

## AGGLUTINATED FORAMINIFERA FROM THE SHELF OF EAST COAST OF INDIA

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### Abstract

Of the benthonic foraminiferal species, the agglutinated forms form one of the distinctive elements by differing in type and the degree of their abundance in the several zones of the marine environment. The role played by the eighteen species belonging to six families, in a depth zone of 35-222 m of the east-coast of India (between Visakhapatnam and Masulipatnam along the continental shelf-slope region) in terms of lithology, faunal assemblage and their percentage distribution are discussed. It is found that the highest concentration of these species is noticed in the quite region of the shelf, and least in the deltaic areas. The population is highest in the region of fine sands at depth (55-74 m) and decrease markedly beyond. Similarly, they are rare in the near shore (upto 55 m depth) from the coast. They also indicate the evidence of slumping in deeper waters. These forms also have a wide range in the composition of the material making up their test which is attributed to the selective power of the organism.

### Introduction

The majority of the foraminifera that inhabit the sea are the bottom dwelling benthonic species. The arenaceous or agglutinated species form one of the distinctive elements of the benthonic species. Unlike the pelagic environment the marine benthonic environment is divided into several depth zones wherein ecologic factors like temperature, salinity, depth, bottom conditions and the like play an important role in the delineation of the different species characteristic of several zones. No doubt, the agglutinated forms are found to be distributed in all these zones but their type and degree of abundance differs in each. It is generally known that the arenaceous forms are abundant in the marsh environment but decrease in number with depth.

An attempt has been made here to investigate the role played by the agglutinated species in a depth zone of 35-222 m (the shelf-slope region) of the east coast of India.

Eighteen species of agglutinated foraminifera are noticed in a faunal assemblage and they are briefly described and illustrated. The sampled area is between Vishakhapatnam and Masulipatnam at depths varying from 35 to 222 m on the continental shelf and slope region. These samples were collected during the 18th cruise of INS KISTNA as part of the International Indian Ocean Expedition, Indian Programme.

The earliest record of foraminifera from the Bay of Bengal was given by John Murray in 1889. Recent investigators are Bhatia (1956), Bhatia & Bhalla (1959), Bhalla (1968), Rao Vedantam (1968), Setty & Almeida (in Press).

### **Lithology**

The eastern continental shelf is very narrow, curved and a region of several river mouths than the wide, almost straight, gently inclining western shelf. Therefore, the lithology of this region is different from the other. The study area is located between the rivers Krishna in the south and Mahanadi in the north including the wide delta of the Godavari in the middle. However, the general expectant pattern of sand, silt and clay distribution from the coast towards the off shore is noticed and appears to be normal. Samples collected at Sta. Nos. 444, 459 and 463 are typically sandy, dark grey in colour and poor in microfauna. Samples collected at Sta. Nos. 445, 457 and 461 are characterised by medium to fine sand with some oolites in it. Whole and fragmented gastropod-pelecypod fauna having a common type of microfauna is noticed in them. Samples from Sta. nos. 467, 472, 476 and 477 are very similar in being silty and partly clayey and being poor in foraminifera since the area is off the mouth of the river Godavari. However, samples from a similar station (No. 453) at the edges of the shelf and the other (Sta. No. 450) on the slope are clayey, rich in foraminifera but particularly in globigerinids.

The generic and suprageneric classification proposed in the Treatise of Invertebrate Paleontology is being followed here :

### **Systematics**

Ammodiscacea Reuss 1862

Astrorhizidae Brady 1881

Hippocrepininae Rhumbler 1895

*Jaculella* Brady 1879

*Jaculella acuta* H. B. Brady

Plate 1, fig. 1

1934 *Jaculella acuta* Brady Earland, *Discovery Repts.*, V. 10, Part 3, pl. 2, figs. 19-20, p. 72.

**Remarks :** This specimen agrees well with the description, but differs only in the nature of the wall, which is made up of oolites instead of coarse sand grains. Only one specimen was found at Sta. no. 461.

Length—1.32 mm.

Saccamminidae Brady 1884

Saccammininae Brady 1884

*Saccammina* M. Sars 1869

*Saccammina* sp.

Plate 1, fig. 2

1964 *Saccamina* sp., Loeblich and Tappan, Treatise Inv. Paleo. fig. 112, p. C 196

*Remarks* : The outer wall composed of oolites and the aperture irregular in shape, subrounded to angular, as it is composed of three or four grains of oolites. Found at sta. no. 461 only.

