

Distribution of Foraminifera in the Lagoons of Certain Islands of the Lakshadweep Archipelago, Arabian Sea

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A total of 107 foraminiferal species belonging to 29 families and 48 genera have been identified from the lagoonal sediments of Agatti, Kavaratti, Suhelipar, and Minicoy atolls of Lakshadweep. The fauna is dominated by calcareous Foraminifera, but arenaceous forms are very rare due to coarse nature of the deposits. Of the families observed, Miliolidae, Calcarinidae, and Amphisteginidae are most abundant and 2 species, *Calcarina calcar* and *Amphistegina radiata* are the most dominant. Planktonic Foraminifera are very rare and those few present in the lagoons have been transported by water currents through passages of the reef. In general, Foraminifera of the coral reefs in the coastal waters of Indian peninsula are similar in their species composition. Larger foraminiferids and typical coral-reef species of the fauna from Lakshadweep have been reported. The role of Foraminifera as reef-builders and their distribution as related to ecology are evaluated. The data suggest that there is a similarity of the reef faunas from tropical Indo-Pacific and Atlantic Oceans.

Marine studies¹⁻⁴ in atolls of Lakshadweep are not adequate especially with regard to Foraminifera, though Chapman⁵ first reported 277 species from the deep-sea sediment samples of the Arabian Sea near Laccadives, Guptha⁶ recorded 20 species from Kavaratti atoll and subsequent faunal studies of the Deep Sea Drilling Project on *USS Glomar Challenger* in the Laccadive Sea include those of Mamgain *et al.*⁷ and Fleisher⁸. Therefore, an attempt has been made to study quantitative distribution of Foraminifera as related to ecology and to evaluate their role as reef-builders. This work forms a sequel to the exhaustive faunistic series presented¹ during 1903-1906.

Study Area

Lakshadweep has 10 inhabited and 17 uninhabited coral islands located in the southeastern Arabian Sea between 8° and 12°N and 71°40' and 74°E. Topographical features of islands selected for investigation (Fig.1) are as follows:

Agatti— This island (inhabited) lies on the most western side of the Lakshadweep (10°51'N, 72°11'E) and is about 5.3 km in length and 1 km wide in the widest northern portion; it tapers towards south to a width of about 100 m. Its lagoon is very wide and somewhat deep in many places with depth exceeding 12 m.

Kavaratti— The inhabited island (10°35'N, 72°36'E) is about 5.8 km in length and its greatest

breadth is about 1.5 km, having an area of 3460 km². Its lagoon is 4.3 km long and 0.8 km wide. The mean water depth is about 2 m.

Suhelipar— This (uninhabited) atoll includes 2 very small islands—Cheriyakara and Valiyakara lying inside a big lagoon surrounded by an extensive reef (10°04'N, 72°15'E). In fact, they are sand banks formed in the middle of the lagoon. As in Agatti, the lagoon is comparatively deep. These islands serve as breeding grounds for turtles.

Minicoy— This inhabited island (8°07'N, 73°18'E), the most important tuna fishing centre in the Indian Ocean, is oval in shape with pointed end towards the northeast. It extends 10 km in length and 820 m in width at the centre and has an area of 4550 km². The lagoon occupies 15.5 km² and the maximum depth in the lagoon reaches up to 15 m.

Materials and Methods

Twenty-four sediment samples were collected with a Van-Veen grab from 4 lagoons of Lakshadweep (Fig.1) during different dates - 8 Dec. 1976 (Agatti, sts 1-9), 5 Dec. 1976 (Kavaratti, sts 10-12), 29 Nov. 1976 (Suhelipar, sts 13-21) and 20 Apr. 1983 (Minicoy, sts 22-24). The samples were washed over a 200 - mesh sieve (63 µm mesh aperture) and calculation of percentage occurrence of foraminiferal species in total fauna was based on 300 specimens.

