

ON SOME FORAMINIFERA FROM THE NORTHEASTERN PART OF THE ARABIAN SEA

BY K. KAMESWARA RAO*

(Field Unit of the National Institute of Oceanography, Sassoon Docks, Bombay)

Received April 20, 1970

(Communicated by Dr. N. K. Panikkar, F.A.Sc.)

ABSTRACT

Sediment core samples collected from the northeastern part of the Arabian Sea during cruise-2 on board I.N.S. 'Darshak' in January to February, 1967 have been analysed for study of the nature and distribution of Foraminifera. Ninety-two species of Foraminifera belonging to 40 genera of 16 families, viz., Textulariidae, Valvulinidae, Miliolidae, Ophthalmitidae, Trochamminidae, Lagenidae, Planorbulinidae, Nonionidae, Camerinidae, Heterohelicidae, Buliminidae, Rotaliidae, Calcarinidae, Globigerinidae, Globorotaliidae and Anomalinidae have been identified and reported. Composition of Foraminifera and their concentration at different stations have been studied with reference to depth and state of preservation, benthic and planktonic Foraminifera being dealt with separately.

Foraminiferal species recorded for the first time in Indian waters are (1) *Textularia pseudocarinata* Cushman, (2) *Virgulina concava* Höglund, (3) *Virgulina pauciloculata* H. B. Brady, (4) *Loxostoma rostrum* Cushman, (5) *Lagena sulcata* (Walker and Jacob) var. *spicata* Cushman and McCulloch, (6) *Lagena costata* (Williamson) var. *amphora* Reuss, (7) *Elphidium oceanicum* Cushman, (8) *Discorbis auracana* Cushman and (9) *Globigerina calida* Parker.

The foraminiferal fauna of the continental shelf waters of the north-western part of India is similar to that of Gulf of Cambay and most of the species reported in this paper are also known from the tropical Pacific and Philippines.

INTRODUCTION

As evident from literature on Foraminifera, our knowledge on the distribution of this group in shallow coastal waters of India is very meagre although work done on systematics is somewhat satisfactory. The most outstanding contribution to the study of Foraminifera in the deeper regions of Arabian

* Present Address : National Institute of Oceanography, Ernakulam, Cochin-18.

Sea is that of Stubbings of John Murray Expedition, 1933-34. This expedition also has given some information on Foraminifera present in shallow waters of south Arabian Sea and Maldiva area. An account of Foraminifera from the Laccadive region has been given by Chapman (1895). Chaudhury and Biswas (1954) reported certain perforate Foraminifera from the Juhu beach, Bombay. Bhatia (1956) recorded some Foraminifera from shore sands of the beaches-Juhu and Chowpatty (Bombay) and Bhogat (Saurashtra). Sethulekshmi Amma (1958) studied Foraminifera from the inshore waters of the Travancore coast and Chatterjee and Gururaja (1967) from the Arabian Sea off Mangalore coast. There is no reference available at present on Foraminifera below 100 fathoms in the coastal waters off the northwestern part of India except the account given by Rao (1970) for the Gulf of Cambay.

The study of core samples is restricted to top one centimeter of the core so as to have a broad picture of the foraminiferal fauna and their horizontal distribution in the investigated area.

METHOD OF STUDY

The sediment cores from the bottom of the continental shelf waters of the northeastern part of the Arabian Sea were obtained by a gravity corer. A total number of eight core samples was collected. For the foraminiferal study the top one centimeter of the core was separated and part of the material from this portion of the sample was then washed through 200 mesh screen. The sieved material was then examined using a Stereo Binocular Microscope. The methods for counting and percentage calculations of different groups of Foraminifera are those of Phleger (1965). Sketches were drawn using a camera lucida of prism type.

TAXONOMY OF FORAMINIFERA FROM THE NORTHEASTERN PART OF THE ARABIAN SEA

Family TEXTULARIIDAE

Subfamily TEXTULARIINAE

Genus *Textularia* DeFrance, 1824

- (1) *Textularia cuneiformis* d'Orbigny, Fig. 8
- (2) *Textularia agglutinans* d'Orbigny, Fig. 9
- (3) *Textularia conica* d'Orbigny, Fig. 10
- (4) *Textularia candeiana* d'Orbigny
- (5) *Textularia pseudocarinata* Cushman, Fig. 11

Family VALVULINIDAE

Subfamily EGGERELLINAE

Genus *Eggerella* Cushman, 1933

- (6) *Eggerella bradyi* (Cushman)

Family MILIOLIDAE

Genus *Spiroloculina* d'Orbigny, 1826

- (7) *Spiroloculina depressa* d'Orbigny
(8) *Spiroloculina depressa* var. *rotundata* Williamson.
(9) *Spiroloculina grateloupi* d'Orbigny

Genus *Quinqueloculina* d'Orbigny, 1826

- (10) *Quinqueloculina seminulum* (Linnaeus)
(11) *Quinqueloculina vulgaris* d'Orbigny
(12) *Quinqueloculina lamarckiana* d'Orbigny
(13) *Quinqueloculina venusta* Karrer, Fig. 12
(14) *Quinqueloculina ferussacii* d'Orbigny, Fig. 13

Genus *Triloculina* d'Orbigny, 1826

- (15) *Triloculina trigonula* (Lamarck)
(16) *Triloculina tricarinata* d'Orbigny
(17) *Triloculina circularis* Bornemann
(18) *Triloculina cuneata* Karrer, 'Biloculine variety', Fig. 14
(19) *Triloculina oblonga* (Montagu)
(20) *Triloculina terquemiana* (H. B. Brady), Fig. 15
(21) *Triloculina linnaeana* d'Orbigny, Fig. 16
(22) *Triloculina echinata* d'Orbigny

Genus *Ammomassilina*, Cushman, 1933

- (23) *Ammomassilina alveoliniformis* (Millett), Fig. 17

Genus *Hauerina* d'Orbigny, 1839

- (24) *Hauerina fragilissima* (H. B. Brady)

Genus *Tubinella* Rhumbler, 1906

- (25) *Tubinella funalis* var. *inornata* (H. B. Brady), Fig. 18

Genus *Pyrgo* DeFrance, 1824

- (26) *Pyrgo subspherica* d'Orbigny, Fig. 19

Family OPHTHALMIDIIDAE

Subfamily CORNUSPIRINAE

Genus *Cornuspira* Schultze, 1854(27) *Cornuspira involvens* (Reuss), Fig. 21Genus *Cornuspiroides* Cushman, 1928(28) *Cornuspiroides foliaceus* (Philippi), Fig. 20

Family TROCHAMMINIDAE

Subfamily TROCHAMMININAE

Genus *Trochammina* Parker and Jones, 1859(29) *Trochammina inflata* (Montagu)

Family LAGENIDAE

Subfamily NODOSARIINAE

Genus *Nodosaria* Lamarck, 1812(30) *Nodosaria radricula* (Montagu)

Subfamily LAGENINAE

Genus *Lagena* Walker and Jacob, 1798(31) *Lagena globosa* (Montagu)(32) *Lagena laevis* (Montagu), Fig. 22(33) *Lagena gracillima* (Seguenza), Fig. 23(34) *Lagena punctulata* Sidebottom Fig. 24(35) *Lagena perlucida* (Montagu), Fig. 25(36) *Lagena hexagona* (Williamson), Fig. 26(37) *Lagena striata* (d'Orbigny)(38) *Lagena semistriata* Williamson, Fig. 27(39) *Lagena sulcata* (Walker and Jacob) var. *spicata* Cushman and McCulloch, Fig. 28(40) *Lagena costata* (Williamson), var. *amphora* Reuss, Fig. 29(41) *Lagena quadrata* (Williamson)(42) *Lagena marginata* (Walker and Boys)(43) *Lagena marginato-perforata* Seguenza; Fig. 30(44) *Lagena lagenoides* (Williamson), Fig. 31(45) *Lagena orbignyana* (Seguenza)

Genus *Robulus* Montfort, 1808

(46) *Robulus limbosus* (Reuss), Fig. 32

Family PLANORBULINIDAE

Genus *Planorbulinella* Cushman, 1927

(47) *Planorbulinella larvata* (Parker and Jones), Fig. 33

Family NONIONIDAE

Genus *Nonion* Montfort, 1808

(48) *Nonion boueanum* (d'Orbigny)

