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Abstract. A group of samples taken from various units in a drill hole at the base of the sea cliffs, about 1½ miles south of Barrow Village, Northern Alaska, have been examined to determine their foraminiferal content. Application of recent knowledge of foraminiferal distribution and ecology served to point out that possible depth changes can be observed in the fossil assemblages. Correlation of these assemblages with existing particle size distribution data to determine paleoecological conditions reveals that the sediments were deposited in relatively shallow water under open-ocean, nearshore conditions and exhibit a shoaling-innundation relationship within the units represented.

Temperatures during this time appeared to become progressively colder.

No pelagic genera or arenaceous forms were found in the samples investigated.

Introduction

This paper presents the results of a study of the foraminiferal assemblages obtained from a sequence of beds from the Pleistocene Gubik formation of Northern Alaska.

Inferences as to paleotemperatures and depths of deposition of the sediments will be made, utilizing known ecologic data of various characteristic species, and particle size distribution analyses of the containing sediments.

The sediment samples were collected by John B. O'Sullivan in August, 1957, primarily for particle size distribution data. They were obtained from the side walls of a 32" diameter auger hole located about 1½ miles south of the beginning of the cliffs at Barrow Village and comprise a total section of 22 feet.

Sample Description and Interpretation

Sample B-2 came from the 1 foot thick lowermost unit and was described by O'Sullivan (1961) as; "black laminated sandy silt and clay with scattered 1" gravel." A total of 8 species were found, totalling 78 individuals; of which, the following species are considered significant by their percentage of relative abundance.

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Eponides frigidus—38.4%
Nonionella auricula—33.3%
Elphidium incertum—9.0%
Elphidium clavatum—7.7%

Size analysis of this sediment reveals that 96% is less than 0.074 mm, having a median diameter of 0.0035 mm.

It is significant that the most predominant species in the assemblage is *Eponides frigidus*, a form which lives attached to sea weeds, rocks, or foreign objects. The preponderance of this species in the typical openocean, nearshore assemblage indicates the possible presence of beds of sea weeds which may have provided places of attachment for this animal. The fact that 96% of the sediments are less than sand size implies that deposition took place at shallow depths, under conditions of low tide and weak wave action effects. The bottom was not subject to scour, was capable of supporting marine plants and, sedimentation was presumed to have been slow.

Sample B-6 came from a 1½ foot "tan silt with black lenses of silt or clay and thin gray sand lenses, indurated and calcareous." (O'Sullivan, 1961). A total of 14 species were found, totaling 70 individuals. The following species are considered significant.

Nonionella auricula—31.4%
Eponides frigidus—14.0%
Elphidium incertum—11.5%
Elphidium clavatum—11.5%

Size analysis shows that this unit is somewhat coarser than the preceeding unit. The sand content increased to 9.0% and the median diameter increased to 0.0084 mm.

Notable is the decrease in the percentage of *Eponides frigidus*, the corresponding increase in the percentage of sand size particles and, the size of the median diameters. This may indicate a decrease in the abundance of sea weeds and deposition in a shoaler, somewhat higher energy environment.

The assemblage is typical of the open-ocean, nearshore environment, and indicates deposition under climatic conditions similar to those of the present Arctic.

Sample B-7 came from a 2 foot "gray silt with pockets of calcareous sand, some concretionary sandstone, some gravel, and a 2½" calcareous sandstone layer. (O'Sullivan, 1961).

Thirteen species, having a total of 63 individuals were found, the significant species being:

Elphidium clavatum—36.6%
Elphidium incertum—15.8%

Eponides frigidus—11.1%
Nonion cf. N. barleeanum—7.9%

A size analysis indicates that this unit is coarser than any of the underlying units. The sand content increased to 27%, with median diameter increasing to 0.065 mm.

Although similar in foraminiferal content to the preceeding units, this unit is characterized by the addition of *Nonion barleeanum*, normally considered to be indicative of waters deeper than 200 meters. However, the distribution of this species may be governed solely by temperature and hence, it could be found at progressively shallower depths as one proceeds northward. Its shallow arctic occurrence may be due to this fact. In addition, *Nonion labradoricum* and *Nonionella auricula*, both considered to be shallow water forms are found in 9.4% of total abundance in this sample and add support to the shallow water origin of this unit.