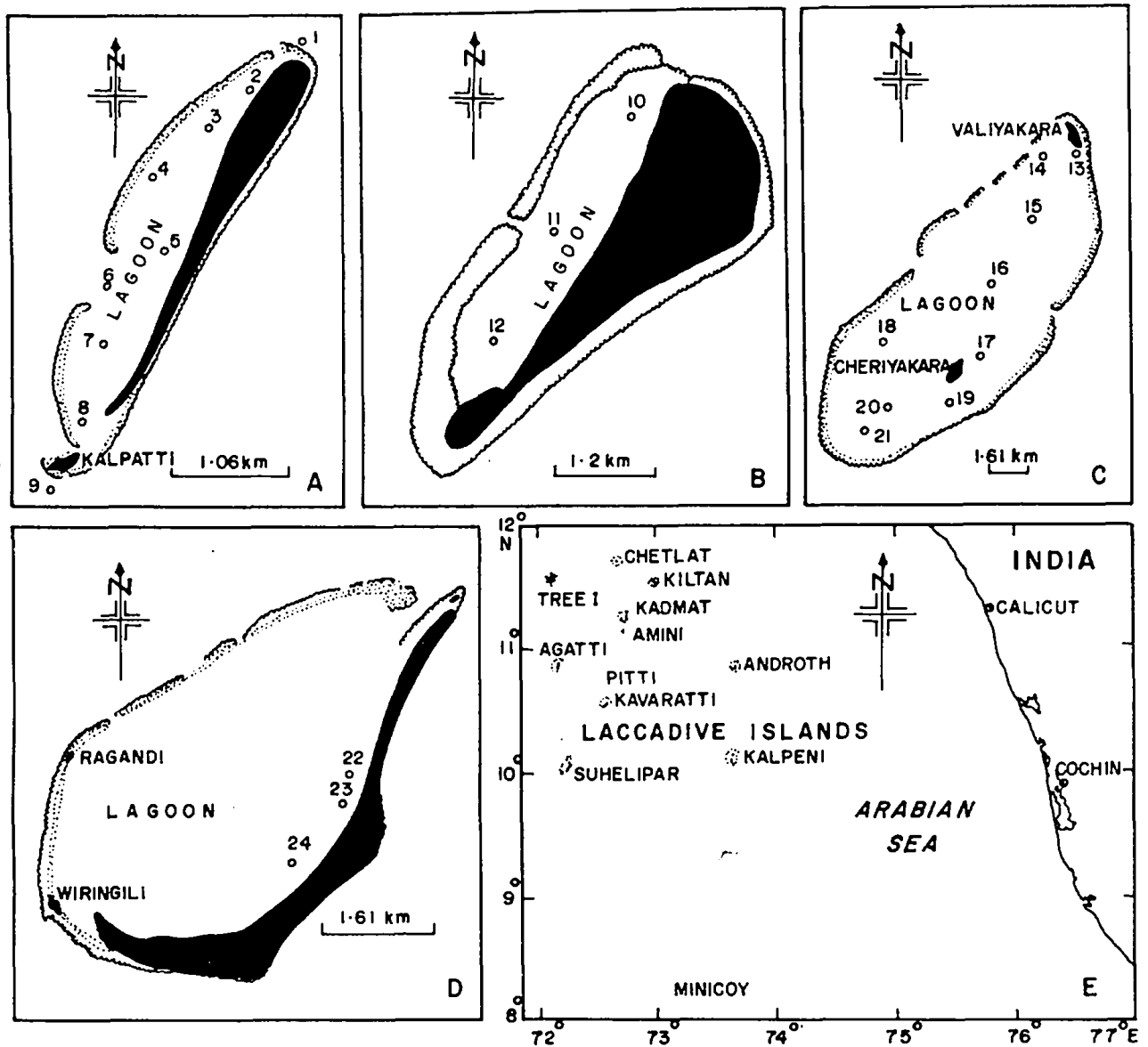


Fig. 1— Maps of Agatti (A), Kavaratti (B), Suhelipar (C), and Minicoy (D) atolls showing sampling sites and Lakshadweep Archipelago (E) in the Arabian Sea

Species diversity index is determined using the formula:

$$H(S) = C \left\{ \log_{10} N - \frac{1}{N} \sum_{r=1}^s nr \log_{10} nr \right\}$$

where nr is numbers found in the r th species, N the total number of individuals, s the number of species, and $c = 3.321928$.

Equitability (ϵ) is the ratio of \hat{s} to s :

$$\epsilon = \frac{\hat{s}}{s}$$

where \hat{s} is obtained from Table 1 given by Lloyd and Ghelardi⁹ and it is solution of equation $H(S) = M(\hat{S})$. Here, $H(S)$ is Shannon - Wiener func-

tion; $M(\hat{S})$ is observed species diversity and \hat{s} is the equivalent number of equitably distributed species.

Results and Discussion

Abundance— Depth has no relation to the abundance [no. of specimens (100 g)⁻¹ of the dry sediment] of Foraminifera as shown in Fig.2. Maximum and minimum values of abundance observed are 97000 (st 5) and 2400 (st 24) respectively. Mean abundance of total Foraminifera for different lagoons is 3556 (Agatti); 65667 (Kavaratti); 25778 (Suhelipar); and 2667 (Minicoy). Furthermore, it is somewhat uniform for different stations in the lagoons of Agatti, Kavaratti, and

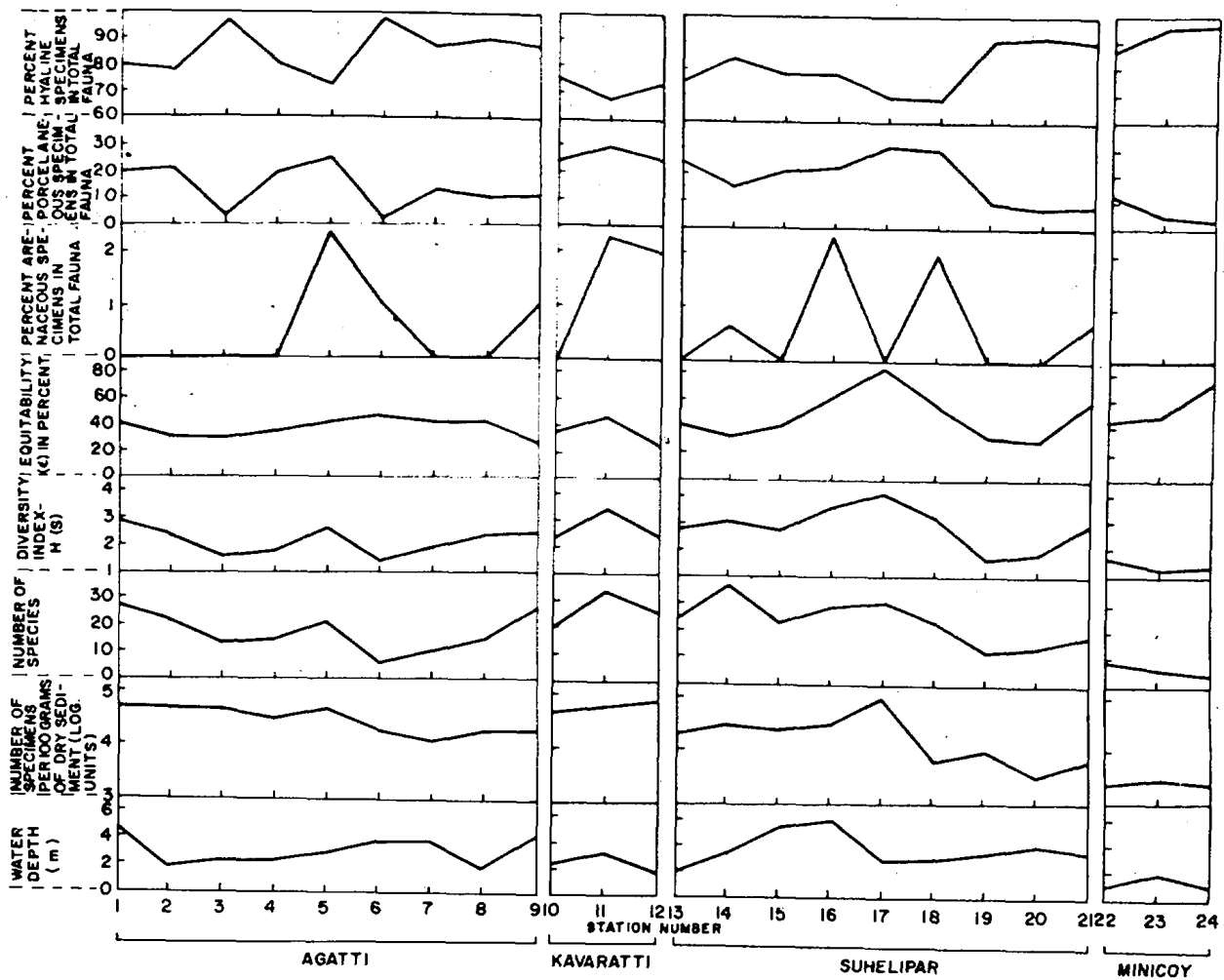


Fig. 2— Distributional trends of foraminiferal fauna

Minicoy, but shows a greater variation between locations from st 16 onwards in Suhelipar, though it is almost the same from sts 13 to 16 in the same lagoon (Fig.2).