(49) *Nonion scapha* (Fichtel and Moll), Fig. 34

Genus *Elphidium* Montfort, 1808

(50) *Elphidium advena* (Cushman), Fig. 35

(51) *Elphidium striato-punctatum* (Fichtel and Moll) Cushman and Leavitt,
Fig. 36

(52) *Elphidium oceanicum* Cushman, Fig. 37

(53) *Elphidium simplex* Cushman, Fig. 38

(54) *Elphidium excavatum* (Terquem), Fig. 39

Family CAMERINIDAE

Subfamily CAMERININAE

Genus *Operculina*, d'Orbigny, 1826

(55) *Operculina gaimairdi*, d'Orbigny

Family HETEROHELICIDAE

Subfamily BOLIVINITINAE

Genus *Bolivinella* Cushman, 1927

(56) *Bolivinella margaritacea* Cushman, Fig. 40

Family BULIMINIDAE

Subfamily BULIMININAE

Genus *Bulimina* d'Orbigny, 1826

(57) *Bulimina marginata* d'Orbigny

Subfamily VIRGULININAE

Genus *Virgulina* d'Orbigny, 1826

- (58) *Virgulina squamosa* d'Orbigny
- (59) *Virgulina concava* Höglund, Fig. 41
- (60) *Virgulina pauciloculata* H. B. Brady, Fig. 42

Genus *Bolivina* d'Orbigny, 1839

- (61) *Bolivina nobilis* Hantken
- (62) *Bolivina vadescens* Cushman
- (63) *Bolivina hantkeniana* H. B. Brady, Fig. 43
- (64) *Bolivina capitata* Cushman, Fig. 44
- (65) *Bolivina striatula* Cushman, Fig. 45

Genus *Loxostoma* Ehrenberg, 1854

- (66) *Loxostoma limbatum* (H. B. Brady)
- (67) *Loxostoma rostrum* Cushman, Fig. 46

Subfamily UVIGERININAE

Genus *Uvigerina* d'Orbigny, 1826

- (68) *Uvigerina ampullacea* H. B. Brady, Fig. 47
- (69) *Uvigerina proboscidea* Schwager, Fig. 48

Family ROTALIIDAE

Subfamily DISCORBINAE

Genus *Discorbis* Lamarck, 1804

- (70) *Discorbis globularis* (d'Orbigny)
- (71) *Discorbis rosacea* (d'Orbigny)
- (72) *Discorbis vilardeboana* (d'Orbigny)
- (73) *Discorbis auracana* (d'Orbigny), Fig. 49
- (74) *Discorbis bertheloti* (d'Orbigny)

Genus *Lamarckina* Berthelin, 1881

- (75) *Lamarckina ventricosa* (H. B. Brady), Fig. 50

Subfamily ROTALIINAE

Genus *Eponides* Montfort, 1808

- (76) *Eponides repandus* (Fichtel and Moll), Fig. 51

Genus *Streblus* Fischer, 1817

(77) *Streblus beccarii* (Linnaeus) var. *koebøeenis* (Le Roy)

Subfamily BAGGININAE

Genus *Cancris* Montfort, 1808

(78) *Cancris auricula* (Fichtel and Moll), Fig. 52

Family CALCARINIDAE

Genus *Calcarina* d'Orbigny, 1826

(79) *Calcarina calcar* d'Orbigny

Family GLOBIGERINIDAE

Genus *Globigerina* d'Orbigny, 1826

(80) *Globigerina bulloides* d'Orbigny

(81) *Globigerina calida* Parker, Fig. 53

Genus *Globigerinella* Cushman, 1927

(82) *Globigerinella aequilateralis* (H. B. Brady)

Genus *Globigerinoides* Cushman, 1927

(83) *Globigerinoides ruber* (d'Orbigny), Fig. 54

(84) *Globigerinoides sacculifer* (H. B. Brady), Fig. 55

Genus *Orbulina* d'Orbigny, 1839

(85) *Orbulina universa* d'Orbigny, Fig. 56

Family GLOBOROTALIIDAE

Genus *Globoquadrina* Finlay, 1947

(86) *Globoquadrina dutertrei* (d'Orbigny)

Genus *Globorotalia* Cushman, 1927

(87) *Globorotalia menardii* (d'Orbigny)

(88) *Globorotalia tumida* (H. B. Brady), Fig. 57

Family ANOMALINIDAE

Subfamily ANOMALININAE

Genus *Planulina* d'Orbigny, 1826

(89) *Planulina ornata* (d'Orbigny), Fig. 58

Genus *Anomalinella* Cushman, 1927

(90) *Anomalinella rostrata* (H. B. Brady), Fig. 59

Subfamily CIBICIDINAE

Genus *Cibicides* Montfort, 1808(91) *Cibicides lobatulus* (Walker and Jacob)(92) *Cibicides pseudoungeriana* (Cushman)

DESCRIPTION OF THE AREA AND LOCATION OF STATIONS

The study area extends between Longitudes $72^{\circ} 2' E$ and $68^{\circ} 16' E$ and Latitudes $19^{\circ} 7' N$ and $23^{\circ} 22' N$. The stations covered in the northeastern part of the Arabian Sea from where samples have been collected are given in Table I (Fig. 1).

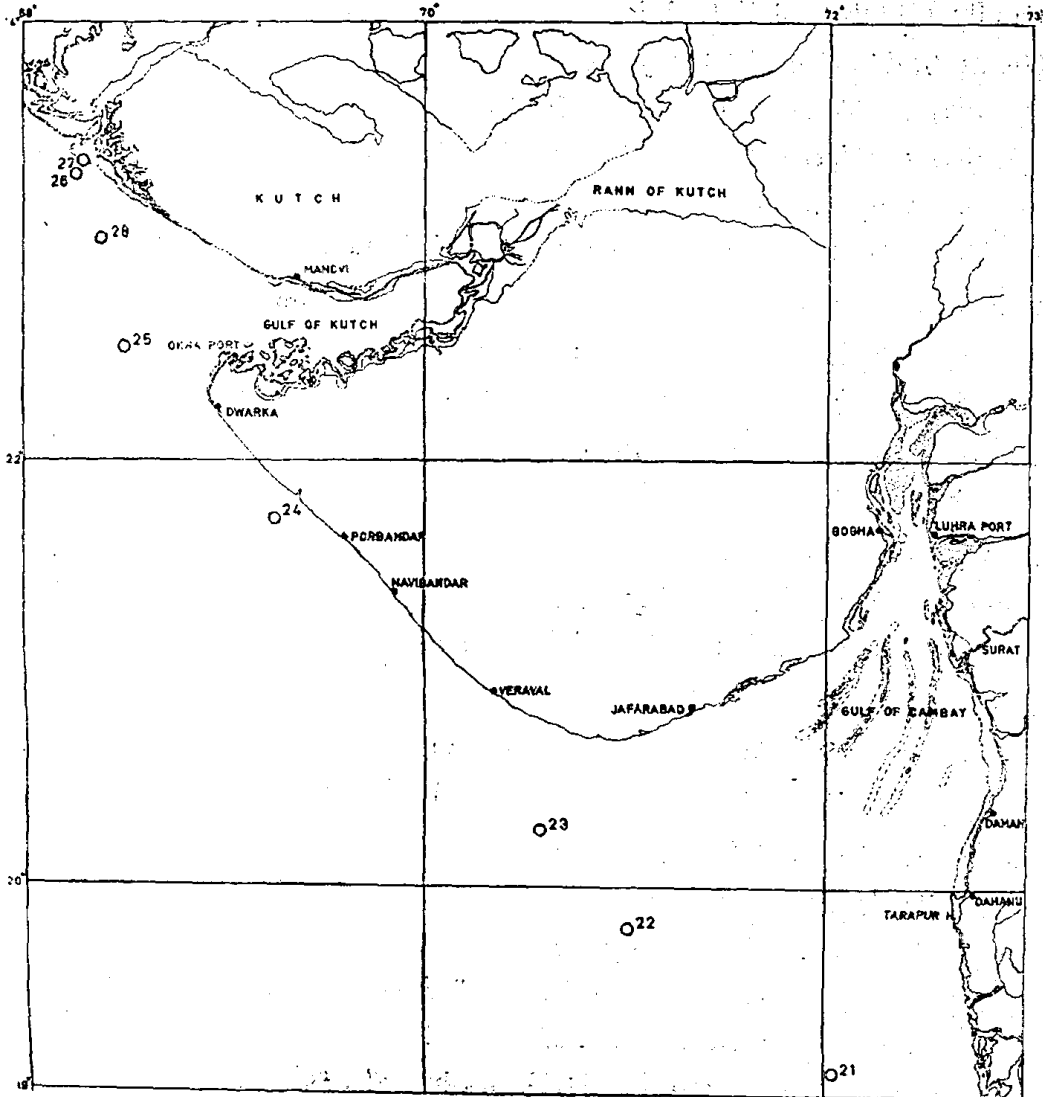


FIG. 1. Map of Northeastern part of the Arabian Sea showing location of stations.

