dorsal side in many specimens nearly flat, periphery rounded, umbilicus in many specimens open; chambers numerous, 10 to 12 in the last-formed whorl, distinct; sutures distinct, on the dorsal side nearly flush with the surface, curved, nearly radial, slightly depressed; wall smooth; aperture on the ventral side between the periphery and the umbilicus, low. Diameter 0.25, to 0.55 mm., height 0.10 to 0.25 mm.

The American species seems to be the same as the European species, although subject to considerable variation in the number of chambers, degree of openness of the umbilicus, and the convexity of the test.

It ranges nearly throughout the Upper Cretaceous.

Found in Sample 4 of the Hilliard formation, Univ. of Utah Micropaleo. Coll. No. 39.

Family GLOBOROTALIIDAE
Genus GLOBOTRUNCANA Cushman, 1927

Globotruncana marginata (Reuss) Thalmann
Plate 9, figs. 27-29

Rosalina marginata Reuss, Verstein, Bohm. Kreideformation, pt. 1, p. 36, pl. 8, figs. 54, 74; pl. 13, fig. 68, 1845.
Globotruncana marginata Thalmann, Eclogae geol. Helvetiae, vol. 27, p. 414, 1934.
Globotruncana marginata (Reuss) Thalmann, Cushman, U. S. Geol. Survey Prof. Paper 206, p. 150, pl. 62, figs. 1, 2, 1946.

This species has been referred to Globigerina by many authors, but the figures are not usually very definite and have not been referred to here. Globigerinid in outline, inflated, definite dorsal and ventral keels, the periphery becoming truncated; chambers have a characteristic overlapping appearance, and are not added in a plane but each in a slightly oblique position. There is considerable variation. 5 or 6 chambers to a whorl, aperture opening ventrally into the umbilicus; umbilucus deep, sometimes covered by a thin transparent series of plates. Height up to 1.0 mm., width up to 0.3 mm.

Reuss first described this species from the Turonian. It ranges from Austin to lower Navarro age formations. Its greatest development is in the Austin. Occasional specimens are found in the Taylor (upper part), but they are few.

Found in Sample 4 of the Hilliard formation Univ. of Utah Micropaleo. Coll. No. 40.

Globotruncana (?) sp.
Plate 10, fig. 5

This specimen has been referred to Globotruncana with some doubt. Its state of preservation was not perfect enough to make identification possible with any degree of certainty. It was recovered from the Hilliard formation at the horizon of Sample 4. Univ. of Utah Micropaleo. Coll. No. 44.

Genus GLOBOROTALIA Cushman, 1927

Globorotalia cushmani Morrow
Plate 10. figs. 1-3

Globorotalia cushmani Morrow, Jour. Paleontology, vol. 8, p. 199, pl. 31, figs. 2a, b, 4a, b, 1934.

Cushman, Prof. Paper 206, p. 152, pl. 62, fig. 9, 1946.

Test trochoid, dorsal side moderately convex with chambers flattened or slightly inflated, dorsal sutures roundly curving, producing a scalloped periphery; the anterior margin sometimes raised slightly, ventral side strongly convex with the chambers strongly inflated, sutures deeply grooved and nearly radiate; only the last whorl, of 4 to 6 chambers visible, the periphery sharply rounded and thickened into a narrow rim. Diameter 0.7 mm., thickness 0.25 mm.

This form is common in the Eagle Ford and Austin formations. Found in Sample 4 of the Hilliard formation. Univ. of Utah Micropaleo. Coll. No. 41.

Globorotalia (?) multiloculata Morrow
Plate 10, fig. 4

Globorotalia (?) multiloculata Morrow, Jour. Paleontology, vol. 8, p. 200, pl. 30, figs. 3a,b, 5a, b, 1934.
Cushman, U. S. Geol. Survey Prof. Paper 206, pl. 62, figs. 10, 11, p. 153, 1946.

Test trochoid, biconvex, compressed; dorsal side strongly convex, ventral side moderately convex; chambers numerous, seven to nine in final whorl, very distinct, inflated, narrowly rounded but not keeled at their periphery, tending in the last whorl to be produced ventrally in the direction of the axis of coiling; umbilical area large and rather deep sutures strongly depressed; wall finely perforate. Diameter 0.7 mm., thickness 0.3 mm.

The species is very close to the border line between Globigerina and Globorotalia. The types are from the Hartland shale member of the Greenhorn formation.

It was recovered from Sample 4 of the Hilliard formation. Univ. of Utah Micropaleo. Coll. No. 43.

Family GLOBIGERINIDAE
Subfamily GLOBIGERININAE
Genus GLOBIGERINA D'Orbigny, 1826

Globigerina cretacea D'Orbigny
Plate 10, figs. 6-11

Globigerina cretacea D'Orbigny, Mim. Soc. Geol. France, ser. 1, vol. 4, p. 34, pl. 3, figs. 12, 13, 14, 1840. (This species has been recorded in so many papers dealing with Upper Cretaceous foraminifera in the United States that its synonymy is too extensive for reproduction.)

Common in Samples 4, 5, 6, 7, and 8 of the Hilliard formation, and is the most abundant and widespread of Upper Cretaceous Foraminifera. Carman gives (in Jour. Pal. vol. 3, pp. 314, 315 pl. 34, fig. 1, 1929), four varieties of Globigerina cretacea. The specimens found in the Hilliard are most like her Variety 2, which was found in both the Benton and the Niobrara formations of Wyoming. Univ. of Utah Micropaleo. Coll.No.45.

Genus PLANULINA D'Orbigny, 1826

Planulina kansasensis Morrow
Plate 10, figs. 12-24

Planulina kansasensis Morrow, Jour. Pal., vol. 8, p. 201, pl. 30, figs. 2a, b, 12a-c, 1934.
Loetterle, Nebraska Geol. Survey Bull., 2d ser., Bull. 12, p. 49, pl. 8, figs. 2a-c, 1937.
Cushman, U. S. Geol. Survey Prof. Paper 206, p. 157, pl. 64, fig. 12, 1946.

Test much compressed, dorsal and ventral sides nearly flat, slightly trochoid and involute; periphery rounded, chambers numerous, 8 to 10 in final whorl, all chambers exposed on the dorsal side, partially covered on the ventral side; sutures distinct between the later chambers, slightly

depressed, curved outward and backward; central area on both sides covered with a calcareous deposit which may be transparent showing the covered chambers; wall smooth perforate; aperture obscure, extending along the base of the last chamber onto the ventral side. Diameter up to 0.52 mm., thickness 0.12 mm.

Found on the Gulf Coast in formations of Austin age, in the Fort Hayes member of the Niobrara in Nebraska. Recovered from Sample 4, 5, 6, 7, 8 and 9 of the Hilliard formation. Univ. of Utah Micropaleo. Coll. No. 46.

(?) Planulina sp. (?)
Plate 10, figs. 25-27,
Plate 7, figs. 17, a, 18

This form is doubtfully referred to Planulina. It has all of the other characteristics of Planulina except that it is becoming too trochoid and has what appears to be a radial aperture. Univ. Utah Micropaleo. Coll. No. 47.

Phylum ARTHROPODA
Class CRUSTACEA
Order OSTRACODA Latrielle
Suborder PLATYCOPA Sars
Family CYTHERELLIDAE Sars, 1865
Genus CYTHERELLA Jones, 1849

Cytherella parallela (Reuss)
Plate 11, figs. 1-5

Cytherina parallela Reuss, Verstein, Bohm. Kreidef., pt. 1, p. 16, pl. 5, fig. 33, 1845.
Cythere truncata, Bosquet, Mem. Soc. Roy. Sci. Kiege, vol. 4, p. 357, pl. 1, figs. 2a-3, 1847.
Cytherella truncata Jones, Monogr. Entom. Cret. Eng., Paleontogr. Soc. London, p. 30, pl. 7, figs. 25a-3, 1849.
Cytherella parallela (Reuss), Denkschr. K. Akad. Wiss. Wein., vol. 7, p. 40, 1854.
Alexander, Univ. Texas Bull. 2907, p. 50, pl. 1, figs. 13, 16, 1929.
Loetterle, G. J., Nebraska Geol. Sur., Bull. 12, 2d ser., pp. 49-50, pl. VIII, figs. 3a,b, 1937.

Carapace in side view oblong-ovate, highest anteriorly. Dorsal margin straight except for marked downward curve just behind antero-dorsal angle. Ventral margin very gently convex downward. Anterior end somewhat obliquely rounded, rimmed and finely denticulate. Posterior end compressed, keel-like, obscurely angled slightly above the middle; convex and denticulate below, slightly excavated above. Continuations of the anterior marginal rim extend along the dorsal and ventral margins, uniting posteriorly to form a continuous peripheral rim. A long median ridge parallels another smaller one, which in turn parallels two more, making four parallel ridges in all, all connected by numerous short, vertical cross ridges. Length, 0.7 mm., height, 0.35 mm., width 0.34 mm.

This species marks the middle of the Taylor formation. Found in Sample 4 of the Hilliard formation. Univ. of Utah Micropaleo. Coll. No.48.

Family CYTHERIDAE
Genus CYTHERE Reuss, 1854

Cythere sphenoides Reuss
Plate 11, figs. 13-16

Cythere sphenoides Reuss, 1854, Denkschr. K. Akad. Wiss. Wien, vol. 7, p. 141, pl. 26, fig. 2.
Cytheropteron sphenoides Jones and Hinde, 1889, Suppl. Monogr. Cret. Entom. Eng. Irel., Paleontogr. Soc. London, p. 33, pl. 1, figs. 18-20.
Alexander, Univ. of Texas Bull. No. 2907, pl. VII, figs. 9, 14, 1929.

Carapace in side view ovate, highest anteriorly. Height equal to somewhat more than two-thirds the length. Dorsal margin strongly arched, ending posteriorly in an obscure angle. Ventral margin gently convex downward. Anterior end compressed narrow, obliquely rounded, minutely denticulate. Posterior compressed, narrow, low, obliquely and roundly truncated, and bearing 3 or 4 short spines along the postero-ventral margin. Left valve slightly larger and overlapping right valve along dorsal and anterior margins. Valves strongly convex, widest behind and below middle. The strongly tumid ventral portion of the valves bears a narrow ridge which runs longitudinally, paralleling the ventral margin. Surface of valves minutely and indistinctly punctate. Length, 0.93 mm.; height, 0.66mm.; width, 0.6 mm.

A very common species extending from the upper Austin to the top of the Wolfe City sand member of the Taylor formation. It has been found rarely above this.

Found in Sample 4 of the Hilliard formation. Univ. of Utah Micropaleo. Coll. No. 49.

Cythere gapensis (Alexander)
Plate 11, figs. 9, 17, 18

Cythere gapensis, Alexander, C. I., Univ. of Texas Bull. No. 2907, pp. 84-85, pl. VI, figs. 16, 17, 1929.

Carapace in side view oblong-ovate, highest anteriorly. Dorsal margin straight except for marked

downward curve just behind antero-dorsal angle. Ventral margin very gently convex downward. Anterior end somewhat obliquely rounded, rimmed and finely denticulate. Posterior end compressed, keel-like, obscurely angled slightly above the middle; convex and denticulate below, slightly excavated above. Continuations of the anterior marginal rim extend along the dorsal and ventral margins, uniting posteriorly to form a continuous peripheral rim. The ventral ridge divides into two just behind the antero-ventral angle, the upper branch extending backward and slightly upward, terminating at a point about one-third the length of the carapace from the posterior end. A longer median ridge parallels this one, arising just behind and free of the anterior marginal rim and ending just beyond the termination of the upper branch of the ventral ridge. The surface thus bears four narrow longitudinally disposed ridges, which are connected by numerous short, vertical cross-ridges.

The specimens referred to this species from the Hilliard formation do not possess the cross-ridges and longitudinally disposed ridges to the marked degree described by Alexander above, but the specific characteristics are recognizable. Found in Sample 4 of the Hilliard formation. Univ. of Utah Micropaleo. Coll. No. 53.

Genus CYTHERIDEA Bosquet, 1852
Subgenus CYTHERIDEA Stephenson, 1936

Cytheridea perforata (F. A. Roemer)
Plate 11, figs. 10-12

Cytheridea perforata (F. A. Roemer), in Alexander, Univ. of Texas Bull. No. 2907, pl. V, figs. 1, 2, 1929.

Carapace in side view ovate, highest at or slightly in front of middle. Height equal to two-thirds length. Dorsal margin strongly arched. Ventral margin very slightly convex downward. Anterior end broadly rounded. Posterior end narrower and obscurely angled slightly below middle. Valves rather strongly convex, widest at middle. In dorsal view, ends similar, bluntly angled. Surface finely punctate. Length 0.52 mm.; height 0.35 mm.; width 0.3 mm.

This species has been found throughout the Taylor formation. It occurs commonly in the lower part of the formation and becomes increasingly rarer upward. Found in Sample 7 of the Hilliard formation. Univ. of Utah Micropaleo. Coll. No.50.

Cythereis (?) sp.
Plate 11, figs. 6-8

A single broken specimen was found in Sample 4 of the Hilliard formation which might be assigned to the genus Cythereis. If this is the genus Cythereis, it will be the first time that the genus has been recorded so high in the Taylor. C. dallasensis Alexander (1929), C. bicornis Israelsky, and C. rugosissima Alexander (1929) are the only Ostracoda of the genus Cythereis recorded from the Taylor, and these species extend only to the lower middle of the Taylor in the Gulf Coast. Univ. of Utah Micropaleo. Coll. No. 51.

Carapace in side view ovate, highest at o slightly in front of middle. Height equal to two thirds length. Dorsal margin strongly arched Ventral margin very slightly convex downward Anterior end broadly rounded. Posterior end narrow er and obscurely angled slightly below middle Valves rather strongly convex, widest at middle In dorsal view, ends similar, bluntly angled Surface finely punctate. Length 0.52 mm.; heigh 0.35 mm.; width 0.3 mm.

This species has been found throughout the Taylor formation. It occurs commonly in the lowe part of the formation and becomes increasingly rarer upward. Found in Sample 7 of the Hilliard formation. Univ. of Utah Micropaleo. Coll. No.50.

Cythereis (?) sp.
Plate 11, figs. 6-8

A single broken specimen was found in Sample 4 of the Hilliard formation which might be assigned to the genus Cythereis. If this is the genus Cythereis, it will be the first time that the genus has been recorded so high in the Taylor. C. dallasensis Alexander (1929), C. bicornis Israelsky, and C. rugosissima Alexander (1929) are the only Ostracoda of the genus Cythereis recorded from the Taylor, and these species extend only to the lower middle of the Taylor in the Gulf Coast. Univ. of Utah Micropaleo. Coll. No. 51.

C. MICROFOSSILS OF THE "WANSHIP"

Robert R. Lankford

Phylum PROTOZOA
Class SARCODINA Butschli, 1882
Order FORAMINIFERA D'Orbigny, 1826
Family LAGENIDAE
Subfamily NODOSARIINAE
Genus DENTALINA D'Orbigny, 1826

Dentalina frontierensis Peterson
Plate 16, fig. 7

All specimens broken and worn. Description based on reconstruction. Test elongate, slender, slightly curved, initial end with spine, tapering with greatest width near apertural end. Initial chambers quite distinct, not inflated; later chambers greatly inflated. Sutures distinct, flush with surface on initial portion, depressed on later portion. Surface ornamented by 8-10 distinct longitudinal costae, present on initial portion, disappearing and absent on later portion. Aperture terminal, radiate.

This species is reported from the upper Frontier formation, Upper Cretaceous of northeastern Utah. It is believed, by the present author, that the specimens found in the "Wanship" were reworked from the underlying Frontier. Found in Samples N-14, N-16. Univ. Utah Micropaleo. Coll. No. 96.

Dentalina coalvillensis Peterson
Plate 16, fig. 8

All specimens broken and worn. Description based on reconstruction. Test elongate, slightly curved, slightly tapering, initial end with spine. Early chambers indistinct, not inflated, strongly overlapping; later chambers distinct, inflated. Sutures on later portion distinct, slightly depressed and oblique. Wall smooth; aperture terminal, radiate.

This species is reported from the upper Frontier formation, Upper Cretaceous of northeastern Utah. It is believed, by the present author, that the specimens found in the "Wanship" were reworked from the underlying Frontier. Found in Samples N-14, N-16. Univ. Utah Micropaleo. Coll. No. 97.

Family MILIOLIDAE
Subfamily QUINQUELOGULININAE
Genus QUINQUELOCULINA

Quinqueloculina sp.
Plate 16, fig. 9

Test broken longitudinally; last chamber gone. Aperture terminal with bifid tooth of moderate size. A single specimen.

This broken specimen was well enough preserved to permit only generic identification. Found only in Sample S-5. Univ. Utah Micropaleo. Coll. No. 98.

Family POTALIIDAE Cushman
Genus PARRELLA Finlay

Parrella cf. P. expansa Toulmin
Plate 16, fig. 10

Truncatulina culter Plummer, 1927, Univ. Texas Bull. 2644, p. 147, pl. 10, figs. 1a-c; pl. 15, figs. 2a, b.
Pulvinulinella culter (Plummer) var. mexicana Cushman, 1940, Contr. Cushman Lab. Foram. Res., vol. 16, p. 72, pl. 12, figs. 12a, b.
Parrella expansa Toulmin, 1943, Jour. Paleontology, vol. 15, no. 6, p. 604, text figs. 30-c, 4F.
Parrella expansa Toulmin, 1951, Harris and Jobe, Microfauna of basal Midway outcrops near Hope, Arkansas, Univ. Oklahoma, Norman, Okla., Transcript Press., p. 48, pl. 9, figs. 4, 5a-b.