Number of species, diversity index, and equitability— Distribution of number of species in the lagoons studied has no correlation with the abundance of Foraminifera (Fig.2); it varies from 4 (st 24) to 37 (st 14). Highest number of species is observed at st 14. Mean number of species for different lagoons is 17 in Agatti, 27 in Kavaratti, 24 in Suhelipar and 6 in Minicoy. The number of species at all the locations is dominated by calcareous fauna.

Ranges of species diversity index for the lagoons are 1.4-2.9 (Agatti), 2.4-3.4 (Kavaratti), 1.6-4.1 (Suhelipar) and 1.3-1.7 (Minicoy). It is obvious from Fig.2 that species diversity index $H(S)$ is directly proportional to the number of species.

Species equitability (ϵ) in percent increases with diversity index for locations in the lagoons of Kavaratti and Suhelipar, whereas in the case of Min-

icoy, diversity index decreases as species equitability increases (Fig.2). In Agatti, both equitability index and diversity index behave independently. This correlation study indicates characteristics of the fauna in different lagoons, besides reflecting prevailing local environmental conditions. Average ϵ values are higher in Minicoy (56) and Suhelipar (49) showing more evenness in the distribution of species than at Kavaratti (36) and Agatti (39).

Distribution of species and families of Foraminifera — A total of 107 species belonging to 29 families have been recorded (Plates I to VIII) from the sediments of lagoons and among them, *Calcarina calcar* and *Amphistegina radiata* are the most abundant species, while others having a good coverage in distribution are *Textularia agglutinans*, *Cyclogyra involvens*, *Spiroloculina antillarum*, *S. antillarum* var. *angulata*, *Massilina annectens*, *Quinqueloculina bradyana*, *Q. crassa* d'Orbigny var. *subcuneata*, *Q. reticulata*, *Q. sem-*