Diameter—0.48 mm to 0.32 mm.

Lituolacea de Blainville 1825

Hormosinidae Haeckel 1894

Hormosininae Haeckel 1894

*Reophax* Montfort 1808

***Reophax* sp.**

Plate 1, fig. 3

1964 *Reophax* sp., Loeblich and Tappan, Treatise Inv. Paleo. fig. 128, p. C 216.

*Remarks* : Chambers (3-4) do not increase in size as added ; aperture not placed at the end of a tubular neck ; wall oolitic. It is rare but found at sta. no. 461 only. When sectioned, chambers clearly seen.

Length—0.85 to 1.38 mm.

Textulariidae Ehrenberg 1838

Textulariinae Ehrenberg 1838

*Bigennerina* D'Orbigny 1826

***Bigennerina nodosaria* d'Orbigny**

Plate 1, fig. 4

1931 *Bigennerina nodosaria* d'Orbigny, Hada, Rept. Biol. Surv. Mutsu Bay. 19. text-fig. 26, p. 73.

1966 *Bigennerina nodosaria* d'Orbigny, Boltovskoy and Lena, Hydrobiologia, Tomo 1, no. 8, pl. 1, fig. 14, p. 284.

*Remarks* : Aperture terminal on a short neck. This species is characteristic of depths of 60-80 m (Mathieu, 1971) but it is found at sta. nos. 444, 445, 457 and 459 at depths ranging from 35 to 74 m.

Length—1.06 to 1.38 mm.

***Bigennerina textularioides* (Goes)**

Plate 1, fig. 5

1954 *Bigennerina textularioides* (Goes) Parker Bull. Mus. Comp. Zool., vol. 111, No. 10, pl. 3, figs. 4-5, p. 492.

*Remarks* : Wall coarsely arenaceous, roughly finished. Very similar to *B. nodosaria*, however chambers being smaller with rough texture and yellowish white colour, found at sta. no. 445 only.

Length 1 to 1.59 mm.

*Textularia* DeFrance 1824

***Textularia agglutinans* d'Orbigny**

Plate 1, figs. 6, 7 and 8.

1941 *Textularia agglutinans* d'Orbigny Lalicker and Bermudez, TORREIA, No. 8, pl. 1, fig. 7, p. 6.

1964 *Textularia agglutinans* d'Orbigny Smith, Geol. Surv. Prof. Paper 429B, p. 1, fig. 7, p. B. 28.

*Remarks* : Some specimens have wall composed of oolites while some others made up of shell fragments and foraminiferan shells. This species is reported off Mexico and Ecuador, at depths of 15 to 25 m (Lalicker and McCulloach 1940) but in this area it is noticed at 55 and 74 m depth.

Length 0.85 to 1.33 mm.

***Textularia panamensis* Cushman**

Plate 1, figs. 9 & 10.

1964 *Textularia panamensis* Cushman Smith, Geol. Surv. Prof. Paper 429-B, pl. 1, fig. 6, p. B28.

*Remarks* : Wall very fine grained, smooth ; sutures less oblique in these specimens than in those described by Smith. Originally described from the Miocene of the Panama Canal Zone. Reported from the Gulf of California to Peru at depths ranging from 18 to 90 m (Lalicker and McCulloach 1940), and from off Central America at depths of 20 to 140 m (Smith 1964). Found in this region at sta. nos. 450, 453 at depths of 222 and 203 m respectively.

Length—0.69 mm. Width—0.48 m.m.

***Textularia alazanensis* Nuttal**

Plate 1, figs. 11-13.

1953 *Textularia alazanensis* Nuttal Drooger, Cushman Found. Foram. Res. Contr. v. 4, pl. 19, fig. 2, p. 119.

*Remarks* : The aperture in this specimen is a small slit in a reentrant in contrast with the big and broad arched aperture in the typical form described by Drooger (1953).

Length—0.58 mm.

***Textularia conica* d'Orbigny**

Plate 1, figs. 14, 15.

1954 *Textularia conica* d'Orbigny Parker, Bull. Mus. Comp. Zool., v. 111, no. 10, pl. 2, fig. 13, p. 490.

1958 *Textularia conica* d'Orbigny Parker, Repts. Swedish Deep-Sea-Expd., v. 8, no. 4, pl. 1, figs. 5-6, p. 254.