Test trochoid, close-coiled; all chambers visible dorsally, only those of last-formed whorl from the ventral side, umbilical area with a distinct solid mass; sutures on both dorsal and ventral sides strongly oblique. Wall calcareous, perforate. Aperture on ventral side, multiple and slit-like.

This species best compares with P. expansa from the Paleocene of the Gulf Coast states. The Utah specimen has a larger solid mass covering the ventral umbilical area than the species figured from the Midway. Five well preserved specimens were found in Sample N-5. Univ. of Utah Micropaleo. Coll. No. 99.

Phylum ARTHROPODA
Class CRUSTACEA
Order OSTRACODA Latrielle
Family CYTHERELLIDAE
Genus CYTHERELLA Jones, 1849

Cytherella excavata Alexander
Plate 16, fig. 4

Cytherella excavata Alexander, 1934, Jour. Paleontology, vol. 8, no. 2, pp. 211-212, pl. 32, figs. 3-4.

Carapace oblong-ovate in side view, highest slightly posterior to middle. Dorsal margin gently arched. Ventral margin nearly straight. Anterior end broadly and evenly rounded. Posterior end broadly rounded, slightly oblique. Left valve overlaps right rather uniformly; overlap slightly less around anterior end. Surface of valves mediumly and evenly pitted, bears a distinct shallow pit corresponding to muscle scar position. Length, .61 mm.; width, .20 mm.; height, .409 mm.

C. excavata is reported from the Paleocene and Eocene of the Gulf Coast States. Occurs rarely in Sample N-5. Univ. Utah Micropaleo. Coll.No.72.

Cytherella ? sp.
Plate 16, figure 6

Carapace in side view quadrate-reniform; highest anterior to center. Dorsal margin straight, ventral margin slightly concave. Posterior end more sharply rounded than anterior. Valves acumenate-oval in dorsal view. Left valve appears slightly larger than right. Surface is finely pitted; pits evenly distributed. Length, .55 mm.; width, .16 mm.; height, .29 mm.

This species is represented by a single specimen which is doubtfully referred to the genus Cytherella on the basis of general outline and ornamentation. Found in Sample N-5. Univ. of Utah Micropaleo. Coll. No. 73.

Family CYTHERIDAE
Genus CYTHEROMORPHA Hirschmann, 1901

Cytheromorpha scrobiculata Alexander
Plate 15, figure 2

Cytheromorpha scrobiculata Alexander, 1934, Jour. Paleontology, vol. 8, no. 2, p. 223, pl. 32, fig. 19.

Carapace in side view narrow, elongate; highest at anterior end. Dorsal margin nearly straight, very slightly arched. Ventral margin slightly sinuate near middle. Anterior end broadly rounded, slightly oblique. Posterior end much narrower than anterior, bluntly rounded. Surface of valves coarsely pitted except along narrow margin on anterior end. Reticulation forms two narrow plications curving slightly upward. A narrow, crescent-shaped area at anterior end is smooth except for a few narrow radiating ridges. Length, .409 mm.; width, .143 mm.; height, .19 mm. This species is very rare, found only in Sample N-5.

C. scrobiculata is reported from the Paleocene and Eocene of the Gulf Coast states. Univ. Utah Micropaleo. Coll. No. 74.

Genus CYTHEROPTERON Sars 1865

Cytheropteron ? sp.
Plate 16, figure 3

Carapace in side view ovate. Highest anterior to middle. Dorsal margin arched. Ventral margin convex downward. Anterior end obliquely rounded; posterior end with short, compressed, acute, beak at middle. Carapace in dorsal view ovate; widest slightly posterior to middle. Surface of shell smoothly arches, ornamented with broad, shallow pits. Length, .59 mm., width, .21 mm.; height, .38 mm.

This specimen is referred to the genus Cytheropteron with reservations. The specimen was too poorly preserved to permit positive identification. Found occasionally in Sample N-17. Univ. Utah Micropaleo. Coll. No. 75.

Genus CYTHERE Muller 1885

Cythere denticulata Lankford, n. sp.
Plate 15, fig. 6

Carapace in side view elongate-ovate; greatest height in front of middle. Anterior end broadly rounded, slightly oblique, and finely denticulate on antero-ventral margin, radial canals strongly visible. Posterior end strongly compressed, acute, may or may not bear a single tubercle just beneath antero-ventral angle. Left valve slightly larger than right; overlap strongest on posterior end. Surface of shell sculptured by broad shallow pits. Carapace in dorsal view keeled-ovate; "eye tubercle" present over anterior end of hinge line. Beneath "eye tubercle" on left valve anterior margin a sharply defined pit, on right valve anterior margin a pit with semi-encircling fold beneath. Hinge consists of a strongly developed tooth at each end of hinge line, connected by a narrow bar in the left valve. Length, .82 mm.; width, .41 mm.; height, .50 mm.

C. denticulata differs from other species in outline, absence of alae, position of denticulation and surface ornamentation. Found sparingly in Samples N-14, N-16. Holotype: Univ. Utah Micropaleo. Coll. No. 76.

Cythere cf. C. delirata Jones and Sherborn
Plate 13, figure 11

Carapace in side view subtriangular to suboblong; greatest height anterior to middle. Posterior end of left valve sharply and evenly rounded; posterior end of right valve more acutely rounded

than left valve. Anterior ends of both valves similar, sharply rounded, oblique ventrally. Dorsal margin slightly arched; ventral margin strongly convex downward. Surface of carapace highly ornamented with furrows and punctae; furrows diverge up and down from median line becoming more or less concentric at the ends; punctae distributed centrally, aligned parallel to and grading intc the furrows. Punctae increase in number and serial proportion with maturity. Hingeline appears straight; hinge structure not seen. Length, .54 mm.; height, .31 mm.

This species compares favorably with C. delirata from Pleistocene deposits and Recent waters of England and northwestern Europe. No specimens of this particular shape and ornamentation have been reported from this country in deposits older than Recent. Found in Samples S-17, S-18. Univ. Utah Micropaleo. Coll. No. 77.

Genus CYTHEREIS Jones 1849

Cythereis coalvillensis Lankford n. sp.
Plate 16, fig. 1

Carapace oblong, highest in front. Dorsal margin straight; ventral margin straight to slightly convex downward. Dorsal and ventral margins subparallel, converging posteriorly. Anterior end slightly rounded, rimmed, moderately denticulate. Continuations of the anterior marginal rim extending as narrow ridges along dorsal and ventral margins; ventral ridges expanding laterally and terminating in pitted flanges; dorsal ridge with prominent node anterior to center and ending opposite ventral ridge. Posterior end rimmed, denticulate, compressed, broadly angled at middle. Surface of valves with median, longitudinal, dissected ridge, highest at middle, beginning behind anterior marginal rim, extending obliquely, posteriorly and upward and terminating at a point opposite the dorso-ventral angle. Short, low ridges connecting this median ridge with the dorsal and ventral

margins form a moderate reticulation. Length, .71 mm.; width, .33 mm.; height, .36 mm.

C. coalvillensis differs from other species in the strong dissection of the high, medial, longitudinal ridge, the sculpturing of the ventral flanges; the possession of the node forward of middle on the anterior margin. Found sparingly in Samples N-14, N-16. Holotype: Univ. of Utah Micropaleo. Coll. No. 78.

Genus CYTHERIDEA Bosquet 1852

Cytheridea cf. C. fabaformis (Berry)
Plate 15, figure 1

Cytherella fabaformis Berry, 1925, Am. Jour. Sci., ser. 5, vol. 9, p. 487, fig. 13.

Carapace in side view elongate-reniform; height equal to slightly more than half the length. Carapace highest anterior to middle. Dorsal margin arched. Ventral margin slightly arched. Anterior end somewhat narrowed, obliquely rounded. Posterior end broadly rounded, slightly oblique. No denticulation on periphery. Surface of valves marked by numerous pits; surface crenulated by furrows and ridges. On the central area of each valve are two or three parallel, slightly oblique, transverse furrows, each bearing a row of pits. A more prominent furrow extends longitudinally along posterior half of valve, slightly below the median line. Length, .517 mm.; width, .23 mm.; height, .27 mm.

This species best compares with C. fabaformis (Berry) reported from the Navarro formation of Texas. The absence of rim denticles anteriorly (present on the Texas specimen) is not sufficient evidence upon which to erect a new species. Other characteristics are identical. Found commonly in Samples N-14, N-16. Univ. Utah Micropaleo. Coll. No. 79.

Cytheridea trisulcata Lankford, n. sp.
Plate 15, figure 5

Carapace in side view elongate-reniform; (greatest height at center.) Dorsal margin broadly arched, ventral margin slightly convex downward, slightly sinuate anteriorly. Anterior end broadly rounded; posterior end bluntly rounded. In dorsal view, hinge line is straight. Left valve overlaps right, least overlap along ventral border. Surface of carapace coarsely pitted. Central portion of shell has three transverse, parallel sulci of equal length, each containing a row of pits. Sulci do not extend to dorsal and ventral margins. No denticles or tubercles present as rim ornamentation. Length, .94 mm.; width, .44 mm.; height, .34 mm.

C. trisulcata appears to be closely related to C. ruginosa Alexander found in the Midway (Paleocene) of Arkansas and Texas but differs in the following characteristics: length-height ratio more than 2:1, greatest height at center and not anterior to middle, presence of three well defined sulci, absence of anterior and posterior rim tubercles. This form is found sparingly in Samples N-14, N-16. Holotype: Univ. of Utah Micropaleo. Coll. No. 80.

Cytheridea posterovata Lankford n. sp.
Plate 15, figure 3

Carapace in side view elongate-ovate; highest anterior to middle. Dorsal margin arched. Ventral margin straight along posterior half, anterior half sinuate. Anterior end broadly rounded, slightly oblique dorsally. Posterior end sharply and evenly rounded. No denticles or tubercles present on anterior or posterior periphery. Left valve larger than right; overlaps dorsal and ventral margins more strongly than at ends. Surface ornamented with shallow punctations distributed centrally and lacking on the marginal areas of valves. Punctations arranged evenly except for a single or occasionally double pitted, transverse furrow. Length, .69 mm.; width, .31 mm.; height, .52 mm.

C. posterovata differs from other species of the genus by having a more gentle rounding when viewed from the side, especially at the posterior end which is ovate rather than acute in outline. This species appears to be closely related to C. fornicata from the Midway of Arkansas and the Kincaid (Paleocene) of Texas but differs in outline and lack of posterior denticulation. Found abundantly in Samples N-2, N-5, N-14 and less abundantly in Sample N-16. Holotype: Univ. Utah Micropaleo. Coll. No. 81.

Cytheridea posterovata Lankford n. sp., var. alta n. var.
Plate 15, figure 4

Carapace in side view subelongate-ovate; highest anterior to middle. Dorsal margin broadly arched. Ventral margin straight to convex downward along posterior half; anterior half sharply sinuate. Anterior end broadly rounded and slightly oblique dorsally. Posterior end evenly and more sharply rounded than anterior. Left valve moderately overlaps right around entire periphery, less pronounced at either end than along dorsal and ventral margins. Surface of carapace ornamented by shallow pits distributed on central portion of valves. Pits form one to three shallow, transverse, pitted furrows. Length, .89 mm.; width, .36 mm.; height, .53 mm.

C. posterovata var. alta has all the characteristics of C. posterovata except for variations of furrowing and the decreased length to height ratio. This variety occurs abundantly in Sample N-14 and less abundantly in Sample N-16. Holotype: Univ. of Utah Micropaleo. Coll. No. 82.

Cytheridea perforata (Roemer)
Plate 16, figure 2

Cytherina perforata F. A. Roemer, Neues, Jahrb. f. Miner., etc., 1838, p. 516, pl. 6, fig. 11.

Cytheridea perforata (Roemer). Jones, Monogr. Tert. Entom. Engl., Paleontogr. Soc. London, 1856, p. 44, pl. 4, figs. 14a-3.
Jones and Hinde, Suppl. Monogr. Cret. Entom. Eng. and Irel., Paleontogr. Soc. London, 1890, p. 29, pl. 1, figs. 1-4.

Carapace in side view elongate-ovate, highest anterior to middle. Anterior end broadly rounded, oblique dorsally; posterior end more sharply rounded than anterior. Dorsal margin arched; ventral margin gently convex downward. Left valve overlapping right nearly equally. In dorsal view, carapace widest at middle, tapering uniformly to very sharply rounded ends. Surface coarsely pitted, evenly distributed. Length, .42 mm.; width, .19 mm.; height, .20 mm.

This species is reported from the Taylor formation of Texas and the Pierre shale of the western interior United States. Found abundantly in Samples N-14, N-16. Univ. Utah Micropaleo. Coll. No. 83.

Family CYPRIDAE Baird, 1846
Genus CANDONA Baird, 1850

Candona acutimarginata Lankford, n. sp.
Plate 13, fig. 1

Carapace in side view elongate-reniform; greatest height posterior to middle. Dorsal margin arched; ventral margin moderately concave downward. Dorsal and ventral margins nearly parallel. Posterior end broadly rounded; anterior end more sharply rounded than posterior, oblique dorsally. On dorsal view, ends of shell flattened toward hingeline; strongest on anterior end. Left valve appears to be slightly larger with elongate, medial flange overlapping right valve. Surface of valve is smooth, unornamented. Length, .54 mm.; width, .13 mm.; height, .23 mm.

C. acutimarginata appears not to be closely related to other known species of Candona and differs in the following aspects: general lateral outline, length-height ratio, the compressed areas at both ends of each valve. Found commonly in Samples S-4, S-17, S-18. Holotype: Univ. Utah Micropaleo. Coll. No. 84.

Candona subovata Jones
Plate 13, fig. 6

Carapace in side view subovate to subreniform; greatest height slightly posterior to or at center. Dorsal margin gently and broadly arched; ventral margin straight along entire length or straight along anterior two-thirds and slightly sinuate and convex downward along posterior one-third. Posterior end broadly rounded; anterior end more sharply rounded than posterior, slightly oblique. Surface of carapace smooth, without ornamentation. Hingeline is straight; hinge appears simple. Length, .57 mm.; height, .35 mm.

C. subovata has been reported only from the 'Montana formation", northeastern Utah (Coalville); exact location is not known. Found commonly in Samples S-4, S-17, S-18. Univ. Utah Micropaleo. Coll. No. 85.

Candona cf. C. subovata Jones
Plate 13, fig. 2

Carapace in side view subovate—reniform; highest slightly anterior or at middle. Dorsal margin gently and broadly arched; ventral margin sinuous, concave submedially. Posterior end broadly rounded; anterior end more sharply rounded than posterior, slightly oblique dorsally. Surface of carapace smooth, without ornamentation. Hinge appears simple. Length, .32 mm.; height,.17 mm.

This species is best compared with C. subovata. Because of its smaller size and thinner appearance, the figured specimens are believed to be immature forms. Found commonly in Samples S-4, S-17, S-18. Univ. of Utah Micropaleo. Coll. No. 86.

Candona pagei Swain
Plate 13, figure 8

Candona pagei Swain, 1949, Jour. Paleontology, vol. 23, no. 2, pp. 174-175, pl. 32, figs. 1-4, 6, 7.

Carapace in side view subovate-reniform; highest anterior to center. Dorsal margin broadly arched; ventral margin slightly sinuate anterior to center. Anterior end broadly rounded, slightly oblique ventrally; posterior end more sharply rounded than anterior, slightly extended submedially. Hinge line of left valve flanged, hinge apparently simple. Surface is ornamented by fine pits more or less aligned medially on central part of valve. Length, .482 mm.; height, .31 mm.

C. pagei has been reported in the Paleocene and basal Eocene of the Rocky Mountain and western interior regions. Found sparingly in Samples S-4, S-5. Univ. of Utah Micropaleo. Coll. No. 87.

Candona cf. C. ? striatula Swain
Plate 13, figure 10

Candona ? striatula Swain, 1946, Jour. Paleontology, Vol. 20, no. 6, p. 546, pl. 83, figs. 4-6.

Carapace in side view subreniform; highest posterior to center. Dorsal margin gently arched; ventral margin straight to gently concave. Anterior end more sharply rounded than posterior; anterior end slightly oblique dorsally. Size relationship of right and left valves not known. Surface of carapace ornamented with fine, closely spaced, longitudinal grooves and ridges which branch and become discontinuous terminally. Length, .42 mm.; height, .29 mm.

This specimen best compares with C. ? striatula, described from the middle Tertiary of Brazil, in shell outline, proportions, and diagnostic striate surface. Occurs abundantly in Sample S-5. Univ. of Utah Micropaleo. Coll. No. 88.

Candona sp.
Plate 13, figures 3,4

Carapace in side view subreniform; greatest height slightly anterior to middle. Dorsal margin moderately arched; ventral straight to slightly concave. Posterior end broadly rounded; anterior end more sharply rounded than posterior, slightly oblique dorsally. Surface and hinge simple. Figure 3: length, .30 mm.; height, .21 mm. Figure 4: length, .43 mm.; height, .31 mm.

These specimens are very fragile and poorly preserved. They have the generic characteristics of Candona; specific determination could not be made. Univ. of Utah Micropaleo. Coll. No. 89.

