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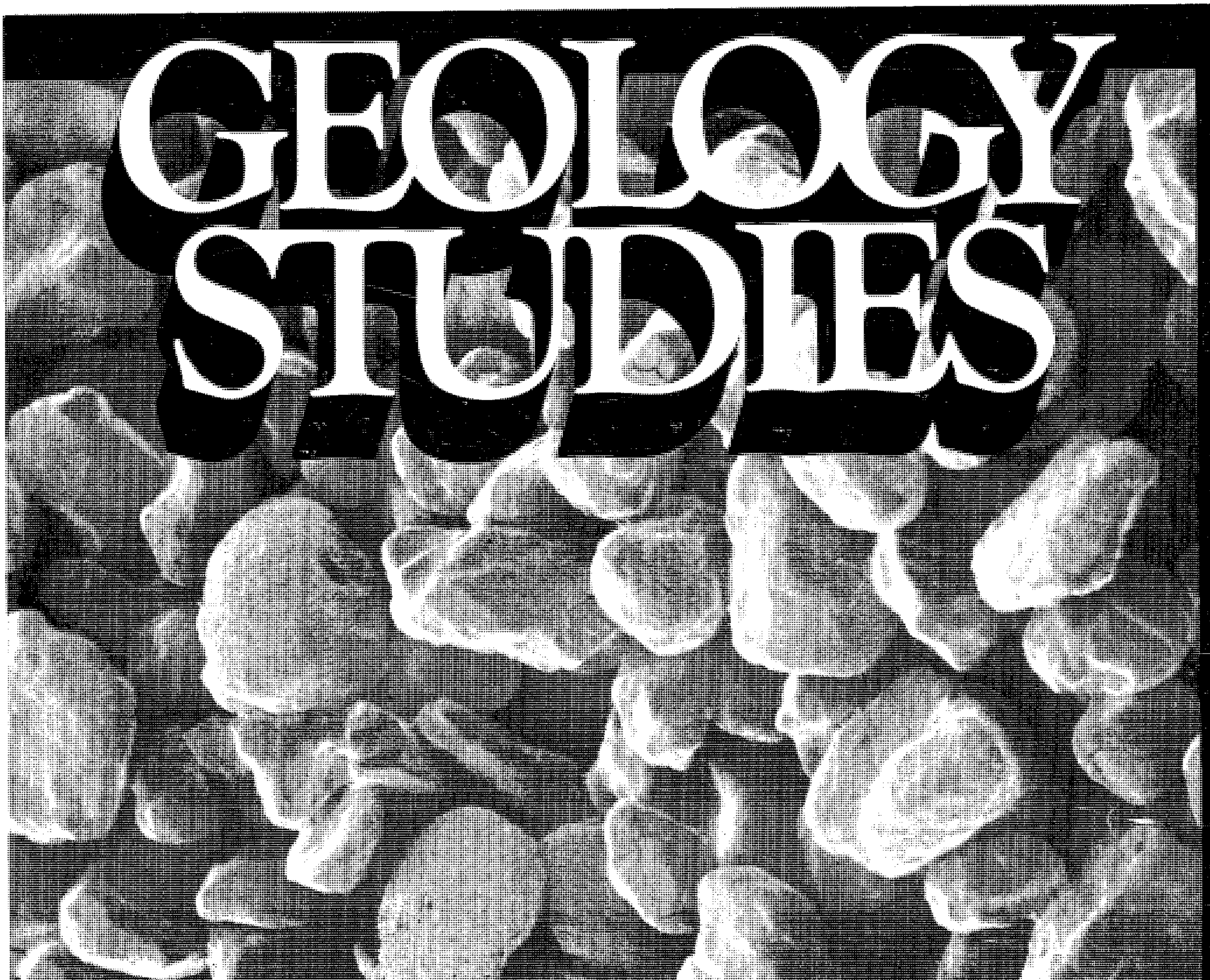

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THE GLORY OF GOD IS INTELLIGENCE

Cover: Sahara dune sand, X130. Photo courtesy Amoco Production Research, Tulsa, Oklahoma, contributed by Paul E. Potter, Department of Geology, University of Cincinnati, Cincinnati, Ohio 45221.

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CONTENTS

Foraminiferal Abundance Related to Bentonitic Ash Beds in the Tununk Member of the Mancos Shale (Cretaceous) in Southeastern Utah*

Rebecca Lillywhite Bagshaw

Abstract.—The Tununk Member of the Cretaceous Mancos Shale contains several thin bentonitic ash beds that are particularly well exposed between Caineville, Utah, and Capitol Reef National Monument. Observations have been made on samples collected at stratigraphic intervals of 5 to 10 cm for five of the lower ash beds and intervening siltstones near Caineville, west of Utah Highway 24. Foraminifera present consist of 11 families, represented by 17 genera, and are mainly planktonic calcareous species. Ash falls did not result in the mass extinction of species. Numbers of specimens decrease in the lowermost parts of each ash bed, whereas the middle part of each ash shows a population bloom up to 12,000 foraminifera per gram. At the top of or immediately above each ash the number of specimens decreases, and another population bloom, up to 18,000 foraminifera per gram, occurs in the siltstone above the ash. The increase in numbers within each ash suggests that the ash falls provided nutrients for organisms upon which the foraminifera may have fed.

INTRODUCTION

Foraminifera are particularly abundant within and around bentonite ash beds in the Tununk Shale, and it is thought that the ash beds have a relationship to the large foraminiferal numbers. The fossiliferous Tununk Shale, of Late Cretaceous (Turonian-Cenomanian) age, is the lowermost member of the Mancos Shale in southeastern Utah (fig. 1) and was named by Gilbert (1877) for exposures in the Henry Mountains. Several thin bentonite beds occur within the Tununk Shale and record ash falls from distant volcanoes.

Maxfield (1976) observed that the numbers of foraminifera increased near the ash beds and that further research (pers. comm. 1975) was needed to determine the effects of ash falls on the foraminiferal populations. Foraminifera were recovered from five of the ash beds and surrounding siltstones, from the lower beds of the member. Eighty-three samples were examined for foraminifera.

The study area is located 3.25 km west of Caineville, Utah (fig. 2), along the valley west of the Caineville Reef. The section sampled is 250 m northwest of Utah Highway 24, on the north side of the series of hills forming the summit between Caineville Wash and the Fremont River, in SE-NW¼ Sec. 3, T. 29 S, R. 8 E. The sampled beds dip 24° to the northeast off the East Caineville Dome and occur 12 to 33 m above the *Gryphaea newberryi* coquina, which here is at the base of the Tununk Shale (Lessard 1973, p. 2) (figs. 1, 3). The bentonitic ash beds are white and unconsolidated and are interbedded with fissile, dark gray siltstones. The Tununk Member is a valley-forming unit and is vertically gradational from the thin, discontinuous, uppermost sandstone of the underlying Dakota Sandstone and to the overlying Ferron Sandstone Member of the Mancos Shale.

Acknowledgments

The writer would like to express gratitude to Dr. J. Keith Rigby for his guidance and direction in completing this thesis and for the use of his microscope. Dr. E. Blair Maxfield provided valuable assistance in helping identify the foraminifera and in lending some of his negatives. Dr. Harold J. Bissell is appreciated for reading the manuscript and offering suggestions. Thanks go to Tom Chidsey, Allen Driggs, Paul Gilmer, Bob Lindsay, and Debbie Reeder for their help in collecting the samples from the ash beds. Financial assistance was provided by the American Association of Petroleum Geologists, Sigma Xi, and the Department of Geology, Brigham Young University.

Previous Work

Lessard (1973) studied the general paleoecology of the Tununk Member of the Mancos Shale and described 20 species of foraminifera. Maxfield (1976) established a foraminiferal biostratigraphic zonation of the Mancos Shale, including the Tununk Member, and described 30 species of foraminifera from Tununk beds.

Young (1951, p. 48) found no foraminifera in bentonite

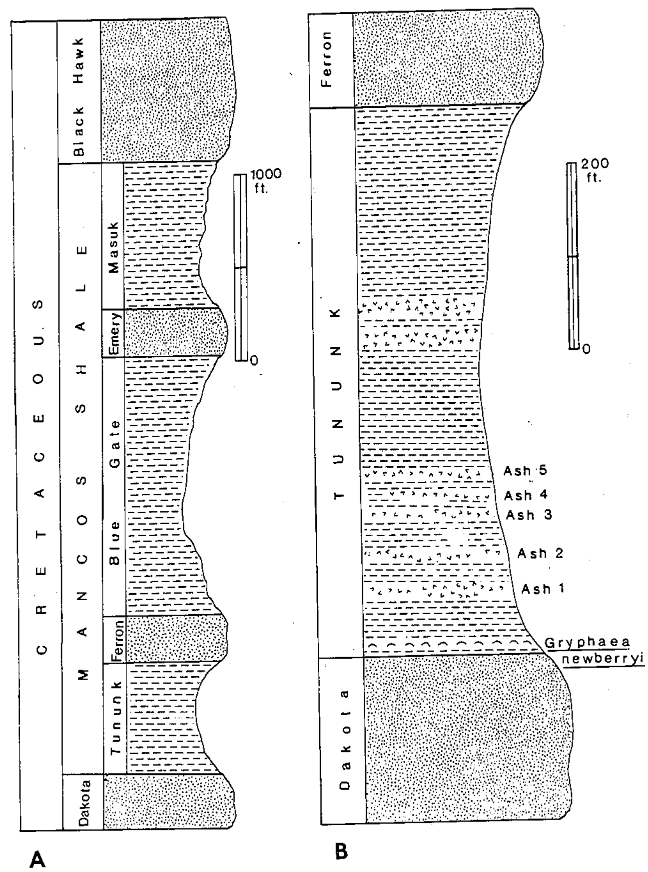

Figure 1.—Stratigraphic section. A. General stratigraphy, B. Tununk stratigraphy.

*A thesis presented to the Department of Geology, Brigham Young University, in partial fulfillment of the requirements for the degree Master of Science, April 1977: J. Keith Rigby, thesis chairman.

beds in the Frontier Formation in Montana. He suggested that conditions unfavorable for their existence were present at the time of deposition or that they might have been destroyed by ground water action after deposition of the beds. Miller (1968, p. 9) reported that the faunal suite of foraminifera in the Smoky Hill Member of the Niobrara Formation in Kansas, which has bentonite beds, lacked arenaceous foraminifera and that most of the genera in the area were stunted. Reeside (1957, p. 520–22) suggested that Turonian volcanism had little effect on life conditions in western Cretaceous seaways, but that Cenomanian volcanism was significant. However, he did not elaborate on those conclusions.

The most detailed published observations on ash-related foraminiferal distributions is that of Mello (1969, p. 24). He studied the Pierre Shale in South Dakota and observed that at three of his measured sections, where bentonite beds were significant, greater numbers of foraminiferal species occur below the ash than above and that the number of arenaceous species was reduced by 50 percent in two of the three cases. He believed that this effect was restricted, however, for it was not apparent in any of his other measured sections. His samples were collected at ten-foot intervals, however, and he most likely missed sampling some of the ash beds.