ECOLOGICAL DATA

Depth and surface water temperature measurements have been made at all the stations covered. The water depths at the stations have been found to vary between 11 and 77 meters (Fig. 2) and the water temperature from 20° C to 24.7° C (Fig. 3). Description of the nature of the substrata at the sampling stations is given in Table I.

TABLE I
Location of stations

Station No.	Location Latitude (North)	Longitude (East)	Depth (m.)	Temperature °C (Surface)	Sediment
21	19° 7' N.	72° 2' E.	64	24.71	Sandy
22	19° 47.5' N.	71° 09.0' E.	64	23.89	Sandy
23	20° 16.7' N.	70° 34.5' E.	77	23.89	Muddy sand
24	21° 43.6' N.	69° 14.6' E.	37	21.71	Sandy mud
25	22° 31.0' N.	68° 30.0' E.	27	21.95	Muddy
26	23° 18.0' N.	68° 16.0' E.	14	21.10	Muddy
27	23° 22.0' N.	68° 18.0' E.	11	21.95	Muddy
28	23° 08.0' N.	68° 23.0' E.	16	20.00	Muddy

DISTRIBUTION OF FORAMINIFERA

Composition of Foraminifera at the stations covered in the area of study is as follows:

Station 21 : Foraminiferal content is very rich. Miliolids are dominant followed by Rotaliidae, Buliminidae, Nonionidae, Textulariidae, Anomalinidae, Ophthalmitidae, Valvulinidae and Planorbulinidae in the order of abundance. Lagenids are common in the sample. Rotalids are represented by genera such as *Discorbis*, *Lamarckina*, *Eponides*, *Streblus* and *Cancris*. Among the miliolids the most common genera are *Spiroloculina*, *Quinqueloculina* and *Triloculina*. *Planorbulinella larvata* is rare.

Planktonic Foraminifera like *Globigerina bulloides*, *Globigerinoides ruber* and *Globoquadrina dutertrei* are common and *Globorotalia tumida* is very rare. These pelagic specimens make upto 23.33%.