Genus METACYPRIS Brady, 1870

Metacypris ? sp.
Plate 13, fig. 5

Carapace in side view oblong-subquadrate. Dorsal margin nearly straight; ventral margin sinuate. Posterior end broadly rounded, very slightly angled dorso-ventrally. Anterior end more sharply rounded than posterior. In dorsal view, carapace slightly constricted centrally. Surface of shell ornamented by small quadrate pits arranged in concentric furrows paralleling the periphery. Valve depressed centrally by a broad, shallow sulcus extending from the ventral margin to a point just above median. Length, .43; height, .26 mm.

This species is doubtfully referred to the genus Metacypris on the basis of poorly preserved shell characters. Found rarely in Samples S-17, S-18. Univ. of Utah Micropaleo. Coll. No. 90.

Metacypris ? sp.
Plate 16, figure 5

This appears to be an internal cast of Metacypris ? sp. The most diagnostic features of the figured species are: the straight ventral margin; the sub-parallel dorsal margin; the broad, deep sulcus, especially prominent in dorsal view; the straight hinge line; the equality of valve size. Length, .63 mm.; width, .30 mm.; height, .34 mm.

This species is represented by 6 specimens from Sample N-2. Univ. Utah Micropaleo.Coll. No.9L

Genus CYPROIS Zenker, 1854

Cyprois cf. C. marginata (Strauss)
Plate 13, figure 9

Cypris marginata Strauss, 1821, Mem. Mus. Paris, vol. 7, p. 59, pl. 1, figs. 20-22.

Cypris flava Zaddach, 1844, Syn. Crust. Prodr., p. 33.
Cypris dispar Fischer, 1851, Ueber das Genus Cypris, p. 142, pl. i, figs. 1-12, pl. ii, figs. 1-6.
Cyprois dispar (Fischer), Zenker, 1854, Archiv. fur. Naturgesch., p. 81.
Cyprois dispar (Fischer), Lilljeborg, 1883, Int. Fish. Exhib., London, Sweden Cat., p. 147.
Cyprois flava (Zaddach), Brady and Norman, 1889, Trans. Roy. Dublin Soc., vol. IV, ser. II, sec. 1, p. 97, pl. viii, figs. 18, 19, pl. xii, figs. 13-21, 38.
Cyprois marginata (Strauss), Sars, 1928, Crustacea of Norway, p. 103, pl. XLVII, fig. 2, pl. XLVIII.
Cyprois cf. C. marginata (Strauss), Swain, 1949, Jour. Paleontology, vol. 23, no. 2, pp. 177-178, pl. 32, figs. 8-10, 14, 15.

Carapace in side view subovata; highest at center. Dorsal margin arched, nearly pointed; ventral margin gently convex downward. Anterior end somewhat more broadly rounded than posterior. Hinge line straight in dorsal view; valve somewhat compressed terminally. Surface smooth, moderately convex. Length, .48 mm.; height, .32 mm.

This specimen is smaller than those described and figured from the Paleocene and Eocene of southwestern Wyoming; in other characteristics, the species appears to be the same. Found very rarely in Sample S-3. Univ.Utah Micropaleo. Coll. No.92.

Genus CYPRIDEA Bosquet, 1852

Cypridea skeeteri Peck
Plate 13, figure 7

Cypridea skeeteri Peck, Jour. Paleontology, vol. 25, no. 3, pp. 316, 318, pl. 49, figs. 15-26.

Carapace in side view elongate-ovate; greatest height anterior to center. Dorsal margin straight; ventral margin straight along posterior half, convex

downward along anterior half. Posterior end broadly rounded, slightly oblique ventrally, may or may not be denticulate. Anterior end more broadly and evenly rounded than posterior end, beaked and notched to a greater or lesser degree antero-ventrally. Anterior margin with or without denticles. Two subparallel, deep, sinuate sulci extending from the dorsal margin, slightly anterior to center, obliquely downward to median. Surface of valve sculptured by shallow pits arranged in concentric semicircles around sulci; ornamented with nodes of different sizes, distributed over anterior and posterior portions. Length, .68 mm.; height, .43 mm.

The diagnostic features of C. skeeteri are the prominent and deep sulci, the pitted surface, and the occurrence of nodes. It is reported from the Upper Cretaceous of southwestern Wyoming. Found primarily as fragment. Occurs sparingly in Samples S-4, S-5, S-17, S-18. Univ. Utah Micropaleo. Coll. No. 93.

Subphylum VERTEBRATA
Class PISCES
Dermal Plate
Plate 14, figure 9

Only one specimen was found (Sample N-4) and is referred to as a dermal plate from an unknown species of fish. Univ. Utah Micropaleo. Coll. No. 100.

Class PISCES (?)

Teeth
Plate 14, fig. 10-13

The four figured specimens represent the four primary types found in all fossiliferous samples. Univ. of Utah Micropaleo. Coll. No. 101.

Class (Undetermined)

Claw
Plate 14, figure 14

Only one specimen was found (Sample N-5) and appears to be of chitinous composition. Univ. Utah Micropaleo. Coll. No. 102.

Phylum CHLOROPHYTA
Class CHARAPHYCEAE
Order CHARALES
Family CHARACEAE
Genus ACLISTOCHARA Peck, 1937, amend. 1941

Aclistochara compressa (Knowlton)
Plate 12, figures 3-7

Chara compressa Knowlton, 1883, Bot. Gazette, vol. 13, pp. 156-157, figs. 1, 2.
Chara compressa Groves, James, 1933, Fossilium Catalogus, II, Plantae, para 19, p. 14.
Aclistochara compressa (Knowlton) Peck, 1948, Jour. Paleontology, vol. 22, no. 1, pp. 87-88, pl. 21, figs. 31-33.

Gyrogonite in lateral view oblate, slightly broader than high; truncate at summit; 10 to 12 convolutions visible between base and summit Gyrogonite has five, sinistrally spiraled enveloping cells. Spirals consist of either intercellular ridges and cellular furrows or filled, convex enveloping cells. In summit view, spirals become narrow, turn abruptly into the center and expand in width. Basal aperture subangular. Node cell a pentagonal plug with near-circular flange above; often found as a discrete microfossil. Height, .75 mm.; width, .89 mm.; diameter of basal aperture, .13 mm.

The species figured and described by the present writer differs from Peck's holotype in the absence of preserved coronula cells. This absence appears not to be a diagnostic difference. A. compressa is reported from the basal Paleocene of Alberta, Canada, and from the Paleocene and Eocene of Utah and Wyoming. Found abundantly in Samples S-4, S-5, S-17, S-18. Univ. Utah Micropaleo. Coll. No. 94.

Aclistochara uintaensis Lankford, n. sp.
Plate 12, figs. 1-2

Gyrogonite in side view ellipsoid, higher than broad; truncate at summit; 11 to 13 convolutions visible between base and summit. Spirals consist of five sinistrally spiraled intercellular ridges and adjacent cellular furrows. In summit view, expanded spirals turn abruptly inward and downward to the depressed center. Basal aperture small, subangular. Node cell not observed. Height, .39 mm.; width, .32mm.; diameter of basal aperture, .03 mm.

This species compares in size and number of visible spirals to Chara inconspicua but the truncate, depressed summit of the species described and illustrated by the present writer removes it from the genus Chara. In outline, size, and number of convolutions, A. uintaensis differs from other reported species of Aclistochara. Found abundantly in Sample S-3, N-2, N-4. Holotype: Univ. Utah Micropaleo. Coll. No. 95.

OTHER PLANT REMAINS

Seeds (?)
Plate 14, figs. 1-8

Due to a lack of available literature, little is known to the author about these interesting but poorly preserved microfossils. The specimens figured on Plate 14 represent the principal types and shapes of seeds (?) found. All specimens observed were strongly compressed and poorly preserved.

Figure 1, Univ. Utah Micropaleo. Coll. No. 103.
Figure 2, Univ. Utah Micropaleo. Coll. No. 104.
Figure 3, Univ. Utah Micropaleo. Coll. No. 105.
Figure 4, Univ. Utah Micropaleo. Coll. No. 106.
Figure 5, Univ. Utah Micropaleo. Coll. No. 107.
Figure 6, Univ. Utah Micropaleo. Coll. No. 108.
Figure 7, Univ. Utah Micropaleo. Coll. No. 109.
Figure 8, Univ. Utah Micropaleo. Coll. No. 110.

Editor's Note

The following illustrative section contains:

Plates I through VIII, pages 112-127.
Tables II through IV, pages 128-132.
Plates IX through XVI, pages 134-149.
Appendix A - Sample Localities - Maps
Figures 6, 7, and 8, pages 150 through 152.

PLATE I

Figures 1, 2. Reophax sp. (p. 29).
3, 4. Haplophragmoides excavata Cushman and Waters, side view (p. 30).
5. Haplophragmoides kirki Wickenden (p. 31).
a. Peripheral view.
b. Side view.
6. Haplophragmoides sp. (?) (p. 31).
a. Side view.
b. Peripheral view.
7, 8. Marginulina austinana Cushman (p.32).
9-15. Marginulina austinana Cushman var. directa Cushman (p. 32).
16-18. Marginulina austinana Cushman var. wasatchensis Peterson, n. var. (p. 33).
19. Dentalina sp. (p. 34).
20-21. Dentalina gracilis D'Orbigny (p.34).
22-23. Dentalina basiplanata Cushman (p35).
24. Dentalina cf. D. angusticostata Cushman (p. 36).
25-26. Dentalina frontierensis Peterson, n. sp. (p. 37).
27. Dentalina solvata Cushman (p.37).

PLATE I.

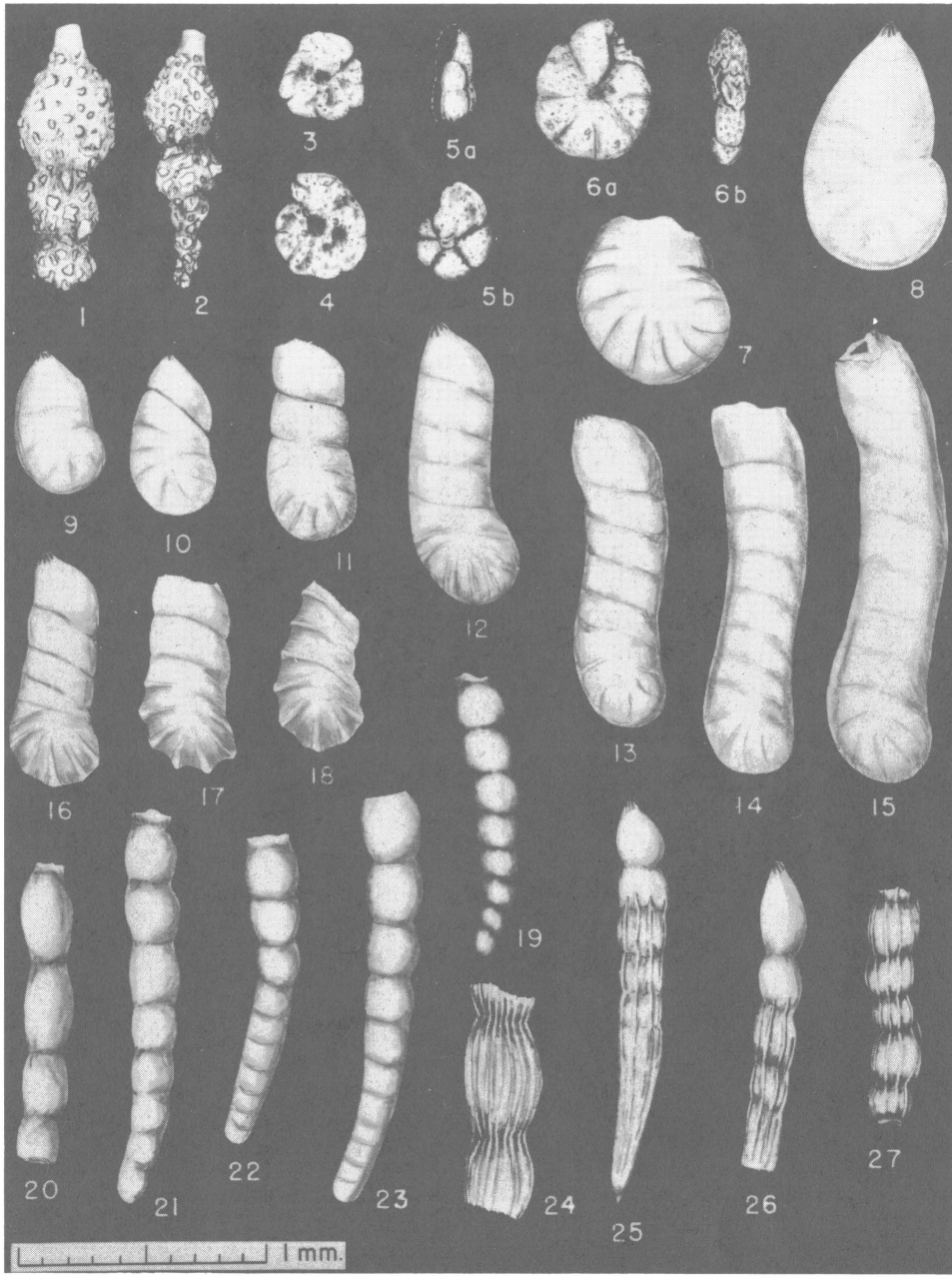

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PLATE II

Figures 1, 2. Dentalina coalvillensis Peterson, n. sp. (p. 38).

3, 4. Dentalina utahensis Peterson, n. sp. (p. 38).

5, 6. Dentalina summitensis Peterson, n. sp. (p. 39).

7, 8, 9. Frondicularia inversa Reuss (p.39).

10, 11. Ramulina arkadelphiana Cushman (p. 41).

12. Valvulineria infrequens Morrow (p.42).
   a. Dorsal view.
   b. Ventral view.
   c. Peripheral view.

13. Gyroidina sp. (?) (p. 42).
   a. Ventral view.
   b. Dorsal view.

14. Epistomina caracolla (Roemer) (p.43).
   a. Ventral view.
   b. Dorsal view.

15. Globigerina cretacea D'Orbigny (p. 45).
   a. Dorsal view.
   b. Ventral view.

PLATE II.

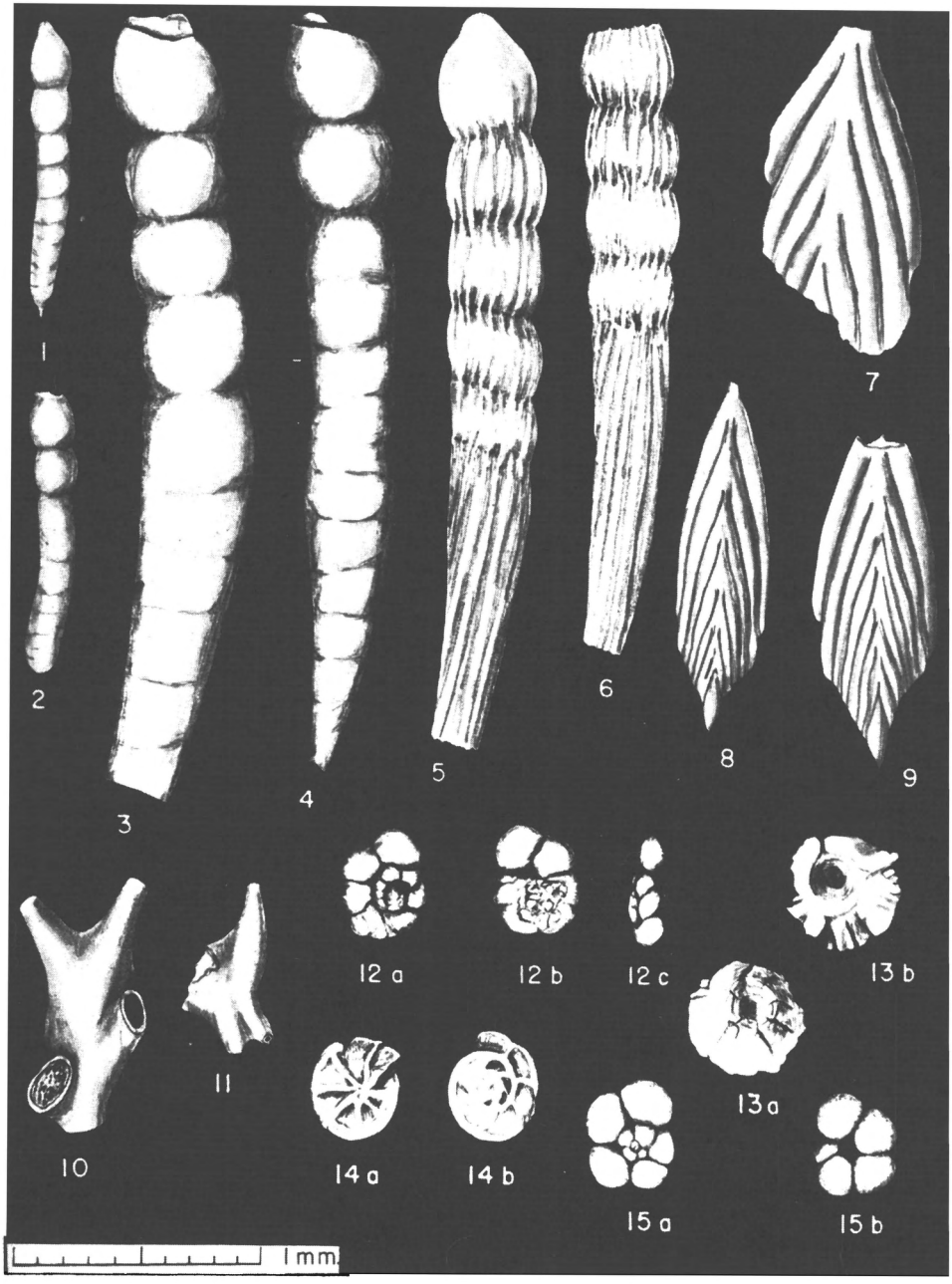

PLATE III

Figures 1. Cytherella parallela (Reuss) (p. 46).
a. Left valve.
b. Right valve.
c. Dorsal view.

