# CONTRIBUTIONS
# FROM THE
# CUSHMAN FOUNDATION
# FOR
# FORAMINIFERAL RESEARCH

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## Contents

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CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
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# 342. ON THE SPATIAL DISTRIBUTION OF FORAMINIFERA

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## ABSTRACT

In Rehoboth Bay, Delaware, a small area (1 sq. ft.) in which homogeneity of environmental variables can be expected and in which several species of Foraminifera occur with varying densities was chosen to study spatial distribution. The area was sampled by means of 3 sets of contiguous cells, each set having 36 cells. The volume of sediment obtained from each cell was about 2 ml. Randomness of foraminiferal species was tested for by comparing the observed distribution with that expected from a binomial distribution. In the living population a random distribution was found in 6 of 12 possible cases for 4 species. In the dead population a random distribution was found in 12 of 15 possible cases for 5 species. Those cases which did not fit the binomial distribution were aggregated and were successfully fitted by the negative binomial distribution. The data indicate that as the density of a species increases there is an increase in aggregation. Quantitatively this can be expressed by the equation $s^2=1.56\bar{x}^{1.44}$ which expresses the variance as a function of the mean. The following model is proposed to explain the observations. The low density random distributions are the result of individuals settling out of the water into the area of observation. The more abundant species have superimposed upon such a random distribution an aggregated one due to asexual reproduction which produces a group of young about a parent. If this is so, then the most abundant species are the ones most actively asexually reproducing within the observed area and the observed increase in aggregation with density is to be expected.

## INTRODUCTION

One of the fundamental characteristics of a biologic population is its spatial distribution. The study of spatial distribution within an area and the pattern of spatial distribution between areas is necessary for an understanding of spatial competition, reproductive-social behavior, homogeneity of environment, and niche. Its study is not only important for these reasons, but also because it is a necessary prerequisite for obtaining an efficient estimate of density, and some knowledge of it is required before certain statistical tests, such as an analysis of variance, can be made.

Plant ecologists, because of the availability and immobility of plants, have pioneered in the study of spatial distributions. Greig-Smith (1964) reviews the progress that they have made. Since the publication of Cole's (1946) important study on the spatial distribution of Cryptozoa there has been much activity in the study of spatial distributions of animals. Among marine studies important contributions have been made by Barnes and Marshall (1951), Connell (1955), Johnson (1959), and Jones (1961).

The work of these investigators has demonstrated that random, regular, and aggregated spatial distributions exist in nature. In the random situation each individual is independent of all other individuals within the area of observation. Regular distributions are usually explained by competition; each individual requiring a definite subarea from which other organisms are excluded. Aggregation, by far the most common type of spatial distribution, is usually explained by non-homogeneity of environmental variables and/or reproductive-social behavior.

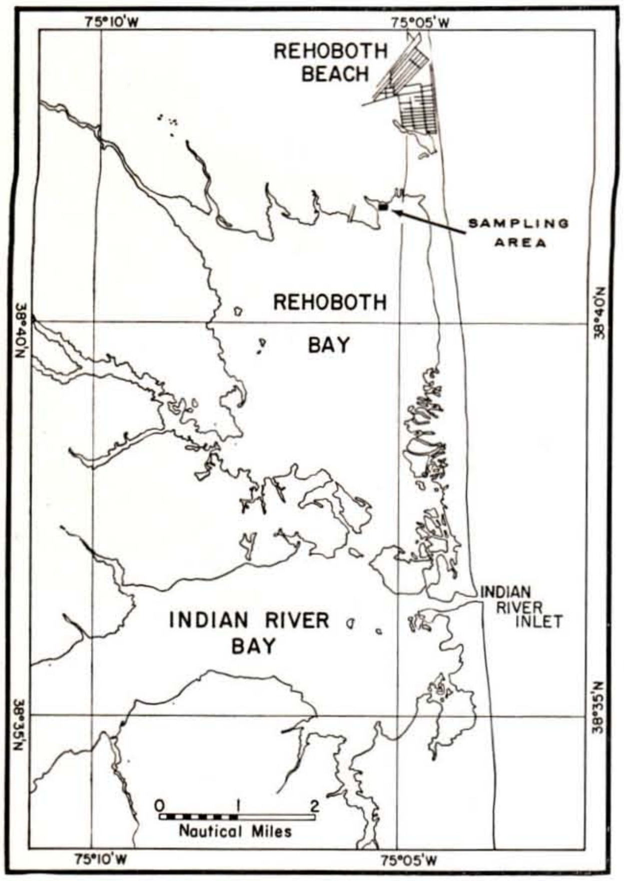
When considering the spatial distribution of a species, it is, of course, important to consider the scale of observation. If the area studied is large enough, any species will be aggregated in its spatial distribution. Conversely, if the observed area is so small that it approaches the size of the individual, aggregation is clearly impossible. Also, if only one or two individuals are present, a study of their spatial distribution is of little interest.

In the present study, the purpose is to examine spatial distribution where homogeneity of environmental variables might be expected. This is desirable, because if it is so, and there is no aggregation due to reproductive-social behavior, then the individuals should be randomly distributed. Because measurement of microenvironments is difficult, another way of approaching the requirement of homogeneity is to choose a relatively small area. At the same time, however, the area must be large enough and the individuals abundant enough so that the study is meaningful. A small area (1 sq. ft.) with varying densities of foraminiferal species in Rehoboth Bay, Delaware, was chosen in the hope of fulfilling these requirements. If we consider the ratio of an individual foraminifer to the size of the 1 sq. ft., the ratio is about the same as a large tree would have to a square mile of forest.

The present study is a first step in a series of studies on spatial distribution. As indicated above, its purpose is simply to find out what the spatial distribution of species is in an area where homogeneity of environmental variables might be expected. On the basis of the results of this inquiry, another study is underway to determine if a particular species changes from a random to an aggregated condition as its density increases. At the present time we do know that species of Foraminifera are not homogeneously distributed, but occur in patches of various sizes (see Buzas, 1965, Ellison, 1966, Lynts, 1966). The present study will aid in designing future studies which will determine how large an area is homogeneous with respect to the spatial distribution and density of a particular species and how these patches are distributed within and between environments.

## METHODS

A pilot study was conducted to see if Foraminifera occurred with sufficient density in Rehoboth Bay, Delaware, to warrant a detailed spatial distribution study. From the initial study a site was chosen which contained several species of Foraminifera with varying densities, was muddy and shallow (1 m depth). The location of the area in Rehoboth Bay is shown in text fig. 1.



TEXT FIGURE 1
Location of sampling area

A one-square-foot quadrat was constructed out of aluminum. Three multiple tube samplers were constructed by cementing aluminium "square tubes", ½-inch on a side, together so that each sampler consists of a set of 36 contiguous cells. The surface of each tube presented to the sediment was milled out so that a series of contiguous knife edges would ease the insertion into the mud. Each sampler, then, takes a sample of 9 sq. inches, and there are 16 such possibilities in one square foot. Before going into the field three of the 16 possibilities were chosen by restricted random sampling and marked on the one-square-foot quadrat.

The field sampling was carried out by arbitrarily placing the one-square-foot quadrat on the bottom at the site previously chosen. Three sets of samples were then secured by pushing the multiple tube samplers into the mud by hand. The sample sets were fixed with neutralized formalin in the field and frozen within a few hours after collection. Hereafter, the sample sets, consisting of 36 cells each, will be referred to as samples A, B, and C.

The frozen mud was removed from each cell by pushing it out from the bottom with a rod onto a plastic ruler. As the frozen sediment lay on the ruler, the sediment was cut with a knife ½-inch below the sediment-water interface, producing a cube of ⅛ cu. in., or about 2 ml. The cubes were placed in jars with neutralized formalin, stained with rose bengal, and washed over a 63μ sieve. The formerly living foraminifers (as deduced by the stain) and the empty tests (no stained protoplasm) were then picked and placed on slides for identification and counting. Due to the delicate nature of the sampling procedure some material was lost; the recovery (out of a possible 36 cells) was 28, 34, and 34 for samples A, B, and C, respectively.

## PROBABILITY MODELS

Consider a relatively small area throughout which environmental variables are homogeneous and favorable. Assuming such a condition, any particular subarea of specified size of this area will be just as inhabitable as any other. An individual which is introduced into such an area by settling out of the water or one which moves over or through the substratum without preference is just as likely to inhabit any of the subareas. If the individuals are independent in the probability sense and there are $N$ subareas, the probability of any particular individual being in any one of them is simply $1/N$, and the individuals are distributed at random. It is important to remember that if the presence or absence of an individual in any subarea influences the presence or absence of another, as, for example, when the number of individuals reaches the maximum possible, so that a newly arriving individual is excluded, the required condition of independence is violated, and, consequently, any particular individual is not as likely to be in any one subarea as another.

If we place a set of $N$ contiguous cells or quadrats on such a homogeneous area and the individuals are randomly distributed, the probability of an individual being in any cell is $1/N = p$, and the probability that it is not is $1-p = q$. If the area under study has $n$ individuals in it, the probability of a cell containing exactly $x = 0,1,2,\ldots,n$ individuals is

$$P(x;p,n) = \frac{n!}{x!(n-x)!} p^x q^{n-x} \quad . \qquad (1)$$

This, the well known binomial distribution, is discussed extensively by Feller (1957). Clearly, if we choose an area in which the number of individuals ($n$) is very small, say one or two, it is most likely that their distribution will fit the binomial. Likewise, if the number of cells ($N$) is very small, any departure from randomness may be difficult to detect. So, while it is true that the number of individuals and the number of cells in no way affect the applicability of the binomial distribution for randomally distributed individuals, its use in extreme cases, such as those mentioned above, is ecologically of limited interest.

Now as $p$ becomes small, that is, the number of cells becomes large and $n$ comparatively large, the binomial distribution is closely approximated by the Poisson distribution (see Feller, 1957). The probability of a cell containing exactly $x = 0,1,2,...,n$ individuals is

$$P(x;m) = \frac{e^{-m}\ m^x}{x!} \qquad (2)$$

where $e$ is the base of the natural logarithms and $m = np$ is the mean. Actually the Poisson distribution can be derived as an approximation to the binomial distribution or it can be derived on its own merits and shown to be the distribution one would expect to find for randomly distributed individuals (Feller, 1957). The study of spatial distribution with a large $N$ and comparatively large $n$ is, of course, the most desirable approach and is the one most often used.

An interesting feature of the Poisson distribution that has been much used by ecologists is that the mean equals the variance and therefore the ratio of the variance to the mean is one. For the binomial distribution the variance is $npq$ and the mean $np$. The approximation to the Poisson is easy to see if we consider the ratio $npq/np$. As the number of cells becomes large $p$ becomes small and $q$ correspondingly large. For example, if the area were divided into 36 cells, the ratio would equal .97, and, as the number of cells increases, $p \rightarrow 0$ and the ratio $\rightarrow 1$. It should be clear that for randomly distributed individuals the number of individuals, providing their number is comparatively large, will in no way affect the applicability of the Poisson. Also the number of cells will affect only the value of $p$ and, providing $p$ is small, not the applicability of the Poisson distribution.

The two possible departures from the random distribution of individuals are when the variance is significantly larger or smaller than the mean. In the first case the resulting distribution has been termed clumped, aggregated, contagious, or overdispersed (Goodall, 1952, gives a history of the usage). In the alternative case the distribution is termed regular. Johnson (1959) has described the latter distribution for *Phoronopsis viridis*. This type of distribution is relatively rare in nature. The most common distribution for animals, as Cole (1946) pointed out, and plants, as Greig-Smith has indicated (1964), is an aggregated one, the two principal reasons given being that the natural habitat is not homogeneous, and that organisms form reproductive and/or social groupings.

Although the size of cells in no way affects the applicability of the binomial and Poisson distributions for a group of randomly distributed individuals, the converse is not true. For example, in an aggregated condition if the cell size is so small that it approaches the size of the individual, the population may fit random expectation, because it will be impossible to sample any of the clumps. Likewise, if the cell size is so large that several clumps can be contained in a single cell, the clumping may not be discernible and the population may agree with random expectation. Realizing this difficulty Greig-Smith (1952) sampled contiguous quadrats of increasing size and compared the variance to block size. If a population is truly randomly distributed, the observed distribution should fit the expected random distribution regardless of quadrat size.

Because of the common occurrence of aggregated distributions, several kinds of distributions have been proposed for them. Bliss and Fisher (1953) reviewed several of these and showed the applicability of the negative binomial distribution to several kinds of aggregated distributions. The negative binomial distribution is an extension of the Poisson distribution in which the population mean varies as $\chi^2$. The distribution is completely defined by $k$, a positive exponent, and $m$, the mean. The probability of a cell containing $x = 0,1,2,...,n$ individuals is given by

$$P(x;k,m) = \frac{(k + x-1)!}{x!\ (k-1)!}\ \frac{p^x}{(1 - p)^{k + x}} \qquad (3)$$

where $p = m/k$. The distribution exhibits a wide range of applicability because as the variance of the negative binomial approaches the mean $k \rightarrow \infty$ and $p \rightarrow 0$, whereas in a completely aggregated condition $k \rightarrow 0$. Bliss and Fisher (1953) have pointed out two models in nature which could produce the observed aggregation and which would be expected to fit the negative binomial distribution. One type of aggregation can result from a mixture of several Poisson distributions with differing means. This kind of aggregation could result, for instance, if we grouped together data from several different areas in which the mean number of individuals differed. Although each of the areas may have had a homogeneous Poisson distribution, because the means in the areas varied, the mixture would not fit the Poisson. A second kind of aggregation can result from reproductive functions of organisms, such as larvae hatching from eggs; the negative binomial (see Bliss and Fisher, 1953) fits such observations very well. Unfortunately, as Skellam (1952) and Bliss and Fisher (1953) have pointed out, there is no way, by observation of data alone, of distinguishing what model produced the observed aggregation. This lack of ability to discriminate between different ecologic models makes the negative binomial of limited use, but, nevertheless, it does enable the investigator to summarize the spatial distribution of his study in terms of two statistics, the estimate of the mean, $\bar{x}$, and $k'$, the estimate of $k$.

## LIVING POPULATIONS

The number of living individuals of *Ammonia beccarii* (Linné), *Ammobaculites* sp., *Elphidium clavatum* Cushman, and *Elphidium tisburyense* (Butcher), in each cell of sample A is shown in text fig. 2. The letters *NS* signify "no sample" and $n$ the total number of individuals for a given species. The same information for samples B and C is shown in text figs. 3 and 4, respectively. These figures are intended to acquaint the reader with the actual data as recorded from the field.

The data for each species were arranged in frequency distribution tables in the following manner. The number of individuals, $x = 0,1,2,...,n$, of each species observed was placed in columns, and tables of the cumulative binomial distribution (Harvard U. Comp. Lab., 1955) were used to calculate the expected number of individuals for a random distribution. The binomial distribution was used instead of the Poisson, because the availability of binomial tables simplifies computation. Equation (3) was used to calculate the probabilities of the negative binomial distribution, the value of $k$ being estimated by the maximum-likelihood method (Bliss and Fisher, 1953). The observed frequencies, expected binomial and negative binomial frequencies for *A. beccarii*, *Ammobaculites* sp., *E. clavatum*, and *E. tisburyense* in samples A, B, and C are shown in tables 1 through 12.

| | | | | | |
|---|---|---|---|---|---|
| 0 | 3 | 2 | 0 | NS | NS |
| 4 | 1 | 1 | 0 | 1 | 1 |
| 0 | NS | 1 | 0 | 0 | 0 |
| 6 | NS | 1 | 0 | 3 | 0 |
| 1 | NS | NS | NS | NS | 0 |
| 3 | 2 | 0 | 1 | 3 | 1 |

Number of live *Ammobaculites* sp.
random n= 35

| | | | | | |
|---|---|---|---|---|---|
| 0 | 0 | 3 | 0 | NS | NS |
| 8 | 12 | 12 | 5 | 1 | 1 |
| 5 | NS | 7 | 3 | 0 | 0 |
| 3 | NS | 3 | 3 | 9 | 2 |
| 3 | NS | NS | NS | NS | 1 |
| 6 | 2 | 4 | 8 | 5 | 5 |

Number of live *Ammonia beccarii*
aggregated n = 111

| | | | | | |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | NS | NS |
| 1 | 0 | 3 | 3 | 0 | 0 |
| 1 | NS | 2 | 1 | 0 | 0 |
| 0 | NS | 0 | 1 | 0 | 0 |
| 1 | NS | NS | NS | NS | 3 |
| 5 | 0 | 0 | 1 | 2 | 0 |

Number of live *Elphidium clavatum*
aggregated n = 24

| | | | | | |
|---|---|---|---|---|---|
| 0 | 1 | 3 | 1 | NS | NS |
| 6 | 11 | 0 | 0 | 4 | 0 |
| 3 | NS | 5 | 0 | 0 | 2 |
| 2 | NS | 1 | 2 | 0 | 2 |
| 4 | NS | NS | NS | NS | 3 |
| 3 | 5 | 1 | 0 | 4 | 3 |

Number of live *Elphidium tisburyense*
aggregated n = 66

TEXT FIGURE 2
Spatial distribution of living species in sample A

| | | | | | |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 4 | 0 | 0 |
| 0 | 5 | 1 | NS | 0 | 0 |
| 2 | 0 | 0 | NS | 1 | 0 |
| 0 | 1 | 1 | 0 | 0 | 2 |
| 1 | 0 | 0 | 0 | 1 | 5 |
| 0 | 1 | 1 | 0 | 0 | 0 |

Number of live *Ammobaculites sp.*
random n= 26

| | | | | | |
|---|---|---|---|---|---|
| 2 | 0 | 0 | 1 | 0 | 2 |
| 0 | 2 | 2 | NS | 3 | 6 |
| 4 | 4 | 0 | NS | 2 | 4 |
| 1 | 0 | 0 | 0 | 1 | 1 |
| 0 | 0 | 2 | 0 | 0 | 4 |
| 2 | 2 | 3 | 3 | 0 | 1 |

Number of live *Ammonia beccarii*
aggregated n = 52

| | | | | | |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | NS | 0 | 0 |
| 2 | 0 | 0 | NS | 1 | 1 |
| 2 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 1 | 0 | 0 | 1 |
| 1 | 0 | 2 | 0 | 2 | 0 |

Number of live *Elphidium clavatum*
random n = 16

| | | | | | |
|---|---|---|---|---|---|
| 2 | 0 | 0 | 5 | 4 | 2 |
| 2 | 3 | 0 | NS | 0 | 0 |
| 0 | 2 | 1 | NS | 2 | 1 |
| 1 | 0 | 2 | 0 | 1 | 1 |
| 0 | 0 | 2 | 0 | 0 | 2 |
| 0 | 1 | 3 | 1 | 0 | 3 |

Number of live *Elphidium tisburyense*
random n = 41

TEXT FIGURE 3
Spatial distribution of living species in sample B

| | | | | | |
|---|---|---|---|---|---|
| NS | 0 | 0 | 2 | 0 | 0 |
| 1 | 2 | 1 | 0 | 1 | 3 |
| NS | 1 | 2 | 2 | 1 | 0 |
| 1 | 0 | 3 | 0 | 0 | 1 |
| 2 | 0 | 1 | 1 | 0 | 1 |
| 2 | 0 | 1 | 1 | 0 | 1 |

Number of live *Ammobaculites* sp.
random n = 31

| | | | | | |
|---|---|---|---|---|---|
| NS | 3 | 1 | 1 | 7 | 4 |
| 0 | 3 | 5 | 1 | 4 | 15 |
| NS | 2 | 8 | 0 | 2 | 2 |
| 4 | 4 | 8 | 15 | 4 | 7 |
| 4 | 3 | 6 | 1 | 1 | 17 |
| 3 | 5 | 10 | 0 | 3 | 6 |

Number of live *Ammonia beccarii*
aggregated n = 159

| | | | | | |
|---|---|---|---|---|---|
| NS | 0 | 0 | 1 | 1 | 0 |
| 0 | 0 | 1 | 0 | 0 | 1 |
| NS | 0 | 1 | 1 | 3 | 0 |
| 0 | 0 | 2 | 3 | 0 | 3 |
| 2 | 0 | 1 | 1 | 0 | 3 |
| 0 | 4 | 1 | 0 | 1 | 0 |

Number of live *Elphidium clavatum*
aggregated n = 30

| | | | | | |
|---|---|---|---|---|---|
| NS | 2 | 2 | 0 | 1 | 1 |
| 3 | 3 | 1 | 1 | 3 | 2 |
| NS | 0 | 2 | 0 | 5 | 1 |
| 2 | 4 | 5 | 4 | 1 | 4 |
| 2 | 1 | 0 | 0 | 1 | 2 |
| 1 | 0 | 2 | 4 | 3 | 1 |

