Cretaceous Foraminifera From the Greenhorn, Carlile and Cody Formations South Dakota, Wyoming

GEOLOGICAL SURVEY PROFESSIONAL PAPER 254-E

Cretaceous Foraminifera From the Greenhorn, Carlile and Cody Formations South Dakota, Wyoming

By STEVEN K. FOX, Jr.

A SHORTER CONTRIBUTION TO GENERAL GEOLOGY

GEOLOGICAL SURVEY PROFESSIONAL PAPER 254-E

Significant Foraminifera from a section north of the Black Hills and a se ction in the eastern Bighorn Basin

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1954

UNITED STATES DEPARTMENT OF THE INTERIOR

Douglas McKay, *Secretary*

GEOLOGICAL SURVEY

W. E. Wrather, *Director*

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. - Price 65 (paper cover)

CONTENTS

ILLUSTRATIONS

TABLES

A SHORTER CONTRIBUTION TO GENERAL GEOLOGY

CRETACEOUS FORAMINIFERA FROM THE GREENHORN, CARLILE, AND CODY FORMATIONS, SOUTH DAKOTA, WYOMING

By Steven K. Fox, Jr.

ABSTRACT

The first of a series of analyses of Cretaceous Foraminifera from the western interior indicates the presence of several useful microfaunal assemblages in the Greenhorn and Carlile shale formations north of the Black Hills. Study of Foraminifera from the basal 388 feet of the Cody shale in eastern Bighorn Basin, Wyo., reveals that assemblages similar to those of the Greenhorn and Carlile, and also to those of the Niobrara formation of the Great Plains, occur in sandy shales far to the west.

Variations in faunal composition across the western interior are discussed as evidence of changing ecological conditions. The fauna of the lower part of the Carlile shale and equivalent formations maintains a more uniform character than faunas from the Greenhorn, upper part of the Carlile, and Niobrara. Faunas representing the lower part of the Carlile shale are essentially arenaceous. Greenhorn faunas are predominantly calcareous but vary chiefly in the presence or absence of species of the genus *Marginulinopsis*. Calcareous benthonic forms dominate the upper part of the Carlile and Niobrara faunas in the Great Plains. Westward, many arenaceous species in the sandy shales of the Cody produce the mixed arenaceous-calcareous aspect of these faunas.

Ten new species from the Greenhorn formation, Carlile shale, and Cody shale are described. Twenty-one other forms, only three referable to previously described species, are illustrated and commented on. Additional already known species are included in two tables of distribution.

INTRODUCTION

This paper describes significant Foraminifera from the Greenhorn formation and Carlile shale in the area north of Belle Fourche, S. Dak., and from the basal part of the Cody shale near Greybull, Wyo., in eastern Bighorn Basin. During August 1949 about one hundred samples were collected at Greenhorn and Carlile localities from detailed sections measured previously by W. A. Cobban. The 120 samples from several localities of the basal 388 feet of Cody shale were obtained from sections measured by the writer in August 1949. Particular care was taken to collect channel samples from well-exposed sections. The writer expects to expand these studies stratigraphically and geographically in the western interior in order to analyze the occurrences of Foraminifera in the Cretaceous of that area.

PREVIOUS INVESTIGATIONS

Records of Foraminifera from the Greenhorn formation and Carlile shale in the Great Plains have been scattered and meager. The early reports included the names of a few species but did not associate species with lithologic units.

The following is a summary of more recent work on the microfaunas of the western interior.

Carman (1929, p. 309) figured and described seven species from the Benton shale near Centennial, Wyo. The Benton includes Carlile and Greenhorn equivalents. Carman's species are long-ranging in the Cretaceous. An eighth form, *Anomalina* sp., is figured but not described.

Applin (1933, p. 215–220) listed five species from the Carlile shale and two from the Niobrara formation of South Dakota. Of those in the Carlile *Haplophragmoides gigas* Cushman is probably the only good Carlile guide fossil. The two Niobrara pelagic species, *Globigerina cretacea* D'Orbigny and *Gumbelina globulosa* (Ehrenberg) are well distributed in Cretaceous rocks.

Morrow (1934, p. 186–205) figured and described from Kansas 13 species from the Greenhorn formation, 3 from the Carlile shale, and 30 from the overlying Niobrara formation. Six of the Greenhorn species are known only from the Hartland shale member, and many of the Niobrara forms are apparently restricted in range in Kansas. Morrow's three Carlile species, *Gumbelina globulosa* (Ehrenberg), *Gumbelina globifera* (Reuss), and *Globigerina cretacea* D'Orbigny, are typical Cretaceous pelagic species of no index value.

Loetterle (1937, p. 1–73) described and figured 63 species of Foraminifera from the Niobrara formation of Kansas, Nebraska, and South Dakota. He noted 27 species restricted to the basal Fort Hays limestone member. Many of these forms verify Morrow's results.

Fox (1941, p. 1967) reported 94 species of calcareous and arenaceous Foraminifera from the Cody shale of the type locality in western Bighorn Basin, Wyo. Sev-

eral faunal zones were recognized within the Cody. Many typical Niobrara species of Morrow and Loetterle were noted in the basal and middle shales of the Cody. The association of arenaceous and calcareous genera in the type Cody was noted as an indication of change of facies as the Niobrara formation is traced westward.

Young (1951, p. 35–68) described a new foraminiferal fauna from the Frontier formation of southern Montana. The 34 species occur in and immediately below the "*Vascoceras* beds" which have been reported by Reeside (1923, p. 25–31) as lower Turonian and the equivalent of at least the upper part of the Greenhorn limestone of the central Great Plains. Young notes that the southern Montana microfossils are distinct from other assemblages reported from the Cretaceous of the western interior. He suggests differences in ecological conditions during the accumulation of the Niobrara formation, the Greenhorn limestone, the Eagle Ford formation, and the Frontier formation of southern Montana. Recent additional data on the relationships of Young's microfauna are presented in the present paper.

Descriptions of Canadian Cretaceous Foraminifera from comparable parts of the section have not been wanting. Wickenden (1932b, p. 203–207) described a fauna in the lower Alberta shale which is closely related to the basal part of the Cody shale of the type locality (Fox, 1941, p. 1967). Wickenden (1932a, p. 85–91; 1945, p. 33) and Nauss (1945, p. 1605–1629; 1947 p. 329–343) have recently reported many species from the Cretaceous of Mantiboa, Saskatchewan, and Alberta. Many of these are apparently restricted geographically to the Canadian area and many have long ranges within the Cretaceous. Several species indicate relationships with the microfaunas described by Loetterle and Morrow from the Niobrara of the Great Plains States.

ACKNOWLEDGMENTS

The writer is indebted to J. B. Reeside, Jr., and W. A. Cobban of the U. S. Geological Survey for their cooperation during joint field work in August 1949. Without Mr. Cobban's guidance in the field of sampling the Belle Fourche shale section previously measured by him, the present collections could not have been made in so short a time. The field and laboratory aid of Richard W. Murphy of Princeton University and Georges His and Ogden Nine of Rutgers University was invaluable. The writer is indebted to the late Mrs. Helen Jeanne Plummer and to Keith Young for many suggestions. Ann Shephard Green of the U. S. Geological Survey made the camera lucida drawings. The use of the laboratory facilities of Rutgers University and Princeton University is gratefully acknowledged.

BELLE FOURCHE AREA, S. DAK. AND WYO.

In the Cretaceous section north of Belle Fourche, S. Dak., the present microfossil study concerns part of the Belle Fourche shale, the Greenhorn formation, and the Carlile shale. At the present time W. A. Cobban is engaged in a detailed study of the molluscan faunas of the entire Cretaceous sequence in the area north of the Black Hills. The sections measured by Cobban for his study were used by the writer in obtaining foraminiferal samples for this paper.

BELLE FOURCHE SHALE

The Belle Fourche shale was named by Collier (1922, p. 83) for exposures of dark-gray shale underlying the Greenhorn limestone along Belle Fourche River near Wind Creek, Crook County, Wyo. Rubey (1930, p. 4) reported marine fossils from the shale in the Black Hills region. According to Reeside (Haas 1949, p. 36), the fauna is probably Cenomanian. Originally described as the upper member of the Graneros formation, the Belle Fourche is now accorded formational rank (Reeside, 1944; Dobbin and Horn, 1949).

GREENHORN FORMATION

The Greenhorn formation was described by Gilbert (1896, p. 564–565) as alternating limestones and shales between the Carlile shale above and the Graneros shale below. He named it for Greenhorn Station near Pueblo, Colo., and for Greenhorn Creek in Pueblo quadrangle. Rubey (1930, p. 4) reported 50–350 feet of similar lithology with marine fossils in the Black Hills region. The marine fossils include *Inoceramus labiatus* (Schlotheim) and *Metoicoceras whitei* Hyatt of early Turonian age (Reeside 1923, p. 25–31; Moreman 1942, p. 195). The Greenhorn is widely distributed in eastern Colorado and Wyoming, southeastern Montana, Nebraska, South Dakota, Kansas, and northeastern New Mexico. It is the equivalent of the Britton formation of the Eagle Ford group in Texas (Moreman 1942, p. 195). In Kansas it includes two members older than the Greenhorn of the type locality. Rubey and Bass (1925, p. 47) adopted the Lincoln limestone as the basal member of the Greenhorn in Kansas. Bass (1926, p. 33) assigned the name Hartland to the chalky shale member above the Lincoln and below the equivalent of the basal Greenhorn of the type locality.

CARLILE SHALE

Gilbert (1896, p. 564–565) also named the Carlile shale. He described it as 175–200 feet of medium gray shale exposed at Carlile Spring and Carlile Station west of Pueblo, Colo., where it underlies the Timpas

(Niobrara) limestone and rests on the Greenhorn limestone. The formation is widely known in the Great Plains States where different members are recognized locally.

Rubey and Bass (1925, p. 36) noted that the upper member of the Carlile shale in Kansas (Blue Hill shale) contained *Prionocyclus wyomingensis* Meek and could probably be correlated with an upper sandy unit in the Carlile of South Dakota and Wyoming. In the Black Hills region Rubey (1930, p. 4) applied the name Turner (150–200 feet) to this upper sandy member of the Carlile, but did not name the lower shale member (75–125 feet). Rubey reported marine fossils in both members of the Black Hills section, and a distinct faunal break between the two units. He identified the overlying Sage Breaks shale as the basal member of the Niobrara formation largely on the presence of the typically Niobrara form *Ostrea congesta* Conrad. In recent years additional collections of ammonites and species of *Inoceramus* from the Sage Breaks indicate strong Carlile affinities. Furthermore, *Ostrea congesta* is recognized as the only megafossil common to the Sage Breaks and to the Fort Hays limestone member of the typical Niobrara (Cobban, W. A., personal communication). The Sage Breaks in the Black Hills area is now considered as the uppermost of three members of the Carlile on this evidence and also on the lithologic similarity between the lower shales of the Carlile and the Sage Breaks. It is so recognized by the Geologic Names Committee of the Survey. Recently Dobbin and Horn (1949) adopted this assignment in Weston County, Wyo. The microfossil evidence is presented in this report.

Reeside (1923, p. 28) identified the Carlile fauna as late Turonian and later indicated two major faunal zones in the Carlile (Thomas 1936, p. 1192). The upper zone contains *Prionocyclus wyomingensis* Meek and *Scaphites warreni* Meek and Hayden; *Scaphites larvaeformis* Meek and Hayden and *Collignoniceras woolgari* (Mantell) characterize the lower zone. The Carlile is the equivalent of the Arcadia Park formation of the Eagle Ford group in Texas (Moreman 1942, p. 195).

NIOBRARA FORMATION

The Niobrara formation was described by Meek and Hayden (1862, p. 419–422) as a chalk and limestone formation 200 feet thick lying between the Pierre and Benton shales. The type section along the Missouri River near the mouth of Niobrara River in Knox County, Nebr., consists of yellow-white chalk overlying white limestone. In Kansas the chalky member was named Smoky Hill by Cragin (1896, p. 51), and the lower limestone member above the Carlile was called Fort Hays by Williston (1893, p. 108–109). The chalks and limestones of the Niobrara of the Great Plains States are replaced westward by calcareous shales, with the upper chalky member persisting farther than the underlying limestone.

Faunally, the Fort Hays limestone member of the Niobrara formation is characterized by *Inoceramus deformis* Meek and the Smoky Hill chalk member by *Inoceramus grandis* (Rubey and Bass, 1925, p. 25–32). Many other species appear in the Niobrara as it is traced westward.

The Niobrara formation of the Black Hills region was divided by Rubey (1930, p. 4) into the basal Sage Breaks shale member (250–325 feet) and the Beaver Creek chalky member (125–200 feet). For reasons outlined above, the Sage Breaks is now recognized as the uppermost member of the Carlile. The name Niobrara has been restored in place of Beaver Creek.

The Niobrara formation is the equivalent of the Austin chalk of Texas. Niobrara faunas also occur in the Cody shale of Bighorn Basin, Wyo., (Reeside, 1927b, p. 1–18) and in the Canadian Cretaceous formations (Wickenden, 1945, p. 42). They represent the European Coniacian and lower Santonian (Reeside 1923, p. 28).

STRATIGRAPHIC SECTION NORTH OF BELLE FOURCHE, S. DAK.

A stratigraphic section in Crook County, Wyo., and Butte County, S. Dak., north of Belle Fourche, S. Dak., was sampled and studied. (See table 1.) Samples having roman numbers were collected from the datum downward, and those with arabic numbers from the datum upward. Wherever possible samples were obtained by channeling unweathered material.

FOSSIL-COLLECTING LOCALITIES

United States Geological Survey localities at which samples were collected are given below. Letters in parentheses indicate the sample designation in table 1, and units are those of table 1.

CARLILE SHALE

24082. Unit 27. Sage Breaks member (CSB). East-facing road cuts south of Windy Hill school on west side of U. S. Highway 85, east edge SE¼SE¼ sec. 34, T. 10 N., R. 2 E., Butte County, S. Dak.

24083. Unit 26. Turner sandy member (CT). West-facing cut of south tributary to Owl Creek, center NE¼ sec. 35, T. 10 N., R. 2 E., Butte County, S. Dak.

24084. Units 25–17. Turner sandy member (CT). Gentle slopes one-half mile west of U. S. Highway 85, center sec. 10, T. 9 N., R. 2 E., Butte County, S. Dak.

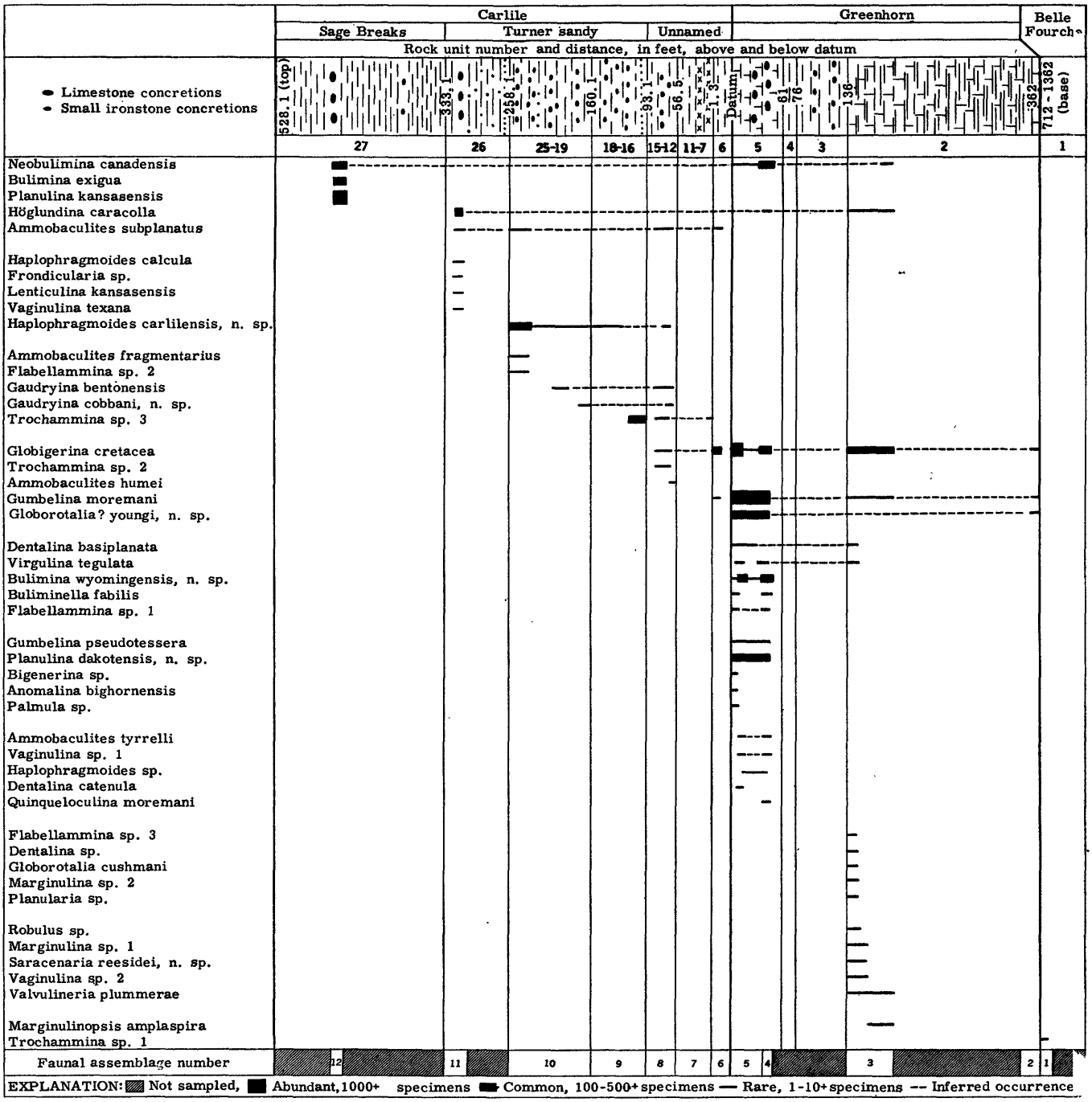
24085. Unit 16. Turner sandy member (CT). Four miles east of U. S. Highway 85, SE¼SW¼ sec. 11, T. 9 N., R. 2 E., Butte County, S. Dak.