2. Cytherella bullata Alexander (p.47).
a. Left valve.
b. Right valve.
c. Dorsal view.

3. Paracypris cf. P. tenuicula Alexander (p. 48).
a. Right valve.
b. Left valve.
c. Dorsal view.

4. Eucythere brownstownensis Alexander (p. 49).
a. Right valve.
b. Left valve.
c. Dorsal view.

5-9. Cythereis thomasi (Israelsky) Alexander (p. 49).
5. Interior right valve.
6. Interior left valve.
7. Dorsal view.
8. Ventral view.
9. Lateral view.

10. Orthonotacythere sp. (p. 49).
a. Lateral view.
b. Dorsal view.

PLATE III.

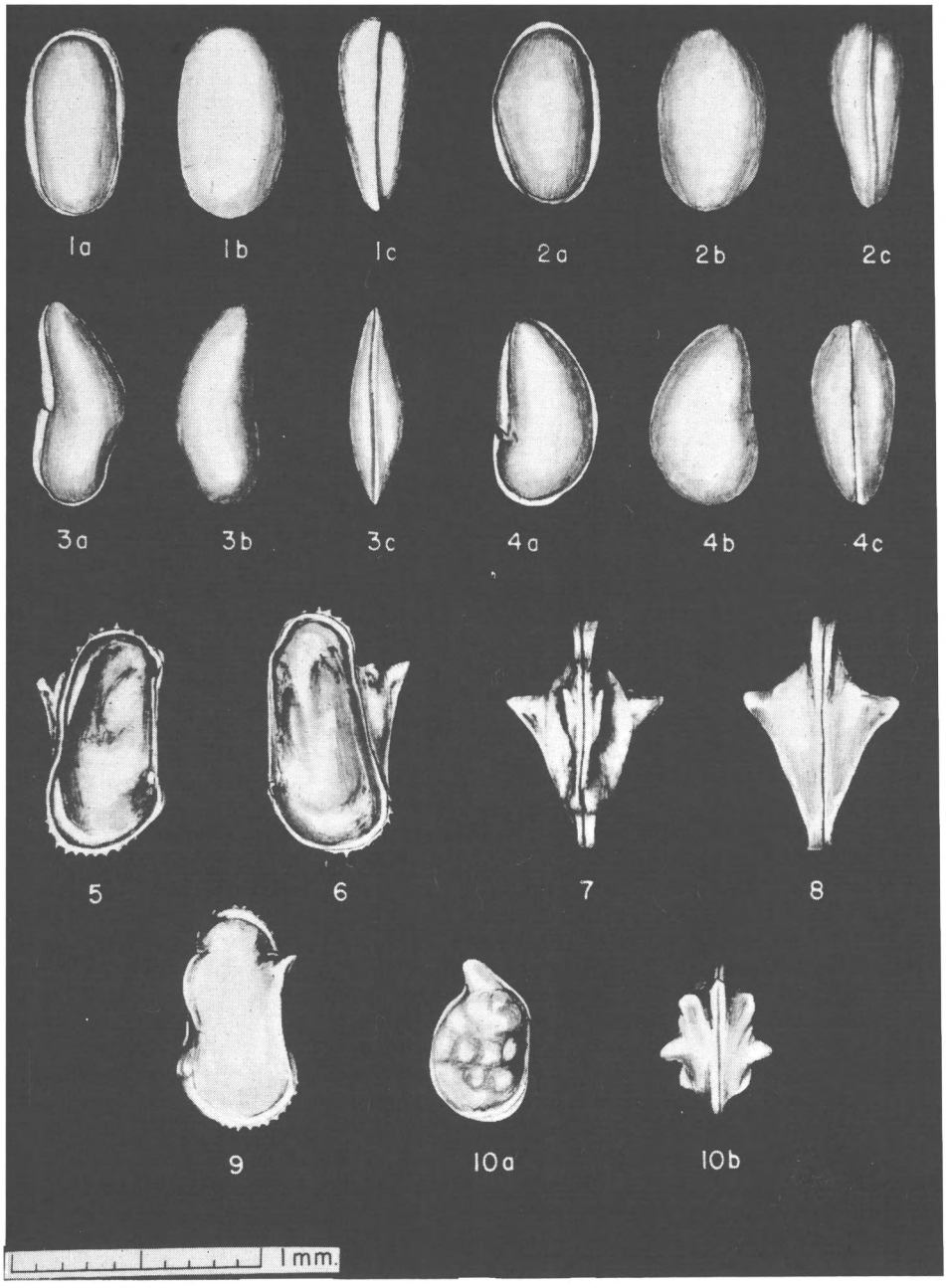

PLATE IV

Figures 1-4. Proteonina difflugiformis (H. B. Brady) Rhumbler, side view, X 70, (p. 52).

5. Reophax constrictus (Reuss) Cushman, side view, X 32, (p. 51).

6. Haplophragmoides rugosa Gauger, n. sp., dorsal view, X 35, (p. 53).

7,8,9,13. Haplophragmoides calcula Cushman and Waters.
- 7. Dorsal view, X 38. (p. 53).
- 8. Dorsal view, X 24. (p. 53).
- 9. Dorsal view, X 34. (p. 53).
- 13. Dorsal view, X 30. (p. 53).

10. Haplophragmoides excavata Cushman and Waters, ventral view, X 27, (p. 54).

11,12. Haplophragmoides inflata Gauger, n. sp., (p. 54).
- 11. Dorsal view, X 32.
- 11a. Peripheral view, X 32.
- 12. Ventral view, X 32.

PLATE IV.

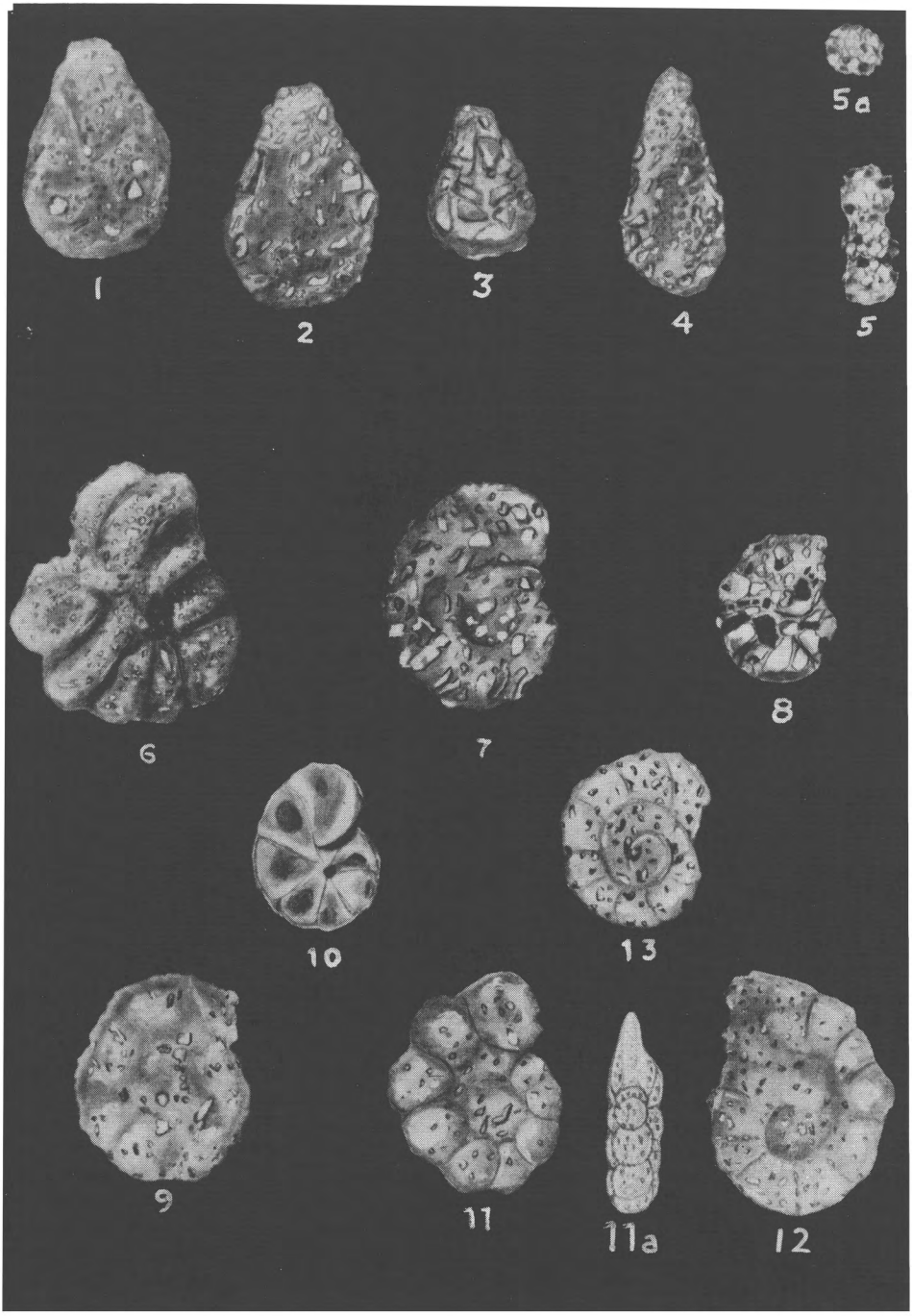

PLATE V

Figures 1-8. Ammobaculites coprolithiformis (Schwager) Cushman, showing slight variations in form, all views X 27. (p. 55).

9-10. Ammobaculites stephensoni Cushman, showing variations showing excavated umbilicus, X 35 . (p. 56).

11-18. Ammobaculites fragmentarius Cushman, showing variations in form, grain size, X 19. (p. 56).

19. Ammobaculites texanus Cushman, ventral view, X 27. (p. 57).

20-24. Spiroplectammina navarroana Cushman X 40. (p. 58).

25-27. Spiroplectammina lalickeri Albritton and Phleger, X 46. (p. 58).

26. Side view showing typical twisted form, X 46.

PLATE V.

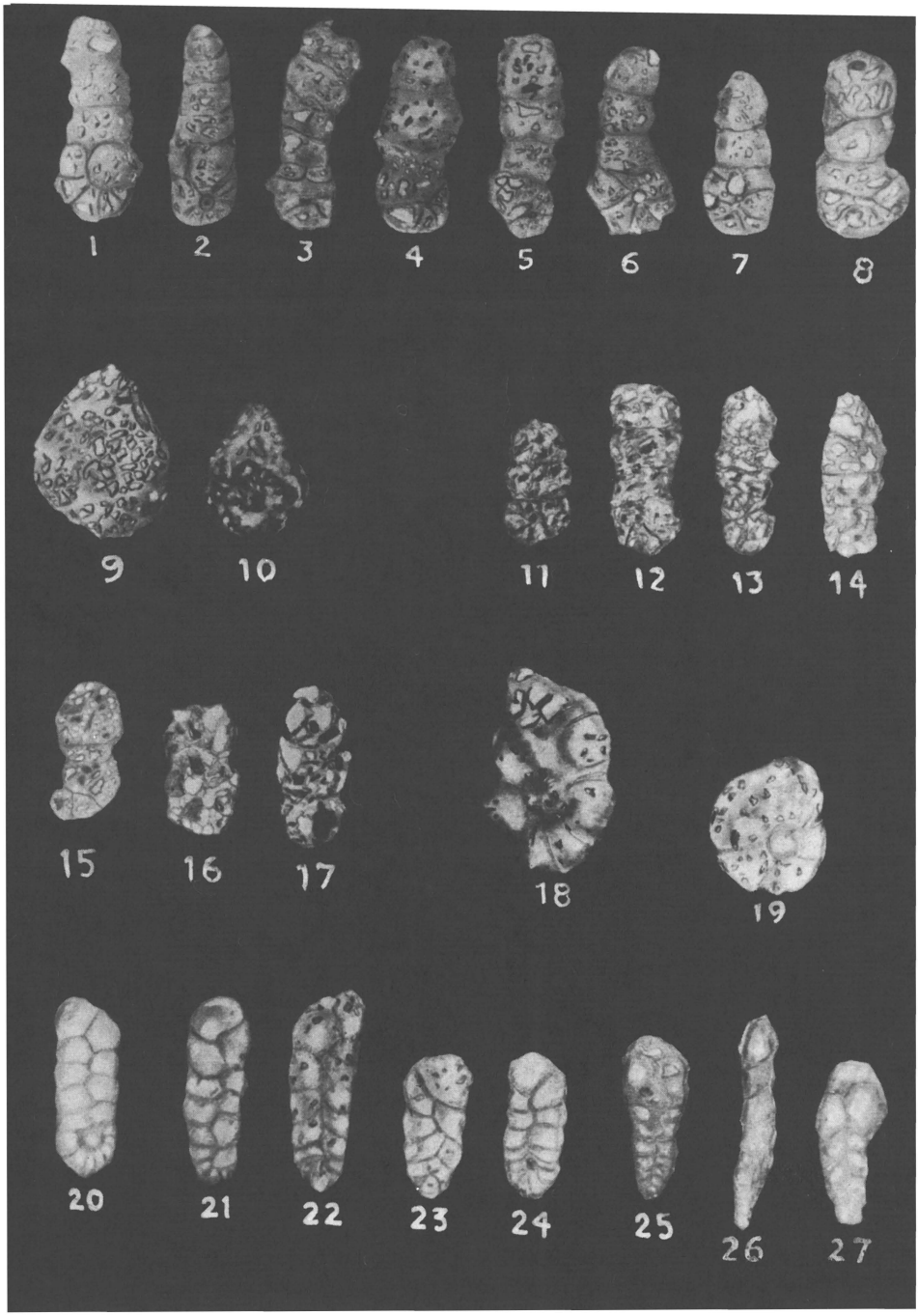

PLATE VI

Figures 1,1a,2. Spiroplectammina dentata (Alth) Cushman (p. 59) and Jarvis var. tenuisa Gauger, n. var.
1. Side view, X 23.
1a. Top view, showing typically compressed test, X 23.
2. Edge view, X 23.

3,3a,4-6. Bigenerina elongata Gauger, n. sp. (p. 59).
3a. Edge view showing imbricate arrangement of chambers, X 32.
3,4-6. Side views, showing variation in this form, X 32.

7-11. Textularia washitaensis Carsey, (p. 60). Side views showing typical tests, X 32.

12,13,13a. Textularia inflata Gauger, n. sp., (p. 60).
12. Edge view showing arrangement of chambers and aperture, X35.
13. Side view showing typically inflated chambers, X 35.
13a. Top view showing lobed final chamber, X 35.

14,14a-16. Marssonella conica Gauger, n. sp.,
14. Bottom view showing tilted axis of test, X 25.(p. 62)
14a. Aperture view of genotype, X 25.
15. Genotype, X 25, side view.
16. Side view of another specimen shows arrangement of chambering, X 25.

17-19. Dorothia bulletta (Carsey) Plummer (p. 62).
17. Side view showing aperture, X 50.
18. Side view, X 50.
18a. Top view showing cylindrical outline, X 50.
19. Side view showing variation in last-formed chamber, X 50

20. Trochammina diagonis (Carsey) Cushman and Waters. Dorsal view X 37. (p.64)

21,22. Trochammina taylorana Cushman (p. 64).
21. Dorsal view, X 57.
22. Ventral view, X 100.