Number of live *Elphidium tisburyense*
random n = 64

TEXT FIGURE 4
Spatial distribution of living species in sample C

The observed data were compared with the expected frequency in each case by the chi-square goodness-of-fit test, where $\chi^2 = \Sigma(0-E)^2/E$ and in which *0* is the observed frequency and *E* the ex-

TABLE 1

Frequency Distribution of Live *Ammobaculites* sp. in Sample A

| No. per cell | Observed Frequency | Expected Binomial | Expected Negative Binomial |
|---|---|---|---|
| x | f | P(x; .04, 35) | P(x; 1.54, 1.25) |
| 0 | 11 | 6.71 | 11.13 |
| 1 | 9 | 9.78 | 7.79 |
| 2 | 2 | 6.94 | 4.44 |
| 3 | 4 | 3.19 | 2.34 |
| 4 | 1 | 1.06 | 1.18 |
| 5 | 0 | 0.27 | 0.58 |
| 6 | 1 | 0.06 | 0.28 |
| 7 | 0 | 0.01 | 0.13 |
| 8 | 0 | 0.00 | 0.06 |
| Totals | 28 | 28.02 | 27.93 |

n=35 binomial $\chi^2_4=6.77$* negative binomial $\chi^2_4=2.74$*

TABLE 2

Frequency Distribution of Live *Ammonia beccarii* (Linné) in Sample A

| No. per cell | Observed Frequency | Expected Binomial | Expected Negative Binomial |
|---|---|---|---|
| x | f | P(x; .04, 111) | P(x; 1.60, 3.96) |
| 0 | 5 | 0.28 | 3.81 |
| 1 | 3 | 1.39 | 4.34 |
| 2 | 2 | 3.19 | 4.02 |
| 3 | 6 | 4.84 | 3.44 |
| 4 | 1 | 5.44 | 2.82 |
| 5 | 4 | 4.85 | 2.25 |
| 6 | 1 | 3.57 | 1.76 |
| 7 | 1 | 2.23 | 1.36 |
| 8 | 2 | 1.21 | 1.04 |
| 9 | 1 | 0.58 | 0.79 |
| 10 | 0 | 0.22 | 0.60 |
| 11 | 0 | 0.09 | 0.45 |
| 12 | 2 | 0.03 | 0.34 |
| 13 | 0 | 0.01 | 0.25 |
| Totals | 28 | 27.93 | 27.27 |

n=111 binomial $\chi^2_7=34.52$ negative binomial $\chi^2_6=6.23$*

TABLE 3

Frequency Distribution of Live *Elphidium clavatum* Cushman in Sample A

| No. per cell | Observed Frequency | Expected Binomial | Expected Negative Binomial |
|---|---|---|---|
| x | f | P(x; .04, 24) | P(x; 0.76, 0.86) |
| 0 | 16 | 10.49 | 15.77 |
| 1 | 6 | 10.71 | 6.35 |
| 2 | 2 | 5.04 | 2.96 |
| 3 | 3 | 1.54 | 1.44 |
| 4 | 0 | 0.34 | 0.72 |
| 5 | 1 | 0.06 | 0.11 |
| Totals | 28 | 28.18 | 27.35 |

n=24 binomial $\chi^2_3=11.11$ negative binomial $\chi^2_3=1.41$*

TABLE 4

Frequency Distribution of Live *Elphidium tisburyense* (Butcher) in Sample A

| No. per cell | Observed Frequency | Expected Binomial | Expected Negative Binomial |
|---|---|---|---|
| x | f | P(x; .04, 66) | P(x; 1.43, 2.36) |
| 0 | 8 | 1.89 | 6.96 |
| 1 | 4 | 5.20 | 6.20 |
| 2 | 4 | 7.05 | 4.69 |
| 3 | 5 | 6.26 | 3.34 |
| 4 | 3 | 4.11 | 2.30 |
| 5 | 2 | 2.12 | 1.55 |
| 6 | 1 | 0.90 | 1.03 |
| 7 | 0 | 0.32 | 0.68 |
| 8 | 0 | 0.10 | 0.44 |
| 9 | 0 | 0.03 | 0.29 |
| 10 | 0 | 0.00 | 0.19 |
| 11 | 1 | 0.00 | 0.12 |
| Totals | 28 | 27.98 | 27.79 |

n=66 binomial $\chi^2_6=22.22$ negative binomial $\chi^2_5=2.50$*

TABLE 5

Frequency Distribution of Live *Ammobaculites* sp. in Sample B

| No. per cell | Observed Frequency | Expected Binomial | Expected Negative Binomial |
|---|---|---|---|
| x | f | P(x; .03, 26) | P(x; 0.52, 0.76) |
| 0 | 21 | 15.40 | 21.24 |
| 1 | 8 | 12.38 | 6.57 |
| 2 | 2 | 4.79 | 2.97 |
| 3 | 0 | 1.18 | 1.49 |
| 4 | 1 | 0.21 | 0.78 |
| 5 | 2 | 0.03 | 0.42 |
| Totals | 34 | 33.99 | 33.47 |

n=26 binomial $\chi^2_3=6.97$ negative binomial $\chi^2_3=.64$*

pected. The calculation of expected values was carried out until the expected value was zero to two decimal places. The smaller values are not always shown in the tables, but were, however, used in the calculation of $\chi^2$. An asterisk after the value of $\chi^2$ indicates that the observed distribution did not differ significantly at the 95% confidence level from the expected.

Six of the twelve observed distributions did not differ significantly from random expectation, and all twelve of the observed distributions were successfully fitted by the negative binomial distribution, attesting to the wide applicability of the latter. Tables 1 through 12 show that even where the observed distribution did not differ significantly from random expectation, the negative binomial often fit better than the binomial. The tables also show that the observed departure from random expectation is due to aggregation, too many cells having too few and too many individuals.

Our earlier consideration of equation (1) indicated that, if a population is truly distributed at random, it will agree with the binomial expectation regardless of the size of the cell sampling it or the density of the population. If, however, the population is not distributed at random, the type of distribution (in this case the amount and arrangement

### TABLE 6

Frequency Distribution of Live *Ammonia beccarii* (Linné) in Sample B

| No. per cell | Observed Frequency | Expected Binomial | Expected Negative Binomial |
|---|---|---|---|
| x | f | P(x; .03, 52) | P(x; 1.71, 1.53) |
| 0 | 13 | 6.98 | 11.40 |
| 1 | 5 | 10.91 | 9.20 |
| 2 | 8 | 0.85 | 5.89 |
| 3 | 3 | 4.56 | 3.44 |
| 4 | 4 | 1.73 | 1.91 |
| 5 | 0 | 0.51 | 1.03 |
| 6 | 1 | 0.16 | 0.54 |
| 7 | 0 | 0.02 | 0.28 |
| Totals | 34 | 33.72 | 33.69 |

$n=52$ binomial $\chi^2_4=11.75$ negative binomial $\chi^2_4=3.32$*

### TABLE 7

Frequency Distribution of Live *Elphidium clavatum* Cushman in Sample B

| No. per cell | Observed Frequency | Expected Binomial | Expected Negative Binomial |
|---|---|---|---|
| x | f | P(x; .03, 16) | P(x; 7.85, 0.47) |
| 0 | 22 | 20.88 | 21.53 |
| 1 | 8 | 10.33 | 9.56 |
| 2 | 4 | 2.40 | 2.39 |
| 3 | 0 | 0.35 | 0.44 |
| Totals | 34 | 33.96 | 33.92 |

$n=16$ binomial $\chi^2_3=2.01$ negative binomial $\chi^2_3=1.86$*

### TABLE 8

Frequency Distribution of Live *Elphidium tisburyense* (Butcher) in Sample B

| No. per cell | Observed Frequency | Expected Binomial | Expected Negative Binomial |
|---|---|---|---|
| x | f | P(x; .03, 41) | P(x; 2.76, 1.20) |
| 0 | 14 | 9.75 | 12.50 |
| 1 | 7 | 12.36 | 10.49 |
| 2 | 8 | 7.65 | 6.00 |
| 3 | 3 | 3.08 | 2.89 |
| 4 | 1 | 0.90 | 1.27 |
| 5 | 1 | 0.21 | 0.52 |
| 6 | 0 | 0.04 | 0.20 |
| 7 | 0 | 0.01 | 0.08 |
| Totals | 34 | 34.00 | 33.95 |

$n=41$ binomial $\chi^2_4=4.80$* negative binomial $\chi^2_4=2.59$*

### TABLE 9

Frequency Distribution of Live *Ammobaculites* sp. in Sample C

| No. per cell | Observed Frequency | Expected Binomial | Expected Negative Binomial |
|---|---|---|---|
| x | f | P(x; .03, 31) | P(x; 9.21, 0.91) |
| 0 | 13 | 13.23 | 14.27 |
| 1 | 13 | 12.68 | 11.84 |
| 2 | 6 | 5.88 | 5.44 |
| 3 | 2 | 1.76 | 1.83 |
| 4 | 0 | 0.38 | 0.50 |
| 5 | 0 | 0.06 | 0.12 |
| 6 | 0 | 0.01 | 0.03 |
| Totals | 34 | 34.00 | 34.03 |

$n=31$ binomial $\chi^2_3=0.14$* negative binomial $\chi^2_3=0.38$*

### TABLE 10

Frequency Distribution of Live *Ammonia beccarii* (Linné) in Sample C

| No. per cell | Observed Frequency | Expected Binomial | Expected Negative Binomial |
|---|---|---|---|
| x | f | P(x; .03, 159) | P(x; 1.76, 4.70) |
| 0 | 3 | 0.26 | 3.52 |
| 1 | 5 | 1.28 | 4.51 |
| 2 | 3 | 3.16 | 4.53 |
| 3 | 5 | 5.15 | 4.13 |
| 4 | 6 | 6.26 | 3.58 |
| 5 | 2 | 6.04 | 3.00 |
| 6 | 2 | 4.82 | 2.46 |
| 7 | 2 | 3.28 | 1.98 |
| 8 | 2 | 1.94 | 1.58 |
| 9 | 0 | 1.01 | 1.25 |
| 10 | 1 | 0.47 | 0.98 |
| 11 | 0 | 0.20 | 0.76 |
| 12 | 0 | 0.07 | 0.58 |
| 13 | 0 | 0.03 | 0.45 |
| 14 | 0 | 0.01 | 0.35 |
| 15 | 2 | 0.00 | 0.27 |
| 16 | 0 | 0.00 | 0.20 |
| 17 | 1 | 0.00 | 0.15 |
| Totals | 34 | 33.98 | 34.28 |

$n=159$ binomial $\chi^2_7=33.35$ negative binomial $\chi^2_7=3.70$*

### TABLE 11

Frequency Distribution of Live *Elphidium clavatum* Cushman in Sample C

| No. per cell | Observed Frequency | Expected Binomial | Expected Negative Binomial |
|---|---|---|---|
| x | f | P(x; .03, 30) | P(x; 1.67, 0.88) |
| 0 | 17 | 13.63 | 16.74 |
| 1 | 10 | 12.65 | 9.66 |
| 2 | 2 | 5.67 | 4.46 |
| 3 | 4 | 1.42 | 1.89 |
| 4 | 1 | 0.34 | 0.76 |
| Totals | 34 | 33.71 | 33.51 |

$n=30$ binomial $\chi^2_3=9.73$ negative binomial $\chi^2_3=2.49$*

TABLE 12

Frequency Distribution of Live *Elphidium tisburyense* (Butcher) in Sample C

| No. per cell | Observed Frequency | Expected Binomial | Expected Negative Binomial |
|---|---|---|---|
| x | f | P(x; .03, 64) | P(x; 12.56, 1.88) |
| 0 | 6 | 4.84 | 5.89 |
| 1 | 10 | 9.58 | 9.63 |
| 2 | 8 | 9.33 | 8.51 |
| 3 | 4 | 5.97 | 5.38 |
| 4 | 4 | 2.80 | 2.73 |
| 5 | 2 | 1.04 | 1.18 |
| 6 | 0 | 0.32 | 0.45 |
| 7 | 0 | 0.08 | 0.16 |
| 8 | 0 | 0.02 | 0.05 |
| Totals | 34 | 33.98 | 33.98 |
| $n = 64$ | | binomial $\chi^2_5 = 1.85$* | negative binomial $\chi^2_5 = .99$* |

of aggregation) may cause the population to agree with random expectation. An attempt to overcome this difficulty was made by doubling the cell size, accomplished by adding the number of individuals in adjacent cells together. These double cell-size frequencies were then compared with expected frequencies of the binomial distribution. In every case the populations which were random remained so, whereas the populations which were aggregated could not be distinguished from random expectation. It should be pointed out, however, that by increasing the cell size of the field sample, more of the cells in the resulting frequency tables had to be pooled, making the chi-square goodness-of-fit test less sensitive. While we must, as a consequence, be somewhat less confident of individual results, the general trend is still apparent.

A glance at text figs. 2-4 indicates that in adding together the adjacent cells, the aggregation which is so apparent was masked because the individual highs were in their sums reduced, whereas the lows were increased. In other words, the cell size became so large in relation to the clumping of the individuals that the aggregation was no longer discernible. In view of our previous discussion, it seems likely that a meaningful cell size was chosen fortuitously and that the populations that were random and remained so are truly distributed at random, whereas the populations that appear aggregated at one cell size and random at another are aggregated.

The variance of each species population was calculated from the frequency tables by

$$s^2 = \frac{\Sigma(fx^2) - (\Sigma fx)^2/N}{N-1}$$

and the mean by $\bar{x} = \Sigma(fx)/N$. As stated above the parameter $k$ of the negative binomial distribution was estimated by the maximum likelihood method. These data are presented in table 13. The column labeled "spatial arrangement" (random or aggregated) is tabulated according to the goodness-of-fit test discussed earlier and not by the statistic

$$\underset{N-1}{\chi^2} = \frac{Ns^2}{\bar{x}}$$

suggested by Fisher (1925). The former test was

TABLE 13

Variance, mean, spatial arrangement and k′ for Living Populations

Living Populations — Sample A

| Species | variance | mean | spatial arrangement | k′ |
|---|---|---|---|---|
| *Ammobaculites* sp. | 2.27 | 1.25 | random | 1.59 |
| *Ammonia beccarii* (Linné) | 27.25 | 3.96 | aggregated | 1.60 |
| *Elphidium clavatum* Cushman | 1.68 | 0.86 | aggregated | 0.76 |
| *Elphidium tisburyense* (Butcher) | 5.85 | 2.36 | aggregated | 1.43 |

Living Populations — Sample B

| Species | variance | mean | spatial arrangement | k′ |
|---|---|---|---|---|
| *Ammobaculites* sp. | 1.88 | 0.76 | random | 0.52 |
| *Ammonia beccarii* (Linné) | 2.56 | 1.53 | aggregated | 1.71 |
| *Elphidium clavatum* Cushman | 0.50 | 0.47 | random | 7.85 |
| *Elphidium tisburyense* (Butcher) | 1.74 | 1.20 | random | 2.76 |

Living Populations — Sample C

| Species | variance | mean | spatial arrangement | k′ |
|---|---|---|---|---|
| *Ammobaculites* sp. | 0.81 | 0.91 | random | 9.21 |
| *Ammonia beccarii* (Linné) | 9.18 | 4.70 | aggregated | 1.76 |
| *Elphidium clavatum* Cushman | 1.32 | 0.88 | aggregated | 1.67 |
| *Elphidium tisburyense* (Butcher) | 2.17 | 1.88 | random | 12.56 |

chosen because it could also compare the data to the expected frequency of the negative binomial. Greig-Smith (1964) discusses the relative merits of the two.

Table 13 shows that the random populations occur at the lower densities and that the variance increases, as one would expect, with the mean. We will further examine this relationship later on.

Bliss and Fisher (1953), in discussing the negative binomial distribution, have indicated that as the variance approaches the mean $k \rightarrow \infty$, and, conversely, as the population becomes progressively aggregated $k \rightarrow 0$. Table 13 shows that k' does have a tendency to be higher in random populations. For most of the species, however, the value of $k'$ is quite variable between the three sample sets. The only species for which the value of $k'$ is relatively constant is *Ammonia beccarii*. Some fluctuation in the value of $k'$ is to be expected, because the mean number of individuals, as well as the spatial distribution, varies from sample to sample. These data indicate that the use of $k'$ as a simple measure of randomness must be viewed with caution. Bliss and Owen (1958) have illustrated methods by which a common value for $k'$ can be calculated, but the required calculations are somewhat laborious and do not seem warranted here.

## DEAD POPULATIONS

In order to save space, counts of the number of individuals for each species as they appeared in the field and in the frequency distribution tables are not presented here. Table 14 shows the species, variance, mean, spatial distribution and $k'$ for the dead populations. The value of $k'$ was estimated only in the case of the non-random distributions, as judged by the chi-square goodness-of-fit criterion discussed above.

Twelve of the fifteen cases studied were randomly distributed, whereas the remaining (all *Ammobaculites* sp.) were aggregated. The relationship between mean and randomness is again apparent, the three aggregated populations all having relatively high means. Interestingly, the value of $k'$ for these populations was relatively high—indicating, once again, that the use of $k'$ as a simple indicator of randomness can be misleading when comparing populations with greatly differing densities.

## RELATIONSHIP OF VARIANCE TO MEAN

Tables 13 and 14 show that as the mean number of individuals increase the variances also increase, but at a higher rate than would be expected in a random situation. A plot of variance *vs.* mean on a log-log scale appears as a straight line, indicating a relationship of the form $s^2 = a\bar{x}^b$. This same relationship was found for a variety of organisms by Taylor (1961). The variance-mean data for the living populations were fitted to this equation by the least squares method to calculate values of the constants $a$ and $b$. The resulting equation is

$$s^2 = 1.56\bar{x}^{1.44} \quad . \qquad (4)$$

TABLE 14

Variance, mean, spatial arrangement and k' for Dead Populations

Dead Populations — Sample A

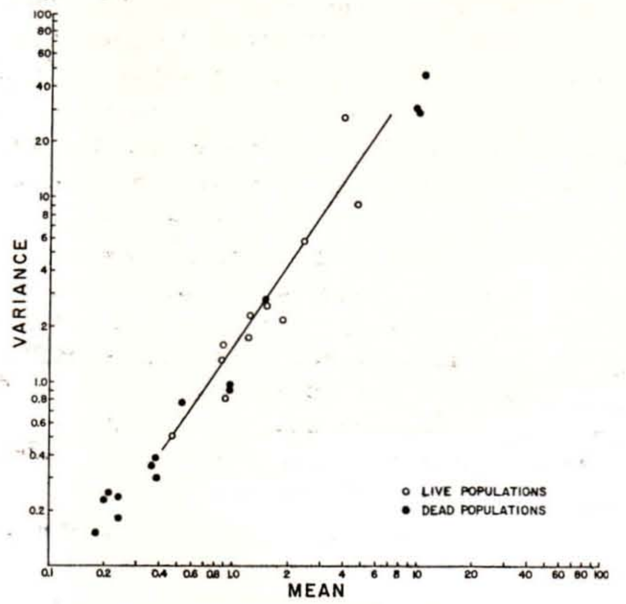
| Species | variance | mean | spatial arrangement | k' |
|---|---|---|---|---|
| *Ammobaculites* sp. | 28.91 | 10.39 | aggregated | 7.70 |
| *Ammonia beccarii* (Linné) | 0.25 | 0.21 | random | —— |
| *Elphidium tisburyense* (Butcher) | 0.78 | 0.54 | random | —— |
| *Trochammina inflata* (Montagu) | 2.85 | 1.50 | random | —— |
| *Trochammina macrescens* (Brady) | 0.15 | 0.18 | random | —— |

Dead Populations — Sample B

| Species | variance | mean | spatial arrangement | k' |
|---|---|---|---|---|
| *Ammobaculites* sp. | 30.03 | 10.29 | aggregated | 4.31 |
| *Ammonia beccarii* (Linné) | 0.23 | 0.20 | random | —— |
| *Elphidium tisburyense* (Butcher) | 0.39 | 0.38 | random | —— |
| *Trochammina inflata* (Montagu) | 0.91 | 0.97 | random | —— |
| *Trochammina macrescens* (Brady) | 0.30 | 0.38 | random | —— |

Dead Populations — Sample C

| Species | variance | mean | spatial arrangement | k' |
|---|---|---|---|---|
| *Ammobaculites* sp. | 46.27 | 11.18 | aggregated | 6.48 |
| *Ammonia beccarii* (Linné) | 0.24 | 0.24 | random | —— |
| *Elphidium tisburyense* (Butcher) | 0.18 | 0.24 | random | —— |
| *Trochammina inflata* (Montagu) | 0.94 | 0.97 | random | —— |
| *Trochammina macrescens* (Brady) | 0.36 | 0.35 | random | —— |



TEXT FIGURE 5

Log-Log plot of variance and mean. Equation of line shown is $s^2 = 1.56\bar{x}^{1.44}$

Taylor (1961) views *a* to be largely a sampling or computing factor, while *b* is considered as an index of aggregation with a continuous graduation from near-regular (at $b \rightarrow 0$) to random (at $b = 1$) and highly aggregated (at $b \rightarrow \infty$). The calculated line and variance-*vs.*-mean plots for the living and dead population are shown in text fig. 5. Although the line was calculated for the living population only, it fits the dead population's data very well. Equation (4) conveniently expresses the observed relationship between variance and mean and quantitatively expresses the fact that as the density increases the distribution of the populations becomes increasingly more aggregated. The values *a* and *b* of equation (4) were calculated for the variances and means of several different species. Data for a living population of a single species having different densities are needed to ascertain whether or not this relationship is meaningful for single species populations. The data from the dead populations suggest that this is so, because the same species that occur with high densities in the living population and with low densities in the dead population plot closely to the calculated line. Undoubtedly, as more data become available the estimates of *a* and *b* in equation (4) will have to be modified. The relationship shown between variance and mean by equation (4) sums up very neatly the trend of increasing aggregation with increasing mean which we have so laboriously examined in the preceding section.