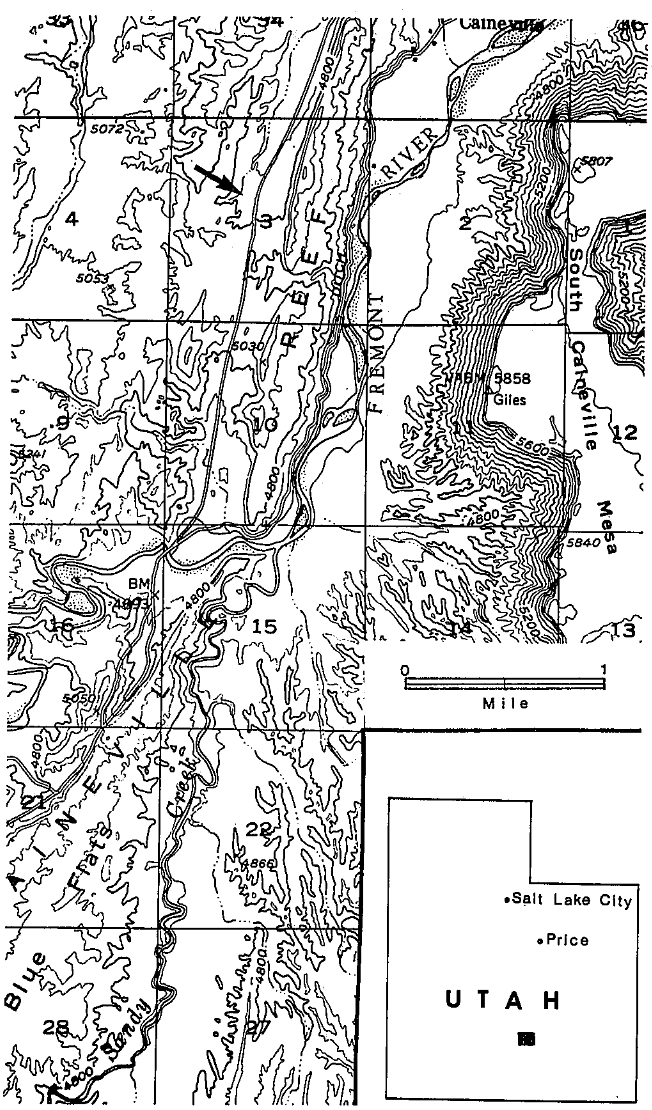

FIGURE 2.–Index map.

Wilcox (1957, p. 456), after studying recent ash falls in Alaska, thought that any effects of ash falls on marine life were only temporary, judging from his review of the scanty literature. Finger (1976) conducted numerous studies on foraminifera within and around a volcanic atoll in Antarctica and found large numbers of calcareous species and few arenaceous ones after two of the three eruptions studied.

Field and Laboratory Methods

The study area was chosen because many well-exposed ash beds occur in a thin sequence of tilted beds (fig. 3) which allow close sampling. The selected ash beds and intervening dark gray siltstones and shale beds were trenched with shovels to provide fresh surfaces and prevent sample contamination (fig. 4). Samples weighing approximately 250 grams each were collected at 5- to 10-centimeter intervals through the ash beds and from approximately 20 centimeters below to 30 centimeters above each bentonite.

One-hundred-gram portions were soaked in water containing a wetting agent for several days. When disaggregated, the samples were washed on a 200-mesh screen. After drying, the residues were split, and 1/64 of the original residue was picked when it became apparent that processing all of it was virtually impossible because each sample contained a large number of foraminifera. The foraminifera retained on a 100-mesh screen were picked. Residues smaller than the 100-mesh screen were again split into varying sizes from 1/16 to 1/4096 original residue weight and picked. Foraminifera smaller than 100-mesh were not picked in ashes 3 and 4. Picked specimens were identified using a Wild binocular microscope. All specimens other than those figured were mounted on gum-tragacanth-coated microfaunal slides and are in collections of the Department of Geology, Brigham Young University.

The figured specimens were mounted on electron microscope stubs and were photographed by the scanning electron microscope at Brigham Young University Electron Optics Laboratory. Figured specimens are housed in the type collections of the Brigham Young University Geology Department.

FAUNA

The microfauna of the sampled Tununk Shale intervals is composed primarily of foraminifera. A few ostracods, fish teeth, and *Inoceramus* prisms were found. Fragments of *Inoceramus* were the only macrofaunal elements observed. Examination of the samples was not conducted for diatoms, radiolarians, spores, or pollen.

The Foraminiferida of the Tununk Shale are represented by 11 families, the Saccamminidae, Hormosinidae, Lituolidae, Nodosariidae, Turrilinidae, Heterohelicidae, Planomalinidae, Rotaliporidae, Cibicidae, Caucasinidae, and Anomalinidae. The first three families are composed of agglutinated forms, and the others are composed of calcareous types. These families are represented by 17 genera and 20 species.

The Nodosariidae are represented by the greatest number of genera (3) and species (4). They occur sporadically and in very small numbers throughout the sampled intervals. Specimens of the Turrilinidae, represented by *Praebulimina prolixa* (Cushman and Parker 1935), are extremely abundant and constitute the largest foraminiferal numbers in most of the sampled intervals for all the ashes. The Heterohelicidae, repre-

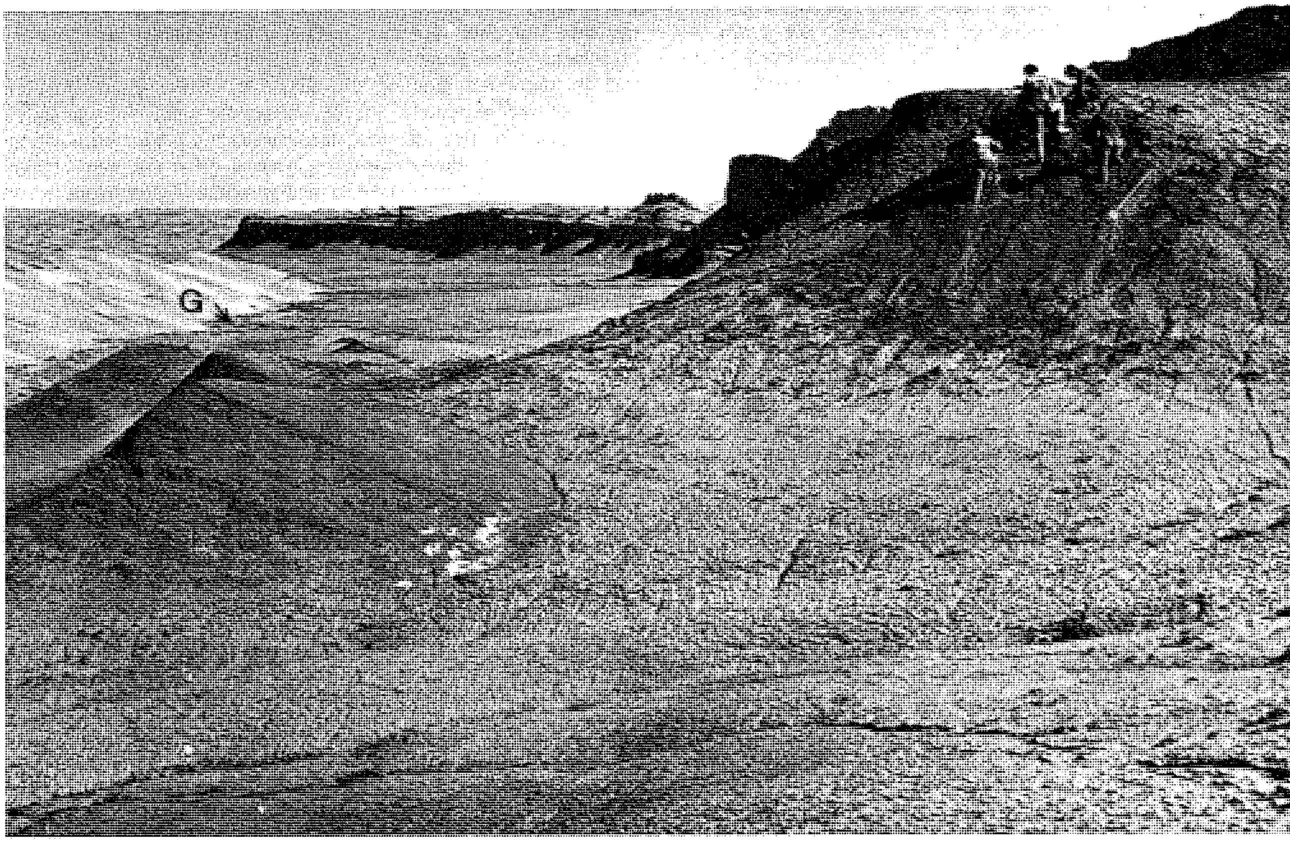

FIGURE 3.–View of Tununk stratigraphy: Ferron Sandstone (F), *Gryphaea newberryi* horizon (G), ash 1 (1), ash 2 (2).

sented by *Heterohelix globulosa* (Ehrenberg) 1840, and Rotaliporidae, represented by *Hedbergella delrioensis* (Carsey 1954), also constitute large foraminiferal numbers throughout the Tununk section. The three agglutinate species, *Saccamminna complanata* (Franke 1912), (?) *Reophax* sp., and *Ammobaculites wenonahae* Tappan 1960 are very rare in the section and occur mainly in ash 5 (fig. 1). The fauna represents Maxfield's Zone A (1976, p. 78) based upon the occurrence of *Ammobaculites wenonahae* and *Planulina austinana* Cushman 1935 in the sampled intervals. His Zone A is composed primarily of planktonic forms and nodosarids and buliminids. The sections studied in this paper, however, have only a few more planktonic than benthonic forms because the buliminids are abundant throughout.

Most of the foraminifera are smaller than those designated as type specimens by the original workers. Several authors thought that smaller specimens are dwarfed or stunted by unfavorable environmental conditions. Apparent stunting in Cretaceous foraminifera has been reported by Green (1959, p. 36) in the Allen Valley Shale of Utah; Miller (1968, p. 9) in the Smokey Hill Member of the Niobrara Formation in Kansas; and Lessard (1973, p. 10) in the Tununk Shale in Utah. Loeblich and Tappan (1964, p. 125), however, state that smaller specimens indicate unusually favorable conditions and rapid reproduction.

PALEOECOLOGY

Ash 1 is 40 cm thick and occurs 12 m above the base of the Tununk Shale. The number of foraminifera per gram decreases in the lower part of the ash (fig. 5), increases to 11,876 per gram in the upper part, and then decreases again at the top of the ash. The foraminiferal number increases in the siltstone above the ash. The sampled interval contains predominantly benthonic foraminifera (57-92 percent). The percentage of planktonic forms is greatest at the base of the ash (43 percent) and above the ash (42 percent). The ratio between the various foraminiferal families remains approximately the same throughout the interval, with a dominance of Turrilinidae and Heterohelicidae (table 1).