*Remarks* : The specimens show a wide variation in the material making up the test. The aperture in specimens from sta. no. 459 is a small slit and is not placed at the base of the last chamber on the inner side near the suture but slightly above it and composed entirely of quartz grains and not of shell fragments as are those at sta. no. 444.

Length—0.42 mm.

**Textularia torquata** Parker

Plate 1, figs. 16, 17.

1952 *Textularia torquata* Parker Phloger, Cushman Found. Foram. Res. Contr., v. 3, pl. 13, figs. 18-19, p. 86.

1964 *Textularia torquata* Parker Cooper, Cushman found. Foram. Res. Contr., v. 15, pt. 3, pl. 5, fig. 9, p. 94.

*Remarks* : The aperture in these specimens is not visible from top because of the presence of a boss like protuberance. Cooper (1964) reported this species from 35 stations in the Chuckchi Sea having a wide range of temperature, salinity, sediment size and depth.

Length 1 to 1.33 mm.

**Textularia thanetana** Lalicker

Plate 1, figs. 18, 19.

1958 *Textularia thanetana* Lalicker Haynes, Cushman Found. Foram. Res. Contr., v. 9, pl. 15, fig. 55, p. 60.

*Remarks* : The aperture in these specimens being placed along the basal suture of the last chamber which is in a reentrant, and the indistinct early planispiral coil. Found at sta. nos. 457 & 461.

Length—0.96 mm.

**Textularia candeiana** d'Orbigny

Plate 2, figs. 1, 2.

1954 *Textularia candeiana* d'Orbigny Parker, Bull. Mus. Comp. Zool., v. 111, no. 10, pl. 2, figs. 16-17, p. 490.

*Remarks* : Specimens similar to those of Parker (1954) but are slightly more compressed. The wall is made up of sand grains.

Length—0.48 to 0.69 mm.

Ataxophragmiidae Schwager 1877

Verneuilininae Cushman 1911

*Gaudryna* d'Orbigny 1839

**Gaudryna arenaria** Galloway and Wissler

Pl. 2, figs. 3-6.

1960 *Gaudryna arenaria* Galloway and Wissler Uchio, Cushman Found. Foram. Res., Sp. Publ., no. 5, pl. 2, figs. 14-15, p. 56.

*Remarks* : Wall fine grained, smooth, specimens from shallow depths have mica flakes. They are found at sta. nos. 445, 450, 457, 461.

Length—0.53 to 0.74 mm.

**Tritaxia tricarinata** (Reuss)

Plate 2, figs. 7, 8.

1964 *Tritaxia tricarinata* (Reuss) Loeblich and Tappan, Treatise Inv. Paleo, fig. 182, p. C 272.

Remarks : Found at station nos. 450, 453 and 461.  
Length—0.43 to 0.86 mm.

Miliolilacea Ehrenberg 1839

Miliolidae Ehrenberg 1839

Quinqueloculininae Cushman 1917

Quinqueloculina d'Orbigny 1826

**Quinqueloculina agglutinata** Cushman

Pl. 2, figs. 9, 10.

1964 *Quinqueloculina agglutinata* Cushman Cooper, Cushman Found. Foram. Res. Contr., vol. 17, pt. 2, pl. 7, figs. 2-4, p. 68.

Remarks : Cooper (1964) reported this species from Chuckchi Sea at depths ranging from 13-39 m. Haman (1966) obtained a single specimen from a fjord in the Faeroe Islands at 15 m depth. Found in the present material at sta. nos. 445, 457 and 461, at depths of 55, 74 and 123 m respectively.

Length—0.58 mm ; Width—0.43 mm.

*Sigmoilopsis* Finlay 1947

**Sigmoilopsis moyi** Atkinson

Plate 2, figs. 11, 12.

1968 *Sigmoilopsis moyi* Atkinson, Cushman Found. Foram. Res. Contr., vol. 19, pt. 4, pl. 18, fig. 3, p. 161.

Remarks : The specimens are similar to those of Atkinson (1968) but differ in having a more ovate outline and flat cross section.

Length—0.80 mm ; Width—0.53 mm.

**Sigmoilopsis woodi** Atkinson

Plate 2, figs. 13, 14.

1968 *Sigmoilopsis woodi* Atkinson, Cushman Found. Foram. Res. Contr., vol. 19, pt. 4, pl. 18, fig. 4, p. 161.

Length—0.69 mm ; Width 0.48 mm.

*Siphonaperta* Vella 1957

**Siphonaperta macbeathi** Vella

Plate 2, figs. 15, 16.