23. Trochammina excavata Gauger, n. sp. (p. 65). Dorsal view of holotype, X 72.

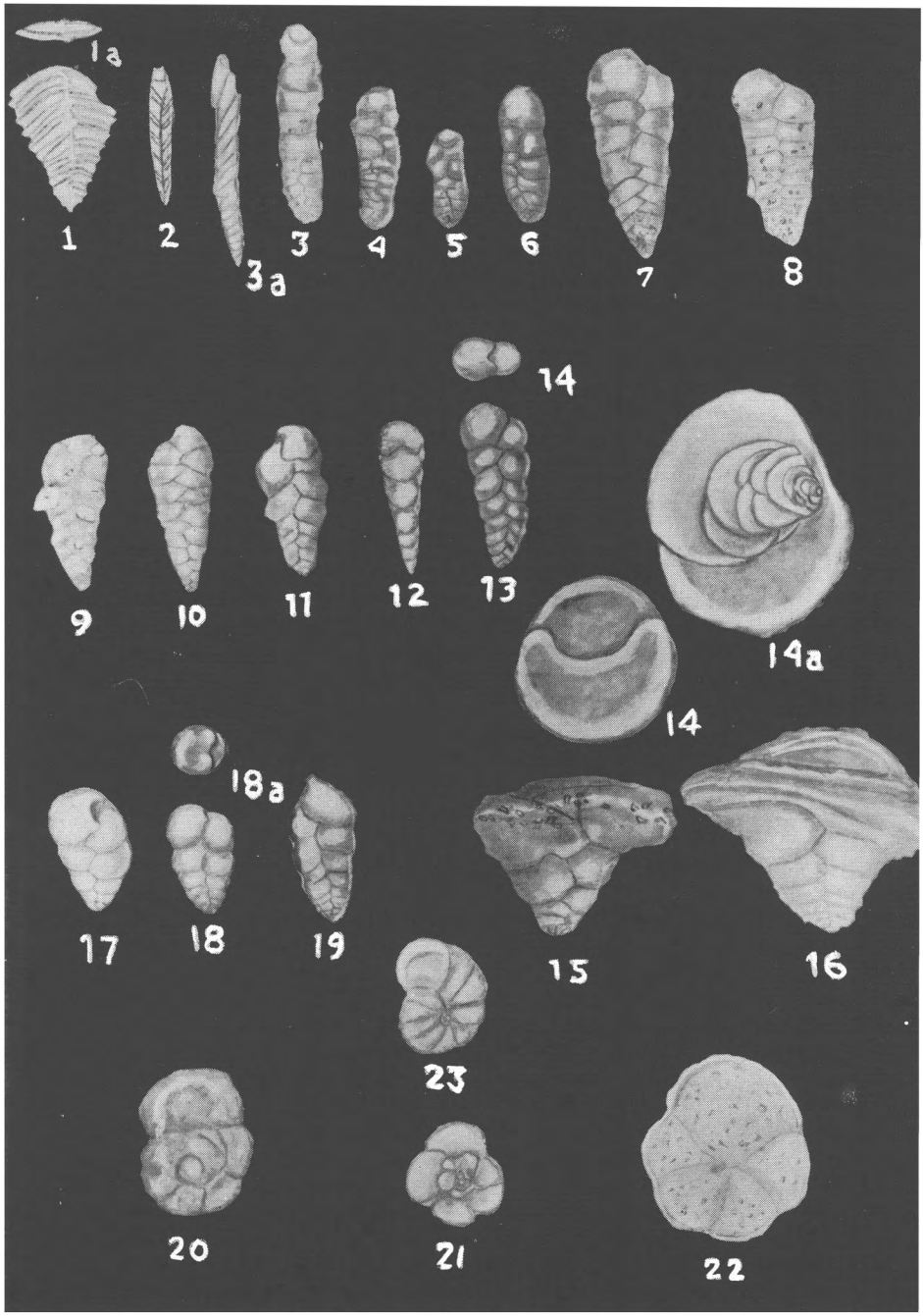
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PLATE VII

Figures 1-2. Robulus munsteri (Roemer) Cushman, (p. 66).
1. Side view showing well developed umbilical plug, X 16.
2. Edge view showing arrangement of sutures across periphery, X 16.

3-5. Lenticulina rotulata Lamarck, (p.67).
3. Dorsal view X 21.
4. Peripheral view showing apertural face, X 21.
5. Ventral view, showing umbilical plug, X 21.

6-10,14-16. Palmula pilulata Cushman (p. 75).
6. Ventral view, X 18.
7. Apertural view, X 18.
8. Dorsal view, X 18.
9. Ventral view, X 15.
10. Dorsal view, X 10.
14. Dorsal view, X 22.
15. Ventral view, X 30.
16. Apertural view, X 30.

11-13. Planularia inflata Gauger n. sp. (p. 67).
11. Ventral view, X 34.
12. Enlarged view of same, X 54.
13. Apertural view, X 34.
13a. Dorsal view, X 34.

17,17a,18. Planulina sp. (p. 86).
17. Dorsal view, X 35.
17a. Apertural view X 35.
18. Ventral view, X 35.

PLATE VII.

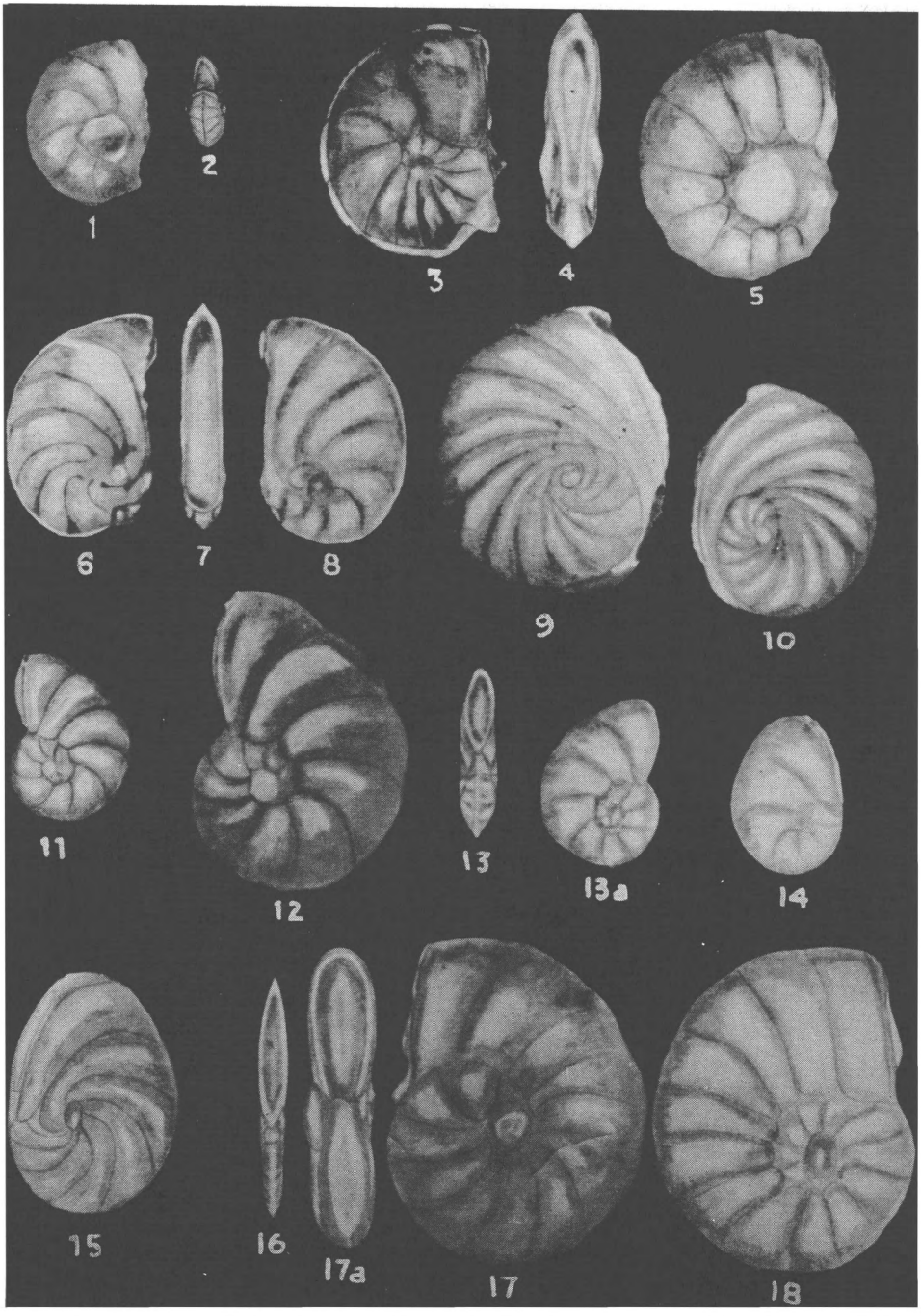

PLATE VIII

Figures 1. Marginulina cretacea Cushman (p. 68). Side view, X 30.

2. Marginulina texasensis Cushman (p.69). Side view, X 34.

3-6. Dentalina gracilis D'Orbigny (p. 70). 3. Microspheric form, X 22. 4-6. Megalospheric form, X 22.

7. Dentalina solvata Cushman (p. 71). Megalospheric form, X 22.

8. Nodosaria affinis Reuss (p. 70). View of final two chambers, X 22 .

9-11. Vaginulina webbervillensis Carsey, Three views of broken specimens, X 22. (p. 72)

12. Frondicularia clarki Bagg. (p.74). Side view of broken specimen, X 22 .

13,15. Frondicularia undulosa Cushman (p.74). Side views showing typical undulating edges, X 22.

14,16-18. Frondicularia archiaciana D'Orbigny, (p. 72). 17. Side view showing typical longitudinal costae, X 22.

PLATE VIII.

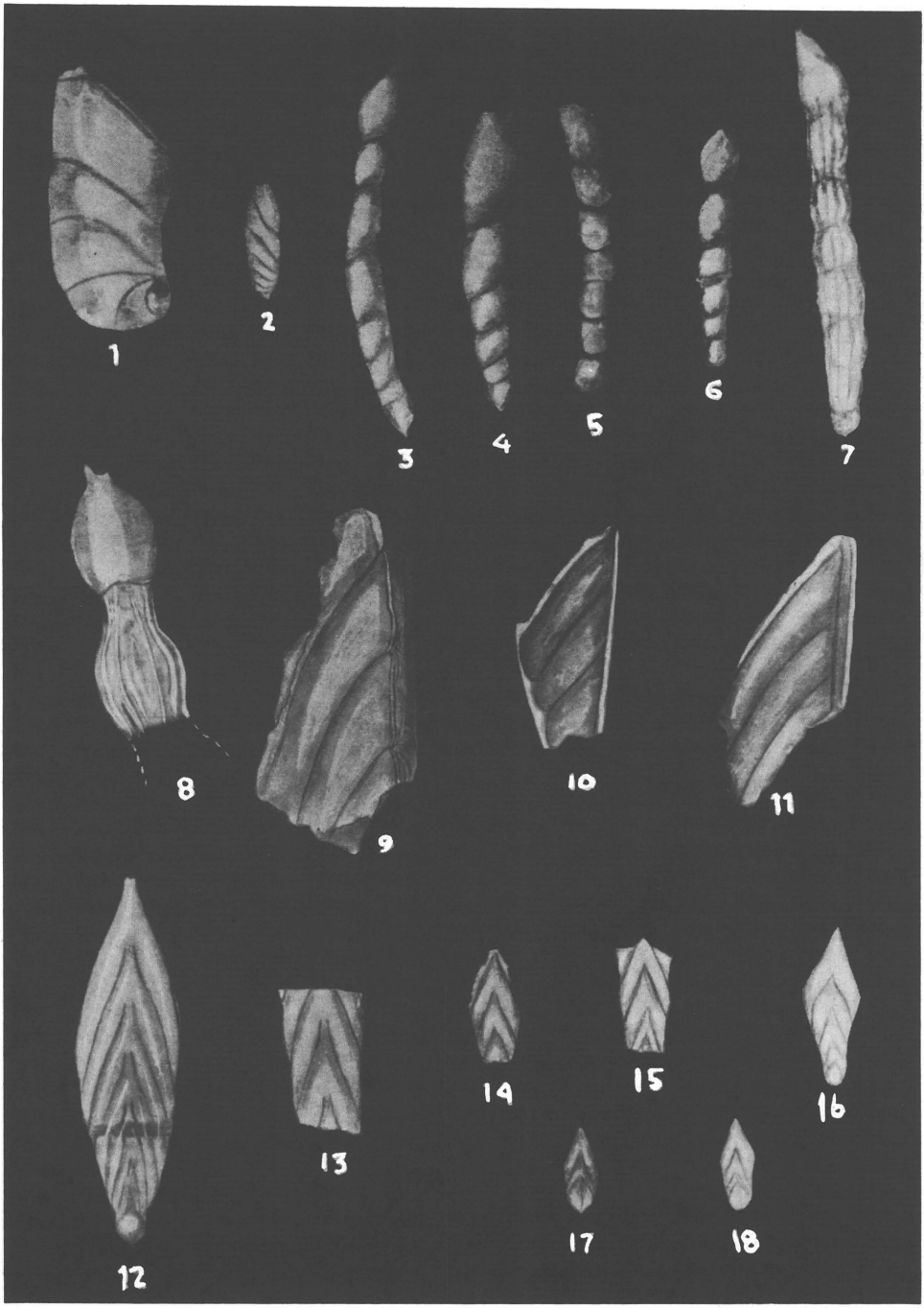

TABLE II
CHECKLIST OF MICROFAUNA OF THE FRONTIER FORMATION

VERTICAL DISTRIBUTION OF FRONTIER FORMATION MICROFOSSILS IN THE GULF COASTAL REGION

SPECIES	Eagle Ford shale	AUSTIN AGE: Eutor tongue	AUSTIN AGE: Bonham marl	AUSTIN AGE: Selma ck. (lower part)	AUSTIN AGE: Austin chalk	AUSTIN AGE: Brownstown marl	AUSTIN AGE: Gober tongue	TAYLOR AGE: Taylor marl (lower part)	TAYLOR AGE: Ozan formation	TAYLOR AGE: Selma ck. (middle part)	TAYLOR AGE: Wolfe City sand	TAYLOR AGE: Pecan Gap chalk	TAYLOR AGE: Annona chalk	TAYLOR AGE: Taylor marl (upper part)	NAVARRO AGE: Saratoga chalk	NAVARRO AGE: Neylandville marl	NAVARRO AGE: Selma ck. (upper part)	NAVARRO AGE: Ripley formation	NAVARRO AGE: Nacatoch sand	NAVARRO AGE: Prairie Bluff chalk	NAVARRO AGE: Owl Creek formation	NAVARRO AGE: Corsicana marl	NAVARRO AGE: Arkadelphia marl	NAVARRO AGE: Kemp clay	SAMPLE NUMBERS: 20	21	25	26	27	28	29	30	31	32	40	41	42	43	44	45	46
FORAMINIFERA:																																								
Haplophragmoides excavata								X		X	X					X		X				X	X	X												C	F	F	
Marginulina																																								
austinana					X	X	X																															R		
Marginulina austinana																																								
var. directa			X		X		X	X			X															R			R		C	F	R	C	F	R	F	F	A	A	A	F
Dentalina																																								
gracilis			X		X	X	X	X					X	X							X		X	X	X												R	F			
Dentalina																																								
basiplanata								X		X	X	X	X	X	X	X	X	X	X	X	X		X	X	X												F	F		

(A) = Abundant
(C) = Common
(F) = Few
(R) = Rare
(?) = Identification questionable

Dentalina																																									
solvata							X						X	X			X																						R		
Frondicularia																																									
inversa					X	X	X								X				X				X														R	F	F	R	
Ramulina																																									
arkadelphiana																					X		X	X														R	R		
Valvulineria																																									
infrequens			X		X	X		X	X																													R			
Epistomina																																									
caracolla								X			X	X		X		X	X	X	X		X	X		X	C	C	F	C	C	F		F	A	A	F	F		F	F	F	F
Globigerina																																									
cretacea	present in most upper Cretaceous strata																																	F		R		A	C	F	
OSTRACODA:																																									
Cytherella																																									
parallela						?	X	X	X	X		X	X	?																								R		R	?
Cytherella																																									
bullata						X	X	X	X	X		X																										C	F	C	?
Eucythere																																									
brownstownensis						X																																F			
Cythereis																																									
thomasi									X				X																									C	F	F	
TOTALS	0	-	3	-	5	6	7	8	4	4	4	4	5	4	2	3	3	3	3	2	2	4	5	5	2	1	1	2	1	2	1	2	2	3	2	3	3	13	11	8	2

TABLE III
CHECKLIST OF MICROFAUNA OF THE HILLIARD FORMATION

SPECIES	STRATIGRAPHIC RANGES IN GULF COASTAL REGION (CUSHMAN - 1946)														HILLIARD SAMPLE NUMBERS								
	AUSTIN	TAYLOR						NAVARRO							1	2	3	4	5	6	7	8	9
		LOWER TAYLOR	SELMA MIDDLE	WOLF CITY	PECAN GAP	ANONA	UPPER TAYLOR	NEYLANDVILLE	UPPER SELMA	RIPLEY	NACATOCH	CORSICANA	ARKADELPHIA	KEMP									
(X) = Present. (O) = Present but not in totals. ( ) = Absent or not reported.																							
FORAMINIFERA:																							
Proteonina difflugiformis									X	X												X	X
Reophax constrictus		X		X			X		X	X								X				X	X
Haplophragmoides rugosa			X				X						X					X				X	
calcula	X	X		X	X		X				X	X		X				X			X	X	
excavata n.sp.		X	X				X						X									X	X
inflata n.sp.																						O	
Ammobaculites coprolithiformis	X		X			X			X			X	X					X					
stephensoni	X			X	X	X	X											X					
fragmentarius	X	X		X	X	X				X								X				X	
texanus												X						X					
Spiroplectammina navarroana														X								X	
lalickeri	X	X				X	X											X					
dentata var. tenuisa n.var.																		O					
Bigenerina elongata n.sp.																		O		O			
Textularia washitaensis																		X					
inflata n.sp.																		O					
Marssonella																							
conica n.sp.																		O					
Dorothia bulleta	X	X	X				X		X	X	X	X	X	X								X	
Trochammina diagonis			X					X				X		X				--				--	

taylorana		X																						
Robulus munsteri	X	X				X	X		X								X							
Lenticulina rotulata	X	X	X	X	X	X	X	X									X							
Planularia advena																	O							
inflata n.sp.																	O							
Palmula pilulata	X																X							
Marginulina cretacea		X		X	X	X	X	X													X			
texasensis					X	X	X										X			?				
Dentalina gracilis	X	X				X	X					X	X	X			X			X	X	X		
solvata	X					X	X		X								X							
Nodusaria affinis	X	X	X	X	X	X	X	X	X	X		X	X	X			X							
Vaginulina webbervillensis											X	X	X	X			X							
Frondicularia archiaciana		X	X	X	X	X	X			X							X							
undulosa	X	X			X		X										X							
clarki												X					X							
Bullopora tuberculata							X										X							
Gümbelina globulosa		X	X	X			X	X	X	X	X	X	X	X			X	X	X	X	X			
Uvigerina semicostata																	O							
inflata n.sp.																	O							
Bulimina kickapooensis	X	X		X	X	X	X	X	X								X	X	X	X	X			
Loxostoma plaitum		X	X				X	X	X	X	X	X	X	X			X							
Gyroidina depressa	X	X	X	X		X	X	X									X							
Globotruncana marginata	X	X	X	X		X	X										X							
Globorotalia cushmani	X																X							
Planulina ? sp.																	X				X			
kansasensis	X																X	X	X	X	X			
taylorana		X	X	X	X	X	X	X	X	X							X							
Globigerinella aspera	X																X			X	X			
Globigerina cretacea	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X			
Globorotalia ? multiloculata																	X							
OSTRACODA:																								
Cytherella parallela	X	X	X	X	X	X	X										X				X			
Cythere gapensis		X	X	X	X	X	X										X							
sphenoides	X	X	X	X													X							
Cytheridae perforata		X	X	X	X	X	X										X							
Cythereis ? sp.																	O				O			
TOTALS	22	25	18	18	15	20	27	10	12	10	10	6	10	10	0	0	0	37	4	4	8	17	5	

