CONTRIBUTIONS
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257. DISTRIBUTION OF LIVING PLANKTONIC FORAMINIFERA IN THE NORTHEASTERN PACIFIC[1]

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ABSTRACT

The planktonic foraminifera collected in 176 tows in the northeastern Pacific Ocean were studied. Of the eight species identified, the four most common were **Globigerina bulloides, G. pachyderma, Orbulina universa** and **Globigerina eggeri.** Maximum concentrations occurred above the **Globigerina**-rich sediments on the sea floor. No direct correlation between physical variables and the distribution of the foraminiferal population was observed. The possible vertical stratification of several species is discussed.

INTRODUCTION

In the early eighteen hundreds, d'Orbigny (1826) was engaged in a taxonomic study of the planktonic foraminifera. This pioneer work was followed by that of Brady (1884), who studied specimens of the group which had been collected during the Challenger expedition. His samples were obtained from net tows in the surface water as well as from dredgings and soundings in the sediments on the sea floor. The majority of his tows were collected in the upper 91 meters of water and represent the first world-wide study of the group. This work was followed by Murray's (1895, 1897) investigations of the same collections.

After this fine beginning considerable time passed before other valuable contributions were made. Schott (1935) studied low latitude forms taken during the Deutsche Atlantische Expedition and was able to infer climatic changes on the basis of faunal changes in the stratigraphic sequence within the cores. He also had samples of living organisms from tows and found that the largest concentrations were in the upper 100 meters. Phleger (1951) studied planktonic foraminifera from material in net tows and bottom sediments taken from the Gulf of Mexico. Phleger, Parker and Peirson (1953) defined the geographic distribution of planktonic species collected from the Atlantic and considered the limiting factors to be temperature and salinity. As Phleger pointed out, the fauna occurring in bottom samples did not necessarily live in water directly above the sample position and interpretations may be misleading unless the distribution and movements of water masses are taken into account. However, planktonic foraminifera from the sediments have frequently been used in interpreting Recent and paleoenvironments before a true understanding of their ecology has been acquired.

Foraminifera, when entombed in ancient sediments, are frequently used as stratigraphic guides. Such studies have been carried out in the belief that planktonic foraminifera are subject to wide and relatively rapid dispersal by ocean currents. A number of papers based upon such an assumption have been published. In view of this trend of using planktonic foraminifera as tools for paleoecology and stratigraphy, it is alarming to see how little is known concerning the ecology and phylogeny of living forms. The work of Bé (1959, 1960a), Bradshaw (1959) and Parker (1960) are among the first attempts at complete ecologic studies. The approach in this paper is similar; however, the study area is more restricted.

The area in question lies between 39° and 51° N. Lat. and the west coast of North America and 141° W. Long. It is within the scope of this paper to: (1) determine the species of planktonic foraminifera present; (2) delimit their geographical distribution and abundance; (3) consider that distribution in terms of chemical and physical data; and (4) outline the vertical distribution of the organisms.

METHODS

One hundred and seventy-six plankton samples were examined. These were obtained by the University of Washington's Department of Oceanography research ship, the M. V. BROWN BEAR, during seven cruises in the northeast Pacific Ocean from 1956 to 1958. Collections were made with either a Clarke-Bumpus sampler (Clarke and Bumpus, 1950) using a nylon net with 74 meshes per inch and an aperture size of 0.239 mm. or with a half-meter net of the same mesh size. The plankton was preserved in glass jars containing formalin neutralized with borax. During this investigation many of the samples were tested for acidity and found to have a pH of approximately 6. However, most of these contained numerous well preserved foraminifera, and it is believed that few specimens were lost due to dissolution. In a few instances, hardened globular masses of protoplasm resembling *Globigerina* in form were found in the samples. In some cases, broken foraminiferal tests contained these bodies. It is believed that occasionally the test dissolves leaving this evidence of its existence. Generally, these masses were found in samples containing no tests and were seldom found where tests were numerous. Consequently, their presence, noted in seven samples, was taken as an indication of solution.

On BROWN BEAR cruise 144, two Clarke-Bumpus samplers were spaced on the wire so that the lower sampler fished from 400 to 200 meters while the upper one fished from 200 meters to the surface. Both sam-

[1] Contribution No. 255 of the Department of Oceanography, University of Washington.

plers were lowered closed. At depth they were opened by messenger. After being opened, they were returned while the ship was moving at slow speed. When the upper sampler surfaced, both devices were closed by messenger. Eight single Clarke-Bumpus stations were taken at varying depths and at one station 20 samples were taken from five separate hauls. During each haul, four samplers were lowered so that they fished at 150, 100, 50 meters and the surface.

On the other six cruises both Clarke-Bumpus and half-meter tows were taken. The material was collected from various depths to the surface. All Clarke-Bumpus tows were oblique while the half-meter hauls were vertical, except for surface hauls.

All of the plankton samples were sorted by hand under a binocular microscope. A small portion of the sample was removed from the whole with a syringe and placed in a petri dish. All foraminifera were then removed with a camel's hair brush and placed on microscope slides to be mounted with gum tragacanth. This was repeated until the entire sample had been sorted. Thus, the total number of foraminifera in each sample was recorded. As the Clarke-Bumpus sampler records the approximate volume of water filtered, it was possible to determine the number of organisms present in a cubic meter of water. As there is some controversy concerning whether a half-meter net fishes while being lowered, figures for water filtered by this device are not included.

SYSTEMATICS

The nomenclature of Parker (1958) is followed. The synonomies are not complete, but include the original reference and a few papers of immediate interest. To simplify comparison with the works of others, the author has included some views concerning his concept of those species present. These remarks are not intended to be taken as taxonomic descriptions. Several species are represented by figures of more than one specimen, one considered to be typical, the others common variants. The figured specimens are deposited in the Museum of Paleontology at the University of Washington, Seattle.

Family GLOBIGERINIDAE Carpenter

Globigerina bulloides d'Orbigny

Plate 1, figures 1-4

Globigerina bulloides D'ORBIGNY, 1826, Ann. Sci. Nat., vol. 7, p. 277, no. 1; Modèles, no. 76; and young, no. 17.

Globigerina bulloides d'Orbigny—BANNER and BLOW, 1960, Contr. Cushman Found. Foram. Research, vol. XI, pt. 1, pp. 3-4, pl. 1, figs. 1, 2, 4.

Remarks.—The typical *G. bulloides* has 4 chambers in the final whorl with a large umbilical aperture opening into all chambers (pl. 1, figs. 1-2). Occasionally a specimen with five chambers is found (pl. 1, fig. 3). Rather compressed forms are not uncommon. In these, the aperture opens into the final chamber and becomes crescent shaped. The shape of the entire test becomes more triangular than the typical form and the chambers are less globular (pl. 1, fig. 4).

Globigerina bradyi Wiesner

Plate 2, figures 24-25

Globigerina sp., BRADY, 1884, Rept. Voy. *Challenger*, Zool., vol. 9, p. 603, pl. 82, figs. 8-9.

Globigerina bradyi WIESNER, 1931, "Die Foraminiferen der deutschen Sudpolar-Expedition 1901-1903" (*in* Drygalski "Deutsche Sud-Polar Expedition 1901-1903") de Gruyter, Berlin u. Leipzig, Bd. 20 (Zool. Bd. 12), p. 133, (no figure).

Globigerinoides minuta NATLAND, 1938, Bull. Scripps Inst. Oceanography, Tech. Ser. vol. 4, no. 5, p. 150, pl. 7, figs. 2-3.

Globigerina bradyi Wiesner—BOLLI, 1957, U. S. Natl. Mus., Bull. 215, pp. 110-111, pl. 23, figs. 5 a-c.

Globigerina bradyi Wiesner—BANNER and BLOW, 1960, Contr. Cushman Found. Foram. Research, vol. XI, pt. 1, pp. 5-6, pl. 3, figs. 1-2.

Remarks.—The specimens found during this study agree, with little variation, with the description of the lectotype designated by Banner and Blow. The only difference being that those from the northeastern Pacific are slightly shorter than that figured for the lectotype.

Globigerina eggeri Rhumbler

Plate 1, figures 8-11

Globigerina dubia Egger—BRADY, 1879, Quart. Jour. Micr. Sci., vol. 19, (n.s.) p. 285.

Globigerina eggeri Rhumbler, 1901, *in* BRANDT, Nordisches Plankton, Lief. 1, Nr. 14, pp. 19-20, text-figs. 20 a-c.

Globigerina eggeri Rhumbler—BANNER and BLOW, 1960, Contr. Cushman Found. Foram. Research, Vol. XI, pt. 1, pp. 11-12, pl. 2, fig. 4.

Remarks.—This is a high-spired form usually with five chambers in the final whorl. Infrequently this whorl has six chambers. The aperture is wide and leads from the final chamber into the umbilicus. Frequently, the interior of the earlier chambers may be seen. The test is nearly circular in outline. The surface shows a rough texture with large pores. The chambers, which taper axially, closely resemble the segments of a peeled orange.

Globigerina pachyderma (Ehrenberg)

Plate 2, figures 15-18

Aristerospira pachyderma EHRENBERG, 1861, Monats. k. preuss. Ak. Wiss. Berlin, p. 303; 1872 (1873), Abhandl. Ak. k. Wiss. Berlin, pl. 1, fig. 4.

Globigerina pachyderma (Ehrenberg)—PARKER, 1958, Repts. Swedish Deep-Sea Exped., vol. VIII, no. 4, p. 278, pl. 5, fig. 9.

Globigerina pachyderma (Ehrenberg)—BÉ, 1960, Contr. Cushman Found. Foram. Research, vol. XI, pt. 2, pp. 64-68, text-fig. 1.

Remarks.—The test is typically square in outline, very low spired with four chambers in the final whorl. The walls are thick and crystalline. The aperture is a narrow slit which runs from the umbilicus toward the periphery of the test, parallel to the suture separating the first and final chambers in the last whorl, (figs. 16-17). Generally, a well-defined lip is present. Often a fifth chamber will be seen in various stages of development, (figs. 15 and 18). This appears to be derived from the lip and often takes the appearance of a porch over the umbilical area. Commonly a rather triangular form is found that closely resembles the compressed variety of *G. bulloides*. A prominent lip, a smaller aperture which is more slit-like, and less globular chambers distinguish it from that species.

Globigerina quinqueloba Natland
Plate 1, figures 5-7

Globigerina quinqueloba Natland, 1938, Bull. Scripps Inst. Oceanography, Tech. Ser. vol. 4, no. 5, pp. 149-150, pl. 6, fig. 7a-c.

Remarks.—The only variation from the type described by Natland is that frequently the lip over the aperture is absent, having been either broken or not developed. Young animals are difficult to separate from young *G. eggeri.*

Globigerinita glutinata (Egger)
Plate 2, figures 26-28

Globigerina glutinata Egger, 1893, Abhandl. K. bay. Akad. Wiss. München, Cl. 11, vol. 18, p. 317, pl. 13, figs. 19-21.—Rhumbler, 1911, Ergeb. Plankton-Exped. Humboldt Stift., vol. 3, p. 148, pl. 29, figs. 14-26; pl. 33, fig. 20; pl. 34, fig. 1.

Globigerinita glutinata (Egger)—Phleger, Parker and Peirson, 1953, Repts. Swedish Deep-Sea Exped., vol. VII, no. 1, p. 16, pl. 2, figs. 12-15.

Remarks.—There are generally four spherical chambers in the final whorl. These enlarge rapidly with a final chamber that is much larger than the others. Frequently there will be but three chambers in the last whorl. In the material studied, few specimens had supplementary apertures. The primary aperture is a crescentic slit adjoining the umbilicus. Some forms closely resemble the more compressed form of *Globigerina bulloides* but may be distinguished from that species by the more rapidly expanding chambers, an aperture that is restricted to the final chamber, and a much smoother texture.

Orbulina universa d'Orbigny
Plate 2, figures 19-20

Orbulina universa d'Orbigny, 1839, *in* de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 3, pl. 1, fig. 1.

Orbulina universa d'Orbigny—Blow, 1956, Micropaleontology, vol. 2, no. 1, pp. 57-70, text-figs. 1-4.

Orbulina universa d'Orbigny—Parker, 1958, Repts. Swedish Deep-Sea Exped., vol. VIII, no. 4, p. 280, pl. 6, fig. 13.

Remarks.—Generally, single-chambered forms were found. However, several multilobate forms were collected (fig. 20). The author follows Parker (1958) in referring both forms to a single species.

Family GLOBOROTALIIDAE
Globorotalia scitula (Brady)
Plate 2, figures 22-23

Pulvinulina scitula Brady, 1882, Proc. Roy. Soc. Edinburgh, vol. 11, p. 716.

Pulvinulina patagonica Brady, 1884 (not *Rotalina patagonica* d'Orbigny, 1839), Rept. Voy. *Challenger,* Zool., vol. 9, p. 693, pl. 103, fig. 7.

Globorotalia scitula (Brady)—Cushman, 1927, Bull. Scripps Inst. Oceanography, Tech. Ser., vol. 1, no. 10, p. 175.

Globorotalia scitula (Brady)—Cushman, 1931, Bull. U. S. Natl. Mus. 104, pt. 8, pp. 100-101, pl. 17, figs. 5 a-c.

Remarks.—The few specimens of this, the only species of *Globorotalia* found, agree closely with the original description.

JUVENILE AND MORPHOLOGIC INTERGRADES OF *GLOBIGERINA*

As Bé (1959, p. 83) has pointed out, "(1) there is an overlapping range of morphologic variation in adult individuals of some closely related species (infra- or interspecific variation), which results in intergradation between forms that have been established as separate species, (2) there is morphologic similarity among juveniles of many different species, (3) there is lack of agreement as to the relative significance of observable characters."

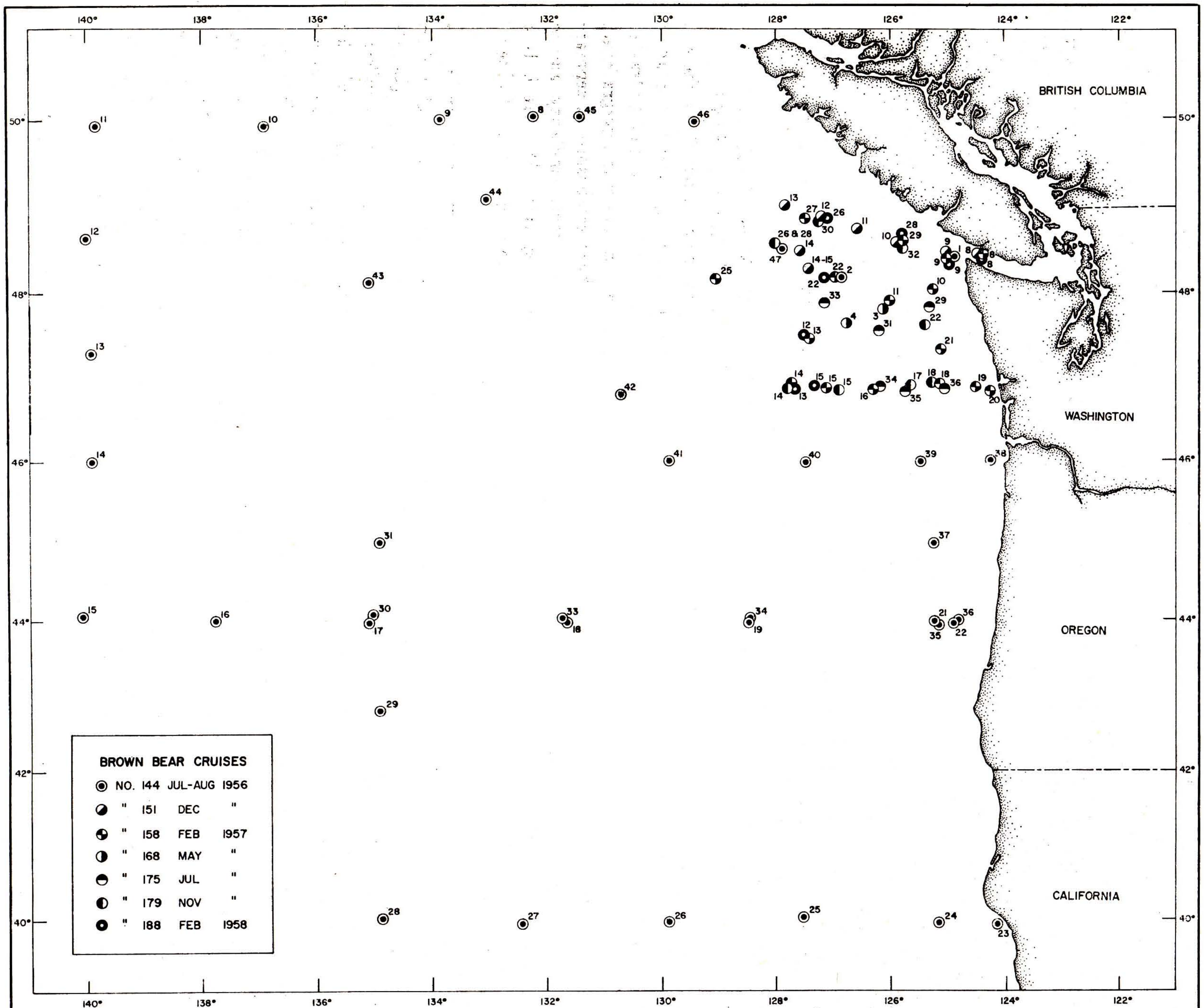
In the case of juveniles, this author has found it impossible to differentiate forms which are smaller than about 50 microns. Some of those that closely resemble one another, when juvenile, are: *Globigerina bulloides* and *Globigerinita glutinata,* compressed *Globigerina bulloides* and *G. pachyderma,* larger *G. pachyderma* and *G. eggeri,* smaller *G. eggeri* and *G. quinqueloba.*

The similarity between the forms of *G. pachyderma* which have a long slit aperture and more distinct sutures than the typical forms and young stages of *G. eggeri* which have not developed the final chambers in the last whorl make separation difficult. These are grouped together as the morphologic intergrade *Globigerina pachyderma-eggeri* and are figured (pl. 1, figs. 12-14, pl. 2, fig. 21).

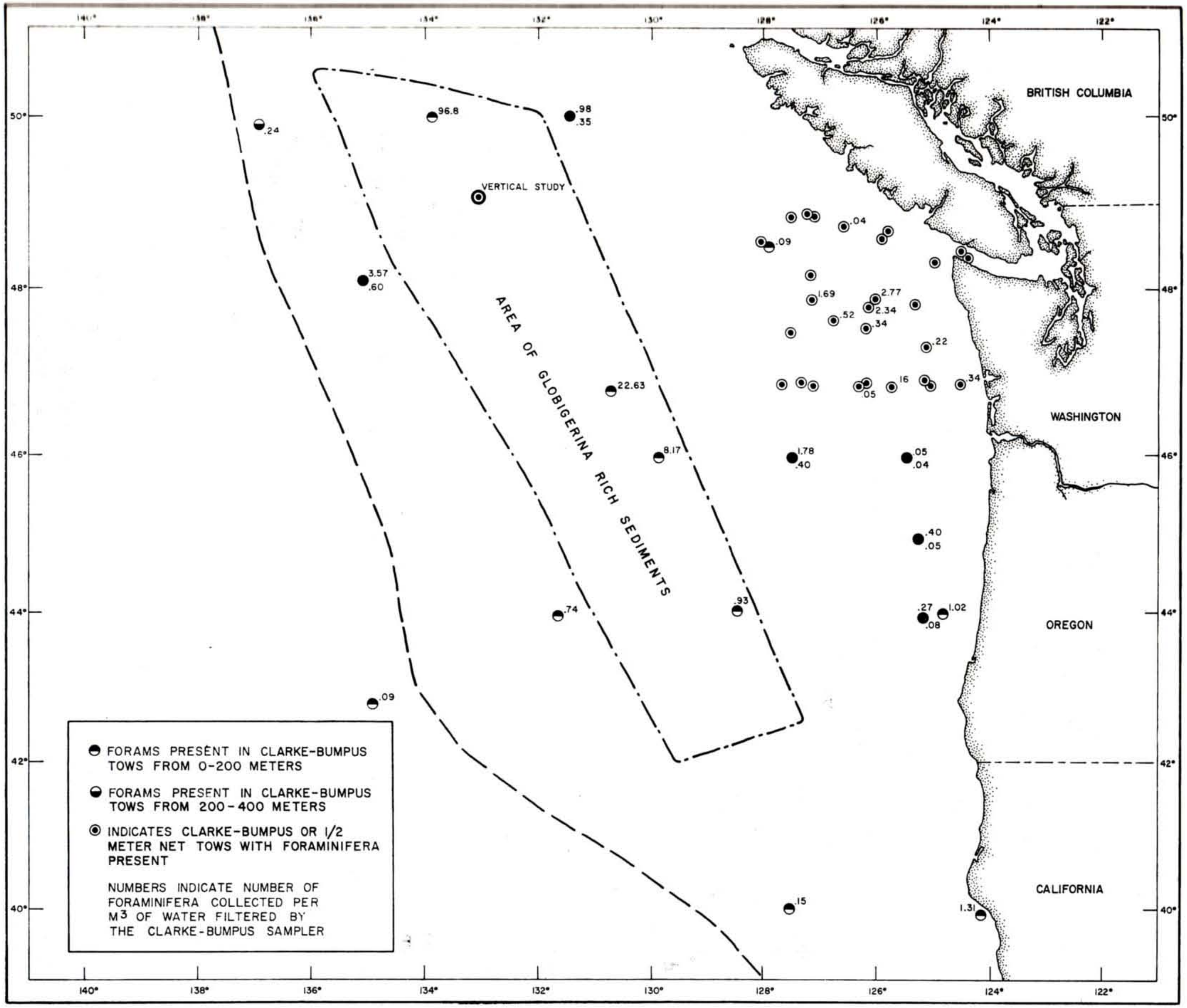
It is doubtful that problems concerning morphologic intergradation in the Globigerinidae can be accurately studied until living animals are collected and observed through various stages of development.