FIGURE 4. View of trench through ash 2.

Ash 2 is 22 m above the base of the Tununk Shale and is 22 cm thick. The number of foraminifera per gram decreases in the lower part of the ash, but then increases in the middle, only to decrease again at the top. The number also shows two increases separated by a minor decrease in the siltstone above the ash (fig. 6). Foraminifera in the ash are dominated by planktonic forms (60-90 percent), but benthonic forms dominate below the ash (50-85 percent) and 30 cm above the ash (53 percent). The ratios between the foraminiferal families vary a little, however: Rotaliporidae, Heterohelicidae, and Turrilinidae comprise most of the forms (table 2).

Ashes 3 and 4 were sampled as a check on the other bentonite beds, but only the foraminifera larger than a 100-mesh screen were picked. Therefore, the results do not reflect the abundance of *Guembelitria cretacea* Cushman 1935, *Globigerinelloides aspera* (Ehrenberg 1854), *Cassidella tegulata* (Reuss) 1951, or the Turrilinidae since they pass through a 100-mesh screen.

Ash 3 is 41 cm thick and is 30 m above the base of the Tununk Shale. The numbers of foraminifera are low below the bottom of the ash (fig. 7), increase in the lower half of the ash, but then decrease in the upper quarter of the ash. Numbers increase again in the uppermost part of the ash and in the basal part of the siltstone above. Numbers decrease at approximately 10 cm above the ash. Foraminiferal assemblages in the ash are dominated by planktonic forms (57-85 percent), except for one interval near the top of the ash. Families present maintain nearly constant abundance ratios throughout the ash, with Rotaliporidae being dominant (table 3).

Ash 4 is 21 cm thick and is 31 m above the base of the Tununk Shale. The foraminiferal number decreases at its base, but increases vertically through the ash. Numbers decrease in the siltstone immediately above the ash, but then increase again (fig. 8). The ash contains principally planktonic forms (55-89 percent), with *Hedbergella delrioensis* (Carsey 1954) dominating the assemblage. Numbers of Anomalinidae and Cibicidae stay fairly constant throughout the sampled interval (11-35 per gram) (table 4).

Ash 5, 32 m above the base of the Tununk Shale, contains a sequence of separate ash falls within the 195 cm that

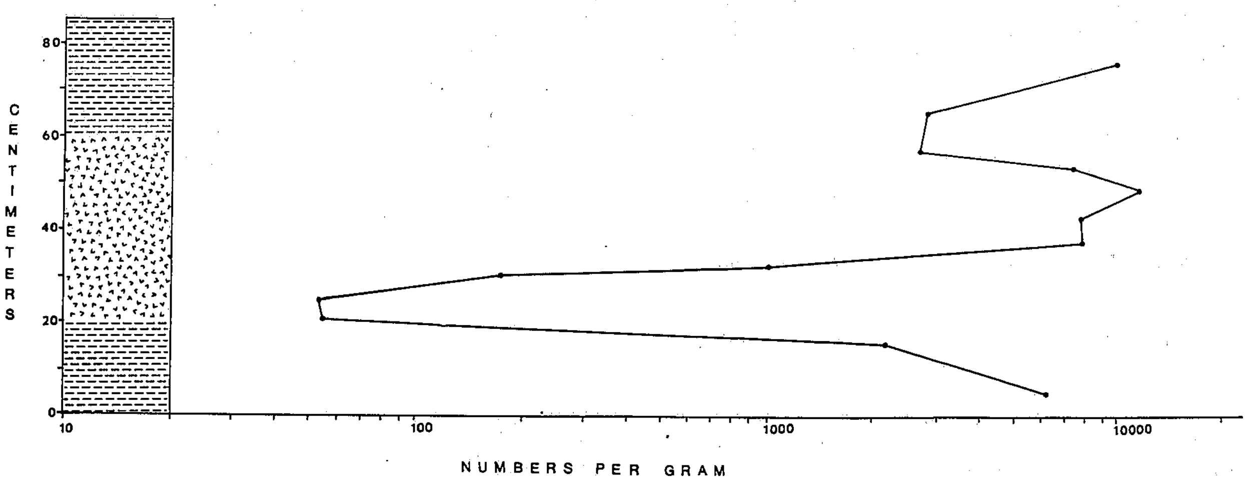

FIGURE 5.—Graph of foraminiferal abundance in ash 1.

TABLE 1

Foraminiferal Occurrence in Ash 1

Interval		Total Number per gram	Rotaliporidae Planomalinidae Number per gram	*Heterohelix globulosa* Number per gram	*Guembelitria cretacea* Number per gram	Planktonic Number per gram	Planktonic Percentage	Turrilinidae Causasinidae Number per gram	Cibicidae Anomalinidae Number per gram	Misc. Juveniles Number per gram	Benthonic Number per gram	Benthonic Percentage
70-80 cm		10016	700	2173	236	3109	31	6433	388	86	6907	69
60-70		2856	198	833	157	1188	42	1485	181	1	1667	58
55-60	Ash 1	2766	303	144	0	447	16	2216	100	1	2317	84
50-55	Ash 1	7546	860	550	0	1410	19	5743	392	1	6136	81
47-50	Ash 1	11876	523	1374	270	2167	18	9295	417	3	9715	82
41-44	Ash 1	8892	486	1393	287	2166	24	6308	581	0	6889	76
38-41	Ash 1	8913	705	860	455	2020	22	6270	621	0	6891	78
35-38	Ash 1	8256	501	1329	295	2124	26	5793	336	1	6130	74
32-35	Ash 1	1029	86	169	10	265	26	718	44	2	764	74
26-30	Ash 1	172	23	25	0	48	28	70	12	8	90	72
24-26	Ash 1	54	0	22	0	22	41	32	0	0	32	59
20-22	Ash 1	56	0.4	24	0	24	43	30	0	0	30	57
10-20		2132	48	141	47	236	11	1662	229	3	1894	89
0-10		6222	197	299	37	533	8	2058	387	37	2482	92

were sampled. The entire sampled interval differs from ashes 1 and 2, for no specimens of *Guembelitria cretacea* were recovered (table 5).

The first ash within the sequence, ash 5A, is 28 cm thick. Numbers of foraminifera decrease at its base, increase in its middle part, and decrease at its top (fig. 9). The foraminifera are mixed benthonic and planktonic, with planktonic forms dominating below, in the lower middle part, and at the top. Within the ash, *Praebulimina prolixa* (Cushman and Parker 1935) dominates the central part, and *Hedbergella delrioensis, Planulina austinana* Cushman 1935, *Gavelinella nelsoni* (W. Berry 1929), and juvenile forms dominate. The ratio between families remains approximately constant as in the other ashes.

Ash 5B is 73 cm thick and occurs 23 cm above ash 5A. Because of its thickness, it may be two ashes with no apparent stratigraphic break between them. Numbers of foraminifera increase at the bottom of the ash, but then decrease in the lower third (fig. 9). In the middle third of the bed, foraminifera again increase and decrease. In the upper third, numbers increase but then show an oscillating decline to the top of the ash. The numbers increase in the siltstone above the ash. The forms within ash 5B are mainly planktonic (50-65 percent), but with benthonic forms dominating twice (table 5) within the upper half of the ash (55-57 percent). None of the species present tends to dominate the ash, but ratios between the species remain approximately constant throughout.

Ash 5C is the thinnest ash studied, for it is only 10 cm thick (fig. 9). It is separated from ash 5B by 11 cm of siltstone and from ash 5D by 5 cm of siltstone. The numbers of foraminifera in ash 5C increase from below the ash steadily to 3 cm from its top. Numbers decrease from there into the lower part of ash 5D. Assemblages in ash 5C are planktonic (53-59 percent), and *Hedbergella delrioensis* dominates the forms in the central part of the ash.

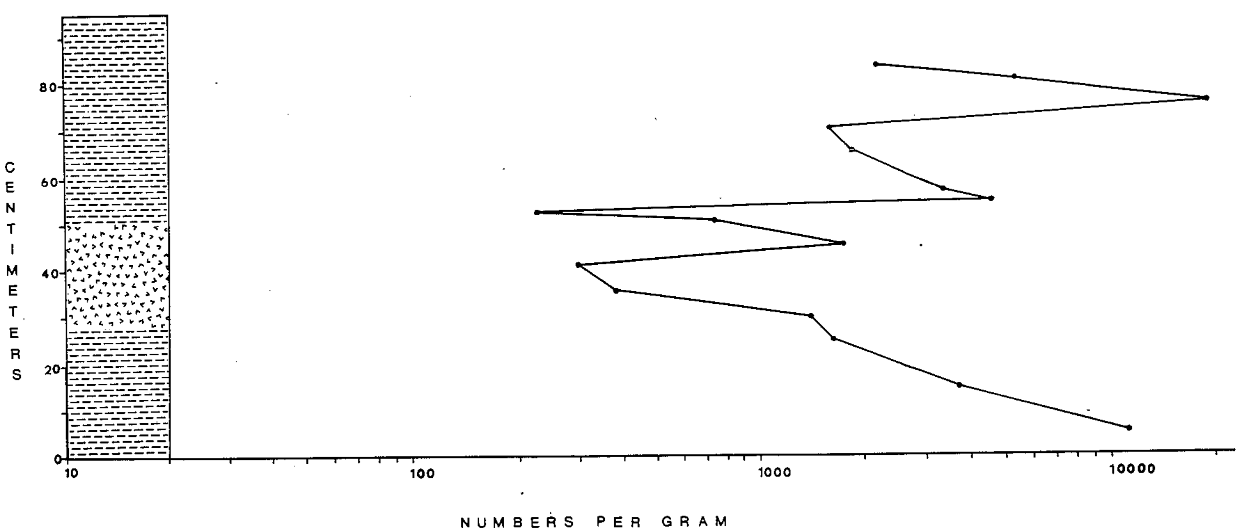

FIGURE 6.—Graph of foraminiferal abundance in ash 2.