TABLE 1.—*Stratigraphic section north of Belle Fourche, S. Dak., where Foraminifera were collected*

Formations	Members	Faunal assemblage number	Rock unit: No.	Rock unit: Thickness (feet)	Samples and their position in the section	Distance (feet) above or below datum	Lithology of units
	Sage Breaks.	12	27	195	*CSB I–CSB VI, taken from 77 to 92 ft below top of Sage Breaks, beginning immediately below a large concretion layer.	528.1 333.1	Shale, gray, noncalcareous, containing light-gray calcareous septarian concretions.
	Turner sandy	11	26	75	*CT 25, 12 ft to 17 ft below top. *CT 24, 17–22 ft below top.	258.1	Shale, light weathering, containing 3 by 5 ft limestone concretions, 17 ft below top
		10	25	24	CT 20–CT 23, taken at base and each 6 ft int above.	234.1	Shale, dark, with fossliferous rusty concretions.
			24	5	Not sampled.	229.1	Shale, sandy, with conspicuous ledge forming orange concretions.
			23	8	CT 19. Top 2 ft of bed.	221.1	Shale, dark, weathering buff, gray, containing small concretions.
			22	17	CT 18, taken 2 ft below top. CT 17, taken 8½ ft above base.	204.1	Shale, dark, with some rusty concretions; small brown concretions at top.
			21	15	CT 16, taken 10 ft from base. CT 15, taken 5 ft from base.	189.1	Shale, dark, with a few conspicuous rusty concretions.
			20	12	CT 14, taken 6 ft above base.	177.1	Shale, dark.
			19	17	*CT 13, 5 ft above base.	160.1	Shale, dark, containing yellow concretions.
Carlile shale.		9	18	30	CT 6–CT 12, taken every 5-ft above base.	130.1	Shale, dark, containing concretions and 6 in of brown bentonite at top.
			17	21	CT 5, taken 13 ft above base. CT 4, taken 10 ft above base.	109.1	Shale, dark, containing concretions at top.
			16	16	*CT 1–CT 3, each 5-ft, measured above ledge.	93.1	Basal Turner sandy member. Shale, gray, with 1 ft sandstone ledge and shark tooth conglomerate at base.
	Unnamed.	8	15	13	*CL 12 and CL 13, each 6.5 ft measured above base.	80.1	Shale.
			14	15.5	*CL 10 and CL 11.	64.6	Shale, containing iron concretions.
			13	0.1	Not sampled.	64.5	Nodules, small, yellow.
			12	8	*CL 8 and CL 9.	56.5	Shale, containing iron concretions.
		7	11	26	Not sampled.	30.5	Shale, poorly exposed.
			10	0.5	do.	30	Bentonite.
			9	6.5	do.	23.5	Shale.
			8	0.5	do.	23	Bentonite.
			7	10	*CL 6 and CL 7, each 5 ft.	13	Shale.
Datum		6	6	13	*CL 1–CL 5, equally spaced above datum.	0	Shale, gray.
		5	5	61	*GU I–GU XX, each 2.5-ft, measured below top of Greenhorn.	0	Shale, brown, calcareous, containing limestone concretions and bentonites.
		4			*GU 1a–GU 1d, taken at fossiliferous limestone concretions 10–12 ft above base of unit 5.	61	
Greenhorn			4	15	Not sampled.	76	Shale, gray, noncalcareous, unfossiliferous.
			3	62	do.	138	Shale and mudstone, with rusty concretions.
		3	2	224	*GL I–GL X, each 5 ft, measured below top of unit 2.		Shale, gray-weathering, calcareous. Limestone, containing shark teeth, at base.
		2			*GL 1 and GL 2, each 2.5 ft measured above base of unit 2.	362	
Belle Fourche shale.		1	1	350–1000	*BF I–BF V, each 3-ft measured below top of Belle Fourche.	712–1362	Shale, black, fissile; and mudstone.

* Indicates composite sample from vertical channel whose length is given.

TABLE 2.—*Stratigraphic distribution of Foraminifera in the Belle Fourche and Carlile shales and the Greenhorn formation near Belle Fourche, S. Dak.*



24086. Units 15–12. Unnamed member (CL). The same place as locality 24085.

24087. Units 11–6. Unnamed member (CL). West-facing cut, NW¼NE¼ sec. 16, T. 9 N., R. 2 E., on north tributary of Crow Creek.

GREENHORN FORMATION

24088. Samples GU I, II of unit 5. The same place as locality 24087.

24089. Samples GU III–VII of unit 5. West-facing cut, center NE¼ sec. 16, T. 9 N., R. 2 E., Butte County, S. Dak.

24090. Samples GU VIII–XX of unit 5. North-facing scarp on southwest-flowing tributary to Crow Creek in SW¼NE¼ sec. 16, T. 9 N., R. 2 E., Butte County, S. Dak.

24091. Samples GU 1a–d of unit 5. E½ sec. 15, T. 57 N., R. 62 W., Crook County, Wyo.

24092. Samples GL I–X of unit 2. Upper 50 feet of SW¼ sec. 10, T. 57 N., R. 62 W., Crook County, Wyo.

24093. Samples GL 1–2 of unit 2. Basal 5 feet, center sec. 9, T. 57 N., R. 62 W., Crook County, Wyo.

BELLE FOURCHE SHALE

24094. Unit 1. Samples BF I–BF V. The same place as locality 24093.

GREYBULL AREA, WYO.

Upper Cretaceous sedimentary rocks in the Bighorn Basin consist of several thousand feet of alternating marine shales and nonmarine or beach sandstones. The upper part of these rocks includes the Cody shale and the Frontier, Mesaverde, Meeteetse, and Lance formations. The last two formations complete the Upper Cretaceous sequence and are entirely terrestrial in origin.

In the vicinity of Greybull, Wyo., the present study concerns the upper 25 feet of the Frontier formation and the basal 388 feet of the overlying Cody shale.

FRONTIER FORMATION

The Frontier formation in the Bighorn Basin is a series of ledge-forming lenticular sandstones and interbedded black and carbonaceous shales that underlie the Cody shale. The formation averages 450–600 feet in the basin, as compared to the thickness of 2,000± feet recorded by Knight (1903, p. 542) in the type section in Lincoln County, Wyo. The sandstones thin northeastward across the basin.

The Frontier formation contains both marine and terrestrial faunas of Colorado age. Marine fossils from the upper part of the Frontier near Cody (Reeside 1927b, p. 2) indicate correlation with the Niobrara formation of the Great Plains. Southeastward in Laramie Basin, Wyo., (Thomas 1936, p. 1194) and near Salt Creek oil field, Wyoming (Reeside, J. B., Jr., personal communication), the upper part of the Frontier is equivalent to the Carlile of the Great Plains. A recent report by Haas (1949, p. 37) of a late Cenomanian-early Turonian ammonite fauna from the Cody shale in the Greybull area would indicate that the underlying Frontier in this area is the equivalent of the Greenhorn of the type locality and probably older (Hartland) elements of the Great Plains sections.

CODY SHALE

The name Cody was applied by Lupton (1915, pp. 171–173) to dark shales above the top of the Frontier formation and below the base of the Mesaverde formation along Shoshone River at Cody. Lupton also described as Cody 3,360 feet of similar shales southeast at Basin, Wyo. He reported marine fossils of late Colorado age in the lower two-thirds of the formation at Basin, and invertebrates of Montana age in the upper 1,000 feet.

The Cody shale is characteristically composed of dark-gray shales at the base and of sandy shales and medium-gray thin shaly sandstones which increase in number toward the top. Limestone concretions and bentonites are numerous in the lower part of the Cody. The base of the first massive sandstone of the Mesaverde formation marks the upper conformable contact; the ledge-forming sandstone of the Frontier formation lies below the Cody. The Cody ranges in thickness in the Bighorn Basin from 1,715 feet at the Garland anticline to 3,600 feet in the west-central part of the basin. In the Greybull area it is about 3,000 feet.

Age determinations of Cody strata have been based principally on marine molluscan faunas. The larger invertebrates indicate that the Cody of the type locality is the equivalent of part of the Niobrara (Coniacian) of the Great Plains and the Telegraph Creek formation (Santonian) and Eagle sandstone (lower Campanian) of southern Montana (Reeside, 1927b, p. 1–2). Foraminiferal evidence sustains this view (Fox, 1941, p. 1967).

In the Bighorn Basin south and east of the type area the Cody shale has been defined as the equivalent of that of the type area (Lupton, 1915, p. 171–172; Reeside, 1927a). Recently, however, Haas (1949, p. 1–39) described a late Cenomanian early Turonian ammonite (*Dunveganoceras*) fauna from the Cody shale near Greybull, in eastern Bighorn Basin. Detailed section measurements throughout this area in August 1949 have revealed that the *Dunveganoceras* fauna also occurs in place in large concretions in the upper sandstone of the Frontier formation in a zone 20–25 feet in thickness below the base of the Cody shale. The basal Cody itself in eastern Bighorn Basin is believed by Reeside to be older than that in the type area and to be the equivalent of the Belle Fourche (late Cenomanian) shale of the

Great Plains (Haas, 1949, p. 37). Foraminiferal material presented herewith is in line with the molluscan evidence.

STRATIGRAPHIC SECTION NEAR GREYBULL, WYO.

The basal part of the Cody shale (388 feet) was measured above the Frontier formation on the slopes of Greybull dome about 3 miles southeast of Greybull in NE. ¼ sec. 27, T. 52 N., R. 93 W., Bighorn County, Wyo., USGS loc. 24095. The section was completed to the fourth prominent ledge above the Frontier. Wherever possible, samples were channelled from unweathered material and represent all but 22 feet of the basal 388 feet of Cody. Table 3 shows the detailed section, and table 4 the distribution of the Foraminifera.

THE MICROFAUNA

Forty-seven species of Foraminifera are reported from the Great Plains region, representing 12 families, and 27 genera (see tables 2 and 4). Calcareous species total 31. Sixteen forms are arenaceous. The families Lagenidae and Lituolidae have 15 and 11 species, respectively. The Greenhorn assemblage comprises the bulk of the calcareous species (26) and has only 5 arenaceous types. The Carlile contains 10 arenaceous and 9 calcareous species.

In the basal 388 feet of the Cody 49 species are recorded; these represent 14 families and 31 genera. Fourteen arenaceous and 35 calcareous species constitute the fauna. The Lagenidae are most common, having 18 species. Representing the Lituolidae are 7 species. The basal shale unit (30 feet) of the Cody carries an overwhelming calcareous-arenaceous ratio of 13–2, which is similar to the ratio in the Greenhorn. The succeeding 63 feet show a 7–1 arenaceous-calcareous ratio, resembling the lower and middle members of the Carlile shale. The ratio of 23 calcareous to 8 arenaceous species in the remaining shales of the basal part of the Cody (295 feet) suggests a relationship with the upper part of the Carlile shale and with the Niobrara formation. Individuals of arenaceous species, however, are more abundant than calcareous individuals in this part of the Cody.

This general faunal resemblance between the major units in the Great Plains with the divisions in the basal part of the Cody shale at Greybull is strengthened by the similarities in restricted species between the two areas (tables 1–4). Such relationships are significant in view of the lithologic variation between sandy shales and small sandstones of the Cody and the more calcareous elements of the Greenhorn and Carlile sequence. Many of the Foraminifera transcend boundaries of facies and are apparently good indices of differences in time. It should be stated, however, that wherever calcareous species are greater in number than arenaceous species in the relatively sandy basal Cody shale, arenaceous individuals are usually more abundant than calcareous individuals in any one sample.

The large number (18) of forms not identified specifically is explained entirely by the lack of sufficient material to describe new species. Whenever suitable populations of 10 or more individuals were not available, new species were not described. Most of such forms from the Great Plains section and from the Cody shale are probably new. They are in the distribution charts (tables 2 and 4), discussed in the systematic paleontology, and are figured. Ten new species are described, 6 from the Great Plains formations, 4 from the Cody.

MICROFAUNAL ZONES

The present study has revealed that useful microfossil zones exist in the Cretaceous formations examined north of the Black Hills and that these zones may be recognized west of the Great Plains in great thicknesses of dark shale. In the Belle Fourche section at least 12 microfossil assemblages can be identified in the succession from the upper part of the Belle Fourche shale to the Sage Breaks member of the Carlile shale. The major elements of these microfaunas appear in the basal part of the Cody shale of eastern Bighorn Basin as five distinct assemblages. Tables 2 and 4 show the distribution of species in the two areas. Only four species found in the Great Plains region and three in the Cody range throughout the section.

The upper 15 feet of the Belle Fourche shale is characterized by a single species *Trochammina* sp. 1.

The Greenhorn formation represents a major faunal zone which at present indicates four distinct elements. *Gumbelina moremani* and *Globorotalia? youngi* occur throughout the Greenhorn and are good index fossils for the entire formation. They are most abundant in the uppermost 50 feet. The former appears rarely in the basal 20 feet of the Carlile shale.

The basal few feet of the Greenhorn formation may be identified by the abundance of *Globigerina cretacea* in association with *Globorotalia? youngi* and *Gumbelina moremani*. This is an entirely pelagic assemblage. In no other part of the Greenhorn are species so few.

The uppermost 50 feet of the lower part of the Greenhorn formation (unit 2) contains many restricted forms: *Dentalina* sp., *Flabellammina* sp. 3, *Globorotalia cushmani*, *Marginulina* sp. 1, *Marginulina* sp. 2, *Planularia* sp., *Robulus* sp., *Saracenaria reesidei*, n. sp., *Vaginulina* sp. 2, and *Marginulinopsis amplaspira*. Despite the variety of restricted forms, *Globigerina cretacea* and *Gumbelina moremani* are most abundant

TABLE 3.—*Stratigraphic section of the Cody shale near Greybull, Wyo., where Foraminifera were collected*

Formations	Faunal assemblage number	Rock unit: No.	Rock unit: Thickness (feet)	Samples and their position in the section (Measurements represent length of vertical channels)	Distance (feet) above datum	Lithology of units
Cody shale.	5	9	90	GD 46–54, each 10 ft.	388 298	Shale, hard, gray, with interbedded bentonites, silty shale, and small sandstones. Small gray-brown silty bentonitic sandstone 3–5 ft thick is 7 ft above base and forms third prominent ledge of the Cody above Frontier. Section capped by fourth ledge of the Cody, 3–5 ft of hard silty shale and bentonitic sandstone.
	4	8	110	GD 35–45, each 10 ft.	188	Shale, hard, gray, somewhat sandy, measured above barren limestone concretions of second ledge of the Cody. Belemnites and shark teeth 30–40 ft above base. Brown limestone siderite concretions with fragments of *Gryphaea* and *Inoceramus* in basal 20 ft.
	3	7	80	GD 23–34, each 6½ ft.	108	Shale, soft, gray-brown, sandy. Fossiliferous gray paper sandstone 8–16 in. 30 ft below top. Barren large limestone siderite concretions form second prominent ledge of the Cody at the top of unit. Upper 22 ft not exposed.
		6	15	GD 20–22, each 5 ft.	93	Shale, gray, interlaminated fissile, and buff sands 1 in. thick.
	2	5	10	GD 18–19 each 5 ft.	83	Shale, massive, hard, gray.
		4	37	GD 11–17, each approximately 5 ft.	46	Shale, gray with many light-brown sands as large as 1 in.
		3	16	GD 8–10, equally spaced.	30	Shale, gray, hard, massive, above limestone siderite concretions which form first ledge of the Cody above Frontier.
Datum	1	2	30	GD 1–7, each approximately 4 ft.	0	Shale, gray, massive, hard, with irregular sandy laminations lying beneath limestone siderite concretions 2 ft by 3 ft. Concretions form first ledge of the Cody above Frontier. Basal 4 in. contain black chert pebbles ¼–1 in. in diameter.
Frontier.		1		Not sampled.		Sandstone, massive, olive-drab, shaly; olive-drab sandy shale, thinly bedded brown sandstone with chert pebbles and yellow, buff to brown sand. Brown sandstone usually forms ledge 3 ft high but is often obliterated by wash from overlying Cody. Contact with Cody sharp. Large brown sandstone concretions 2½ ft in diameter bearing *Dunveganoceras* fauna occur in upper 25 ft. Wood, chert pebbles, *Inoceramus* fragments, and small gastropods are also in concretions.