The Foraminifera from this unit appear large and healthy, particularly the *Elphididae* and *Nonionidae*. Bradshaw (1961), in laboratory studies of cultured Foraminifera, observed that the largest tests were found at the lowest temperatures and salinities.

The increase in the percentage of sand sizes and median diameters indicate deposition in shoal depths. Ice rafting may have contributed to the sediments.

The temperature may have been somewhat lower than the present Arctic temperature. with lower salinity of the surface waters, creating blackish water conditions, further indicative of a shallow water environment.

Samples B-4 and B-1 were taken from a 7 foot section of "coarse gravel, silty to clayey matrix at upper contact. Coarse gravel, less sand, 4" x 3" gravel common. Some particles up to 6" in diameter." (O'Sullivan, 1961). Sample B-4, taken from the bottom of this unit, contains 6 species totaling 34 individuals. The following species are considered significant.

Elphidium clavatum—41.2%
Elphidium incertum—20.6%
Nonion orbiculare—14.7%
Eponides frigidus—11.8%

The entire assemblage appears extremely battered and worn, so much so that some identifications are very difficult.

A particle size distribution analysis of this sediment shows a bimodal frequency curve which indicates two sources for the material making up the sediments. The coarse gravel and sand fraction comprises 95% of the sample with the remaining 5%

being of silt and clay. The median diameter was greater than 2.0 mm.

The coarseness of the sediments and the bimodal distribution curve may indicate a beach environment. It is suggested that the coarser material has been contributed to the sediments by ice-rafting.

Climatic inferences are hazardous as the Foraminifera are not believed to be indigenous to the depositional site but to have been carried by the ice floes. The Foraminifera show indications of having been extensively reworked. Campbell and Collin (1958 have shown similar assemblages being carried by modern sea ice in the Fox Basin.

Sample B-1 was taken from the top of the preceeding 7 foot gravel unit and was found to be barren of fossils.

Samples B-3 and B-5 were taken from a 7½" section of "blue-black clay with contorted stringers, lenses and bifurcating layers of a brown clay containing more ice than the black clay. Lenses average 3-4" thick." (O'Sullivan, 1961). Twenty-two species are found in Sample B-5, comprising a total of 1564 individuals. The significant species are as follows:

Elphidium incertum—47.4%
Elphidium clavatum—14.9%
Elphidium spp.—10.4%
Elphidium excavatum—5.3%

A size analysis of this sample indicates that 97% is less than 0.074 mm. and 3% is greater than sand size. The median diameter is 0.0024 mm.

Sample B-3 was taken from a brown clay lens within the above described unit. Eighteen species, comprising 1449 individuals are found, the significant species being the same as in Sample B-5 with the exception of *Cyclammina bradyi,* which increases from 1.1% to 8.4%. (See summary table.)

This entire sedimentary unit shows indications of deeper water deposition. The abrupt decrease in median diameters and large content of silt size particles point toward deposition under deeper and quieter conditions.

The Foraminifera, still conforming to the open-ocean, near-shore pattern, show an increase in several deeper water forms. The large increase in percentage of *Elphididae* would seem to indicate colder temperatures as pointed out by Carsola (1952). A temperature profile across the Chukchi Sea shows a striking decrease of temperature with increased depth, in places dropping 5°F with a depth change of 50 meters. (U.S.H.O. Pub. No. 705).

Sample B-9 was taken from the uppermost unit sampled. It

Summary Table. Species frequency per sample.