1957 *Siphonaperta macbeathi* Vella, New Zealand Geol. Surv., Palaeo. Bull., no. 28, pl. 4, figs. 60-61, 63, p. 19.

Remarks : The specimens are not angled, and wall composed of oolites. An aberrant specimen having two last chambers instead of one in the normal quinqueloculine arrangement was reported by Setty and Almeida (in Press).

Length—0.74 mm ; Width—0.59 mm.

## Discussion

The sediment in the sampled area varies from fine sand to silt and clay. The agglutinated foraminifera also vary from less than one per cent (in most of the samples) to nearly about 8% (sta. no. 457) in the outer shelf (Fig. 1). Of the 12 samples analysed, 2 samples (from sta. nos. 457 and 445) contain the highest percentage (7.86% and 7.5%) followed by sta. no. 461 having 2.66% while the rest (9 stations) contain less than 1% of which two stations, 477 and 453 (at the edge of the shelf) have only traces (.02 and 0.06) of agglutinated forms in the total benthonic foraminiferal population (Table 1). The highest concentration is in the quite region of the shelf where the influx of sediment discharge and the fresh water is practically nil or least and quite water conditions prevail. This region (offshore of the shelf) lies between Kakinada and Visakhapatnam. This is in contrast to the deltaic offshore region (sta. nos. 463, 467, 472 and 476) of the river Godavari where the agglutinated forms are practically non-existent. In addition, even the other kind of microfauna is reported to be meagre and small sized.

It appears that the population of the agglutinated benthic foraminifera is highest in the region of fine sands at depths between 60 to 80 m depth. Textularians are common throughout the shelf (at all depths) but they are abundant in the near shore (sta. nos. 445 and 457) though some of the species are characteristic of certain depths only (Table 2). Mathieu (1971) contends that the Textularians form about 2% beyond 80 m. depth while the agglutinated forms have never exceeded 10% in the samples of the present day seas. In the present samples, it is noticed that the highest percentage of agglutinated forms are confined to 55-74 m depth and decrease markedly beyond this depth zone. Similarly, they are rare in the near shore region (upto 55 m depth) from the coast.

The absence of agglutinans in the region of the stations 476, in the south, through 472, 467 to 463 indicates that the area is inundated by fresh water flow and sediment discharge by the rivers Krishna and Godavari and the spread of their delta. Stations 477 and 463 are at the edge of the shelf hence traces of these foraminifera are noticed. This may possibly be due to the fact that the delta has not spread and reached this far or that the overload of the deltaic sediment has been removed exposing the underlying sediment. This possibility may apply to sta. 461 also, however, the exposure of the relict oolite bearing structure may be presumed to be at the margin of the Godavari delta.

The higher percentage noticed at sta. 450 at 222 m depth compared to sta. no. 453 at 203 m depth may be attributed to a deposit of slumped material on the slope.

The agglutinated forms described here have a wide range in the composition of the material making up the test. It varies from coarse to fine grains of quartz, foraminiferal shells, shell fragments and oolites. In some forms like *Textularia panamensis* Cushman, *Gaudryna arenaria* Galloway & Wissler, and *Tritaxia tricarinata* (Reuss) the tests are made up of very fine material and have a smooth appearance. This indicates a relationship between the nature of the sediment and the composition of the test. At station no. 461, the agglutinans (*Jaculella acuta* Brady, *Saccammina* sp. and *Reophax* sp.) are mostly made up of oolites; but there are also forms like *Textularia agglutinans* d'Orbigny made up of foraminiferal tests; other shells, their fragments and also quartz grains. These however

may be attributable to the selective power of the organism. There is no doubt that the foraminiferan plays an important role in its selection of the material for its wall and therefore the tests of fine grains are found along with tests composed of coarse grains in mainly coarse grained samples.

Naidu (1968) who collected a sample nearby the station 461 gave the radio carbon dating for the oolite fraction of the sediment as  $10800 \pm 155$  years. Another sample collected one mile north of this station consisting of coarse calcareous sand and oolites and shallow marine foraminifera at a depth of 93 to 185 m is referred to as a relict structure (Rao 1957).

An aberrant and unusual form of *Siphonaperta* sp. from these samples found at station no. 461 is described and discussed (Setty and Almeida, in Press) separately.