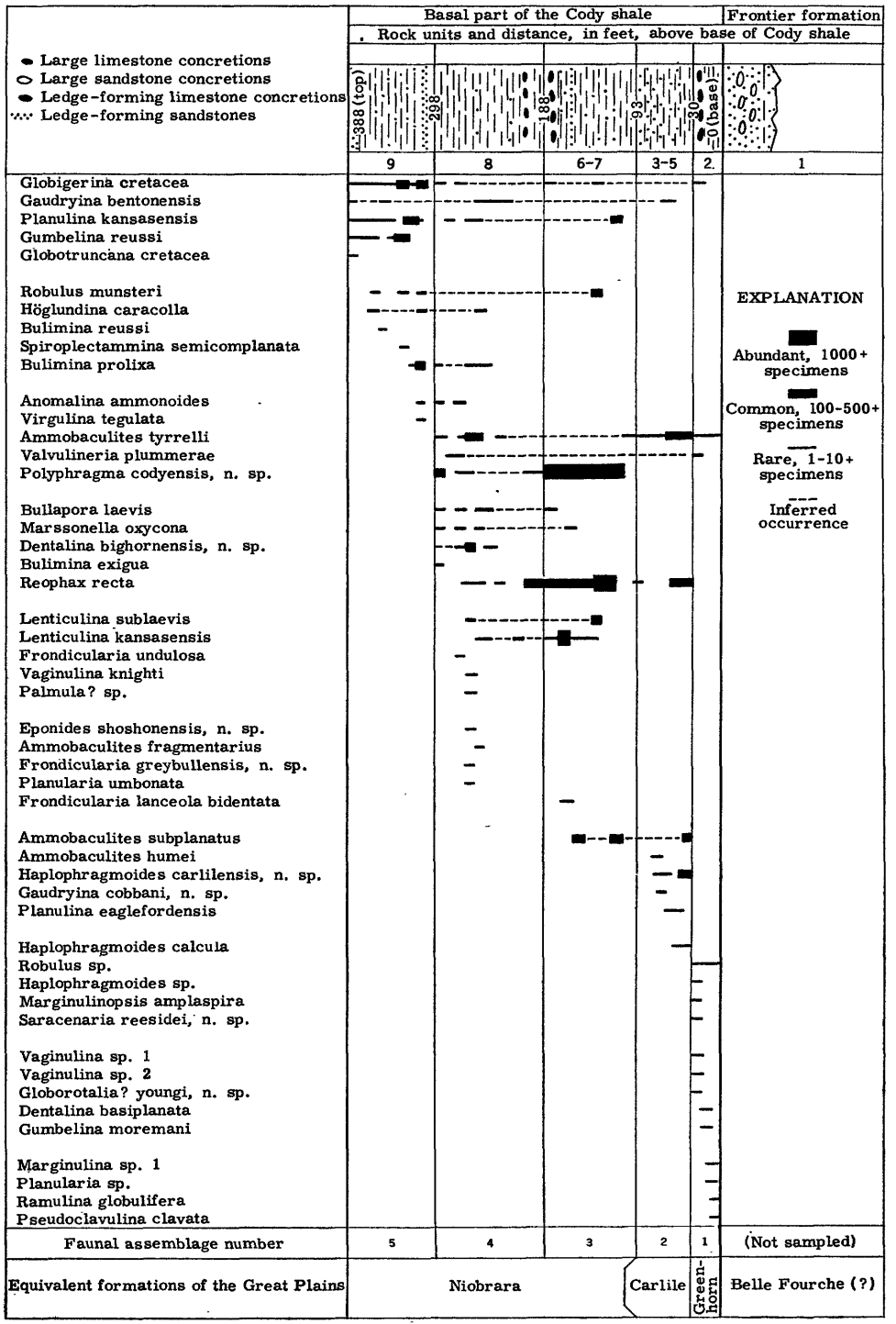
individually but they are not so common as they are in the upper part of the Greenhorn (unit 5). Six of the restricted lower Greenhorn species appear in the basal 30 feet of the Cody.

Unit 5, the uppermost 61 feet of the Greenhorn formation, may be recognized by the restriction of *Planulina dakotensis* n. sp., *Bulimina wyomingensis*, n. sp., *Flabellammina* sp. 1, *Haplophragmoides* sp., *Vaginulina*, sp. 1, *Buliminella fabilis*, and *Gumbelina pseudotessera*. Most abundant here are *Gumbelina moremani*, *Globigerina cretacea*, *Planulina dakotensis*, *Bulimina wyomingensis*, and *Globorotalia? youngi*, n. sp. *Buliminella fabilis* and *Gumbelina pseudotessera* have considerable ranges in the Cretaceous of the Gulf Coast. The basal 12 feet of unit 5 is distinguished by *Quinqueloculina moremani*, a restricted Eagle Ford species. Above this, *Palmula* sp., *Anomalina bighornenis*, *Bigenerina* sp., and *Dentalina catenula* are characteristic, but "floods" of *Globigerina cretacea* dominate the top 30 feet. *Bulimina wyomingensis* is most abundant 30–40 feet below the top of unit 5. *Dentalina catenula* has been reported in both Taylor and Navarro rocks on the Gulf Coast and in Lower Cretaceous sedimentary rocks in Europe.

The Carlile shale (with the exception of the uppermost part of the Turner sandy member and the Sage Breaks member) may be considered another major faunal zone, and its composition is principally arenaceous. *Haplophragmoides carlilensis* n. sp., *Gaudryina cobbani*, n. sp., and *Trochammina* sp. 3 are the key fossils for the unnamed member and the Turner sandy member of the Carlile shale. *Haplophragmoides carlilensis*, n. sp. is most abundant in the middle part of the Turner. It does not extend to the lower or upper limits of the Carlile. *Gaudryina cobbani*, n. sp. appears in the top of the unnamed member and at the base of the Turner. *Trochammina* sp. 3 is most abundant in the basal 16 feet of the Turner but occurs throughout its 67 feet. Both of these new species occur in the Cody shale 30–94 feet above the base.

The basal 13 feet of the unnamed member of the Carlile shale is distinguished by the presence of several

TABLE 4.—*Stratigraphic distribution of Foraminifera in the basal part of the Cody shale near Greybull, Wyo.*



species of radiolarians, including *Dictyomitra* sp. Many samples contain nothing but radiolarian remains. A few specimens of *Gumbelina moremani* and *Ammobaculites subplanatus* appear in samples.

The middle part (units 7–11) of the unnamed member of the Carlile shale contains only *Trochammina* sp. 3. Samples from this part of the section are easily recognized by the hundreds of crushed specimens of this species. A few radiolarians are also present.

The shales in the uppermost 37 feet (units 12–15) of the unnamed member of the Carlile shale are recognized by the restriction of *Ammobaculites humei*, in association with *Gaudryina cobbani*, n. sp., *Trochammina* sp. 3, and *Haplophragmoides carlilensis*, n. sp.

The lower part of the Turner sandy member of the Carlile shale (units 16–18) is relatively unfossiliferous. Dozens of unidentifiable crushed specimens appear in many samples. *Trochammina* sp. 3 is common at the base. *Haplophragmoides carlilensis* occurs alone in the top 40 feet.

The middle part of the Turner carries the main Carlile microfauna. *Haplophragmoides carlilensis*, n. sp. is most abundant here and is associated with the restricted *Flabellammina* sp. 2. *Gaudryina cobbani*, n. sp. occurs in the basal 20 feet. The restriction of *Ammobaculites fragmentarius* has no stratigraphic significance because this form has a long range in the Cretaceous.

The upper sandy shales and siltstones in the Turner sandy member present an assemblage with strong Niobrara and Austin affinities. The abundance of *Lenticulina kansasensis* and the presence of *Vaginulina texana* 17 feet below the top of the Turner indicate relationship to the Fort Hays fauna of Kansas and Nebraska and to the Austin of Texas. Both species are restricted to the Fort Hays in Kansas, Nebraska, and South Dakota, and to that part of the Cody shale in the type Cody which bears other restricted Niobrara elements. *Vaginulina texana* is a good index species for the Austin chalk on the Gulf Coast. Associated with these two Niobrara species are *Frondicularia* sp., *Höglundina caracolla*, *Haplophragmoides calcula*, and *Ammobaculites subplanatus*. *Frondicularia* sp. is restricted to this occurrence. *H. caracolla* and *H. calcula* are long-ranging Cretaceous species. *A. subplanatus* was described from the Austin of Texas but it occurs in the lower part of the Carlile shale near Belle Fourche and also in the lower part of the Cody shale with other Carlile elements. The occurrence in the upper part of the Turner of typical Niobrara microfossils may well indicate an extension downward of the range of these forms. The main *Prionocyclus wyomingensis* ammonite zone occurs in the middle part of the Turner, but the upper part of the Turner and the Sage Breaks members still yield the characteristic Carlile genus *Prionocyclus* (Cobban and Reeside, oral communication). Such an association of Carlile ammonities and typical Niobrara Foraminifera is not confusing but shows probable transitional Carlile and Niobrara conditions.

The Sage Breaks microfauna is known from a few samples representing 15 feet beginning 77 feet below the top of the formation. The assemblage of *Planulina kansasensis*, *Bulimina exigua*, and *Neobulimina canadensis* is clearly related to the Niobrara formation of Kansas and Nebraska. *Planulina kansasensis* is a restricted Niobrara species in Kansas and Nebraska. It has been recognized in the Sage Breaks member of the Carlile shale of Laramie Basin (Thomas, 1936, p. 1193) and it occurs in the type Cody shale restricted to strata which bear other Niobrara species. *Bulimina exigua* is essentially an Austin form on the Gulf Coast. It appears with *Planulina kansasensis* in the Cody. *Neobulimina canadensis* frequently occurs with these species but its association is of no stratigraphic value. It ranges from the Eagle Ford shale to the Navarro formation on the Gulf Coast. According to Reeside and Cobban (personal communication), the Sage Breaks carries a molluscan fauna of Carlile type, including the genus *Prionocyclus*. The only megafossil common to the Sage Breaks and to the Niobrara (Fort Hays) is *Ostrea congesta* Conrad. Therefore, as in the uppermost part of the sandy member, Turner, it is apparent that the Sage Breaks fauna is a mixture of Carlile molluscan elements and essentially Niobrara-type microfossils.

In the basal 388 feet of Cody shale exposed in continuous section southeast of Greybull, five faunal assemblages in three major faunal zones are clearly recognizable. The major zones are related to the Greenhorn, Carlile, and basal Niobrara elements in the Great Plains.

The massive hard gray shales in the basal 30 feet of the Cody contain an overwhelmingly calcareous fauna (table 4, fauna 1) of 16 species, of which 13 are restricted to this zone at Greybull. Ten species are restricted to the Greenhorn formation in the Belle Fourche section. The forms restricted at Greybull, and also to the Greenhorn, are *Marginulinopis amplaspira*, *Globorotalia? youngi*, *Vaginulina* sp. 1, *Vaginulina* sp. 2, *Saracenaria reesidei*, *Robulus* sp., *Planularia* sp., *Marginulina* sp. 1, *Haplophragmoides* sp., *Gumbelina moremani*, and *Dentalina basiplanata*. *D. basiplanata* has a long range in the Cretaceous on the Gulf Coast. Species restricted at Greybull but with longer ranges elsewhere

in the Cretaceous are *Pseudoclavulina clavata* and *Ramulina globulifera.*

The succeeding 63 feet of gray massive shales of the Cody, containing many interbedded light brown sands, bear the dominantly arenaceous *Haplophragmoides carlilensis* fauna (table 4, fauna 2) of nine species. Restricted to this zone are *Haplophragmoides carlilensis*, n. sp., *Gaudryina cobbani*, n. sp., *Ammobaculites humei*, *Haplophragmoides calcula*, and *Planulina eaglefordensis.* The first four are known only from the Carlile shale in the Great Plains and the last is an Eagle Ford species in Texas. *Haplophragmoides calcula* ranges considerably higher in the Cretaceous both in Canada and in Texas. It is apparent that this part of the Cody in eastern Bighorn Basin is the equivalent of at least part of the Carlile of the Great Plains. The sediments at Greybull contain considerably more sand. Longer ranging species associated with the Carlile species are frequently common. They are *Ammobaculites tyrrelli*, *Ammobaculites subplanatus*, *Reophax recta*, and *Gaudryina bentonensis.*

The next 295 feet of the Cody (table 4, units 6–9) are characterized by gray-brown shales and sandy shales which contain three faunal assemblages, each indicating relationship with Foraminifera from the Niobrara of Kansas and Nebraska (Morrow, 1934, and Loetterle, 1937). The oldest assemblage (table 4, fauna 3) occurs in sandy shales with many 1-inch buff sands and is distinguished by the relative abundance of arenaceous individuals, particularly of the species *Polyphragma codyensis* and *Reophax recta.* The presence in this fauna of *Lenticulina kansasensis*, *Lenticulina sublaevis*, and *Planulina kansasensis* in association with *Frondicularia lanceola bidentata* suggests relationship to the Niobrara formation of Kansas and Nebraska where these forms are restricted Niobrara species. However, the occurrence in the Belle Fourche area of *Planulina kansasensis* in the Sage Breaks and of *Lenticulina kansasensis* in the upper part of the Turner sandy member of the Carlile shale has been noted above.

A strongly calcareous assemblage (table 4, fauna 4) appears in the less sandy 110 feet representing unit 8 (table 4). It is marked by the presence of *Vaginulina knighti*, *Frondicularia undulosa*, *Palmula?* sp., *Dentalina bighornensis*, *Bulimina exigua*, *Frondicularia greybullensis*, *Eponides shoshonensis*, and *Planularia umbonata. Planulina kansasensis*, *Lenticulina kansasensis*, *Lenticulina sublaevis*, and *Polyphragma codyensis* occur more rarely than in fauna 3. Since *Vaginulina knighti*, *Frondicularia undulosa*, *Lenticulina kansasensis*, *Lenticulina sublaevis*, and *Planularia umbonata* are restricted in Kansas and Nebraska to the basal (Fort Hays) member of the Niobrara formation, this assemblage indicates strong relationship to the Niobrara of the central part of the Great Plains.

The uppermost 90 feet (unit 9) of the basal part of the Cody shale at Greybull contain fauna 5 (table 4) consisting principally of *Bulimina reussi*, *Globotruncana cretacea*, *Gumbelina reussi*, and *Planulina kansasensis.* Despite the disappearance of the characteristic Niobrara forms of fauna 4, this assemblage is also typical of the Niobrara of the Great Plains.

In considering all species in faunal assemblages 3 and 4 (table 4), the relationship to a zone 200 feet thick near the top of the Alberta shale in Canada (Wickenden 1932b, p. 203–207) is evident. The presence of the arenaceous species *Polyphragma codyensis* (*Clavulina?* sp. of Wickenden), *Reophax recta*, *Marssonella oxycona*, *Ammobaculites tyrrelli*, and the calcareous form, *Bullopora laevis*, suggests affinity with Wickenden's essentially arenaceous fauna. The mixed arenaceous-calcareous nature of the Cody fauna is thus effective in indicating the relationship between the highly calcareous Niobrara assemblages of the Great Plains and the more arenaceous suites of the Canadian section.