	B-2	B-6	B-7	B-4	B-3	B-5	B-9
Elphidium incertum	9.0	11.5	15.8	20.6	47.4	40.1	22.0
Elphidium bartletti	. .	1.4	3.2	8.8	2.6	3.4	. .
Elphidium clavatum	7.7	11.5	26.6	41.2	14.9	12.3	12.2
Elphidium subarcticum	2.5	. .	1.6	. .	0.1	3.6	4.0
Elphidium discoidale	. .	. .	. .	. .	0.5	. .	. .
Elphidium articulatum	. .	. .	. .	. .	0.1	2.3	. .
Elphidium selseyense	. .	. .	. .	. .	2.4	0.6	. .
Elphidium excavatum	. .	. .	. .	. .	5.3	13.6	. .
Elphidium frigidum	. .	. .	. .	. .	1.9	1.0	. .
Elphidium nitida°	. .	. .	. .	. .	0.8	. .	. .
Elphidium advenum	. .	. .	. .	. .	0.1	. .	. .
Elphidium spp.	. .	. .	. .	. .	10.4	. .	. .
Elphidium greenlandicum	. .	. .	. .	. .	. .	. .	. .
Elphidiella arctica	. .	. .	1.6	. .	1.3	2.5	. .
Nonion orbiculare°	1.2	4.3	. .	14.7	0.2	1.6	16.6
Nonion Pompiloides°	. .	. .	. .	. .	. .	. .	. .
Nonion barleeanum°	. .	2.8	7.9	. .	. .	2.2	. .
Nonionella atlanticum	. .	. .	. .	. .	. .	. .	. .
Nonionella auricula	33.3	31.4	4.7	2.9	0.1	1.1	22.0
Nonion labradoricum°	. .	. .	4.7	. .	. .	. .	. .
Nonion spp.	. .	8.6	6.4	. .	. .	4.3	. .
Rotalia beccarii°	. .	. .	. .	. .	0.3	. .	. .
Eponides frigidus°	38.4	14.0	11.1	11.8	4.0	0.1	16.6
Cyclammina bradyi°	. .	2.8	. .	. .	1.1	8.4	. .
Pseudopolymorphina novanglia	2.5	2.8	3.2	. .	1.4	0.2	. .
Guttalina lactea	. .	. .	. .	. .	0.1	. .	. .
Trochammina inflata	. .	1.4	. .	. .	0.9	. .	. .
Quinqueloculina seminulum	. .	. .	. .	. .	. .	0.3	. .
Cribroelphidium arcticum	2.9	. .	1.6	. .	1.6	2.0	. .
Pullenia quinqueloba°	. .	. .	. .	. .	0.5	. .	. .
Cibides deprimus	2.5	. .	. .	. .	. .	. .	. .
Discorbis squamata	. .	1.4	. .	. .	. .	. .	. .
Discorbis spp.	. .	2.9	. .	. .	. .	. .	. .
Cassidulina norcrossi°	. .	. .	1.6	. .	. .	. .	. .

° Deeper water species.

consists of 1½ feet of "dark brownish-black, silty clay; fossiliferous (mainly pelecypods)." (O'Sullivan, 1961). Six species are found in this sample, comprising a total of 24 individuals. The significant species are as follows:

Elphidium incertum—22.0%
Nonionella auricula—22.0%
Nonion orbiculare—16.6%
Eponides frigidus—16.6%

A size analysis of this sample indicates that 96% is less than 0.074 mm. and 4% is sand size. The median diameter is 0.010 mm.

This final unit indicates deeper and quieter water deposition, although appearing somewhat coarser than the preceeding unit.

The forminiferal assemblage is typical of the open-ocean, nearshore assemblage and exhibits an arctic appearance. It is believed that the temperatures were not much different from those of the present Arctic.

Summary

The foraminiferal assemblages found in all the samples have been described previously by various workers, and are considered to be typically arctic assemblages (Carsola, 1952; Loeblich and Tappan, 1953; Phleger, 1952 and 1960). These assemblages have been observed to occur at depths ranging from 2 to 200

meters, being found in greatest abundance in the shallower half of this range. They have been designated as the "open-ocean, nearshore" assemblage by Phleger (1960), and also compare well with the assemblages of Natland's (1933) Zone II (3½ to 42 meters). Although both of the previously mentioned workers were also concerned with temperature effects, these effects are negligible in the Arctic as temperatures are practically isothermal, varying generally between 1.70°C and 0.58°C. (Green, 1960).

The open-ocean, nearshore environment persists throughout the entire sequence. The character of the foraminiferal assemblages exhibits some variations, primarily through changes in the relative abundance of the characteristic species. Analysis of these changing percentages indicates a period of shoaling through samples B-2, B-6, and B-7. The character of the sediments, shown by the median diameters, changes gradually which would also indicate a progressive withdrawal of the sea. It is believed that the climate, although differing little in general aspect from the present day, became somewhat more rigorous during the deposition of B-7.

A 3' 5" varied section, from which no samples were taken, overlies unit B-7. It is not possible to extend faunal interpretation through this barrier. However, the relative thinness of the various units through this section seems to indicate general activity, primarily of shallow nature, as evidenced by the abundance of coarse material.