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#### EXPLANATION OF PLATE 1

- |       |  |    |    |    |    |     |
|-------|--|----|----|----|----|-----|
| 1     | <i>Jaculella acuta</i> Brady hypotype  | .. | .. | .. | .. | 13X |
| 2     | <i>Saccammina</i> sp. hypotype   | .. | .. | .. | .. | 16X |
| 3     | <i>Reophax</i> sp. hypotype  | .. | .. | .. | .. | 13X |
| 4     | <i>Bigenerina nodosaria</i> d'Orbigny hypotype   | .. | .. | .. | .. | 13X |
| 5     | <i>Bigenerina textularioidra</i> (Goes) hypotype   | .. | .. | .. | .. | 13X |
| 6- 8  | <i>Textularia agglutinans</i> d'Orbigny hypotype 5-/ lateral view (test made of shell fragments) ; 7-apertural view ; 8-lateral view, (test made of oolites) | .. | .. | .. | .. | 13X |
| 9-10  | <i>Textularia panamensis</i> Cushman, hypotype 9-apertural view ; 10-lateral view  | .. | .. | .. | .. | 16X |
| 11-13 | <i>Textularia alazanensis</i> Nuttal, hypotype 11-apertural view ; 12-lateral view, 13-side view of another specimen (broken)                                | .. | .. | .. | .. | 16X |
| 14-15 | <i>Textularia conica</i> d'Orbigny, hypotype 14-apertural view ; 15-lateral view   | .. | .. | .. | .. | 16X |
| 16-17 | <i>Textularia torquata</i> Parker, hypotype 16-side view showing the aperture ; 17-lateral view  | .. | .. | .. | .. | 13X |
| 18-19 | <i>Textularia thanetana</i> Lalicker, hypotype 18-apertural view ; 19-lateral view   | .. | .. | .. | .. | 13X |

#### EXPLANATION OF PLATE 2

- |       |   |    |     |
|-------|---|----|-----|
| 1- 2  | <i>Textularia candeiana</i> d'Orbigny hypotype, 1-lateral view; 2-apertural view  | .. | 17X |
| 3- 4  | <i>Gaudryna arenaria</i> Galloway and Wissler, hypotype, 3-lateral view; 4-apertural view of a specimen showing quadrangular later stage. | .. | 17X |
| 5- 6  | <i>Gaudryna renaria</i> Galloway and Wissler, hypotype, 5-lateral view; 6-apertural view of another specimen.                             | .. | 17X |
| 7- 8  | <i>Tritaxia tricarinata</i> (Reuss), hypotype 7-lateral view; 8-apertural view.   | .. | 17X |
| 9-10  | <i>Quinqueloculina agglutinata</i> Cushman, hypotype 9-apertural view; 10-side view   | .. | 17X |
| 11-12 | <i>Sigmioilopsis moyi</i> Atkinson, hypotype 11-apertural view; 12-lateral view.  | .. | 17X |
| 13-14 | <i>Sigmioilopsis woodi</i> Atkinson, hypotype 13-lateral view; 14-apertural view.   | .. | 17X |

15-16 *Siphonaperta macbeathi* Vella, hypotype 15-lateral view; 16-apertural view, ... 17X

#### EXPLANATION OF TABLE—I

Table 1: Percentage distribution of agglutinated foraminifera in the benthonic population along with station locations.

#### EXPLANATION OF TABLE—II

Table 2: Distribution chart of the agglutinated foraminifera in terms of depth and Stations.

#### EXPLANATION OF FIGURE—I

Fig. 1: Location map of the sampled areas on the coast of India.