AREAL DISTRIBUTION

One hundred and fifty-six of the one hundred and seventy-six samples were considered for the study of geographical distribution. The remaining 20 are discussed under vertical distribution. Thirty-three of the former were taken from 400 to 200 meters. The others



TEXT FIGURE 1
Locations of all plankton stations.



TEXT FIGURE 2

Locations of all tows capturing foraminifera (only 1 tow seaward of dashed line contained any specimens).

were taken from various depths, generally near 200 meters, to the surface. Text figure 1 shows the locations of all stations.

The patchiness of the plankton has been mentioned repeatedly by earlier workers (Phleger, 1951, King and Demond, 1953). The latter, in their study of the zooplankton of the central Pacific, found an extremely erratic distribution of planktonic foraminifera. These organisms were found to constitute as much as 60 percent of the total plankton at one station while at others, they were absent. In the current study, foraminifera were collected in only 65 of the 156 samples. Such extreme fluctuations between stations makes it difficult to define the geographical boundaries of these organisms. A great many samples are necessary before one can have any confidence that the sampling is not selective.

The close agreement between the area where foraminifera are found in the surface waters and the *Globigerina*-rich sediments described by Nayudu [1959] may be seen in text figure 2. The three tows having the greatest number of foraminifera per cubic meter of water filtered are directly above this zone. However, it should be noted that two stations within this area did not yield foraminifera. The lack of foraminifera seaward of the area of maximum numbers may be a reflection of the patchiness of the plankton rather than a definite geographical restriction of the organisms. This agreement between the area of maximum numbers in the plankton and the *Globigerina*-rich sediments is to some degree surprising. The fact that planktonic foraminifera are subject to wide dispersal by surface currents would seem to require that living populations be offset from the zone of occurrence on the bottom since they would be subject to transport after death. However, Murray (1897) and Schott (1935) found evidence that transport was slight after death and that the animals were deposited close to where they lived. This appears to be true in this case. However, future sampling seaward of the area of maximum numbers might reveal large populations of planktonic foraminifera which could be carried coastward.

Coastward of the *Globigerina*-rich sediments, moderate sized populations of foraminifera were collected in the plankton. Here, planktonic foraminifera constituted a small proportion of the sediment. This apparent discrepancy with the material collected from the sediment may be explained quite simply. Near the coast, terrigenous sediments comprise a large percentage of the surface sediments while seaward of the slope their presence is negligible. For a sediment to be considered *Globigerina*-rich, foraminifera must make up 30 percent or more of the volume. Nearshore the foraminiferal population is masked by the terrigenous components.

Many workers studying the sediments in other areas have noted that the percentage of planktonic foraminifera increases seaward (Bandy, 1961). No evidence of a similar trend in the living plankton could be found during this investigation. Other than above the *Globigerina*-rich sediments, the location of larger populations seems to be random. Enbysk [1960] in her study of the foraminifera from the sediments in the same area was unable to find any seaward trends that were not related to topography or other factors of sedimentation.

Temperature, salinity, dissolved oxygen, and inorganic phosphate concentrations were determined at a depth of 50 meters in an attempt to correlate the occurrence of planktonic foraminifera with these variables. This depth was selected for three reasons. The vertical study showed that foraminifera were most abundant at this depth. Secondly, the physical environment at depth is more stable than at the surface and thus provides a better index for correlation. Finally, a preliminary study indicated a closer correlation with the organisms and the physical environment at 50 meters. The physical data were obtained from samples taken at the time the plankton samples were collected. Charts for the average temperature, salinity, dissolved oxygen and inorganic phosphate concentrations at 50 meters, compiled by the editors of the NORPAC Atlas (1960), are shown (text figs. 3-6).

Temperature and Salinity

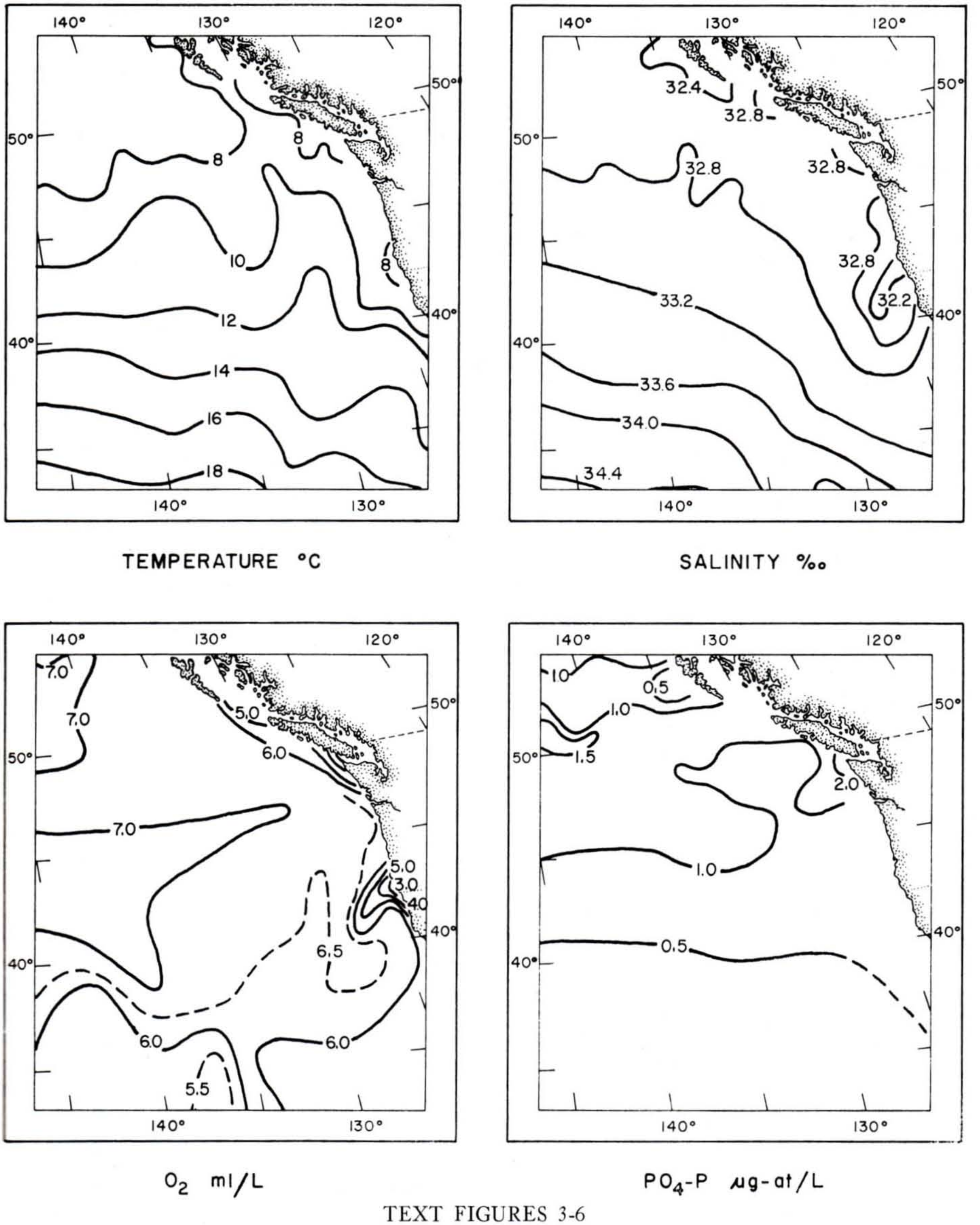
Temperatures within the area studied varied between about 6° and 16°C. at 50 meters. The majority of readings were between 7° and 10.5°C. Salinity ranged from 31.11 to 33.75 parts per thousand, the majority being between 32.20 and 33.20 parts per thousand.

Text figure 7 shows the temperature and salinity at all stations where these data were collected. The tows were divided into two groups, those containing fewer than five foraminifera and those capturing more than five. The relationship between these two groups and temperature and salinity is similar. Thus, it may be seen that no correlation between these factors and the distribution of foraminifera is evident.

Dissolved Oxygen and Inorganic Phosphate

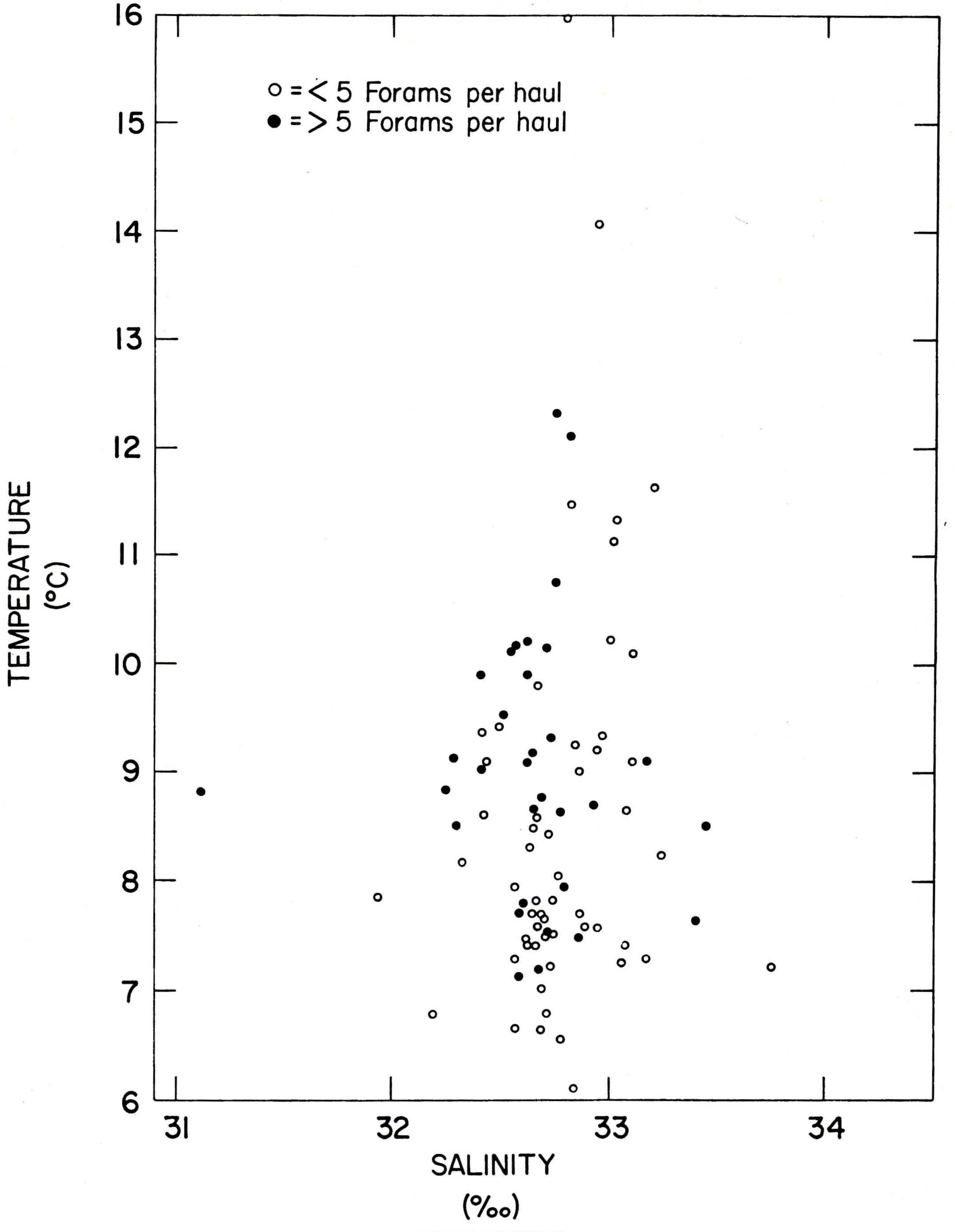
The range in dissolved oxygen concentrations is between 0.117 and 0.652 mg-at/l. However, the majority of samples showed concentrations of 0.400 to 0.650 mg-at/l. All but four stations where foraminifera were collected in numbers greater than five organisms per haul showed a dissolved oxygen concentration that was greater than 0.500. Text figure 8 shows the relationship between the two groups of tows and dissolved oxygen and inorganic phosphate concentrations at 50 meters.

Inorganic phosphate concentrations range between about 0.50 and 2.70 μg-at/l. The majority were from 0.50 to about 1.70 μg-at/l. Foraminifera were found in waters with concentrations greater than 1.30 at five stations; none were found in waters where the concentrations were less than 0.67 μg-at/l.



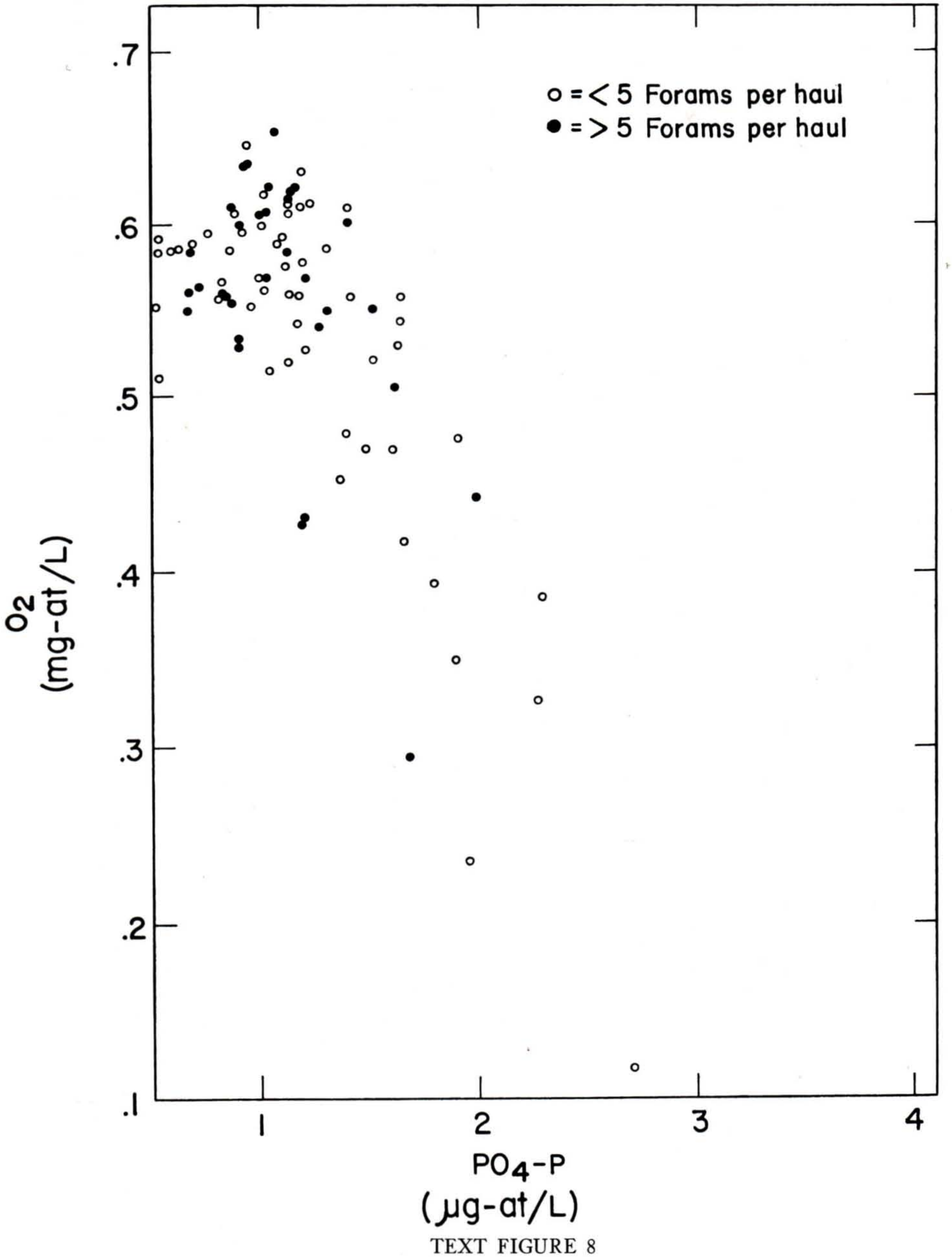
TEXT FIGURES 3-6

Sea temperatures, salinities, dissolved oxygen, and inorganic phosphate concentrations at 50 meters (after NORPAC Atlas, 1960).



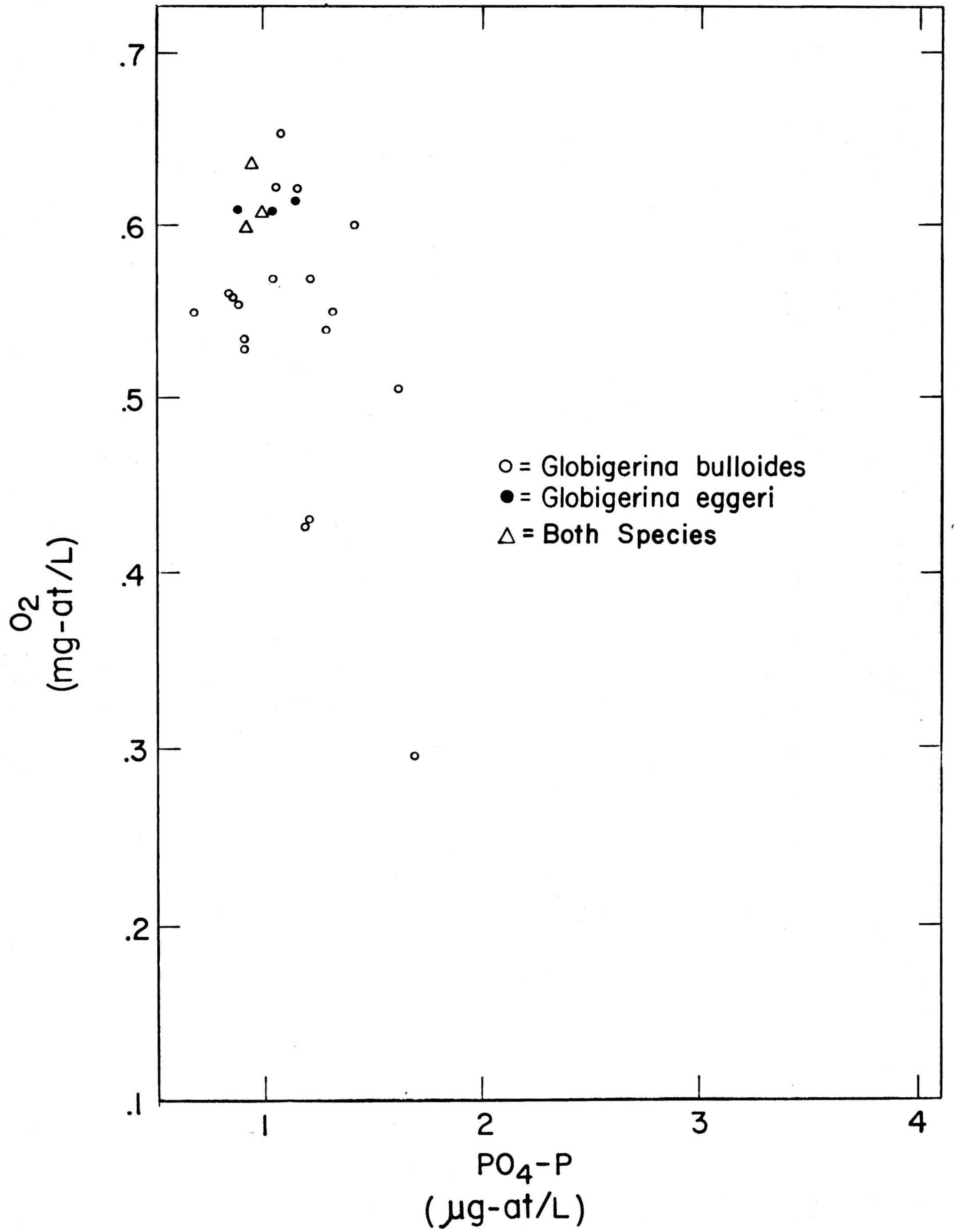
TEXT FIGURE 7

Abundance of planktonic foraminifera as related to temperature and salinity at 50 meters.