TABLE 2
Foraminiferal Occurrence in Ash 2

Interval		Total Number per gram	Rotaliporidae Planomalinidae Number per gram	*Heterohelix globulosa* Number per gram	*Guembelitria cretacea* Number per gram	Planktonic Number per gram	Planktonic Percentage	Turrilinidae Causasinidae Number per gram	Cibicidae Anomalinidae Number per gram	Misc. Juveniles Number per gram	Benthonic Number per gram	Benthonic Percentage
80-83 cm		2197	374	603	64	1041	47	1056	32	68	1156	53
75-80		5452	1868	1705	178	3751	69	1344	33	0	1377	31
70-75		18881	3996	7145	538	11679	62	6992	168	41	7201	38
65-70		1610	659	535	22	1216	75	370	22	0	392	25
63-65		1868	785	675	32	1492	80	432	38	6	476	20
54-57		3408	2238	935	22	3195	94	136	61	15	212	6
52-54		4600	1686	1986	115	3787	82	580	115	6	701	18
50-52		225	186	27	1	214	95	8	1	1	10	5
48-50		751	627	111	4	742	99	7	0	2	9	1
40-45	Ash 2	1783	906	705	30	1641	92	135	3	2	140	8
35-40		299	187	91	0	278	93	10	3	8	21	7
30-35		383	68	139	23	230	60	151	0	1	152	40
28-30		1441	73	456	0	529	37	793	1	117	911	63
20-25		1687	149	110	0	259	15	1243	0	185	1428	18
10-15		3760	224	1120	180	1524	40	2021	72	121	2214	60
0-5		10943	464	4699	317	5480	50	4763	127	571	5461	50

Ash 5D is 25 cm thick. The foraminiferal numbers decline in the lower third of the ash (fig. 9), but then increase in the upper third, only to decline immediately above the ash. In the siltstones above the ash, the number of foraminifera increases and declines in a pattern similar to that in ashes 2 and 3. The foraminifera in ash 5D are mainly planktonic (54-78 percent) except in the lower 10 cm of the ash where benthonic forms, mainly *Praebulimina prolixa,* dominate (51-62 percent). Above the benthonic layers of the ash, *Hedbergella delrioensis* is the dominant planktonic form.

In summary, the effects on foraminifera of the five ash falls studied are approximately the same. All the ashes except 5B and 5D show a decrease in the foraminiferal number at the ash base, but a population bloom within the ash, followed by another decrease in numbers occurring near the top of the ash. Another population bloom occurs immediately above the ash.

All the ashes, except ash 1, are dominated by planktonic foraminifera, mainly *Hedbergella delrioensis* and *Heterohelix globulosa* (Ehrenberg) 1840. *Praebulimina prolixa* is the dominant benthonic species. The ratio between the species contained within each ash remains approximately equal, with very little domination by any one species. It is suggested that the ash fell and, after the initial shock on the foraminifera population, provided nutrients which created population blooms. When the immediate nutrient supply was exhausted, the numbers of foraminifera dropped. The return to normal marine conditions or further solution of the ashes might have caused the population bloom above each ash.

Maxfield (1976, p. 82) postulates the depth of the Tununk Sea to be 22.5 to 60 m (75-200 ft.). Lessard (1973, p. 16) concludes that the water was 90 to 180 m (300-600 ft.) deep, as indicated by the dominance of planktonic species. Both Lessard and Maxfield suggest that the distance from shore is more of a factor determining the high planktonic assemblage than water depth. This writer agrees with Maxfield's conclusion regarding water depths and also with the idea that distance from shore determines the planktonic assemblage. The environment of the sampled intervals in this study is interpreted as being a prodeltaic sequence.

The Tununk Sea was of normal salinity as suggested by the presence of authigenic glauconite (Lessard 1973, p. 15) and the lack of agglutinated species (Maxfield 1976, p. 82). Greiner (1969, p. 169) states that hyaline calcareous foraminifera live in water with moderate salinity and temperature—also with a moderate calcium carbonate content. The Tu-

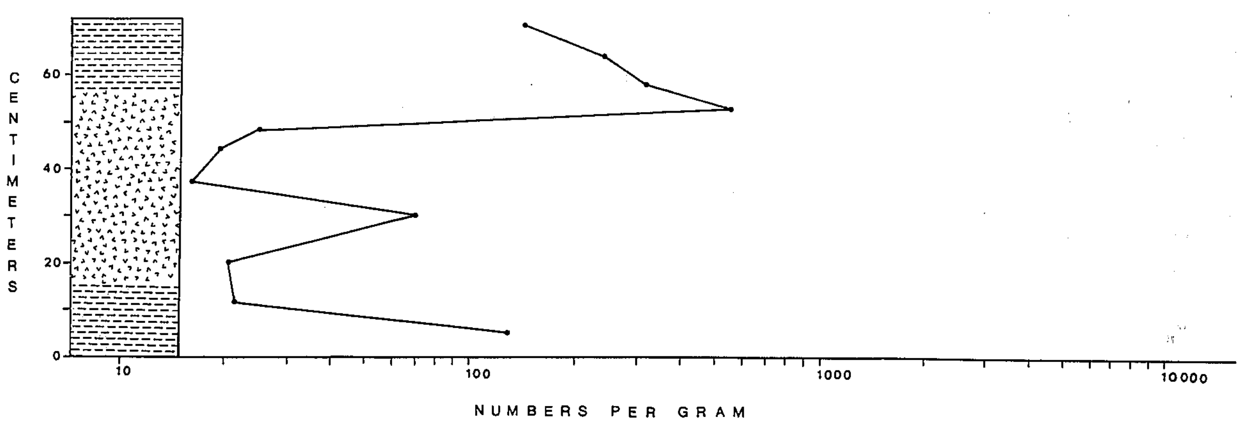

FIGURE 7.—Graph of foraminiferal abundance in ash 3.

TABLE 3

Foraminiferal Occurrence in Ash 3

Interval		Total Number per gram	Rotaliporidae Planomalinidae Number per gram	*Heterohelix globulosa* Number per gram	*Guembelitria cretacea** Number per gram	Planktonic Number per gram	Planktonic Percentage	Turrilinidae* Causasinidae* Number per gram	Cibicidae Anomalinidae Number per gram	Misc. Juveniles Number per gram	Benthonic Number per gram	Benthonic Percentage
66-76 cm		147	75	30	-	105	71	-	13	30	43	29
61-66		242	157	43	-	200	82	-	16	25	41	18
56-61		324	136	68	-	204	63	-	38	81	119	37
50-56	Ash 3	562	215	164	-	369	66	-	61	121	182	34
46-50		25	0.6	6	-	6	24	-	2	17	19	76
40-46		19	8	4	-	12	63	-	1	5	6	37
35-40		16	9	2	-	11	69	-	3	2	5	31
25-35		70	41	10	-	51	73	-	0	18	18	27
15-25		20	12	2	-	14	70	-	0	6	6	30
8-15		21	12	0.6	-	12	57	-	0.6	7	7	43
2-8		131	97	15	-	112	85	-	2	22	24	15

*Not in sizes picked

nunk Sea in which the studied sequence accumulated was a warm shallow sea.

Turbidity created by the ash falls decreased the number of calcareous benthonic species, as calcareous planktonic forms become more dominant in the four upper ash beds. These results differ slightly from those of Loeblich and Tappan (1964, p. 133–34). They noted that bentonitic sediments commonly carry radiolarians and diatoms, and that these forms occur in an inverse ratio to the numbers of foraminifera. It is then suggested that ash falls increased the turbidity and allowed the survival of planktonic siliceous forms, but greatly reduced the calcareous foraminiferal faunas.

CONCLUSIONS

The Tununk Member of the Upper Cretaceous Mancos Shale represents a transgressive seaway. The sediments are prodeltaic siltstones with interbedded bentonite beds derived from volcanic ash falls originating far to the west. The sea was shallow, of normal salinity and moderate temperature.

Five bentonite ash beds in the lower Tununk Shale were sampled on 5- to 10-cm intervals to determine the effect of ash falls on the foraminifera inhabiting the Tununk sea. Eleven foraminifera families, represented by 17 genera, were recovered. Assemblages for each ash are predominately planktonic, except for ash 1 where benthonic forms are most common.

Each of the ash sequences which was totally picked shows that the number of foraminifera decreases at the base of each ash, increases within the ash, and decreases at the top or immediately above the ash. The foraminifera population also increases above each ash. It is suggested that the ashes provided nutrients for organisms upon which the foraminifera fed and thus created a circumstance favorable for the bloom within the ash, judging from the large number of small adult and immature forms in each ash and the slight number of large forms. Initial shock caused by the ash fall most likely created the decrease in numbers at the base of the ashes. The reason for the decrease in numbers near the top of the ash may be nutrient depletion caused by the population's multiplying at a rate faster than nutrients could be supplied. The population bloom above each ash may be related to an increase in nutrients and food supply. For example, diatoms or radiolarians may have flourished immediately following the ash accumulation.

Further study needs to be conducted on the diatom and radiolarian populations to evaluate variations in their numbers as significant food sources. Other Cretaceous bentonite beds should be studied to see if foraminiferal numbers show parallel marked fluctuations.

SYSTEMATIC PALEONTOLOGY

The classification followed here is that of Loeblich and Tappan (1964) and Maxfield (1976). No synonymies are presented, except for *Cassidella tegulata* (Reuss) 1951, since the main emphasis of this paper is the relationship of the foraminifera to the ash beds and not systematics. Current synonymies are found in Maxfield (1976).

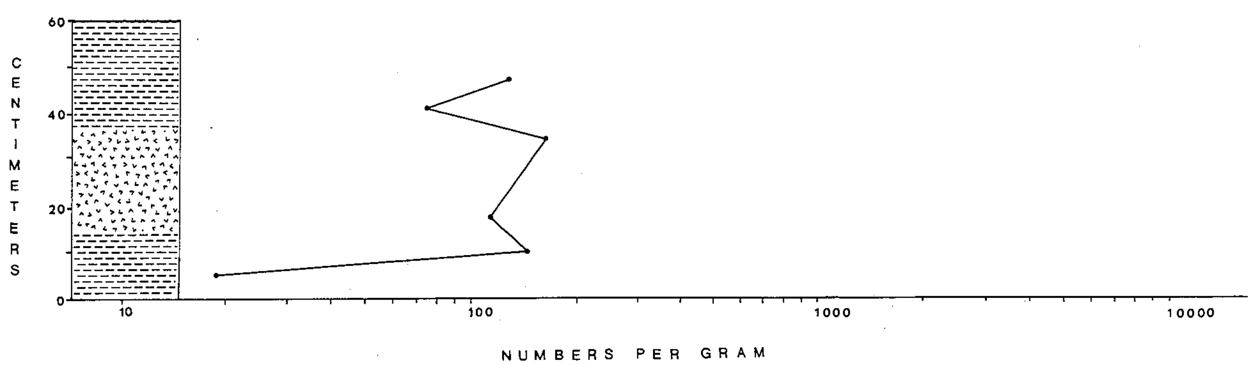

FIGURE 8.—Graph of foraminiferal abundance in ash 4.