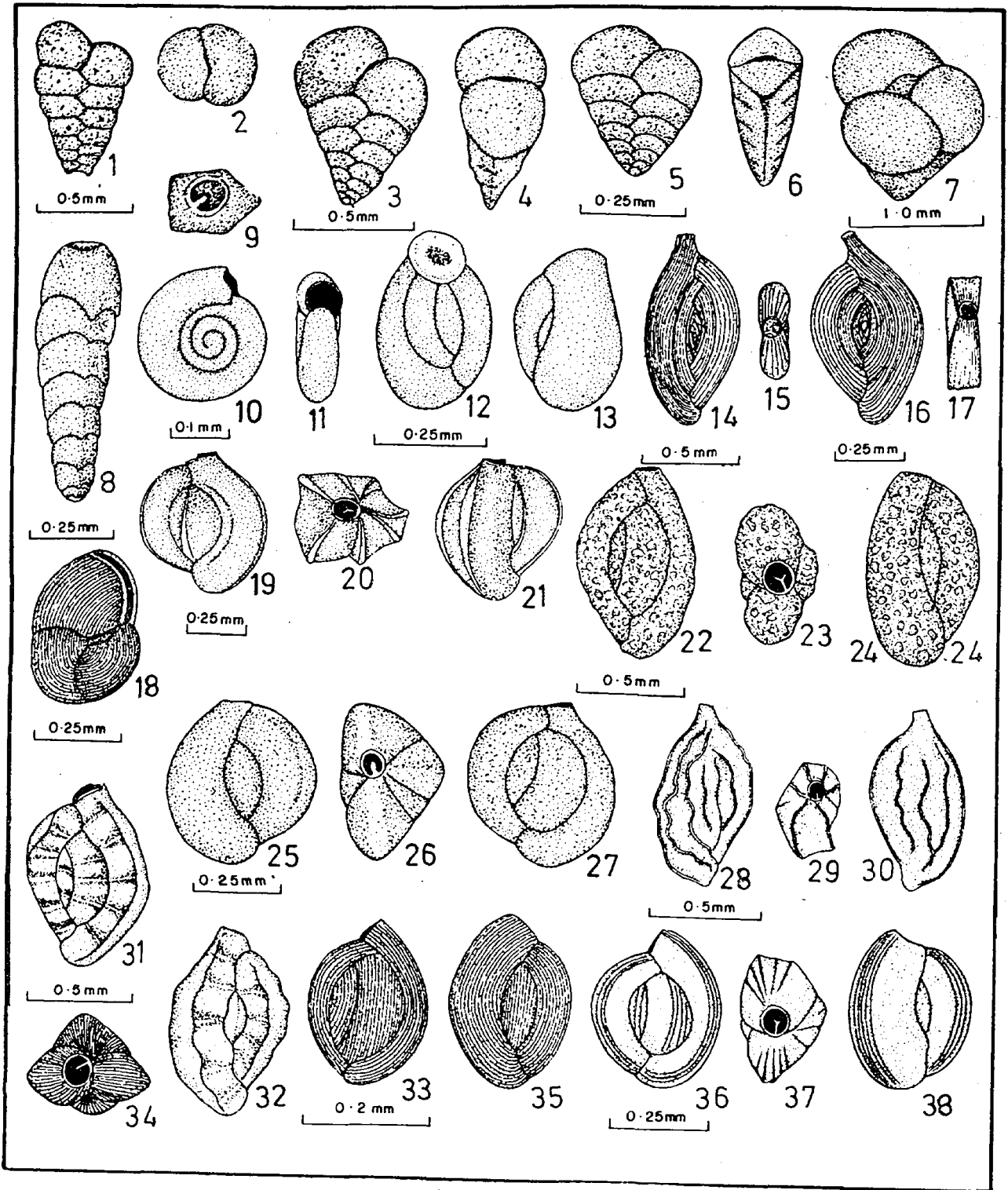


Plate 1— Foraminiferal species [*Textularia agglutinans* d'Orbigny: 1, side view; 2, apertural view. *T. candeiana* d'Orbigny: 3, side view; 4, peripheral view. *T. cuneiformis* d'Orbigny: 5, side view; 6, peripheral view. *Valvulina oviedoiana* d'Orbigny: 7, front view. *Clavulina difformis* Brady: 8, front view; 9, apertural view. *Cyclogyra involvens* (Reuss): 10, side view; 11, peripheral view. *Wiesnerella auriculata* (Egger): 12, 13, opposite sides. *Spiroloculina antillarum* d'Orbigny: 14, side view; 15, apertural view. *S. antillarum* d'Orbigny var. *angulata* Cushman: 16, side view; 17, apertural view. *Vertebralina striata* d'Orbigny: 18, side view. *Massilina annectens* Schlumberger: 19, 21, opposite sides; 20, apertural view. *Quinqueloculina agglutinans* d'Orbigny: 22, 24, opposite sides; 23, apertural view. *Q. agglutinata* Cushman: 25, 27, opposite sides; 26, apertural view. *Q. berthelotiana* d'Orbigny: 28, 30, opposite sides; 29, apertural view. *Q. bradyana* Cushman: 31, 32, opposite sides. *Q. crassa* d'Orbigny var. *subcuneata* Cushman: 33, 35, opposite sides; 34, apertural view. *Q. curta* Cushman: 36, 38, opposite sides; 37, apertural view.]

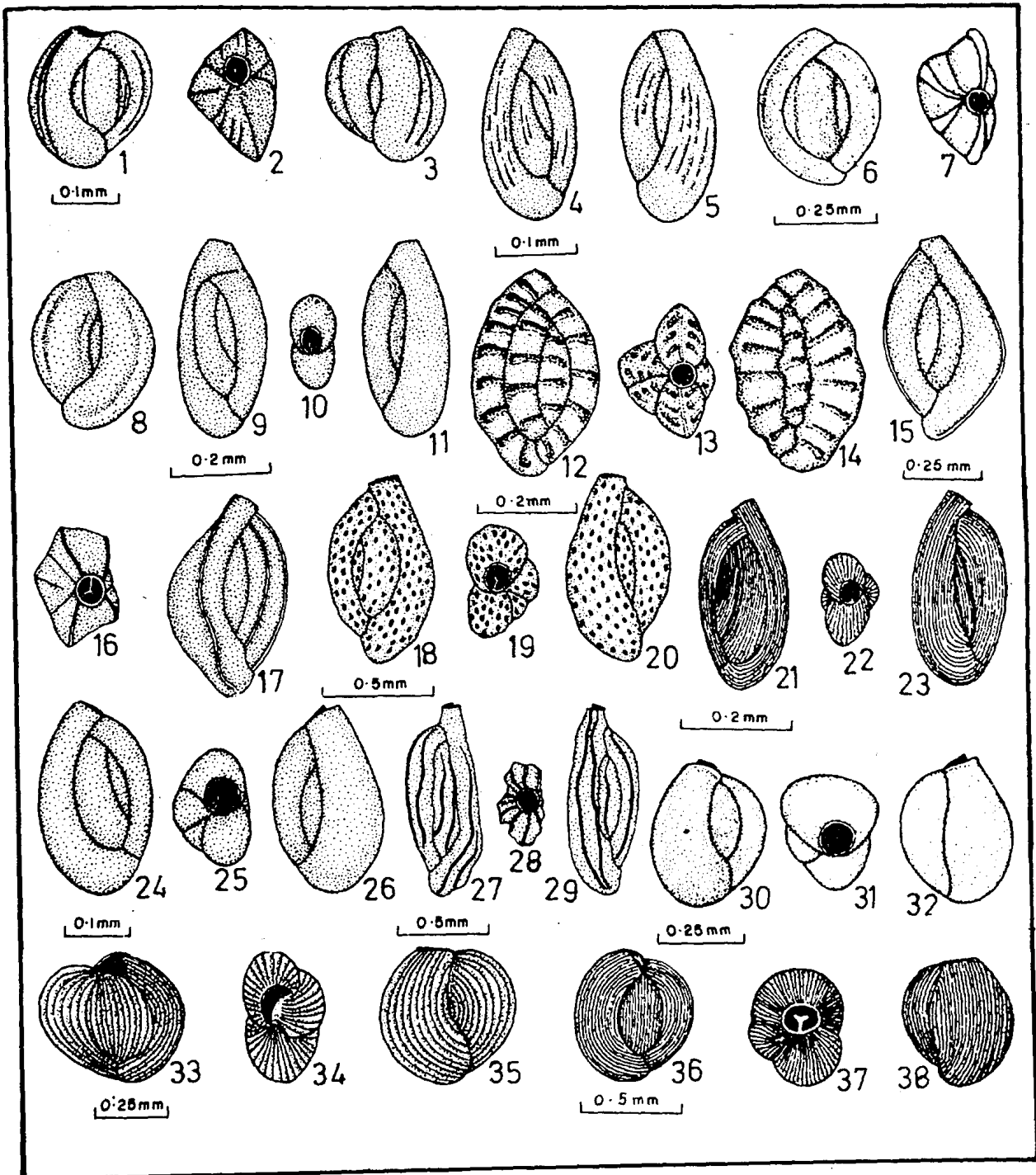


Plate II— Foraminiferal species [*Quinqueloculina cuvieriana* d'Orbigny: 1, 3, opposite sides; 2, apertural view. *Q. laevigata* d'Orbigny: 4, 5, opposite sides. *Q. lamarckiana* d'Orbigny: 6, 8, opposite sides; 7, apertural view. *Q. oblonga* (Montagu): 9, 11, opposite sides; 10, apertural view. *Q. parkeri* (Brady): 12, 14, opposite sides; 13, apertural view. *Q. polygona* d'Orbigny: 15, 17, opposite sides; 16, apertural view. *Q. reticulata* (d'Orbigny): 18, 20, opposite sides; 19, apertural view. *Q. rhodiensis* Parker: 21, 23, opposite sides; 22, apertural view. *Q. seminulum* (Linné): 24, 26, opposite sides; 25, apertural view. *Q. sulcata* d'Orbigny: 27, 29, opposite sides; 28, apertural view. *Triloculina austriaca* d'Orbigny: 30, 32, opposite sides; 31, apertural view. *T. fichteliana* d'Orbigny: 33, 35, opposite sides; 34, apertural view. *T. insignis* (Brady): 36, 38, opposite sides; 37, apertural view.]