MICROFAUNAL ANALYSIS

The 24 genera reported in this paper from the Greenhorn formation represent a new American Cretaceous microfauna. Sixteen of the 31 species are either new or are not referable to previously described forms. Comparisons with other faunas in the western interior which are equivalent to the Greenhorn of the Black Hills suggest the varying ecological conditions during the deposition of the Greenhorn and other formations of the same age. Lithologically, shales equivalent to the Greenhorn formation contain less calcareous material as they are traced westward.

Faunas most closely related to the new Greenhorn assemblages are from the basal 30 feet of the Cody shale at Greybull, Wyo., from similar shales in the Cody near Buffalo, Wyo., and from shale 900 feet above the base of the Colorado formation at Mosby, Mont. The samples from Buffalo were collected by R. K. Hose and W. J. Mapel, those from Mosby by W. A. Cobban. As in the Greenhorn, these faunas are characterized by the absence of several species of the genus *Marginulinopsis.* Twelve of 14 genera and 14 of 16 species in the basal 30 feet of the Cody at Greybull occur also in the Greenhorn, and the 10 genera in the Buffalo fauna and 9 of 10 species appear in the Greenhorn. The relationship of the fauna at Mosby to the fauna of the Greenhorn is demonstrated by the presence in the latter of 8 of 10 genera and species from Mosby.

In contrast, other faunas equivalent in age to those of the Greenhorn formation suggest varying ecological

conditions. Young (1951, p. 35–68) described 34 species assigned to 17 genera from the Frontier formation of southern Montana. Eight of Young's genera and only four of his species appear also in the Greenhorn. Furthermore, the genus *Marginulinopsis*, so characteristic of the Frontier in southern Montana, is of a minor significance in the Greenhorn. Recently the writer examined a microfauna collected by W. A. Cobban and J. B. Reeside, Jr., from the Frontier formation at Cumberland Gap in western Wyoming. Nine of the 13 genera and 8 of 15 species occur also in the Greenhorn, but the presence of many species characteristic of the Frontier of southern Montana, including abundant specimens of *Marginulinopsis*, suggests closer environmental relationship between these two faunas than either maintains with the faunas of the Greenhorn of the Black Hills. In Kansas, the Jetmore and Pfeifer members of the Greenhorn have yielded no benthonic Foraminifera for comparison with the faunas above. Morrow (1934, p. 188) reported two pelagic genera from these beds. As more material is examined, it should be possible to set a clearer pattern of faunal variations in the Greenhorn and its equivalents throughout the western interior.

The Greenhorn formation contains seven species reported by Cushman (1946, p. 9–13) and Moreman (1942, p. 195) from the Eagle Ford group of Texas. Only two pelagic species are restricted Eagle Ford forms on the Gulf Coast. However, the ecological difference between the Greenhorn and Eagle Ford assemblages is indicated by the presence in the Greenhorn of only 15 of 31 Eagle Ford genera and 7 of 34 species.

Records of the Carlile and equivalent faunas, either published or otherwise known to the writer, are not so extensive as those of the Greenhorn. However, reports that are available do indicate more uniform conditions during much of the time represented by the deposition of the Carlile and sediments of the same age.

The Carlile fauna in the Belle Fourche area is best described as comprising three principal elements. The first is found in the unnamed member of the Carlile and the lower and middle parts of the Turner sandy member (table 2, faunas 6–10). It consists of 11 species referable to 7 genera. Its five benthonic genera are arenaceous. The upper part of the Turner contains a mixed arenaceous and calcareous fauna (table 2, fauna 11) of six species assigned to six genera. The Sage Breaks fauna of three calcareous genera and three species (table 2, fauna 12) is the youngest Carlile assemblage.

The fauna of the Carlile shale below the upper part of the Turner sandy member consists of arenaceous benthonic genera, with several associated calcareous pelagic types. The arenaceous character of the benthonic forms in equivalent sediments in the western interior and the presence of many of the same genera and species suggest the essential similarity of ecological conditions over a wide area during this time. Four of six genera and seven of nine species in faunal assemblage 2 (table 4) of the Cody shale occur also in the Carlile below the upper part of the Turner. The four comparable genera are arenaceous. The writer has noted the occurrence of faunas containing one arenaceous (benthonic) and one calcareous (planktonic) species in the basal part of the Cody shale near Buffalo, Wyo., and in the Frontier formation as far west as Cumberland Gap in western Wyoming. In each instance the faunas occur just above Greenhorn species, and the benthonic arenaceous species are identical with restricted types from the unnamed part of the Carlile. Applin (1933, p. 219) reported three species of the arenaceous genus *Haplophragmoides* and two calcareous planktonic forms from the Carlile of Meade County, S. Dak. Only in Kansas, where Morrow (1934, p. 188) described two pelagic genera from the lower (Fairport) member of the Carlile, are the typical arenaceous species absent.

The faunas in the upper part of the Turner and in the Sage Breaks (table 2, fauna assemblages 11 and 12) in the Belle Fourche area, and the Niobrara fauna of Kansas and Nebraska (Morrow, 1934, p. 188; Loetterle, 1937, p. 1–73) are overwhelmingly calcareous. Traced westward the units bearing these faunas reveal an increase in coarse clastic material. At Greybull, in the sandy shales of the Cody the association of arenaceous genera with many of the typical calcareous forms of the Great Plains reflects the changing environments.

Faunal assemblages 3–5 (table 4) at Greybull contain, in addition to eight arenaceous species referred to seven genera, many of the calcareous species restricted in Kansas and Nebraska to the Niobrara. The writer suggests that faunal assemblage 3 in the Cody shale may well represent the westward equivalent of the upper part of the Turner and Sage Breaks faunas. As in the upper part of the Turner and in the Sage Breaks, fauna 3 contains the Niobrara forms *Lenticulina kansasensis* and *Planulina kansasensis* but lacks several of the other typical Niobrara species which first appear in the Cody in fauna 4. It does, however, contain *Lenticulina sublaevis* and *Frondicularia lanceola bidentata*, two species restricted to the Niobrara in Kansas but unknown from the Carlile in the Belle Fourche area. Faunas 4 and 5 are clearly related to the Niobrara of the Great Plains, as shown by the presence of calcareous species restricted to that formation in Kansas and Nebraska and absent from the Carlile of the Belle Fourche area. The associated arenaceous species serve to link these faunas with Canadian Foraminifera described by Wickenden

(1932b, p. 203–207) from part of the Alberta shale. Studies of additional sections throughout the western interior should clarify these relationships and indicate the extent to which arenaceous forms may be used in correlation. It is apparent that microfaunas of Greenhorn and Niobrara affinities vary more in generic composition throughout the western interior than do those of the Carlile.

CHECK LIST OF SPECIES

BELLE FOURCHE SHALE

(1 species)

Arenaceous

Trochammina sp. 1

GREENHORN FORMATION

(24 genera, 31 species)

Arenaceous (4 genera, 5 species)

Haplophragmoides sp.
Ammobaculites tyrrelli Nauss
Flabellammina sp. 1
sp. 3
Bigenerina sp.

Calcareous (20 genera, 26 species)

Quinqueloculina moremani Cushman
Robulus sp.
Planularia sp.
Saracenaria reesidei Fox, n. sp.
Marginulina sp. 1
sp. 2
Marginulinopsis amplaspira Young
Dentalina basiplanata Cushman
catenula Reuss
sp.
Vaginulina sp. 1
sp. 2
Palmula sp.
Gumbelina moremani Cushman
pseudotessera Cushman
Buliminella fabilis Cushman and Parker
Bulimina wyomingensis Fox, n. sp.
Neobulimina canadensis Cushman and Wickenden
Virgulina tegulata Reuss
Valvulineria plummerae Loetterle
Höglundina caracolla (Roemer)
Globigerina cretacea D'Orbigny
Globorotalia cushmani Morrow
Globorotalia? youngi Fox, n. sp.
Anomalina bighornenis Young
Planulina dakotensis Fox, n. sp.

CARLILE SHALE

(14 genera, 19 species)

Arenaceous (5 genera, 10 species)

Haplophragmoides calcula Cushman and Waters
Haplophragmoides carlilensis Fox, n. sp.
Ammobaculites fragmentarius Cushman
humei Nauss
subplanatus Cushman and Deaderick
Flabellammina sp. 2
Gaudryina bentonensis (Carman)
cobbani Fox, n. sp.
Trochammina sp. 2
sp. 3

Calcareous (9 genera, 9 species)

Lenticulina kansasensis Morrow
Vaginulina texana Cushman
Frondicularia sp.
Gumbelina moremani Cushman
Höglundina caracolla (Roemer)
Globigerina cretacea D'Orbigny

SAGE BREAKS MEMBER

(3 genera, 3 species)

Calcareous

Bulimina exigua Cushman and Parker
Neobulimina canadensis Cushman and Wickenden
Planulina kansasensis Morrow

CODY SHALE (BASAL 388 FEET)

(31 genera, 49 species)

Arenaceous (8 genera, 14 species)

Reophax recta (Beissel)
Haplophragmoides calcula Cushman and Waters
Haplophragmoides carlilensis Fox, n. sp.
sp.
Ammobaculites tyrrelli Nauss
fragmentarius Cushman
humei Nauss
subplanatus Cushman and Deaderick
Spiroplectammina semicomplanata (Carsey)
Gandryina bentonensis (Carman)
cobbani Fox, n. sp.
Pseudoclavulina clavata (Cushman)
Marssonella oxycona (Reuss)
Polyphragma codyensis Fox, n. sp.

Calcareous (23 genera, 35 species)

Lenticulina kansasensis Morrow
sublaevis Morrow
Robulus munsteri (Roemer)
sp.
Planularia umbonata Loetterle
sp.
Saracenaria reesidei Fox, n. sp.
Marginulina sp. 1
Marginulinopsis amplaspira Young
Dentalina basiplanata Cushman
bighornensis Fox, n. sp.
Vaginulina knighti Morrow
sp. 1
sp. 2
Palmula? sp.
Frondicularia greybullensis Fox, n. sp.
lanceola bidentata Cushman
undulosa Cushman
Bullopora laevis (Sollas)
Ramulina globulifera Brady
Gumbelina moremani Cushman
reussi Morrow

Bulimina exigua Cushman and Parker
prolixa Cushman and Parker
reussi Morrow
Virgulina tegulata Reuss
Valvulineria plummerae Loetterle
Eponides shoshonensis Fox, n. sp.
Höglundina caracolla (Roemer)
Globigerina cretacea D'Orbigny
Globotruncana cretacea Cushman
Globorotalia? youngi Fox, n. sp.
Anomalina ammonoides (Reuss)
Planulina eaglefordensis (Moreman)
kansasensis Morrow

DESCRIPTIONS OF SPECIES

Order FORAMINIFERA

Family REOPHACIDAE

Genus REOPHAX Montfort, 1808

Reophax recta (Beissel)

Plate 24, figure 1

Trochammina recta Beissel, 1891, Preuss. geol. Landesanstalt Abh., n. ser., v. 3, 1891, p. 22, pl. 5, fig. 1–3.
Reophax recta Franke, 1928, Idem. n. ser. v. 3, p. 19, pl. 2, fig. 3.
Brotzen, 1936, Sveriges geol. Undersökning, ser. C, no. 396, p. 30, pl. 1, fig. 2.
Cushman, 1942, Cushman Lab. Foram. Research Contr., v. 18, p. 3, p. 50–66.
Reophax texana Wickenden, 1932, (not Cushman and Waters), Jour. Paleontology, v. 6, no. 2, p. 203–207, pl. 29.

From 30–268 feet above the base of the Cody shale, at Greybull, Wyo., *Reophax recta* (Beissel) is rare to abundant in most samples.

The Cody specimens agree very well with Franke's topotypes. They differ from *Reophax texana* Cushman and Waters in their generally smaller size, the greater height of their chambers relative to the breadth, and in less overlap of chambers. *Reophax constricta* (Reuss) has fewer chambers, and more constricted sutures.

Reophax recta (Biessel) has been identified by the writer throughout the Cody shale in the type section and seems to be associated at Greybull with forms which are diagnostic of the Carlile shale and the basal part of the Niobrara formation of the Great Plains. Cushman has reported it from the Brownstown marl of Arkansas, and Wickenden (1932b) from a zone in the Alberta shale which is presumably equivalent to part of the Niobrara of the Great Plains. Hundreds of specimens appear in the Greybull material, but none has been observed in the Belle Fourche section.

Length of figured specimen 0.90 mm; breadth 0.30 mm. Other specimens from 0.60–1.00 mm in length.

Occurrence.—Figured specimen (USNM 106805) from sample GD 8 about 30 feet above the base of the Cody shale.

Family LITUOLIDAE

Genus HAPLOPHRAGMOIDES Cushman, 1910

Haplophragmoides carlilensis Fox, n. sp.

Plate 24, figures 2, 3

Test close coiled, planispiral, deeply umbilicate; periphery broadly rounded; chambers distinct, usually 10 in the final whorl, of uniform shape, gradually increasing in size, last 2 or 3 slightly inflated; sutures straight, slightly curved toward periphery, limbate, flush with surface between early chambers, depressed between last 2 or 3 producing slightly lobulate periphery; wall finely arenaceous, with much cement; color usually light; aperture a low opening at the base of the last chamber.

Diameter of holotype 0.72 mm; thickness 0.30 mm. Other specimens from 0.50–0.90 mm in diameter, and from 0.20–0.40 in thickness, depending largely on distortion. The holotype represents the average for undeformed specimens.

Remarks.—The distinguishing features of *Haplophragmoides carlilensis* are its large size, broad periphery, deep umbilicus, inflation of last few chambers, limbate sutures flush with the surface in the early portion, and the depressed last 2 or 3 sutures.

Haplophragmoides glabra Cushman is similar in side view, in being umbilicate, and in having the same number of chambers, but it is one-half to two-thirds the size and does not have so broadly rounded a periphery or limbate early sutures. The new form may be distinguished from *Haplophragmoides* sp. in the Greenhorn formation by its greater diameter and smaller number of chambers. A great many of the Carlile and Cody specimens are so badly crushed that proper identification would be impossible without the presence in the same sample of perfect individuals. In general, the greater the crushing, the more lobulate the periphery. A number of the deformed specimens closely resemble *Haplophragmoides gigas* Cushman, a large compressed form often reported from the Carlile shale of the Great Plains (Applin, 1933, p. 215–220). The writer has been unable to identify any of the numerous flattened Carlile and Cody forms as *Haplophragmoides gigas* Cushman which normally shows sigmoidally curved sutures.

Haplophragmoides carlilensis is common in the middle part of the Turner sandy member of the Carlile shale. Its rare occurrence in all other Carlile strata except in the unnamed member would appear to indicate that the new species is a good index fossil for the Carlile. At Greybull it is common from 30–60 feet above the base of the Cody shale where it is associated with *Gaudryina cobbani*, n. sp. Hundreds of speci-

mens from the Cody and Carlile samples have been examined. Of these, several dozen are perfect, undeformed individuals.

Types and occurrence.—Holotype (USNM 106806) and unfigured paratypes (USNM 106808) from sample CT 15. Figured paratype (USNM 106807) and unfigured paratypes (USNM 106809) from sample CT 16. All types are from the middle part of the Turner sandy member of the Carlile shale.

Haplophragmoides sp.

Plate 24, figures 4, 5

A few poorly preserved specimens of *Haplophragmoides* are reported because they are distinctive and occur in both the upper part of the Greenhorn and the basal part of the Cody samples.

Distinguishing features of the species are the close coiled deeply umbilicate test, broadly rounded periphery, and many (12–13) chambers. The sutures are indistinct and only slightly depressed. The wall is finely arenaceous, with a smooth finish. Color is light gray.

Diameter of figured specimens 0.33 mm, thickness 0.18 mm.

Remarks.—The specimens are similar to *Haplophragmoides glabra* Cushman and Waters, but they are considerably smaller, have more chambers, and are more deeply umbilicate. They resemble *Haplophragmoides carlilensis* n. sp. in general form and in being deeply umbilicate but the Carlile species is more than twice as large and has fewer chambers.

Occurrence.—Figured specimens (USNM 106810, 106811) from sample GU XV. Other individuals are known only from units of the Greenhorn formation and from the basal 30 feet of the Cody at Greybull.