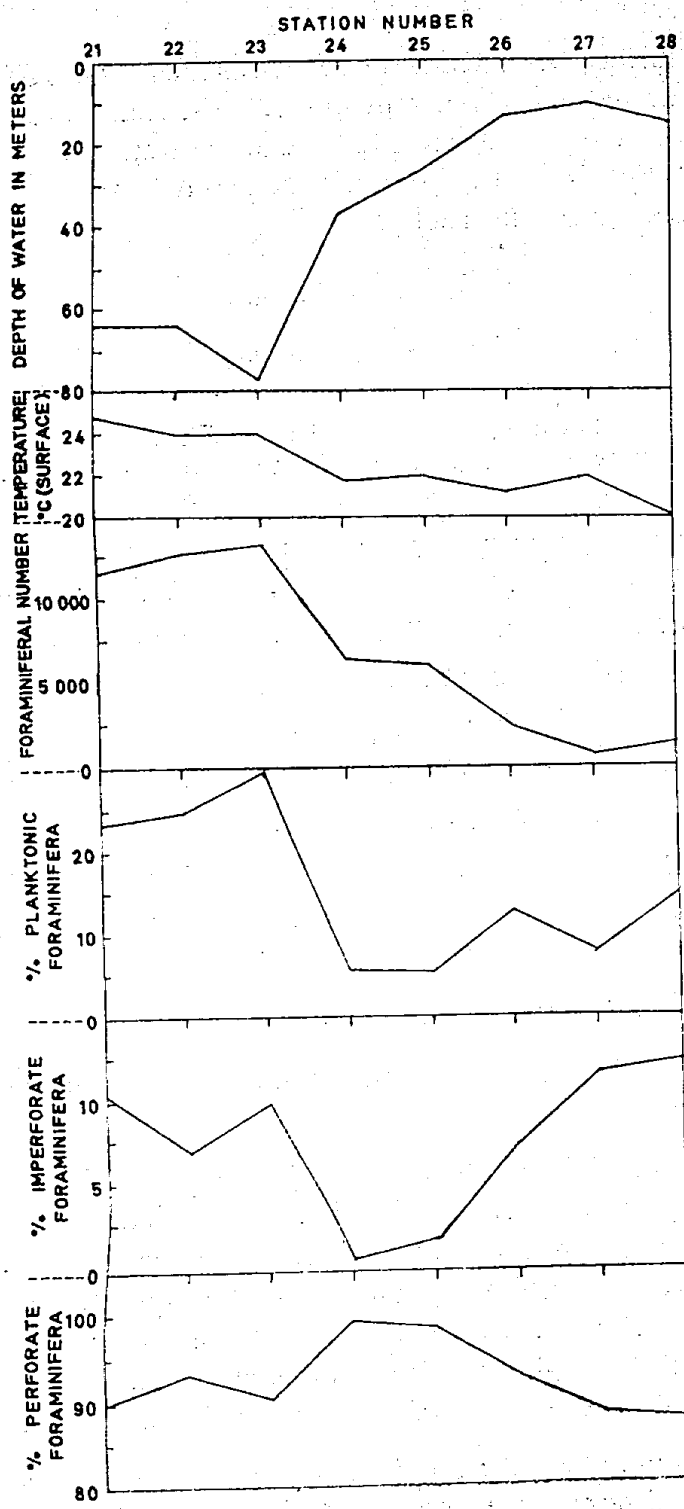


FIG. 2

FIG. 3

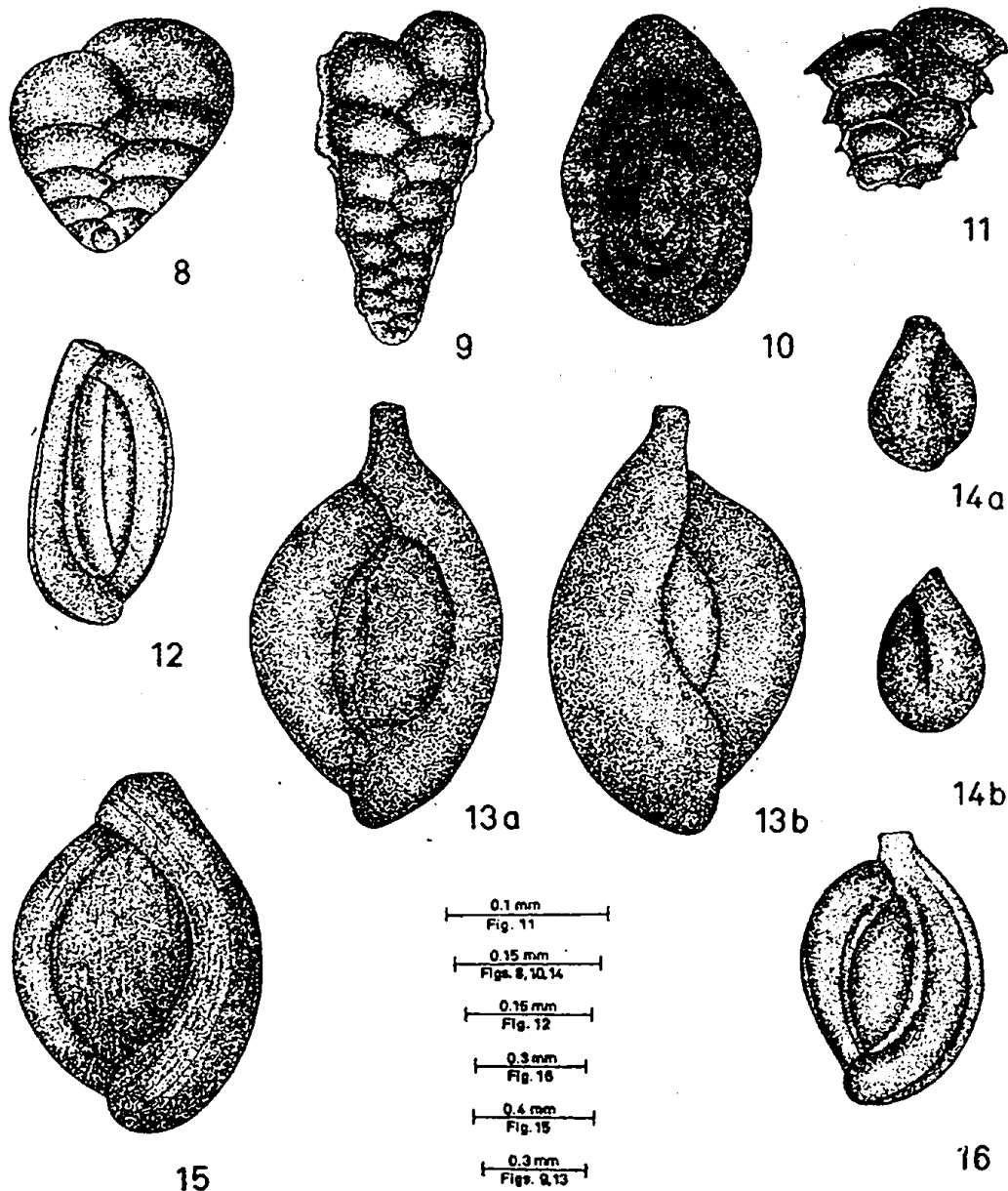
FIG. 4

FIG. 5

FIG. 6

FIG. 7

Figs. 2-7. Ecological factors and distribution analyses of foraminiferal fauna.



FIGS. 8-16. Fig. 8. *Textularia cuneiformis*. Fig. 9. *Textularia agglutinans*. Fig. 10. *Textularia conica*. Fig. 11. *Textularia pseudocarinata*. Fig. 12. *Quinqueloculina venusta*. Fig. 13. *Quinqueloculina ferussacii*. (a, dorsal view; b, ventral view.) Fig. 14. *Triloculina cuneata* Karrer, 'Biloculine variety'. (a, dorsal view; b, ventral view.) Fig. 15. *Triloculina erquemiana*. Fig. 16. *Triloculina linnaeana*.

Station 22 : The fauna at this station is as rich as at the previous station so far as the number of specimens is concerned but represented by relatively lesser number of families, Textulariidae, Miliolidae, Lagenidae, Nonio-

nidae, Buliminidae and Rotaliidae are found at this station. The dominant species of Foraminifera are *Streblus beccarii* (Linnaeus) var. *koeboeensis*, *Bulimina marginata*, *Bolivina nobilis*, *Uvigerina ampullacea*, *Lagena striata* and *Lagena globosa*. Miliolids are less frequent.

Many planktonic Foraminifera, i.e., *Globigerina bulloides*, *Globigerinoides ruber*, *Orbulina universa*, *Globoquadrina dutertrei* and *Globorotalia menardii* have been found forming up 24.66% of the total fauna.

Station 23: The fauna is comparatively very rich and the greatest abundance of specimens of Foraminifera is found at this station. Miliolidae, Rotaliidae, Buliminidae, Nonionidae, Lagenidae, Anomalinidae and Valvulinidae have been reported from this station. Some of the dominant genera at this station are *Spiroloculina*, *Quinqueloculina*, *Streblus*, *Discorbis*, *Bulimina* and *Nonion*. *Virgulina pauciloculata*, *V. concava*, *V. squamosa* and *Uvigerina proboscidea* are rare. Lagenids are common.

The most dominant species of planktonic Foraminifera are *Globigerinella aequilateralis* and *Globigerinoides ruber*. *Globoquadrina dutertrei* is present. *Globigerina calida* and *Globigerinoides sacculifer* are very rare species. Planktonic Foraminifera are most abundant constituting 30.66% of the total fauna.

Station 24 : The fauna at this station is relatively poor compared to the previous stations. Families of Foraminifera represented at this station are Rotaliidae, Buliminidae, Nonionidae, Lagenidae, Miliolidae, Ophthalmitidae and Trochamminidae in the order of abundance. *Discorbis rosacea*, *D. vilardeboana*, *Bolivina nobilis*, *B. striatula* and *Bulimina marginata* are common. *Trochammina inflata* is a very rare specimen at this station. *Elphidium advena* is very dominant. Miliolids are very sparse.

A few specimens of *Globigerina bulloides* are observed at this station.

Station 25: Foraminiferal families represented at this station are Rotaliidae, Miliolidae, Nonionidae, Buliminidae, Camerinidae and Lagenidae. Some very dominant rotalids are *Streblus beccarii* (Linnaeus) var. *koeboeensis* and *Discorbis rosacea*. Miliolids and lagenids are sparsely present. *Operculina gaimairdi* is rare. *Elphidium simplex* and *El. advena* are very abundant. *Bolivina*, *Bulimina* and *Virgulina* are dominant genera of the family Buliminidae. *Nonion boueanum*, *Bolivina striatula*, *Bulimina marginata* and *Virgulina squamosa* are common.

Planktonic Foraminifera make up 5.33% of the total fauna and are represented by the lone species of *Globigerina bulloides*.

Station 26: The foraminiferal fauna at this station is very poor compared to the previous stations. Some families of this group reported from this station are Miliolidae, Rotaliidae, Buliminidae and Camerinidae. Miliolids of the genera *Triloculina* and *Quinqueloculina* are rare. Rotalids belonging to the genera *Streblus* and *Discorbis* have been observed. *Bolivina* and *Bulimina* are sparsely present.

Only a few specimens of *Globigerina bulloides* have been observed.

Station 27: As compared with the previous station the fauna is still poorer. Some families of Foraminifera that have been reported are Miliolidae, Rotaliidae, Buliminidae, Lagenidae, Anomalinidae and Heterohelidae. The dominant family at this station is Miliolidae and dominant genera of this family are *Quinqueloculina* and *Triloculina*. *Quinqueloculina vulgaris*, *Q. seminulum*, *Triloculina circularis*, *Tr. oblonga* and *Tr. tricarinata* are common. The family Rotaliidae is represented by the same genera as reported at the previous station. *Bolivinella margaritacea*, a rare species is present.

TABLE II

Frequency of occurrence of foraminiferal species at different stations

Station Number	21	22	23	24	25	26	27	28
Depth in Meters	64	64	77	37	27	14	11	16
Benthic Species								
(1) <i>Textularia cuneiformis</i>		*						
(2) <i>Textularia agglutinans</i>	**	*						
(3) <i>Textularia conica</i>	*							
(4) <i>Textularia candeiana</i>	*	*						
(5) <i>Textularia pseudo-carinata</i>		*						
(6) <i>Eggerella bradyi</i>	*		**					
(7) <i>Spiroloculina depressa</i>	**	*	*	*	*			
(8) <i>Spiroloculina depressa</i> var. <i>rotundata</i>			*					

TABLE II (Contd.)