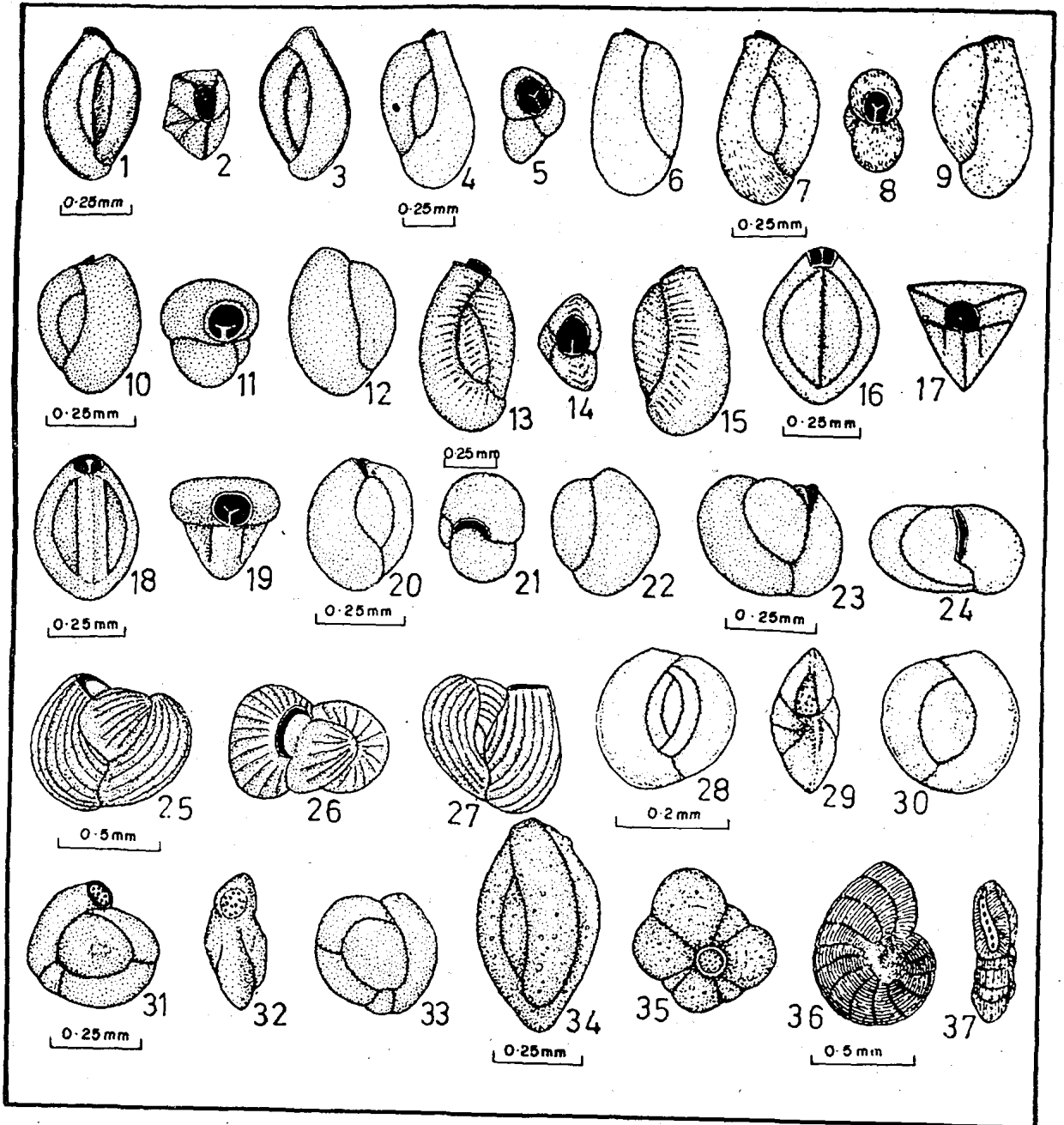


Plate III— Foraminiferal species [*Triloculina irregularis* (d'Orbigny): 1, 3, opposite sides; 2, apertural view. *T. oblonga* (Montagu): 4, 6, opposite sides; 5, apertural view. *T. planciana* d'Orbigny: 7, 9, opposite sides; 8, apertural view. *T. rotunda* d'Orbigny: 10, 12, opposite sides; 11, apertural view. *T. transversestriata* (Brady): 13, 15, opposite sides; 14, apertural view. *T. tricarinata* d'Orbigny: 16, front view; 17, apertural view. *T. trigonula* (Lamarck): 18, front view; 19, apertural view. *Miliolinella circularis* (Bornemann): 20, 22, opposite sides; 21, apertural view. *M. labiosa* (d'Orbigny): 23, side view; 24, apertural view. *M. labiosa* d'Orbigny *sparsicostata* Cushman: 25, 27, opposite sides; 26, apertural view. *Hauerina miocenica* Cushman: 28, 30, opposite sides; 29, apertural view. *H. pacifica* Cushman: 31, 33, opposite sides; 32, apertural view. *Schlumbergerina alveoliniformis* (Brady): 34, side view; 35, apertural view. *Peneroplis pertusus* (Forskål): 36, side view; 37, apertural view.]