Samples taken from unit B-4 indicate a beach environment with its resulting ice floe grounding. This area is generally barren of fossils as would be expected in such a zone of high energy. Samples B-5 and B-3 indicate a resumption of deeper water deposition under progressively colder conditions.

The final unit of this sequence again exhibits the typical open-ocean, nearshore assemblage and a tendency toward the resumption of the present arctic temperatures.

Thus, the evidence afforded by the assemblages, when combined with the data from particle size distribution analyses of the sediments, seems to indicate a period of offlap and onlap in an arctic environment.

Tappan (1951), in her studies of Arctic Foraminifera, noted that no pelagic genera were found. In the present investigation, particular attention was devoted to the recovery of some pelagic forms and extreme care in processing was used, lest these fragile forms be destroyed. However, no pelagic forms were encountered in any of the sediments investigated.

Finally, there was a distinct lack of agglutinated and arenaceous forms in the sediments investigated.

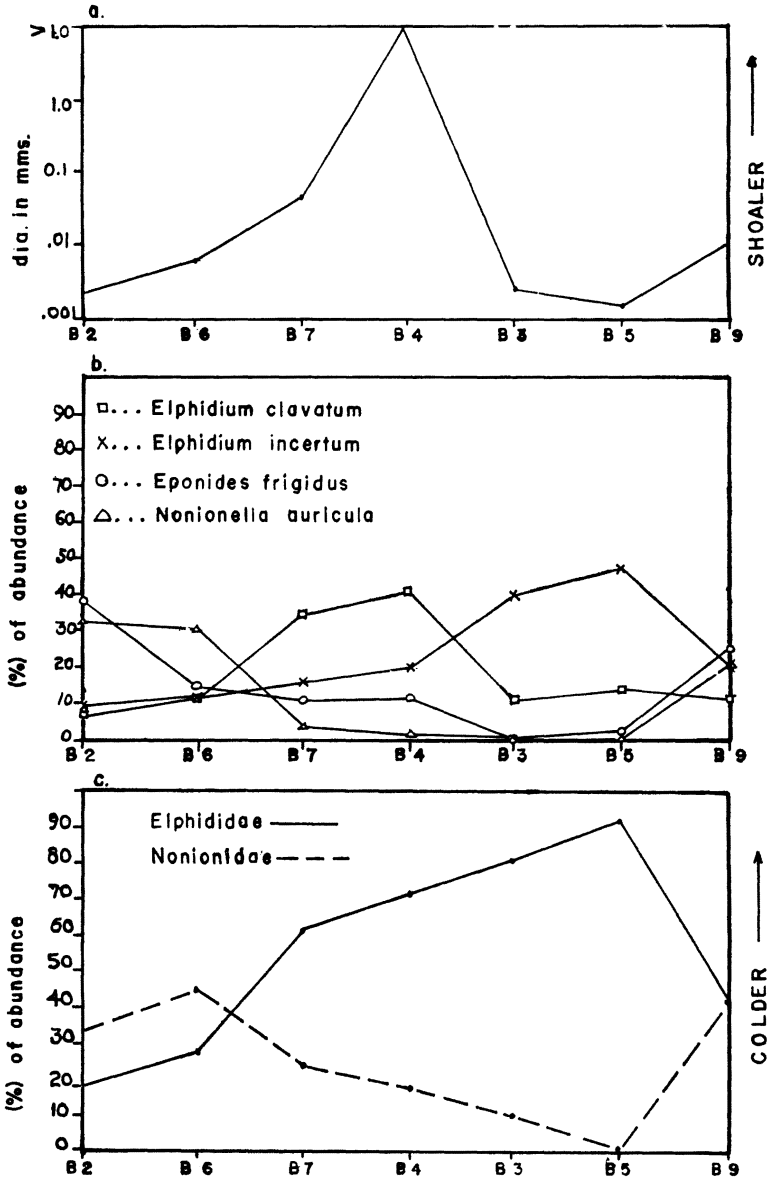

Figure 1. *a.* Average particle size distribution of the several samples studied. The coarser fragments are interpreted to be associated with a shoal of environment of deposition.

b. Relative abundance of species present in the sampled sequence.

c. Temperature preference of the families *Elphididae* and *Nonionidae*, and their application to the paleocologic interpretation of the Gubic formation.

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