TABLE 4

Foraminiferal Occurrence in Ash 4

Interval	Total Number per gram	Rotaliporidae Planomalinidae Number per gram	*Heterohelix globulosa* Number per gram	*Guembelitria cretacea** Number per gram	Planktonic Number per gram	Planktonic Percentage	Turrilinidae* Causasinidae* Number per gram	Cibicidae Anomalinidae Number per gram	Misc. Juveniles Number per gram	Benthonic Number per gram	Benthonic Percentage
43-50 cm	130	106	0	-	106	82	-	15	13	28	18
38-43	77	42	0	-	42	55	-	25	9	34	45
30-38	162	115	2	-	117	72	-	25	19	44	28
25-30	141	123	2	-	125	89	-	11	5	16	11
15-20	115	80	3	-	83	72	-	25	6	31	28
8-15	144	101	4	-	115	73	-	35	4	39	27
2-8	19	15	0	-	15	79	-	0	4	4	21

*Not in sizes picked

Subphylum SARCODINA Schmarda, 1871
Class RHIZOPODEA von Siebold, 1845
Subclass LOBOSIA Carpenter, 1861
Order FORAMINIFERIDA Eichwald, 1830
Suborder TEXTULARIINA Delage and Hérouard, 1896
Superfamily AMMODISCACEA Reuss, 1862
Family SACCAMMINIDAE Brady, 1884
Subfamily SACCAMMININAE Brady, 1884
Genus SACCAMMINA M. Sars in Carpenter, 1869
SACCAMMINA COMPLANATA (Franke 1912)
Fig. 10(6)

Description.—Test free, consisting of a single bulbous chamber, crushed in the material at hand; wall very fine-grained sand particles; aperture single, round, with short neck. Dimensions: breadth, approximately 0.26 mm.

Remarks.—Only two specimens were found in the material; the smaller one is badly crushed. Specimens are not as smoothly finished as those described by Cushman (1946).

Figured specimen BYU 1973.

Superfamily LITUOLACEA de Blainville, 1825
Family HORMOSINIDAE Haeckel, 1894
Subfamily HORMOSININAE Haeckel, 1894

Genus REOPHAX Montfort, 1808
(?) REOPHAX sp.
Fig. 10(2)

Description.—Test elongate, consisting of three uniserial chambers: chambers rounded in section; sutures straight, distinct; wall agglutinated with fine sand grains. Dimensions: length, approximately 0.7 mm; diameter, approximately 0.3 mm.

Remarks.—Only one specimen was found in the samples. It is incomplete with only half of the third chamber present. It could possibly be a fragment of *Ammobaculites,* with the planispiral early portion missing.

Figured specimen BYU 1974.

Family LITUOLIDAE de Blainville, 1825
Subfamily LITUOLINAE de Blainville, 1825
Genus AMMOBACULITES Cushman, 1910
AMMOBACULITES WENONAHAE Tappan, 1960
Fig. 10(7)

Description.—Test free, elongate, slightly compressed; early portion close coiled, with five to seven chambers in the coil and a large umbilicus; later portion uniserial with nearly parallel

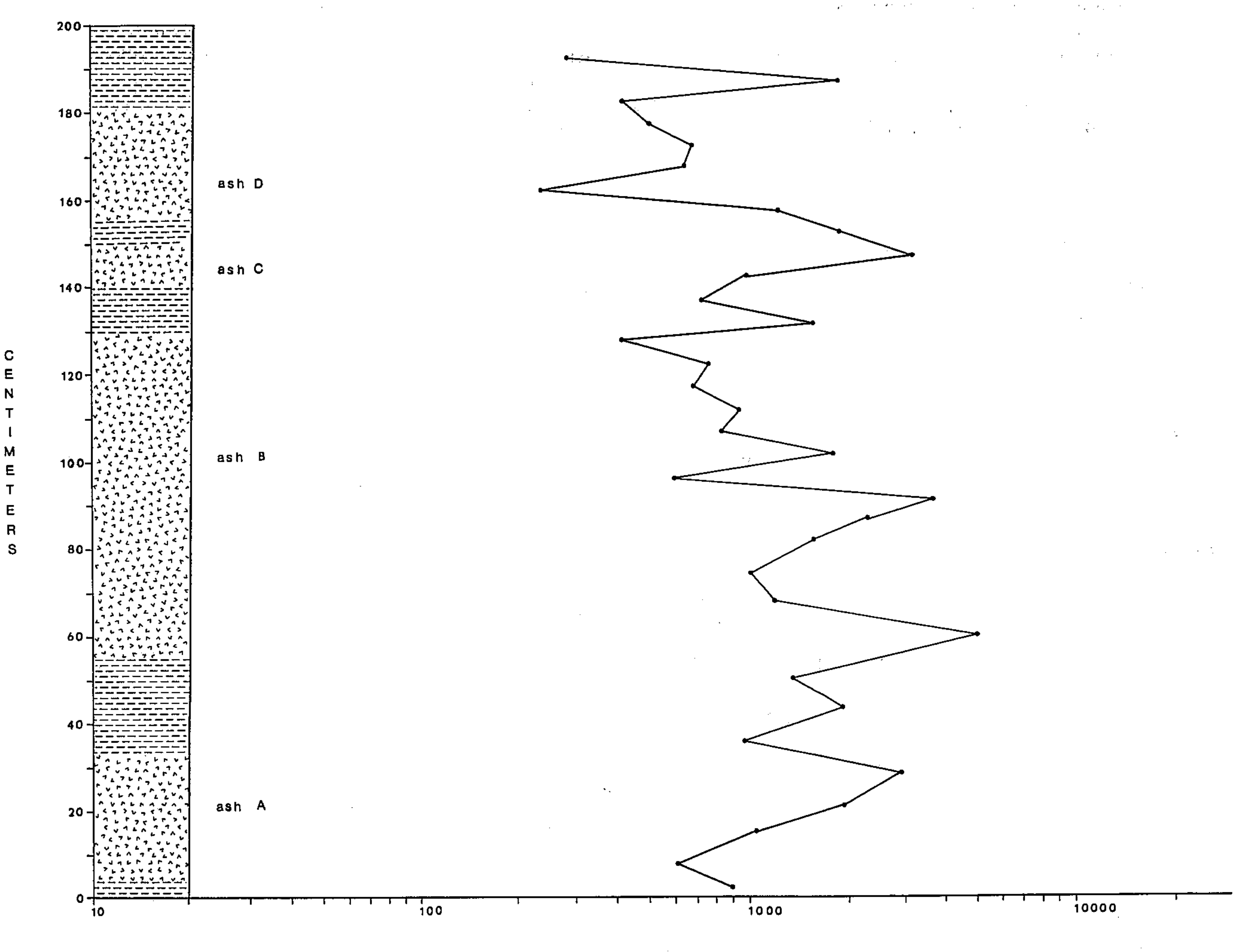

FIGURE 9.—Graph of foraminiferal abundance in ash 5.

sides, early uniserial portion of equal or less breadth than the coil, peripheral margin broadly rounded; chambers numerous, inflated in the coil, ranging from subrounded to low and broad in the uniserial portion; uniserial chamber increasing very little in diameter as added; sutures distinct, straight, and depressed; wall agglutinated, texture varying, aperture terminal rounded. Dimensions: length, 0.3-0.6 mm; diameter of coil, 0.2-0.3 mm; thickness, 0.15-0.2 mm.

Remarks.—Four specimens were found, two of which are crushed. The specimens are smaller than those described by Tappan (1960). This species was originally described from the Upper Cretaceous of the North Slope of Alaska (Tappan 1951).

Figured specimen BYU 1975.

Suborder ROTALIINA Delage and Herouard, 1896
Superfamily NODOSARIACEA Ehrenberg, 1838
Family NODOSARIIDAE Ehrenberg, 1838
Subfamily NODOSARIINAE Ehrenberg, 1838
Genus DENTALINA Risso, 1826
DENTALINA BASIPLANATA Cushman, 1938
Fig. 10(3, 4)

Description.—Test very elongate, slightly tapering, usually slightly curved; early portion showing oblique costae that indicate coiling, especially in the microspheric form, often slightly compressed; chambers distinct, earlier chambers not inflated, later chambers become increasingly inflated as added; earlier chambers much more strongly overlapping; sutures distinct, somewhat limbate, earlier sutures flush with the surface, oblique, later sutures progressively more depressed and more nearly at right angles to the elongate axis; wall smooth, or the earliest portion sometimes slightly roughened; aperture terminal, radiate. Dimensions: length, approximately 1.7 mm; breadth, 0.2-0.24 mm.

Remarks.—Representatives of the species occur sporadically in all the ash beds, but all the recovered specimens are broken. The species is consistently present in both Maxfield's (1976) and Lessard's (1973) Tununk sections. It ranges through beds of Taylor and Navarro age in the Gulf Coastal region of the United States (Maxfield 1976, p. 112).

Figured specimens BYU 2450, 2451.

Genus FRONDICULARIA DeFrance in d'Orbigny, 1826
FRONDICULARIA GOLDFUSSI Reuss, 1860
Fig. 10(5, 10)

Description.—The species has a basal spine and a rounded or slightly elongate proloculum, the following chambers increasing very slightly in width as added, the sutures becoming progressively more curved, slightly limbate, but not rising above the flattened, broad face of the test; wall may be smooth to a few fine vertical costae on each chamber, and not crossing the sutures; periphery distinctly truncate, even slightly concave; apertural end usually projects slightly into a very short apertural neck; at the base the chambers reach well back, forming a broadly wedge-shaped base with the

TABLE 5
Foraminiferal Occurrence in Ash 5

Interval	Zone	Total Number per gram	Rotaliporidae Planomalinidae Number per gram	*Heterohelix globulosa* Number per gram	*Guembelitria cretacea* Number per gram	Planktonic Number per gram	Planktonic Percentage	Turrilinidae Gausasinidae Number per gram	Cibicidae Anomalinidae Number per gram	Misc. Juveniles Number per gram	Benthonic Number per gram	Benthonic Percentage
190-195 cm		280	82	82	0	164	58	82	19	15	116	42
185-190		1836	706	298	0	1004	55	594	202	36	832	45
180-185		406	171	83	0	254	62	61	53	36	150	38
175-180		497	279	43	0	322	65	71	56	28	155	35
170-175		662	173	184	0	357	54	123	145	37	305	46
165-170	D	646	381	123	0	504	78	82	48	12	142	22
160-165		236	30	61	0	91	38	133	10	1	144	62
155-160		1225	405	194	0	599	49	415	148	62	625	51
150-155		1877	562	543	0	1105	59	409	298	63	770	41
145-150	C	3134	1305	653	0	1958	62	350	468	355	1173	38
140-145		997	379	151	0	530	53	236	155	75	466	47
134-140		703	261	154	0	415	59	128	98	60	286	41
129-134		1554	400	517	0	917	59	401	168	67	636	41
124-129		408	147	78	0	225	55	61	82	38	181	45
119-124		766	142	202	0	344	45	201	102	101	404	55
114-119		682	257	99	0	356	52	123	164	36	323	48
109-114		939	257	284	0	541	57	164	175	55	394	43
104-109		829	128	230	0	358	43	256	109	114	479	57
99-104		1795	340	556	0	896	50	450	350	98	898	50
94-99	B	591	116	242	0	358	60	143	41	47	231	40
89-94		3649	615	1483	0	2098	57	1075	397	78	1550	43
84-89		2307	549	623	0	1172	51	676	306	216	1198	49
79-84		1559	200	820	0	1020	65	307	99	133	539	35
71-79		1000	313	300	0	613	61	215	161	10	386	39
63-71		1183	409	209	0	618	52	194	270	98	562	48
56-63		5066	1607	1328	0	2935	58	1013	933	182	2128	42
48-56		1349	621	288	0	849	63	220	191	89	500	37
40-48		1905	757	278	0	1035	54	261	428	180	869	46
33-40		967	464	162	0	626	65	157	105	77	339	35
25-30		2907	798	399	0	1197	41	497	611	601	1709	59
18-25	A	1934	272	250	0	522	27	803	221	385	1409	73
13-18		1028	483	217	0	700	68	101	122	127	350	32
5-13		604	107	118	0	225	37	89	231	59	379	63
0-5		905	309	231	0	540	59	100	148	115	363	41