Species	Marine	Brackish	Non Marine	Upper Cret.	Paleocene	Eocene	Mid. Tertiary	Pleist.
Cytherella excavata								
Cytherella sp.								
Cytheromorpha scrobiculata								
Cytheropteron sp.								
Cythere denticulata								
Cythere delirata								
Cythereis coalvillensis				New Species				
Cytheridea fabaformis								
Cytheridea trisulcata				New Species				
Cytheridea posterovata				New Species				
Cytheridea perforata								
Candona acutimarginata				New Species				
Candona subovata								
Candona pagei								
Candona? striatula								
Candona sp								
Metacypris sp. (1)								
Metacypris sp. (2)								
Cyprois cf C. marginata								
Cypridea skeeteri								
Aclistochara compressa								
Aclistochara uintaensis				New Species				
* Dentalina frontierensis								
* Dentalina coalvillensis								
* Quinqueloculina sp.								
* Parrella expansa								
TOTALS				4	4		1	1

*Considered as reworked specimens.

TABLE IV GEOLOGICAL & ENVIRONMENTAL RANGES OF WANSHIP MICROFOSSILS

Plates IX to XVI

Continued on the following pages.

PLATE IX.

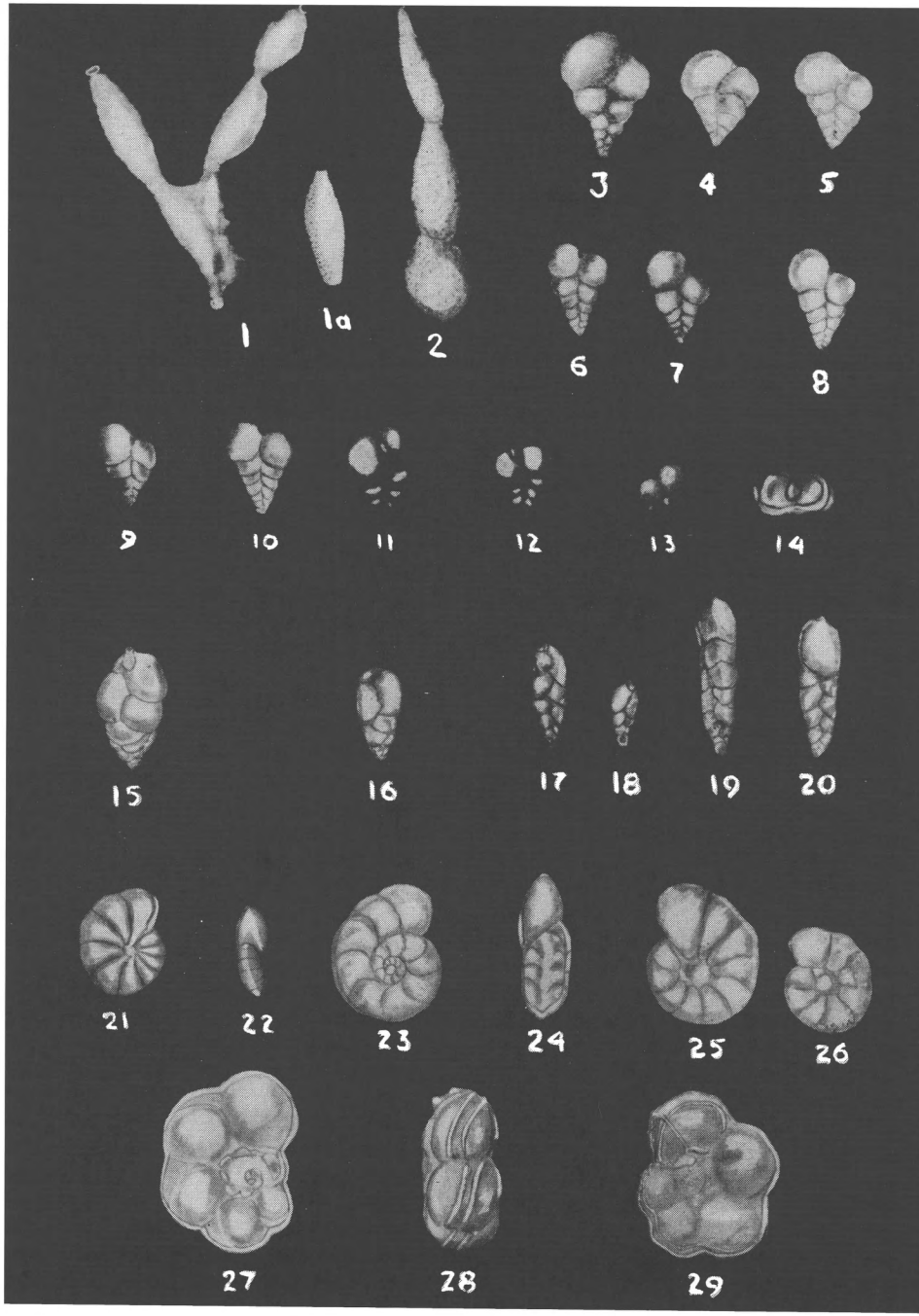
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PLATE IX

Figures 1,1a,2. Bullopora tuberculata (Sollas) Cushman, X 20. (p. 76).
1a. Specimen as usually found, a single chamber, X 20.

3-14. Gumbelina globulosa (Ehrenberg) (p. 77) Egger.
3. Side view, X 62.
4-13. Side views, X 50.
14. Top view, showing peculiar rim around top of final two chambers, X 62.

15. Eouvigerina inflata Gauger n. sp., (p. 77) X 20.

16. Bulimina kickapooensis Cole (p.79). Typical microspheric form, X 31.

17-20. Loxostoma plaitum (Carsey) Cushman (p. 79) X 34.
19. Edge view showing twisted test, X 34.
20. Side view showing test changing from biserial to uniserial, X 34.

21-26. Gyroidina depressa (Alth) Cushman (p. 80) and Church, X 36.
21. Ventral view showing lobe which almost covers umbilicus, X 26.
22. Front view, X 36.
23, Dorsal view, X 40.
24. Front view, X 40.
25. Ventral view, X 40.
26. Dorsal view, X 36.

27-29. Globotruncana marginata (Reuss) (p. 82) Thalmann, X 25.
27. Dorsal view.
28. Peripheral view, showing double keel.
29. Ventral view.

PLATE X

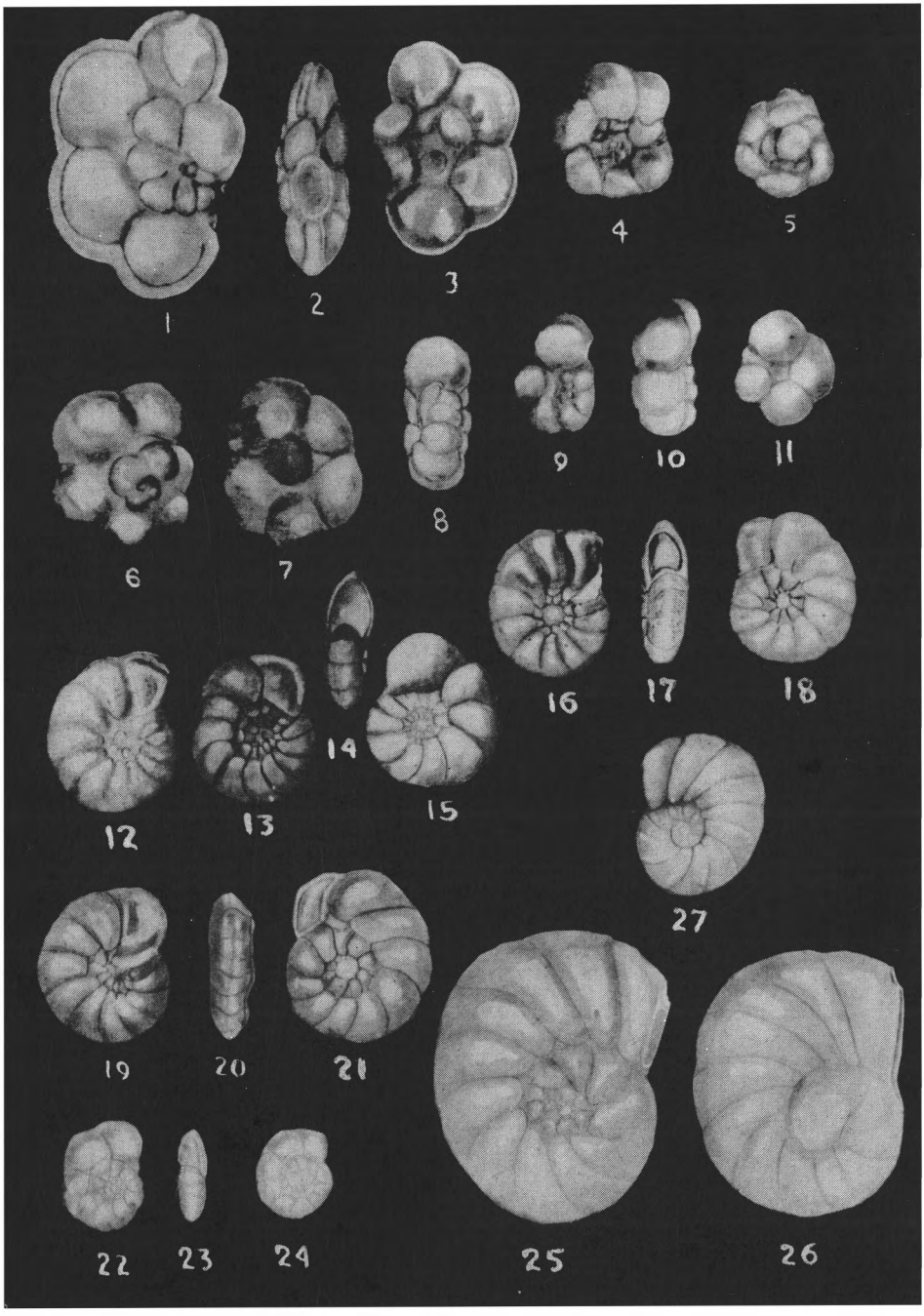


PLATE X

Figures 1-3. Globorotalia cushmani Morrow (p. 83).
1. Dorsal view, X 45.
2. Peripheral view, X 36.
3. Ventral view, X 36.

4. Globoratalia (?) multiloculata Morrow. (p. 83), dorsal view, X 31.

5. Globotruncana sp. Dorsal view, X 30. (p. 82)

6-11. Globigerina cretacea D'Orbigny (p.85).
6. Dorsal view, X 34.
7. Ventral view, X 34.
8. Apertural view, X 34.
10. Peripheral view, X 32.

12-24. Planulina kansasensis Morrow (p. 85).
12-18, X 44; 19-21, X 48;
22-24, X 38;
12,18,22,24. Dorsal views.
13,15,16,19. Ventral views.
14,23. Apertural views.
20. Peripheral view.

25-27. Planulina (?) sp. (p. 86) X 35 , (Fig. 27, X 18.)
25. Ventral view.
26. Dorsal view.
27. Ventral view of twisted test.

PLATE XI

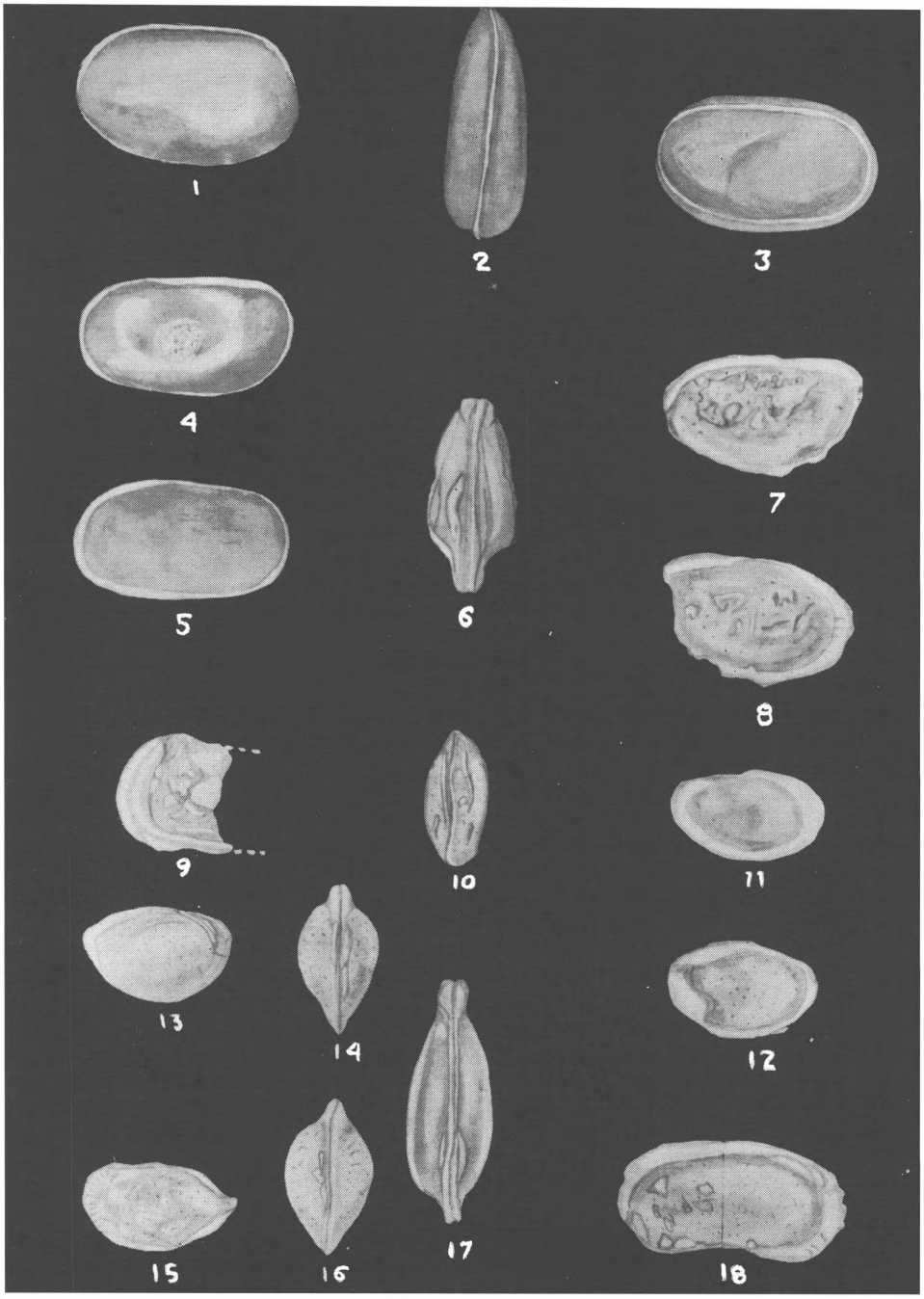


PLATE XI

Figures 1-5. Cytherella parallela (Reuss) (p. 87).
1. Top view, right valve, X 26.
2. Edge view, X 26.
3. View inside right valve, X 26 .
4. Inside left valve showing muscle (?) scars, X 20.
5. Inside right valve, X 20.

6-8. Cythereis (?) sp., X 24. (p. 90).

9,17,18. Cythere gapensis (Alexander) (p. 88) .
9. Fragment of anterior portion of left valve, X 24.
17. Dorsal view, X 24.
18. Right valve, X 24.

10-12. Cytheridea perforata (F. A. Roemer) (p. 89).
10. Dorsal view, X 24.
11. Left valve, X 24.
12. Right valve, X 24.