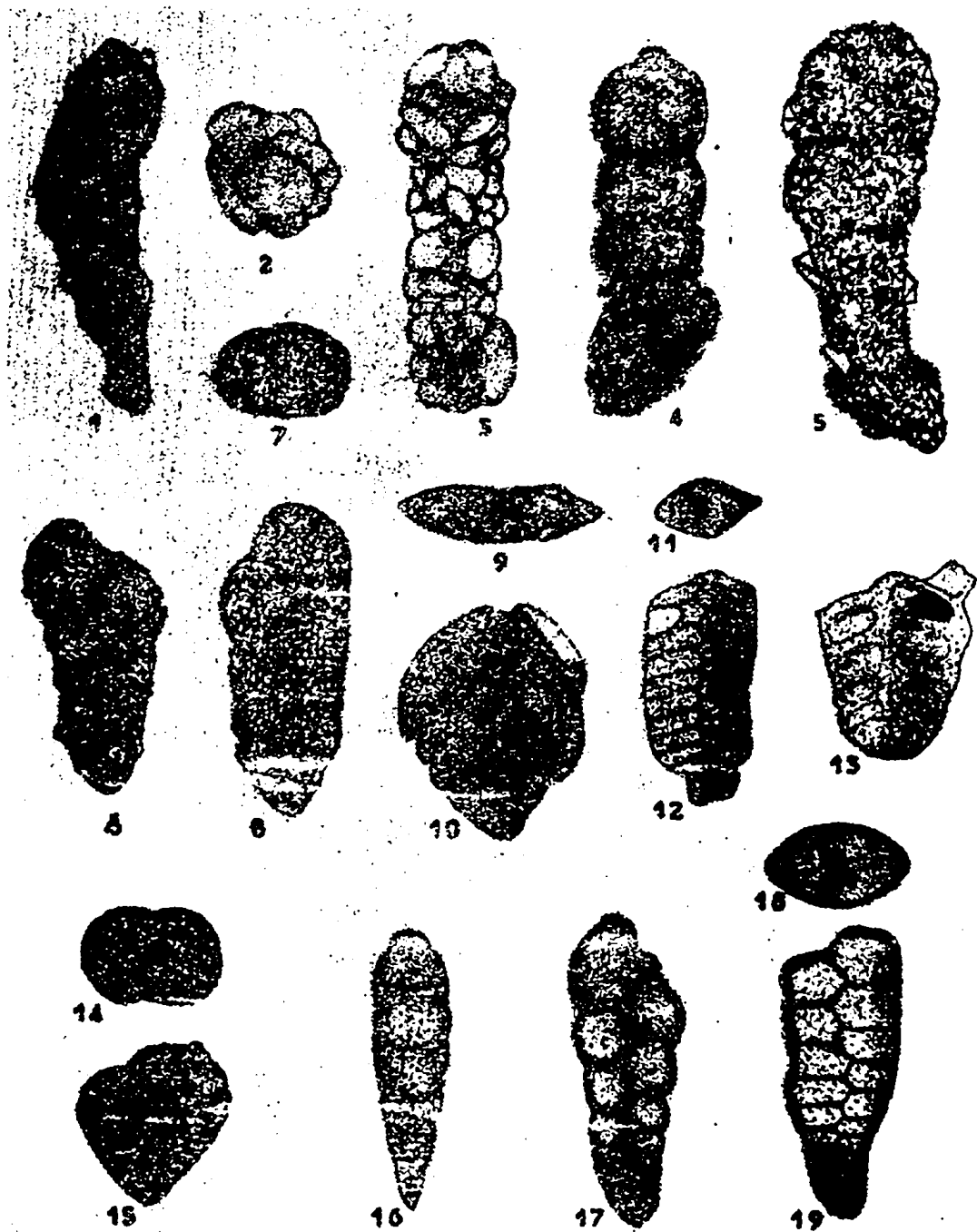
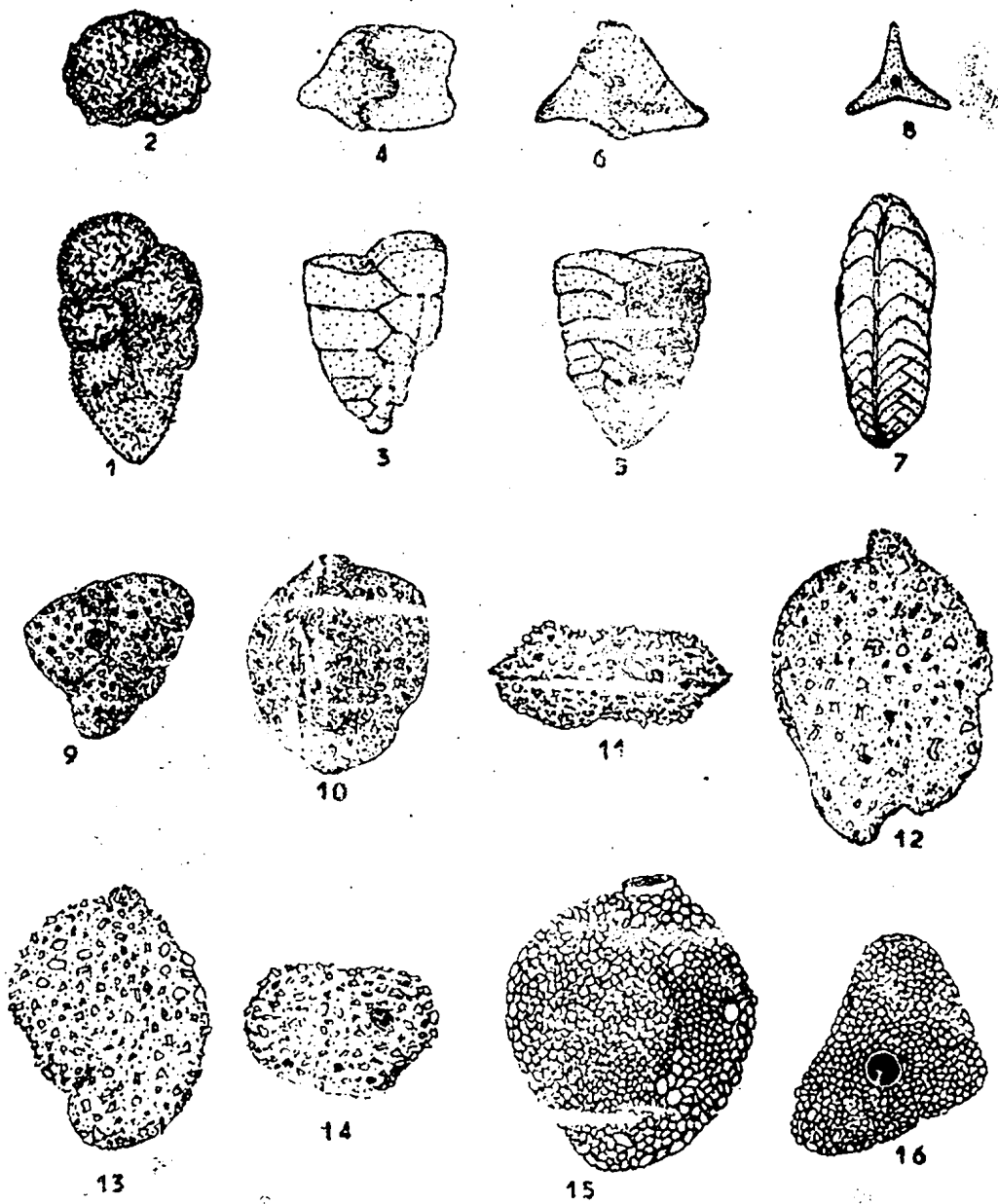