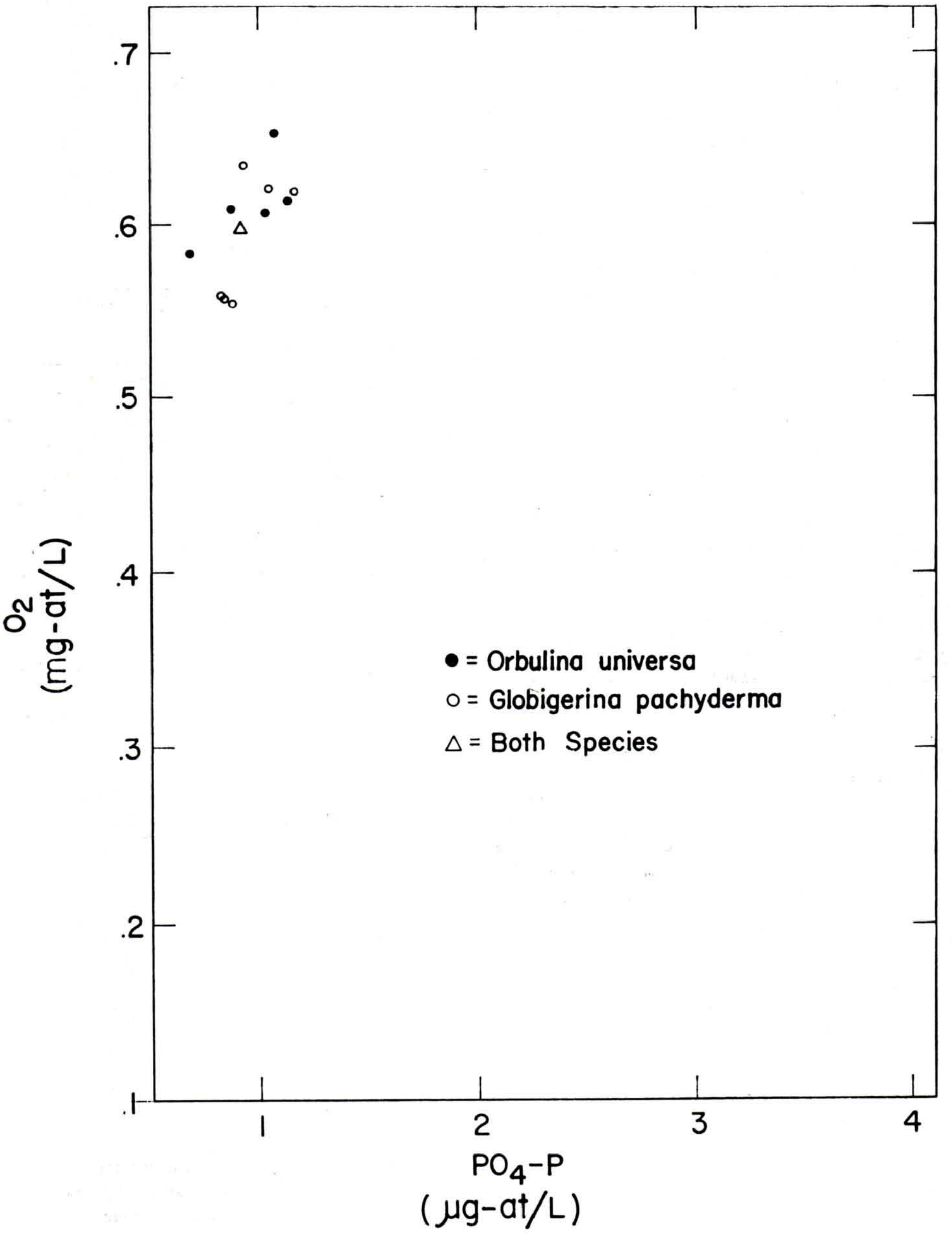
TEXT FIGURE 8

Abundance of planktonic foraminifera as related to dissolved oxygen and inorganic phosphate concentrations at 50 meters.



TEXT FIGURE 9

Distributions of *Globigerina eggeri* and *G. bulloides* as related to dissolved oxygen and inorganic phosphate concentrations at 50 meters.



TEXT FIGURE 10

Distribution of *Globigerina pachyderma* and *Orbulina universa* as related to dissolved oxygen and inorganic phosphate concentrations at 50 meters.

SPECIES DISTRIBUTION

The areal distributions of the eight species, *Globigerina bulloides, G. bradyi, G. eggeri, G. pachyderma, G. quinqueloba, Globigerinita glutinata, Orbulina universa,* and *Globorotalia scitula* are basically similar. *Globigerina bulloides* exhibits the most widespread distribution, being found throughout the area where the organisms were present. *Globigerinita glutinata* shows the most restricted distribution, being found only in a narrow band extending from the northern edge of the area of maximum numbers to the coast. The most abundant species are *Globigerina bulloides, G. pachyderma, Orbulina universa,* and *Globigerina eggeri,* in that order.

The fact that the area under study is small and the physical factors restricted in range makes it difficult to determine which conditions limit the distribution of the planktonic foraminifera. Text figure 9 represents the distribution of *G. eggeri* and that of *G. bulloides* in relation to dissolved oxygen and inorganic phosphate concentrations. The values for these variables at 50 meters, for all stations where these species were present in numbers greater than five, are plotted. *G. bulloides* showed no restriction as regards these variables other than those mentioned for the entire foraminiferal population. However, *G. eggeri* was found only in waters where dissolved oxygen concentrations were greater than 0.590 mg-at/l and where inorganic phosphate concentrations ranged from 0.85 to 1.15 µg-at/l. This is by no means sufficient evidence to infer that *G. eggeri* is restricted to such an environment but it does suggest an area for further study. *G. pachyderma* and *Orbulina universa* (text fig. 10), show a restriction as regards dissolved oxygen and inorganic phosphate concentration but not to the degree of *G. eggeri.* The other species did not occur in sufficient numbers to warrant plotting. None of the species show distribution patterns that can be correlated directly with temperature and salinity.

Vertical Distribution

Only seven of 33 samples taken from 400 to 200 meters contained planktonic foraminifera. In these, concentrations were never greater than 0.6 organisms per cubic meter of water filtered. Of the eight species identified from the area of study, only *Globigerina bradyi* and *Globigerinita glutinata* were absent from the deeper tows. Fifty-eight of the 127 tows taken above 200 meters contained foraminifera.

The 20 samples collected during the special vertical station were taken in an effort to determine possible vertical stratification in the upper 150 meters of water. The procedure was explained earlier. Casts were taken at two-hour intervals commencing at midnight and continuing until 8:00 a.m. In the three night tows, animals were collected in all samples except the two earliest ones at 50 meters. The midnight sample at 150 meters was discarded due to a malfunction of the sampling device. Table 1 shows the physical data collected from the surface to 200 meters for this station. These were collected about two hours before the first haul.

TABLE 1
Physical data for 144-44 vertical station

Depth	Temperature °C	Salinity o/oo	Dissolved Oxygen mg-at/l	Inorganic Phosphate µg-at/l
0	16.10	32.73	0.529	0.62
10	16.08	32.72	0.528	0.67
20	16.06	32.72	0.530	0.57
30	14.90	32.74	0.554	0.58
50	10.74	32.78	0.599	0.91
75	6.74	32.79	0.605	1.09
100	6.42	32.81	0.583	1.20
150	5.56	33.16	0.535	1.62
200	5.89	33.80	0.360	2.06

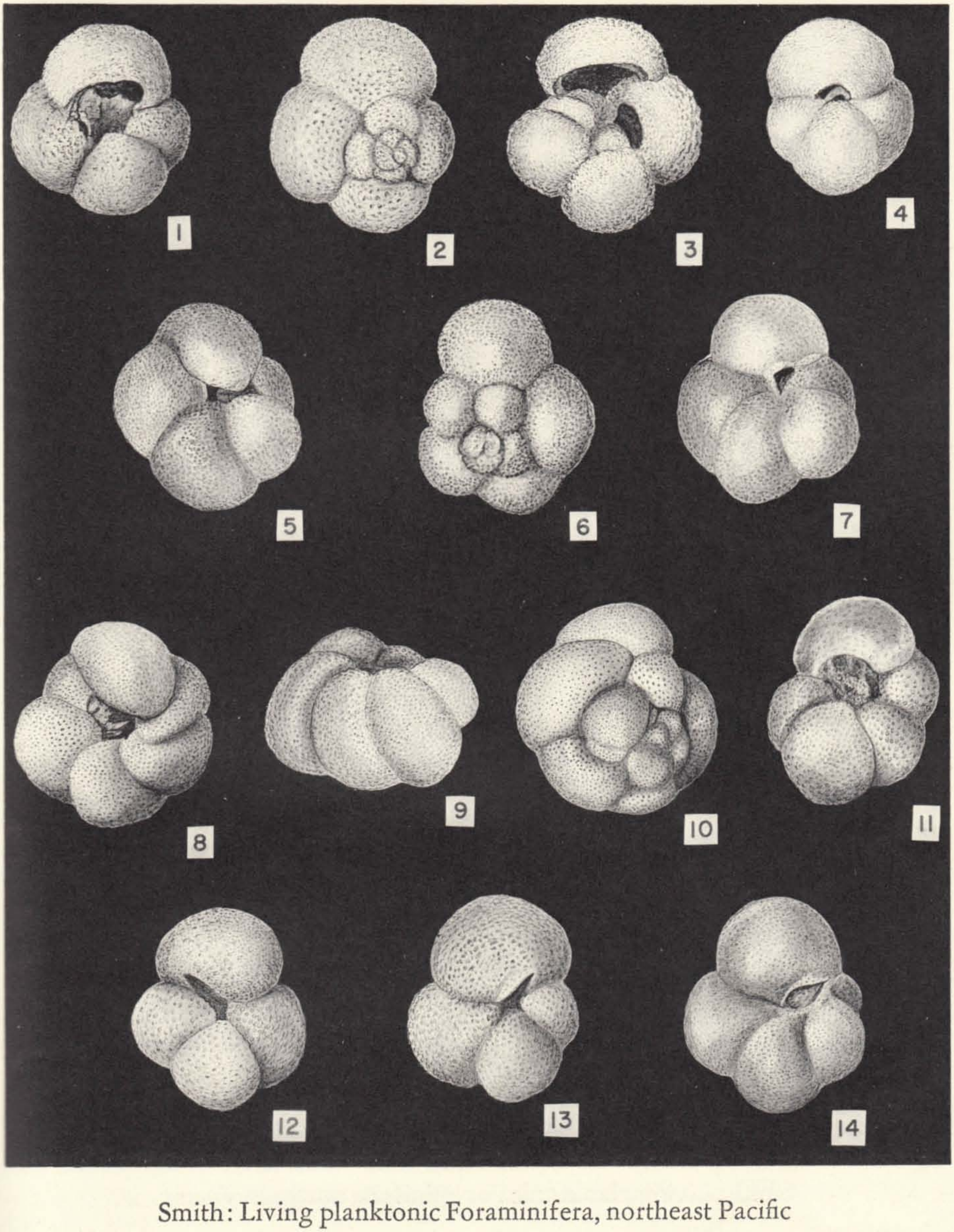
Only the 50-meter samples of the daylight tows contained foraminifera. Over one hundred organisms were collected at 0600, while 569 organisms were collected at 0800. This suggests a vertical migration from the surface to about 50 meters with the coming of light. A secondary migration from deeper waters upwards may also take place. The data obtained from the 20 samples (table 2) show that, on the average, concentrations at 50 meters were 1.3 times those at the surface, 3.5 times those at 100 meters, and 12.5 times greater than those from 150 meters. These averages disregard the time of day during which the material was collected.

Globigerina bradyi and *G. quinqueloba* were not collected below 50 meters. *Globigerinita glutinata* was rare at 100 meters and absent from the 150-meter samples, but at 50 meters it comprised 17.3, 26.6 and 27.1 percent of the total samples and was present in four surface tows. Thus, these three species appear to be restricted, with minor exceptions, to the upper 50 meters.

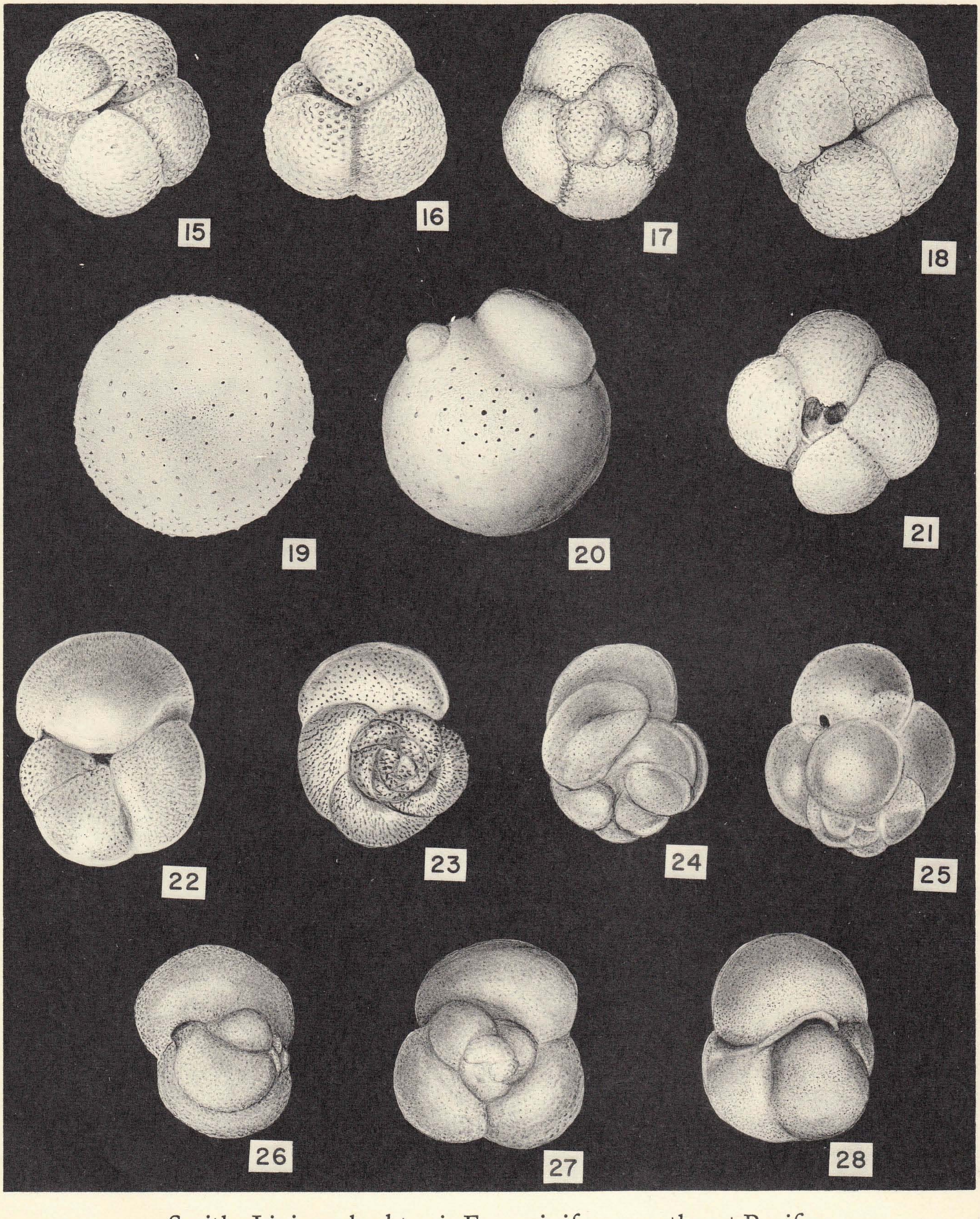
The morphologic intergrade *Globigerina pachyderma-eggeri* was most abundant at the surface, making up over 47 percent of the total in all but one sample. It was present, in smaller numbers, throughout the 150

EXPLANATION OF PLATE 1

Figs.		Page
1-4.	*Globigerina bulloides* d'Orbigny. 1, × 56; 2, × 62; 3, × 54; 4, × 64.	2
5-7.	*Globigerina quinqueloba* Natland. 5, × 87; 6, × 106; 7, × 152.	2
8-11.	*Globigerina eggeri* Rhumbler. 8, × 55; 9, × 58; 10, × 52; 11, × 62.	2
12-14.	Morphologic intergrade *Globigerina pachyderma-eggeri.* 12, × 74; 13, × 122; 14, × 125.	3



Smith: Living planktonic Foraminifera, northeast Pacific



Smith: Living planktonic Foraminifera, northeast Pacific meters. *G. pachyderma* was never abundant. The largest numbers (7 and 8) were from 150-meter samples. Single specimens were found on two occasions at the surface. Bé (1960b, p. 67) pointed out that *G. pachyderma,* in arctic waters, does appear in near surface waters but is significantly different morphologically from the typical form which is found on the bottom. At the surface this species closely resembles small *G. bulloides* and/or *G. eggeri.* This is probably the case in the northeastern Pacific. Many specimens of the morphologic intergrade *G. pachyderma-eggeri* may in reality be early stages of *G. pachyderma* and typical forms of this species may exist only in deeper waters. However, since *G. bulloides* and *G. eggeri* are present in abundance at the surface, it is impossible to differentiate between young specimens of these species and early stages of *G. pachyderma.*

Globigerina bulloides and *G. eggeri* occurred throughout the 150 meters, however few of either were collected below 100 meters. *G. eggeri,* by far the most abundant species in this vertical study, was present in the greatest numbers at 50 meters, making up over 60 percent of the total sample on three occasions. *G. bulloides* was most abundant at the surface but never made up more than 27.7 percent of the total sample.

Orbulina universa was found in one surface sample. Single specimens were found in two samples at 50 meters. At 100 meters this species was present in three samples in an abundance greater than 50 percent, and at 150 meters it composed 64.8 and 37.5 percent of the two samples at this depth in which foraminifera were found. A possible explanation for this vertical stratification may be found in the work of Le Calvez (1936). He found that *Globigerina*-like chambers inside the spherical test of *O. universa* dissolve during the formation of gametes. A study of the vertical distribution of specimens taken from plankton tows indicated a strong correlation between the amount of destruction and depth. At 50 meters the *Globigerina*-like bodies are displaced from the central position which they occupy while at the surface. At 100 meters they are nearly dissolved and only yellow protoplasm remains in the test. At 300 meters the test is completely empty.

Fifty specimens were broken open during this investigation. Those collected above 50 meters contained poorly preserved *Globigerina*-like bodies. Those from 100 and 150 meters contained only hardened protoplasm. It is likely that a population which was in the process of producing gametes was sampled and that the organisms were in that stage of development where they were concentrated between 100 and 150 meters.

SUMMARY

The distribution of planktonic foraminifera in this area of the northeastern Pacific is extremely patchy; concentrations ranged from nil to 96.8 organisms per cubic meter of water filtered. The area of maximum concentration is directly above the area of *Globigerina*-rich sediments about 350 miles off the coast of Washington and Oregon. No foraminifera were collected seaward of 137° W. Long.

No direct correlation between temperature, salinity, dissolved oxygen, or inorganic phosphate concentrations and the distribution of the foraminiferal population was observed.

Globigerina eggeri showed the closest correlation with the physical factors, being limited to an area where the inorganic phosphate concentrations were between 0.85 and 1.15 µg-at/l and dissolved oxygen concentrations were between 0.590 and 0.650 mg-at/l.

Foraminifera were rare below 200 meters and most abundant within the upper 100 meters.

Globigerinita glutinata, Globigerina bradyi and *G. quinqueloba* appear to be restricted to the upper 50 meters.

G. pachyderma was most abundant at 150 meters. However, the morphologic intergrade *G. pachyderma-eggeri* was most abundant at the surface. It is believed that juvenile forms of *G. pachyderma* are present at the surface but are indistinguishable from small *G. bulloides* and *G. eggeri.*

The vertical stratification of *Orbulina universa* at 100 and 150 meters is, possibly, related to the production of gametes.

With the coming of light, diurnal vertical migration from the surface to about 50 meters was observed.

ACKNOWLEDGMENTS

The excellent drawings of the foraminifera illustrated were done by Mrs. Zella Schultz.

Thanks are extended to Dr. Betty J. Enbysk of the Department of Oceanography at the University of Washington for her helpful criticism of the manuscript.