13-16. Cythere sphenoides Reuss (p. 88).
13. Right valve, X 24.
14. Dorsal view, X 24.
15. Left valve, X 24.
16. Ventral view, X 24.

PLATE XII.

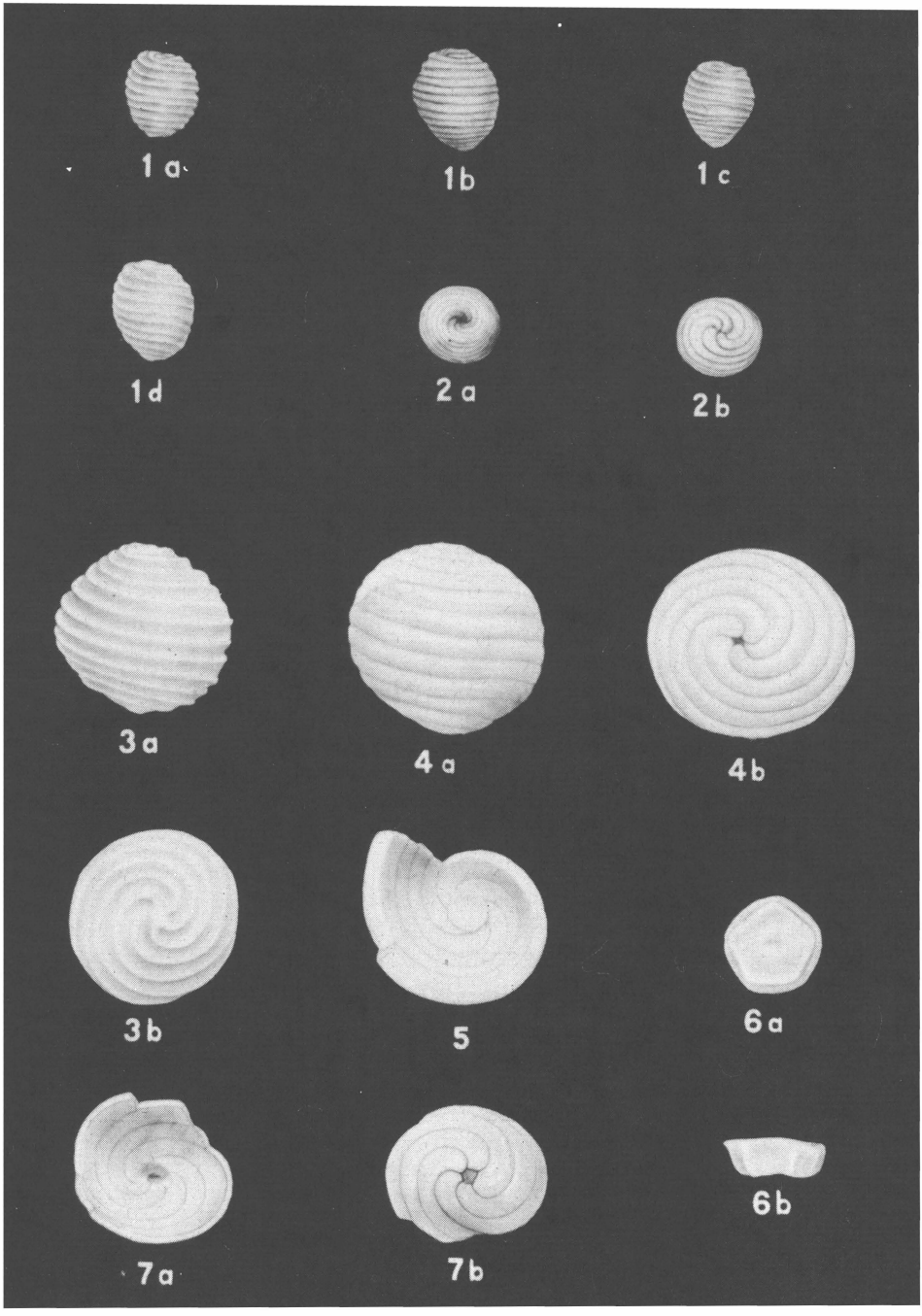


PLATE XII

Figures 1-2. Aclistochara uintaensis n.sp. 1a-d. Lateral view; 2a, summit view; 2b, basal view. (p. 110).

3-7. Aclistochara compressa (Knowlton). 3a, lateral view showing intercellular ridges; 3b, summit view, same specimen as 3a. 4a, lateral view showing spiral cells (in part, reconstructed); 4b, basal view, same specimen as 4a. 5, interior basal view showing node cell in place. 6, node cell, X 75; 6a, basal view; 6b, lateral view; 7a, interior basal view showing node cell removed; 7b, exterior view of 7a. (p.109)

PLATE XIII

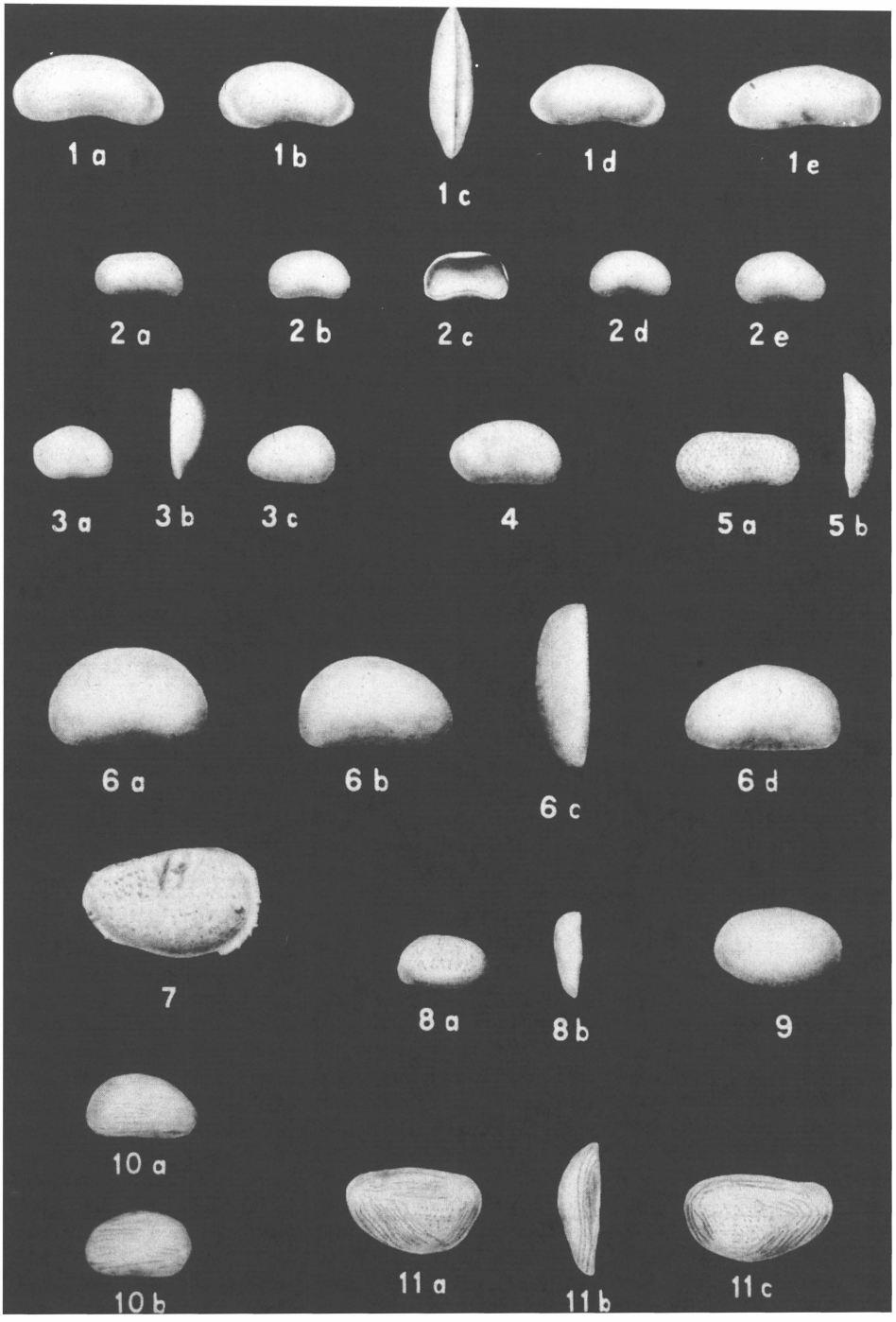

1a
1b
1c
1d
1e
2a
2b
2c
2d
2e
3a
3b
3c
4
5a
5b
6a
6b
6c
6d
7
8a
8b
9
10a
10b
11a
11b
11c

PLATE XIII

Figure 1. Candona acutimarginata n. sp.(p. 102).
a-b, right valve view; c, dorsal view; d-e, left valve view.

2. Candona cf. C. subovata Jones.(p. 103).
a, right valve view; b, left valve view; c, interior left valve view; d-e, left valve view.

3-4. Candona sp. (p. 104).
3a, left valve view; 3b, right dorsal view; 3c, right valve view; 4, left valve view.

5. Metacypris (?) sp. (p. 105).
a, left valve view; b, right dorsal view.

6. Candona subovata Jones. (p. 102).
a-b, right valve view; c, left dorsal view; d, left valve view.

7. Cypridea skeeteri Peck. (p. 106).
- right valve view.

8. Candona pagei Swain. (p. 103).
a, left valve view; b, left dorsal view.

9. Cyprois cf. C. marginata (Strauss).
(p. 105).

10. Candona cf. C. ? striatula Swain.
a, right valve view; b, left valve view.
(p. 104).

11. Cythere cf. C. delirata Jones and Sherborn
a, right valve view; b, dorsal view; c, left valve view. (p. 96).

PLATE XIV

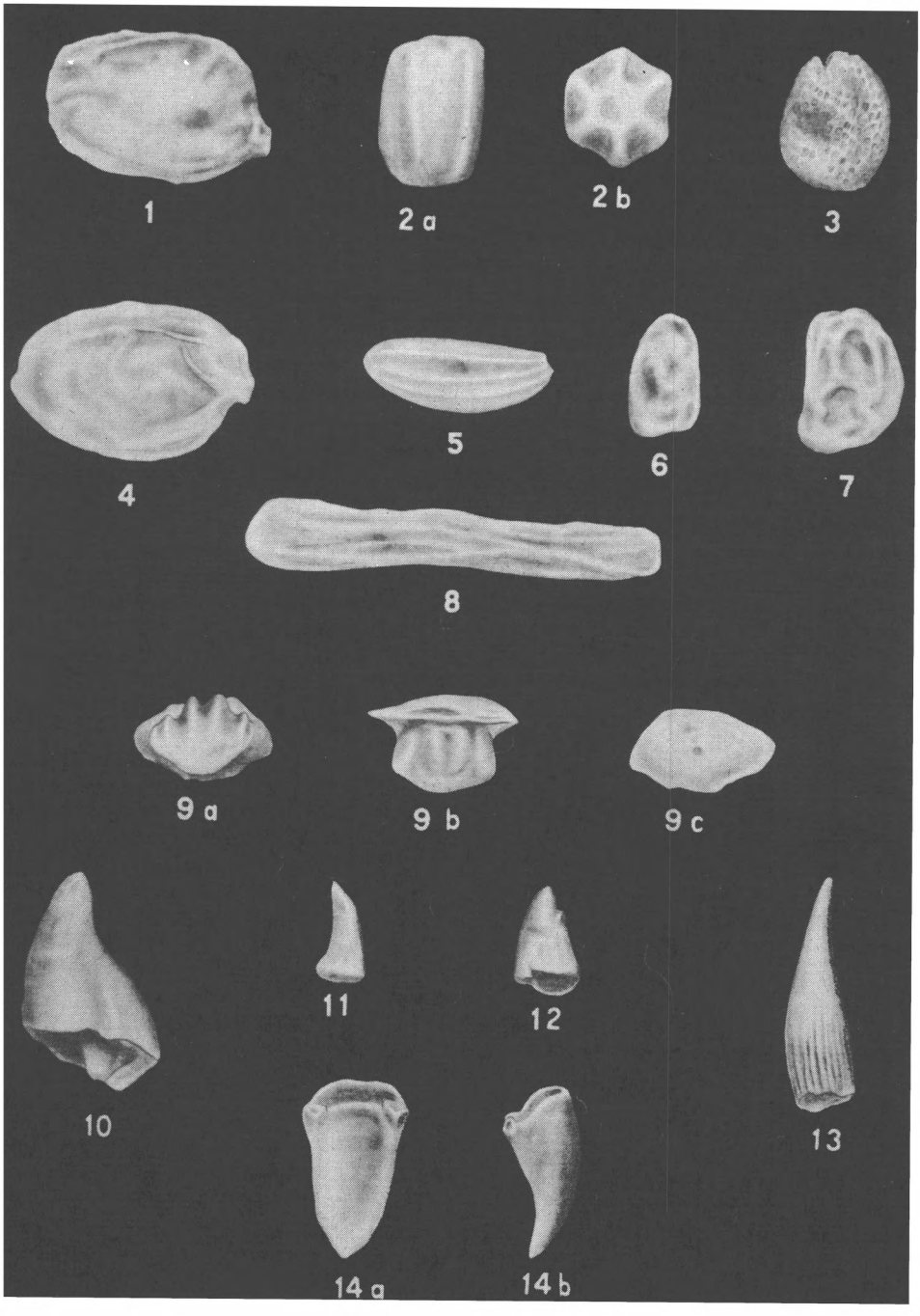


PLATE XIV

Figures 1-8. Plant fossils (seed cases?).(p.110)
1,3. From Samples S-17, S-18.
5,7-8. From Samples S-4, S-5.
2. From Samples N-4, N-5, N-8, N-14, N-16; 2a, lateral view; 2b, top view.
6. From Samples S-4, S-5, N-4.
4. From Sample S-3.

9. Dermal plate (fish), from Sample S-4; 9a, interior view; 9b, lateral view; 9c, exterior view. (p. 108).

10-13. Teeth (fish?) showing four principal types in side view; found in all fossiliferous samples. (p. 108).

14. Claw (Class - ?); 14a, ventral view; 14b, side view; found in Sample N-5. (p. 108).

PLATE XV.

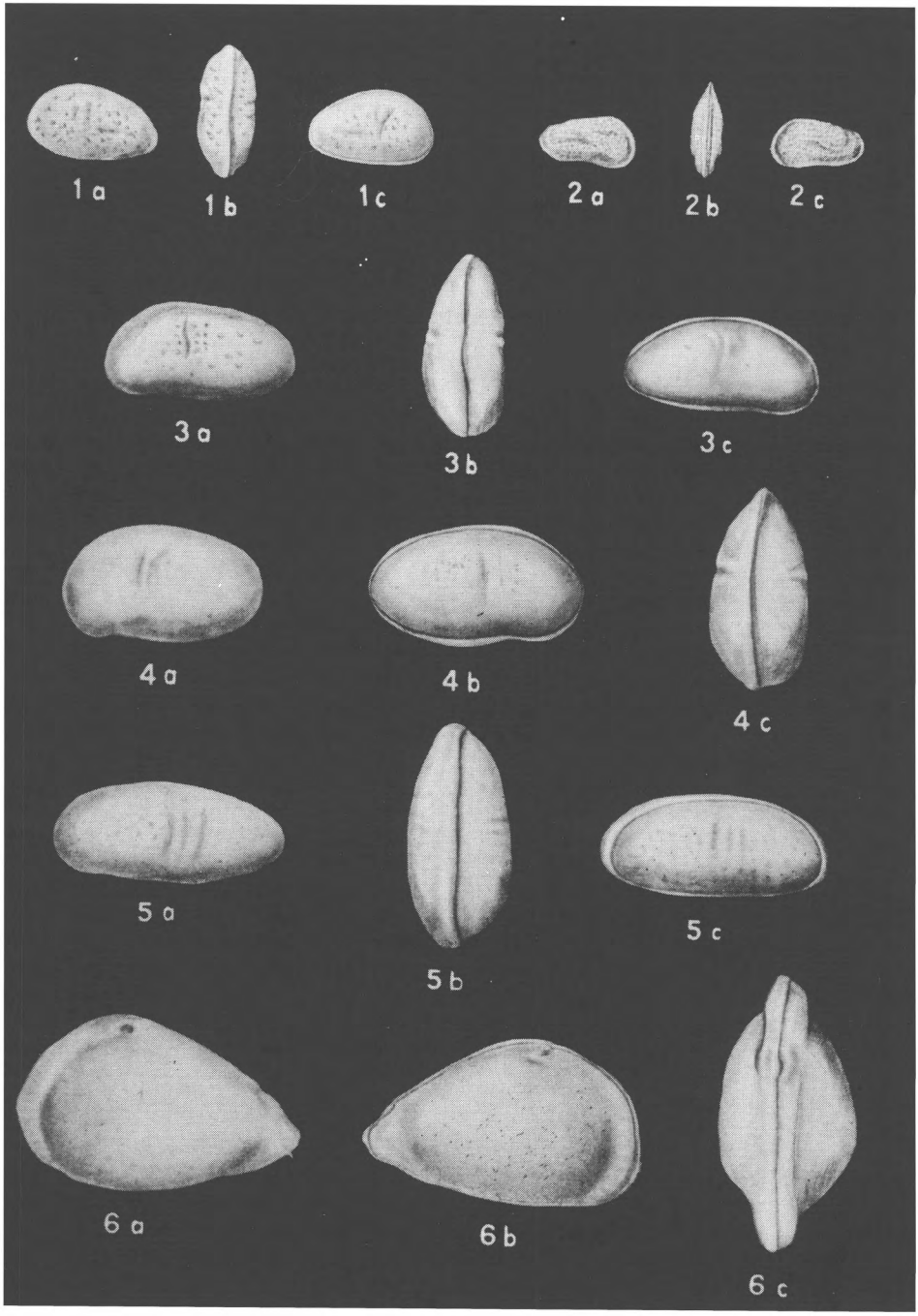


PLATE XV

Figure 1. Cytheridea cf. C. fabaformis (Berry).
a, left valve view; b, dorsal view; c, right valve view. (p. 98).