Station Number	21	22	23	24	25	26	27	28
Depth in Meters	64	64	77	37	27	14	11	16
Benthic Species								
(9) <i>Spiroloculina grateloupi</i>	**	*	*					
(10) <i>Quinqueloculina seminulum</i>	**	*	*	*	*	*	**	**
(11) <i>Quinqueloculina vulgaris</i>	**					*	**	*
(12) <i>Quinqueloculina lamarckiana</i>							*	
(13) <i>Quinqueloculina venusta</i>								*
(14) <i>Quinqueloculina ferussacii</i>	**	*	*					
(15) <i>Triloculina trigonula</i>	**	*	*					**
(16) <i>Triloculina tricarinata</i>	**			*		*	**	*
(17) <i>Triloculina circularis</i>	**						**	*
(18) <i>Triloculina cuneata</i> Karrer, 'Biloculine variety'								*
(19) <i>Triloculina oblonga</i>	*	*				*	**	
(20) <i>Triloculina terquemiana</i>							*	
(21) <i>Triloculina limaeana</i>			*					*
(22) <i>Triloculina echinata</i>	*		*					
(23) <i>Ammomassilina alveoliniformis</i>							*	
(24) <i>Hauerina fragilissima</i>		*		*				
(25) <i>Tubinella funalis</i> var. <i>inornata</i>				*				
(26) <i>Pyrgo subspherica</i>	*							
(27) <i>Cornuspira involvens</i>	*			*				
(28) <i>Cornuspiroides foliaceus</i>				*				
(29) <i>Trochammina inflata</i>				*				
(30) <i>Nodosaria radicularia</i>	**	*	*					
(31) <i>Lagena globosa</i>	**	***						
(32) <i>Lagena laevis</i>	**	**			*			*

TABLE II (Contd.)

Station Number	21	22	23	24	25	26	27	28
Depth in Meters	64	64	77	37	27	14	11	16
Benthic Species								
(33) <i>Lagena gracillima</i>		*	*					
(34) <i>Lagena punctulata</i>			*					
(35) <i>Lagena perlucida</i>	*	*						
(36) <i>Lagena hexagona</i>								*
(37) <i>Lagena striata</i>	**	***	**	*	*			*
(38) <i>Lagena semistriata</i>	*		*					
(39) <i>Lagena sulcata</i> (Walker and Jacob) var. <i>spicata</i>	*							
(40) <i>Lagena costata</i> (Williamson) var. <i>amphora</i>			*					
(41) <i>Lagena quadrata</i>	*	*	*					
(42) <i>Lagena marginata</i>	**	*	*	*	*			
(43) <i>Lagena marginato- perforata</i>			*					
(44) <i>Lagena lagenoides</i>		*						
(45) <i>Lagena orbignyana</i>			*					
(46) <i>Robulus limbosus</i>	*							
(47) <i>Planorbulinella larvata</i>	*							
(48) <i>Nonion boueanum</i>	**	**	*	*	**			*
(49) <i>Nonion scapha</i>				*				
(50) <i>Elphidium advena</i>	*			***	***			
(51) <i>Elphidium striato- punctatum</i>	*			*				
(52) <i>Elphidium oceanicum</i>	*							
(53) <i>Elphidium simplex</i>		*			***			
(54) <i>Elphidium excavatum</i>	*				*			
(55) <i>Operculina gaimairdi</i>					*	*		
(56) <i>Bolivina margaritacea</i>							*	
(57) <i>Bulimina marginata</i>	**	***	***	**	**	*		*
(58) <i>Virgulina squamosa</i>	*	*	*		**			

TABLE II (Contd.)

Station Number	21	22	23	24	25	26	27	28
Depth in Meters	64	64	77	37	27	14	11	16
Benthic Species								
(59) <i>Virgulina concava</i>			*					
(60) <i>Virgulina pauciloculata</i>	*		*					
(61) <i>Bolivina nobilis</i>	**	***	***	**				
(62) <i>Bolivina vadeszens</i>	**	*	*					
(63) <i>Bolivina hantkeniana</i>	*		*					
(64) <i>Bolivina capitata</i>					*			
(65) <i>Bolivina striatula</i>	*	*	*	**	**			
(66) <i>Loxostoma limbatum</i>	**	*						
(67) <i>Loxostoma rostrum</i>	*							
(68) <i>Uvigerina ampullacea</i>	*	***	*					
(69) <i>Uvigerina proboscidea</i>	*		*					
(70) <i>Discorbis globularis</i>	*							
(71) <i>Discorbis rosacea</i>	**	**	**	**	***			**
(72) <i>Discorbis vilardeboana</i>	**	**	**	**	*			*
(73) <i>Discorbis auracana</i>		*	*		*			
(74) <i>Discorbis bertheloti</i>	*		*					
(75) <i>Lamarckina ventricosa</i>	*							
(76) <i>Eponides repandus</i>	*							
(77) <i>Streblus beccarii</i> (Linnaeus) va <i>koeboensis</i> (Le Roy)	***	***	*	**	***	*	*	***
(78) <i>Canceris auricula</i>	*							
(79) <i>Calcarina calcar</i>	**	**	*		*			*
(80) <i>Planulina ornata</i>	*							
(81) <i>Anomalinella rostrata</i>							*	
(82) <i>Cibicides lobatulus</i>	*		*					
(83) <i>Cibicides pseudo- ungeriana</i>	*		*					
Planktonic Species								
(84) <i>Globigerina bulloides</i>	**	**	**	*	*	*	*	*

TABLE II (Contd.)

Station Number	21	22	23	24	25	26	27	28
Depth in Meters	64	64	77	37	27	14	11	16
Planktonic Species								
(85) <i>Globigerina calida</i>			*					
(86) <i>Globigerinella aequilateralis</i>	**	*	***					
(87) <i>Globigerinoides ruber</i>	**	**	***					*
(88) <i>Globigerinoides sacculifer</i>			*					
(89) <i>Orbulina universa</i>		*						*
(90) <i>Globorotalia menardii</i>		*						
(91) <i>Globorotalia tumida</i>	*							
(92) <i>Globoquadrina dutertrei</i>	**	**	**		*			*

*** Dominant

** Subdominant

* Rare

The only representative of planktonic Foraminifera, *Globigerina bulloides* is also met with.

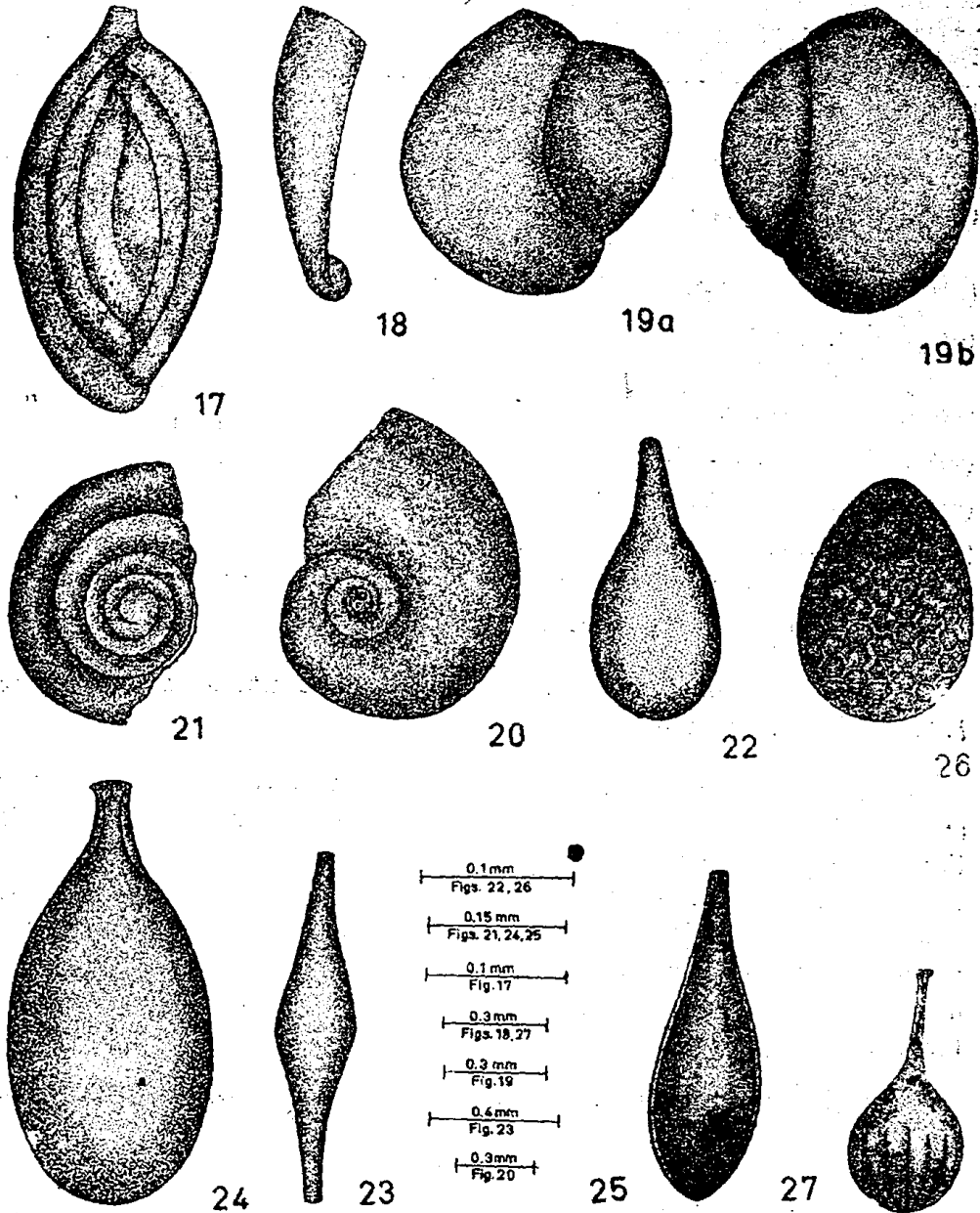
Station 28: The faunal content is almost same as the previous station and families of Foraminifera represented at this station are Rotaliidae, Miliolidae, Buliminidae, Lagenidae and Nonionidae. The most dominant species of rotalids is *Streblus beccarii* (Linnaeus) var. *koeboenis*. *Discorbis rosacea* is a common species in the sample. Miliolids belonging to genera *Quinqueloculina* and *Triloculina* are frequent. *Quinqueloculina seminulum* and *Triloculina trigonula* are some of the common species of the miliolid group at this station.