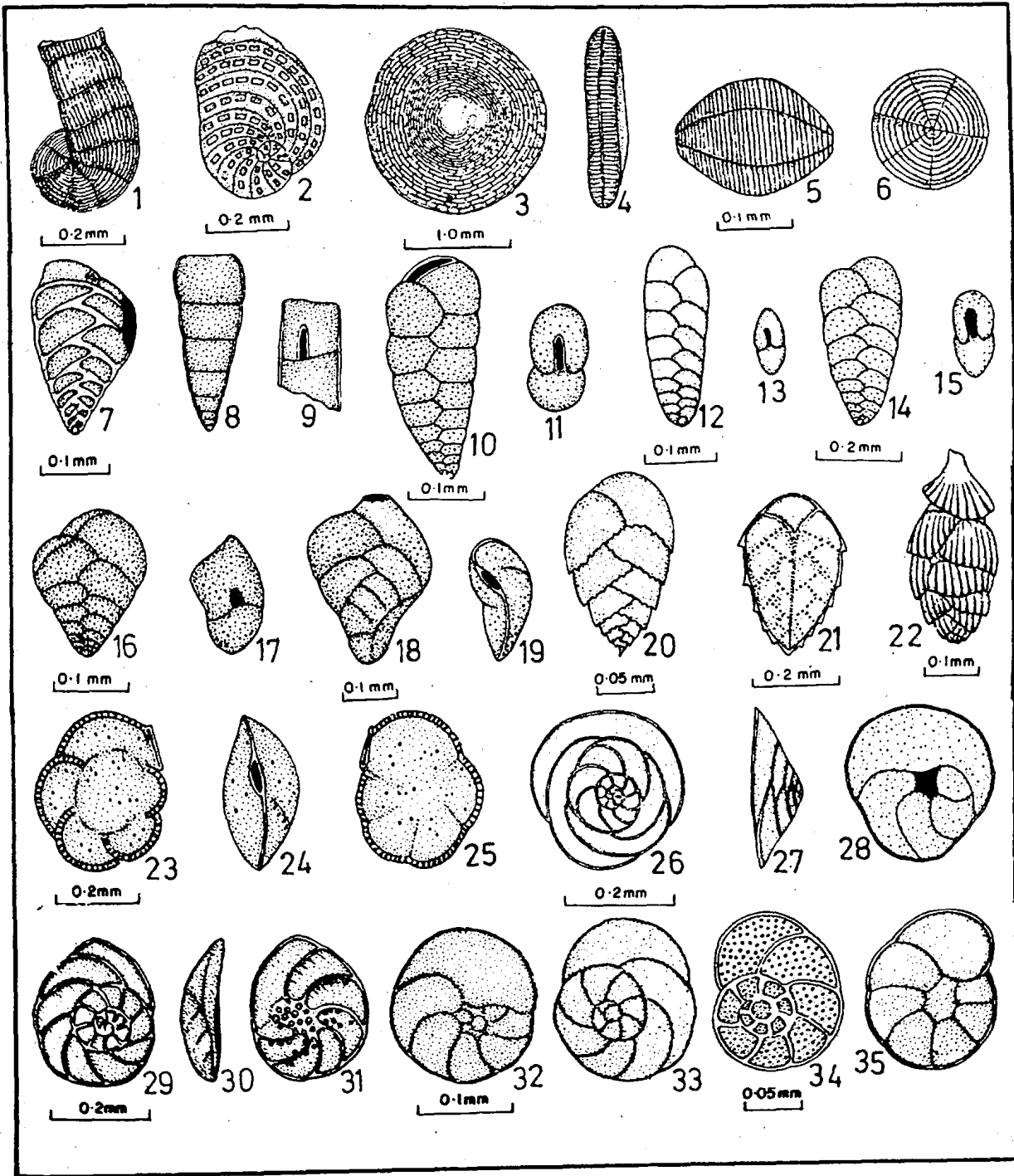


Plate IV— Foraminiferal species [*Spirolina arietina* (Batsch): 1, side view. *Sorites marginalis* (Lamarck): 2, side view. *Amphisorus hemprichii* Ehrenberg: 3, side view; 4, peripheral view. *Borelis pulchra* (d'Orbigny): 5, side view; 6, end view. *Bolivinita quadrilatera* (Schwager): 7, side view; 8, peripheral view; 9, apertural view. *Bolivina abbreviata* Heron-Allen and Earland: 10, side view; 11, apertural view. *B. cf. paula* Cushman and Cahill: 12, side view; 13, apertural view. *B. compacta* Brady: 14, side view; 15, apertural view. *B. rhomboidalis* (Millett): 16, side view; 17, apertural view. *B. tortuosa* Brady: 18, side view; 19, apertural view. *Bulimina marginata* d'Orbigny: 20, side view. *Reussella spinulosa* (Reuss): 21, front view. *Uvigerina porrecta* Brady: 22, front view. *Siphonina reticulata* (Czjzek): 23, 25, opposite sides; 24, peripheral view. *Neoconorbina crustata* (Cushman): 26, dorsal view; 27, peripheral view; 28, ventral view. *Discorbis parisiensis* (d'Orbigny): 29, dorsal view; 30, peripheral view; 31, ventral view. *Rosalina bertheloti* (d'Orbigny): 32, ventral view; 33, dorsal view. *R. bradyi* (Cushman): 34, dorsal view; 35, ventral view.]