## DISCUSSION

Life cycles have been worked out for several species of Foraminifera (see Loeblich and Tappan, 1964 for a review). In general there is an asexual and sexual phase. Sexual reproduction usually occurs by release of gametes into the water, the resulting zygote then being free to settle onto a substratum. Asexual reproduction usually produces a brood of young which are grouped about the parent. The number of sexual *vs.* asexual generations, the expected number of offspring, and their survivorship are unknown for the species studied here, but observations by various workers indicate that asexually-produced individuals usually far outnumber sexually-produced ones.

The discussion will be facilitated if we focus our attention on the small area of observation in the present study and consider how random and aggregated distributions might have come about there. There are two possible ways in which an individual foraminifer could have gotten into the area of our observation: it either came in from outside the area or was produced within it. An individual which was produced within the area but was subsequently transported from it only to re-enter later is, for our purposes, considered as coming from outside the area sampled.

Introduction of individuals by settling out of the water is the simplest explanation for the arrival of individuals from outside the area of observation. Sexually-produced individuals which were formed by the union of gametes in the water would seem to be the most likely to have the necessary floating stage. These individuals could settle into the area of observation from gametes produced within or outside the area of observation. Asexually-produced individuals are also likely to be introduced in this way, because their small size allows them to be easily transported by currents. Indeed, as Murray (1965) has pointed out, transportation of small specimens of benthonic Foraminifera is a common occurrence. If the environmental variables in the area of observation are homogeneous so that there is no preferential survival, individuals which enter the area of observation by settling out of the water should have a random distribution.

Aggregation due to substratal non-homogeneity has been suggested by plant ecologists (see Greig-Smith, 1964, and Goodall, 1952, for reviews), but this seems unlikely here. Lee *et al.* (1966) have demonstrated that the species of Foraminifera they studied had a preference for certain species of diatoms and bacteria, did better on mixtures of organisms, and fed better at a higher concentration of food organisms. If the area of this study is heterogeneous with respect to food, then it is so only for the more abundant species, because they are the only ones that are aggregated.

Another alternative for explaining aggregation, which we have already mentioned, is that the observed distribution is a mixture of several Poissons with differing means. Because our observations have been made on contiguous cells in each case, this model cannot explain our observations.

Finally, introduction into the area of observation could be accomplished by reworking or any type of movement of sediment into the observed area from just outside it. The resulting distribution of Foraminifera would depend on the nature of such an introduction as well as on their original distribution in the material being introduced. If the adjacent area is very much like the areas of our observation and the movement of sediment is into as well as out of the observed area in a random fashion, then such movement would have very little effect on the observed area.

Within the area of observation, individuals which are asexually produced and therefore grouped about the parent could, perhaps, given sufficient time and means of dispersal, become randomly distributed. The more plausible alternative is that asexual reproduction within the observed area causes aggregation. Providing the offspring are not too greatly dispersed, the expected distribution would be the negative binomial, as Bliss and Fisher (1953) have pointed out. If this type of aggregation is present in our material, then, providing there has not been an additional settling of individuals whose density is relatively large compared to the density of the asexually produced individuals, we would expect that the age of the individuals in the clumps would be less than those outside of them. Unfortunately, at the present time, there is no way of telling how old a form is. Hopefully, there may be a linear correlation between age and size. If this is so, then individuals within a clump should have smaller mean size than individuals outside of a clump. A glance at text figs. 2, 3 and 4 will show that a clump in this case is rather difficult to define. Consideration of text figs. 2-4 and the frequency distribution tables indicates that a reasonable definition is a cell in which there are individuals and the binomial expectation is less than two. For *A. beccarii* sample A (see text fig. 2) this consisted of two cells of eight, one cell of nine, and two cells of twelve. The mean of the clumped individuals was 231.04μ and of the non-clumped 259.34μ. A test to determine if the mean of the non-clumped exceeded the mean of the clumped when the variances are unknown (see Natrella, 1963, p. 3-26) indicated that at the 95% level there is no reason to believe that the mean of the non-clumped individuals exceeds that of the clumped. In sample B live *A. beccarii* (text fig. 3) were considered clumped in four cells of four and one cell of six. The mean of the non-clumped individuals is 236.07μ and of the clumped 254.54μ. In sample C (text fig. 4) two cells of eight, one cell of ten, two cells of fifteen, and one cell of seventeen live *A. beccarii* were considered clumped. The mean of the non-clumped is 237.94μ and of the clumped 235.37μ. The difference is not significant. *Elphidium clavatum* is aggregated in samples A and C. In sample A (text fig. 2), the clumped individuals were three cells of three and one cell of five. The mean of the non-clumped is 251.66μ and of the clumped 180.00μ. The difference is significant at the 95% level. In sample C four cells of three and one cell of four *E. clavatum* were considered clumped. The mean of the non-clumped is 240.00μ and the clumped 233.33μ. The difference is not significant. In sample A, *E. tisburyense* is clumped in one cell of six and one cell of eleven. The mean of the non-clumped is 294.46μ and of the clumped 260.00μ. The difference is significant at the 95% level.

The results of the size analyses do not strongly support the hypothesis that aggregation is due to asexual reproduction. On the other hand they do not indicate that this mechanism is not at work, because we do not know what the relationship of size and age is, and, conceivably, the individuals in clumps may be grouped about a parent but have had sufficient time to increase their size. Moreover, the asexually-produced population within the area of observation is probably being continually added to by arrivals from outside the observed area.

The following model is proposed as the most likely explanation for the observed increase in aggregation with density. The low-density random populations are the result of individuals randomly settling out of the water into the observed area. The more abundant species probably have a greater number of individuals settling out (because they are probably more abundant in adjacent areas), but superimposed upon this random population is one in which individuals are asexually produced within the area of observation, thereby causing aggregation. The most abundant species are the ones most actively undergoing asexual reproduction within the observed area; the observed increase in aggregation is to be expected.

As pointed out above, an alternative explanation is that the environment is heterogeneous with respect to the abundant species. Even if this is so, however, these preferred subareas would, especially if particularly rich in the needed requirement, be areas for active asexual reproduction. The trend of increasing aggregation with density is still accounted for by an increase in asexual reproduction on the part of the abundant species, but because of this reproductive behavior we do not know whether this is so because the whole area is homogeneously favorable or only parts of it are.

It should be stressed that the model presented here is based on observations of populations composed of several species. Data on a single species from several areas having varying densities is required to see if populations of a single species behave in the same manner.

The dead populations show the same trend of increasing aggregation with density. Consideration of the dead population in terms of the species densities (see table 14), however, is difficult, because, with the exception of *Ammobaculites* sp., the species studied are much less abundant in the dead than in the living population. Such high live-to-dead ratios are considered (see Phleger, 1960) indicative of rapid sedimentation. The fact that *Ammobaculites* sp. has an abundant dead population and a very small living one is in opposition to this view in this situation. A more likely explanation is that the role of dominance in the populations has changed hands. *Ammobaculites* sp., once the most abundant species, is now much less so. The role of dominance has been taken over by the calcareous *Elphidium* group.

The observations presented here are like a single frame from a motion picture. Detailed observations over a period of time are required if one would gain an understanding of the true dynamic aspect of the populations.

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CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
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# 343. AN INTERTIDAL *MARGINOPORA* COLONY IN SUVA HARBOR, FIJI

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## ABSTRACT

A colony of the attached large foraminifer **Marginopora vertebralis** Quoy and Gaimard was found living on an intertidal muddy sand flat in front of a mangrove swamp in Suva Harbor, Fiji. **Marginopora** here was in the interesting and hitherto unreported condition of being exposed to direct sunlight, air, and heavy rainfall for up to several hours daily. The foraminifer was densely and fairly regularly distributed on all substrata large enough for attachment, including algae, grass, rock clasts, and reef debris. Immature specimens were clumped, but adults were not. The flat occupied was bordered by the mangrove swamp, an active tidal channel, deeper and turbid water, and a trough extending outward from the swamp to deeper water. Beyond the trough, another flat was found which, while very similar, was not occupied by **Marginopora**. It may be a more recent topographic feature which has not yet had time or developed the necessary characteristics for colonization or the considerably greater seaward extension of the intertidal zone in front of this flat may in some way render it unsuitable for colonization.

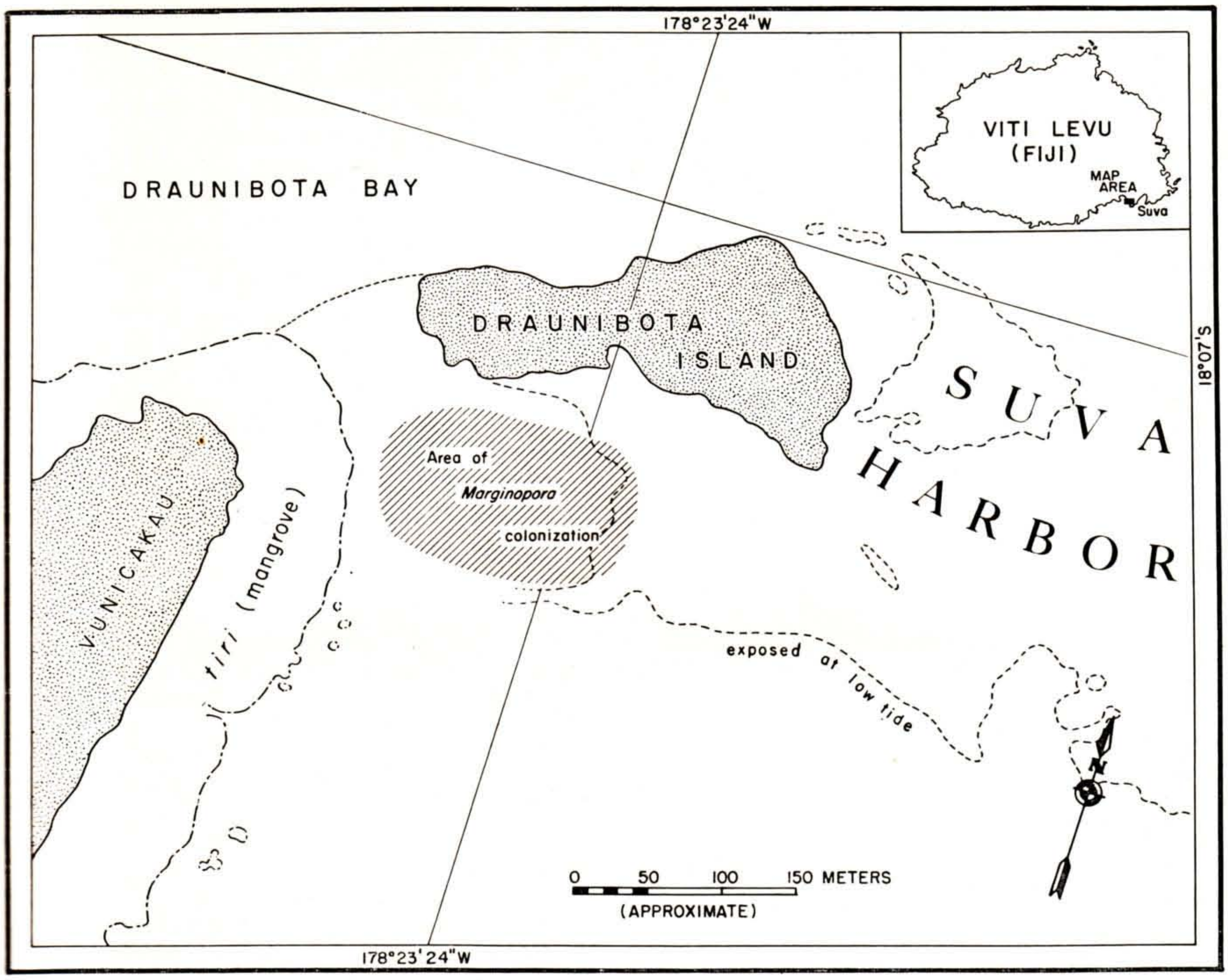
## INTRODUCTION

In May of 1965, I found an intertidal area in Suva Harbor, Fiji, to be densely populated with the attached large foraminifer *Marginopora vertebralis* Quoy and Gaimard. This species was living attached to all types of substrata of suitable size, resting on the muddy sand of an intertidal flat on the south side of the harbor (see text fig. 1). The foraminifer was seen from the seaward edge of a mangrove swamp, completely exposed for hours during low tide, downslope to where approximately a meter of water covers at low tide. The area occupied extended alongshore for only a short distance (approximately 100 meters). On the north, an active tidal channel sharply marked the boundary of *Marginopora* colonization. Beyond this channel, the intertidal zone is very narrow and rocky. On the south, the boundary was a zone about 20 meters wide at which the population density of *Marginopora* decreased to zero. This boundary zone showed a vertical descent into a trough about 10 meters wide, depressed about one-half meter below the flats on either side and containing fewer suitable objects for attachment. To the south of this feature, depths are shallower again, but the sediment is harder and sandier and water flows across the flat more rapidly than in the *Marginopora*-populated area. Further, this flat projects on a reef base much farther out into the harbor than does that occupied by *Marginopora* (see text fig. 1).

## PREVIOUS WORK

Biological studies of living Foraminifera have been made by a few workers, including Myers (1935, 1936, 1943b), Arnold (1956), and Lee *et al.* (1961). *Marginopora* has never been studied, however. A number of ecological and distributional studies of Foraminifera have been made. Of these, that of Myers (1943a) is most closely related to the present work. He reports that, among larger Foraminifera of the tropics, those with planispiral, fusiform, or discoidal shapes, including *Marginopora*, live on firm sandy or sand-mud bottoms of the sublittoral zone within the depth limits required by photosynthetic organisms. In the present case, however, *Marginopora* is living above the sublittoral zone.

The distribution of foraminiferal species around some low-latitude reefs has been described (see Cushman, Todd, and Post, 1954; Todd, 1957; 1961; Todd and Low, 1960). These studies were not made with the intent of relating the species to ecological variables and, thus, allow only the generalization that *Marginopora* is common to abundant in shallow water around Fiji and other Pacific Islands. Careful observations on the distribution of living Foraminifera in shallow water, mainly of reduced salinites, have been made by Myers (1943b), Parker and Athearn (1959), Todd and Low (1961), Buzas (1965), and others. Because these studies have been conducted on the smaller Foraminifera of mid and higher latitudes, the information is not directly applicable to the present situation, although the *Marginopora* do, apparently, have a wide salinity tolerance. Todd and Brönnimann (1957) and Saunders (1958) have described some smaller Foraminifera from tidal mud flats, estuaries, and mangrove swamps of Trinidad, and Phleger (1965) has described some from a Florida mangrove swamp. Studies of the Foraminifera of beaches include those along the Adriatic by d'Orbigny (1826), the sands at Rimini by Fornasini (1902), shore sands at Quequen, Argentina, by Boltovskoy (1955), three beaches in western India by Bhatia (1956), and Santa Monica Bay, California, by Reiter (1959). The fossil Foraminifera of Fiji have been treated by Brady (1888), Ladd and Whipple (1930), Cushman (1931, 1934), Whipple (1934), Ladd (1936), Cole (1945), and Kleinpell (1954).



TEXT FIGURE 1

A summary of foraminiferal ecology and an excellent list of references is given by Myers and Cole (1957). Phleger (1960) presents much useful information in his book on ecology and distribution of Recent Foraminifera, although nothing directly comparable to the present observation was included.

## CHARACTERISTICS OF THE AREA OCCUPIED BY *MARGINOPORA*

The bottom sediment in the area occupied by *Marginopora* consists of muddy sand. The surface is uneven, marked by hummocks approximately one-half to one meter in diameter, up to a half meter higher than surrounding sediment, and separated by flat stretches and sub-circular depressions. The hummocks decrease in number seaward, with a corresponding relative flattening of the general surface of the flat. Sand is more abundant in the hummocks than in the flat patches and depressions, although it is remarkably loose and muddy over this entire flat. The vegetation consists of turtle grass, eel grass, calcareous and non-calcareous algae, and, near the edge of the swamp, living shoots of *Rhizophora mangle*. The larger debris resting on the flat includes rounded pebbles, cobbles, and boulders, wood from the mangrove swamp, coconut shells, calcareous shells, and chunks of corals and other reef organisms.

Although not measured, the salinity of the environment clearly varies greatly. Heavy rain storms drench the flat with fresh water. Furthermore, water flows across the flat from the mangrove swamp, where salinities are less than normal marine (taken as 32-35‰). Some measurements of the pH of mangrove-swamp water nearby indicated tendencies to be slightly acidic.

## DISTRIBUTION OF *MARGINOPORA* WITHIN ITS HABITAT

*Marginopora* showed no obvious substratal preference among all the vegetation and debris mentioned above, so long as the substratum was large enough for attachment. Within the colony, the distribution of adults appeared relatively uniform, although *Marginopora* was not attached to all apparently suitable substrata. These substratal objects themselves were concentrated more in the flat areas and depressions, but some on the hummocks did carry *Marginopora*.

Immature specimens tended to occur in obvious clumps. For example, a single five-to-ten-centimeter-square patch of algae, or one large coconut husk might have 20 or 30 immature *Marginopora* attached to it, while the next patch of algae, only a few centimeters to a meter away, might have attached one or two adults and three or four immature specimens (adults and immature were roughly divided on the basis of relative size). Apparently, juvenile forms tend to settle close to their parents, but in such cases most do not attain maturity. The sediment includes many dead tests of *Marginopora,* with a preponderance of small immature forms.

The area occupied by *Marginopora* ranges in depth from approximately a meter below low tide upward to where the tide covers it for only about an hour. At the higher levels, the sand remains damp during subaerial exposure, although many objects to which *Marginopora* attach become quite dry. On these, *Marginopora* received direct sunlight and sometimes became dry on their upper surface. None, however, were observed to be dry on their lower surface; this may be a critical requirement for survival. Perhaps specimens need only brief immersion to allow them to retain moisture internally and between test and substrate. Many smaller Foraminifera were found in the muddy sand where the rigors of exposure would be considerably less.

A comparable intertidal occurrence of *Marginopora* in Borneo has been reported by W. H. Blow (1966, personal communication). There the living specimens were purple in color (perhaps indicative of type of food), whereas the present specimens were white.

## BOUNDARY CONDITIONS

### Northern Boundary

*Marginopora vertebralis* occurs elsewhere in Suva Harbor; no detailed examination of other occurrences was made. The genus is, however, commonly found attached to corals and other substrata around reefs. Reef organisms form the substratum in the deeper water along the outer part of the northern boundary of the *Marginopora* colony, but no *Marginopora* were observed attached to them. The northern boundary was very sharply marked. The fact that immediately to the north lies an incised channel subjected to the rapid flow of very turbid tidal water may well explain the sharpness of the boundary. The greater depth and nature of the substratum of the channel likely had little independent role, as nowhere does the channel reach depths greater than those occupied by *Marginopora,* and only the section floored by sand is not a suitable substratum.

Turbidity appears to play the major role in the outer part of the channel, the force of flow being secondary, but the roles are reversed in the shallowest part of the channel where the water is not so deep that turbidity should be a limiting factor. Some attached *Marginopora* placed in this area during tidal flow shortly were torn from their moorings and swept away, although others held fast. It seems apparent that a juvenile form would find it impossible to attach under such conditions.

Immediately to the north of the channel, within the intertidal area floored by large clasts, lies a small embayment next to the island. Although the flow is not particularly rapid nor the hours of exposure greater than where *Marginopora* thrives, no *Marginopora* were found there. Perhaps the area is too small for successful colonization or the pavement of larger clasts is not a suitable environment.