Pelagic forms form 14.66% of the total fauna represented at the station.

GENERAL REMARKS

Some aspects on the concentration of Foraminifera from the area studied.
—A total number of 92 species was observed and they were grouped under 40 genera and 16 families, viz., Textulariidae, Valvulinidae, Miliolidae, Ophthal-midiidae, Trochamminidae, Lagenidae, Planorbulinidae, Nonio-

nidae Camerinidae, Heterohelicidae, Buliminidae, Rotaliidae, Calcarinidae, Globigerinidae, Globorotaliidae and Anomalinidae.



FIGS. 17-27. Fig. 17. *Ammomassilina alveoliniformis*. Fig. 18. *Tubinella funalis* var. *inornata*. Fig. 19. *Pyrgo subspherica*. (a, dorsal view; b, ventral view.) Fig. 20. *Cornuspiroides foliaceus*. Fig. 21. *Cornuspira involvens*. Fig. 22. *Lagena laevis*. Fig. 23. *Lagena gracillima*. Fig. 24. *Lagena punctulata*. Fig. 25. *Lagena perlucida*. Fig. 26. *Lagena hexagona*. Fig. 27. *Lagena semistriata*.

From the study of the relationship between foraminiferal number, *i.e.*, the total number of foraminiferal specimens present in one gram of sediment (dry weight) and depth, it is observed that a definite relationship exists. With the increase of depth, the number of Foraminifera increases (Fig. 4). In general, specimens of Foraminifera observed at the collecting stations are in a good state of preservation as they must have been buried in the sediments without being exposed on the surface of the seafloor.

A detailed study of the foraminiferal fauna at species level has revealed that some forms are dominant, others subdominant and still others rare. On the above-said classification the order of frequencies is given in Table II.

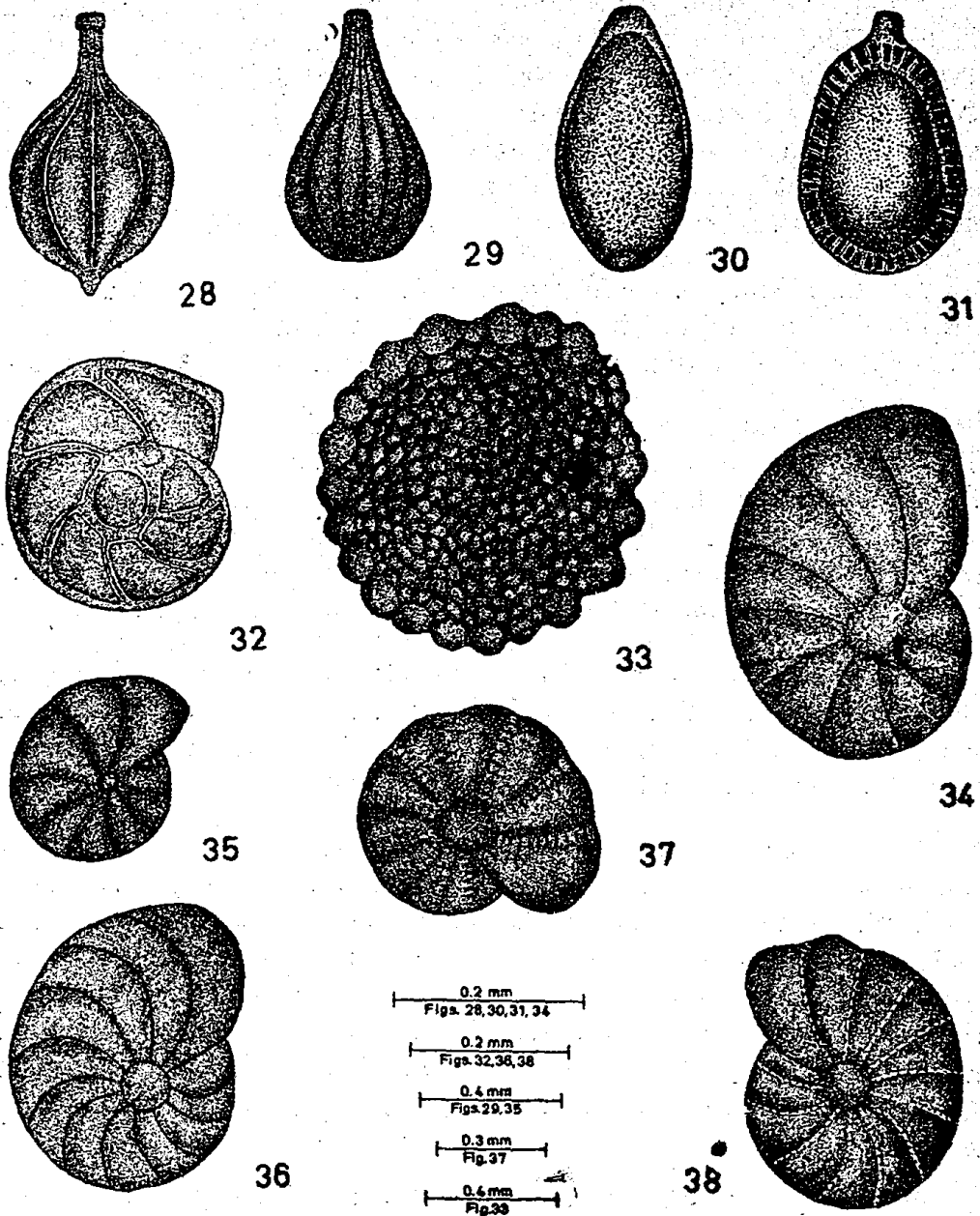
Foraminiferal species recorded for the first time in Indian waters are (1) *Textularia pseudocarinata* Cushman, (2) *Virgulina concava* Höglund, (3) *V. pauciloculata* H. B. Brady, (4) *Loxostoma rostrum* Cushman, (5) *Lagena sulcata* (Walker and Jacob) var. *spicata* Cushman and McCulloch, (6) *Lagena costata* (Williamson) var. *amphora* Reuss, (7) *Elphidium oceanicum* Cushman, (8) *Discorbis auracana* Cushman and (9) *Globigerina calida* Parker.

The foraminiferal fauna of the continental shelf waters of the study area is almost identical with that of Gulf of Cambay (Rao, 1970). Most of the species observed from the northeastern part of the Arabian Sea have also been recorded from the tropical Pacific and Philippines.