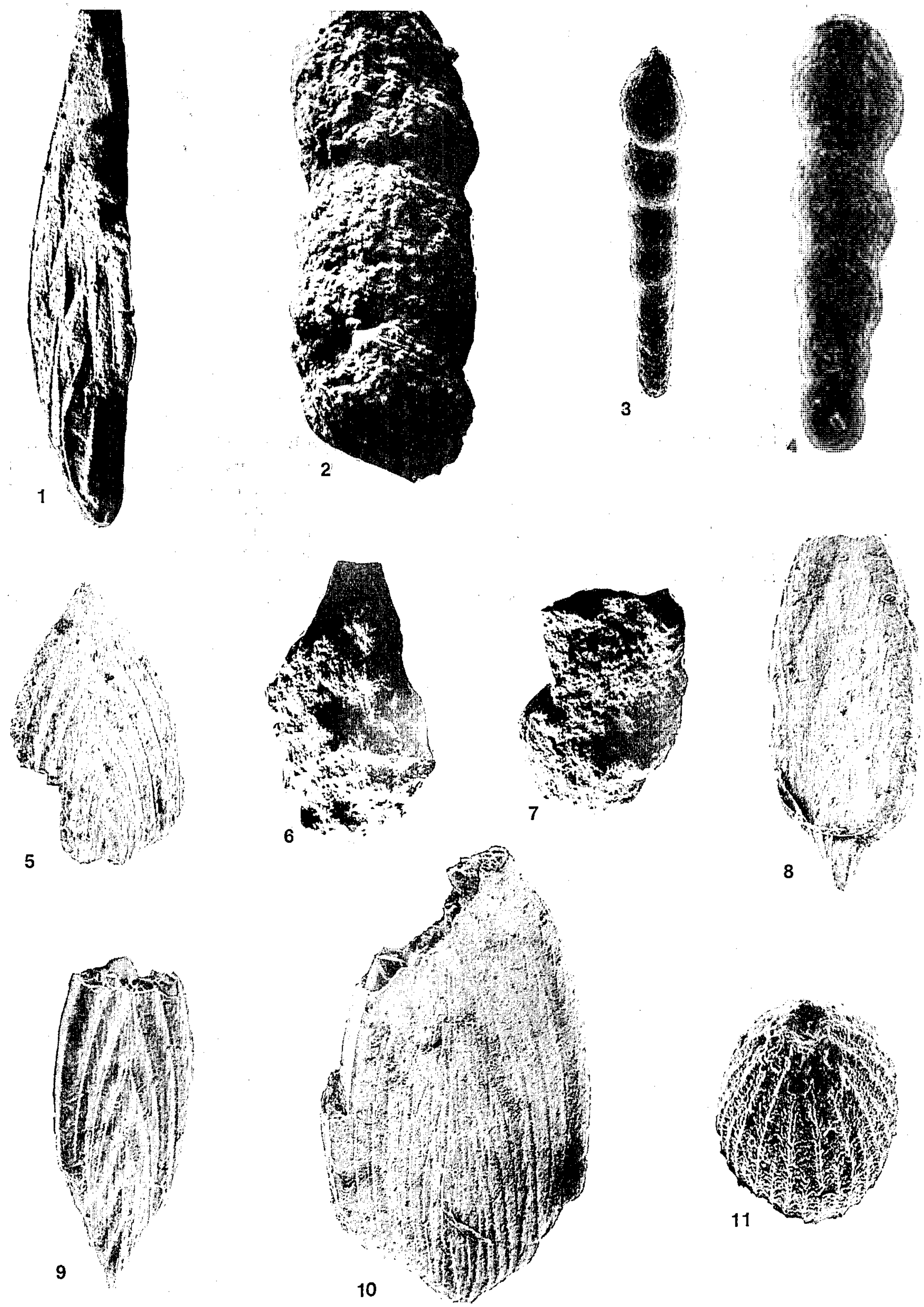

FIGURE 10.–Foraminiferal fauna: (1) *Frondicularia inversa* Reuss. Side view, X170. (BYU 1976). (2) (?) *Reophax* sp. Side view, X190. (BYU 1974). (3) *Dentalina basiplanata* Cushman. Side view, X60. (BYU 2451). (4) *Dentalina basiplanata* Cushman. Side view, X125. (BYU 2450). (5) *Frondicularia goldfussi* Reuss. Side view, X30. (BYU 2491). (6) *Saccammina complanata* (Franke). Side view, X180. (BYU 1973). (7) *Ammobaculites wenonahae* Tappan. Side view, X185. (BYU 1975). (8) *Frondicularia inversa* Reuss. Side view, X65. (BYU 2489). (9) *Frondicularia inversa* Reuss. Side view, X65. (BYU 2490). (10) *Frondicularia goldfussi* Reuss. Side view, X60. (BYU 2492). (11) *Lagena sulcata* (Walker & Jacob) Parker & Jones. Apertural view, X320. (BYU 2493).

central portion projecting. Dimensions: length, approximately 1.5 mm; breadth, approximately 1.04 mm.

Remarks.—Only one specimen was found in the samples. It is broken across its breadth.

Figured specimens BYU 2491, 2492.

FRONDICULARIA INVERSA Reuss, 1844
Fig. 10(1, 8, 9)

Description.—Test elongate, elliptical, very strongly compressed; periphery rounded, base with a short, stout spine; chambers distinct, the proloculum narrow, elongate; later chambers gradually failing to reach the base, giving a narrow tapering shape to that part of the test; sutures distinct, flush with the surface to slightly indented, gently curved, usually crossed by fine discontinuous vertical costae, especially near the apertural end; aperture terminal radiate. Dimensions: length, approximately 0.76 mm; breadth, approximately 0.22 mm.

Remarks.—Only one specimen was found in the ashes; however it is a complete specimen that is slightly crushed. Maxfield (1976, p. 117) found that the species was limited to the Tununk Shale in all his sections except one.

Figured specimens BYU 1976, 2489, 2490.

Genus LAGENA Walker and Jacob in Kanmacher, 1798
LAGENA SULCATA (Walker and Jacob) Parker and Jones, 1929
Fig. 10(11), fig. 11(1, 2)

Description.—Test spherical to elliptical with hyaline, calcareous walls; unilocular; well-formed vertical costae widely varying in number, terminating at neck; aperture is a centrally located, simple opening at the end of a short neck. Dimensions: length, approximately 0.24 mm; breadth, approximately 0.16 mm.

Remarks.—Three complete and one broken specimen of the species were found in ash 5. Maxfield (1976) and Lessard (1973) found *Lagena sulcata* in all their Tununk Shale measured sections.

Figured specimens BYU 2493, 2498, 1977.

Superfamily BULIMINACEA Jones, 1875
Family TURRILINIDAE Cushman, 1927
Subfamily TURRILININAE Cushman, 1927
Genus NEOBULIMINA Cushman and Wickenden, 1928
NEOBULIMINA CANADENSIS Cushman and Wickenden, 1928
Fig. 11(4, 5, 6)

Description.—Test elongate, fusiform, greatest width near the middle, tapering slightly toward either end, about 2½ times as long as wide in adult specimens; early triserial stage of twelve to eighteen chambers, the biserial adult stage of four to six chambers, each part making about one-half the mass of the test; chambers distinct, subglobular, inflated; sutures very distinct, depressed; wall calcareous, coarsely perforate; aperture in the early triserial portion oblique and comma shaped, in the adult biserial stage broader, the portion at the basal edge of the chamber broad and the elongate axis nearly at right angles to the margin of the chamber; the whole aperture in the adult at the base of a distinct depression. The microspheric form is often somewhat irregular and twisted. Dimensions: length, 0.2-0.3 mm; breadth, 0.1-0.14 mm.

Remarks.—The species occurs in all the ash beds, but not in large numbers. Agreement with the figured type specimen and description is good in all respects.

Figured specimens BYU 1979, 2437, 2440.

PRAEBULIMINA PROLIXA (Cushman and Parker 1935)
Fig. 11(3)

Description.—Test long and narrow, about 2½ times as long as broad, tapering very slightly through the whole length, triangular in section, with angles broadly rounded, often somewhat twisted on its axis toward the initial end; chambers numerous, six to seven whorls in adults, those of successive whorls placed directly over others particularly in the initial part, becoming less so in the later portions, adjacent series meeting in a zigzag line; sutures very slightly depressed; aperture elongate, well removed from the juncture of the third preceding chamber. Dimensions: length, 0.22-0.3 mm; breadth, 0.1-0.16 mm.

Remarks.—Specimens occur abundantly in all sections of the ashes, with as many as 9000 per gram sample for one interval and an average of 600 per gram sample. Agreement with the type figure and description is good.

Figured specimen BYU 1978.

PRAEBULIMINA VENUSAE (Nauss 1947)
Fig. 11(7, 8)

Description.—Test free, small, short, triserial throughout, rapidly flaring from a tiny early portion to an inflated later portion of greatest breadth, rounded in section; chambers triserially arranged in about four whorls, increasing quickly in size and becoming inflated; suture distinct, depressed; wall calcareous, finely perforate, with smooth finish; aperture a loop-shaped opening extending up the face of the final chamber. Dimensions: length, approximately 0.2 mm; breadth, approximately 0.1 mm.

Remarks.—The species occurs sporadically in all the sampled intervals. Specimens occurring in the Tununk Shale are slightly smaller than those described elsewhere.

Figured specimens BYU 2386, 2389.

Superfamily GLOBIGERINACEA Carpenter, Parker and Jones, 1862
Family HETEROHELICIDAE Cushman, 1927
Subfamily GUEMBELITRIINAE Montanaro Gallitelli, 1957
Genus GUEMBELITRIA Cushman, 1933
GUEMBELITRIA CRETACEA Cushman, 1933
Fig. 12(1, 2, 3)

Description.—Test triserial, small; chambers globular, nearly spherical, sutures much depressed; wall smooth, finely perforate; aperture large, semicircular or semielliptical at the inner margin of the last-formed chamber. Dimensions: length, 0.2-0.3 mm; breadth, 0.16-0.22 mm.

Remarks.—The species occurs only in ashes 1 and 2; none were found in ash 5. Maxfield (1976, p. 132) states that it appears to be a useful marker in the lower Tununk Shale. Agreement with the figured type material and description is very good.

Figured specimens BYU 2550, 2552, 2553.