### Southern Boundary

The southern boundary of the colonized area is more gradational than the northern. Across a lateral distance of approximately 20 meters, the population density could be seen to decrease as the bottom, losing relief and containing fewer suitable objects for attachment, changed. This change culminates in a trough-like depression about 10 meters wide, which, while it shallows regularly shoreward, contains water through much of its length, even at low tide. This feature is floored by loose, muddy sand and has little internal relief. It contains few objects to which *Marginopora* could attach. It appears to function as a channel through which water flows into and out of the mangrove swamp either directly or indirectly across the flat to the south. That the rate of flow in this trough is not nearly as rapid as it is in the tidal channel beyond the flat to the north is reflected in the relatively unsorted, loose, and soft nature of the muddy-sand bottom.

### Western Boundary

The western boundary of the area of colonization by *Marginopora* parallels the edge of the mangrove swamp, a few meters out. The sediment becomes quite muddy, the surface is level, and few suitable substratal objects are present directly in front of the swamp. The sediment remains damp, although it is covered by water only for a short time during the high tides. No *Marginopora* were observed in the swamp itself.

### Eastern Boundary

The outer, offshore boundary of the area of colonization could not be determined with certainty. Apparently it ran along a line covered by approximately one-half meter of water at low tide. Before this line had been reached, however, the population density of *Marginopora* decreased. Along with this, vegetation decreased, the bottom leveled, and fine sediment covered such large clasts as were present. Reef growth also begins in this area. Absence of *Marginopora* probably results from lack of suitable substrata and the great turbidity of the water. The reef provides suitable substrata, so turbidity sufficient to make it difficult to discern the nature of the bottom below tide marks seems to be the limiting factor there.

## COMPARISON OF FLATS OCCUPIED AND NOT OCCUPIED BY *MARGINOPORA*

South of the trough marking the southern boundary of *Marginopora* occupation lies a sloping flat covered with micro-relief and very similar in its shoreward part to the one on the north, but, unlike it, devoid of *Marginopora*. The flat differs from the one to the north in that it extends much farther out into the harbor, becoming a reef flat in the outer part. In the inner, sandy area, comparable to the northern flat, the sand is cleaner and firmer and water flows across it more rapidly and extensively. Numerous narrow, shallow, circuitous, anastomosing channels cross the flat from the mangrove swamp to the trough and elsewhere into deeper water. The fairly rapid flow through the channels would winnow the sediment and produce the cleaner and firmer sand of this flat.

Locally, near the swamp, patches of muddy "quicksand" occur. Dotting this flat, crabs have erected mounds of sand and fragmented molluscan and other shells above their burrows. These mounds are approximately one-fourth to one meter in greatest diameter and reach heights of one-fourth meter above their surroundings. Other features of surface relief consist of small (10 cm. to 1 meter diameter), shallow (rarely reaching one-half meter), irregular to subcircular depressions and larger, nearly flat patches. Considering the area as a whole, channels, depressions, and flats all occupy about the same amount of space, while mounds occupy about one-third as much. The first three are fairly evenly distributed, but the mounds decrease in number seaward, as the flat becomes a more typical reef flat.

The same vegetation, green and coralline algae, eel grass and turtle grass, occupies the inner area of this flat in about the same abundance and distributional pattern as on the flat to the north. The major difference in vegetation appears to be the lack of algae in the channels, features themselves not well-defined on the north flat. *Rhizophora* shoots are common near the edge of the mangrove swamp. Some coconut shells, chunks of coral and other reef debris, and large rock clasts also are present, but not so abundantly as on the north flat.

The comparison of physical features of the two flats suggests an interesting relationship. The hummocks of the north flat resemble the crab-burrow mounds of the south flat, but no burrows or crabs are seen in them and the sediment on the hummocks contains considerable silty and clayey material as well as sand. (Unfortunately, no hummocks were sectioned to see if they were homogeneous throughout). The hummocks, in combination with the generally more rounded nature of the relief features of the north flat (although the vertical relief is just as great), the lack of pronounced channels, and the poorer sorting of sand suggest that the north flat represents a more "mature phase" than the south flat, both having been formed in the same way but under locally different conditions. The formation of these features may be related to the development and drainage of the mangrove swamp. The swamp may have advanced southward and/or its drainage patterns may have shifted slightly. Mangrove swamps around Viti Levu are known to have advanced markedly during the past century.

Although *Marginopora* perhaps could not maintain itself in the currents of the east-flat channels, much of the flat surface superficially appears as well suited to colonization as that of the west flat. An explanation for the absence of *Marginopora* can only be suggested. Perhaps unrecognized environmental variables may be unfavorable for colonization. It is possible that nutrients are used up crossing the extensive outer reef flat. Another explanation is that the east flat is quite a recent feature, one which has not yet had time for colonization by *Marginopora*.

## SUMMARY

In summary, the intertidal occurrence of this population of *Marginopora vertebralis* in Fiji is notable because the foraminifer here thrives exposed to air and direct sunlight up to several hours per day as well as to torrential downpours of fresh water and to salinity variation of the bottom waters. Although other, smaller Foraminifera occur in the same area, they are protected from the air and sun and, to some extent, the salinity changes, because they live in the sediment. The *Marginopora*, especially, appear to thrive in conditions not generally thought possible for habitation by Foraminifera.

The relationship between the flat occupied by *Marginopora* and the flat next to the south was considered because of the interesting question of why one abounds in *Marginopora* and the other has none, although they superficially appear equally suitable for occupation.

## ACKNOWLEDGMENTS

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# 344. EOCENE FAUNULE FROM THE BASAL SAN JUAN BAUTISTA FORMATION OF CALIFORNIA

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ABSTRACT

The San Juan Bautista formation, until now unyielding of microfossils, has been considered to be of Oligocene age on the basis of megafossils. A small, poorly preserved foraminiferal faunule indicates a middle Eocene age for the basal part of the formation.

## INTRODUCTION

The San Juan Bautista formation, forming the low grassy hills northwest of the town of San Juan Bautista, San Benito County, California, lies in depositional contact upon the Santa Lucia granite. It consists of "as much as 1500 feet of poorly bedded, fine grained, fossiliferous, argillaceous and calcareous sandstone, carbonaceous grits often containing numerous wood fragments and shale," (Allen, 1946, p. 27). The overlying Pinecate formation, consisting of about 1000 feet of massive quartzose sandstone, is, in turn, conformably overlain by the Vaqueros sandstone.

The San Juan Bautista and Pinecate formations, proposed by Kerr and Schenck in 1925, have been considered to be of Oligocene age on the basis of marine mollusca, primarily from the San Juan Bautista formation. These are *Bruclarkia gravida* (Gabb), *Fusinus ohehalisensis* Weaver, *Acila muta* Clark, *Epitonium wagneri* Durham and *Modiolus kirkerensis* Clark. The Pinecate formation has yielded *Spisula mulinaformis* Wagner and Schilling and *Antigona mathewsoni* (Gabb). The San Juan Bautista and Pinecate formations were compared with the San Emigdio and Pleito formations, respectively, by Kerr and Schenck. In 1936 Schenck and Kleinpell, on the basis of the mollusca, considered the San Juan Bautista and, questionably, the Pinecate to be part of the foraminiferal Refugian Stage (latest Eocene - early Oligocene).

## OBSERVATIONS

A small badly leached and sugary foraminiferal sample has been obtained from an outcrop stratigraphically low in the San Juan Bautista formation, just a few feet above the contact with the granite. The sample contains pyritized casts of *Allomorphina macrostoma* Karrer (?) and *Chilostomella cylindroides* Reuss (?) from one lamina and leached specimens, in which neither of the above are present, from an adjacent lamina. The leached specimens include *Bathysiphon*, *Ammodiscus*, *Spiroplectammina* (?), *Cyclammina* (?), *Haplophragmoides* (?), *Trochammina*, *Robulus*, *Saracenaria*, *Dentalina*, *Nodosaria*, *Bulimina*, *Eponides*, *Gyroidina*, *Globigerina*, *Globorotalia*, and *Cibicides*. Most species present are rare, and specific identifications are indeterminate in most instances.

Stratigraphically, the most diagnostic species in the fauna is *Globorotalia aragonensis* Nuttall which indicates that this sample is of lower or middle Eocene age (Penutian or Ulatisian Stage of Mallory, 1959) and that deposition of the San Juan Bautista formation began during Eocene time, apparently middle Eocene at the latest.

If the San Juan Bautista-Pinecate sequence actually represents continuous deposition, then, on the basis of superpositional evidence, some, at least, of the massive bodies of sandstone stratigraphically above the foraminiferal faunule herein recorded and below the megafossiliferous horizons may represent time-equivalents of the Butano sandstone of the Santa Cruz Mountains, the The Rocks sandstone formation of the Santa Lucia Mountains, the Matilija sandstone of the Santa Ynez Range, the Point of Rocks and the Yokut-Domengine sandstone sequences of the San Joaquin Valley, and sandstones at or near the Tres Pinos-Los Muertos

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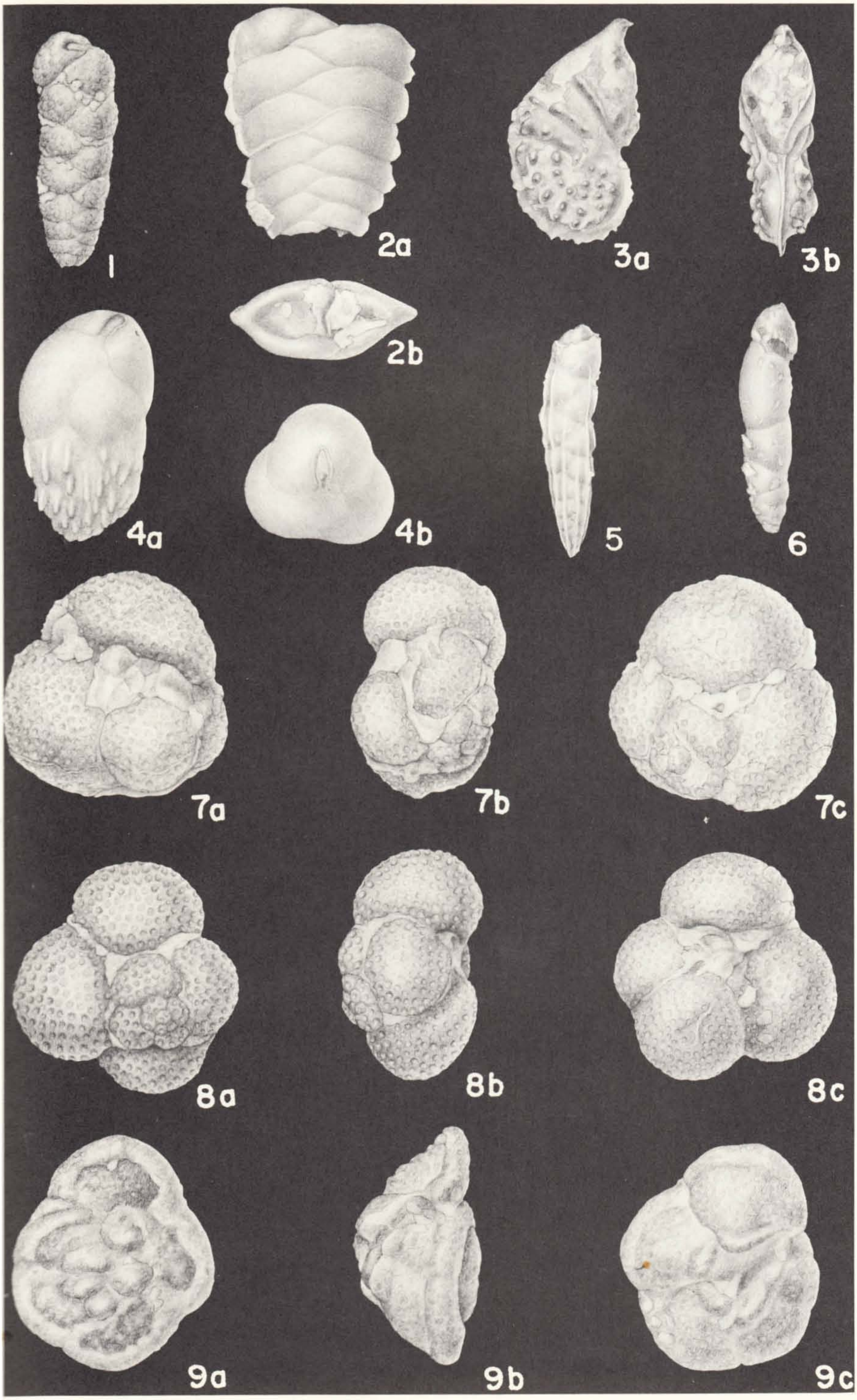
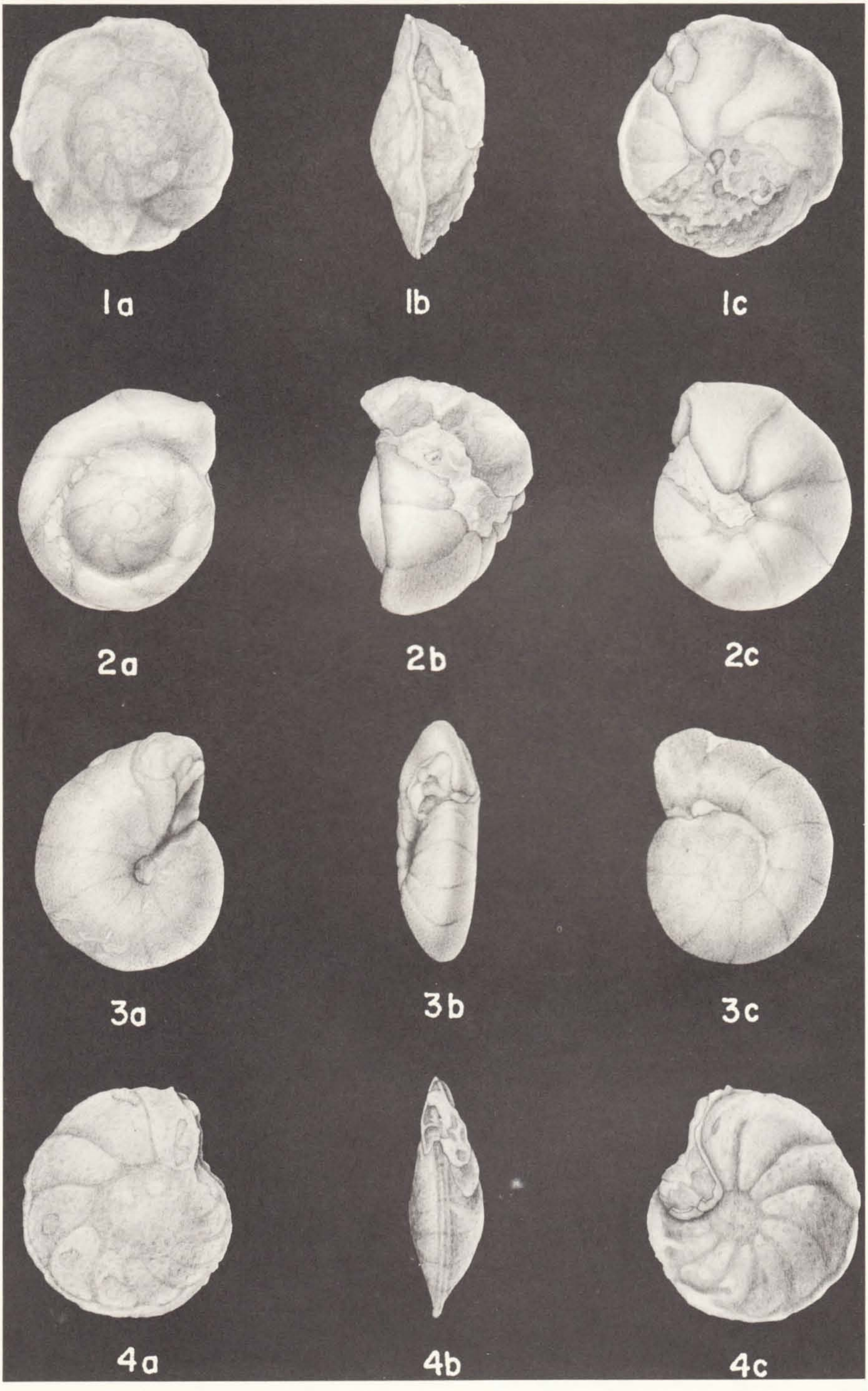
[1] A contribution from the Museum of Paleontology.

## EXPLANATION OF PLATE 1

| FIGS. | | PAGE |
|---|---|---|
| 1. | *Dorothia* sp. Hypotype 40286, × 33. | 19 |
| 2a, b. | *Spiroplectammina* (?) sp. Hypotype 40285, × 55. | 19 |
| 3a, b. | *Vaginulinopsis mexicanus* (Cushman) var. Hypotype 40287, × 36. | 19 |
| 4a, b. | *Bulimina* sp. Hypotype 40288, × 67. | 19 |
| 5. | *Loxostomum* sp. Hypotype 40289, × 30. | 19 |
| 6. | *Pleurostomella* sp. Hypotype 40290, × 36. | 19 |
| 7a, b, c. | *Globigerina triloculinoides* Plumer. Hypotype 40296, × 91. | 20 |
| 8a, b, c. | *Globigerina triloculinoides* Plumer. Hypotype 40295, × 71. | 20 |
| 9a, b, c. | *Globorotalia aragonensis* Nuttall. Hypotype 40297, × 53. | 20 |



Waters: San Juan Bautista's Eocene Age



Waters: San Juan Bautista's Eocene Age

formational contact farther east in San Benito County. *Gyroidina* cf. *G. orbicularis planata* is very close to forms recorded from the upper Eocene (upper Ulatisian and Narizian Stages) of the West Coast Ranges (Mallory, 1959, p. 87). Collectively the fauna demonstrates a probable medium depth with surface waters having access to the open ocean.

## LOCALITY DESCRIPTION

The single sample studied here (UCMP no. D-515) was collected from the northwestern part of San Benito County, in the central Coast Ranges of California. The location on the 1955 edition of the U.S.G.S. 7½′ topographic map of the San Juan Bautista Quadrangle (scale 1:24000) is 7400′ east of the R 4 E line and 6550′ north of the T 12 S line, MDBM. The sample was collected from a long low outcrop of yellowish-tan silty mudstone stratigraphically just above the Santa Lucia Granite and exposed in a road cut on the north side of a creek along an indistinct farm road.

## SYSTEMATICS

Although many of the foraminifers from U.C.M.P. locality D-515 are specifically indeterminate, the few better preserved specimens warranting illustration are referred to in the systematic notes that follow.

Order FORAMINIFERA d'Orbigny, 1826
Family TEXTULARIIDAE
Genus **Spiroplectammina** Cushman, 1927
**Spiroplectammina** (?) sp.
Plate 1, figures 2a, b

Hypotype 40285

Family VALVULINIDAE
Genus **Dorothia** Plummer, 1931
**Dorothia** sp.
Plate 1, figure 1

Hypotype 40286

Family LAGENIDAE
Genus **Vaginulinopsis** Sylvestri, 1904
**Vaginulinopsis mexicanus** (Cushman) var.
Plate 1, figures 3a, b

Hypotype 40287

Family BULIMINIDAE
Genus **Bulimina** d'Orbigny, 1826
**Bulimina** sp.
Plate 1, figures 4a, b

Hypotype 40288

Genus **Loxostomum** Ehrenberg, 1854
**Loxostomum** sp.
Plate 1, figure 5

Hypotype 40289

Family ELLIPSOIDINIDAE
Genus **Pleurostomella**
**Pleurostomella** sp.
Plate 1, figure 6

Hypotype 40290

Family ROTALIIDAE
Genus **Gyroidina** d'Orbigny, 1826
**Gyroidina** cf. **G. orbicularis** d'Orbigny
var. **planata** Cushman
Plate 2, figures 2a-c

Hypotype 40291

Specimens are close to Cushman's variety, recorded from upper Ulatisian and Narizian horizons in the West Coast Ranges (see Mallory, 1959, p. 235).

Genus **Eponides** Montfort, 1808
**Eponides** (?) sp.
Plate 2, figures 1a-c

Hypotype 40292

Family CHILOSTOMELLIDAE
Genus **Chilostomella** Reuss, 1850
**Chilostomella cylindroides** Reuss (?)

Hypotype 40293

Questionably identified casts appear to be close to Reuss' species, recorded from Paleocene to upper Eocene horizons in the Coast Ranges (see Mallory, 1959, p. 243).

Genus **Allomorphina** Reuss, 1850
**Allomorphina macrostoma** Reuss (?)

Hypotype 40294

Pyritized casts appear to be close to Reuss' species.