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EXPLANATION OF PLATE 2

FIGS.		PAGE
15-18.	*Globigerina pachyderma* (Ehrenberg). 15, × 82; 16, × 78; 17, × 85; 18, × 102.	2
19, 20.	*Orbulina universa* d'Orbigny. 19, × 49; 20, × 58.	3
21.	Morphologic intergrade *Globigerina pachyderma-eggeri.* 21, × 62.	3
22, 23.	*Globorotalia scitula* (Brady). 22, × 74; 23, × 64.	3
24, 25.	*Globigerina bradyi* Wiesner. 24, × 160; 25, × 174.	2
26-28.	*Globigerinita glutinata* (Egger). 26, × 85; 27, × 98; 28, × 86.	3

TABLE 2

Data from the vertical hauls where five casts using four Clarke-Bumpus samplers simultaneously were made, showing the vertical distribution of the species collected (p-e = morphologic intergrade *Globigerina pachyderma - eggeri. G.* = *Globigerina*)

Station 144-44

Time	0020 to 0042		0214 to 0238		0434 to 0455		0614 to 0635		0815 to 0835		
Haul	1		2		3		4		5		
Depth (m)	15.571		17.883		13.926		14.380		16.039		m^3 Water Filtered
	155		166		219		0		16*		Total Population
	No.	%	No.	%	No.	%	No.	%	No.	%	
	84	54.1	100	60.2	103	47.0	0	0	0	0	*Globigerina p-e*
	43	27.7	42	25.3	29	13.2	0	0	0	0	*G. bulloides*
	6	3.8	13	7.8	56	25.5	0	0	0	0	*G. eggeri*
0	2	1.2	0	0	0	0	0	0	0	0	*Orbulina universa*
	1	.6	0	0	1	.4	0	0	0	0	*Globigerina pachyderma*
	12	7.7	7	4.2	13	5.9	0	0	1	6.2	*Globigerinita glutinata*
	3	1.9	4	2.4	11	5.0	0	0	0	0	*Globigerina bradyi*
	4	2.5	0	0	4	1.8	0	0	0	0	*G. quinqueloba*
Depth (m)	11.555		14.091		14.302		11.068		10.104		m^3 Water Filtered
	0*		0		75		114		569		Total Population
	No.	%	No.	%	No.	%	No.	%	No.	%	
	0	0	0	0	2	2.6	0	0	70	12.3	*G. p-e*
	0	0	0	0	2	2.6	0	0	18	3.1	*G. bulloides*
	0	0	0	0	47	62.6	81	71.0	344	60.4	*G. eggeri*
50	0	0	0	0	0	0	1	.8	1	.1	*Orbulina universa*
	0	0	0	0	20	26.6	31	27.1	99	17.3	*Globigerinita glutinata*
	0	0	0	0	1	1.3	0	0	3	.5	*Globigerina bradyi*
	0	0	0	0	3	4.0	0	0	34	5.9	*G. quinqueloba*
Depth (m)	17.640		19.697		17.270		13.097		16.438		m^3 Water Filtered
	54		124		36		0		0*		Total Population
	No.	%	No.	%	No.	%	No.	%	No.	%	
	0	0	12	9.6	0	0	0	0	0	0	*G. p-e*
	1	1.8	26	20.9	5	13.8	0	0	0	0	*G. bulloides*
100	20	37.0	19	15.3	7	19.4	0	0	0	0	*G. eggeri*
	27	50.0	65	52.4	24	66.6	0	0	0	0	*Orbulina universa*
	3	5.5	2	1.6	0	0	0	0	0	0	*Globigerinita glutinata*
Depth (m)	.058		18.394		18.769		11.862		13.612		m^3 Water Filtered
	0		37		24		0		0		Total Population
	No.	%	No.	%	No.	%	No.	%	No.	%	
	0	0	1	2.7	1	4.1	0	0	0	0	*Globigerina p-e*
	0	0	4	10.8	1	4.1	0	0	0	0	*G. bulloides*
150	0	0	0	0	5	20.8	0	0	0	0	*G. eggeri*
	0	0	24	64.8	9	37.5	0	0	0	0	*Orbulina universa*
	0	0	7	18.9	8	33.3	0	0	0	0	*Globigerina pachyderma*

* Possible Solution

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FOR FORAMINIFERAL RESEARCH
VOLUME XIV, PART 1, JANUARY, 1963

258. FOSSIL FORAMINIFERA IN ADRIATIC BEACH SANDS

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ABSTRACT

Foraminiferal faunas in beach sands along the Adriatic coast from Ancona to the Po delta contain fossil foraminifera (mostly Plaisancian) derived from shore deposits.

Many species of foraminifera from the beach sands of the Adriatic coast of northern Italy have been described by Linnaeus, de Wulfen, Fichtel and Moll, Schroeter, d'Orbigny, Fornasini and others. The most famous localities are Rimini and Porto Corsini, but the entire coast from Ancona to the Po delta has fine beaches with foraminiferal sand. The fauna of the beach sand is unusual, however, in that planktonics and other forms more characteristic of deeper water deposits are common along with typical shallow-water species.

It has long been suspected that many of the foraminifera might have been reworked from older deposits exposed inland. During 1961 a sample was taken of the mud in the Fiume Marecchio at the Ponte di Verrucchio some 20 km. upstream from the coast. This sample contained globigerinids and other foraminifera in an excellent state of preservation. The main part of the residue on a 200 mesh screen was composed of mixture of angular quartz and calcite grains with abundant flakes of mica, mostly muscovite. This micaceous fine sand residue was very similar to that from a sample collected at a depth of 4 meters about 300 meters offshore from Rimini. The beach sand at Rimini differs only in being somewhat better sorted. It is evident that the rivers emptying into the Adriatic in this region are bringing in numbers of fossil foraminifera, which are mixed with the indigenous Recent forms. Some of the larger rivers, such as the Fiume Marecchio, have headwaters in the Upper Cretaceous-Paleogene Scaglia of the Appenines, but most of the area near the coast is underlain by richly fossiliferous Pliocene deposits, chiefly Plaisancian beds with a foraminiferal fauna similar to that found at Castel Arquato. From the extensive areal distribution of the Plaisancian beds it is suspected that most of the reworked foraminifera come from them. Many small streams are eroding the Pliocene deposits and bringing microfossils down to the coast. Along the coast the sediments are swept northward by a strong longshore current. There is a large clockwise eddy between Ancona and the Po delta with circulation counter to that generally prevalent in the Adriatic.

The beach fauna varies with the seasons. During the rainy season, more fossil foraminifera are brought down and deposited on the beaches and the fossils may predominate over Recent species. During the dryer seasons, the indigenous foraminifera become more common.

CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
FOR FORAMINIFERAL RESEARCH
VOLUME XIV, PART 1, JANUARY, 1963

259. FUSULINIDS FROM THE WORD FORMATION (PERMIAN), GLASS MOUNTAINS, TEXAS

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ABSTRACT

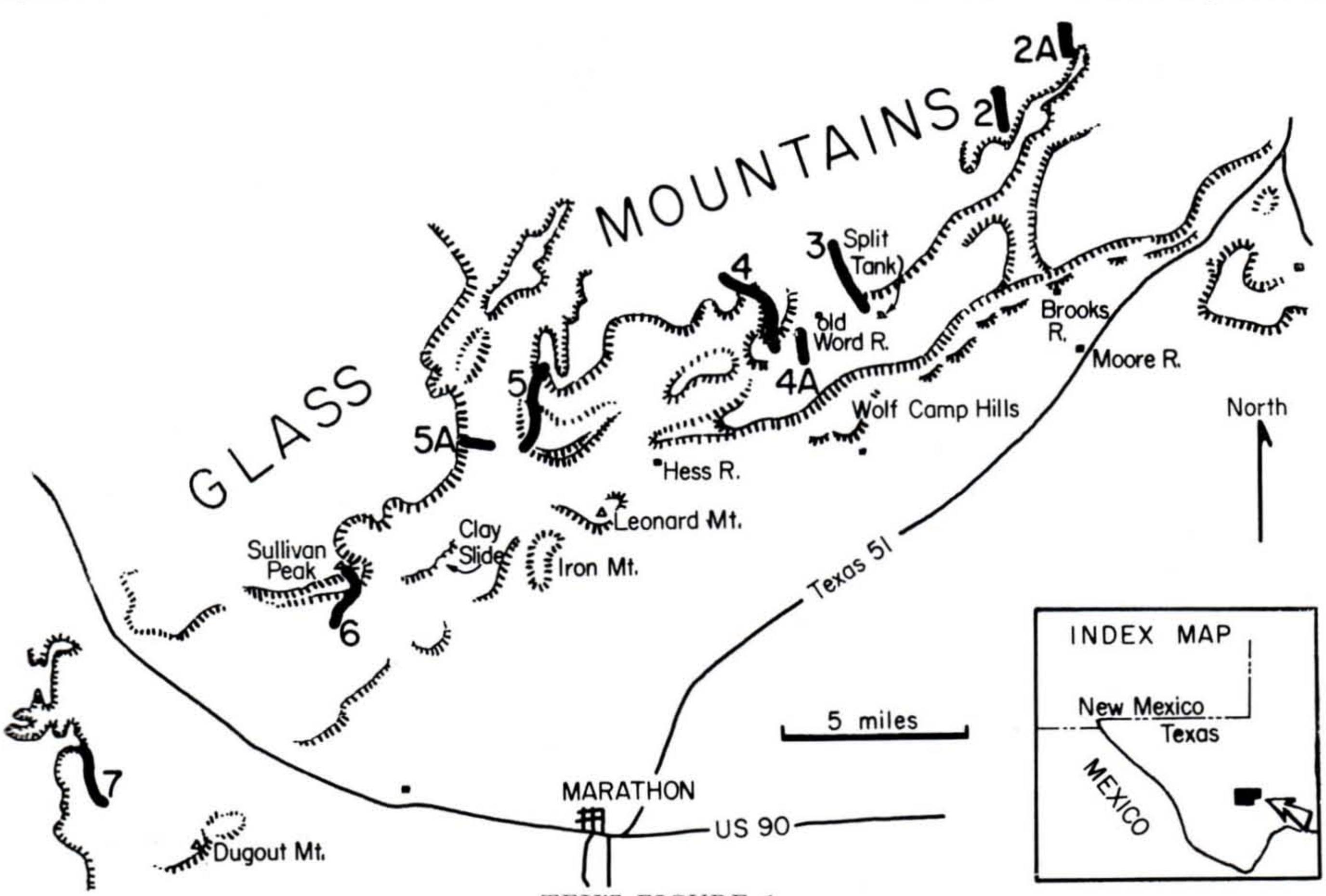
Within the Permian Word Formation, Glass Mountains, Texas, five ecological associations based on fusulinid species intertongue complexly. The lateral ranges of species apparently relate to lateral changes of the dominant rock type in the formation and the vertical ranges reflect the expansion of newly evolved species and the gradual extinction of old species.

Of the ten species described, the following four are new: **Parafusulina wildei**, **P. sullivanensis**, **P. ironensis**, and **Parafusulina** sp. A. The geographic ranges of **P. lineata**, **P. deliciasensis**, and **P. antimonioensis** are extended to include the Word Formation in the Glass Mountains.

INTRODUCTION

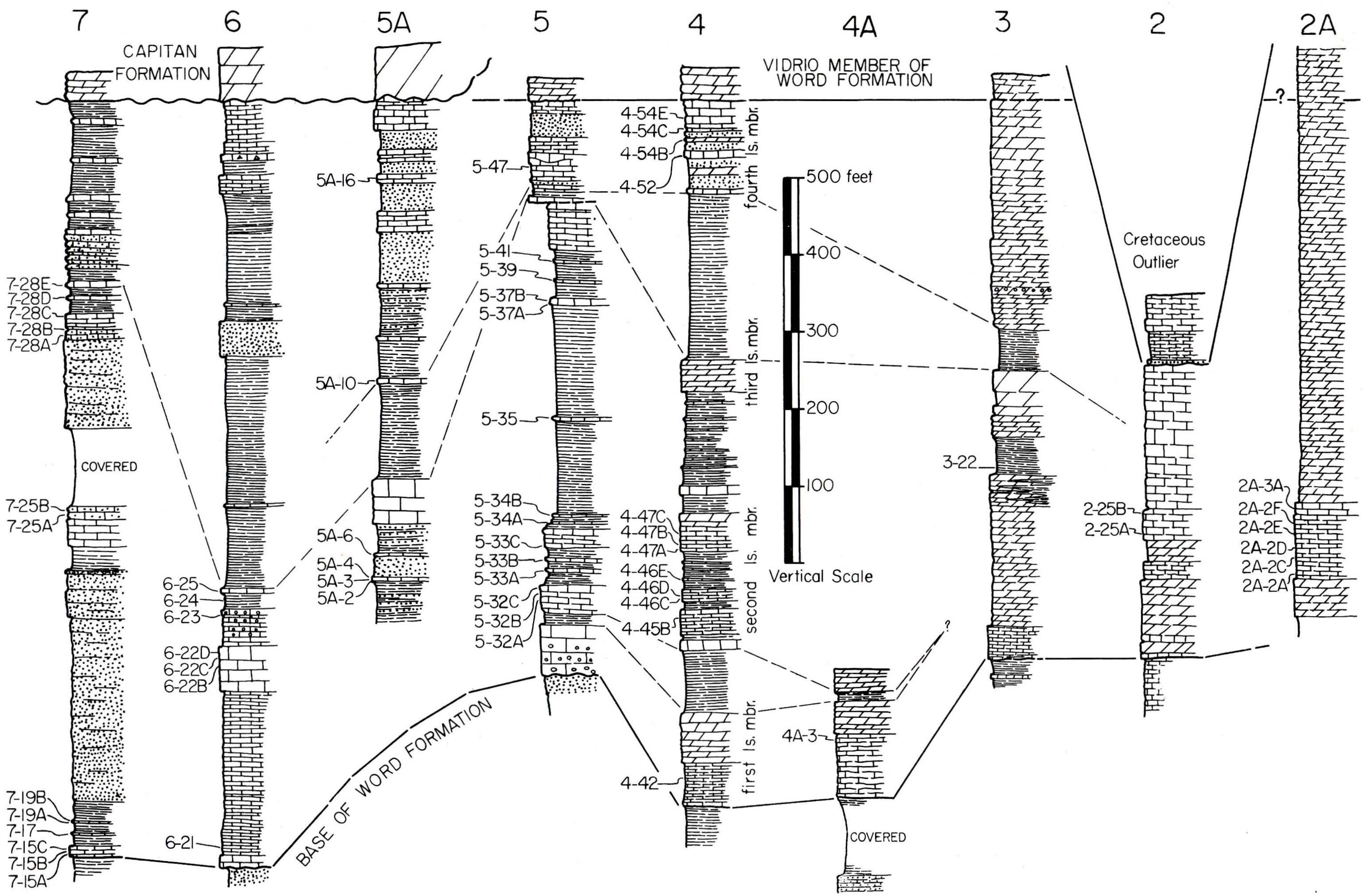
This study investigates the detailed stratigraphic range, distribution and morphologic variation of the fusulinid species in the Word Formation. The fusulinids of the Word Formation are of unusual significance in helping to determine the age relationships of the two Early Permian standard series, the Wolfcampian and the Leonardian in the Glass Mountains, with the two Late Permian standard series, the Guadalupian and Ochoan 150 miles to the northwest in the Guadalupe Mountains and Delaware Basin. In the Glass Mountains, the Word Formation represents the lower part of the Guadalupian Series and it is the youngest unit with abundant and well-preserved fusulinid faunas. In a few localities, the overlying Capitan Limestone has abundant fusulinids; however, these seldom yield well-preserved specimens.

The lateral changes in lithology within the Word Formation are considerable, as is true for the older Permian units of the Glass Mountains (Ross, 1959, 1962). The details of the stratigraphic succession of the Word were discussed by P. B. King (1931, 1937, and 1942) who greatly extended the earlier work of Udden (1917). King (1931, p. 71) recognized four main ledges of limestone within the Word Formation in the middle part of the Glass Mountains and he (King, 1931, p. 72) traced them eastward into dolostone that forms most of the formation in the eastern part of the Glass Mountains. The eastern sections of the Word Formation (text figs. 1 and 2) are predominantly dolostone with only a few fossiliferous limestone beds near the base. In the western part of the



TEXT FIGURE 1

Map of the Glass Mountains showing location of the measured sections shown in text fig. 2



TEXT FIGURE 2

Measured sections of the Word Formation (Vidrio Member at the top of the eastern part is not included). Numbers to left of columns indicate the position of collecting localities in measured sections.

Glass Mountains tongues of shale and sandstone are interbedded with thin limestone lenses which carry abundant and well-preserved fossils. It is in these western exposures that coarse conglomerate is present in the lower third of the formation.

The best reference sections of the Word Formation are sections 4 and 5 near the middle part of the Glass Mountains (text fig. 1) and represent the intertonguing of the two principal facies where they are most fossiliferous (text fig. 2). P. B. King (1942, p. 656) suggested that the thick sequence of dolostone (Vidrio Member) in the eastern part of the Glass Mountains was the reef and back-reef facies of the upper part of the Word Formation. In these eastern exposures the dolostone of the Vidrio Member and similar dolostone lower in the Word Formation can not be readily separated into members.

The upper part of the Word Formation in the western part of the Glass Mountains is a yellow-weathering limestone and shale which is separated from the Capitan Limestone by an unconformity having as much as 20 feet of relief in 200 yards. The base of the Word Formation is placed at the base of a thick unit of thin-bedded calcilutite which contains in its lower part interbedded siliceous siltstone that is typical of the underlying Leonard Formation. The calcilutite is interbedded in its upper part with lenses of calcarenite typical of the massive limestone units higher in the formation. Throughout most of the Glass Mountains this basal unit is well defined and only at the southwest and east ends of the outcrop belt (text fig. 2) does this unit become difficult to trace. Clifton (1945, p. 1774), P. B. King (1947, p. 775) and Miller and Furnish (1957, p. 1052) considered the ammonoid fauna from this basal unit of the Word Formation and concluded that *Perrinites hilli*, a typical Leonardian ammonoid, ranges upwards into this basal calcilutite. The first appearance of *Waagenoceras*, the ammonoid typical of the lower part of the Guadalupian, is slightly higher in the sequence, although the genus *Stacheoceras*, a primitive ancestor of *Waagenoceras*, does occur here in the basal part of the Word Formation with *Perrinites*.

PREVIOUS FUSULINID STUDIES

The fusulinids from the Word Formation were studied by Dunbar and Skinner (1931, 1936, and 1937) from a total of 22 localities. They (Dunbar and Skinner, 1937) recognized the following seven species and one variety of *Parafusulina*: *P. boesei* Dunbar and Skinner, *P. boesei* var. *attenuata* Dunbar and Skinner; *P. deliciasensis* Dunbar and Skinner?, *P. kingorum* Dunbar and Skinner, *P. rothi* Dunbar and Skinner, *P. sellardsi* Dunbar and Skinner, *P. splendens* Dunbar and Skinner, and *P. wordensis* Dunbar and Skinner. Several of their collections had only silicified specimens and it was from these silicified collections that the types of *Parafusulina wordensis*, the type species of *Parafusulina*, and *P. kingorum* were described.

DISTRIBUTION OF *PARAFUSULINA*

In addition to the species listed by Dunbar and Skinner (1937) *Parafusulina antimonioensis* Dunbar (*in* Cooper *et al.*, 1953) occurs in the fourth limestone member near the top of the Word Formation. *Parafusulina wildei* n. sp., *P. ironensis* n. sp., *P. sullivanensis* n. sp., and *Parafusulina* sp. A are new species not previously described from the Word Formation.

Of the species listed by Dunbar and Skinner (1937, p. 595) only the giant *Parafusulina wordensis, P. kingorum,* and *P. rothi* have not been found. Because the syntypes of *P. wordensis,* the type species of *Parafusulina,* are silicified and their internal features difficult to observe, the precise morphology of the species remains a question, although the cuniculi, that are the diagnostic feature of the genus, are well displayed in the type specimens. It is possible that the specimens of *P. rothi* from the Word Formation mentioned by Dunbar and Skinner may belong to *P. deliciasensis* in its expanded concept as used in this study. The syntypes of *P. kingorum* are also silicified and their identification in unsilicified material may be difficult as the species is similar to *P. sellardsi* in size and shape, although it appears to differ in several internal characters.

The distribution of the ten species of *Parafusulina* in the collections are shown in Table 1. Within the formation, five ecological associations based on fusulinid species are recognized and their distributions are shown in text fig 3.

Parafusulina boesei is the most abundant species in the western part of the outcrop belt of the Word Formation and occurs in thin limestone beds that intertongue with the sandstone and silty shale which form the major part of the formation in this area. It is common in medium- to coarse-, poorly- to well-sorted calcarenite (biomicrite) and ranges from the base of the Word Formation to the base of the third limestone member. *P. boesei* usually occurs by itself but occasionally it is found with either *P. deliciasensis, P. sullivanensis, P. sellardsi,* or *P. ironensis.* The lower part of the *P. boesei* association intertongues with the lower part of the *P. sullivanensis* association in the western sections (text fig. 3).

Parafusulina sullivanensis is the abundant species in most of the outcrops in the lower part of the formation. It occurs in poorly-sorted calcarenite (biomicrite and biosparite) that intertongues with the more massive biohermal limestone beds in this dominantly shale and limestone part of the formation. Both *P. boesei* and *P. deliciasensis* are occasionally associated with *P. sullivanensis.* The *P. sullivanensis* association intertongues with the *P. boesei* association in its western extent and intertongues with the *P. sellardsi* association above (text fig. 3).