2. Cytheromorpha scrobiculata Alexander.
a, right valve view; b, dorsal view; c, left valve view. (p. 95).

3. Cytheridea posterovata Lankford n. sp. (p. 99).
a, left valve view; b, dorsal view; c, right valve view.

4. Cytheridea posterovata Lankford n. sp. var. alta n. var. (p. 100).
a, left valve view; b, right valve view; c, dorsal view.

5. Cytheridea trisulcata Lankford n. sp. (p. 99).
a, left valve view; b, dorsal view; c, right valve view.

6. Cythere denticulata Lankford n. sp. (p. 96).
a, left valve view; b, right valve view; c, dorsal view.

PLATE XVI.

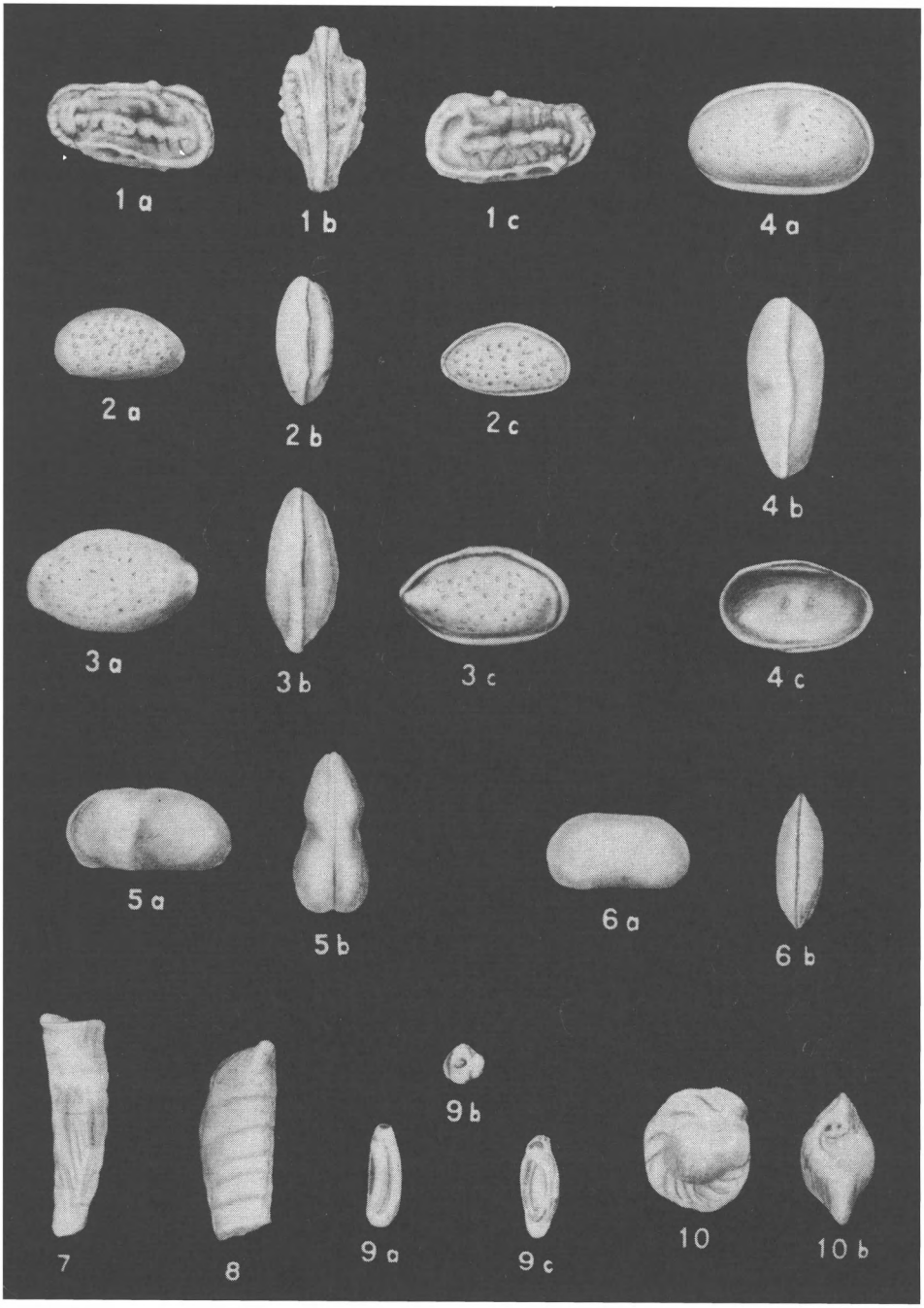


PLATE XVI

Figure 1. Cythereis coalvillensis Lankford n. sp. (p. 97).
a, right valve view; b, ventral view; c, left valve view.

2. Cytheridea perforata (Roemer) (p. 100).
a, left valve view; b, dorsal view; c, right valve view.

3. Cytheropteron sp. (p. 95).
a, left valve view; b, dorsal view; c, right valve view.

4. Cytherella excavata Alexander. (p. 94).
a, right valve view; b, dorsal view; c, right valve interior view.

5. Metacypris ? sp. (p. 105).
a, left valve view; b, dorsal view.

6. Cytherella ? sp. (p. 94).
a, left valve view; b, dorsal view.

7. Dentalina frontierensis Peterson; broken specimen. (p. 91).

8. Dentalina coalvillensis Peterson; broken specimen. (p. 91).

9. Quinqueloculina sp.; broken specimen.
a, lateral view; b, apertural view; c, view of broken surface. (p. 92).

10. Parrella cf. P. expansa Toulmin.
a, ventral view; b, apertural view. (p. 93).

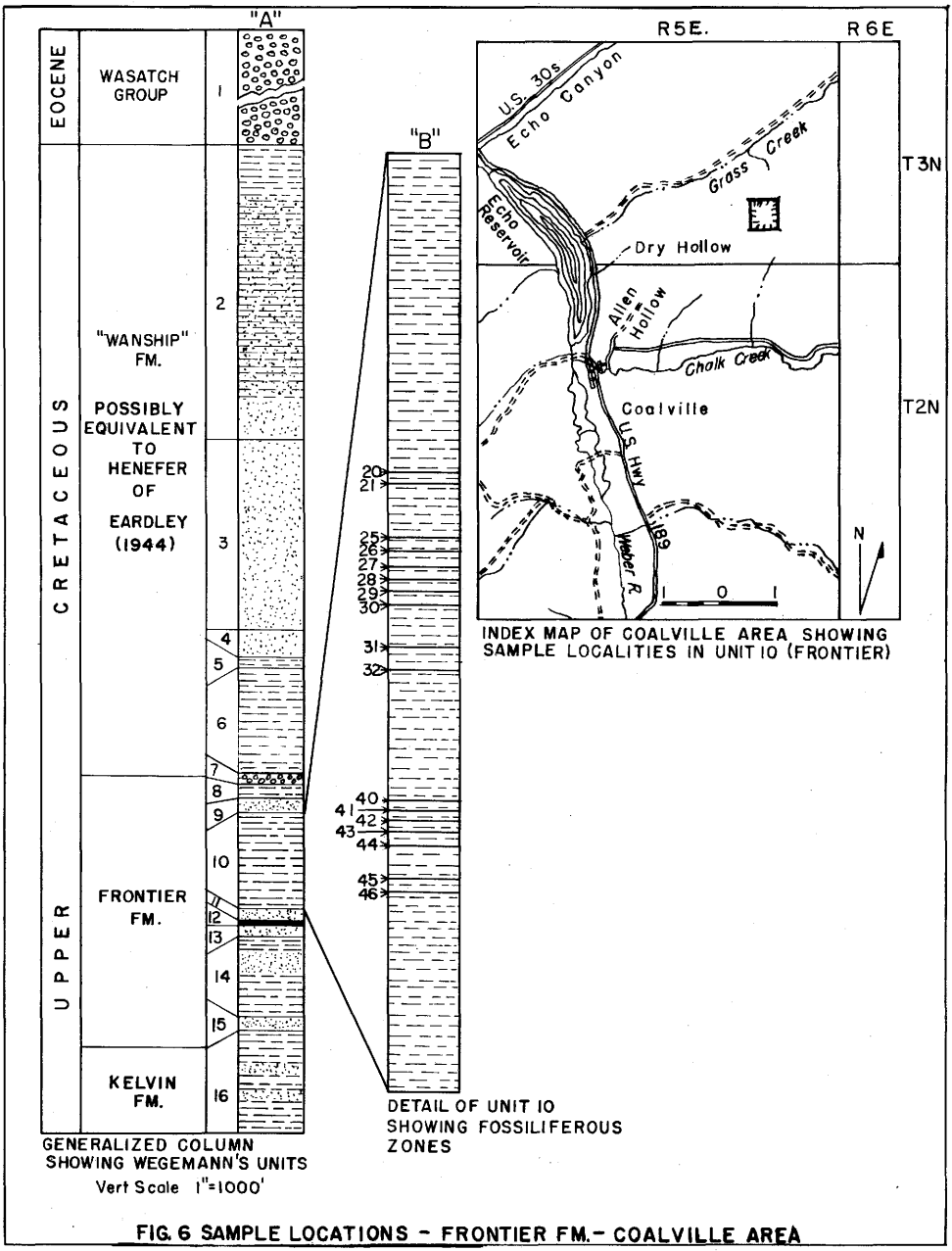
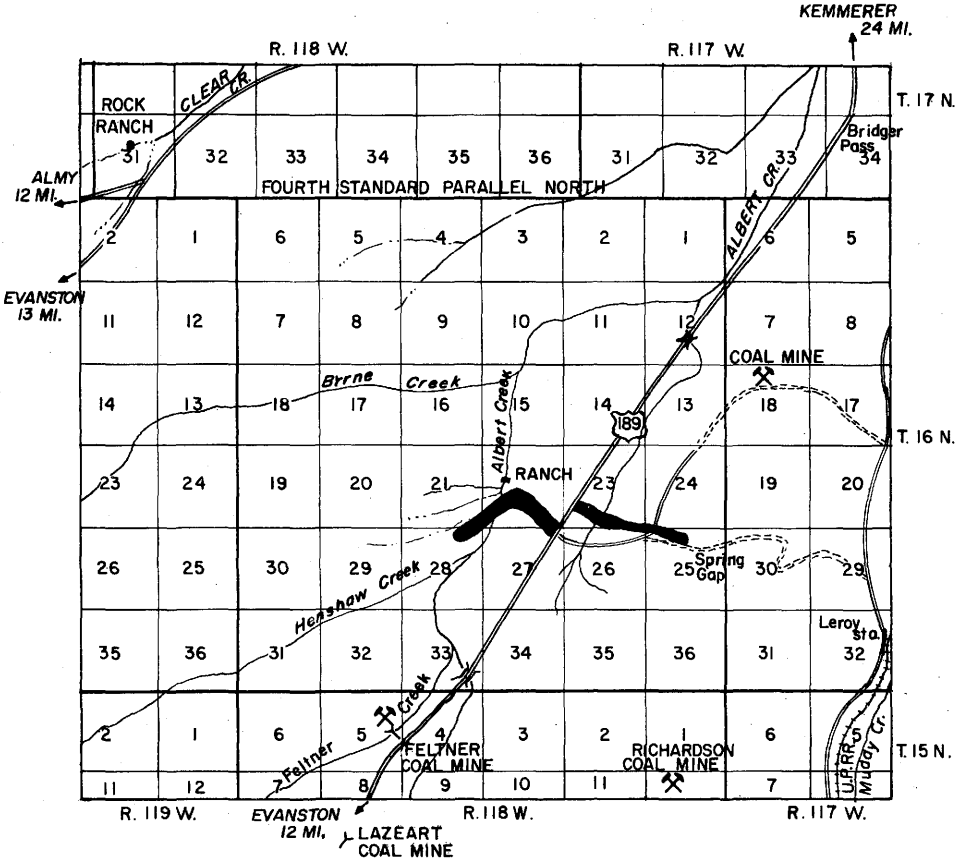


FIG. 6 SAMPLE LOCATIONS - FRONTIER FM.- COALVILLE AREA



SAMPLE LOCALITIES HILLIARD FORMATION
EVANSTON AREA, CARBON CO., WYO.

FIGURE 7

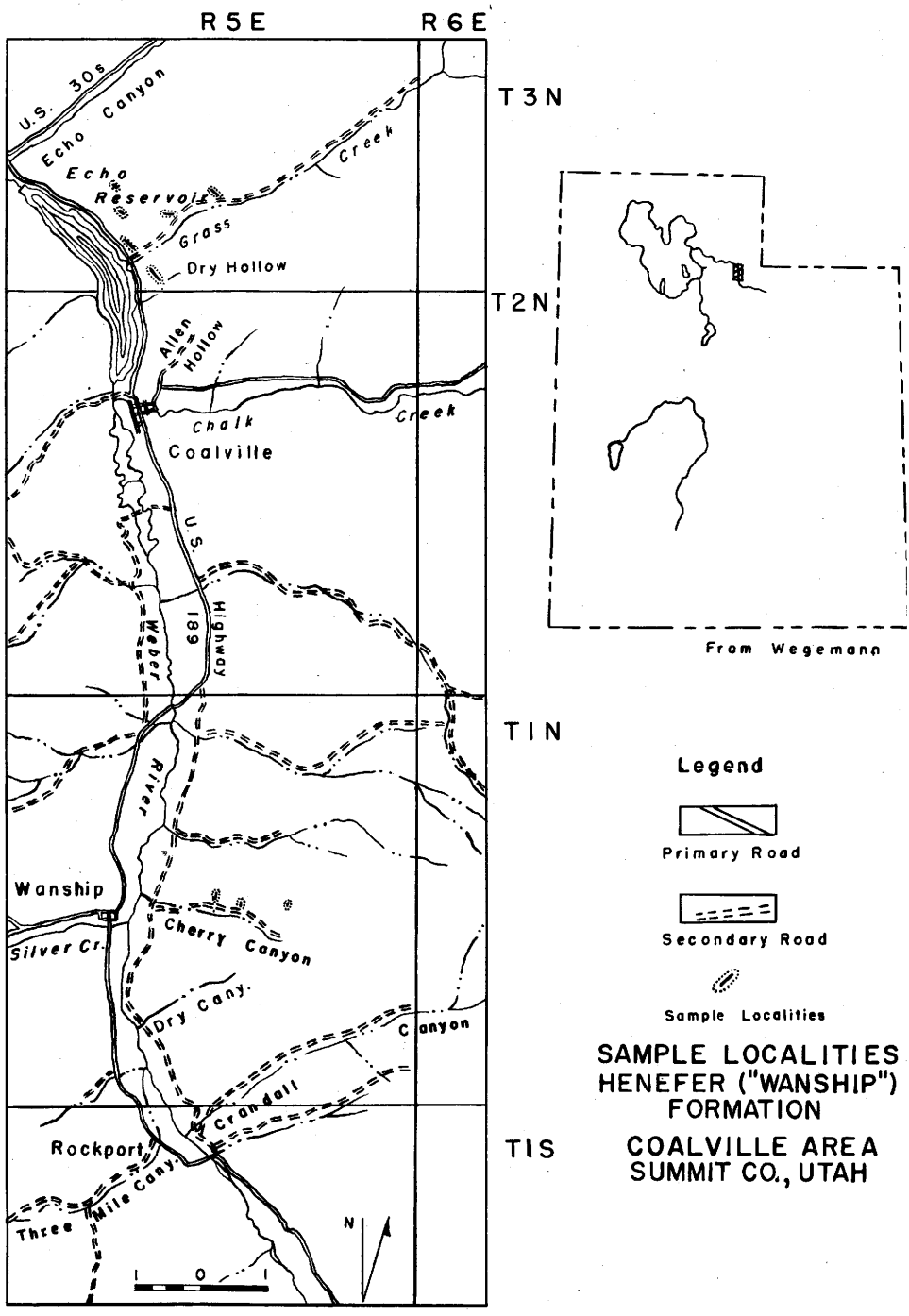

R5E
R6E
T3N
T2N
T1N
T1S
U.S. 30S
Echo Canyon
Echo Reservoir
Creek
Grass
Dry Hollow
Allen Hollow
Chalk
Creek
Coalville
U.S. 189 Highway
Weber
River
Wanship
Silver Cr.
Cherry Canyon
Dry Cany.
Canyon
Crandall
Rockport
Three Mile Cany.
N
1 0 1
From Wegemann
Legend
Primary Road
Secondary Road
Sample Localities
SAMPLE LOCALITIES
HENEFER ("WANSHIP")
FORMATION
COALVILLE AREA
SUMMIT CO., UTAH

FIGURE 8

APPENDIX B

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