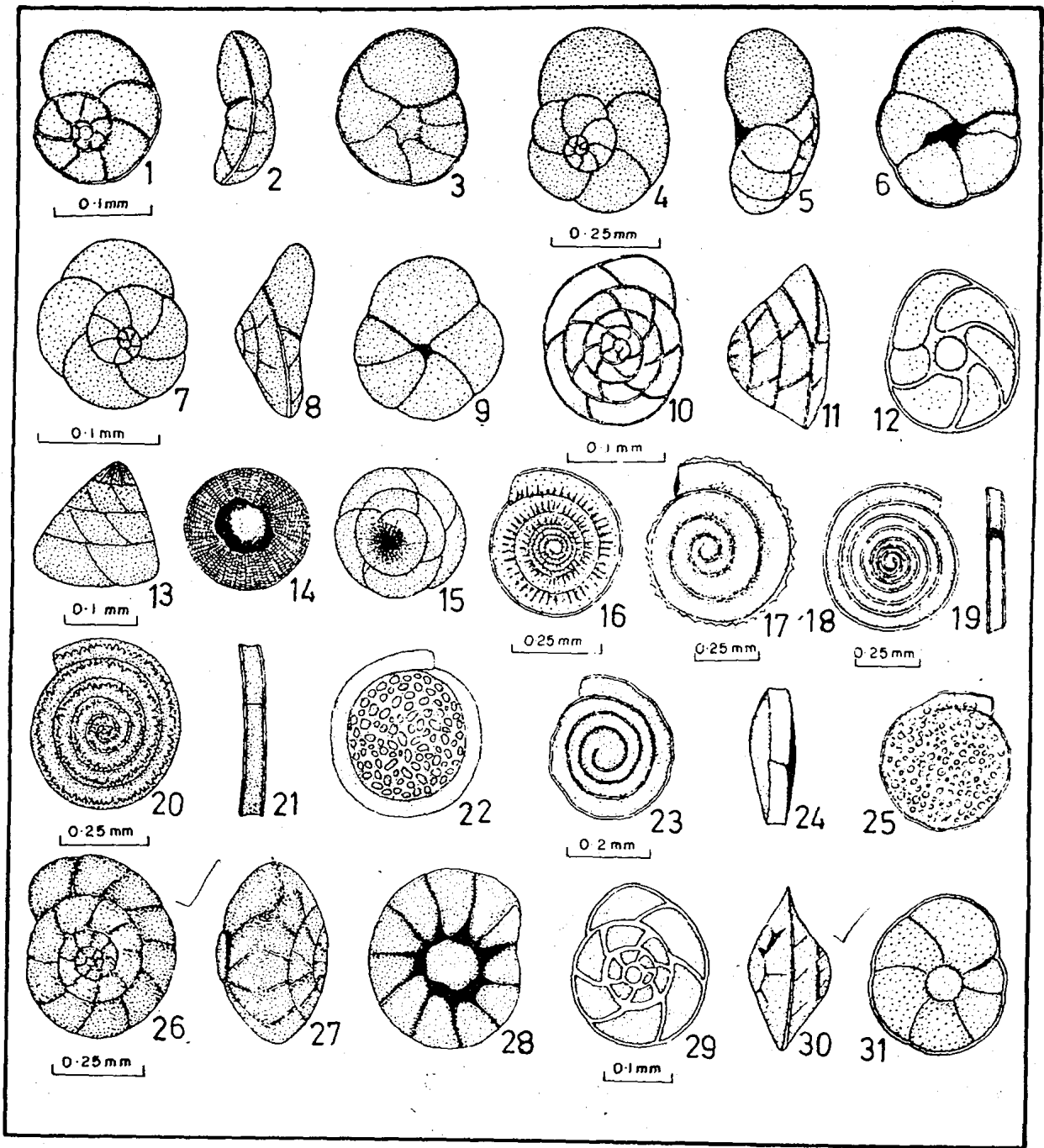


Plate V— Foraminiferal species [*Rosalina floridana* (Cushman): 1, dorsal view; 2, peripheral view; 3, ventral view. *R. globularis* d'Orbigny: 4, dorsal view; 5, peripheral view; 6, ventral view. *R. vilardeboana* d'Orbigny: 7, dorsal view; 8, peripheral view; 9, ventral view. *Gavelinopsis praegeri* (Heron-Allen and Earland): 10, dorsal view; 11, peripheral view; 12, ventral view. *Glabratella tabernacularis* (Brady): 13, side view; 14, ventral view; 15, dorsal view. *Spirillina decorata* Brady: 16, side view. *S. lateseptata* Terquem: 17, side view. *S. limbata* Brady: 18, side view; 19, peripheral view. *S. limbata* Brady var. *papillosa* Cushman: 20, 22, opposite sides; 21, peripheral view. *S. limbata* Brady var. *denticulata* Brady: 20, 22, opposite sides; 24, peripheral view. *Ammonia beccarii* (Linné) variant: 26, dorsal view; 27, peripheral view; 28, ventral view. "*Rotalia*" *translucens* Phleger and Parker: 29, dorsal view; 30, peripheral view; 31, ventral view.]