Subfamily HETEROHELICINAE Cushman, 1927
Genus HETEROHELIX Ehrenberg, 1843
HETEROHELIX GLOBULOSA (Ehrenberg), 1840
Fig. 12(5)

Description.—Test rapidly tapering, greatest breadth toward the apertural end, initial end subacute, 1½ to 2 times as long as

FIGURE 11.–Foraminiferal fauna: (1) *Lagena sulcata* (Walker & Jacob) Parker & Jones. Side view, X460. (BYU 2498). (2) *Lagena sulcata* (Walker & Jacob) Parker & Jones. Apertural view, X320. (BYU 1977). (3) *Praebulimina prolixa* (Cushman & Parker). Side view, X440. (BYU 1978). (4) *Neobulimina canadensis* (Cushman & Wickenden). Side view, X330. (BYU 2440). (5) *Neobulimina canadensis* (Cushman & Wickenden). Side view, X460. (BYU 1979). (6) *Neobulimina canadensis* (Cushman & Wickenden). Side view, X290. (BYU 2437). (7) *Praebulimina venusae* (Nauss). Side view, X360. (BYU 2389). (8) *Praebulimina venusae* (Nauss). Side view, X350. (BYU 2386).

broad, in side view, with the chambers regularly enlarging to the greatest width at the last-formed chamber, periphery distinctly indented throughout; chambers inflated throughout, increasing in size rather more rapidly toward the apertural end, nearly spherical; sutures distinct, depressed throughout; wall smooth, finely perforate, aperture broad, low, with a slightly thickened rim. Dimensions: length, 0.26-0.42 mm; breadth, 0.20-0.28 mm.

Remarks.—Small specimens are more abundant than large ones throughout the entire sampled intervals of all the ashes. This species shows considerable variability of position of the final chamber, presence of the initial planispiral coil, and presence or absence of surface ornamentation, but remains within the limits of figured and described types from other areas. The species has a very wide distribution (Maxfield 1976, p. 134).

Figured specimen BYU 2532.

Family PLANOMALINIDAE Bolli, Loeblich, and Tappan, 1957
Genus GLOBIGERINELLOIDES Cushman and Ten Dam, 1948
GLOBIGERINELLOIDES ASPERA (Ehrenberg 1854)
Fig. 12(4, 6)

Description.—Test free, small planispiral, biumbilicate, periphery moderately lobate, six to seven chambers in the final whorl, inflated, globular, slightly overlapping; sutures distinct, depressed radial, wall calcareous, finely perforate, surface smooth to finely hispid; aperture a moderately high arch at the base of the final chamber, with small lip. Dimensions: diameter, approximately 0.16 mm; thickness, approximately 0.08 mm.

Remarks.—Specimens occur sporadically throughout all the ashes. These specimens agree very well with the type specimens figured and described by Barr (1966, 1968) and by Pessagno (1967) and are therefore considered conspecific. The species has a reported stratigraphic range from the Upper Coniacian to Maestrichtian and a wide areal distribution (Maxfield 1976, p. 137).

Figured specimens BYU 1980, 2521.

Family ROTALIPORIDAE Sigal, 1958
Subfamily HEDBERGELLINAE Loeblich and Tappan, 1961
Genus HEDBERGELLA Brönniman and Brown, 1958
HEDBERGELLA DELRIOENSIS (Carsey 1954)
Fig. 12(7, 8, 9)

Description.—Test free, in a low trochospiral coil of about two volutions, early whorl flush to slightly depressed below the final whorl on the spiral side, opposite side deeply umbilicate, peripheral outline strongly lobulate; chambers much inflated, nearly spherical, increasing rapidly in size as added, with four to six chambers in the final whorl, most commonly five; sutures distinct, straight to slightly curved, deeply constricted; wall calcareous, distinctly perforate, earlier chambers with a papillate surface, final chambers less ornamented, no indication of a keel or poreless margin; aperture an arch on the umbilical side, interiomarginal and extraumbilical-umbilical. Dimensions: diameter, 0.3-0.68 mm; thickness, 0.2-0.4 mm.

Remarks.—The specimens recovered vary a great deal in size; however, most are small. Those in ash 5 are flatter. Specimens were found in all five ashes.

Figured specimens BYU 1981, 1982, 1983.

Genus CLAVIHEDBERGELLA Banner and Blow, 1959
CLAVIHEDBERGELLA SIMPLEX (Morrow 1934)
Fig. 12(10, 11)

Description.—Test free, of medium size, trochospirally coiled, subglobular to elongate chambers forming about two to two and one-half whorls, the early whorl with about five globular chambers, the final whorl with four to six chambers, the last two or three radially elongate to subclavate; sutures distinct, depressed; wall calcareous, finely perforate, surface finely spinose; aperture an interiomarginal arch extending from the periphery to the umbilicus, with a narrow bordering lip. Dimensions: diameter, 0.2-0.5 mm; thickness, 0.1-0.24 mm.

Remarks.—Specimens occur sporadically throughout all the sampled intervals. The immature portions of the specimens are very close to the form of *Hedbergella* and would certainly be placed under that genus.

Figured specimens BYU 1984, 1985.

Superfamily ORBITOIDACEA Schwager, 1876
Family CIBICIDAE Cushman, 1927
Subfamily PLANULININAE Bermudez, 1952
Genus PLANULINA d'Orbigny, 1826
PLANULINA AUSTINANA Cushman, 1938
Fig. 13(2, 5)

Description.—Test very much compressed, partially evolute on both sides, particularly the dorsal side, which is very slightly umbonate; ventral side slightly umbilicate; periphery subacute, lobate; chambers distinct, somewhat inflated, of uniform shape, increasing very gradually in size as added, six to eight in the adult whorl; sutures distinct, only slightly depressed; wall smooth, finely perforate; aperture a low opening at the base of the last-formed chamber at the periphery and extending over along the dorsal side. Dimensions: diameter, 0.18-0.38 mm; thickness, 0.05-0.1 mm.

Remarks.—Specimens were recovered from all sampled intervals; however, fewer examples were recovered from ash 2. Most of the specimens are juvenile forms. Maxfield (1976, p. 144) states that the species is a useful marker for the Tununk Shale. Specimens from the Tununk Shale differ from those of the type description in that they have fewer chambers in the adult whorl and are somewhat smaller. *P. austinana* differs from *P. kansasensis* in that the periphery of *P. austinana* is more acute and there is less calcareous deposit in the central area, particularly on the ventral side. This species has been reported from the Austin Chalk of Texas (Cushman 1938).

Figured specimens BYU 1986, 1987.

PLANULINA KANSASENSIS Morrow, 1934
Fig. 13(6, 9)

Description.—Test much compressed, dorsal and ventral sides nearly flat, dorsal side evolute, ventral side partially involute; periphery rounded, chambers numerous, eight to ten in final whorl; sutures distinct between the later chambers, slightly depressed, curved outward and backward; central area on both sides covered by a calcareous deposit varying in thickness from a film to a thick rounded plug, which may be transparent showing the covered chamber; wall smooth perforate; aperture obscure, extending along the base of the last chamber onto the ventral side. Dimensions: diameter, 0.3-0.36 mm; thickness, 0.1-0.12 mm.

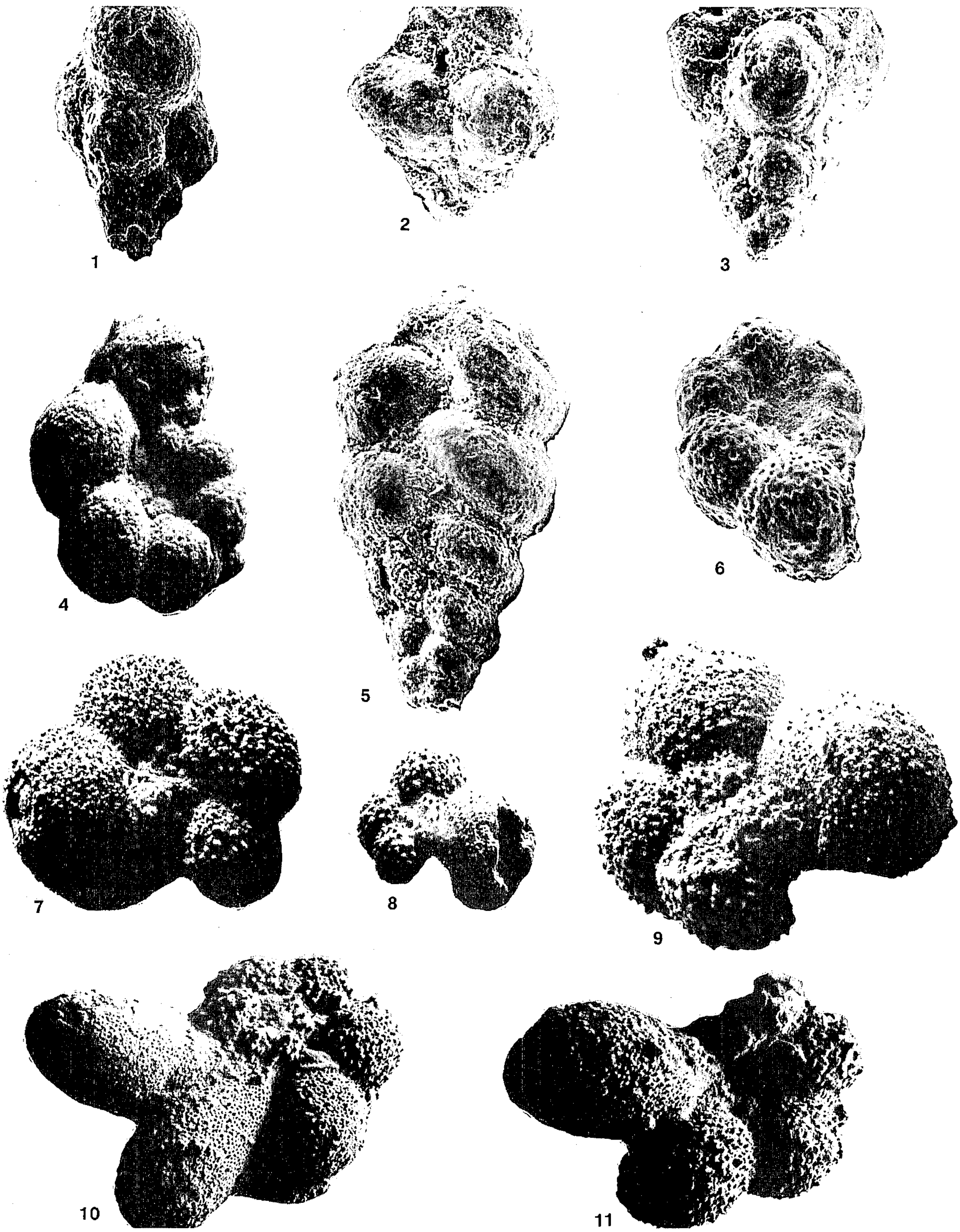

FIGURE 12.—Foraminiferal fauna: (1) *Guembelitria cretacea* Cushman. Side view, X335. (BYU 2550). (2) *Guembelitria cretacea* Cushman. Apertural view, X305. (BYU 2552). (3) *Guembelitria cretacea* Cushman. Side view, X370. (BYU 2553). (4) *Globigerinelloides aspera* (Ehrenberg). Side view, X505. (BYU 1980). (5) *Heterohelix globulosa* (Ehrenberg). Side view, X335. (BYU 2532). (6) *Globigerinelloides aspera* (Ehrenberg). Side view, X315. (BYU 2521). (7) *Hedbergella delrioensis* (Carsey). Ventral view, X210. (BYU 1981). (8) *Hedbergella delrioensis* (Carsey). Dorsal view, X175. (BYU 1982). (9) *Hedbergella delrioensis* (Carsey). Dorsal view, X190. (BYU 1983). (10) *Clavihedbergella simplex* (Morrow). Dorsal view, X180. (BYU 1984). (11) *Clavihedbergella simplex* (Morrow). Ventral view, X175. (BYU 1985).