## EXPLANATION OF PLATE 2

| FIGS. | | PAGE |
|---|---|---|
| 1a, b, c. | *Eponides* (?) sp. Hypotype 40292, × 63. | 19 |
| 2a, b, c. | *Gyroidina* cf. *G. orbicularis* d'Orbigny var. *planata* Cushman. Hypotype 40291, × 77. | 19 |
| 3a, b, c. | *Anomalina* sp. Hypotype 40298, × 55. | 20 |
| 4a, b, c. | *Cibicides* sp. Hypotype 40299, × 71. | 20 |

### Family GLOBIGERINIDAE

Genus **Globigerina** d'Orbigny, 1826

**Globigerina triloculinoides** Plummer

Plate 1, figures 7a-c, 8a-c

*Globigerina triloculinoides* Plummer, MALLORY, 1959, p. 250, pl. 30, fig. 6a, b; pl. 38, fig. 3a, b.

Hypotypes 40296, 40295

### Family GLOBOROTALIIDAE

Genus **Globorotalia** Cushman, 1927

**Globorotalia aragonensis** Nuttall

Plate 1, figures 9a-c

*Globorotalia aragonensis* Nuttall, MALLORY, 1959, p. 252, pl. 35, fig. 2a-c.

Hypotype 40297

This species, well represented in the lower San Juan Bautista Formation, has been recorded from no lower than Penutian and no higher than Ulatisian horizons elsewhere in the Eocene of the West Coast Ranges (see Mallory, 1959, pp. 87, 252).

### Family ANOMALINIDAE

Genus **Anomalina** d'Orbigny, 1826

**Anomalina** sp.

Plate 2, figures 3a-c

Hypotype 40298

Genus **Cibicides** Montfort, 1808

**Cibicides** sp.

Plate 2, figures 4a-c

Hypotype 40299

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# 345. THE MICROFAUNA AND AGE OF THE "GYPSEOUS SHALES," WESTERN KUTCH, INDIA*

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ABSTRACT

The typical microfauna from "Gypseous shales" exposed in the vicinity of Lakhpat, Naredi, Nareda, Beranda and Matanomadh in Western Kutch is illustrated and its stratigraphical and palaeontological significance discussed. The gypseous shales exposed near Matanomadh range in age from Middle Eocene to Oligocene, but in other localities they are of Lower Eocene age.

## INTRODUCTION

The "Gypseous shales" exposed in Western Kutch have been mapped by various geologists. This rock unit, considered by Wynne to be of Lower Eocene age on the basis of the presence of *Assilina granulosa*, has more or less attained the status of a stratigraphic unit by now. Recently, S. K. Biswas, P. K. Srivastava, P. Mitra, and others of the Oil & Natural Gas Commission carried out detailed mapping of the Tertiary deposits in Western Kutch. A representative collection from the localities near Lakhpat (23°49′30″ : 68°47′), Naredi (23°39′40″ : 68°40′38″), Nareda (23°34′23″ : 68°39′), Beranda (23°26′25″ : 68°33′10″) and Matanomadh (23°32′30″ : 68°57′10″) has been critically examined by the authors to ascertain the correct age of these shales and to correlate the different outcrops on the basis of the microfauna. It is suggested that the "Gypseous shales" range in age from Lower Eocene to Oligocene and were possibly formed under lagoonal conditions.

## PREVIOUS WORK

Wynne (1872) subdivided the Lower Tertiary of Kutch into Sub-Nummulitics, Gypseous shales, Nummulitic group, Arenaceous group and Argillaceous group and considered the "Gypseous shales" to be basal Eocene. Medlicott and Blandford (1879) considered the Sub-Nummulitics, together with the "Gypseous shales," as equivalent to the Ranikot of Sind, while Nuttal (1926) equated them to the lower part of the Middle Kirthar. While summarising the geology of Kutch, Aggarwal (1956), as quoted by Tandon (1962), opined that the "Gypseous shales" of Wynne may be of Laki age. Krishnan (1956) regarded gypseous, pyritous, and Carbonaceous shales underlying the Kirthar Limestone to be of Laki age. Wadia (1956) states "The bottom beds (Tertiary sequence) are argillaceous with bituminous, gypseous, pyritous shales, which by their constitution recall the Laki series of the much more perfectly studied Tertiary sequence of Sind." Tiwari (1957) assigned a Lower Eocene age to the gypseous shales exposed in the Waghopadar - Sanosara section in Kutch. Tandon (1962) reported the occurrence of fossiliferous Laki beds (Lower Eocene) containing *Nummulites attacicus*, *N.* cf. *N. mamilla*, *Assilina spinosa*, *A. subspinosa*, *A. daviesi*, *A. granulosa*, etc., from Nareda and correlated them with the Sakesar Limestone and/or the Bhadrar beds of West Pakistan. He mentioned the occurrence of Laki beds in the vicinity of Beranda (23°34′20″ : 68°43′10″), Chakrai (23°33′35″ : 68°46′40″), Harudi (23°30′20″ : 68°43′40″) and Lakhmirani (23°34′ : 68°38′20″). Poddar (1963) assigned a Lower Eocene age to the "Gypseous shales" and listed the important species. Mathur (1963) examined the "Gypseous shales" from the Matanomadh region and assigned a Middle Eocene age to them on the basis of the microflora. Biswas (1965) proposed a new classification for the Tertiary deposits of Kutch, assigned the "Gypseous shales" to the Kakdi Stage and correlated it with the Lower Eocene Laki Series of Sind Baluchistan.

## GEOLOGY AND FAUNA

The generalized succession of the Paleogene sediments (after Biswas, 1965) is given on page 22.

The "Gypseous shales" has recently been designated the Kakdi Stage by Biswas (1965). Since the Gypseous shales are now known to range in age from Lower Eocene (Beranda, etc.) to Middle Eocene - Oligocene (Matanomadh), the authors prefer to retain the old name of the formation for the present discussions.

The "Gypseous shales" occupy different stratigraphic positions in the Paleogene sequence of Western Kutch. The lithological succession and microfauna from these shales from different localities are discussed below. (Also see text fig. 1)

## LAKHPAT

About 84 meters of the sediments, consisting mainly of grey, gypsiferous shales, chocolate brown shales, glauconitic clays with thin bands of hard, brown-yellow fossiliferous marls, underlie the shales

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The views expressed in the paper are those of the authors and are not necessarily of the O.N.G. Commission

NEOGENE

Para-Conformity

| | | | | | |
|---|---|---|---|---|---|
| PALEOGENE | Oligocene | Lakhpat Series (12 m) | | | Dirty white and yellow banded marl and impure limestone. |
| | Eocene | Berwali Series (130 m) | Babia Stage (85 m) | Upper: (60 m) | Cream and buff massive limestone, packed with fossils. |
| | | | | Lower: (25 m) | Greenish-gray fossiliferous, calcareous clays. |
| | | | Disconformity | | |
| | | | Kakdi Stage (45 m) | Upper: (20 m) | Grey shales and red laterites. |
| | | | | Lower: (25 m) | Brown gypseous shales and green oolitic shales with fossiliferous marls. Also Gypseous shales with red ochre and black shales with lignite beds. |
| | | Unconformity | | | |
| | ? Paleocene | Madh Series (37 m) | | | Lateritic conglomerates, laterites, bauxites; tuffaceous shales, sandstones & grits; bentonitic clays. |

Upper Cretaceous Deccan Traps

and brown marls containing *Nummulites obtusus* of Middle Eocene age. Further south, at Umarsar (68°49′ : 23°44′30″), these shales are well exposed, but the contact between supratrappeans and "Gypseous shales" is not seen.

Fauna: *Nonion* sp., *Nummulites* cf. *N. subatacicus*, *Assilina subspinosa*, *A. granulosa*, *A. dandotica*, *Operculinoides* sp., *Operculina* sp., *Bulimina* sp., *Bolivina* sp., *Loxostomum* sp., *Reussella* sp., rotaliids and *Globigerina* sp. The faunal assemblage is suggestive of Lower Eocene age.

### NAREDI

The "Gypseous shales" sequence in this area is 27 meters thick and consists of brown-grey shales, light green sandy clays, brownish-grey gypseous shales, chocolate brown gypseous clays and thin marl bands. As in the Lakhpat area, it is overlain by chocolate brown clays with *Nummulites obtusus* of Middle Eocene age. The contact is marked by lateritic gravels and laterites.

Fauna: *Clavulinoides* sp., *Assilina subspinosa*, *A. granulosa*, *A. leymeriei*, *Nummulites subataci-*

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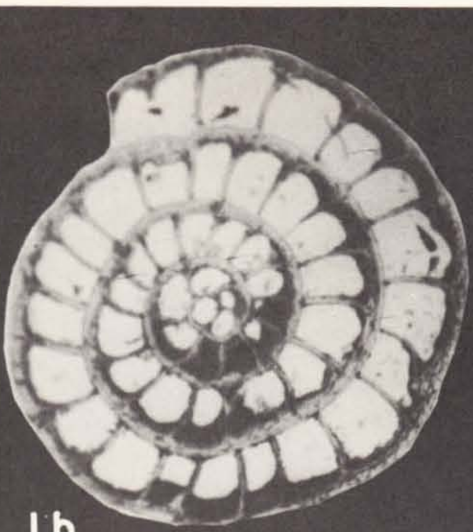
## EXPLANATION OF PLATE 3

| FIGS. | | PAGE |
|---|---|---|
| 1. | *Assilina subspinosa* Davies, Ypresian, Nareda, Western Kutch. a, exterior × 8; b, equatorial section × 10; and c, axial section × 10. | 23 |
| 2. | *Assilina leymeriei*, Ypresian. Nareda, Western Kutch. a, exterior × 15; b, equatorial section × 15; and c, axial section × 10. | 23 |
| 3. | *Nummulites subatacicus* Douville, Ypresian, Nareda, Western Kutch, × 16. a, exterior; b, equatorial section; and c, axial section. | 23 |
| 4. | Reticulate *Nummulites* (*N. fichteli* group), Oligocene. a, exterior × 10; b, equatorial section × 15; c, axial section × 15; and d, tangential section showing the structure of "filets cloisonnates" × 50. | 23 |

1a



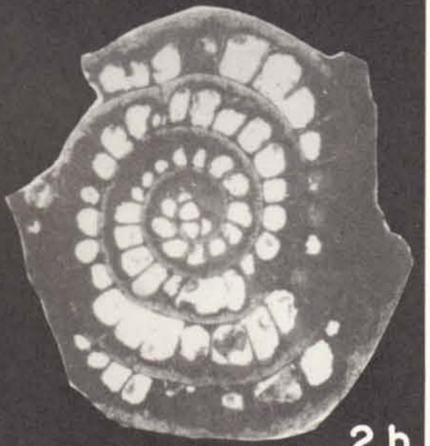
1b

2a

3a

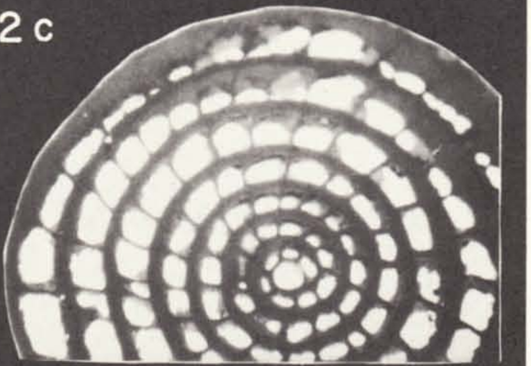
1c

2c

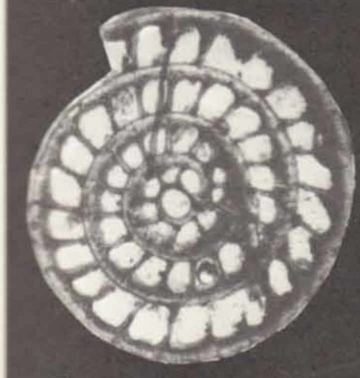


2b

3c



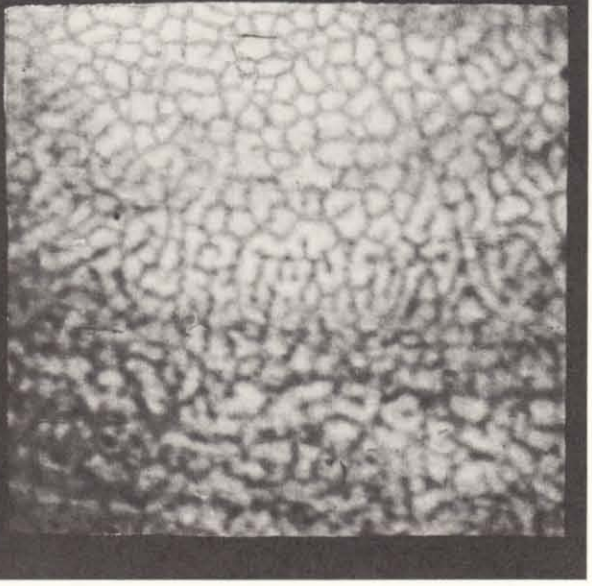
4b



3a

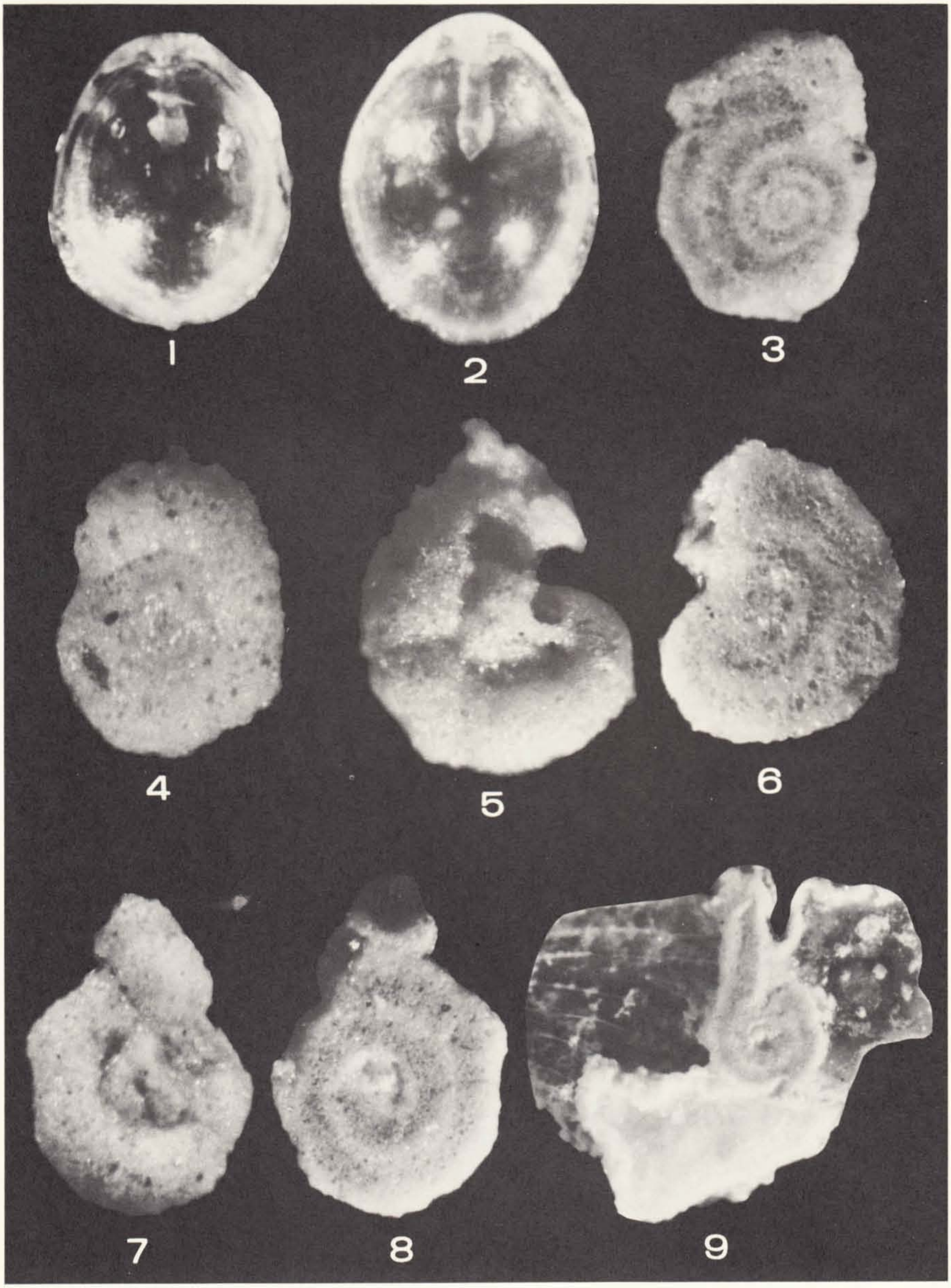
4a

4c



4d

Mohan and Gupta: Gypseous shales of Kutch, India



Bock: Two new species from the Florida Keys *cus*, *Operculina* sp., *Operculinoides* sp., *Rotalia* sp., *Lockhartia tipperi*, *Cibicides* sp., *Trachyleberis* sp., *Echinocythereis* sp., *Cythereis* sp., *Bairdia* sp., etc. The assemblage suggests a Lower Eocene age.

## NAREDA

In the vicinity of Nareda the lower part of the shales contains abundant *Nummulites subatacicus*. The associated species include *Rotalia* sp., *Cibicides* sp., *Globigerina* sp., *Krithe* sp., *Paracypris* sp., *Leguminocythereis* sp., *Tracyleberis* sp., etc. These are overlain by grey shales containing abundant *A. granulosa*, along with *A. subspinosa*, *A. leymeriei*, *Operculina* sp., *Rotalia* sp., *Eponides* sp., *Globorotalia* cf. *G. perclara*, *Cibicides* sp., *Paracypris* sp., *Bairdoppilata* sp., *Cythereis* sp., *Trachyleberis* sp., etc. Higher up in the sequence *Nonion* sp., *Bolivina* sp., and *Cycloloculina* sp. are recorded, in addition to the forms met in the grey shales. The microfauna indicates a Lower Eocene age.

## BERANDA

About 45 meters of the sediments, consisting mainly of grey, gypsiferous clays and greenish-yellow marls, constitute the "Gypseous shales." They overlie supratrappean laterites and bentonitic clays, and are, in turn, overlain by Khaki marls and clays, with occasional gypsum containing *Nummulites obtusus* of Middle Eocene age.

Fauna: *Assilina subspinosa*, *A. leymeriei*, *A. granulosa*, *Nummulites* cf. *N. subatacicus*, *Operculinoides* sp., *Operculina* sp., *Gyroidina* sp., *Eponides* sp., *Rotalia* sp., *Bairdia* sp., etc. The faunal assemblage indicates a Lower Eocene age.

## MATANOMADH

A thickness of about 44 meters of the gypseous shales, clays and impure marls is exposed along the Khari river south of Matanomadh. Structurally it forms a gentle low-dipping syncline. The gypseous shales overlie the Supratrappeans and are overlapped by sediments belonging to the "Arenaceous group" of Wynne, now known to be Lower Miocene in age. The fauna obtained from the lower part of the sequence includes: *Ammodiscus restinensis*, *Ammobaculites expansus*, *Textularia zipotensis*, *Clavulina elegans*, *Clavulinoides cubensis*, *Quinqueloculina*, *Pyrgo* cf. *P. bulloides*, *Globulina gibba*, *Guttulina* aff. *G. irregularis*, *Dentalina mauricensis*, *Glandulina laevigata*, *Nonion grateloupi*, *Elphidium* cf. *E. ibricum*, *E. minutum*, *E. latidorsatum*, *Buliminella elegantissima*, *Entosolenia laevigata*, *Reussella*, *Bolivina*, *Asterigerina* spp., *Bitubulogenerina ellisi*, *Halkyardia minima*, *Coskinolina* cf. *C. balsilliei*, *Daviesina* sp. A, *Discorbis*, etc., suggesting a Middle Eocene age.

The upper part is sparsely fossiliferous. Reticulate *Nummulites* (*N. fichteli* group) of Oligocene age have been recovered from the upper part of the sequence.