Genus AMMOBACULITES Cushman, 1910
Ammobaculites tyrrelli Nauss

Ammobaculites coprolithiforme (Schwager). Cushman, 1927, Royal Soc. Canada Trans., 3d ser., v. 21, sec. 4, p. 130, pl. 1, figs. 6, 7;
Cushman and Jarvis, 1932, U. S. Natl. Mus. Proc., v. 80, art. 14, p. 13, pl. 3, figs. 4, 5.
Ammobaculites coprolithiformis (Schwager). Wickenden, 1932, Jour. Paleontology, v. 6, no. 2, p. 204, pl. 29, fig. 2
Cushman, 1946, U. S. Geol. Survey Prof. Paper 206, p. 22, pl. 3, figs. 7–9.
Ammobaculites tyrrelli Nauss, 1947, Jour. Paleontology, v. 21, no. 4, p. 333, pl. 48, fig. 2.
Tappan, 1951, Cushman Lab. Foram. Research Contr., v. 2, pt. 1, p. 3, pl. 1, figs. 12–14.

Many specimens from the upper unit of the Greenhorn formation and from the basal part of the Cody shale agree with the species described by Nauss from the Lloydminster shale of Alberta, Canada. The circular outline of the coiled portion, the sutures at right angles to the long axis, the apertural necks, and the nearly parallel sides of the uniserial portion are typical.

Specimens in the upper Alberta shale referred by Wickenden to *A. coprolithiformis* (Schwager) are believed to be of the same species as those in the Greenhorn and Cody material.

Genus FLABELLAMMINA Cushman, 1928
Flabellammina sp. 1

Plate 24, figure 6

A few specimens from unit 5 of the Greenhorn formation indicate a large, strongly compressed *Flabellammina* similar to *Flabellammina compressa* (Beissel) in shape and in the curvature of the sutures. The test is broadly oval, with the greatest breadth in the middle.

The Greenhorn forms are longer and wider than Beissel's species and possess 4 or 5 chambers in the uniserial portion instead of 3. Furthermore, chambers and sutures both are indistinct. There is no evidence of sutural depression. Because of the variations which most species of this genus show, a few specimens do not justify the description of a new species.

Length of figured specimen 2.82 mm; breadth 2.0 mm.

Occurrence.—Figured specimen USNM 106812 from sample GU VII in the uppermost unit of the Greenhorn formation

Flabellammina sp. 2

Plate 24, figure 7

A few specimens found about 80 feet below the top of the Turner sandy member of the Carlile shale indicate an elongate, compressed *Flabellammina* which is different from other species in the Belle Fourche section and from *Flabellammina compressa* (Beissel).

The specimens agree in shape and size with Beissel's species but the coiled portion is umbilicate and the uniserial portion shows a rough uneven surface, with sutures and chambers both indistinct. They differ from *Flabellammina* sp. 1 in being narrower and more rectangular, and from *Flabellammina* sp. 3 in the greater elongation and compression of the test. The periphery is bluntly rounded. Uniserial chambers are usually 3 in number and increase rapidly in size. The wall is coarsely arenaceous.

Length of figured specimen 1.9 mm; breadth 1.1 mm. Other specimens, length as much as 2.2 mm.

Occurrence.—Figured specimen USNM 106813 from sample CT 23 in the upper part of the Carlile shale.

Flabellammina sp. 3

Plate 24, figure 8

A single specimen of a large *Flabellammina* is figured for reference. It is easily distinguished from other

Cretaceous species of this genus by the compressed coiled portion which constitutes nearly one half of the test, and by the inflation and thickness of the two uniserial chambers which increase rapidly in size toward the aperture. The sutures are indistinct and the wall is coarsely arenaceous, composed of light colored sand grains.

The greatest breadth 1.7 mm, occurs in the middle of the last formed chamber. The length is 2.6 mm, and the thickness of the inflated uniserial portion 0.55 mm.

Occurrence.—Figured specimen (USNM 106814) from sample GL I in lowermost unit (2) of the Greenhorn formation.

Family TEXTULARIIDAE

Genus BIGENERINA D'Orbigny, 1826

Bigenerina sp.

Plate 24, figure 9

In the uppermost unit of the Greenhorn formation a single specimen of *Bigenerina* appears with other species, such as *Anomalina bighornensis* Young and *Flabellammina* sp. 1, that are restricted to this part of the Belle Fourche section. It is associated with thousands of individuals of *Globigerina cretacea* D'Orbigny.

The Greenhorn specimen is not compressed. The elongate, cylindrical test consists of an early biserial portion which tapers gradually toward the initial end. The uniserial portion occupies about one half of the test and has parallel sides and chambers that are wider than high. Throughout the gray test the sutures are distinct and depressed. The wall is finely arenaceous and the aperture terminal.

Bigenerina sp. is easily distinguished from *Bigenerina hastata* Cushman by its circular transverse section, the gently tapering uniserial portion, and its depressed sutures.

Length of figured specimen 0.78 mm; breadth and thickness 0.18.

Occurrence.—Figured specimen (USNM 106815) from sample GU V in the uppermost unit (5) of the Greenhorn formation.

Family VERNEUILINIDAE

Genus GAUDRYINA D'Orbigny, 1839

Gaudryina cobbani Fox, n. sp.

Plate 24, figure 10

Test large, only slightly compressed; early portion triserial, comprising less than one-third of test; biserial portion long, usually with 4 pairs of chambers and parallel sides; chambers fairly distinct, increasing in size only slightly in the biserial portion, about as high as broad, gently inflated, frequently giving lobulate outline on both sides; sutures in smoother specimens distinct, limbate, depressed, horizontal, often becoming oblique toward apertural end; wall coarsely arenaceous with a roughened finish; color usually light; aperture elongate and at the inner margin of the last-formed chamber.

Length of holotype 0.75 mm; breadth 0.30 mm; other specimens are from 0.60–0.75 mm in length, and from 0.25–0.30 in breadth.

Remarks.—*Gaudryina cobbani* is distinguished principally by the small triserial portion, the great breadth relative to the length of the test, the parallel sides of the biserial end, the almost equal size and configuration of the slightly inflated biserial chambers, and the relatively small number of pairs of chambers. The species is associated in the Carlile shale and in unit 3 of the Cody shale with *Gaudryina bentonensis* (Carman) from which it differs in being longer and broader and in having fewer and inflated chambers in both biserial and triserial portions. The later chambers of *Gaudryina foeda* (Reuss) resemble those of the new species, particularly when specimens are crushed. However, the tapering initial portion of Reuss's species and the greater number of chambers are diagnostic.

Gaudryina cobbani occurs rarely in the upper part of the unnamed member of the Carlile shale with *Gaudryina bentonensis* (Carman) and also in the middle of the Turner sandy member of the Carlile where it is associated with *Haplophragmoides carlilensis* n. sp. Its appearance at Greybull with these same species 30 feet above the base of unit 3 in the Cody is helpful in relating these strata to the Carlile. Several dozen uncrushed specimens of *Gaudryina cobbani* have been studied from the Belle Fourche and Greybull exposures.

Types and occurrence.—Holotype (USNM 106816), unfigured paratypes (USNM 106817 and 106818) from sample CL 8, unit 15, about 30 feet below the top of the unnamed member of the Carlile shale.

Family TROCHAMMINIDAE

Genus TROCHAMMINA Parker and Jones, 1859

Trochammina sp. 1

Plate 24, figures 11–13

The top 15 feet of the Belle Fourche shale (unit 1) have yielded hundreds of crushed specimens of a small white species. Several of the specimens are well enough preserved to indicate that the entire assemblage may be referred to *Trochammina*. Until additional good specimens are available, the writer will not attempt description of a new species.

The test is small and delicate, trochoid, and slightly compressed. The periphery is slightly lobulate. Chambers are usually 5 in number, and are inflated

ventrally but not dorsally. They increase in size dorsally, with the last chamber being much enlarged. Sutures are oblique, flush, and slightly curved dorsally, but depressed and radial on the ventral side. The wall is finely arenaceous, with much cement. The aperture is narrow and on the ventral side at the inner margin of the last-formed chamber.

Length of figured specimens 0.30 mm; breadth 0.25 mm; thickness 0.15 mm. Other specimens are from 0.28–0.32 mm in length.

Remarks.—*Trochammina* sp. 1 is distinguished by its small size, oblique dorsal sutures, radial depressed ventral sutures, and the ventral inflation of the chambers. It differs from *Trochammina albertensis* Wickenden in the lack of a high dorsal spire and in the lack of curved ventral sutures. It is smaller and less compressed than *Trochammina texana* Cushman and Waters. Crushed specimens of *Trochammina* sp. 1 are easily confused with those of *Trochammina* sp. 3 from the Carlile shale. The Carlile form is generally larger, more inflated dorsally, has straight, depressed dorsal sutures, and is more coarsely arenaceous.

In the present study *Trochammina* sp. 1 is found only in the top 15 feet of the Belle Fourche shale where it occurs alone. Hundreds of crushed specimens have been examined.

Occurrence.—Figured specimens (USNM 106819–106821) from sample BF II about 10 feet below the top of the Belle Fourche shale.

Trochammina sp. 2

Plate 24, figures 14–16

A compressed, many-chambered *Trochammina* is represented by a few individuals in the uppermost part of the unnamed member of the Carlile shale.

The test is trochoid, with 8 uninflated chambers and limbate radial sutures on both sides. It differs from *Trochammina ribstonensis* Wickenden in being less evolute, larger, and in having straight sutures. *Trochammina diagonis* (Carsey) is larger and has a lobulate periphery. Another Carlile form, *Trochammina* sp. 3, may be distinguished by the inflation of the chambers, the smaller number of chambers, and the lobulate periphery.

Length of figured specimen 0.50 mm; breadth 0.41 mm; thickness 0.18 mm.

Occurrence.—Figured specimen (USNM 106822) from sample CL 13 in the uppermost part of the unnamed member of the Carlile shale.

Trochammina sp. 3

Plate 24, figures 17–19

The basal 15 feet of the Turner sandy member and the upper part of the unnamed member of the Carlile shale frequently contain nothing but hundreds of flattened tests of a small white arenaceous species. The few identifiable individuals indicate an inflated, coarsely arenaceous *Trochammina* different from the associated Carlile form and from the smaller delicate tests in the Belle Fourche shale.

The test is rounded with lobulate periphery and 5 or 6 inflated chambers which increase progressively in size. Sutures are limbate, radial, and depressed on both sides. The wall is distinctly arenaceous, with the rather uniformly sized sand grains firmly cemented. The aperture is ventral at the inner margin of the last formed chamber.

Diameter of figured specimen 0.40 mm; thickness 0.21 mm. Other specimens are from 0.28–0.42 mm in diameter.

Remarks.—*Trochammina* sp. 3 is distinguished from the Belle Fourche form by its larger size, dorsal inflation of chambers, its radial dorsal sutures, and its more coarsely arenaceous test. *Trochammina albertensis* Wickenden has oblique dorsal and curved ventral sutures, and a higher dorsal spire.

Occurrence.—Figured specimen (USNM 106823) from sample CL 13 in the unnamed member of the Carlile shale.

Family PLACOPSILINIDAE

Genus POLYPHRAGMA Reuss, 1871

Polyphragma codyensis Fox, n. sp.

Plate 25, figures 1–4

Clavulina? sp. Wickenden, 1932b, Jour. Paleontology, v. 6, p. 205, pl. 29, fig. 5.

Polyphragma sp. Cushman, 1946, U. S. Geol. Survey Prof. Paper 206, p. 15, pl. 15, figs. 15, 16.

Test large, elongate, cylindrical, tapering slightly toward initial end which is always broken; chambers numerous, often arranged irregularly, inflated, usually twice as wide as long, all about the same height except the last formed which is enlarged; sutures depressed, straight; walls thick, of coarse sand grains with variable amount of cement; light gray or brown; aperture terminal, cribrate, usually indistinct.

Length of holotype 1.95 mm; diameter 0.8 mm. Other specimens as much as 2.5 mm. in length.

Remarks.—*Polyphragma codyensis* is one of the most easily recognized species in the Cody shale at Greybull and throughout the Bighorn Basin. The irregular, slightly tapering, cylindrical form; the wide, inflated chambers of uniform size; and the broken initial portion characterize the hundreds of specimens examined. The species is apparently an attached form. Its apertural end has an enlarged, rounded final chamber. Many tests are twisted and contorted.

The species occurs abundantly in the Cody shale at Greybull in a 200-foot zone beginning about 115 feet above the base of the formation. It is associated with species which appear in the basal 200 feet of the type Cody at Cody, Wyo. (Fox, 1941, p. 1967) and also with forms which Wickenden (1932b, p. 203–207) has reported from a zone 200 feet thick in the Alberta shale of Canada. The forms in the Cody of the type locality and Wickenden's Alberta specimens occur in sediments equivalent in age to part of the Niobrara formation of the Great Plains. Greybull species restricted to the basal type Cody include *Bulimina exigua* Cushman and Parker, *Bullapora laevis* (Sollas), *Dentalina bighornensis*, n. sp., *Frondicularia lanceola bidentata* Cushman, *Marssonella oxycona* (Reuss), *Palmula?* sp., *Lenticulina kansasensis* Morrow, *Lenticulina sublaevis* Morrow, and *Vaginulina knighti* Morrow. Most of Wickenden's restricted Alberta shale species occur with *Polyphragma codyensis* at Greybull. The widespread occurrence of the *Polyphragma codyensis* fauna suggests the existence of a well-recognized faunal zone in the Cretaceous of the western interior from Canada south into the Bighorn Basin of Wyoming.

Types and occurrence.—Holotype (USNM 106824); figured paratypes (USNM 106825 and 106826) from sample GD 41, about 268 feet above the base of the Cody shale at Greybull; figured paratype (USNM 106827) from sample GD 25 in the Cody shale.

Family LAGENIDAE

Genus ROBULUS Montfort, 1808

Robulus sp.

Plate 25, figure 5

Several fragmentary specimens of *Robulus* are reported because they occur only in the upper part of the lower unit of the Greenhorn formation and in the basal part of the Cody shale at Greybull. One specimen is figured.

The specimens are similar to *Robulus munsteri* (Roemer) in size and in the tendency to become evolute in the adult. However, the prominent keel disappears in the last 4 chambers, the gently curved limbate sutures are slightly raised and curve back as they near the periphery, the chambers are more numerous (13 in final whorl), and the prominent umbonal boss is more irregular than in *Robulus munsteri* (Roemer). The aperture is radiate at the peripheral angle. The writer has examined many individuals of *Robulus munsteri* (Roemer) from exposures higher in the Cretaceous of the western interior. They are very easily distinguished from the Greenhorn and basal Cody material.

Length of figured specimen 0.90 mm; breadth 0.68 mm; thickness 0.32 mm.

Occurrence.—Figured specimen (USNM 106828) from sample GL I in lowest unit (2) of the Greenhorn formation.

Genus PLANULARIA Defrance, 1824

Planularia sp.

Plate 25, figure 6

A few specimens of this distinctive form appear in samples from the upper part of the basal unit of the Greenhorn formation and also in the basal part of the Cody shale at Greybull. Although the features are constant in individuals from the two areas, it seems wise to inspect additional material before describing the species.

This form may be easily distinguished by the large compressed test, with a prominent boss covering the early portion, initial close coiling followed by a loose coiling, the sharp peripheral keel which disappears in the last 2 chambers, the inflation of the last chamber, limbate and raised sutures except for the depressed suture between the last 2 chambers, and the strong curving back of the otherwise gently curved sutures as they near the periphery. The truncate apertural face is sharply bordered. The wall is smooth, and the aperture is terminal, radiate, and at the peripheral angle.

Length of figured specimen 0.95 mm; breadth 0.7 mm; thickness across boss 0.3 mm, across last chamber 0.18 mm. Other specimens from 0.45–0.7 mm in length.

Remarks.—This form is a good index fossil for the Greenhorn formation. At present it has been noted only in the basal unit of the Greenhorn. It appears 10–15 feet above the base of the Cody at Greybull.

Occurrence.—Figured specimen (USNM 106829) from sample GL I in the lowest unit (2) of the Greenhorn formation.

Genus SARACENARIA Defrance, 1824

Saracenaria reesidei Fox, n. sp.

Plate 25, figures 7–9

Test elongate, early portion coiled, later chambers uncoiled, triangular in transverse section; periphery often sharply keeled; chambers distinct, 4 or 5 in uncoiled portion, gradually increasing in size as added, inflated on apertural face; sutures limbate, flush with the surface, perpendicular to periphery, curving strongly toward initial end as they approach the apertual face; wall smooth with carinae at the sides of the apertural face; apertural face and sides often with variable longitudinal costae which are broken by sutures on apertural

face but independent of sutures on the sides; aperture at the angle of the upper end, radiate.