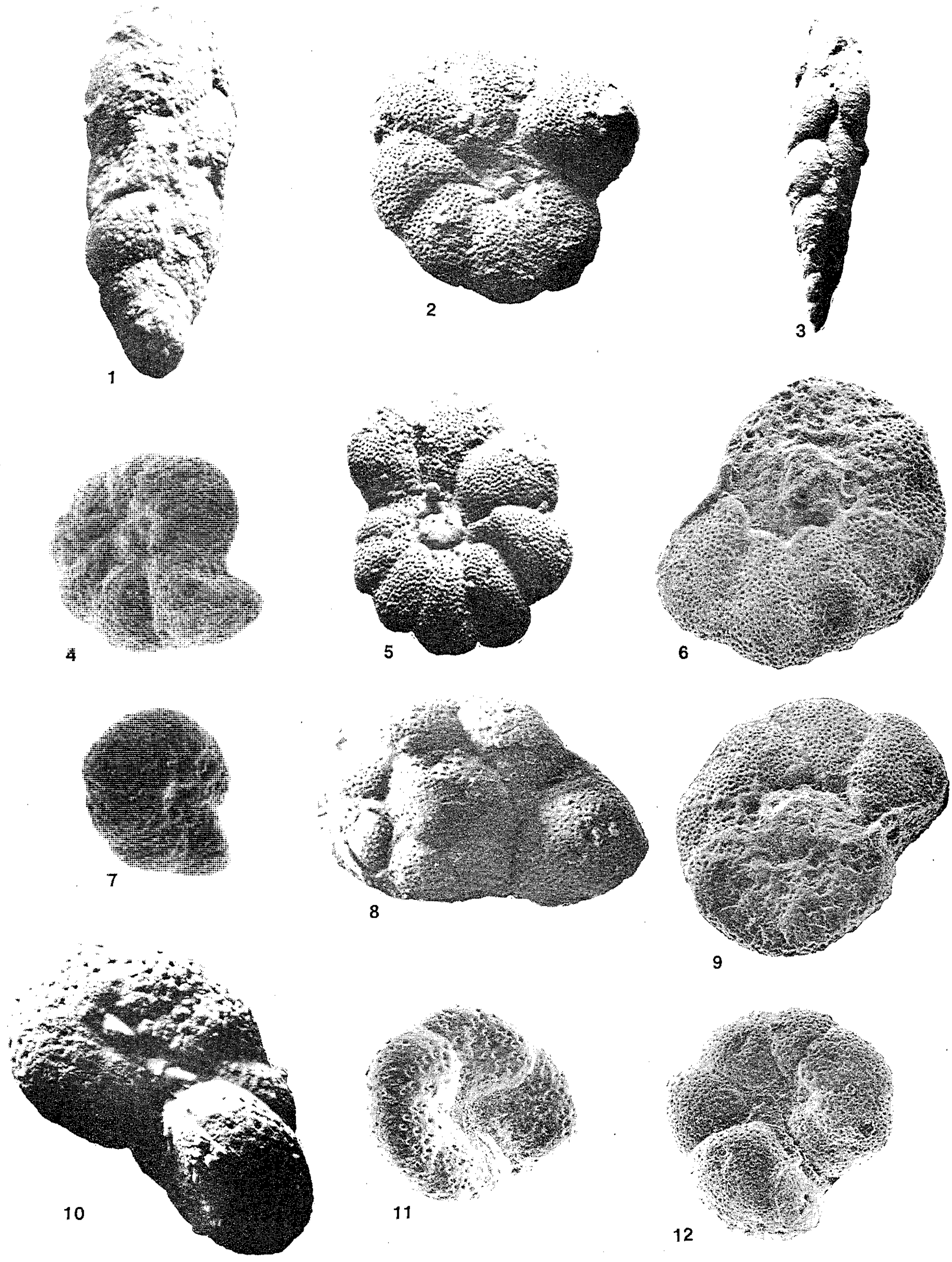

FIGURE 13.—Foraminiferal fauna: (1) *Cassidella tegulata* (Reuss). Side view, X200. (BYU 1988). (2) *Planulina austinana* Cushman. Ventral view, X180. (BYU 1986). (3) *Cassidella tegulata* (Reuss). Side view, X220. (BYU 1989). (4) *Anomalina tennesseensis* W. Berry. Side view, X125. (BYU 2393). (5) *Planulina austinana* Cushman. Dorsal view, X210. (BYU 1987). (6) *Planulina kansasensis* Morrow. Ventral view, X150. (BYU 2414). (7) *Anomalina tennesseensis* W. Berry. Side view, X135. (BYU 2395). (8) *Gavelinella nelsoni* (W. Berry). Dorsal view, X180. (BYU 1991). (9) *Planulina kansasensis* Morrow. Dorsal view, X135. (BYU 2416). (10) *Anomalina tennessensis* W. Berry. Apertural view, X435. (BYU 1990). (11) *Gavelinella nelsoni* (W. Berry). Ventral view, X120. (BYU 2399). (12) *Gavelinella nelsoni* (W. Berry) Ventral view, X135. (BYU 2397).

Remarks.—Specimens identified as *P. kansasensis* Morrow are very rare in the sampled sections, and may actually be variants of *P. austinana.* As originally defined this species differs from *P. austinana* in having a more rounded periphery, more calcareous deposits in the central portion, and a more distinct aperture with a slight flap extending into the ventral area. The species was originally described from the Fort Hays Member of the Niobrara Formation of Kansas (Morrow 1934).

Figured specimens BYU 2414, 2416.

Superfamily CASSIDULINACEA d'Orbigny, 1839
Family CAUCASINIDAE N. K. Bykova, 1959
Subfamily FURSENKOININAE Loeblich and Tappan, 1961
Genus CASSIDELLA Hofker, 1951
CASSIDELLA TEGULATA (Reuss), 1951
Fig. 13(1, 3)

Virgulina tegulata Reuss 1845, p. 40, pl. 13, fig. 81; Cushman 1937, p. 4-5, pl. 1, figs. 8-12; Bolin 1952, p. 46-47, pl. 3, fig. 8.

Bolivina tegulata Reuss 1851, p. 29, pl. 4, fig. 12; Morrow 1934, p. 196, pl. 30, fig. 21.

Loxostomum tegulatum (Reuss), Cushman 1931, p. 51, pl. 8, fig. 8; Young 1951, p. 64, pl. 14, fig. 13; Green 1959, pl. 63, pl. 3, fig. 8; Lessard 1973, p. 25, pl. 2, fig. 8.

Loxostoma tegulatum (Reuss), Cushman 1937, p. 168–69, pl. 20, figs. 17, 18; Loetterle 1937, p. 40, pl. 6, fig. 3.

Cassidella tegulata (Reuss), Hofker 1951, p. 265, fig. 175; Loeblich & Tappan 1964, p. C732–33, figs. 600–5-7.

Virgulina sp. #1 Bolin 1952, p. 47, pl. 3, figs. 9a,b.

Description.—Test free, narrow, elongate, gently tapering, periphery rounded; triserial in earliest chambers, becoming biserial in early part, biserial portion making up most of test; later chambers show a slight tendency toward uniserial development; many specimens are slightly twisted around long axis; chambers are numerous, very lightly inflated; sutures distinct, slightly depressed, tending to be horizontal; wall calcareous, finely perforate, granular in structure, surface smooth; aperture elongate, narrow, extending up face from base of final chamber. Dimensions: length, 0.24-0.48 mm; breadth, 0.1-0.14 mm.

Remarks.—The species occurs sporadically throughout all the sampled intervals. A few of the specimens have been partially altered to hematite. The taxonomic position of the species is uncertain because of conflicting statements and some confusion in the literature. Kent (1967, p. 1450) discussed the confusion about its position. The Tununk Shale specimens fit Kent's description and figured specimen very well (1967). Species which are similar have been described from the Allen Valley Shale of Utah, the Tununk Shale of Utah, the Frontier Formation of southern Montana, and the Taylor, Austin, and Eagle Ford groups of Texas. It has also been found in the Fort Hays Member of the Niobrara Formation in Kansas, Nebraska, South Dakota, and Colorado. The species was originally described from the Turonian of Bohemia (Reuss 1845).

Figured specimens BYU 1988, 1989.

Family ANOMALINIDAE Cushman, 1927
Subfamily ANOMALININAE Cushman, 1927
Genus ANOMALINA d'Orbigny, 1826
ANOMALINA TENNESSEENSIS W. Berry, 1929
Fig. 13(4, 7, 10)

Description.—Test small, planispiral, slightly compressed laterally, composed of eight to nine chambers in the last whorl, slightly evolute on the dorsal side, only the last whorl visible on the ventral side, immature forms completely involute; sutures slightly depressed, more or less distinct; aperture a narrow curved slit at the base of the final chamber. Dimensions: diameter, 0.14-0.3 mm; thickness, 0.1-0.15 mm.

Remarks.—Very few specimens were found in the samples, and most of these are immature. The species has been reported previously from the Marlbrook Marl of Arkansas and from the Selma Chalk of Mississippi. This species was originally described from the Coon Creek Tongue of the Ripley Formation of Tennessee (Berry and Kelley 1929).

Figured specimens BYU 1990, 2393, 2395.

Genus GAVELINELLA Brotzen, 1942
GAVELINELLA NELSONI (W. Berry, 1929)
Fig. 13(8, 11, 12)

Description.—Test inflated, dorsal side slightly convex, ventral side deeply umbilicate; periphery broadly rounded, lobate; chambers numerous, seven to eight in the last-formed coil, inflated, gradually increasing in size; sutures distinct, depressed; wall punctate; umbilical cavity usually filled with shell material; aperture an arched slit with a slight lip above it as the base of the last chamber. Dimensions: diameter, 0.32-0.4 mm; thickness, 0.1-0.15 mm.

Remarks.—The species occurs in all of the sampled intervals in fairly large numbers. The species has been reported as ranging from the highest beds of Navarro age down through the upper beds of Taylor age in deposits of the Gulf Coastal region.

Figured specimens BYU 1991, 2397, 2399.

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