## PALAEOECOLOGY AND AGE

The microfauna of the "Gypseous shales" is confined to certain localised bands, the intervening beds being either barren or only poorly fossiliferous. In general, a similar microfaunal assemblage occurs in these shales exposed in the vicinity of Lakhpat, Naredi, Nareda and Beranda. The following species are common to all these localities: *Assilina subspinosa*, *A. leymeriei*, *A. granulosa*, *A. dandotica*, *Nummulites subatacicus*, *Operculinoides* sp., *Nonion* sp., and *Rotalia* sp. *Globorotalia* cf. *G. perclara*, by contrast, is restricted to Nareda. *Lockhartia tipperi* is fairly abundant in the samples from Naredi. The larger foraminifera dominate the assemblage. They range in diameter from 0.9 mm. to 6 mm., the common size being 2.5 mm. The smaller foraminifera are less numerous and their size ranges between 0.15 and 1.15 mm., the average being 0.5 mm. The larger foraminifera are stoutly built and fairly well ornamented, the smaller foraminifera usually fragile and smooth shelled. The total number of species is about 20, including four species of *Assilina*, two species each of *Nonion*, *Rotalia* and *Bolivina*, and one each of *Nummulites*, *Operculinoides*, *Quinqueloculina*, *Globorotalia* and *Globigerina*. The genus *Cibicides* occurs abundantly in samples from Nareda and is represented by about 6 species. The arenaceous forms are practically absent in the assemblage. The above assem-

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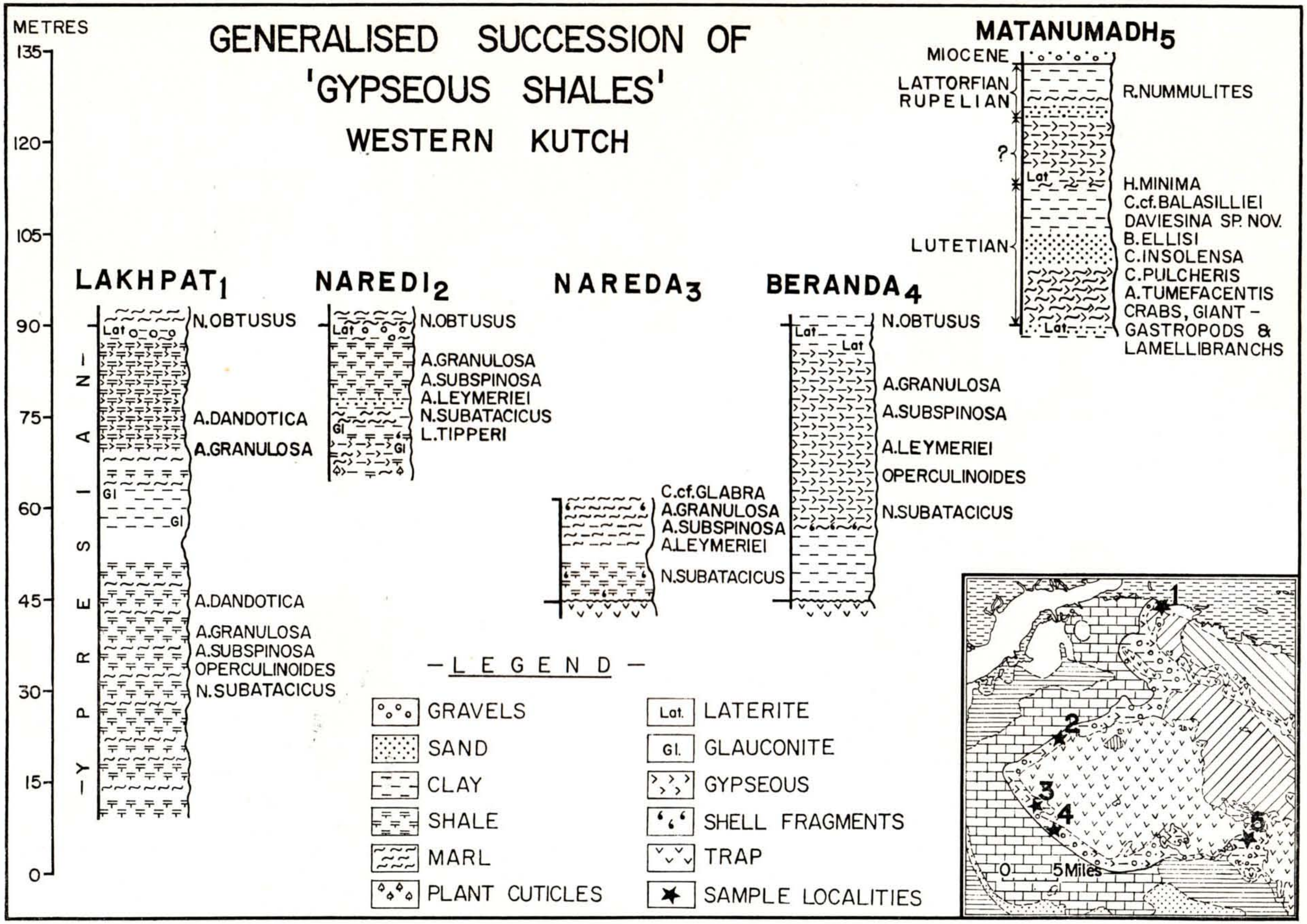
## EXPLANATION OF PLATE 4

| Figs. | | Page |
|---|---|---|
| 1. | *Fissurina pellucida* n. sp. Holotype. (USNM 643162). Found living on a blade of *Thalassia* at 24°37.7′N., 81°23.7′W. in the Florida Keys. × 295. | 28 |
| 2. | *Fissurina pellucida* n. sp. Paratype. × 325. | 28 |
| 3, 4. | *Hemidiscella palabunda* n. sp. Holotype. (USNM 643161.) Found attached to a blade of *Thalassia* at 24°37.7′N., 81°23.7′W. in the Florida Keys. Fig. 3. Attached ventral side. Fig. 4. Free dorsal side. × 290. | 27 |
| 5-9. | *Hemidiscella palabunda* n. sp. Paratypes. Figs. 5 & 7. Free dorsal sides. Figs. 6 & 8. Attached ventral sides. Fig. 9. Ventral view of specimen with dorsal side attached to mollusk fragment, both removed from blade of *Thalassia*. Figs. 5 & 6. × 125. Figs. 7 & 8. × 90. Fig. 9. × 40. | 27 |



TEXT FIGURE 1

blage is dominated by benthonic forms; planktonic forms are rare. The microfaunal assemblage suggests a Lower Eocene (Ypresian) age for the "Gypseous shales" exposed in these localities.

In the vicinity of Matanomadh, the lower part of the "Gypseous shales" contains a fairly rich microfauna, but the upper part is comparatively poor. From the lower part, 35 species, belonging to 24 genera of smaller foraminifera, could be identified. They range in size from 0.2 to 1.25 mm. Ornamented forms are present, but good ornamentation is wanting. The arenaceous component of the fauna is relatively poorer and is represented by *Ammodiscus*, *Ammobaculites* and *Textularia*. Planktonic forms are either absent or very poorly represented. The occurrence of *Halkyardia minima*, *Coskinolina* cf. *C. balsilliei*, *Bitubulogenerina ellisi*, *Textularia zipotensis*, *Elphidium minutum* and *Daviesina* sp. A in these shales is noteworthy and indicates a Middle Eocene age.

Although the reticulate nummulites of the *Nummulites fichteli* group are present in good numbers in the upper part of the "shales," their preservation is rather poor. The size of the specimens ranges from 3.5 to 10 mm., with an average of 5 mm. On account of the state of preservation, the possibility of these Oligocene reticulate *Nummulites* being derived cannot be ruled out, but it nevertheless suggests that the upper age limit of the "Gypseous shales" may go up to Oligocene, or even younger, if they are derived.

At places, these shales contain native gypsum in considerable quantity and sometimes provide very large crystals of gypsum, an indication of deposition in small enclosed bodies of sea water. This conclusion is corroborated by the faunal evidence. Throughout most of their thickness these shales are either very poorly fossiliferous or barren. The fossiliferous zones are thin but extremely rich. Strictly speaking, none of these bands at different places are synchronous, but in general all those from localities west of Matanomadh fall in the limited time limit of Ypresian. These bands are of limited lateral extent, possibly owing to the fact that the deposition of the "Gypseous shales" took place in separate enclosed bodies of sea water having possible connections with one another and also with the open sea. These intermittent connections appear to have been more extensive and frequent in Ypresian than in Middle Eocene times. Such restricted or lagoonal deposits of Lower Eocene (Ypresian) age are found at several places and have a more or less similar outcrop pattern, as is also the case of the open sea sediments. Lagoonal facies equivalents of Middle Eocene and Oligocene age are now known from the Matanomadh region, where the underlying lithomarge and ferruginous laterites (constituting the Supratrappean sediments) may presumably be of Paleocene to Lower Eocene age.

## CONCLUSIONS

The present study of the "Gypseous shales" opens a new chapter in the Lower Tertiary stratigraphy of Kutch. In the region west of Matanomadh, the middle and upper parts of these shales are definitely of Ypresian age. The lower part contains a poor, non-diagnostic microfauna, but on stratigraphical grounds these, along with the Supratrappeans, may be considered to be of Paleocene age. In the Matanomadh region these shales are Middle Eocene to Oligocene in age.

It could be concluded from the foregoing discussions that the "Gypseous shales" represent the lateral facies variations of the corresponding open sea sediments.

## ACKNOWLEDGEMENTS

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CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
FOR FORAMINIFERAL RESEARCH
VOLUME XIX, PART 1, JANUARY 1968

# 346. TWO NEW SPECIES OF FORAMINIFERA FROM THE FLORIDA KEYS[1]

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ABSTRACT

One new species belonging to a new genus, **Hemidiscella palabunda**, and one new species of **Fissurina**, **F. pellucida**, are described and discussed. Both species are from waters adjacent to Big Pine Key, Florida, and both are found living on a substratum of **Thalassia testudinum** König.

## INTRODUCTION

Two new species of living Foraminifera were found in collections made by the author during the period June, 1964 to May, 1965. The area collected is situated between the Torch Keys and Big Pine Key, Florida (text fig. 1). The water is very shallow ranging from 0.5 feet at station 8 to 6.5 feet at station 10. The distribution of both new species appears to be controlled by the distribution of the sea grass *Thalassia testudinum* König, as live specimens were found only at those stations where the grass occurred. At stations 4 and 7, where there was no grass, no live specimens were found. (Table 1).

## ACKNOWLEDGMENTS

The author wishes to express his sincere thanks to Miss Ruth Todd who examined some of the material and made helpful comments. The Office of Naval Research [Grant No. 4008(02)] provided funds for this investigation.

## SYSTEMATICS

Order FORAMINIFERIDA Eichwald, 1830
Suborder TEXTULARIINA Delage and Herouard, 1896
Superfamily AMMODISCACEA Reuss, 1862
Family AMMODISCIDAE Reuss, 1862
Subfamily TOLYPAMMINIDAE Cushman, 1928
Genus **Hemidiscella** n. gen.

*Description.*—Similar to *Ammodiscella* Ireland, but found living attached to blades of *Thalassia testudinum* König. Test attached, early portion with proloculus followed by undivided planispirally enrolled second chamber, hemispherical in cross section, later coiling irregular on one side; wall finely agglutinated; aperture at open end of tube.

Genotype: *Hemidiscella palabunda* n. sp.

### **Hemidiscella palabunda** n. sp.

Plate 4, figures 3-9

*Description.*—Test small, attached, early portion planispiral, later portion irregular; wall agglutinated; aperture at open end of tube.

Test small, attached, early portion with proloculus followed by undivided, planispirally enrolled second chamber, hemispherical in cross section, later coiling irregular but always remaining attached by one side, may coil irregularly upon earlier portion, become straight, or wander about in an irregular course, early portion of second chamber gradually increasing in diameter, later irregular portion with nearly constant diameter; sutures somewhat indistinct on free side, distinct on attached side; wall finely agglutinated, composed of fine calcareous grains held together by fine white cement, surface rather smooth; aperture terminal, hemispherical opening at end of tube.

*Material.*—Holotype, from waters near Big Pine Key, Florida, (24°37.7′N., 81°23.7′W., depth of 6.5 feet), December 1964, collector, Wayne D. Bock; maximum diameter 200 microns, minimum diameter 150 microns. Deposited in the Division of Micropaleontology, U. S. National Museum, No. 643161. Paratypes, collected by Wayne D. Bock near Big Pine and the Torch Keys, Florida. Two series of paratypic material were sent to Dr. Lloyd Henbest and Miss Ruth Todd, both of the U. S. Geological Survey at the U. S. National Museum. Remaining paratypes all deposited in the micropaleontological collection at the Institute of Marine Sciences, University of Miami.

*Name.*—The name *palabunda* is the feminine of *palabundus*, Latin for "wandering about," and refers to the irregular coiling in the later portion of the test.

*Discussion.*—*Hemidiscella palabunda* is similar to *Ammodiscella virgilensis* Ireland, a species belonging to a monotypic genus described from the Virgilian of Kansas, but has a more symmetrical initial planispiral portion.

This species was comparatively rare, 317 specimens from all stations for the entire sampling period, but occurred at all stations where *Thalassia* was growing. Only six live specimens were found on the sediment itself, suggesting that the grass substratum was the true habitat for this species. No specimens were found at the two stations devoid of grass (Table 1). It had a population increase during the months of January and February, 1965,

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[1] Contribution No. 851 from the Institute of Marine Sciences, University of Miami.

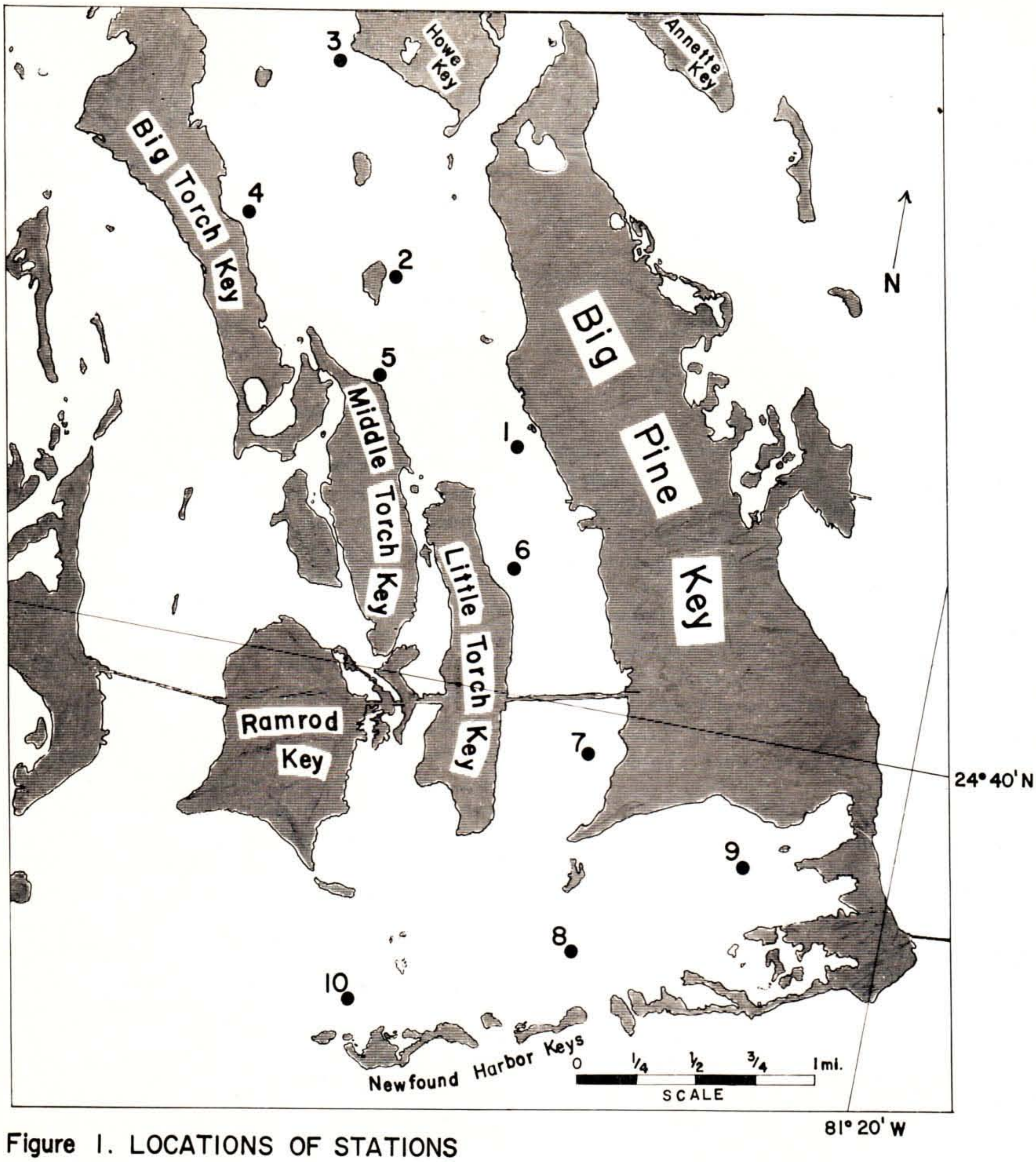

Figure 1. LOCATIONS OF STATIONS

when the temperature range was 19-23°C. and the salinity range was 30-37‰. No live specimens were found during the months June through August, 1964, and it occurred very rarely from September through December, 1964. Its optimum size range appeared to be 125-350 microns, although there were rare specimens both above and below this range. The largest sizes attained were also in the months of January and February. The above data suggest that the *Thalassia* substratum, salinity and temperature are the three factors controlling the distribution and reproduction of *Hemidiscella palabunda*, it being unable to tolerate high temperatures and salinities varying too greatly from those of normal seawater.

Suborder ROTALIINA Delage
and Herouard, 1896
Superfamily NODOSARIACEA Ehrenberg, 1838
Family GLANDULINIDAE Reuss, 1860
Subfamily OOLININAE Loeblich
and Tappan, 1961
Genus **Fissurina** Reuss, 1850
**Fissurina pellucida** n. sp.
Plate 4, figures 1, 2

*Description.*—Test very small, compressed, with thin keel; wall smooth, transparent; aperture slit-like, with entosolenian tube.

Test very small, longer than broad, ovate in outline, basal end broadly rounded, apertural end very slightly, if at all, drawn out, somewhat compressed, elliptical in section, periphery with very thin, narrow keel; wall smooth, calcareous, completely transparent, with no ornamentation; aperture slit-like, in center of fissure-like cavity, connecting with interior by entosolenian tube which extends more than one-third of way into chamber.

*Material.*—Holotype, from waters adjacent to Middle Torch Key, Florida, (24°41.9′N., 81°24.7′ W.; depth 3 feet), March 1965, collector, Wayne D. Bock; length, 150 microns, width, 120 microns, thickness, 80 microns. Deposited in the Division of Micropaleontology, U. S. National Museum, No. 643162. Paratypes, collected by Wayne D. Bock near Big Pine Key and the Torch Keys, Florida. Deposited in the micropaleontological collection at the Institute of Marine Sciences, University of Miami.

*Name.*—The name *pellucida* is the feminine of *pellucidus,* Latin for "transparent," and refers to the transparent property of the test.

*Discussion.*—This species somewhat resembles *Fissurina laevigata* Reuss, but is smaller, more rounded in outline, has a thin, narrow keel, and every specimen is transparent. The apertural end of *F. laevigata* is much more drawn out. It is also somewhat similar to *Fissurina lucida* Herrmann, but the latter is much more lenticular and is not completely transparent.

*Fissurina pellucida* was quite rare, 37 total specimens for the entire year, but was represented at every station where *Thalassia* was growing, with the exception of station 9. As only four specimens were found on the sediment and it was completely absent from the two stations devoid of grass, its true habitat appears to be the *Thalassia* substratum. All specimens were within the 63-177-micron size range. There were insufficient numbers to determine any dependence on the measured ecological parameters.

| Sta. | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | 13 | 13 | 8 | | 4 |
| 2 | | | | | 2 | 1 | 2 | 3 | 2 | 4 | 2 | 6 |
| 3 | | | | | | | 4 | 1 | 5 | 7 | | 2 |
| 4 | | | | | | | | | | | | |
| 5 | | | | 3 | | | 2 | | 1 | 3 | | 9 |
| 6 | | | | | | 1 | | 10 | 10 | 4 | 7 | 3 |
| 7 | | | | | | | | | | | | |
| 8 | | | | | 1 | 2 | 3 | 12 | 6 | 4 | 12 | 3 |
| 9 | | | | | 2 | 3 | | 6 | 1 | 1 | 4 | 2 |
| 10 | | | | 6 | 1 | 11 | 16 | 24 | 30 | 3 | 6 | 26 |

TABLE 1

Number of live specimens of *Hemidiscella palabunda* occurring throughout the year 1964-1965.