TABLE 1. — Distribution of species of *Parafusulina* in localities from the Word Formation

Locality	*P. sellardsi*	*P. deliciasensis*	*P. boesei*	*P. wildei*	*P. ironensis*	*P. sullivanensis*	*P. lineata*	*P. splendens*	*P. antimonioensis*	*Parafusulina* sp. A
2A-2A						×				
2A-2C						×				
2A-2D						×				
2A-2E		×				×				
2A-2F		×								
2A-3A						?				
2-25A		×								
2-25B		×								
3-22	×									
4A-3						×	×			
4-42				×		×				
4-45B		×				×				
4-46C	×					×				
4-46D	×			×						×
4-46E	×									
4-47A	×									
4-47B	?									
4-47C	×									
4-52		×								
4-54B									×	
4-54C		?							×	
4-54E		×								
5-32A		×								
5-32B		×						?		
5-32C		×								
5-33A					×	×				
5-33B						×				
5-33C			×							
5-34A			×					×		
5-34B								×		
5-35		×				×				
5-37A				×						
5-37B			×			×				
5-39						×				
5-41	×									
5-47									×	

TABLE 1—Continued

Locality	*P. sellardsi*	*P. deliciasensis*	*P. boesei*	*P. wildei*	*P. ironensis*	*P. sullivanensis*	*P. lineata*	*P. splendens*	*P. antimonioensis*	*Parafusulina* sp. A
5A-2				×	?					
5A-3						×				
5A-4			×			×				
5A-6	?			×						
5A-10		×							×	
5A-16									×	
6-21						×				
6-22B			×							
6-22C			×							
6-22D						×				
6-23			×							
6-24						×				
6-25	×		?	×						
7-15A			×			?				
7-15B						×				
7-15C			×							
7-17			?			×				
7-19A			×			×				
7-19B						×				
7-25A			×							
7-25B			×							
7-28A			×							
7-28B		×								
7-28C			×							
7-28D	?		×							
7-28E	×									

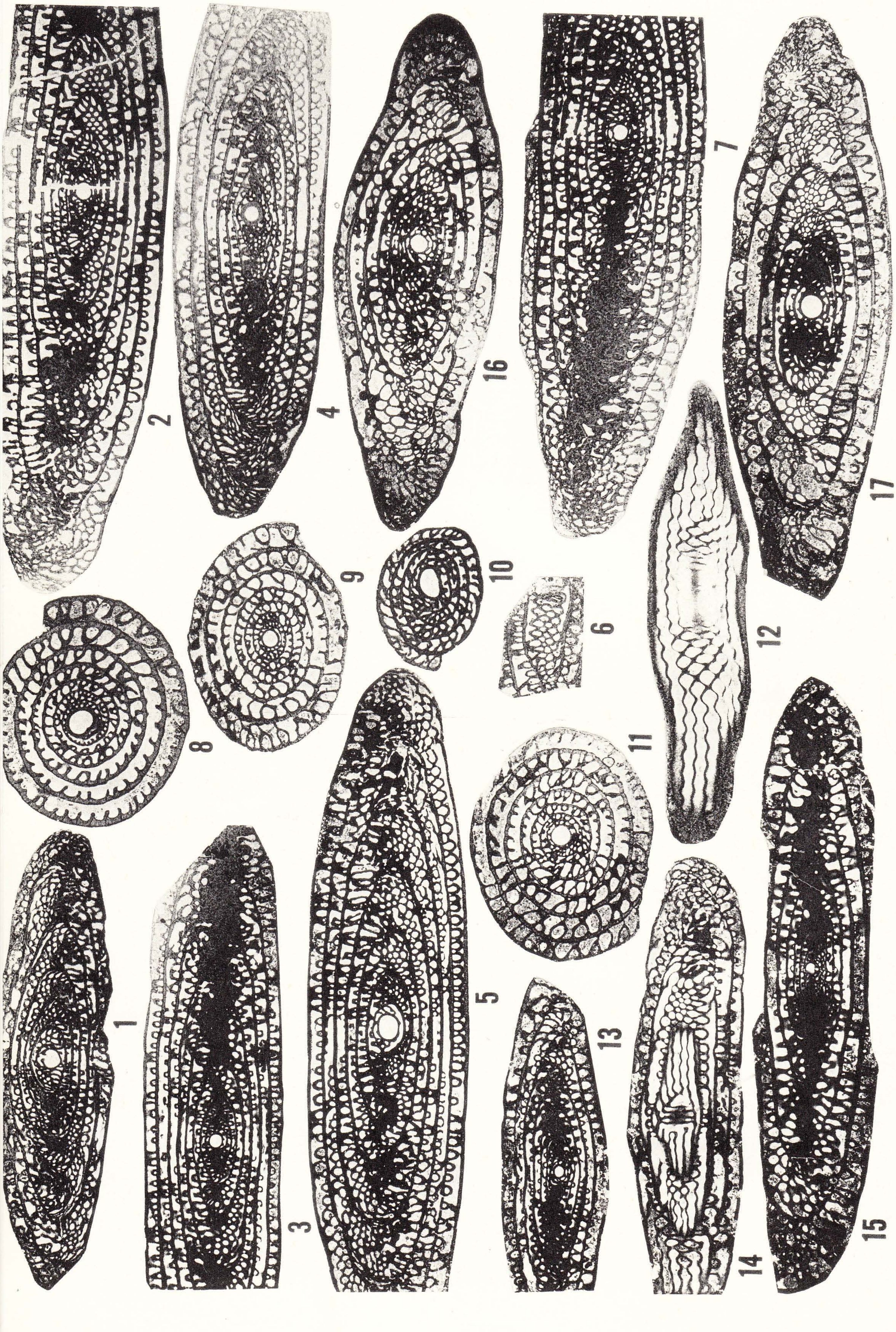
Parafusulina sellardsi is abundant in the coarse calcarenite composed of large fossil fragments in a fine-grained matrix (biomicrite) in the second and third limestone members of the Word Formation where they are well developed near the middle part of the outcrop belt. This association intertongues to the west with the upper part of the *P. sullivanensis* association and to the east with the dominantly dolostone part of the formation (text fig. 3). It is interbedded with small lenses containing the *P. boesei* and *P. deliciasensis* association.

EXPLANATION OF PLATE 3

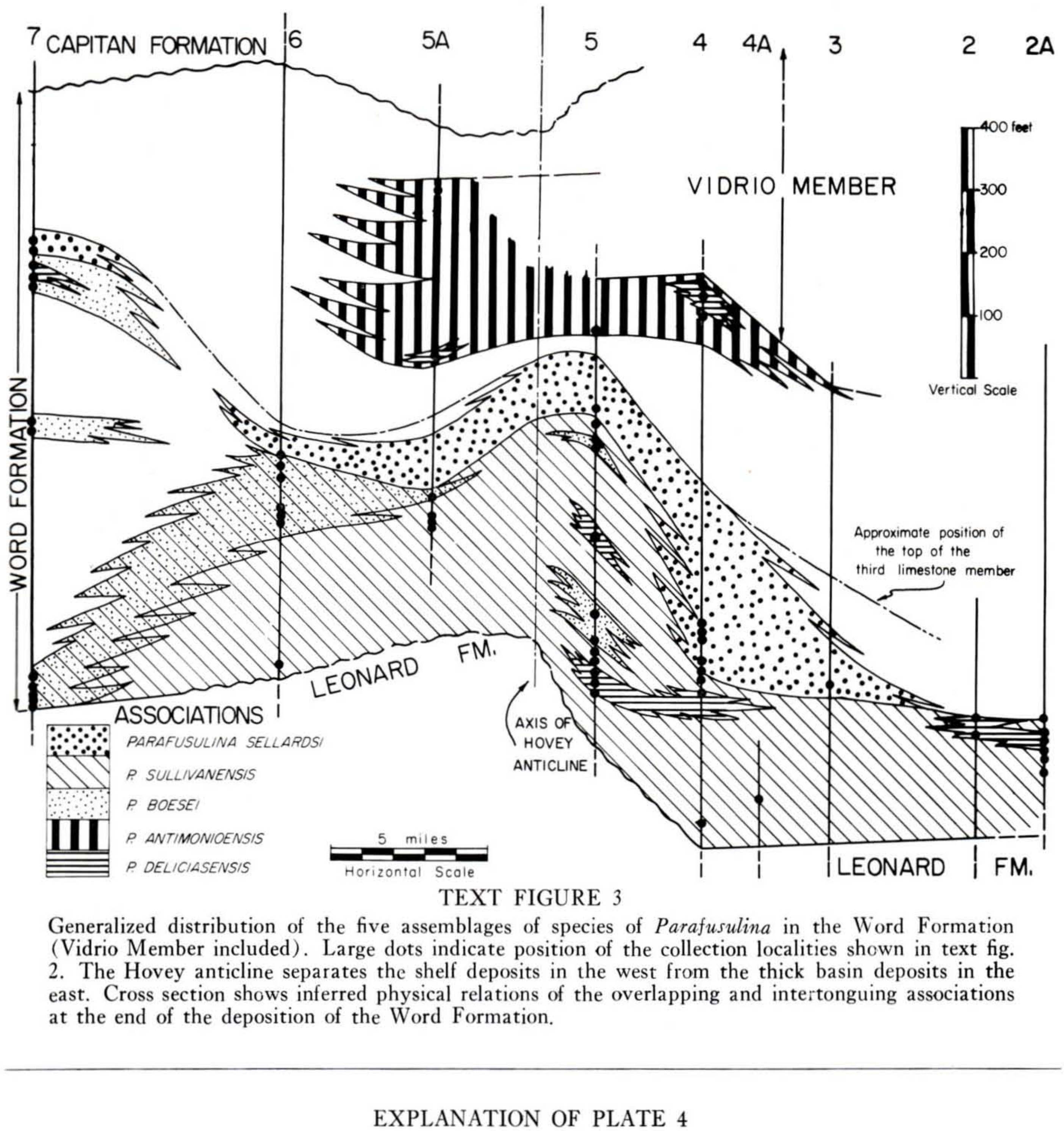
All figures ×10

Figs.		Page
1-10.	*Parafusulina boesei* Dunbar and Skinner, lower part of Word Formation, western Glass Mountains	26
	1. Axial section, locality 5A-4, YPM 21969. 2. Axial section, locality 7-15A, YPM 21970. 3. Tangential section, locality 7-28A, YPM 21971. 4. Axial section, locality 3-D, YPM 21972. 5, 6. Axial sections, locality 6-22B, YPM 21973 and 21974. 7. Axial section, locality 6-23, YPM 21975. 8. Sagittal section, locality 6-22B, YPM 21976. 9. Axial section, locality 7-28A, YPM 21977. 10. Axial section, locality 3-E, YPM 21978.	
11.	*Parafusulina* sp. A, second limestone member of the Word Formation	30
	11. Slightly oblique axial section, locality 4-46D, YPM 21979.	
12, 13.	*Parafusulina lineata* Dunbar and Skinner, first limestone member of the Word Formation	29
	12. Axial section, locality 4A-3, YPM 21980. 13. Sagittal section not cutting the proloculus, locality 4A-3, YPM 21981.	

Permian fusulinids from Texas



Ross: Permian fusulinids from Texas



TEXT FIGURE 3

Generalized distribution of the five assemblages of species of *Parafusulina* in the Word Formation (Vidrio Member included). Large dots indicate position of the collection localities shown in text fig. 2. The Hovey anticline separates the shelf deposits in the west from the thick basin deposits in the east. Cross section shows inferred physical relations of the overlapping and intertonguing associations at the end of the deposition of the Word Formation.

EXPLANATION OF PLATE 4

All figures ×10

Figs.		Page
1-7, 10.	*Parafusulina wildei* n. sp., second and third limestone members of the Word Formation 1, 4, 7. Axial sections, locality 4-46D, YPM 21982, 21983, and 21984. 2. Axial section, locality 4-42A, YPM 21985. A. Axial section, locality 5A-2, YPM 21986. 5. Axial section of holotype, locality 6-25, YPM 21987. 6. Tangential section, locality 4-46D, YPM 21988. 10. Sagittal section, locality 4-46D, YPM 21989.	24
8.	*Parafusulina sellardsi* Dunbar and Skinner, middle part of the Word Formation 8. Sagittal section, locality 5A-4, YPM 21990.	26
9, 12.	*Parafusulina sullivanensis* n. sp., lower and middle part of the Word Formation 9. Sagittal section, locality 3-C, YPM 21991. 12. Tangential section, locality 3-C, YPM 21992.	23
11, 16, 17.	*Parafusulina splendens* Dunbar and Skinner, top of the second limestone member of the Word Formation 11. Slightly oblique sagittal section, locality 5A-4, YPM 21993. 16, 17. Axial sections, locality 5-34B, YPM 22019, 22020.	29
13-15.	*Parafusulina ironensis* n. sp., lower part of the second limestone member of the Word Formation 13, 15. Axial sections, locality 5-33A, YPM 21994, 21995 (holotype). 14. Tangential section, locality 5-33A, YPM 21996.	25

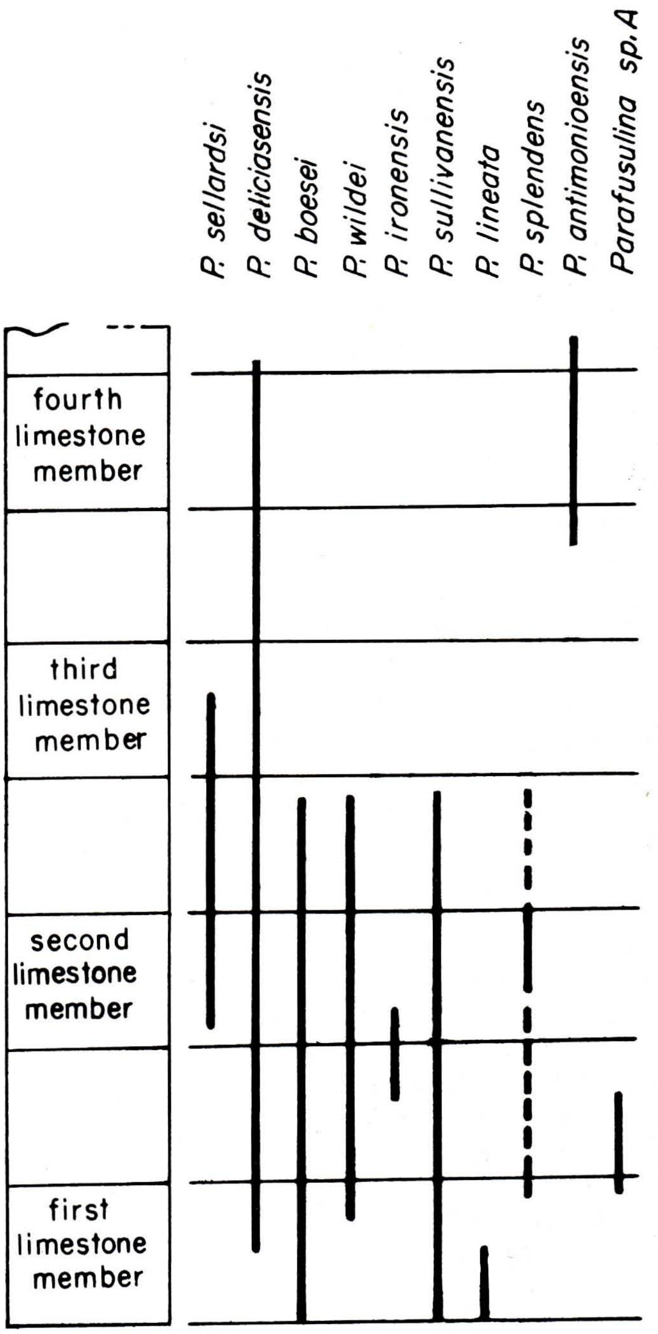
Parafusulina antimonioensis is rare to common in the upper part of the Word Formation and occurs in medium to coarse, well-sorted calcarenite commonly with *P. deliciasensis*. The *P. antimonioensis* association appears to lie above the *P. sellardsi* association (text fig. 3).

Parafusulina deliciasensis is common in well-sorted, coarse calcarenite which is composed largely of crinoidal fragments (crinoidal biosparite). Calcareous algal rims commonly surround the sand-size grains. This rock type occurs as lenses at many places in the Word Formation and the distribution of the *P. deliciasensis* association is apparently closely related to this particular lithology (text fig. 3). Where *P. deliciasensis* does occur it is commonly very abundant, almost to the exclusion of other species (table 1).

Parafusulina wildei is rare and occurs scattered with *P. sellardsi* and less commonly with *P. sullivanensis* in poorly-sorted calcarenite (biomicrite) in the middle and western part of the Glass Mountains. *P. lineata, P. splendens, P. ironensis,* and *Parafusulina* sp. A are rare and are found in very fine calcarenite or lenses of calcilutite (biomicrite) in the Word Formation in the middle part of the Glass Mountains.

The stratigraphic ranges of the ten species are shown in text fig. 4. *Parafusulina deliciasensis* has the longest range and includes almost the entire thickness of the formation. *P. sullivanensis, P. boesei,* and *P. wildei* form an assemblage zone typifying the lower part of the Word strata from the base up to the third limestone member. This zone may be subdivided into a lower part having *P. lineata,* a middle part having *P. ironensis,* and an upper part having *P. sellardsi* which ranges from the second limestone member into the third limestone member where it reaches its peak abundance. *P. antimonioensis* first appears above the third limestone member and reaches its peak abundance in the fourth limestone member.

This vertical succession of species (text fig. 4) appears to represent the gradual extinction of old species and the expansion of newly evolved species, although one or two species of *Parafusulina* tend to be dominant in a particular lithology within the Word Formation so that their lateral distribution closely parallels major lithofacies. Thus the formation can be divided into a number of fusulinid assemblage zones having great value in correlation with strata of similar age in other regions.



TEXT FIGURE 4
Stratigraphic ranges of species of *Parafusulina* in the Word Formation.

CORRELATION

The fusulinids from the Word Formation resemble most closely those from the Delaware Mountain Sandstone Group of the Guadalupe region described by Dunbar and Skinner (1937) and listed in their stratigraphic occurrence by P. B. King (1948, p. 30). The Brushy Canyon Formation (basal Guadalupian) contains *Parafusulina rothi* Dunbar and Skinner, *P. sellardsi, P. maleyi* (a synonym of *P. deliciasensis*), and *P. lineata*. The first three of these species are also known from the Getaway Limestone Member near the middle of the overlying Cherry Canyon Formation. Above the Getaway Limestone Member, the South Wells Limestone Member has *Leella fragilis* Dunbar and Skinner and a species of *Parafusulina,* which is the youngest known occurrence of the genus in the Guadalupe area.

Based on fusulinid ranges, the first limestone member of the Word Formation is equivalent to the Brushy Canyon Formation and represents the zone of *Parafusulina lineata* as far as the distribution of that species is at present understood. The overlying units of the Word Formation up to and including the third limestone member are equivalent to that part of the Cherry Canyon Formation up to and including the

Getaway Limestone Member. The overlying part of the Word Formation below the Vidrio Member is probably equivalent to the overlying South Well Member of the Cherry Canyon Formation.

The fusulinids from the middle part of the Permian section near Las Delicias, Mexico, (Dunbar, *in* King *et al.*, 1944) are closely comparable to those from the second and third limestone members of the Word Formation and to those from the lower part of the Cherry Canyon Formation, including the Getaway Limestone Member. These faunas include *Parafusulina sellardsi*, *P. deliciasensis*, and *P. boesei* and they form a distinctive assemblage zone in the three regions.

At El Antimonio in western Sonora, Mexico, the occurrence of *Parafusulina antimonioensis* Dunbar (*in* Cooper *et al.*, 1953) suggests that fusulinid-bearing beds near the middle part of that Permian succession are equivalent to the fourth limestone member of the Word Formation.

The fusulinids described by Knight (1956) from the Arcturus Formation, White Pine County, Nevada, have no closely similar species in the Leonard or Word Formations of the Glass Mountains although Knight regarded several of the species that he described as conspecific with those from the Glass Mountains. In the general stage of evolution the fusulinid species from the Arcturus Formation appear to include late Wolfcampian, Leonardian, and possibly early Guadalupian forms.

The Nosoni Formation in the Lake Shasta area in northern California contains *Parafusulina virga* Thompson and Wheeler, *P. nosonensis* Thompson and Wheeler, and *P. californica* (Staff) as described by Thompson, Wheeler, and Hazzard (1946). Coogan (1960) also identified *P. maleyi* (a synonym of *P. deliciasensis*) in this formation. Both *P. virga* and *P. nosonensis* resemble the elongate forms of *P. boesei*, and *P. californica* is similar in many features to *P. antimonioensis* Dunbar. These similarities suggest that the lower 200 feet of the Nosoni Formation are equivalent in age to the first through third limestone members of the Word Formation and the succeeding 400 feet of the Nosoni Formation are in part as young as the fourth limestone member of the Word Formation.

Outside of the western United States and northern Mexico, species of *Parafusulina* that have reached an evolutionary state similar to those in the early Guadalupian are rare. From Japan, Morikawa and Horiguchi (1956) described *P. nakamigawai* from the Adoyama Formation near Kuzu-City, Tochigi Prefecture, which has a large size, elongate shape, and high, well-developed cuniculi that are similar to *P. sellardsi*, *P. sullivanensis*, or *P. splendens* from the Word Formation. As primitive species of *Neoschwagerina* occur near the top of the underlying Nabeyama Formation, it seems likely that the zone of *Neoschwagerina* is largely of early Guadalupian age as suggested by Morikawa and Horiguchi (1956, p. 262) although it probably had its beginning slightly earlier in the later part of Leonardian time.

Acknowledgements.—The field work for this study was made possible by grants-in-aid from the Research Committee of the American Association of Petroleum Geologists, the Penrose Fund of the American Philosophical Society, and the Schuchert Fund of Peabody Museum, Yale University. I am grateful to Dr. June Phillips Ross of the Illinois State Geological Survey for critically reading the manuscript, and to Professor C. O. Dunbar of Yale University and Dr. G. A. Cooper of the United States National Museum for permitting me to examine specimens in their collections.

Repository.—The type and illustrated specimens and the rock samples are housed in Peabody Museum, Yale University (abbreviated in text to YPM). The bulk of the collections for this and the two Leonardian fusulinid studies by Ross (1960 and 1962) bear YPM accession No. 6753. Type and illustrated specimen YPM numbers refer to catalog numbers at that institution.

SYSTEMATIC PALEONTOLOGY

Genus **Parafusulina** Dunbar and Skinner, 1931

Parafusulina sullivanensis n. sp.

Plate 4, figures 9, 12; Plate 5, figures 13-15, 17-22

Description.—This species has large fusiform tests of about 8 volutions that commonly reach 16 mm. in length and 3.5 mm. in diameter. The proloculus is generally small (0.2 to 0.4 mm. outside diameter) and the first volution is low and subglobose. Succeeding volutions become more elongate and increase in height to give the test an open appearance. The lateral slopes taper to sharply rounded poles (Pl. 5, fig. 17).