The benthic Foraminifera.—These are bottom dwelling forms on the surface of the sea floor. Arenaceous Foraminifera belonging to the families Textulariidae and Trochamminidae have been reported from Stations 21 and 22 and are entirely lacking in other stations. These forms are somewhat common in regions where the type of bottom sediments is an admixture of sand and mud. Besides the above-said families, the benthic Foraminifera are represented by Valvulinidae, Lagenidae, Planorbulinidae, Nonionidae, Camerinidae, Heterohelicidae, Buliminidae, Rotaliidae, Calcarinidae and Anomalinidae.

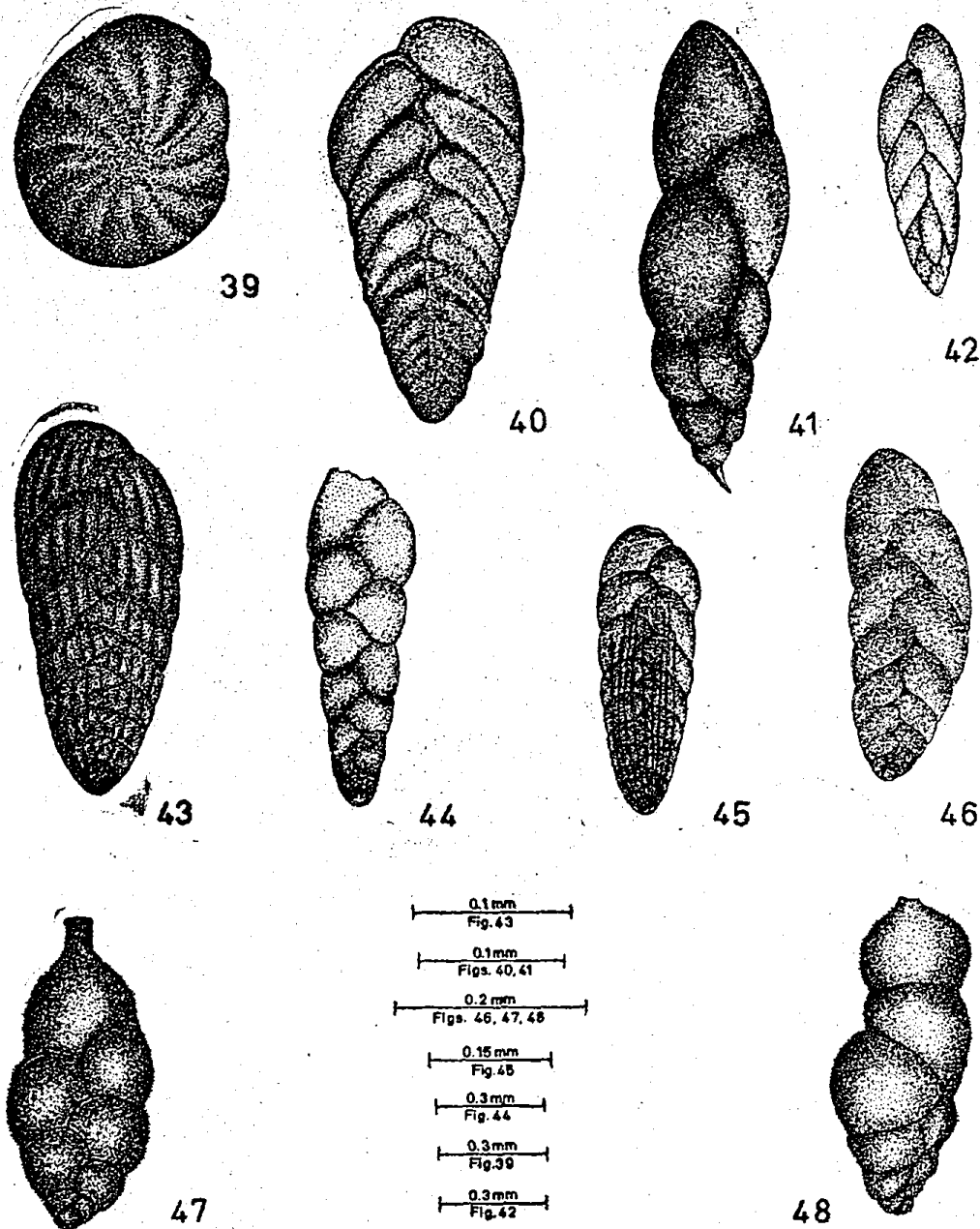
Relatively high percentages of perforate benthic and planktonic Foraminifera have been observed at Stations 24 and 25 (Fig. 7).

Imperforate Foraminifera belonging to the families Miliolidae and Ophthalmitidae have been reported and very high percentages of these Foraminifera are found at Stations 27 and 28 (Fig. 6) where depth is below 20 meters. It is evident that heavy concentration of these forms is due to their preference for shallow nearshore regions where water is usually warm.



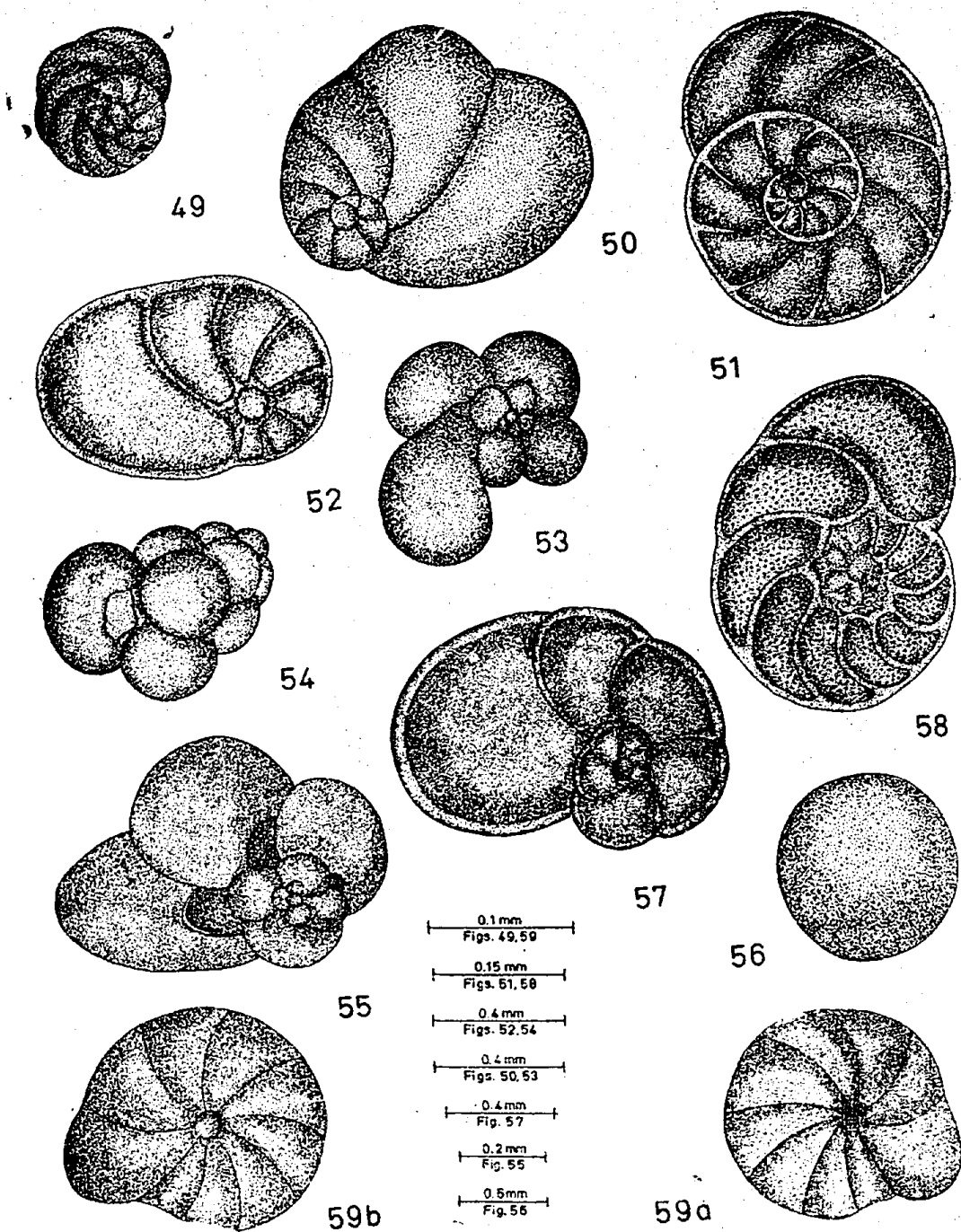
FIGS. 28-38. Fig. 28. *Lagena sulcata* (Walker and Jacob) var. *spicata*. Fig. 29. *Lagena* (Williamson) var. *amphora*. Fig. 30. *Lagena marginato-perforata*. Fig. 31. *Lagena lagenoides*. Fig. 32. *Robulus limbosus*. Fig. 33. *Planorbulinella larvata*. Fig. 34. *Nonion scapha*. Fig. 35. *Elphidium advena*. Fig. 36. *Elphidium striato-punctatum*. Fig. 37. *Elphidium oceanicum*. Fig. 38. *Elphidium simplex*.