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# 347. NOTES ON THE SYNONYMY OF *REICHELINELLA* AND *ARCANISPIRA*

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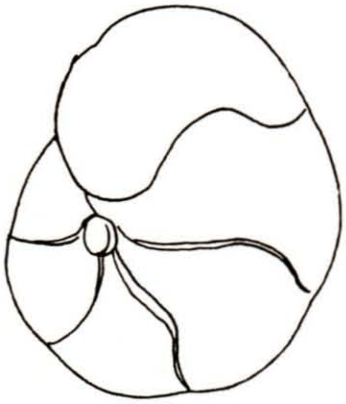
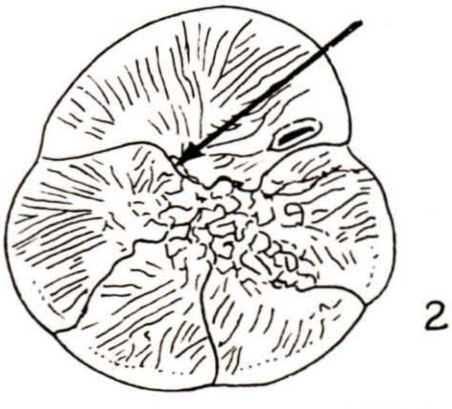
The foraminiferal genus *Reichelinella* Seiglie and Bermúdez was established in July 1966 on the basis of *"Discorbis" baitoensis* Bermúdez as the type species. In October 1966 the genus *Arcanispira* Poag was proposed, with *A. bacata* Poag as its type species. It was immediately apparent to the senior author that *Arcanispira* was probably congeneric with *Reichelinella*. Subsequently, he compared topotype specimens of *A. bacata* with the holotype and paratype of *R. baitoensis* at the U. S. National Museum, concluding that *Arcanispira* Poag should be considered a junior synonym of *Reichelinella* Seiglie and Bermúdez. The junior author examined typotypes of *R. baitoensis* and concurs with this conclusion.

Since the specimens of *R. baitoensis* originally used in the description of *Reichelinella* were not perfect specimens (the apertures were covered with


1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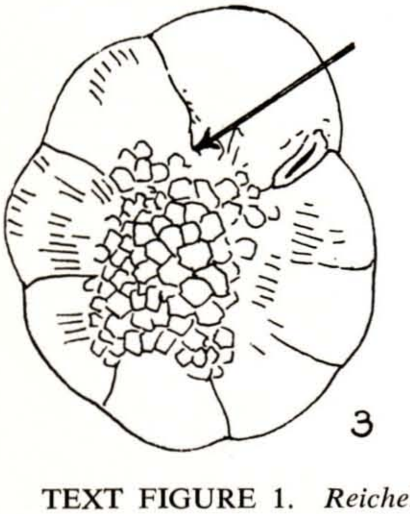
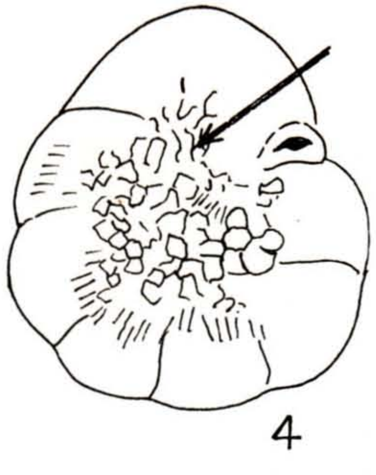
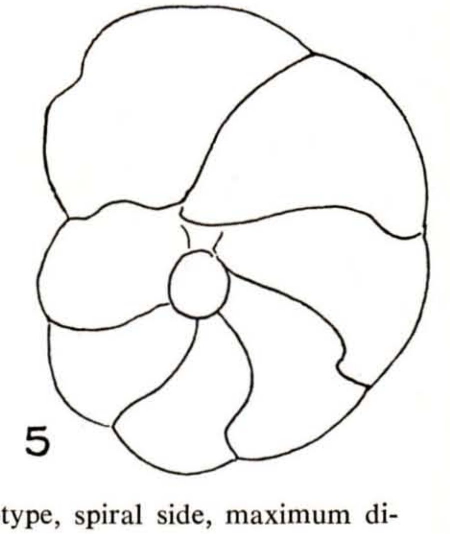

3


4


5

TEXT FIGURE 1. *Reichelinella baitoensis* (Bermúdez), holotype, spiral side, maximum diameter 0.49 mm.
TEXT FIGURE 2. *R. baitoensis* (Bermúdez), paratype, umbilical side, oblique view of the specimen, largest dimension in figure 0.49 mm. Holotype and paratype are in the U. S. National Museum.
TEXT FIGURE 3. *R. bacata* (Poag), umbilical side, maximum diameter 0.55 mm.
TEXT FIGURE 4. *R. bacata* (Poag), umbilical side, maximum diameter 0.50 mm.
TEXT FIGURE 5. *R. bacata* (Poag), spiral side, maximum diameter 0.57 mm.

Arrows indicate position of partly obscured secondary apertures. Topotypes of *R. bacata* (Poag) shown were deposited in the U. S. National Museum. They are from locality S19 (Poag, 1966a).

extraneous calcareous material and they appeared to be part of the pustulose ornamentation of the umbilical side) and, due to the addition of two new species (Poag, 1966a, b), a redescription of *Reichelinella* is considered appropriate.

Thanks are due to Dr. Martin L. Buzas and Dr. Ruth Todd for their help and for providing facilities at the U. S. National Museum. Illustrations are by the senior author. Chevron Oil Company has granted the junior author permission to publish.

## TAXONOMY

Family ROTALIIDAE Ehrenberg, 1839
Subfamily CUVILLIERININAE Loeblich and Tappan, 1964
Genus **Reichelinella** Seiglie and Bermúdez, 1966

*Type species: Discorbis baitoensis* BERMÚDEZ, 1949, Cushman Lab. Foram. Res. Spec. Publ. No. 25, p. 236, pl. 15, fig. 1-3.

*Reichelinella* SEIGLIE and BERMÚDEZ, 1966 (July), Eclog. geol. Helv., vol. 59, no. 1, p. 434.

*Arcanispira* POAG, 1966 (October), Micropaleontology, vol. 12, no. 4, p. 413.

*Diagnosis.*—Test free, plano-convex, small to medium; each whorl nearly or completely enveloping the preceding whorl, leaving the test involute on both sides; chambers simple; periphery keeled; walls of radially fibrous calcite, canaliculate, with double septa formed secondarily; flattened side of the test with pustular area, sometimes radially arranged from the central pillars to periphery; canal system present among pillars; primary aperture an areal slit with encompassing lip, on flat side near periphery; secondary aperture present in reentrant of final suture on flat side; tube extends from secondary aperture downward through chamber to periphery of previous whorl (see Poag, 1966a, p. 413, text-fig. 12; 1966b, pl. 11, fig. 7).

*Remarks.*—Specimens of *Reichelinella baitoensis* (Bermúdez) and *R. bacata* (Poag) are illustrated in text fig. 1 to 5, to show the generic similarities of both species. At present the genus is composed of three species: *R. baitoensis* (Bermúdez), *R. bacata* (Poag), and *R. depressa* (Poag), all of Miocene age. It has not been recorded outside of the Gulf Coast-Caribbean region.

## REFERENCES

POAG, C. W., 1966a, Paynes Hammock (Lower Miocene?) foraminifera of Alabama and Mississippi: Micropaleontology, vol. 12, no. 4, pp. 413-414, text-fig. 12, pl. 6, figs. 4-7.

———, 1966b, *Arcanispira depressa* n. sp. from the Florida Miocene Chipola Formation: Cushman Found. Foram. Res., Contr., vol. 17, pt. 4, pp. 140-141, pl. 11, figs. 1-7.

SEIGLIE, G. A., and BERMÚDEZ, P. J., 1966, Tres géneros nuevos y una especie nueva de foraminiferos del terciario de las Antillas: Eclog. geol. Helv., vol. 59, no. 1, p. 434, pl. 1, figs. 5-8a-c.

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## CORRECTIONS

The following changes should be made in paper no. 326 (Vol. XVIII, Part 1, January, 1967), *Globotruncana caliciformis* . . . ," by El-Naggar and Haynes:

p. 1, right column, 3rd paragraph: change "Vogler (1961)" to "Vogler (1941)."

p. 4, 13th line from top: read "redefined" for "refined."

p. 5, lines 5 and 7 from top: change "1916" to "1918" in each.

p. 9, plate explanation, figs. 2a-c: insert "[=" after "*plicata* White;" insert "[" after "Lapparent;" insert "1928" after second "White."

p. 12, plate explanation: fig. 1, change "*Rosalini*" to "*Rosalina*;" fig. 2, replace "Vogler, Vogler" with "de Lapparent;" fig. 3, add "1951" after Bolli; figs. 7, 8, add "Axial and" before "tangential;" add "*caliciformis*" after "*caliciformis*;" replace "rocks of Biarritz, southwestern France" with "Sharawna Shale of Egypt;" add ", × 120 respectively" after "× 100."

p. 13, plate explanation: add "Random" before "Section;" delete second "*caliciformis*."

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# RECENT LITERATURE ON THE FORAMINIFERA

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

Bandy, Orville L., Ingle, James C., Jr., and Frerichs, William E. Isomorphism in "*Sphaeroidinella*" and "*Sphaeroidinellopsis*."—Micropaleontology, v. 13, No. 4, Oct. 25, 1967, p. 483-488, pl. 1, text-fig. 1 (diagram).—Removal of cortex reveals *Globigerinoides trilobus sacculifer* inside some specimens and *G. conglobatus* inside other specimens of both "*Sphaeroidinella*" and "*Sphaeroidinellopsis*" which are, hence, only growth forms and not valid genera.

Bartenstein, Helmut. *Pseudoreophax* Geroch 1961, ein Bindeglied zwischen vershiedenen Gattungen der Unterkreide-Lituolidea? (Foram., Agglut.).—Rev. Bulgarian Geol. Soc., v. 27, pt. 2, 1966, p. 179-183, text figs. 1, 2 (drawings, comparison table).—A connecting link joining *Lituola*, *Ammobaculites*, *Haplophragmium*, *Reophax*, and other genera.

Berggren, William A., Olsson, Richard K., and Reyment, Richard A. Origin and development of the foraminiferal genus *Pseudohastigerina* Banner and Blow, 1959. Part I: Taxonomy and phylogeny (by William A. Berggren and Richard K. Olsson). Part II: Biometric analysis (by Richard A. Reyment).—Micropaleontology, v. 13, No. 3, July 25, 1967, p. 265-288, pl. 1, text figs. 1-12 (drawings, map, graphs), tables 1-13.—The genus developed from low-spired, non-keeled globorotaliids of the Paleocene, first appeared in the lower Eocene, and became extinct within the Oligocene. Three species—*Globorotalia chapmani*, *Pseudohastigerina wilcoxensis*, and *P. sharkriverensis*, n. sp.—are described and illustrated with their variations to demonstrate their evolutionary connections.

Bhalla, S. N. Foraminifera from the Inter-trappean beds (Lower Eocene) of the Pangadi area, India.—Micropaleontology, v. 13, No. 3, July 25, 1967, p. 351-368, pl. 1, text figs. 1-5 (map, drawings), tables 1, 2.—Illustrated systematic catalog of 18 species (4 new and 2 indeterminate).

Bolli, Hans M. The subspecies of *Globorotalia fohsi* Cushman and Ellisor and the zones based on them.—Micropaleontology, v. 13, No. 4, Oct. 25, 1967, p. 502-512, text figs. 1-4 (drawings, range chart, correl. charts).—Distinctions between *G. fohsi* and *G. barisanensis* indicate the latter belongs in the *G. archeomenardii-praemenardii-menardii* lineage rather than the *G. fohsi* lineage. The form known as *G. fohsi barisanensis* sensu Bolli is *G. fohsi peripherorondo* Blow and Banner. *G. fohsi fohsi* sensu Bolli is subdivided into the two subspecies *peripheroacuta* Blow and Banner and *praefohsi* Blow and Banner. *G. fohsi* s.s. is defined as possessing a completely keeled periphery. *G. fohsi lobata* and *G. fohsi robusta* belong as subspecies making up the final two taxa in the *fohsi* lineage and top two zones in the zonation. The revised zonation includes 4 zones, the second one having 2 subzones.

Bouckaert, J., Conil, R., and Thorez, J. Position stratigraphique de quelques gîtes famenniens à Foraminifères.—Bull. Soc. Belge Géol., Paléont. et Hydrol., tome 75, fasc. 2, 1966 (June 30, 1967), p. 159-175, pls. 1-4.—Two new Devonian species are described.

Bouysse, Ph., and Le Calvez, Y. Étude des fonds marins compris entre Penmarc'h et Groix (Sud-Finistère).—Bull. Bureau Recherches Géol. Min., 1967, No. 2, p. 39-73, pls. 1, 2, text figs. 1-4 (maps), tables 1-6.—Quantitative investigation of the Foraminifera on the shelf down to 100 meters. Distribution of species plotted according to geographic location, nature of sediment, and depth. Ninety-three species are recorded; a few are illustrated.

Brant Ribeiro, A. *Stainforthia concava* Hoglund, 1947, em águas do litoral paulista.—Riosonia, Bol. No. 2, 1966, p. 1-6, pl. 1.

Brazhnikova, N. E., and Rostovtheva, L. F. On the study of early Visean Endothyranopsinae of the Donetz Basin and other areas (in Russian).—Akad. Nauk Ukrains. SSR, Instit. geol. nauk, Kiev, 1967, p. 10-17, pls. 1-3.—A new species and a new subspecies.

Brönnimann, Paul. *Pseudotextulariella courtionensis*, n. sp., from the Valanginian of well Courtion 1, Courtion, Canton of Fribourg, Switzerland.—Archives des Sciences, v. 19, fasc. 3, Sept.-Dec. 1966 (July 1967), p. 265-278, pls. 1-3, text figs. 1-8 (drawings).

Brouwer, J. Foraminiferal faunas from a graded-bed sequence in the Adriatic Sea.—Proc. Kon. Nederl. Akad. Wetenschappen, ser. B, v. 70, No. 3, 1967, p. 231-238, text figs. 1, 2 (map, photomicrograph, graphs), table 1.—A quantitative study of 5 samples from a 24-cm section from the lower part of a core taken from 1198 meters reveals a rich shallow-water benthonic assemblage within the graded beds.

Burckle, Lloyd H., Saito, Tsunemasa, and Ewing, Maurice. A Cretaceous (Turonian) core from the Naturaliste Plateau, southeast Indian Ocean.—Deep-Sea Research, v. 14, No. 4, Aug. 1967, p. 421-426, text figs. 1-4 (map, drawings, seismic profiles).—Five planktonic species are illustrated.

Burmistrova, I. I. Modern distribution of Foraminifera and stratigraphy of the Late Quaternary sediments in the Barents Sea (English summary of Russian text).—Akad. Nauk SSSR, Oceanologija, tom 7, vyp. 2, 1967, p. 302-308, text figs. 1-4 (maps, graphs).—Analysis of cores shows 4 layers indicating 2 sea regressions.

Butterlin, Jacques. Macroforaminifères de l'Éocène de Colombie.—Bull. Soc. Géol. France, ser. 7, tome 8, No. 5, 1966, p. 627-629, pl. 14, text fig.—A few species illustrated.

Au sujet de la présence en Europe du genre *Sulcoperculina* Thalmann, 1939.—Revue de Micropaléontologie, v. 10, No. 1, June 1967, p. 61-64, pl. 1.

Caron, Michèle. Étude biométrique et statistique de plusieurs populations de Globotruncanidae. 2. le sous-genre *Rotalipora* (*Thalmanninella*) dans l'Albien supérieur de la Breggia (Tessin).—Eclogae Geol. Helvetiae, v. 60, No. 1, Aug. 31, 1967, p. 47-79, pls. 1, 2, text figs. 1-22 (diagrams, graphs, range chart, drawings), table 1.—Biometric diagnoses and illustrations of transitional forms between several species and subspecies.

Chang, Li-Sho. Tertiary biostratigraphy of Taiwan and its correlation.—From Tertiary Correlations and Climatic Changes in the Pacific, Feb. 28, 1967, p. 57-65, text fig. 1 (map), table 1 (correl. chart).—Between Eocene and Miocene, 11 foraminiferal zones have been recognized.

A biostratigraphic study of the Tertiary in the coastal range, eastern Taiwan, based on smaller Foraminifera (I: Southern part).—Proc. Geol. Soc. China, No. 10, April 1967, p. 64-76, pls. 1-6, text fig. 1 (map), tables 1-7 (check lists).—Illustrations and tables showing occurrence and abundance in 256 samples are given for 255 species and subspecies. Four zones and 2 subzones are correlated with the worldwide planktonic zonation of Miocene and Pliocene.

Christodoulou, G. Der geologische Bau der Ebene von Thessaloniki-Jannitza nach den Ergebnissen der mikropaläontologischen Untersuchungen am Bohrgut von drei Tiefbohrungen (German summary of Greek text with English abstract).—Bull. Geol. Soc. Greece, v. 6, No. 2, 1967, p. 249-296, pls. 1-6, text figs. 1-7 (map, columnar sections, geol. section).—Foraminifera illustrated from the penetrated sections: Pleistocene, Pontian, Sarmatian, lower Burdigalian, and upper Eocene.

Christodoulou, G., and Maragoudakis, N. Study of a rich *Globotruncana* fauna isolated from the Upper Campanian sediments of the Olonos series near Kiveri village, Argos area (NE Peloponnesus) (English abstract of Greek text).—Bull. Geol. Soc. Greece, v. 6, No. 2, 1967, p. 308-318, pl. 1, text figs. 1-4 (map, drawings).—Five species, none new.

Closs, Darcy. Miocene planktonic Foraminifera from southern Brazil.—Micropaleontology, v. 13, No. 3, July 25, 1967, p. 337-344, pl. 1.—Twenty-one species and 9 subspecies from test wells in the coastal plain. Correlation is tentatively with the boundary between the *Globigerinatella insueta* zone and the *Globorotalia fohsi barisanensis* zone.

Closs, Darcy, and de Medeiros, Vera Maria F. New observations on the ecological subdivision of the Patos Lagoon in southern Brasil.—Bol. Instit. Ciencias Nat., No. 24, 1965, p. 1-33, pl. 1, text figs. 1-3 (map, range chart, check list).—Study based on 11 samples from inner to outer parts of the lagoon. Seventeen species of Foraminifera occur in different parts.

Cockbain, A. E. *Asterocyclina* from the Plantogenet Beds near Esperance, W. A.—Australian Jour. Sci., v. 30, No. 2, Aug. 1967, p. 68, 69, table 1.

Colalongo, Maria Luisa. Biostratigrafia del Mesozoico nei dintorni del passo del Diavolo (Parco Nazionale d'Abruzzo).—Giornale di Geol., Ann. Museo Geol. Bologna, ser. 2, v. 34, fasc. 1, 1966, p. 1-36, pls. 10-13, text figs. 1-3 (map, correl. chart, columnar section), tables 1, 2.—Thin-section illustrations of several species in the Cretaceous.

Datta, A. K., and Banerji, R. K. Palaeocene species of *Dictyoconoides*, *Lockhartia* and *Dictyokathina* from the Subathu subgroup in Simla and Nahan-Dadahu areas.—Bull. India Oil & Gas Comm., v. 3, No. 2, Dec. 1966, p. 61-66, pl. 1.—Four species; *Dictyokathina dadahuensis* new.

Efimova, N. A. O faune Foraminifer iz Triasovykh otlozhenij Sovetskikh Karpat, *in* Ocherki po geologii Sovetskikh Karpat, vyp. 1.—

Moskov. Gosud. Univer., Minister. Geol. USSR, 1966, p. 35-47, pls. 1, 2.—Ten Triassic species (3 new and 7 indeterminate).

Foury, Geneviève, and Vincent, Edith. Morphologie et répartition stratigraphique du genre *Kilianina* Pfender. (Foraminifère).—Eclogae Geol. Helvetiae, v. 60, No. 1, Aug. 31, 1967, p. 33-45, pls. 1, 2, text figs. 1-6 (photomicrographs, drawings, graphs, map).—Restudy of internal structure of the genus and description and illustration of 2 species, one new, from the basal Kimmeridgian.

Gheorghian, Mihaela, Gheorghian, M., and Iva, Mariana. Aspects microfauniques et considérations paléogéographiques concernant le Tortonien des environs de Sibiu (Bassin de Transylvanie) (French résumé of Rumanian text).—Dari de Seama ale Sedintelor, Romania Comit. Stat Geol., Instit. Geol., v. 53 (1965-66), pt. 1a, 1967, p. 329-340, pls. 1-3 (geol. map, columnar sections, range chart).—Four foraminiferal biozones in the Tortonian and one in the lower Sarmatian.

Gibson, G. W. Foraminifera and stratigraphy of the Tongaporutuan stage in the Taranaki coastal and six other sections. Part I. Systematics and distribution.—Trans. Royal Soc. New Zealand, Geol., v. 5, No. 1, March 21, 1967, p. 1-70, pls. 1-19.—Illustrated systematic catalog of 155 species (9 new). Age is late Miocene.

Gibson, Thomas G., and Walker, William M. Flotation methods for obtaining Foraminifera from sediment samples.—Jour. Paleontology, v. 41, No. 5, Sept. 1967, p. 1294-1297, tables 1, 2.—Bromoform preferred.