The wall is composed of a tectum and a keriotheca that becomes coarsely alveolar in the outer two volutions. The septa are thin and folded into high, slightly irregular folds that commonly have pointed crests. The tunnel is wide, the tunnel angle commonly reaching 50 degrees in the next to last volution, and the path of the tunnel is irregular (Pl. 5, figs. 14, 15, 17, 21). Chomata are lacking. Secondary deposits are commonly heavy in the axial region of the first four volutions. Cuniculi are high and well displayed.

Remarks.—*Parafusulina sullivanensis* n. sp. is similar in size to *P. sellardsi* Dunbar and Skinner, *P. deliciasensis* Dunbar and Skinner, *P. wildei* n. sp., and *Parafusulina antimonioensis* Dunbar but differs from these in the mode of septal folding and shape of the lateral slopes and poles. Specimens having prominent axial deposits commonly occur in the same collection as those having thin axial deposits and a complete gradation in the amount of axial deposits suggests that *P. sullivanensis* has a wide range of morphological variation.

Occurrence.—*Parafusulina sullivanensis* is a common species in the Word Formation in the western part of the Glass Mountains. Table 1 shows the distribution of this species in collections studied. The holotype, YPM 22013, (Pl. 5, fig. 17) is from locality 3-C, about 25 feet below the top of the first limestone member of the Word Formation near the Sullivan Ranch road.

MEASUREMENTS OF
PARAFUSULINA SULLIVANENSIS
YPM SPECIMENS

	Volution	22013	22012	22017	22014
	0	.15	.15	.12	.15
	1	.30	.25	.15	.25
	2	.40	.35	.22	.35
Radius	3	.55	.45	.32	.50
vector	4	.70	.65	.45	.70
(mm.)	5	.90	.80	.65	.90
	6	1.15	1.05	.95	1.20
	7	1.45	1.30	1.35	1.50
	8	1.75	1.60	1.55	1.85
	1	.65	.50	.40	.55
	2	1.00	.90	.90	.90
Half	3	1.50	1.30	1.40	1.50
length	4	2.10	1.90	1.90	2.10
(mm.)	5	2.90	3.10	2.50	3.10
	6	4.30	4.20	3.40	4.40
	7	5.70	5.60	4.80	6.40
	8	7.40	6.40	6.30	7.50
	1	2.2	2.0	2.6	2.2
	2	2.5	2.6	4.1	2.6
	3	2.7	2.9	4.4	3.0
Form	4	3.0	2.9	4.2	3.0
ratio	5	3.2	3.9	3.8	3.4
	6	3.7	4.0	3.6	3.7
	7	3.9	4.3	3.6	4.3
	8	4.2	4.0	4.1	4.1

MEASUREMENTS OF
PARAFUSULINA SULLIVANENSIS (Continued)
YPM SPECIMENS

	Volution	22013	22012	22017	22014
	0	.02	.02	.02	.02
	1	.02	.02	.01	.01
	2	.02	.02	.02	.02
Wall	3	.03	.04	.03	.03
thickness	4	.04	.03	.03	.04
(mm.)	5	.05	.03	.04	.04
	6	.05	.04	.05	.07
	7	.07	.04	.06	.09
	8	.07	.05	.08	.09
	1	35	40	25	25
	2	30	40	25	35
Tunnel	3	30	45	25	30
angle	4	40	25	40	40
(°)	5	35	45	45	40
	6	45	....	50	45
	7	50	....	80?	....

Parafusulina wildei n. sp.

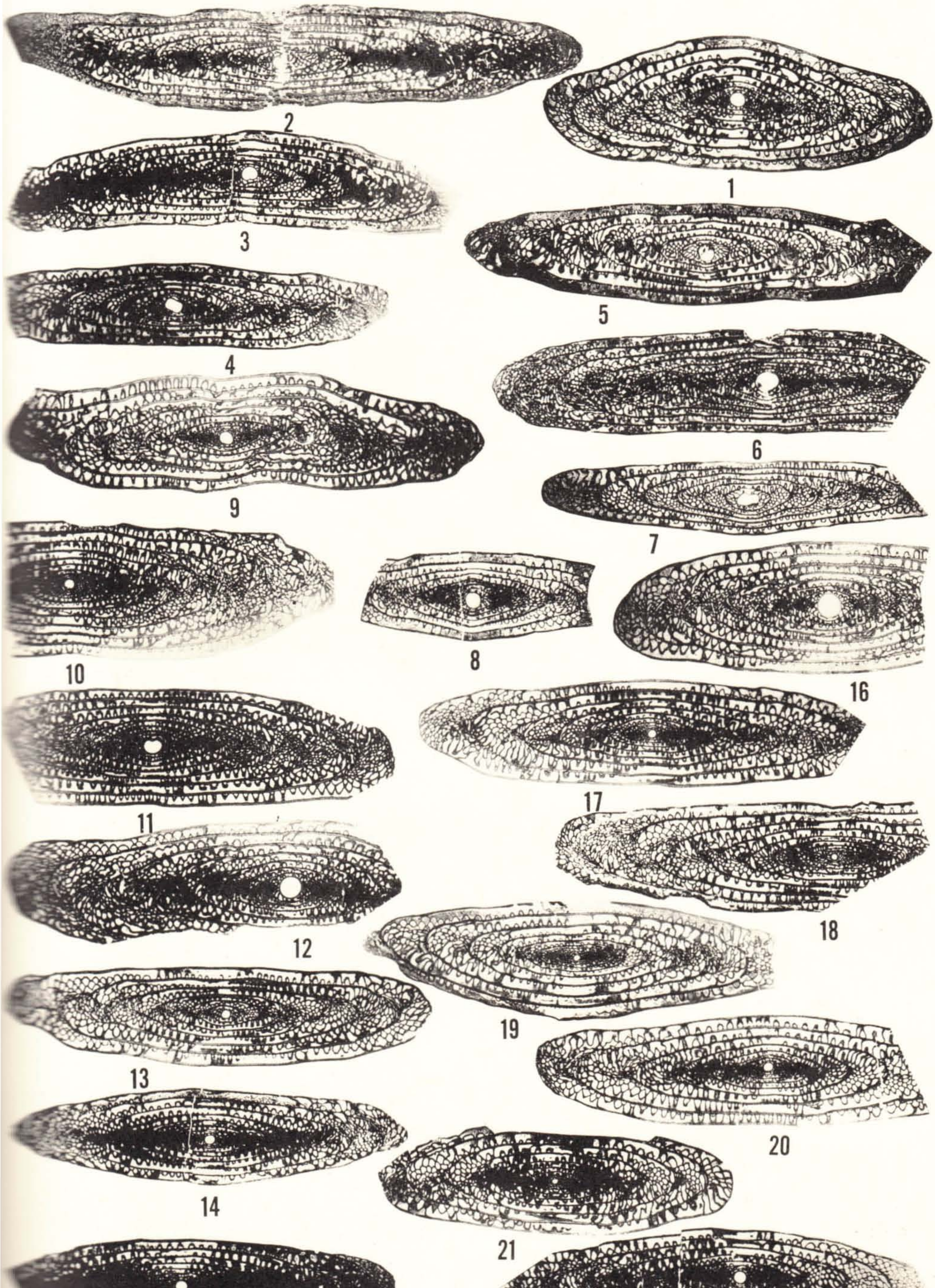
Plate 4, figures 1-7, 10

Description.—This species is elongate to subcylindrical and of 7 to 8 volutions. It commonly reaches 13 mm. in length and 3 mm. in diameter. The proloculi range between 0.2 to 0.4 mm. in diameter and early volutions are subglobose. After the second volution, the test becomes markedly elongate and the gently convex lateral slopes taper to smoothly rounded poles (Pl. 4, figs. 2, 5, 7). The wall is composed of a tectum and a thin, finely alveolar keriotheca. The septa are intensely folded into regular septal folds having rounded crests that rise to the roof of the low chambers.

Rudimentary chomata girth the proloculus but are

EXPLANATION OF PLATE 5
All figures ×5

Figs.		Page
1.	*Parafusulina splendens* Dunbar and Skinner, top of the second limestone member of the Word Formation .... 1. Slightly oblique axial section of a large individual, locality 5-34B, YPM 21997.	29
2, 3.	*Parafusulina antimonioensis* Dunbar, fourth limestone member of the Word Formation 2. Axial section, locality 4-54B, YPM 21998. 3. Axial section, locality 5A-10, YPM 21999.	28
4-8.	*Parafusulina deliciasensis* Dunbar and Skinner, lower and middle part of the Word Formation 4. Axial section, locality 4-52A, YPM 22000. 5. Axial section, locality 5-32B, YPM 22001. 6. Axial section, locality 2B, YPM 22002. 7. Axial section, locality 4-52A, YPM 22003. 8. Partial axial section, locality 7-28B, YPM 22004.	27
9-12, 16.	*Parafusulina sellardsi* Dunbar and Skinner, second and third limestone members of the Word Formation .... 9, 10, 11. Axial sections, locality 5-41A (topotypes), YPM 22005, 22006, and 22007. 12. Axial section, locality 4-47A, YPM 22008. 16. Axial section, locality 6-25, YPM 22009.	26
13-15, 17-22.	*Parafusulina sullivanensis* n. sp., lower and middle part of the Word Formation .... 13, 15. Axial sections, locality 5-37B, YPM 22010, 22011. 14, 17, 20, 22. Axial sections, locality 3-C, YPM 22012, 22013 (holotype), 22014 and 22015. 18. Axial section, locality 6-21, YPM 22016. 19. Axial section, locality 4A-3, YPM 22017. 21. Axial section, locality 4-42A, YPM 22018.	23



Ross: Permian fusulinids from Texas

lacking in the volutions. Secondary deposits commonly line the rounded crests of the septal folds above the level of the cuniculi and may fill the folds in the polar extremities (Pl. 4, figs. 2, 3, 7).

Remarks.—*Parafusulina wildei* is smaller at corresponding volutions and much more slender than *P. ringorum* Dunbar and Skinner which also has the same type of septal folds. *P. lineata* Dunbar and Skinner is more elongate and most other species of *Parafusulina* have higher volutions and more widely spaced septal folds.

MEASUREMENTS OF *PARAFUSULINA WILDEI*

YPM SPECIMENS

	Volution	Holotype 21987	21985	21983	21984
Radius vector (mm.)	0	.20	.15	.15	.20
	1	.30	.22	.30	.30
	2	.45	.30	.40	.40
	3	.55	.45	.55	.55
	4	.75	.55	.75	.75
	5	.90	.75	.95	.90
	6	1.10	.95	1.20	1.15
	7	1.35	1.20	....	1.35
	8	....	1.40	....	....
Half length (mm.)	1	.50	.45	.70	.50
	2	1.00	.80	1.25	.90
	3	1.70	1.25	1.90	1.55
	4	2.80	1.95	2.90	2.50
	5	4.10	3.20	3.70	3.40
	6	4.90	4.10	4.70	4.60
	7	5.90	5.40	....	5.90
	8	....	6.60	....	....
Form ratio	1	1.7	2.0	2.3	1.7
	2	2.2	2.7	3.1	2.2
	3	3.1	2.8	3.5	2.8
	4	3.7	3.6	3.9	3.3
	5	4.6	4.3	3.9	3.8
	6	4.5	4.3	3.9	4.0
	7	4.4	4.5	....	4.4
	8	....	4.7	....	....
Wall thickness (mm.)	0	.02	.03	.08	.02
	1	.03	.04	.03	.04
	2	.03	.04	.03	.04
	3	.04	.05	.06	.04
	4	.04	.06	.05	.06
	5	.05	.06	.06	.07
	6	.06	.08	.10	.08
	7	.07	.08	....	.08
	8	....	....	....	....
Tunnel angle (°)	1	25	30	30	....
	2	30	35	30	....
	3	35	35	30	35
	4	50	45	45	40
	5	60	50	45	45
	6	....	55	....	....

Occurrence.—*Parafusulina wildei* is rare in individual collections, but is widely distributed in the lower part of the Word Formation where it appears to have a restricted stratigraphic range. It is found at localities 4-42A, 4-46D, 5-37A, 5A-2, and 7-25 (see Table I). The holotype, YPM 21987, is from locality 6-25, about 350 feet above the base of the Word Formation (Pl. 4, fig. 5).

Parafusulina ironensis n. sp.

Plate 4, figures 13, 14, 15

Description.—A small fusiform species of the genus having 7 to 8 volutions that reaches 11 mm. in length and 2.5 mm. in diameter. The proloculi are small, between 0.15 and 0.25 mm., in specimens examined. The first two or three volutions are low and elongate and their walls are thin (0.02 mm.). Succeeding volutions increase progressively in height and the lateral slopes curve gently into the subpointed poles (Pl. 4, figs. 13, 15).

The wall is composed of a tectum and a keriotheca in which the alveoli increase in coarseness in latter volutions. The septa are thin and closely spaced (Pl. 4, fig. 14) and are folded into openly spaced, regular folds having rounded crests. Cuniculi are well developed and are high (Pl. 4, fig. 14). Chomata are lacking. Secondary deposits tend to fill the axis and the septal folds in the polar extremities of the early volutions.

Remarks.—This is a small species for the genus in this stratigraphic interval, a feature which readily separates the species from most other species in the Word Formation. *Parafusulina lineata* Dunbar and Skinner is much more slender, and *P. boesei* Dunbar and Skinner lacks the heavy axial deposits and closely-spaced

MEASUREMENTS OF *PARAFUSULINA IRONENSIS*

Volution	Radius vector (mm.)	Half length (mm.)	Form ratio	Wall thickness (mm.)	Tunnel angle (°)
YPM SPECIMEN 21994					
0	.09	....	....	.02	....
1	.15	.30	2.0	.02	20
2	.20	.55	2.7	.02	25
3	.30	.85	2.8	.02	30
4	.45	1.25	2.8	.03	30
5	.55	1.75	3.2	.04	35
6	.75	2.70	3.6	.05	35
7	.95	3.50?	3.7?	.07	....
YPM SPECIMEN 21995					
0	.09	....	....	.02	20
1	.12	.40	3.3	.01	30
2	.18	.65	3.6	.03	30
3	.28	.95	3.4	.04	35
4	.40	1.35	3.4	.04	40
5	.55	2.05	3.7	.05	....
6	.80	3.50	4.4	.06	....

septa. The high and well-developed cuniculi of *P. ironensis* contrast markedly with the low cuniculi found in Leonardian species of about the same size.

Occurrence.—Parafusulina ironensis is known from a single locality, 5-33A, in the upper part of the first limestone member of the Word Formation on the Iron Mountain Ranch, from which the species takes its name.

MEASUREMENTS OF
PARAFUSULINA SELLARDSI
YPM SPECIMENS

	Volution	22005	22007	22008
	0	.25	.30	.35
	1	.32	.40	.45
	2	.45	.55	.65
Radius	3	.60	.70	.85
vector	4	.80	.85	1.10
(mm.)	5	1.05	1.10	1.40
	6	1.35	1.30	1.75
	7	1.65	1.60	2.10
	8	....	1.90	....
	1	.60	.70	1.00
	2	1.10	1.10	1.90
Half	3	1.80	1.60	2.60
length	4	2.30	2.50	3.50
(mm.)	5	4.60	3.70	5.90
	6	5.80	4.70	7.80
	7	7.40	6.40	9.10
	8	....	7.80?	....
	1	1.9	1.8	2.2
	2	2.5	2.0	2.9
	3	3.0	2.3	3.1
Form	4	2.9	2.9	3.2
ratio	5	4.4	3.4	4.2
	6	4.3	3.6	4.5
	7	4.5	4.0	4.3
	8	....	4.1?	....
	0	.04	.06	.03
	1	.04	.04	.03
	2	.03	.04	.04
Wall	3	.05	.04	.04
thickness	4	.06	.06	.06
(mm.)	5	.04	.08	.07
	6	.08	.09	.08
	7	.08	.09	.10
	8	....	.10	....
	1	25	20	20
	2	25	30	20
Tunnel	3	30	40	30
angle	4	35	40	35
(°)	5	50	40	45
	6	....	45	....
	7	....	....	....

Parafusulina sellardsi Dunbar and Skinner

Plate 4, figure 8, Plate 5, figures 9-12, 16

Parafusulina sellardsi DUNBAR and SKINNER, 1937, p. 688, pl. 78, figs. 1-11; DUNBAR, 1944, p. 44, pl. 11, fig. 2, pl. 14, figs. 1-4.

Description.—A large, subcylindrical species of 7 to 9 volutions that commonly reaches 18 to 20 mm. in length and 3.5 to 4.0 mm. in diameter. The proloculi in specimens measured range from 0.3 to 0.8 mm. outside diameter. The first 2 or 3 volutions, particularly in specimens having the smaller proloculi, are low and elongate so that the test attains its characteristic shape early in its ontogeny. The succeeding volutions gradually increase in height and length and their lateral slopes which meet in broad, rounded poles are gently convex. (Pl. 5, figs. 9, 10, 11).

The wall is composed of a tectum and a keriotheca which is thin in early volutions, but becomes thick in later volutions where it displays coarse alveoli. The septa are thick (Pl. 4, fig. 8) and are folded into high, regular septal folds.

The tunnel is of medium width and the tunnel angle commonly reaches 45 degrees in the sixth volution. Chomata are lacking and thick secondary deposits coat the septa mainly in the first three volutions. Cuniculi are well developed.

Remarks.—Parafusulina sellardsi is smaller and stouter than *P. wordensis* Dunbar and Skinner and it is stouter than species of similar size such as the elongate species *P. deliciasensis* Dunbar and Skinner, *P. sullivanensis* n. sp., and *Parafusulina* sp. A.

Occurrence.—The syntypes of *Parafusulina sellardsi* Dunbar and Skinner (1937, p. 816) are from the third limestone member of the Word Formation near the top of the hill that is one mile south of the junction of Road and Gilliland Canyons, Glass Mountains, Texas. The collections examined in this study that contain *P. sellardsi* are shown in Table 1.

Parafusulina boesei Dunbar and Skinner

Plate 3, figures 1-10

Parafusulina bösei DUNBAR and SKINNER, 1937, p. 679, pl. 73, figs. 1-9; DUNBAR, 1944, p. 41, pl. 11, figs. 3-7.

Parafusulina bösei var. *attenuata* DUNBAR and SKINNER, 1937, p. 680, pl. 74, figs. 5-13.

Description.—This fusiform species commonly reaches 10 to 11 mm. in length and 3 to 4 mm. in diameter in 7 volutions. The proloculi range from 0.25 to 0.40 mm. in diameter, the larger ones are commonly irregular. The first one or two volutions are low and have thin walls but succeeding volutions gradually increase in height and their walls become progressively thicker. The lateral slopes are convex and taper to evenly rounded poles.

The wall is composed of a tectum and a thin keriotheca having well-defined, fine alveoli. The septa are widely spaced and are folded into high, regular folds that are openly spaced. Cuniculi are low and well displayed in the fifth volution.

Chomata are lacking and the tunnel occupies the lower half of the chambers. The tunnel angle increases from about 30° in the second volution to as much as 60° in the fifth. The tunnel may be incompletely developed, as in the fourth volution of Pl. 3, fig. 7.

Remarks.—The variation within this species is remarkable and includes such widely diverse individuals as small elongate forms (Pl. 3, figs. 5, 6) and large fusiform forms (Pl. 3, figs. 2, 7) with gradational forms in between (Pl. 3, figs. 4, 9, 10). As the variation within the species is considerable and greater than was suggested by Dunbar and Skinner (1937) when they separated the variety *attenuata* for the more elongate

MEASUREMENTS OF *PARAFUSULINA BOESEI*
YPM SPECIMENS

	Volution	21969	21970	21972	21975
	0	.18	.15	.12	.20
	1	.25	.30	.18	.32
Radius	2	.38	.45	.30	.45
vector	3	.55	.60	.45	.65
(mm.)	4	.75	.80	.65	.85
	5	.98	1.05	.80	1.10
	6	1.25	1.30	1.20	1.40
	7	....	....	1.55	....
	1	.75	.85	.40	.60
	2	1.10	1.10	.75	1.35
Half	3	2.40	1.65	1.40	1.90
length	4	3.50	2.10	2.00	2.30
(mm.)	5	5.10	2.70	2.85	3.80
	6	6.30	3.20	3.90	5.10
	7	....	....	5.10	....
	1	3.0	2.8	2.2	1.9
	2	2.8	2.4	2.5	3.0
Form	3	4.4	2.8	3.1	2.9
ratio	4	4.7	2.6	3.1	2.7
	5	5.2	2.6	3.6	3.5
	6	5.0	2.4	3.2	3.6
	7	....	....	3.2	....
	0	.03	.03	.02	.04
	1	.04	.03	.02	.03
Wall	2	.04	.03	.02	.04
thickness	3	.04	.04	.06	.06
(mm.)	4	.06	.05	.08	.08
	5	.08	.07	.08	.09
	6	....	.07	.08	.09
	7	....	....	.09	....
	1	25	25	25	25
Tunnel	2	28	35	30	35
angle	3	35	40	30	50
(°)	4	40	45	45	30
	5	40	....	35	60

forms, the species is here recognized as a single taxon with wide morphological limits.

The species is most comparable to late Leonardian species such as *Parafusulina durhami* Thompson and Miller (see Ross, 1962) and *P. leonardensis* Ross which differ in having more irregular septal folds and subcylindrical shapes. It seems possible that *P. boesei* is a later representative of this lineage of the genus *Parafusulina*. *P. boesei* differs from *P. wildei* n. sp. in its septal folds and chamber heights. It is larger than *P. ironensis* n. sp. and has more widely spaced septa and fewer secondary deposits. It is smaller than *P. sellardsi* Dunbar and Skinner and most other species of *Parafusulina* from the Word Formation.