Length of holotype 0.62 mm, breadth 0.21 mm. Other specimens are from 0.35 mm to 0.8 mm in length, and as much as 0.3 in breadth.

Remarks.—*Saracenaria reesidei* is a variable species. Distinguishing features are the elongate test, relatively small size, sharply keeled edges of the apertural face and periphery, and the frequent presence of longitudinal costae on the sides and on the apertural face. In these features it differs from *Saracenaria triangularis* (D'Orbigny).

The species is fairly common in the upper 20 feet of the basal unit (2) of the Greenhorn formation in the Belle Fourche area. It is apparently a good index fossil for this basal unit. At Greybull it occurs rarely in the lowermost 30 feet of the Cody shale (unit 2) where it is associated with other Greenhorn species. Several dozen specimens have been examined.

Types and occurrence.—Holotype USNM (106830) and figured paratype (USNM 106831) from sample GL I; figured paratype (USNM 106832) from sample GL II. All types from lowest unit (2) of the Greenhorn formation.

Genus MARGINULINA D'Orbigny, 1826

Marginulina sp. 1

Plate 25, figure 11

Several fragmentary specimens of a large arcuate *Marginulina* appear in the material from the top of the lowest unit of the Greenhorn formation and also from the basal 30 feet of the Cody shale. They probably represent a new species. A Greenhorn individual is figured for the record.

Characteristic of the fragments is the large size, the arcuate form of the test with concave dorsal and convex ventral margins, slight compression, the narrow coiled portion with initial uncoiled chambers broadening rapidly, and the limbate, slightly curved sutures heavily thickened and raised in the middle portion of the uncoiled part. The aperture is radiate, and at the peripheral angle. The specimens differ from *Marginulina plummerae* Cushman in the arcuate shape of the test and in the excessive sutural thickening in the middle portion. From *Marginulina silicula* (Plummer) they may be distinguished by the lack of spinose, early coiled stages and by the narrow initial portion.

Marginulina sp. 1 is known only from the top of the basal unit of the Greenhorn formation and from the lowermost part of the Cody shale (unit 2) at Greybull.

Length of the figured fragment 1.8 mm; diameter 0.42 mm.

Occurrence.—Figured specimen (USNM 106833) from sample GL I in the Greenhorn formation.

Marginulina sp. 2

Plate 25, figures 10, 12

Three specimens of a small, costate, easily recognizable *Marginulina* are from the uppermost part of the basal unit of the Greenhorn formation. They resemble *Marginulina navarroana* Cushman in general form and in possessing longitudinal costae independent of sutures. However, they are smaller; the periphery is not lobulate; the costae are fewer, more uniform in coarseness, and less twisted initially; and the earliest portion is not compressed. The 4 uncoiled chambers increase gradually in height. The sutures are distinct, oblique, not depressed. The aperture is radiate, projecting at the peripheral angle.

Length 0.52–0.61 mm; diameter 0.18–0.2 mm.

Occurrence.—Figured specimens (USNM 106834) from sample GL I at the top of the basal unit of the Greenhorn formation.

Genus MARGINULINOPSIS Silvestri, 1904

Marginulinopsis amplaspira Young

Plate 25, figures 13, 14

Marginulinopsis amplaspira Young, 1951, Jour. Paleontology v. 25, no. 1, p. 54–55, pl. 11, figs. 15, 17–21; pl. 12, figs. 1–4, 6, 8–14; figs. 5, 14–16, 18–21, 23–25; figs. 6, 2–16, 20

A few specimens referred to this species appear 30 feet above the base of the Cody shale at Greybull and also in the upper part of unit 2 in the Greenhorn formation north of Belle Fourche.

The specimens agree with Young's species in the circular to polygonal peripheral outline of the coiled series, the angles at the junctions of the sutures with the periphery, the closely appressed early chambers of the uniserial series, and in the more loosely joined later uniserial chambers. The aperture is radiate, protruding.

Length 0.65–0.90 mm; minimum diameter of coiled series 0.35–0.42 mm.

Remarks.—This species is abundant in the Frontier formation of southern Montana where Young reports it from the "*Vascoceras* beds." A few individuals have been observed from the Greenhorn formation of the Belle Fourche section. The writer has also identified the species from the Frontier formation below the Oyster Ridge sandstone member in the Cumberland Gap section, Lincoln County, Wyo., where it is asso-

ciated with other species characteristic of the "*Vascoceras* beds" of southern Montana.

Occurrence.—Figured specimens (USNM 106835) from sample 30 feet above the base of the Cody shale (unit 2) at Greybull.

Genus DENTALINA D'Orbigny, 1826

Dentalina bighornensis Fox, n. sp.

Plate 2, figures 16–18

Test large, elongate, tapering to a pointed initial end in the microspheric form, megalospheric form tapering slightly with enlarged proloculum, greatest width 3 or 4 chambers from apertural end; chambers wider than high in early stages, increasing in height as added, last 4 or 5 becoming increasingly inflated; sutures distinct, limbate, slightly oblique in early portion, depressed only between last few chambers; wall ornamented by strong longitudinal costae which become progressively fainter from the middle of the test toward the apertural end, and which also die out toward the proloculum in microspheric forms, last 1 or 2 chambers at both ends often without costae; aperture protuberant at the inner angle of the terminal face of the last formed chamber.

Length of holotype (with initial chambers missing) 3.4 mm; greatest diameter 0.58 mm. Other specimens as much as 3.8 mm in length and 0.60 mm in diameter.

Remarks.—This large distinctive species is easily recognized by the strong longitudinal costae which fade toward both ends, the initially oblique sutures, the wider than high chambers in the early stages, the inflation of the final chambers, and the position of the radiate aperture at the inner angle of the terminal face. Microspheric forms are distinctly more tapered, with megalospheric chambers relatively uniform in width. Although hundreds of specimens have been studied by the writer from the Cody shale of the type locality and from the Greybull section, no complete individuals are known. Fragments of the central portion may be confused with *Nodosaria affinis* Reuss. The uniformity of costae across the sutures, the oblique early sutures, and the position of the aperture are all useful in distinguishing *Dentalina bighornensis*. The new form is easily differentiated from all known Cretaceous species of *Dentalina*.

Dentalina bighornensis is restricted to the upper half of unit 8 in the Cody shale at Greybull where it occurs commonly and is associated with forms characteristic of the basal part of the Niobrara formation of the Great Plains. The species appears with the same assemblage in the type section at Cody in the basal 100 feet. It has not been reported from the Canadian Cretaceous or from the basal Niobrara of the Great Plains. The writer noticed several specimens in Brownstown marl (sample 222) (Cushman 1942 p. 50–66) during recent studies at the Cushman laboratory. The form is apparently a good index fossil for rocks equivalent in age to the Austin chalk of the Gulf Coast and to the basal Niobrara of the Great Plains.

Types and occurrence.—The types of this species are from the type locality of the Cody shale on the south bank of Shoshone River 2 miles east of Cody, Wyo., in sec. 29, T. 53 N., R. 10 W., USGS loc. 24096. Holotype (USNM 106836) and figured paratypes (USNM 106837), (USNM 106838) from a channelled sample 20–25 feet above the base of the Cody and the top of the Frontier formation.

Dentalina sp.

Plate 25, figure 15

A single specimen of *Dentalina* is recorded from the top of the basal unit (2) of the Greenhorn formation.

The test is elongate, with initial end broadly rounded. The greatest breadth is in the middle of the next to the last-formed chamber, tapering rapidly toward the aperture. Chambers are 6 in number, indistinct, not inflated. The last chamber is twice as long as broad. Sutures are slightly oblique in the early portion, indistinct, flush with surface. The aperture is terminal, radiate.

Length of figured specimen 0.7 mm; greatest diameter 0.18 mm.

Remarks.—*Dentalina* sp. is much smaller than *Dentalina basiplanata* Cushman. It lacks the inflation of the final chambers and it tapers rapidly from the greatest width toward the aperture.

Occurrence.—Figured specimen (USNM 106839) from sample GL I in lowermost unit of the Greenhorn formation.

Genus VAGINULINA D'Orbigny, 1826

Vaginulina sp. 1

Plate 25, figure 21

The uppermost unit (5) of the Greenhorn formation and the basal 30 feet of the Cody shale at Greybull have yielded several specimens of what is probably a new *Vaginulina*. Several specimens have been noted from shale 900 feet above the base of the Colorado formation at Mosby, Mont., in association with other Greenhorn forms. The one complete specimen is figured and additional notes on others are recorded.

Diagnostic features of this form are the nearly parallel sides, the truncate periphery on both margins, and the upturned acute dorsal and ventral edges which create the impression of a deeply concave surface on both sides. The test is small, flattened, with a straight dorsal and an uneven, almost parallel ventral margin. The

bulbous proloculum bears the continuation of the acute dorsal and ventral edges. Chambers and sutures are distinct, the latter limbate, gently curved, and only slightly raised. Specimens with as many as 8 or 9 chambers have been observed. The surface is smooth and without ornamentation. The aperture is radiate on the dorsal margin.

Length of figured specimen 0.72 mm; breadth 0.25 mm; thickness 0.12 mm. Other specimens as much as 0.90 mm in length and 0.28 in breadth.

Occurrence.—Figured specimen (USNM 106840) from sample GU VIII in the uppermost unit (5) of the Greenhorn formation.

Vaginulina sp. 2

Plate 25, figures 19, 20

A few specimens of *Vaginulina* from the uppermost part of the basal unit of the Greenhorn formation and from the basal part of the Cody shale apparently represent a new species. Until more individuals are available for study, it seems unwise to select types from these variable forms for species description.

Characteristic of all specimens is the initially curved dorsal side which becomes straight after the second chamber; the uneven ventral edge which parallels the dorsal margin in the middle of the test; strongly oblique, straight, or gently curved sutures flush with the surface; and the small initial spine.

Several specimens are less compressed and bear 4 to 6 clear costae which are more strongly oblique than the sutures and do not cross the entire test. Other specimens are smaller, strongly compressed, and lack costae. Such forms may be young individuals or perhaps may eventually be referred to a species of *Citharina*.

Length of figured specimen 1.17 mm, width 0.26 mm; smaller specimens from 0.30–0.58 mm in length, and from 0.10–0.20 mm in breadth.

Remarks.—Specimens of *Vaginulina multicostata* Cushman are similar, but they lack the parallel sides in the middle of the test, the oblique costae, and the initially curved dorsal margin.

Vaginulina sp. 2 is apparently restricted to the top 15 feet of the basal unit of the Greenhorn formation in the Belle Fourche section. It occurs rarely in the basal 30 feet of the Cody shale at Greybull.

Occurrence.—The two figured specimens (USNM 106841 and 106842) are from sample GL I in the lowest unit (2) of the Greenhorn formation.

Genus PALMULA Lea, 1833

Palmula sp.

Plate 26, figure 1

A single fragment of a strongly compressed distinctive *Palmula* is figured as a member of the uppermost Greenhorn assemblage.

The specimen resembles *Palmula pilulata* Cushman in shape, compression, in the relation between coiled and uncoiled portions, and in the fact that the adult chevron-shaped chambers do not extend backward on the sides to include much of the coiled portion. It may be distinguished from Cushman's species by the rounded rather than truncate and carinate periphery of the coiled portion, by the smaller size, and by the lack of a raised bead at the inner end of the earlier sutures. The early sutures are limbate, gently curved, slightly raised, and faintly beaded. Later sutures are depressed.

Length of figured specimen 0.75 mm; breadth 0.50 mm.

Occurrence.—Figured specimen (USNM 106843) from sample GU VIII in the uppermost unit (5) of the Greenhorn formation.

Palmula? sp.

Plate 26, figures 2, 3

Several fragmentary specimens of a large compressed *Palmula* occur in the upper part of the *Polyphragma codyensis* zone at Greybull. The apertural ends are broken so that positive generic designation cannot be made. Nevertheless, the early portions of the test are so distinct that they cannot be confused with other species.

The periphery is subacute, with a thick keel. The early portion is coiled and the later chambers extend back on the inner margin to include much of the coiled chambers. Adult chambers are broken and the features of the last-formed chambers cannot be observed. Sutures are indistinct, limbate, flush with the surface or gently raised, and strongly curved between both coiled and uncoiled chambers. The wall is smooth; some individuals have a prominent boss over the coiled portion.

Length of the longest fragment 1.80 mm; breadth 1.82 mm. Length of complete specimen is probably 3.00 mm.

Remarks.—This species is similar to *Palmula pilulata* Cushman in size, general form, and curvature of early sutures. However, the peripheral keel is much thicker than that of Cushman's species, the tests lack the raised beads at the inner ends of the early sutures, and the sutures are indistinct.

Palmula? sp. occurs only in the upper part of unit 8 about 268 feet above the base of the Cody shale. The writer has examined similar fragments from the basal 100 feet of the Cody shale of the type locality where the form is also associated with species representing the basal part of the Niobrara formation of the Great Plains.

Occurrence.—Figured specimens (USNM 106844) from sample GD 41, about 268 feet above the base of the Cody shale (unit 8) at Greybull.

Genus FRONDICULARIA De France, 1826

Frondicularia greybullensis Fox, n. sp.

Plate 26, figures 4–6

Frondicularia aclis Cushman 1942 [not Morrow] Cushman Lab. Foram. Research Contr., v. 18, pt. 3, p. 60, pl. 13, fig. 4.

Test elongate, tapering, strongly compressed, greatest breadth near the base of the last-formed chamber in the approximate middle of the test; periphery truncate, slightly undulating below last chamber; chambers distinct, slightly inflated toward apertural end; both ends bluntly pointed; proloculum bulbous; sutures distinct, straight, depressed between last 2 or 3 chambers; wall smooth with no ornamentation; aperture radiate, slightly projected.

Length of holotype 1.41 mm; greatest breadth 0.55 mm. Other specimens as much as 2.20 mm in length and 0.95 mm in diameter.

Frondicularia greybullensis is similar to Morrow's two species *Frondicularia dunbari* and *Frondicularia aclis* from the basal part of Niobrara formation of the Great Plains. It differs from the latter in its greater breadth and length, depressed later sutures, and in the absence of lirae. *Frondicularia dunbari* is generally shorter, less than half as broad, with the greatest breadth nearer the apertural end.

This species occurs only in one sample in the upper part of unit 8 about 268 feet above the base of the Cody shale. It is associated with species characteristic of the basal part of the Niobrara formation of the Great Plains. Only six specimens represent the species, but in each individual the diagnostic features listed above are constant. The species is not known from the Great Plains section but Cushman has reported it from the Brownstown marl of Arkansas.

Types and occurrence.—Holotype (USNM 106845) and figured paratypes (USNM 106846) from sample GD 41, about 268 feet above the base of the Cody shale (unit 8) at Greybull.

Frondicularia sp.

Plate 26, figure 7

A single specimen found 17 feet below the top of the Turner sandy member of the Carlile shale is figured. The compressed, nearly elliptical, flattened test bears a truncate periphery, a slightly projected apertural neck, and gently curved, limbate, raised sutures which in the later chambers are broken by short vertical costae. The chambers reach back and form a prominent wedge-shaped base with the central part produced. The surface of the test, other than the costae on the sutures, is smooth.

The Carlile specimen is similar to *Frondicularia hebronensis* Moreman in shape, and in the backward projection of its early chambers. However, its sutures are less curved, raised instead of depressed, and bear vertical costae in later stages.

The Carlile specimen differs from *Frondicularia austinana* Cushman in having raised sutures, in lacking vertical costae on the chamber surfaces, and in the backward projection of the basal central portion. It is distinguished from *Frondicularia goldfussi* Reuss by the lack of a rounded proloculum and by the limbate, raised, and often costate sutures. It is associated principally with *Vaginulina texana* Cushman, *Lenticulina kansasensis* Morrow, and *Höglundina caracolla* (Roemer).

Length of figured specimen 2.95 mm; breadth 1.0 mm; thickness 0.8 mm.

Occurrence.—Figured specimen (USNM 106847) from sample CT 24, about 20 feet below the top of the Turner sandy member of the Carlile shale.

Family BULIMINIDAE

Genus BULIMINA D'Orbigny, 1826

Bulimina wyomingensis Fox, n. sp.

Plate 26, figures 8–11

Test small, about twice as long as broad, tapering sharply, broadest at apertural end, triangular in transverse section, with angles broadly rounded; chambers regularly arranged, 4 or 5 whorls, globular, particularly in last 2 whorls, increasing rapidly in size after second or third whorl; sutures distinct, strongly depressed in later portion; wall smooth, perforate; aperture broad, with a faint lip at the inner margin of the last-formed chamber.