Gohrbandt, K. H. A. Some new planktonic foraminiferal species from the Austrian Eocene.—Micropaleontology, v. 13, No. 3, July 25, 1967, p. 319-326, pl. 1, text figs. 1, 2 (maps). Five species and one subspecies from lower and middle Eocene.

Gordon, W. A. Foraminifera from the Callovian (Middle Jurassic) of Brora, Scotland.—Micropaleontology, v. 13, No. 4, Oct. 25, 1967, p. 445-464, pls. 1-4, tables 1-3.—Illustrated systematic catalog of 50 species, 7 indeterminate, none new.

Groiss, J. Th., and Winter, B. Das Vorkommen von *Pseudocyclammina* und *Lituola* (Foram.) in den Neuburger Bankkalken (Mittel-Tithon).—Geol. Blätter für Nordost-Bayern, Erlangen, Band 17, Heft 3, Aug. 18, 1967, p. 109-127, pls. 5, 6, text figs. 1-6 (diagrams, drawings, graphs).—*Pseudocyclammina perplexa* n. sp. and *Lituola nautiloidea minor* n. ssp.

Grossman, Stuart. Living and subfossil rhizopod and ostracode populations. Part 1 of Ecology of Rhizopodea and Ostracoda of southern Pamlico Sound region, North Carolina.—Univ. Kansas Paleont. Contribs., ser. no. 44, Oct. 18, 1967, p. 3-82, pls. 1-21 [1-10, Foraminifera; 11-21, Ostracoda], text figs. 1-17 (maps, graphs), tables 1-13.—Over 50 species of Foraminifera (2 new in *Ammobaculites*) recorded and illustrated from 5 biofacies: estuarine, open-sound, salt-water lagoon, tidal-delta, and salt-marsh. Study based on 215 samples (cores, dredge and sieve samples).

Haake, Friedrich-Wilhelm. Zum Jahresgang von Populationen einer Foraminiferen-Art in der westlichen Ostsee.—Meyniana, Band 17, Oct. 1967, p. 13-27, pls. 1, 2, text figs. 1-20 (map, drawings, graphs).—Study based on seasonal samples from Kiel Bay light-boat stations and tidal flat. Population densities of *Cribrononion excavatum* range from 97 to 0.2 individuals per square centimeter, highest during spring and summer and least on the tidal flat.

Hansen, Hans Jorgen. A technique for depiction of grind sections of Foraminifera by aid of compiled electron-micrographs.—Bull. Geol. Soc. Denmark, v. 17, pt. 1, 1967, p. 128, 129, pls. 1, 2.

Harsono P. Some significant Upper Cretaceous Foraminifera from Groisbach, Morzger Hugel, and Michelstetten, Austria.—Instit. Technology Bandung, Contr. from Dept. Geol., No. 60, 1965, p. 19-65, pls. 1-7, text figs. 1, 2 (maps), table 1.—Illustrated catalog of species from 3 faunas: 6 from the Cenomanian, 14 from the Santonian, and 16 from the upper Maestrichtian. *Marssonella morzgensis* nov. sp. described from the Santonian.

Hay, William W., and Sandberg, Philip A. The scanning electron microscope, a major breakthrough for micropaleontology.—Micropaleontology, v. 13, No. 4, Oct. 25, 1967, p. 407-418, pls. 1, 2, table 1.—Elegant examples of photographs of forams.

Honjo, Susumu, and Berggren, W. A. Scanning electron microscope studies of planktonic foraminifera.—Micropaleontology, v. 13, No. 4, Oct. 25, 1967, p. 393-406, pls. 1-4, text figs. 1, 2 (diagrams), table 1.—More elegant examples of high and medium magnifications of *Hantkenina alabamensis* and several other planktonic species.

Huang, Tunyow. Late Tertiary planktonic Foraminifera from southern Taiwan.—Sci. Repts. Tohoku Univ., 2nd Ser. (Geol.), v. 38, No. 2, March 27, 1967, p. 165-192, pls. 15, 16, text figs. 1-6 (maps), tables 1-8, chart 1 (range chart).—Six zones based on planktonic forams recognized in southern Taiwan; 4 in the Miocene, 2 in the Pliocene. Listed and illustrated are 42 species and subspecies of planktonics.

*Lenticulina stachi*, a new species of Foraminiferida from the Lower Pliocene of southern Taiwan.—Proc. Geol. Soc. China, No. 10, April 1967, p. 151-153, pl. 1, text fig. 1 (map).

JARTSEVA, M. V. Nummulites of the Upper Eocene of the Ukrainian Shield and western Black Sea region (in Russian).—Mezhvedom. Respublik. Nauchn. Sbornik, Izdatel, L'vov. Univ., Paleont. Sbornik No. 3, vyp. vtoroj, 1966, p. 3-13, pls. 1-3.—Includes one new species and 2 new subspecies.

JONES, JAMES I. Significance of distribution of planktonic foraminifera in the Equatorial Atlantic Undercurrent.—Micropaleontology, v. 13, No. 4, Oct. 25, 1967, p. 489-501, text figs. 1-36 (graphs), table 1.—Six species are useful in characterizing the Undercurrent: high relative amounts are shown by *Globigerinoides trilobus* and *G. ruber* above the current; by *Globigerina dutertrei* and *Pulleniatina obliquiloculata* within the current; and by *Globorotalia crassaformis* and *G. cultrata* beneath the current.

KAHLER, FRANZ and GUSTAVA. Fusulinida (Foraminiferida). Teil 4.—Fossilium Catalogus. 1: Animalia, Pars 114, 's-Gravenhage, June 30, 1967, p. 871-974.—Bibliography and index.

KALMYKOVA, M. A. Permskie Fuzulinidy Darvaza. —Vses. nauchno-issl. geol. instit. (VSEGEI), Trudy, n. ser., tom 116, Biostratigraficheskij Sbornik, vyp. 2, 1967, p. 116-287, pls. 1-32, text figs. 1-14 (maps, diagrams, geol. sections, stratigraphic sections), tables 1-14, 4 check lists.—Sixty species and subspecies (2 species and 1 subspecies new).

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LATIF, M. A. Some related groups of pelagic Foraminifera in the Paleocene-Eocene of the Rakhi Nala, West Pakistan.—Geol. Bull. Panjab Univ., No. 3, Oct. 1963, p. 19-24, text figs. 1-3 (drawings, phylogenetic range charts).—Thirty-one species are grouped into 9 phylogenetic groups and their ranges between Paleocene and upper Eocene are indicated.

Variations in abundance and morphology of pelagic Foraminifera in the Paleocene-Eocene of the Rakhi Nala, West Pakistan.—Geol. Bull. Panjab Univ., No. 4, Dec. 1964, p. 29-100, pls. 1-11, text fig. 1 (range chart).—Descriptions and illustrations of 56 species with their ranges indicated in the Rakhi Nala section, encompassing Paleocene to upper Eocene.

LINDENBERG, HANS GEORG. Gehäuse aus Sand bei einzelligen Tieren.—Natur und Museum, Frankfurt a. M., Band 97, Heft 7, July 1967, p. 244-258, text figs. 1-9.

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Some new species of Foraminifera from the Miocene of Poland.—Ann. Soc. Geol. Pologne, v. 37, fasc. 2, 1967, p. 233-241, pls. 8, 9, text figs. 1-7.—Five species.

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MARKS, P. *Rotalipora* et *Globotruncana* dans la Craie de Théligny (Cénomanien; Dépt. de la Sarthe).—Proc. Kon. Nederl. Akad. Wetenshappen, ser. B, v. 70, No. 3, 1967, p. 264-275, pls. 1-3, text figs. 1-4 (map, geol. sections), tables 1-3.—*Rotalipora cushmani* and *Praeglobotruncana stephani.*

MATOBA, YASUMOCHI. Younger Cenozoic foraminiferal assemblages from Choshi District, Chiba Prefecture.—Sci. Repts. Tohoku Univ., 2nd Ser. (Geol.), v. 38, No. 2, March 27, 1967, p. 221-263, pls. 25-30, text figs. 1-8 (maps, columnar section, graphs, correl. diagram, drawings), table 1 (check list).—Illustrated catalog of 118 species (2 new) from a section encompassing upper Miocene to Pleistocene, with the Pliocene and Pleistocene part subdivided into 7 foram zones.

MERIC, ENGIN. An aspect of *Omphalocyclus macroporus* (Lamarck).—Micropaleontology, v. 13, No. 3, July 1967, p. 369-376, pls. 1-4, text figs. 1-4 (drawings, diagrams).—A demonstration that the appearance of the embryonic apparatus (trilocular, bilocular, or unilocular instead of the normal quadrilocular) may result from the position of the thin section.

Michelson, Olaf. Foraminifera of the Late-Quaternary deposits of Laesø.—Medd. Dansk Geol. Forening, bd. 17, hefte 2, 1967, p. 205-263, pls. 1-7 (Foraminifera), 8 (check list), 9 (graph), text figs. 1-7 (map, boring sections, drawings, graphs), table 1.—Based on 40 samples from 5 borings in Late-Glacial *Yoldia* Clay and Post-Glacial Sands. A total of 72 species (1 new and 11 indeterminate) are described, illustrated, and quantitatively recorded.

Miklukho-Maklaj, A. D. Nekotorye Srednepaleozojskie Foraminifery Srednej Azii.—Ezhegodnik Vses. Paleont. Obshchestva, tom 17, 1957-1964, 1965, p. 30-40, pls. 1-3, text fig. 1 (phylogenetic diagram).—From the middle Paleozoic, 12 species (all but one new) in the families Psammosphaeridae, Saccamminidae, and Tuberitinidae. Two genera and a subgenus are new: *Turcmeniella* (type species *T. astra* sp. nov.) and *Bituberitina* (type species *B. bicamerata* sp. nov.) and *Parphia* (type species *P. robusta* sp. nov.), subgenus of *Cribrosphaeroides*.

Montanari, L. Geologia dei monti di Trabia (Sicilia).—Riv. Min. Siciliana, Anno 17, No. 97-99, Jan.-June 1966, p. 35-81, pls. A-D, text figs. 1-23 (maps, photo-micrograph, outcrop photo, columnar sections, geol. sections).—Includes illustrations of Foraminifera from various beds between Jurassic and Oligocene.

Morozova, V. G., Kozhevnikova, G. E., and Kuryleva, A. M. Danian-Paleocene heterofacial deposits of Kopet-Dag and methods of their correlation according to foraminifers (in Russian).—Akad. Nauk SSSR, Geol. Instit., Trudy, vyp. 157, 1967, p. 1-204, pls. 1-7, text figs. 1-6 (map, columnar sections, graphs), tables 1-21.—Zonation and correlation based on planktonics. Nine zones between upper Maestrichtian and Ypresian. Includes a section describing 25 species (23 new) and 4 new subspecies and *Kolchidina* gen. nov. (type species *Ammobaculites manyschensis* N. Bykova 1953).

Mouravieff, N., and Bultynck, P. Quelques Foraminifères du Couvinien et du Frasnien du bord sud du Bassin de Dinant.—Bull. Soc. Belge Géol., Paléont. et Hydrol., tome 75, fasc. 2, 1966 (June 30, 1967), p. 153-156, pl. 1.—A few illustrated, *Semitextularia* and related genera.

Myers, Donald A. Fusulinidae from the Graford Formation and Winchell Limestone, Canyon Group, Upper Pennsylvanian in Brown County, Texas.—U. S. Geol. Survey Prof. Paper 573-C, June 23, 1967, p. 1-17, pls. 1, 2, text figs. 1-8 (map, graphs).—Seven species, 5 new.

Nemkov, G. I. Nummulitides of the Soviet Union and their biostratigraphic significance (in Russian with English summary).—Moscow Soc. Naturalists, Proc. of the Study of the Geol. Structure of the USSR, n. ser., No. 16 (20), 1967, 318 p., 44 pls., 15 text figs. (maps, phylogenetic diagrams, drawings), 8 tables.—Illustrated systematic catalog includes 87 species (1 new), classified in 15 groups. Three new subgenera of *Nummulites* are erected: *Nummulites*, *Granulites*, and *Globulites*.

Neumann, Madeleine. Manuel de Micropaléontologie des Foraminifères (Systématique-Stratigraphie). Tome I, Généralités, Systématique: Saccamminidae à Ataxophragmiidae.—Paris, Gauthier-Villars, 1967, 297 p., 60 pls., 182 text figs., 12 tables.—A teaching textbook, including chapters on the living animal, the test, preparation methods, and a first section of systematics.

Nikitina, J. P. Some new species of Foraminifera from Paleogene deposits of Lower Don Basin (in Russian).—Mezhvedom. Respublik. Nauchn. Sbornik, Izdatel. L'vov. Univ., Paleont. Sbornik, No. 3, vyp. pervyj, 1966, p. 12-19, 2 pls.—Four species and subspecies, all new, from the Eocene and Oligocene.

Oba, Tadamichi. Planktonic Foraminifera from the Deep-Sea cores of the Indian Ocean.—Sci. Repts. Tohoku Univ., 2nd Ser. (Geol.), v. 38, No. 2, March 27, 1967, p. 193-219, pls. 17-24, text figs. 1-10 (maps, profiles, graphs), tables 1-3.—About 30 planktonic species from 2 piston cores are illustrated and fluctuations of percentages in the cores are shown graphically. Coiling directions are also recorded.

Orr, W. N. Secondary calcification in the foraminiferal genus *Globorotalia*.—Science, v. 157, No. 3796, Sept. 29, 1967, p. 1554-1555, text figs. 1, 2 (map, diagrams).—Depths below which thickening takes place are determined in the northwestern Gulf of Mexico for 4 different species; 120 meters for *G. cultrata*, 200 meters for *G. tumida*, 300 meters for *G. truncatulinoides*; and 700 meters for *G. crassaformis*.

Pessagno, Emile A., Jr. Upper Cretaceous planktonic Foraminifera from the western Gulf Coastal Plain.—Palaeontographica Americana, v. 5, No. 37, July 28, 1967, p. 243-445, pls. 48-101, text figs. A, B, 1-63 (diagrams, maps, correl. chart, range charts, phylogenetic diagrams, graphs, form analysis data tables, drawings), tables 1, 2.—Illustrated systematic catalog includes 113 species (12 new) in 23 genera (3 new) and 7 families (2 new). New are families Marginotruncanidae and Abathomphalidae, subfamily Loeblichellinae, and genera *Loeblichella* (type species *Praeglobotruncana hessi* s.s. Pessagno), *Whiteinella* (type species *W. archaeocretacea* n. sp.), and *Archaeoglobigerina* (type species *A. blowi* n. sp.). Phylogenetic relationships between genera and between species are indicated, and stratigraphic ranges of species are shown.

POROSCHINA, L. A. O Novom Rode *Epistominitella* iz Nizhnemelovykh Otlozhenij Severo-Vostochnogo Azerbajdzhana.—Akad. Nauk Azerbajdzhan SSR, Meruzeler Doklady, tom 22, No. 9, 1966, p. 62-65, text figs.—*Epistominitella elongata* gen. et sp. nov. from the Lower Cretaceous of northeastern Azerbaijan.

RAJU, D. S. N. Note on Cenozoic planktonic Foraminifera from Cauvery Basin, South India. —Bull. India Oil & Nat. Gas Comm., v. 3, No. 2, Dec. 1966, p. 14-19, table 1.—Species of worldwide occurrence present in Paleocene to Quaternary well samples in Madras State.

RANGHEARD, Y., and COLOM, G. Microfaunas del Cretácico de Ibiza (Baleares).—Bol. Instit. Geol. Min. España, v. 76, 1967, p. 1-30, pls. 1-6, text figs. 1-4 (map, geol. sections), tables A-D.—Includes illustrations of 17 species from the Lower Cretaceous, 2 species and 1 subspecies new. *Pityusina conica* nov. gen., nov. sp. seems related to the Valvulinidae.

ROBINSON, E. The *Globoquadrina altispira*/*Globorotalia truncatulinoides* zone in Jamaica.—Bol. Informativo, Asoc. Venez. Geol., Min. y Petrol., v. 10, No. 3, March 1967, p. 97, 98.—The occurrence of these 2 species together results from reworking of *G. altispira*.

ROMANOVA, V. I. Nekotorye Rannemelovye Vidy Foraminifer Zapadno-Sibirskoj Nizmennosti.—Vses. nauchno-issl. geol. instit. (VSEGEI), Trudy, n. ser., tome 129, Biostratigraficheskij Sbornik, vyp. 3, 1967, p. 52-57, pl. 1.—Nine Lower Cretaceous species, none new.

RUGET, CHRISTIANE. Variations morphologiques chez quelques espèces de frondiculaires costulées du Lias de Lorraine (Lotharingien).—Revue de Micropaléontologie, v. 10, No. 1, June 1967, p. 22-36, pls. 1-4.—Eight species, 1 new, 2 indeterminate.

SADA, KIMIYOSHI, and YOKOYAMA, TSURUO. Upper Permian fusulinids from Taishaku Limestone in West Japan.—Trans. Proc. Palaeont. Soc. Japan, n. ser., No. 63, Sept. 30, 1966, p. 303-315, pls. 33, 34, text fig. 1 (map), tables 1-5. —Four species and a subspecies, none new, one indeterminate.

SAIDOVA, KH. M. Distribution of benthonic Foraminifera and depths of the Pacific Ocean during Holocene-Wisconsin (English summary of Russian text).—Akad. Nauk SSSR, Oceanologija, tom 7, vyp. 3, 1967, p. 483-489, text figs. 1-4 (maps).—Analysis of cores.

SARTONI, SAMUELE. Stratigrafia dei terreni sedimentari del Foglio 208-Dorgali.—Giornale di Geol., Ann. Museo Geol. Bologna, ser. 2, v. 33, fasc. 1, 1965, p. 159-173, pls. 15, 16.—Thin section illustrations of 3 species in the Malm.

SEROVA, M. YA. Foraminifera from Paleocene deposits of eastern Kamchatka (in Russian).—Akad. Nauk SSSR, geol. instit., Trudy, vyp. 127, 1966, p. 1-94, pls. 1-12, tables 1-3.—Includes illustrated systematic catalog of 56 species, 11 new.

SOSNINA, M. I. Novye Vidy Lagenid Juzhnogo Primor'ja, Izuchennye s Primeneniem Lakovykh Plenok.—Vses. nauchno-issl. geol. instit. (VSEGEI), Trudy, n. ser., tom 129, Biostratigraficheskij Sbornik, vyp. 3, 1967, p. 61-75, pls. 1-6, text figs. 1-8 (diagrams, drawings).—Eight new species, 5 of them in *Marginulinella* gen. nov. (type species *M. typica* sp. nov.), all of Permian age.

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TURYK, O. S. The distribution of Foraminifera in the Carboniferous deposits of Khorkov test hole (in Russian).—Mezhvedom. Respublik. Nauchn. Sbornik, Izdatel. L'vov. Univ., Paleont. Sbornik No. 3, vyp. vtoroj, 1966, p. 14-18, pls. 1-6.

UCHIO, TAKAYASU. Is the geologic age of the Nobori formation, Shikoku, Japan, Miocene or Pliocene?—Trans. Proc. Palaeont. Soc. Japan, n. ser., No. 67, Sept. 20, 1967, p. 114-124, text fig. 1 (map).—Early Pliocene based on evidence of mollusks and Foraminifera.

VDOVENKO, M. V. Some representatives of Endothyridae, Tournayellidae and Lituolidae from the Lower Visean deposits of Greater Donbas (in Russian).—Akad. Nauk Ukrains. SSR, Instit. geol. nauk, Kiev, 1967, p. 18-29, pls. 4-15. —Seven species (2 new) and 1 new subspecies. *Pseudolituotubella* gen. nov. (type species *P. multicamerata* sp. nov.) described in the Tournayellidae.

VIALOV, O. S. Remarks on Foraminifera with siliceous test (in Russian).—Mezhvedom. Respublik. Nauchn. Sbornik, Izdatel. L'vov. Univ., Paleont. Sbornik No. 3, vyp. pervyj, 1966, p. 3-11.—Four new genera named in the Silicinifera, the group having siliceous tests.

VIALOV, O. S., and PISHVANOVA, L. S. On the new foraminiferal genus *Bogdanowiczia* from the upper Tortonian of western districts of the Ukraine (in Russian with English summary).—Dopovidi Akad. Nauk Ukrains. RSR, ser. geol., geofiz., khim., i biol., 1967, No. 7, p. 575, 576, text figs.—*Bogdanowiczia pocutica* sp. nov. similar to *Dendrophrya robusta*.

WOSZCZYNSKA, STANISLAWA. Foraminifers of the Lower Carboniferous from Walbrzych and from certain areas of Sowie Mts. (English summary of Polish text).—Poland Instyt. Geol., Kwart. Geol., tom 11, No. 1, 1967, p. 76-90, pl. 1, text fig. 1 (map).—Fourteen upper Visean species, none new.

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