PLATE I

Setty and Almeida



Station no.	Depth ( m )	Location		Total Number Agglutinates	P E R C E N T		
		Lat. N	Long. E		Aggluti- nates	Bentho- nics	Agglutinates in Benthonics
444	35	17°24'0	83°02'0	25	0.25	83.38	0.29
445	55	17°24'0	83°07'5	642	643	85.65	7.50
450	222	17°03'0	83°12'0	25	0.25	59.80	0.29
453	203	17°02'0	83°00'0	9	0.04	57.27	0.06
457	74	17°14'0	83°06'0	559	5.60	71.19	7.86
459	35	17°13'0	82°40'5	40	0.41	84.86	0.48
461	129	16°58'5	82°45'0	223	2.23	83.62	2.66
463	74	16°54'5	82°34'0	—	—	74.08	—
467	203	16°25'0	82°16'5	—	—	87.70	—
472	37	16°15'0	81°57'0	—	—	83.23	—
476	44	16°04'0	81°21'0	—	—	89.52	—
477	152	16°00'0	81°27'5	3	0.02	85.23	0.02

TABLE - 1

Setty and Almeida

Species	Depth m	sta. nos.	35	55	222	203	74	35	129	152
			444	445	450	453	457	459	461	477
<i>Jaculella acuta</i>									R	
<i>Saccamina</i> sp.									R	
<i>Reophax</i> sp.									R	
<i>Bigennerina nodosaria</i> d'Orbigny				R				R		
<i>Bigennerina textularioides</i> (Goebl)				R						
<i>Textularia agglutinans</i> d'Orbigny				R			R			
<i>Textularia alazanensis</i> Nuttall					R					
<i>Textularia candeiaria</i> d'Orbigny			R	A	R	.	C		R	.
<i>Textularia conica</i> d'Orbigny			R	A		R	F	R	R	R
<i>Textularia panamensis</i> Cushman					R	R				
<i>Textularia lhanetana</i> Lakeker							R		R	
<i>Textularia torquata</i> Parker									R	
<i>Textularia</i> sp.							R		R	
<i>Gaudryna arenaria</i> Galloway & Wissler				R	R		R		R	
<i>Tritaxia tricarinata</i> (Reuss)					R	R			R	
<i>Quinqueloculina agglutinata</i> Cushman				R			A		R	
<i>Sigmoilopsis moyi</i> Atkinson							F			
<i>Sigmoilopsis woodi</i> Atkinson				R			F			
<i>Sigmoilopsis</i> sp.				R						
<i>Siphonaperta macbeathi</i> Vella					R				R	