Length of holotype 0.27 mm, diameter 0.15 mm. Other specimens are from 0.2–0.42 mm in length, and from 0.12–0.17 mm in diameter. The average length is 0.3 mm.

Remarks.—*Bulimina wyomingensis* is similar to *Bulimina prima* Terquem but may be distinguished from that species by the tapering test and the rapid increase in chamber size. It differs from *Bulimina prolixa* Cushman and Parker in having globular chambers and a broader aperture. The distinguishing features of the species are the tapering test, the regular arrangement of the globular last chambers, the rapid increase in chamber size after the second or third whorl, and the broad aperture.

This species is probably a good index fossil for the upper unit of the Greenhorn formation where it is common in many samples. Several hundred specimens were examined from the Belle Fourche exposures of the

Greenhorn but no individuals have as yet been collected from the Cody shale. The writer has noted its occurrence 900 feet above the base of the Colorado shale at Mosby, Mont., in association with other typical Greenhorn species.

Types and occurrence.—Holotype (USNM 106848), figured paratype (USNM 106850), and unfigured paratype (USNM 106849) from sample GU XIX; figured paratypes (USNM 106851 and USNM 106852) from samples GU XVIII and GU Id, respectively; all from the uppermost unit (5) of the Greenhorn formation.

Family ROTALIIDAE

Genus EPONIDES Montfort, 1808

Eponides shoshonensis Fox, n. sp.

Plate 26, figures 12–14

Test trochoid, biconvex, dorsal side slightly more convex, umbilical plug on ventral side; periphery rounded, slightly lobulate; chambers indistinct in most specimens, 6 to 9 in the adult, usually 6 or 7, inflated on ventral side, last 2 or 3 inflated dorsally; sutures limbate, usually indistinct, gently curved, slightly oblique, the last 2 depressed on the dorsal side; ventral sutures depressed, gently curved; wall smooth, finely perforate; aperture elongate, with a prominent lip, on the ventral side between the periphery and the umbilicus.

Diameter of holotype 0.52 mm; thickness 0.25 mm. Other specimens from 0.50–0.75 mm in diameter and as much as 0.40 mm in thickness.

Remarks.—This species is differentiated from *Eponides haidingerii* (D'Orbigny) by less oblique and less distinct sutures, and by fewer perforations.

Eponides shoshonensis is rare in the Cody shale at Greybull. It occurs with the typical basal Niobrara species in the upper part of unit 8 about 270 feet above the base of the formation. In the Cody of the type locality the writer has identified hundreds of specimens in all but the uppermost beds of the formation. It is apparently restricted to beds equivalent to the entire Niobrara formation of the Great Plains.

Types and occurrence.—The types of *Eponides shoshonensis* are from the type locality of the Cody shale on the south bank of the Shoshone River, 2 miles east of Cody, Wyo., in sec. 29, T. 53 N., R. 10 W. Holotype (USNM 106853) from a channelled sample 510 feet above the base of the Cody, USGS loc. 24097. Figured paratypes (USNM 106854 and 106855) from channelled sample 726 feet above the base of the Cody, USGS loc. 24098.

Genus GLOBOROTALIA Cushman, 1927

Globorotalia? youngi Fox, n. sp.

Plate 26, figures 15–18

Test small, trochoid, biconvex; chambers distinct, inflated, last 3 considerably enlarged, 6 or 7 in final whorl; periphery broadly rounded; sutures strongly depressed, gently curved; umbilical area deep; aperture umbilical at the base of the last chamber.

Diameter of holotype 0.20 mm, thickness 0.1 mm. Other specimens from 0.18 to 0.2 mm. in diameter and from 0.09 to 0.1 mm in thickness.

Remarks.—This species is distinguished by its small size, the 6 or 7 chambers of the last whorl, and by the greater size of the last 3 chambers. In general form it resembles the larger *Globorotalia? multiloculata* Morrow but the chambers in Morrow's species are equal in size throughout.

Globorotalia? youngi is common in unit 5 and appears rarely at the base of unit 2 in the Greenhorn formation north of Belle Fourche. A few specimens have been noted from the basal 30 feet of the Cody shale at Greybull where they are associated with other Greenhorn species. The species has not been reported from the Frontier formation of southern Montana or from other exposures of rocks known to be equivalent to the Greenhorn.

Types and occurrences.—The types of *Globorotalia? youngi*, n. sp. are from unit 5 of the Greenhorn formation North of Belle Fourche. Holotype (USNM 106856), figured paratypes (USNM 106857 and P2147), and unfigured paratypes (USNM P2147) from channelled sample GU XX, about 50 feet below the top of the Greenborn on north-facing scarp on southwest-flowing tributary of Crow Creek in SW¼NE¼ sec. 16, T. 9 N., R. 2 E. Paratype (USNM 106858) and unfigured paratypes (USNM P2148) from channelled sample GU Ia, about 10–12 feet above base of unit 5 on southwest flank of Bull Creek anticline in E½ sec. 15, T. 57 N., R. 62 W., Crook County, Wyo.

Family ANOMALINIDAE

Genus PLANULINA D'Orbigny, 1826

Planulina dakotensis Fox, n. sp.

Plate 26, figures 19–21

Test small, much compressed, slightly biconvex, dorsal side partly evolute, often with small central boss; ventral side mostly involute, often somewhat umbilicate in the center; periphery rounded, lobulate in the later chambers; chambers distinct, the last 3 or 4 inflated, usually 7 to 9 in the final whorl, increasing gradually in size as added, inner margin on ventral side raised in small ring of clear shell material; sutures distinct, gently curved, limbate and slightly raised in early portion of last whorl, later depressed; wall smooth, finely but distinctly perforate; aperture low, and at the base of the last formed chamber onto the ventral side.

Greatest diameter, holotype 0.3 mm; paratypes 0.3 mm; least diameter, holotype 0.21 mm, paratypes 0.2 mm; thickness, holotype 0.09 mm, paratypes 0.08–0.1 mm.

Planulina dakotensis, n. sp. is easily distinguished by its relatively small size, the raised and limbate early sutures, the depressed nonlimbate later sutures, and by the inflation of the final 3 or 4 chambers. It differs from *Planulina kansasensis* Morrow in its smaller size, fewer chambers, and in the lack of a calcareous deposit over the central area on both sides.

This species is common throughout the uppermost unit of the Greenhorn formation to which it is restricted on present evidence. Specimens are particularly well developed in the basal part of this unit where the species is associated principally with *Guembelina moremani* Cushman, *Globorotalia? youngi*, n. sp., *Globigerina cretacea* D'Orbigny, and *Bulimina wyomingensis*, n. sp. Several hundred specimens have been studied. Samples from shale 900 feet above the base of the Colorado shale on the bank of the Mussellshell River at Mosby, Mont., have yielded several dozen specimens of this species.

Types.—Holotype (USNM 106859) and figured paratypes (USNM 106860 and 106861) from sample GU Ia; unfigured paratypes (USNM 106862) from sample GU Id; all types are from the upper part of the Greenhorn formation (unit 5).

REFERENCES

Applin, E. R., 1933, A micro-fossiliferous Upper Cretaceous section from South Dakota: Jour. Paleontology, v. 7, no. 2, p. 215–220.

Bass, N. W., 1926, Geologic investigations in western Kansas: Kansas Geol. Survey, Bull. 11, p. 33.

Beissel, I., 1891, Die Foraminiferen der Aachener Kreide: Preuss. Geol. Landesanstalt, Abh., n. ser., v. 3, 1891, p. 22, pl. 5, figs. 1–3.

Brotzen, F., 1936, Foraminiferen aus dem Schwedischen Untersteten Senon von Eriksdal in Sahonen: Sveriges geol. undersökning, ser. C, no. 396, p. 30, pl. 1, fig. 2.

Carman, Katherine, 1929, Some Foraminifera from the Niobrara and Benton formations of Wyoming: Jour. Paleontology, v. 3, p. 309.

Collier, A. J., 1922, The Osage oil field, Weston County, Wyo.: U. S. Geol. Survey Bull. 736.

Cragin, F. W., 1896, On the stratigraphy of the Platte series, or Upper Cretaceous of the Plains: Colorado Coll. [Univ.] Studies, v. 6, p. 50–52.

Cushman, J. A., 1942, Cretaceous Foraminifera from the Brownstown marl of Arkansas: Cushman Lab. Foram. Research Contr., v. 18, pt. 3, p. 50–66.

——— 1946, Upper Cretaceous Foraminifera of the Gulf Coastal region of the United States and adjacent areas: U. S. Geological Survey Prof. Paper, 206, p. 1–241.

Dobbin, C. E., and Horn, G. H., 1949, Geologic map of Mush Creek and Osage oil fields and vicinity, Weston, County, Wyo.: U. S. Geol. Survey Oil and Gas Inv. Prelim. Map. 103.

Fox, S. K., Jr., 1941, Relationship of Late Cretaceous Cody shale Foraminifera from northern Wyoming and southern Montana to Great Plains and Canadian faunas: Geol. Soc. America Bull., v. 52, no. 12, pt. 2, abs.; p. 1967.

Franke, A., 1928, Die Foraminiferen der Oberen Kreide Nord– und Mitteldeutschlands: Preuss. Geol. Landesanstalt Abh., n. ser. v. 111, 1928, p. 19, pl. 2, fig. 3.

Gilbert, G. K., 1896, The underground water of the Arkansas valley in eastern Colorado: U. S. Geol. Survey, 17th Ann. Rept. pt. 2.

Haas, Otto, 1949, Acanthocerated Ammonoidea from near Greybull, Wyo.: Am. Mus. Nat. History Bull., v. 93, art. 1, 39 p.

Knight, W. C., 1903, Coal fields of southern Vinta County, Wyo., (Abs.) Geol. Soc. America Bull., v. 13, p. 542–544.

Loetterle, G. J., 1937, The micropaleontology of the Niobrara formation in Kansas, Nebraska, and South Dakota: Nebraska Geol. Survey Bull. 12, p. 1–73.

Lupton, C. T., 1915, Oil and gas near Basin, Big Horn County, Wyo., U. S. Geological Survey Bull. 621, p. 159–190.

Meek, F. B., and Hayden, F. V. 1862, Descriptions of new Lower Silurian, Jurassic, Cretaceous, and Tertiary fossils: Acad. Nat. Sci. Philadelphia Proc., v. 13, p. 419–422.

Moreman, W. L., 1942, Paleontology of the Eagle Ford group of north and central Texas: Jour. Paleontology, v. 16, no. 2, p. 192–220.

Morrow, A. L., 1934, Foraminifera and Ostracoda from the Upper Cretaceous of Kansas: Jour. Paleontology, v. 8, no. 2, p. 186–205.

Nauss, A. W., 1945, Cretaceous stratigraphy of Vermilion area, Alberta: Am. Assoc. Petroleum Geologists Bull., v. 29, no. 11, p. 1605–1629.

——— 1947, Cretaceous microfossils of the Vermilion area, Alberta: Jour. Paleontology, v. 21, no. 4, p. 329–343.

Reeside, J. B., Jr., 1923, A new fauna from the Colorado group of southern Montana: U. S. Geol. Survey Prof. Paper 132-B, p. 25–31.

——— 1927a, the cephalopods of the Eagle sandstone and related formations in the western interior of the United States: U. S. Geol. Survey, Prof. Paper 151.

——— 1927b, Cephalopods from the lower part of the Cody shale of Oregon Basin, Wyoming: U. S. Geol. Survey, Prof. Paper. 150-A.

——— 1944, Thickness and general character of the Cretaceous deposits in the western interior of the United States: U. S. Geological Survey Oil and Gas Inv. Series Prelim. Map 10.

Rubey, W. W., 1930, Lithologic studies of fine-grained Upper Cretaceous sedimentary rocks of the Black Hills region: U. S. Geol. Survey, Prof. Paper, 165-A.

Rubey, W. W., and Bass, N. W., 1925, The geology of Russell County, Kans.: Kansas Geol. Survey Bull. 10, pt. 1, p. 25–65.

Tappan, Helen, 1951, Northern Alaska index Foraminifera, Cushman Lab. Foram. Research Contr., v. 2, pt. 1, p. 1–8.

Thomas, H. D., 1936, Frontier-Niobrara contact in Laramie Basin, Wyo.: Am. Assoc. Petroleum Geologists Bull., v. 20, no. 9, p. 1189–1197.

Wickenden, R. T. D., 1932a, New species of Foraminfera from the Upper Cretaceous of the Prarie Provinces: Royal Soc. Canada Proc. and Trans., ser. 3, v. 26, sec. 4., p. 85–91, pl. 1.

——— 1932b, A useful Foraminifera horizon in the Alberta shale of southern Alberta: Jour. Paleontology, v. 6, no. 2, p. 203–207, pl. 29.

——— 1932c, Notes on some deep wells in Saskatchewan: Royal Soc. Canada Proc. and Trans., ser. 3, v. 26, sec. 4, p. 177–196, figs. 1–2.

——— 1941, Cretaceous marine formations penetrated in wells near Lloydminster, Saskatchewan: Royal Canadian Inst. Trans., v. 23, p. 147–155.

——— 1945, Mesozoic stratigraphy of the Eastern Plains, Manitoba and Saskatchewan: Canada Geol. Survey Mem. 239, p. 1–87.

Williston, S. W., 1893, The Niobrara Cretaceous of western Kansas: Kansas Acad. Sci. Trans. for 1891–1892, v. 13, p. 108–109.

Young, Keith, 1951, Foraminifera and stratigraphy of the Frontier formation (Upper Cretaceous), southern Montana: Jour. Paleontology, v. 25, p. 35–68.

INDEX

[Italic numbers indicate descriptions]

PLATES 24–26

PLATE 24

FIGURE 1. *Reophax recta* (Beissel) (p. 110).
Front view, × 68. USGS loc. 24095, USNM 106805 from Cody shale, Greybull, Wyo.

2, 3. *Haplophragmoides carlilensis* Fox, n. sp. (p. 110).
Middle part of Turner sandy member of the Carlile shale.
2. Side view of paratype, × 70. USGS loc. 24085, USNM 106807.
3. Peripheral view of holotype, × 70. USGS loc. 24086, USNM 106806.

4, 5. *Haplophragmoides* sp. (p. 111).
Uppermost unit (5) of Greenhorn formation
4. Side view, × 160. USGS loc. 24090, USNM 106810.
5. Peripheral view, × 160. USGS loc. 24090, USNM 106811.

6. *Flabellammina* sp. 1 (p. 111).
Front view, × 23. USGS loc. 24089, USNM 106812, from uppermost unit (5) of Greenhorn formation.

7. *Flabellammina* sp. 2 (p. 111).
Front view, × 33. USGS loc. 24084, USNM 106813, from middle part of Turner sandy member of Carlile shale.

8. *Flabellammina* sp. 3 (p. 111).
Front view, × 23. USGS loc. 24092, USNM 106814, from lowermost unit (2) of Greenhorn formation.