Lectotype.—Here designated as the specimen illustrated by Dunbar and Skinner (1937, pl. 73, fig. 6) from near the middle part of the Word Formation, about 410 feet above its base, on the south slope of Sullivan Peak, Glass Mountains, Texas.

Occurrence.—The types of both *Parafusulina boesei* and *P. boesei* var. *attenuata* are from the same collection on the south slope of Sullivan Peak. Dunbar and Skinner (1937) report occurrences elsewhere in the lower part of the Word Formation in the western part of the Glass Mountains. Table 1 shows the distribution of this species in the collections examined in this study.

Parafusulina deliciasensis Dunbar and Skinner

Plate 5, figures 4-8

Parafusulina deliciasensis DUNBAR and SKINNER, 1936, p. 179, pl. 1, figs. 1-9; DUNBAR, 1944, p. 42, pl. 12, figs. 1-9.

Parafusulina maleyi DUNBAR and SKINNER, 1937, p. 686, pl. 77, figs. 1-12.

Parafusulina maleyi var. *referta* DUNBAR and SKINNER, 1937, p. 687, pl. 77, figs. 13-18.

Description.—This elongate species commonly reaches 19 to 20 mm. in length and 3.5 mm. in diameter in 8 volutions. The proloculi are large, 0.3 to 0.7 mm. in diameter, and usually are irregular in shape. The lateral slopes taper gently into the acutely rounded poles. Septa are closely folded into regularly spaced folds having rounded crests. The walls of the proloculi are thin as are the septa, the spiral wall is of medium width and the finely alveolar structure of the keriotheca is well displayed. The tunnel widens gradually and the tunnel angle reaches 40 degrees in the fourth or fifth volution. Chomata are lacking and light secondary deposits may line the polar extremities of the inner volutions.

Remarks.—This is one of the more abundant species in the Word Formation and the range of variation includes with continuous gradation both *Parafusulina maleyi* and *P. maleyi* var. *referta* described by Dunbar and Skinner (1937). It has very thin walls and septa in comparison to *P. sellardsi* Dunbar and Skinner, *P.*

sullivanensis n. sp., and *Parafusulina antimonioensis* Dunbar and a different shape in comparison to *P. boesei* Dunbar and Skinner.

Occurrence.—Dunbar and Skinner found *Parafusulina maleyi* and its variety *referta* (= *P. deliciasensis* Dunbar and Skinner) in the lower and middle divisions of the Delaware Mountain Sandstone, Guadalupe Mountains, and designated several unsectioned specimens as cotypes. The localities containing *P. deliciasensis* in the Word Formation in the Glass Mountains is shown in Table 1.

MEASUREMENTS OF
PARAFUSULINA DELICIASENSIS
YPM SPECIMENS

	Volution	22001	22002	22003
	0	.30	.35	.15
	1	.40	.50	.35
	2	.55	.60	.50
Radius	3	.75	.70	.60
vector	4	1.00	.90	.80
(mm.)	5	1.25	1.00	1.00
	6	1.55	1.20	1.20
	7	....	1.40	....
	8	....	1.60	....
	1	.75	.80	.90
	2	1.40	1.20	1.70
Half	3	2.40	2.50	2.40
length	4	3.80	3.60	3.40
(mm.)	5	5.00	5.50	4.70
	6	6.40	6.80	6.60
	7	....	7.50	....
	8	....	8.20	....
	1	1.9	1.6	2.6
	2	2.8	2.0	3.4
	3	3.2	3.6	4.0
Form	4	3.8	4.0	4.3
ratio	5	4.0	5.5	4.7
	6	4.1	5.7	5.5
	7	....	5.4	....
	8	....	5.1	....
	0	.02	.01	.02
	1	.03	.02	.02
	2	.03	.02	.03
Wall	3	.04	.03	.03
thickness	4	.05	.04	.03
(mm.)	5	.05	.04	.04
	6	.06	.05	.04
	7	....	.05	....
	8	....	.05	....
	1	35	35	30
Tunnel	2	35	40	40
angle	3	45	40	35
(°)	4	50	40	40
	5	....	35	....
	6	....	40	....

Lectotype.—Dunbar (1944, p. 135) selected as the lectotype the specimen illustrated as pl. 1, fig. 2, by Dunbar and Skinner (1936), YPM 14674, from near El Tordillo, near Las Delicias, Coahulia, Mexico.

Parafusulina antimonioensis Dunbar

Plate 5, figures 2, 3

Parafusulina antimonioensis DUNBAR, 1953, p. 15, pl. 2, figs. 1-8, pl. 3, figs. 1-3.

Discussion.—A large, elongate to subcylindrical species that commonly reaches 18 to 20 mm. in length and 3 mm. in diameter in 6 to 7 volutions. The proloculi are large, 0.20 to 0.50 mm. in specimens examined, and the first volution is thickly fusiform. Succeeding volutions increase markedly in length and are low across the center of the test so as to give the test an elongate shape. The lateral slopes taper irregularly to subpointed poles (Pl. 5, figs. 2, 3).

The septa are folded into openly spaced folds that nearly reach the top of the chambers. Tunnel angle may reach 50° in the third volution and the tunnel is high, occupying the entire height of the chambers. Chomata are lacking but axial deposits fill the septal folds in the polar extremities (Pl. 5, figs. 2, 3).

Remarks.—*Parafusulina antimonioensis* differs from other large species from the Word Formation in its elongate to subcylindrical shape, its heavy axial deposits and its low septal folds. It is larger than *P. lineata* Dunbar and Skinner and has less closely folded and thicker septa than *P. deliciasensis* Dunbar and Skinner and *P. wildei* n. sp.

MEASUREMENTS OF
PARAFUSULINA ANTIMONIOENSIS

Volution	Radius vector (mm.)	Half length (mm.)	Form ratio	Wall thickness (mm.)	Tunnel angle (°)
YPM SPECIMEN 21998					
0	.22	....	....	.03	....
1	.35	.80	2.3	.03	30?
2	.50	1.50	3.0	.04	35?
3	.65	2.70	4.2	.04	40?
4	.85	4.10	4.8	.04	45?
5	1.05	5.50	5.2	.04	....
6	1.30	6.80	5.2	.06	....
7	1.55	9.00?	5.8?	.05	....
YPM SPECIMEN 21999					
0	.25	....	....	.02	....
1	.30	.80	2.7	.03	40
2	.45	1.90	4.2	.04	45
3	.60	3.20	5.3	.04	55
4	.80	4.90	6.1	.04	50
5	1.10	7.40	6.7	.06	60
6	1.40	9.00?	6.4	.08	...

Occurrence.—Parafusulina antimonioensis is rare but is apparently widely distributed in the fourth limestone member of the Word Formation in the central part of the Glass Mountains. It is known from localities 4-54B, 4-54C, 5-47, and 5A-16. The type specimens described by Dunbar (1953) are from near the Moreno house, 2¼ miles northeast of El Antimonio, Sonora, Mexico.

MEASUREMENTS OF
PARAFUSULINA SPLENDENS
YPM SPECIMENS

	Volutions	22019	22020	21997
	0	.18	.20	.22
	1	.25	.35	.35
	2	.35	.45	.50
Radius	3	.50	.60	.70
vector	4	.65	.80	.80
(mm.)	5	.90	1.10	1.25
	6	1.20	1.40	1.55
	7	1.40?	....	1.75
	8	....	....	2.20
	1	.50	.50	.80
	2	.85	1.10	1.40
Half	3	1.35	1.60	1.90
length	4	1.90	2.35	2.80
(mm.)	5	2.40	3.40	3.60
	6	3.60	4.80	4.80
	7	4.80	....	5.60
	8	....	....	6.20
	1	2.0	1.4	2.3
	2	2.4	2.5	2.8
	3	2.7	2.7	2.7
Form	4	2.9	2.9	3.5
ratio	5	2.7	3.1	2.9
	6	3.0	3.4	3.1
	7	3.4	....	3.2
	8	....	....	2.8
	0	.02	.03	.03
	1	.02	.03	.03
Wall	2	.02	.03	.04
thickness	3	.03	.05	.04
(mm.)	4	.04	.05	.04
	5	.06	.08	.05
	6	.08	.08	.05
	7	.08	....	.07
	8	....	....	.05
	1	30	40	30
Tunnel	2	30	45	30
angle	3	30	45	40
(°)	4	45	50	40
	5	40	....	40
	6	....	....	40

Parafusulina splendens Dunbar and Skinner

Plate 4, figures 11, 16, 17; Plate 5, figure 1

Parafusulina splendens DUNBAR and SKINNER, 1937, p. 682, pl. 75, figs. 1-11; pl. 73, fig. 10.

Description.—This fusiform species reaches a length of 15 mm. and a diameter of 4 mm. in 8 volutions. The proloculi are large, 0.3 to 0.5 mm. in diameter in specimens examined, and the early volutions are low and short. Succeeding volutions gradually increase in height and length giving the mature test a fusiform shape. The lateral slopes are gently convex and taper smoothly into small, rounded poles (Pl. 4, fig. 17).

The wall is composed of a tectum and a keriotheca which thickens in the outer four volutions where the alveoli become coarse. The septa are folded into high, regular folds (Pl. 4, figs. 16, 17) and cuniculi are well developed.

The tunnel reaches about one-half chamber height and the tunnel angle reaches 50 degrees in the sixth or seventh volution. Rudimentary chomata girth the proloculus but are lacking in the volutions. Secondary deposits are particularly distinct and heavily coat the septal folds in the first three volutions of mature tests (Pl. 4, figs. 16, 17).

Remarks.—Parafusulina splendens differs from other species of the genus of similar size in having high volutions which taper to small, rounded poles and in having heavy secondary deposits on the lateral slopes of the first two or three volutions.

Occurrence.—Dunbar and Skinner (1937) described the syntypes of this species from near the middle part of the Word Formation near Sullivan Peak and also reported the species from near the top of the "Clay Slide." Table 1 shows its occurrence at localities examined in this study.

Parafusulina lineata Dunbar and Skinner

Plate 3, figures 12, 13

Parafusulina lineata DUNBAR and SKINNER, 1937, p. 681, pl. 74, figs. 1-4.

Discussion.—This small and very slender species for the genus reaches 14 mm. in length and 2.0 to 2.4 mm. in diameter in 7 to 8 volutions. The volutions are low, septa are regularly and intensely folded, and the tunnel is wide (tunnel angle about 55° in the fourth volution). The wall is thin and the alveolar structures are well displayed in the thin keriotheca. Secondary deposits are poorly represented and chomata are lacking. This species is rare in the Glass Mountains but the specimens studied agree in all aspects with the holotype and paratypes described by Dunbar and Skinner (1937).

Occurrence.—The holotype (YPM 15123) and paratypes (YPM 15124 and 15181) are from the lower part of the Delaware Mountain Sandstone, Guadalupe Mountains, four miles south-southeast of Guadalupe

Point. In the Glass Mountains, this species occurs in a thin calcarenite (biosparite) bed in the lower part of the first limestone member of the Word Formation (locality 4A-3).

MEASUREMENTS OF *PARAFUSULINA LINEATA* YPM SPECIMEN 21980

Volution	Radius vector (mm.)	Half length (mm.)	Form ratio	Wall thickness (mm.)	Tunnel angle (°)
0	.12			.02	
1	.18	.25	1.4	.02	25
2	.25	.80	3.2	.03	40
3	.35	1.40	4.0	.03	45
4	.50	2.50	5.0	.03	55?
5	.70	3.70	5.3	.03	....
6	.80	4.70	5.9	.04	....
7	.95	5.60	5.9	.04	....

Parafusulina sp. A

Plate 3, figure 11

Discussion.—A single specimen shows this species to be formed of 9 to 10 volutions that reach 12 mm. in length and 3.5 mm. in diameter. The proloculus is 0.30 mm. in diameter and the first volution is short and low, having thin walls. Succeeding volutions increase markedly in length although the chamber height remains low. The lateral slopes are gently convex and meet in broadly rounded poles. The last volution may be aberrant and irregular protuberances may be present (Pl. 3, fig. 11).

The wall is composed of a tectum and keriotheca which has fine to medium alveoli. The septa are folded into low, closely spaced folds that reach to about one-half chamber height. The folds become more widely spaced in older volutions but remain low. The septa are numerous as seen in Pl. 3, fig. 11 which is cut slightly obliquely to the direction of growth in the outer volutions. The tunnel path is very irregular. Chomata are lacking but heavy secondary deposits completely fill the chambers in the axial region of the inner volutions.

Remarks.—*Parafusulina* sp. A differs from other large species of *Parafusulina* in the Word Formation such as *P. sellardsi* Dunbar and Skinner, *P. kingorum* Dunbar and Skinner, and *P. wordensis* Dunbar and Skinner in having heavy axial deposits and low septal folds. It also appears to be the only species of *Parafusulina* in the Word Formation showing a trend toward aberrant growth in the last volution although this may possibly be the result of injury.

Occurrence.—This species is known from the middle part of the second limestone member of the Word Formation at locality 4-46D.

MEASUREMENTS OF *PARAFUSULINA* sp. A YPM SPECIMEN 21979

Volution	Radius vector (mm.)	Half length (mm.)	Form ratio	Wall thickness (mm.)	Tunnel angle (°)
0	.15	....	....	.05?	...
1	.25	.40	1.6	.02	25
2	.32	.75	2.3	.02	25
3	.45	1.15	2.6	.04	30
4	.60	1.60	2.7	.04	40
5	.75	2.20	2.9	.05	45
6	.95	2.80	3.0	.07	....
7	1.20	3.40	2.8	.08	....
8	1.50	4.40	2.9	.09	....
9	1.80	6.10	3.4	.08	....

MISCELLANEOUS COLLECTING LOCALITIES WORD FORMATION

1. Second or third limestone member, 3.5 miles N 28° E of the Hess Ranch house, in gully by road. *Parafusulina wildei*?
2. Base of fourth limestone member, 4.7 miles N 31° E of the Hess Ranch house, at 5250 feet elevation. Coll. 2-A, 12 feet above base of limestone ledge; *Parafusulina antimonionensis*?. Coll. 2-B, 16 feet above the base of limestone ledge; *P. deliciasensis.*
3. Basal limestone, 1.3 miles S 55° E of Sullivan Peak (BM 6125), on ridge north of road to old Sullivan Ranch house. Coll. 3-C, 20 feet above base of exposure; *Parafusulina sullivanensis.* Coll. 3-D, 25 feet below top of limestone; *P. boesei.* Coll. 3-E, 6 feet below top of limestone; *P. boesei.*
4. Basal limestone, 3.9 miles N 36° W of old Skinner Ranch house (at Iron Mountain); *Parafusulina deliciasensis* and *P. sellardsi*?
5. Basal limestone, at the locality called the "Clay Slide," 2.6 miles S 86° E of Sullivan Peak (BM 6125) where the section is as follows:

Top of ridge Word Formation	Thickness in feet
4. Calcilutite, light gray, 1-inch beds, a few calcarenite lenses about 20 feet above base of unit containing *Parafusulina sullivanensis*	37
3. Calcilutite and calcarenite, light to medium gray, lenticular bedding	23
2. Sandstone and chert, black-to-orange weathering, with minor lenses of calcarenite, 2-inch beds	14
1. Shale, yellow-to-orange weathering, very silty and sandy, mostly covered	about 110

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KNIGHT, R. L., 1956, Permian fusulines from Nevada: Jour. Paleontology, v. 30, p. 773-792.

MILLER, A. K. and FURNISH, W. M., 1957, Ammonoids of the basal Word Formation, Glass Mountains, Texas: Jour. Paleontology, v. 31, p. 1052-1056.

MORIKAWA, ROKURD, and HORIGUCHI, MANKICHI, 1956, *Parafusulina nakamigawai* n. sp. from the Adoyama Formation in the neighborhood of Kuzu City, Tochigi Prefecture: Saitama Univ. Sci. Repts., ser. B, v. II, p. 261-264.

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ROSS, C. A., 1959, The Wolfcamp Series (Permian) and new species of fusulinids, Glass Mountains, Texas: Wash. Acad. Sci., Jour., v. 49, p. 299-316.

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THOMPSON, M. L., WHEELER, H. E., and HAZZARD, J. C., 1946, Permian fusulinids of California: Geol. Soc. America, Memoir 17, 77 p.

UDDEN, J. A., 1917, Notes on the geology of the Glass Mountains: Texas Univ., Bull. 1753, p. 3-59.

CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
FOR FORAMINIFERAL RESEARCH
VOLUME XIV, PART 1, JANUARY, 1963

RECENT LITERATURE ON THE FORAMINIFERA

Below are given some of the more recent works on the Foraminifera that have come to hand.

ANTROPOV, I. A. Foraminifery Devona Tatarii.—Akad. Nauk SSSR, Kazanskij Filial, Izvestija, ser. geol. nauk, No. 7, 1959, p. 11-34, pl. 1, tables 1-7.—Four new species and 1 new genus, *Uslonia* (type species *U. permira* sp. nov.), in the Devonian.

AYALA-CASTANARES, AGUSTIN, and FURRAZOLA-BERMUDEZ, GUSTAVO. *Nummoloculina heimi* Bonet en el Cretacico Inferior de Cuba.—Univ. Nac. Auto. de Mexico, Instit. Geol., Paleont. Mex. No. 12, 1962, p. 1-9, pls. 1, 2, text figs. 1-4 (maps, graphs).

BALDI, T., KECSKEMETI, T., NYIRO, M. R., and DROOGER, C. W. Neue Angaben zur Grenzziehung zwischen Chatt und Aquitan in der Umgebung von Eger (Nordungarn).—Ann. Hist.-Nat. Mus. Nat. Hungarici, tom. 53, 1961, p. 67-132, pls. 1-4, text figs. 1-10 (map, geol. section, photomicrographs, drawing, columnar sections).—Many Foraminifera are listed and a few of both larger and smaller Foraminifera are described; 3 are new.

BARTENSTEIN, HELMUT. Taxionomische Revision und Nomenklator zu Franz E. Hecht "Standard-Gliederung der Nordwest-deutschen Unterkreide nach Foraminifera" (1938). Teil 3: Apt.—Senckenbergiana lethaea, Band 43, Nr. 2, May 16, 1962, p. 125-134.

Neue Foraminiferen aus Unterkreide und Oberkeuper NW-Deutschlands und der Schweiz.—Senckenbergiana lethaea, Band 43, Nr. 2, May 16, 1962, p. 135-149, pl. 15, text figs. 1-3 (range and abundance charts).—Seven species (6 new) are described.

BELMOUSTAKOV, E. Stratigraphie du Paléogène Inférieur des plateaux de la Bulgarie Septentrionale (French résumé of Bulgarian text).—Bull. "Strasimir Dimitrov" Instit. Geol., Bulgarian Acad. Sci., v. 10, 1962, p. 89-118, text figs. 1-13 (geol. sections), tables 1, 2, 3 maps.—Zonation by planktonics and nummulites.

BOLLI, HANS M. *Globigerinopsis*, a new genus of the foraminiferal family Globigerinidae.—Eclogae Geol. Helvetiae, v. 55, No. 1, 1962, p. 281-284, pl. 1.—A globigerinid with spiroumbilical aperture from the *Globorotalia fohsi robusta* zone of eastern Venezuela and the Dominican Republic.

BORSETTI, A. M. Una microfauna Oligocenica delle marne variegate di Vigoleno (Piacenza).—Nota preliminare.—Mem. Soc. Geol. Ital., v. 3, 1962, p. 379-393, text figs. 1, 2 (graphs), illustrated range chart.—Ranges in Europe and America are indicated for 85 species from this lower Oligocene fauna.

BRAZHNIKOVA, N. E. *Quasiendothyra* i Blizkie k nim formy iz Nizhnego Karbona Donethkogo Bassejna i Drugikh Rajonov Ukrainy.—Akad. Nauk URSR, Kiev, Instyt. geol. nauk, Trudy, ser. strat. pal., vyp. 44, 1962, p. 3-48, pls. 1-14, evolutionary diagram.—Illustrated systematic catalog of species of *Quasiendothyra, Dainella* gen. nov. and *Loeblichia*, 4 species new.

CATI, F. Ricerche micropaleontologiche nella *scaglia cinerea* Marchigiana.—Mem. Soc. Geol. Ital., v. 3, 1962, p. 429-434.—Four planktonic Foraminifera zones between lower Eocene and lower Miocene.

CHANG, LI-SHO. Tertiary planktonic foraminiferal zones of Taiwan and overseas correlation.—Mem. Geol. Soc. China, No. 1, July 1962, p. 107-112, pls. 1, 2, table 1 (correl. table).—Illustrations of 10 species and subspecies of planktonics useful in zonation, one subspecies new.

CHANG, YI-MAW. A taxonomic note on the Foraminifera "*Textularia hosonoi* Ishizaki."—Proc. Geol. Soc. China, No. 5, April 1962, p. 141-143, pl. 1.—A junior synonym of *Dorothia karreri* (Stache).

COUREL, LOUIS. Découverte de Foraminifères dans le Trias de la bordure nord-est du Massif central (Note préliminaire).—C. R. S. Soc. Géol. France, No. 7, June 18, 1962, p. 198-200, text figs. a-h.