The Planktonic Foraminifera.—These are pelagic forms preferring exclusively open sea habitat and they are represented by two families, viz., Globi-



FIGS. 39-48. Fig. 39. *Elphidium excavatum*. Fig. 40. *Bolivinella margaritacea*. Fig. 41. *Virgulina concava*. Fig. 42. *Virgulina pauciloculata*. Fig. 43. *Bolivina hantkeniana*. Fig. 44. *Bolivina capitata*. Fig. 45. *Bolivina striatula*. Fig. 46. *Loxostoma rostrum*. Fig. 47. *Uvigerina ampullacea*. Fig. 48. *Uvigerina proboscidea*.

gerinidae and Globorotaliidae. Planktonic species which are common in this region are *Globigerina bulloides*, *Globigerinoides ruber*, *Orbulina universa*,



FIGS. 49-59. Fig. 49. *Discorbis auracana*. Fig. 50. *Lamarckina ventricosa*. Fig. 51. *Eponides repandus*. Fig. 52. *Cancris auricula*. Fig. 53. *Globigerina calida*. Fig. 54. *Globigerinoides ruber*. Fig. 55. *Globigerinoides sacculifer*. Fig. 56. *Orbulina univrsa*. Fig. 57. *Globorotalia tumida*. Fig. 58. *Planulina ornata*. Fig. 59. *Anomalinella rostrata*. (a, dorsal view; b, ventral view.)

Globoquadrina dutertrei and *Globorotalia menardii*. *Globigerina calida*, *Globigerinoides sacculifer* and *Globorotalia tumida* are rare.

Further observations have shown that forms belonging to the genus *Globigerina* are bigger and mature in deeper waters and those found in the shallower depths are smaller and immature types. Percentages of planktonic Foraminifera at the stations covered range between 5.33% and 30.66% (Fig. 5). Relatively large percentages of planktonic Foraminifera have been observed near the mouth of Gulf of Cambay and Gulf of Kutch. In general, percentage of planktonic Foraminifera increases with depth.

ACKNOWLEDGEMENTS

The author is grateful to Dr. N. K. Panikkar, Director, National Institute of Oceanography, Panaji, Goa, for suggesting the problem on the study of Foraminifera and offering guidance during the course of the investigations and to Dr. Allan W. H. Bé of Lamont Geological Observatory of Columbia University, Palisades, New York, U.S.A., for helpful discussion concerning the subject. Thanks are due to the officers and crew of I.N.S. 'Darshak' for their co-operation for collections of samples and data and to Drs. B. N. Desai and M. G. A. P. Setty of National Institute of Oceanography, India, for reading the manuscript.

REFERENCES

- Asano, Kiyoshi .. "The Foraminifera from the adjacent seas of Japan, collected by the S. S. Soyomaru, 1922-1930. Part 2, Miliolidae," *Sci. Repts. Tohoku Univ.*, 2nd ser. (Geo), 1956, 27, Pt. 2, 57-83, pls. 7-9.
- Bé, A. W. H. .. *Distribution of Planktonic Foraminifera in the World Oceans*, Abstracts of Papers, 2nd International Oceanographic Congress, Moscow, 1966, p. 26.
- Bhatia, S. B. .. "Recent Foraminifera from shore sands of western India," *Contr. Cushman Found. Foram. Res.*, 1957, 7, 15-24.
- Brady, H. B. .. "Report on the Foraminifera," *Challenger, Zoology*, 1884, 9, 1-814.
- Chapman, F. .. "On some Foraminifera obtained by the Royal Indian Survey Ship. S.S. 'Investigator' from the Arabian Sea," *Proc. Zool. Soc.*, 1895, 1-55.
- Chatterjee, B. P. and Gururaja, M. N. .. "Foraminifera off Mangalore coast, South India," *Proc. Symp. Indian Ocean, Bull. Natn. Inst. Sci. India*, 1967, 38, Pt. 1, Section II, 393-97.
- Chaudhury, A. and Biswas, B. .. "Recent perforate Foraminifera from Juhu beach, Bombay," *Micropaleontologist*, 1954, 8 (4), 30-32.

- Cushman, J. A. .. "A monograph of the Foraminifera of the North Pacific Ocean," *U.S. Nat. Mus. Bull.*, 1910-17, 71.
- "The Foraminifera of the Atlantic Ocean," *Ibid.*, 1918-31; 104.
- Daniel, C. J. .. "The Foraminifera of Krusadi Island and adjacent areas," *M.Sc. Thesis, Univ. of Madras, Dept. of Zoology*, 1949.
- Ganapati, P. N. and .. "Report on the Foraminifera in bottom sediments in the Bay
Satyavati, P. of Bengal off the east coast of India," *Andhra Univ. Mem. Oceanogr.*, 1958, 11, 100-27.
- Gnanamuthu, C. P. .. "Foraminifera of Krusadi Island," *Bull. Madras Govt. Mus.*, 1943 (2), Pt. 5, 1-21.
- Heron-Allen, E. and .. "The Foraminifera of the Kerimba Archipelago," *Trans. Zool. Soc. London*, 1914, 20, Pt. I; 1915, Pt. II.
- Earland, A.
- Kameswara Rao, K. .. "Foraminifera of the Gulf of Cambay," *J. Bombay nat. Hist. Soc.*, 1970, 66 (3), 584-596, 67 (2), 259-273 (to be continued).
- "On a little known miliolid foraminifer from northeastern part of the Arabian Sea," *Curr. Sci.*, 1970, 39 (4), 87-88.
- Millett, F. W. .. "Report on the recent Foraminifera of the Malay Archipelago," *Jour. Roy. Micr. Soc.*, 1898-1904.
- Moura, A. R. .. "Foraminiferos da Ilha da Inhaca," *Revista dos estudos gerais universitarios de Mocambique*, 1965, Serie II, 2.
- Phleger, F. B. .. *Ecology and distribution of Foraminifera*, The Johns Hopkins Press, Baltimore, U.S.A., 1965.
- Said, R. .. "Foraminifera of the northern Red Sea," *Cushman Lab. Foram. Res., Spec. Publ.*, 1949 (26), 1-44, pls. 1-4.
- "Additional Foraminifera from the northern Red Sea," *Contr. Cushman Found. Foram. Res.*, 1950, 1, Pts. 1-2, 4-9, pl. 1.
- Schott, W. .. "Die Foraminiferen in dem aquatorialen Teil des Atlantischen Ozeans," *Deutsche Sudpolar-Exped.*, 1935, 11, Pt. 6, 411-616.
- Sethulekshmi Amma, J. .. "Foraminifera of the Travancore coast," *Bull. Res. Inst. Univ. Kerala, Ser. C.*, 1958, 6 (1), 1-88.
- Stubbings, H. G. .. "Stratification of biological remains of marine deposits of the Arabian Sea (British Mus. Nat. Hist.), John Murray Exped., 1933-34," *Sci. Rept.*, 1939, 3 (2), 31.
- Todd, Ruth., and .. "Recent Foraminifera and Thecamoebina from the eastern
Bronnimann, Paul Gulf of Paria," *Contr. Cushman Found. Foram. Res. Spec. Publ.*, 1957 (3), 1-43, Pls. 1-12. text-figs. 1-7, tables 1-5.
- Uchio, T. .. "New genera and species of Foraminifera from Hachijo Island, Tokyo prefecture," *Japanese J. Geol and Geogr.*, 1952, 22, 145-59, pls. 6 and 7.