TABLE - 2

Setty and Almeida

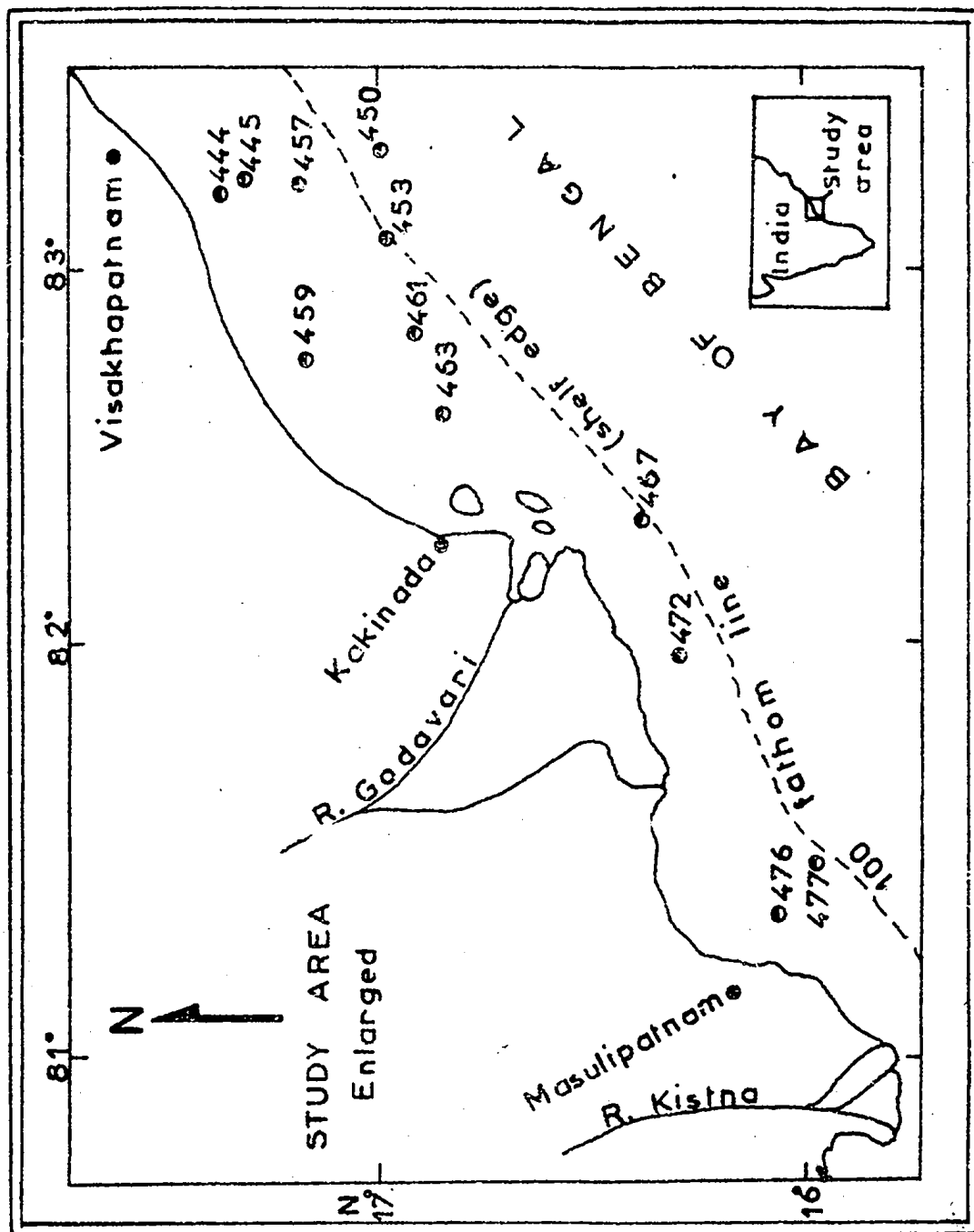


FIG. 1