FUJII, KEIZO. Foraminifera in the vicinity of Odose, Nishitsugaru-gun, Aomori Prefecture.—Bull. Geol. Survey Japan, v. 13, No. 4, April, 1962, p. 31-38, text figs. 1, 2 (columnar section, map), tables 1-3. —Quantitative analysis shows a lower zone of *Operculina* and shallow water species and an upper zone correlated with the *Globorotalia fohsi barisanensis* zone.

GEIGER, M. E. Planktonic foraminiferal zones in the Upper Tertiary of Taranaki, New Zealand.—New Zealand Jour. Geol. Geophys., v. 5, No. 2, May 1962, p. 304-308, text figs. 1, 2 (map, range chart).—Seven zones and 4 subzones are recognized between Oligocene and Recent. Restricted ranges of 35 planktonic and 44 benthonic species are indicated.

GIMBREDE, LOUIS DE A. Evolution of the Cretaceous foraminifer *Kyphopyxa christneri* (Carsey).—Jour. Paleontology, v. 36, No. 5, Sept. 1962, p. 1121-1123, text figs. 1-3 (map, columnar section, line drawings).—Progressive change from *Palmula suturalis* within 30 feet of Austin Chalk.

HAGN, H., HÖLZL, O., and HRUBESCH, K. Zur Gliederung des Oligozäns im östlichen Oberbayern und in Nordtirol.—Neue Jahrb. Geol. Paläont. Mh., v.

8, Aug. 1962, p. 423-447, text fig. 1 (map), table 1 (correl. table)—A few smaller Foraminifera useful in marking lower and upper boundaries of the Oligocene.

HENBEST, L. G. *Endothyra bowmani* Phillips, [1846] v. *Endothyra bowmani* Brown, 1843 (Foraminifera).—Bull. Zool. Nomenclature, v. 19, pt. 4, July 16, 1962, p. 199-201.—In favor of *E. bowmani* Phillips, 1846, as type species of *Endothyra* Phillips, 1846.

VON HILLEBRANDT, AXEL. Das Paleozän und seine Foraminiferenfauna im Becken von Reichenhall und Salzburg.—Abhandl. Bayer. Akad. Wissenschaften, München, Math.-nat. Klasse, n. f., heft 108, 1962, p. 1-182, pls. 1-15, text figs. 1-12 (drawings, range chart, correl. chart).—An illustrated systematic catalog includes 257 species and subspecies (10 species new). Seven zones are recognized, extending from Danian to Ilerdian.

Nummulites (?) *paleocaenicus* n. sp., eine neue Nummuliten-Art aus dem Paleozän des Beckens von Reichenhall und Salzburg.—Mitteil. Munich Bayer. Staatssammlung Paläont. hist. Geol., heft 2, August 1, 1962, p. 1-7, pls. 1, 2, text figs. 1, 2, table 1 (correl. chart).—A small (0.5 mm. diameter) primitive nummulite with trochospiral initial part, from the middle Paleocene.

HOFKER, J. Les Foraminifères du Tuffeau arénacé de Folx-les-Caves.—Ann. Soc. Geol. Belgique, tome 84, June 1961, p. 549-579, 11 pls. (bearing figs. 1-73), text figs. 1, 2 (sections).—The fauna (one species new) is listed and illustrated and is regarded as upper Santonian or very low Campanian.

Foraminifera from the Cretaceous of South-Limburg, Netherlands. LVII. Some Foraminifera from the lower Paleocene above the Md in the quarry Curfs, near Houthem.—Natuurhist. Maandblad, Jrg. 51, No. 1, Jan. 1, 1962, p. 8-11, text figs. 1-9. —Nine species, 4 new.

LVIII. *Gaudryina supracretacea* Hofker.—Natuurhist. Maandblad, Jrg. 51, No. 2, Feb. 28, 1962, p. 26, 27, text figs. 1-6.—A guide fossil first appearing below the Cretaceous-Danian boundary and ending some time above it.

LIX. The genus *Nonionella* in the Upper Cretaceous of Holland.—Natuurhist. Maandblad, Jrg. 51, No. 3, March 31, 1962, p. 35-37, text figs. 1-8. —An evolution from older to younger beds proceeds from *N. troostae* (including 2 new subspecies) through *N. cretacea* to *N. soldadoensis*.

LX. The evolution of *Daviesina fleuriausi* (d'Orbigny) in the Maestrichtian Tuff Chalk.—Natuurhist. Maandblad, Jrg. 51, No. 6, June 27, 1962, p. 79-82, text figs. 1-17.—Using morphologic characters of size, shape, and ornamentation, 4 named forms are recognized as useful for the finer subdivision of the section.

Änderung des Generationswechsels der Foraminiferen-Arten während der Periode ihres Daseins.—Neue Jahrb. Geol. Paläont. Mh., Band 6, June 1962, p. 316-329.—A change of mode of reproduction may result in the appearance of different generations simulating the splitting off of new species.

Correlation of the Tuff Chalk of Maestricht (type Maestrichtian) with the Danske Kalk of Denmark (type Danian), the stratigraphic position of the type Montian, and the planktonic foraminiferal faunal break.—Jour. Paleontology, v. 36, No. 5, Sept. 1962, p. 1051-1089, text figs. 1-28 (maps, columnar sections, outcrop photographs, diagrams, line drawings.).—Orthogenetic sequences of Foraminifera indicate that type Danian belongs in uppermost Cretaceous, beneath the Cretaceous-Tertiary planktonic foraminiferal faunal break, and that where a distinct orthogenetic gap exists, Danian is lacking. Species characteristic of various parts of the Upper Cretaceous to Montian sequence are illustrated.

HORNIBROOK, N. DE B. The Cretaceous-Tertiary boundary in New Zealand.—New Zealand Jour. Geol. Geophys., v. 5, No. 2, May 1962, p. 295-303, text fig. 1 (graph), tables 1-3.—The sequence, extending from typical Maestrichtian planktonics through the zone of *Globigerina triloculinoides* to the initial appearance of keeled species of *Globorotalia*, coincides with similar sequences from most other parts of the world.

HOTTINGER, LUKAS. Recherches sur les Alvéolines du Paléocène et de l'Eocène.—Schweizer. Pal. Abhandl., Basel, v. 75/76, 1960, p. 1-243, pls. 1-18 (in atlas), text figs. 1-117 (diagrams, range charts, maps, drawings, photographs, graphs, columnar sections, geol. sections), table 1.—About 75 species and subspecies (43 species and 2 subspecies new) are classified in 19 groups, and their restricted ranges in 16 biozones of the Paleocene and Eocene shown. Illustrated by excellent photomicrographs.

HUANG, TUNYOW. Notes on *Elphidium tikutoensis* Nakamura, 1937.—Mem. Geol. Soc. China, No. 1, July 1962, p. 193-195, pl. 1, text fig. 1 (map).—Clarification of a misinterpreted specimen, and illustration of 2 species from the Pliocene and Pleistocene of western Taiwan.

Upper Pleistocene Foraminifera from Lungkang, near Miaoli, Taiwan.—Mr. K. Y. King's 60th Birthday Jubilee Volume (1), Petroleum Geol. of Taiwan, July 1962, p. 167-172, pl. 1, text figs. 1, 2 (map, diagram).—Quantitative analysis of a small fauna, dominated by *Ammonia beccarii* and including redeposited specimens.

HUANG, TUNYOW, and LEE, P. J. Stratigraphy of the Kuanyin Well, Taoyuan, and its relation to that of the Peikang well, Yunlin, Taiwan.—Mr. K. Y. King's 60th Birthday Jubilee Volume (1), Petroleum Geol. of Taiwan, July 1962, p. 67-74, text fig. 1 (columnar sections), tables 1, 2.—Nine zones between Miocene and lower Pleistocene based on Foraminifera. Occurrence and abundance of the rich fauna is shown in one well and its correlation indicated with the other well.

ISHIZAKI, KUNIHIRO. Stratigraphical and paleontological studies of the Onogahara and its neighbouring area, Kochi and Ehime Prefectures, southwest Japan.—Sci. Repts. Tohoku Univ., Sendai, 2nd Ser. (Geol.), v. 34, No. 2, August 1962, p. 95-185, pls. 7-12, text figs. 1-20 (columnar sections, graphs), tables 1-34, geol. map.—Includes descriptions and illustrations of 25 species (1 new) and 7 subspecies (3 new) of fusulinids.

JACOBSEN, JOHN M. Vertical distribution of Foraminifera in the Lower Chalk Member of the Austin Formation, Southern Dallas County, Texas.—Jour. Grad. Research Center (Southern Methodist Univ.), v. 29, No. 3, Dec. 1961, p. 179-187, pl. 1 (map and columnar sections), text fig. 1 (diagram), table 1 (distrib. and abund. table).—Quantitative analysis of about 50 species in 44 samples comprising a composite section.

KECSKEMÉTI, T. Symptômes pathologiques observés sur des *Nummulites* (French summary of Hungarian text).—Földtani Közlony, Bull. Hungarian Geol. Soc., Köt. 92, füz. 2, April-June 1962, p. 209-216, text figs. 1-6 (drawings).

KIESEL, YVONNE. Die oligozänen Foraminiferen der Tiefbohrung Dobbertin (Mecklenburg).—Freiberger Forschungshefte, ser. C, No. 122, Feb. 1962, p. 1-123, pls. 1-12, text fig. 1 (map), tables 1-3.—Illustrated systematic catalog of 160 species, none new, from a well section in middle Oligocene (Rupelian) and upper Oligocene (Eochattian).

DE KLASZ, IVAN, and RÉRAT, DANIEL. Une nouvelle espèce d'*Eponidopsis* (Foraminifera) de l'Afrique occidentale.—C. R. S. Soc. Géol. France, No. 4, April 2, 1962, p. 112, text fig.—From lower Miocene.

KOPEK, G., and KECSKEMÉTI, T. La classification des assises eocènes de la Montagne de Bakony (Transdanubien) d'après les grands-Foraminifères.—Ann. Hist.-Nat. Mus. Nat. Hungarici, tom. 53, 1961, p. 51-65, text figs. 1-4 (graphs), tables 1, 2.

KUSTANOWICH, S. A foraminiferal fauna from Capricorn Seamount, south-west equatorial Pacific.—New Zealand Jour. Geol. Geophys., v. 5, No. 3, Aug. 1962, p. 427-434, text figs. 1-3 (map, photomicrograph, pie diagram).—Sample composed predominantly of species of *Globigerinoides* and interpreted as of Plio-Pleistocene? age.

LARSEN, GUNNAR, and DINESEN, ARNE. The Vejle Fjord Formation at Brejning. Sediments [by G. Larsen] and Foraminiferal Fauna (Oligocene-Miocene) [by A. Dinesen] (English summary of Danish text).—Geol. Survey of Denmark, ser. II, No. 82, 1959, p. 1-114, pls. 1-9, text figs. 1-21 (maps, geol. sections, photos, diagrams, graphs, outline drawing), tables 1-14.—Illustrated catalog of 63 species, none new, from a sequence covering the interval middle-upper Oligocene to lower Miocene in which 4 faunizones are recognized.

LE CALVEZ, Y. Microfaune et faciès du Pliocène.—Océanographie Géologie et Géophysique de la Mediterranée Occidentale, Colloques Nationaux du Centre Nat. Recherche Sci., Villefranche sur Mer, 4-8 April 1961, 1962, p. 111-116, pls. 1-4.—Beautiful photographs of about 20 species of Foraminifera.

LUTERBACHER, H. P., and PREMOLI SILVA, I. Note préliminaire sur une révision du profil de Gubbio, Italie. I. Observations stratigraphiques. II. Sur quelques Foraminifères planctoniques du Crétacé.—Riv. Ital. Paleont., v. 68, No. 2, 1962, p. 253-288, pls. 19-23, text figs. 1-3 (table, columnar sections, range chart).—Planktonics are used in the section from Aptian/Albian to Paleogene and a few of the Cretaceous ones are illustrated.

LUTZE, GERHARD F. Variationsstatistik und Ökologie bei rezenten Foraminiferen.—Paläont. Zeitschrift, Band 36, Nr. 3/4, Aug. 1962, p. 252-264, pl. 24, text figs. 1-3 (diagrams, graphs).—Using *Bolivina argentea*, *B. pseudobeyrichi*, and *B. spissa* in offshore basins of California, variability in such features as length-breadth index, keel, ribs, spine, and pore-free wall, is found to be related to ecologic factors such as depth, temperature, oxygen content.

MAJZON, L. The Palaeogene Foraminifera horizons of Hungary.—Acta Geologica, Acad. Sci. Hungar., tom. 7, fasc. 3-4, 1962, p. 405-413, pl. 1, text fig. 1 (map), tables 1, 2.—Fourteen horizons between Londonian and Chattian based on Foraminifera. Two new species of *Heterostegina* are described.

MORIKAWA, ROKURO. A solidgraphic study of Fusulinid foraminifera (I).—Sci. Repts. Saitama Univ., ser. B, v. 4, No. 2, 1962, p. 139-147, pls. 5-7, text figs. 1-7 (diagrams).—Neoschwagerininae studied by a technique in which a cut surface is etched in acid.

MOURA, ARMANDO REIS. Contribuição para o conhecimento dos Foraminiferos das praias levantadas de S. Tomé e Principe.—Garcia de Orta, Rev. Junta Invest. Ultramar, Lisbon, v. 9, No. 4, 1961, p. 751-757, 1 pl.—Raised beaches having a com-

position identical with that of the present beaches. Four species reported and illustrated.

NARCHI, WALTER. A new genus of Foraminifera from South Atlantic.—Anais Acad. Brasil. Ciencias, v. 34, No. 2, 1962, p. 277-279, figs. 1-12.—*Goatapitigba* (type species *G. jurara* n. sp.), an attached form of the Saccamminidae, and its 2 new species.

NEAGU, THEODOR. The study of arenaceous Foraminifera from the Upper Cretaceous clays in the Sadova valley and upper basin of the River Buzau (English abstract of Rumanian text).—Acad. Repub. Pop. Romine, sec. Geol. Geogr., tom. 7, No. 1, 1962, p. 45-81, pls. 1-6, text fig. 1 (chart), table 1.—Illustrations of 38 species and subspecies, 2 new and 1 given a new name.

NYIRO, M. R. A new Foraminifer species from the Oligocene layers of Törökbálint.—Ann. Hist.-Nat. Mus. Nat. Hungarici, tom. 53, 1961, p. 49-50, text figs. 1, 2.—*Amphicoryne marginuliniformis*.

OBERHAUSER, RUDOLF. Foraminiferen und Mikrofossilien *"incertae sedis"* der ladinischen und karnischen Stufe der Trias aus den Ostalpen und aus Persien.—Jahrbuch Austria Geol. Bundes., Sonderband 5, Nov. 1960, p. 5-46, pls. 1-6, text figs. 1-5 (maps, geol. section, drawings).—Descriptions and illustrations of 52 species (25 new) and a new genus, *Austrocolomia* (genotype *A. marschalli* nov. sp.).

PETRI, SETEMBRINO. Foraminíferos Cretáceos de Sergipe.—Fac. Fil., Ciencias Let. Univ. São Paulo, Bol. No. 265, Geol. No. 20, 1962, p. 1-140, pls. 1-21, text figs. 1-3 (maps, columnar sections), tables 1-8.—Illustrated systematic catalog of nearly 100 species from a group of formations encompassing Albian to lower Maestrichtian. Six zones based on smaller Foraminifera are recognized. Forty-nine new species are described, 25 species are left indeterminate, and *Mendesia* gen. nov. (genotype *M. minuta* sp. nov.) is erected in the Trochamminidae.

PICCOLI, G., and PROTO DECIMA, F. Studio micropaleontologico di una serie nel Flysch di Capodistria.—Mem. Soc. Geol. Ital., v. 3, 1962, p. 9-48, text figs. 1-5 (maps, geol. section, plates of fossils).—Includes illustrated systematic catalog of 56 species and subspecies (none new) from upper Eocene beds.

PIETRZENUK, ERIKA. Zur Mikrofauna einiger Liasvorkommen in der Deutschen Demokratischen Republik.—Freiberger Forschungshefte, ser. C, No. 113, Nov. 1961, p. 1-129, pls. 1-15, text figs. 1-21 (maps, occurrence charts, diagrams, drawings).—Quantitative and qualitative analyses from several occurrences. Includes an illustrated systematic catalog of 122 species and subspecies of Foraminifera, none new.

POKORNY, VLADIMIR. Zur Kenntnis der Oligomiozänen Schichten am aussenrande des Zdanicer-Waldes (German summary of Czech text).—Casopis pro Min. Geol., v. 7, No. 3, 1962, p. 296-300, text figs. 1-6 (drawings).—Illustrations of 6 characteristic species.

POTIEVSKAJA, P. D. Predstaviteli Nekotorykh Semejstv Melkikh Foraminifer iz Nizhnej Permi Severo-Zapadnoj Okrainy Donbassa.—Akad. Nauk URSR, Kiev, Instyt. geol. nauk, Trudy, ser. strat. pal., vyp. 44, 1962, p. 49-94, pls. 1-8.—Illustrations and descriptions of 30 Permian species, 10 new, mostly nodosarian forms.

RAKHMANOVA, S. G. Opyt Korreljathii Produktivnykh Otlozhenij Tul'skogo i Aleksinskogo Gorizontov Volgogradskoj Oblasti Putem Uvjazki Ehlektro-karotazhnykh Reperov s Mikrofaunisticheskimi Dannymi.—Vses. nauchno-issl. instit. prirod. gazov, Trudy, vyp. 16/24, 1962, p. 161-175, charts.—Includes illustrations of endothyrids and related species from well sequences.

RENZ, H. H. Stratigraphy and paleontology of the type section of the Santa Anita Group, and the overlying Merecure Group, Rio Querecual, State of Anzoategui, northeastern Venezuela.—Boletin Informativo, Asoc. Venez. Geol., Min. Petr., v. 5, No. 4, April 1962, p. 89-108, pl. 1 (distrib. and abund. chart), text figs. 1, 2 (map, correl. chart).—Distribution of Foraminifera and zonation by planktonics and benthonics in a section between Maestrichtian and upper Eocene.

ROCHA, A. TAVARES, and UBALDO, MARIA DE LOURDES. Algumas observaçoes micropaleontológicas referentes ao Miocénico de Lisboa.—Garcia de Orta, Rev. Junta Invest. Ultramar, Lisbon, v. 9, No. 3, 1961, p. 539-547, pls. 1, 2, table 1.—Systematic catalog of 41 Burdigalian smaller Foraminifera, with photographs of a few.

ROSOVSKAYA, S. E. *Endothyra bowmani* Phillips, [1846] v. *Endothyra bowmani* Brown, 1843 (Foraminifera); an alternative proposal.—Bull. Zool. Nomenclature, v. 19, pt. 4, July 16, 1962, p. 202-204.—In favor of *E. bradyi* Mikhailov, 1939 (= *E. bowmani* Brady, 1876 (non Phillips)) as type species of *Endothyra* Phillips in Brown, 1843.

ROSS, CHARLES A., and DUNBAR, CARL O. Faunas and correlation of the Late Paleozoic rocks of northeast Greenland.—Medd. Grønland, Bd. 167, Nr. 5, 1962, p. 1-55, pls. 1-7.—Illustrations and descriptions of 21 species (4 new and 2 indeterminate) indicating correlations with the Moscovian series and with the Permian of the USSR.

ROTH, ERIKA. Regenerations-Bildung an einem *Dentalina*-Gehäuse (Foraminifera).—Senckenbergiana lethaea, Band 43, Nr. 3, June 15, 1962, p. 231-234, text fig. 1 (photomicrographs).—Damage to the

end-chamber resulted in a lateral end-chamber and closing of the original aperture.

SAWAI, KIYOSHI. *Orbulina universa* d'Orbigny in central Japan.—Mem. College Sci., Univ. Kyoto, ser. B, v. 29, No. 2, June 1962, p. 113-159, pls. 1-4, text figs. 1-18 (maps, columnar sections), tables 1-4.—The *Orbulina* surface is within the Tertiary f_3 stage and may indicate the first invasion of the modern warm temperate zone into Japan. Distribution and abundance of smaller and larger Foraminifera in the Miocene of several areas is indicated, and some species are illustrated.

SCHROEDER, ROLF. Orbitolinen des Cenomans Südwesteuropas.—Paläont. Zeitschrift, Band 36, Nr. 3/4, Aug. 1962, p. 171-202, pls. 20, 21, text figs. 1-7 (diagrams, tables, drawings, graphs).—Three species, two with subspecies (1 new). *Mesorbitolina,* new subgenus, is erected to include *O. texana.*

SKINNER, HUBERT C. Arkadelphia Foraminiferida.—Tulane Studies in Geol., v. 1, No. 1, Aug. 31, 1962, p. 1-72, pls. 1-6, text figs. 1, 2 (map, distrib. table).—Illustrated systematic catalog of 118 species from a measured section in Arkansas.

UCHIO, TAKAYASU. Recent Foraminifera thanatocoenoses of beach and nearshore sediments along the coast of Wakayama-ken, Japan.—Publ. Seto Marine Biol. Lab., v. 10, No. 1, July 1962, p. 133-144, text fig. 1 (map), tables 1, 2.—Quantitative analysis of 9 samples.

VENGLINSKY, I. V. New findings of Foraminifera of the *Vulvulina* species.—Geol. Sbornik, L'vovskogo Geol. Obshchestva, No. 7-8, 1961, p. 427-429, figs. 1, 2.—*V. porfiryevi* sp. nov. from upper Tortonian.

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