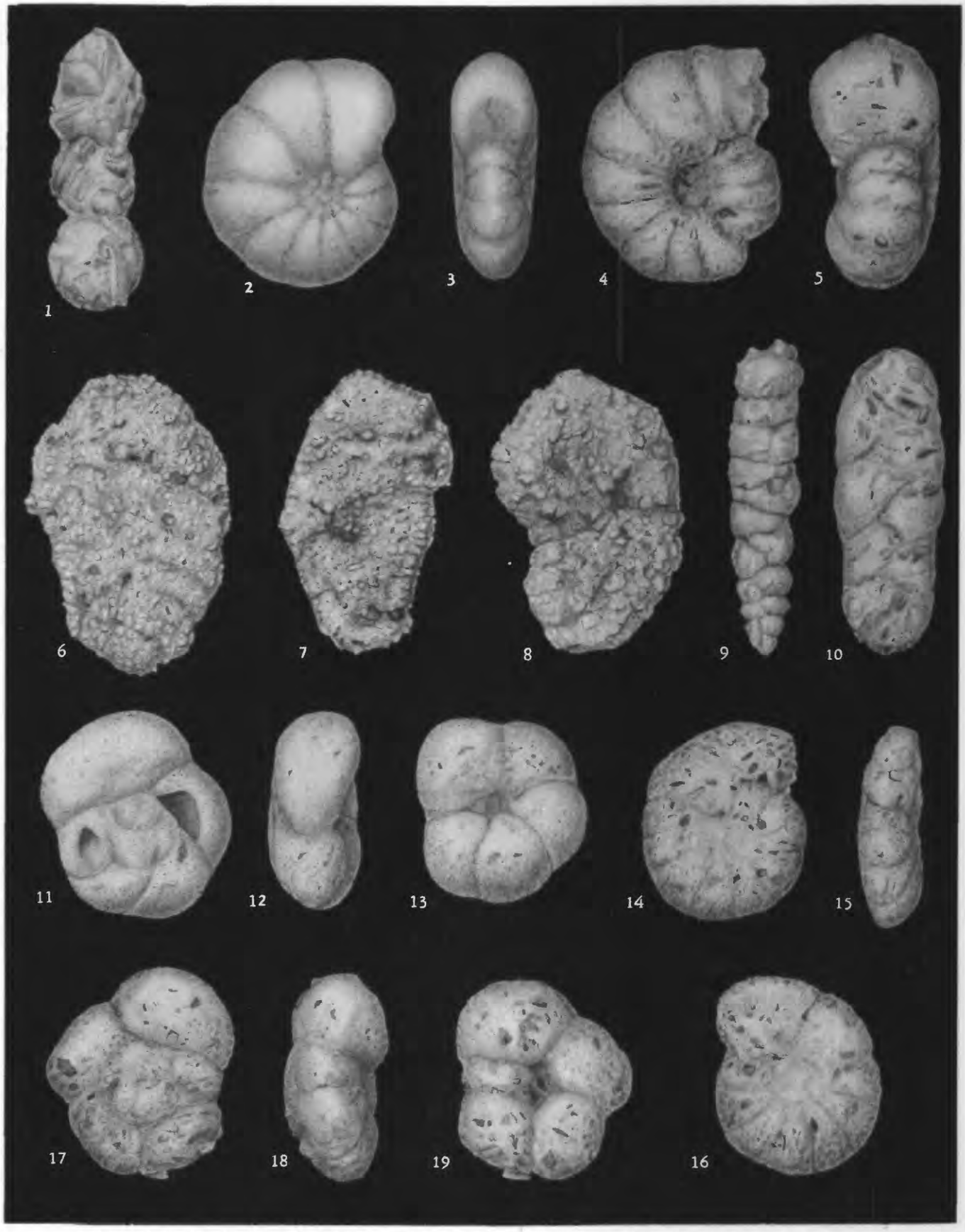
9. *Bigenerina* sp. (p. 112).
Front view, × 90. USGS loc. 24089, USNM 106815, from uppermost unit (5) of Greenhorn formation.

10. *Gaudryina cobbani* Fox, n. sp. (p. 112).
Front view of holotype, × 90. USGS loc. 24086, USNM 106816, from unnamed member of Carlile shale.

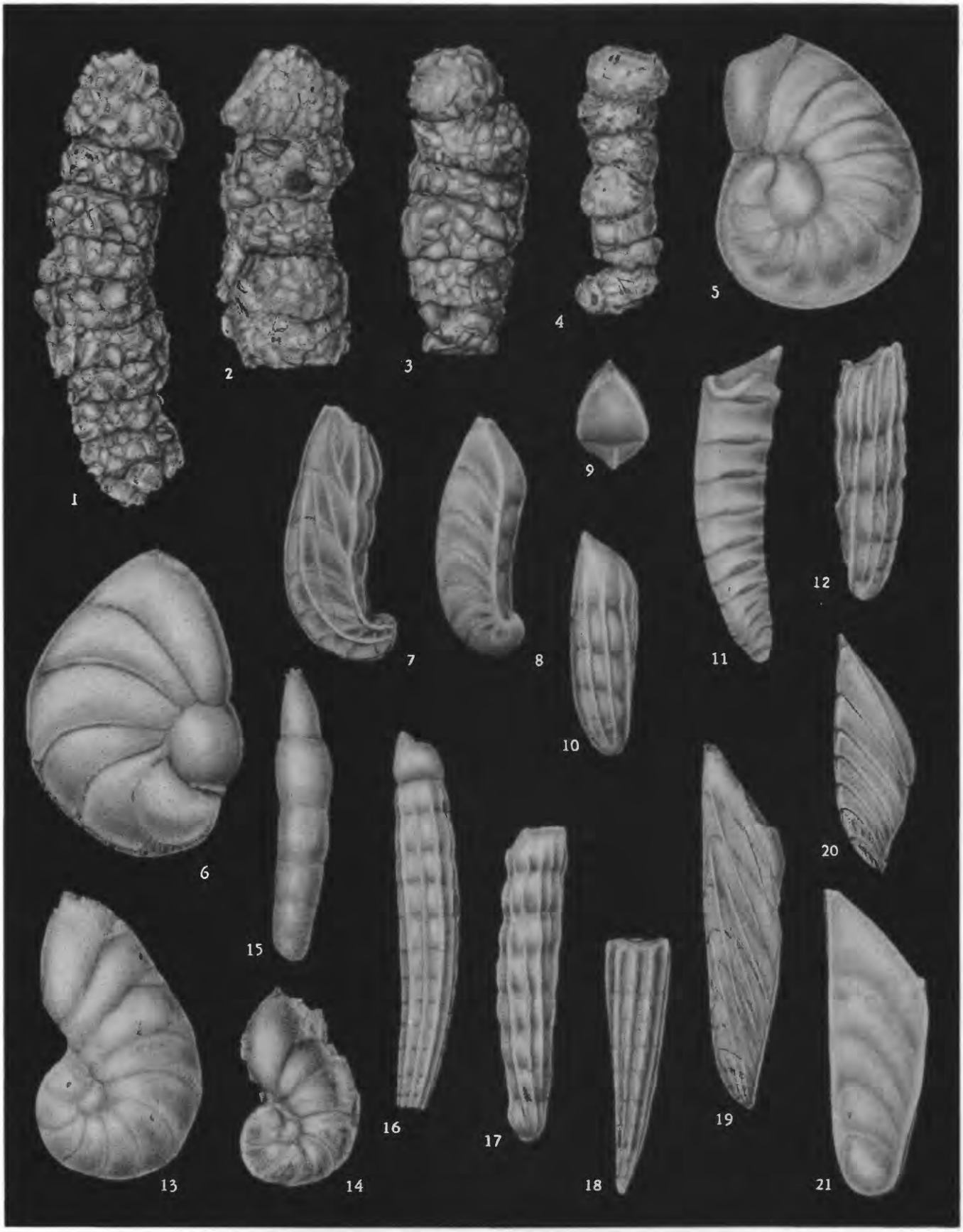
11–13. *Trochammina* sp. 1 (p. 112).
Upper part of Belle Fourche shale.
11. Dorsal view, × 150. USGS loc. 24094, USNM 106820.
12. Peripheral view, × 150. USGS loc. 24094, USNM 106819.
13. Ventral view, × 150. USGS loc. 24094, USNM 106821.

14–16. *Trochammina* sp. 2 (p. 113).
Unnamed member of the Carlile shale.
14. Dorsal view, × 90. USGS loc. 24086, USNM 106822.
15. Peripheral view, × 90. USGS loc. 24086, USNM 106822.
16. Ventral view, × 90. USGS loc. 24086, USNM 106822.

17–19. *Trochammina* sp. 3 (p. 113).
Unnamed member of the Carlile shale.
17. Dorsal view, × 108. USGS loc. 24086, USNM 106823.
18. Peripheral view, × 108. USGS loc. 24086, USNM 106823
19. Ventral view, × 108. USGS loc. 24086, USNM 106823.



REOPHACIDAE, LITUOLIDAE. TEXTULARIIDAE, VERNEUILINIDAE, AND TROCHAMMINIDAE FROM THE WESTERN INTERIOR



PLACOPSILINIDAE AND LAGENIDAE FROM THE WESTERN INTERIOR

PLATE 25

FIGURES 1–4. *Polyphragma codyensis* Fox, n. sp. (p. 113).
Cody shale, Greybull, Wyo.
1. Front view of paratype, × 35. USGS loc. 24095, USNM 106825.
2. Front view of paratype, × 35. USGS loc. 24095, USNM 106826.
3. Front view of holotype, × 35. USGS loc. 24095, USNM 106824.
4. Front view of paratype, × 35. USGS loc. 24095, USNM 106827.

5. *Robulus* sp. (p. 114).
Side view, × 70. USGS loc. 24092, USNM 106828, from lowest unit (2) of Greenhorn formation.

6. *Planularia* sp. (p. 114).
Side view, × 70. USGS loc. 24092, USNM 106829, from lowest unit (2) of Greenhorn formation.

7–9. *Saracenaria reesidei* Fox, n. sp. (p. 114).
Lowermost unit (2) of Greenhorn formation.
7. Side view of holotype, × 92. USGS loc. 24092, USNM 106830.
8. Side view of paratype, × 92. USGS loc. 24092, USNM 106832.
9. End view of paratype, × 92. USGS loc. 24092, USNM 106831.

10, 12. *Marginulina* sp. 2 (p. 115).
Side views of figured specimens, × 92. USGS loc. 24092, USNM 106834, from the lowermost unit (2) of Greenhorn formation.

11. *Marginulina* sp. 1 (p. 115).
Side view, × 41, USGS loc. 24092, USNM 106833, from lowest unit (2) of Greenhorn formation.

13, 14. *Marginulinopsis amplaspira* Young (p. 115).
Side views of two typical speciments, × 70. USGS loc. 24095, USNM 106835, from basal part of Cody shale (unit 2) Greybull, Wyo.

15. *Dentalina* sp. (p. 116).
Side view, × 92. USGS loc. 24092, USNM 106839, from lowermost unit (2) of Greenhorn formation.

16–18. *Dentalina bighornensis* Fox, n. sp. (p. 116).
Cody shale in the type locality, Cody, Wyo.
16. Side view of microspheric holotype, × 25. USGS loc. 24096, USNM 106836.
17. Side view of megalospheric paratype, × 25. USGS loc. 24096, USNM 106837.
18. Side view of microspheric paratype, × 25. USGS loc. 24096, USNM 106838.

19, 20. *Vaginulina* sp. 2 (p. 117).
Lowermost unit (2) of Greenhorn formation.
19. Side view, × 70. USGS loc. 24092, USNM 106842.
20. Side view, × 92. USGS loc. 24092, USNM 106841.

21. *Vaginulina* sp. 1 (p. 116).
Side view, × 92. USGS loc. 24090, USNM 106840, from uppermost unit (5) of Greenhorn formation.

PLATE 26

FIGURE 1. *Palmula* sp. (p. 117).
Side view of fragmentary specimen, × 70. USGS loc. 24090, USNM 106843, from uppermost unit (5) of Greenhorn formation.

2, 3. *Palmula?* sp. (p. 117).
Side views of fragmentary specimens, × 23. USGS loc. 24095, USNM 106844, from Cody shale, Greybull, Wyo.

4–6. *Frondicularia greybullensis* Fox, n. sp. (p. 118).
Cody shale, Greybull, Wyo.
4. Front view of holotype, × 41. USGS loc. 24095, USNM 106845.
5, 6. Front views of paratypes, × 33. USGS loc. 24095, USNM 106846.

7. *Frondicularia* sp. (p. 118).
Front view, × 33. USGS loc. 24084, USNM 106847 from upper part of Turner sandy member of the Carlile shale.

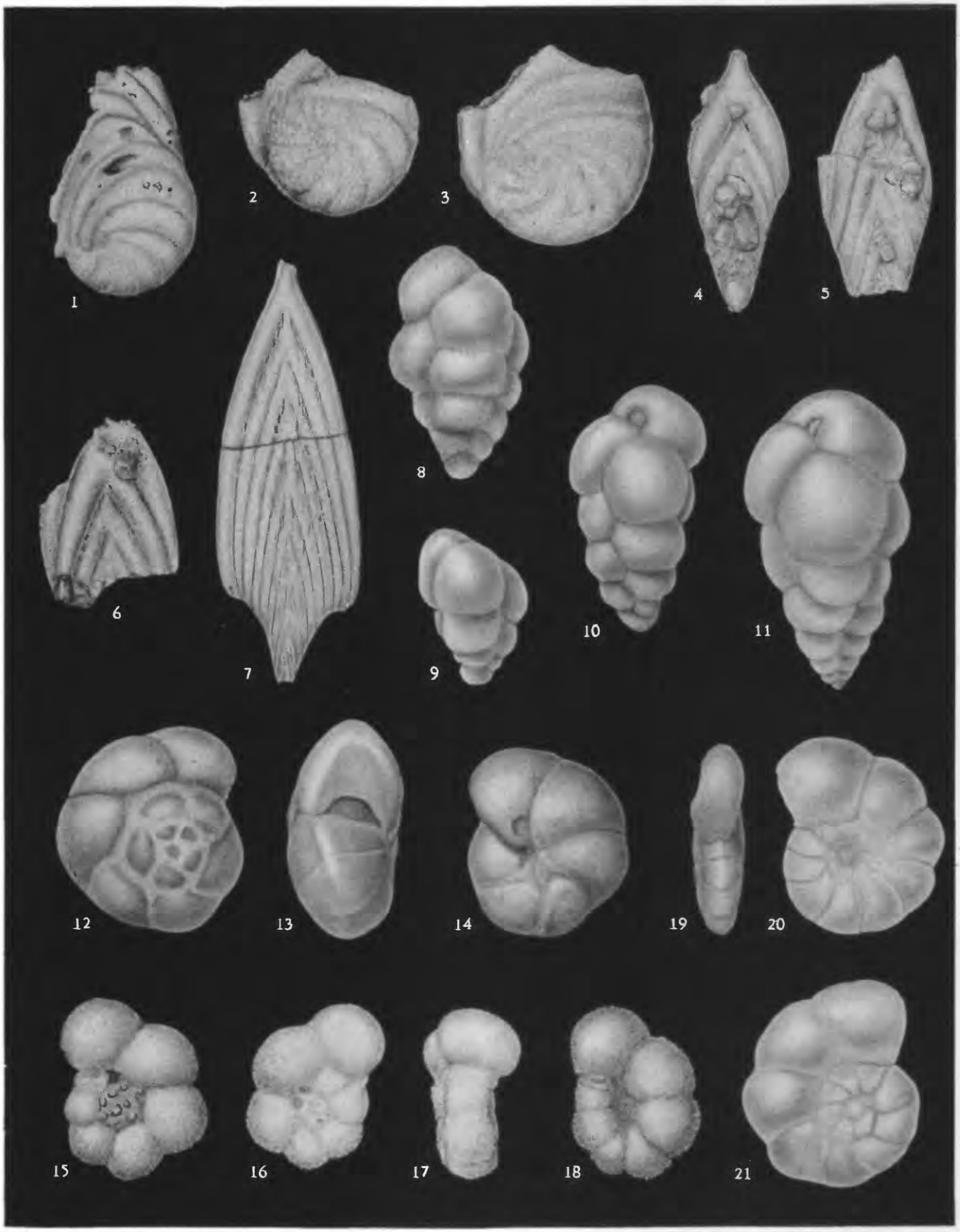
8–11. *Bulimina wyomingensis* Fox, n. sp. (p. 118).
Uppermost unit (5) of Greenhorn formation.
8. Rear view of holotype, × 212. USGS loc. 204090, USNM 106848.
9. Rear view of paratype, × 212. USGS loc. 24091, USMN 106852.
10. Front view of paratype, × 212. USGS loc. 24090, USNM 106851.
11. Front view of paratype, × 212. USGS loc. 24090, USNM 106850.

12–14. *Eponides shoshonensis* Fox, n. sp. (p. 119).
Basal part of Cody shale of the type locality, Cody, Wyo.
12. Dorsal view of paratype, × 92. USGS loc. 24098, USNM 106855.
13. Peripheral view of holotype, × 92. USGS loc. 24097, USNM 106853.
14. Ventral view of paratype, × 92. USGS loc. 24098, USNM 106854.

15–18. *Globorotalia? youngi* Fox, n. sp. (p. 119).
Uppermost unit (5) of the Greenhorn formation.
15. Dorsal view of holtype, × 190. USGS loc. 24090, USNM 106856.
16. Dorsal view of paratype, × 190. USGS loc. 24090, USNM 106857.
17. Peripheral view of paratype, × 190. USGS loc. 24091, USNM 106858.
18. Ventral view of paratype, × 190. USGS loc. 24090, USNM P2147.

19–21. *Planulina dakotensis* Fox, n. sp. (p. 119).
Uppermost unit (5) of the Greenhorn formation.
19. Peripheral view of paratype, × 160. USGS loc. 24091, USNM 106861.
20. Ventral view of paratype, × 160. USGS loc. 24091, USNM 106860.
21. Dorsal view of holotype, × 160. USGS loc. 24091, USNM 106859.

U. S. GOVERNMENT PRINTING OFFICE: 1954



LAGENIDAE, BULIMINDAE, ROTALIIDAE, AND ANOMALINIDAE FROM THE WESTERN INTERIOR