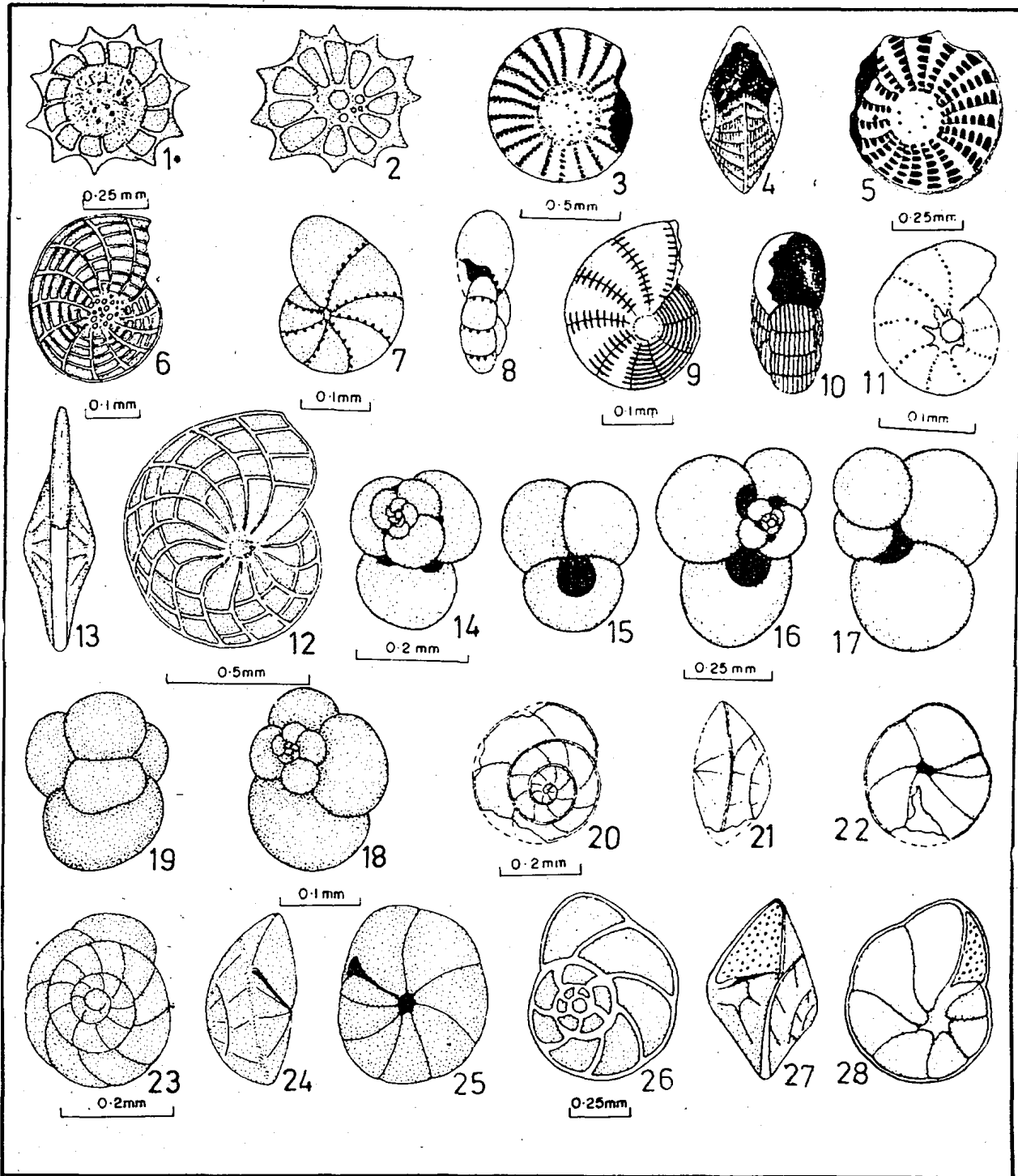


Plate VI - Foraminiferal species [*Calcarina calcar* d'Orbigny: 1, dorsal view; 2, ventral view. *Elphidium craticulatum* (Fichtel and Moll): 3, side view; 4, peripheral view. *E. crispum* (Linné): 5, side view. *E. jenseni* (Cushman): 6, side view. *E. poeyanum* (d'Orbigny): 7, side view; 8, peripheral view. *E. cf. reticulosum* Cushman: 9, side view; 10, peripheral view. *E. simplex* Cushman: 11, side view. *Heterostegina depressa* d'Orbigny: 12, side view; 13, peripheral view. *Globigerinoides ruber* (d'Orbigny): 14, dorsal view; 15, ventral view. *G. sacculifer* (Brady): 16, dorsal view; 17, ventral view. *Globigerinita glutinata* (Egger): 18, dorsal view; 19, ventral view. *Eponides antillarum* (d'Orbigny): 20, dorsal view; 21, peripheral view; 22, ventral view. *E. broeckhianus* (Karrer): 23, dorsal view; 24, peripheral view; 25, ventral view. *E. repandus* (Fichtel and Moll): 26, dorsal view; 27, peripheral view; 28, ventral view.]

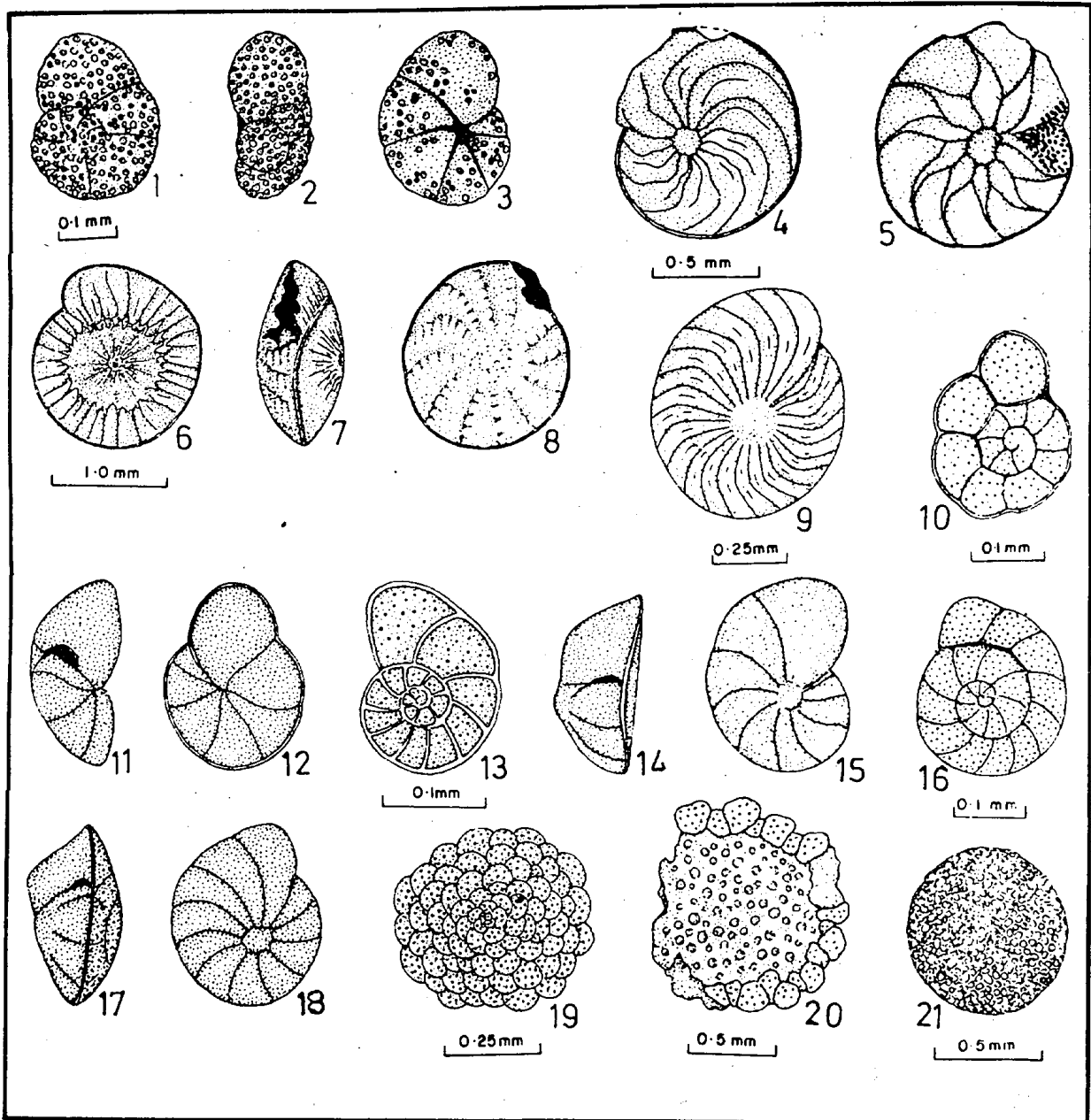


Plate VII - Foraminiferal species [*Eponides* (?) *tuberculata* (Balkwill and Wright): 1, dorsal view; 2, peripheral view; 3, ventral view. *Amhistegina lessonii* d'Orbigny: 4, 5, opposite sides. *A. madagascariensis* d'Orbigny: 6, 8, opposite sides; 7, peripheral view. *A. radiata* (Fichtel and Moll): 9, side view. *Cibicides lobatulus* (Walker and Jacob): 10, dorsal view; 11, peripheral view; 12, ventral view. *C. refulgens* Montfort: 13, dorsal view; 14, peripheral view; 15, ventral view. *C. pseudoungerianus* (Cushman): 16, dorsal view; 17, peripheral view; 18, ventral view. *Planorbulina mediterraneanensis* d'Orbigny: 19, dorsal view. *Planorbulinella larvata* (Parker and Jones): 20, dorsal view. *Sphaerogypsina globulus* (Reuss): 21, side view.]

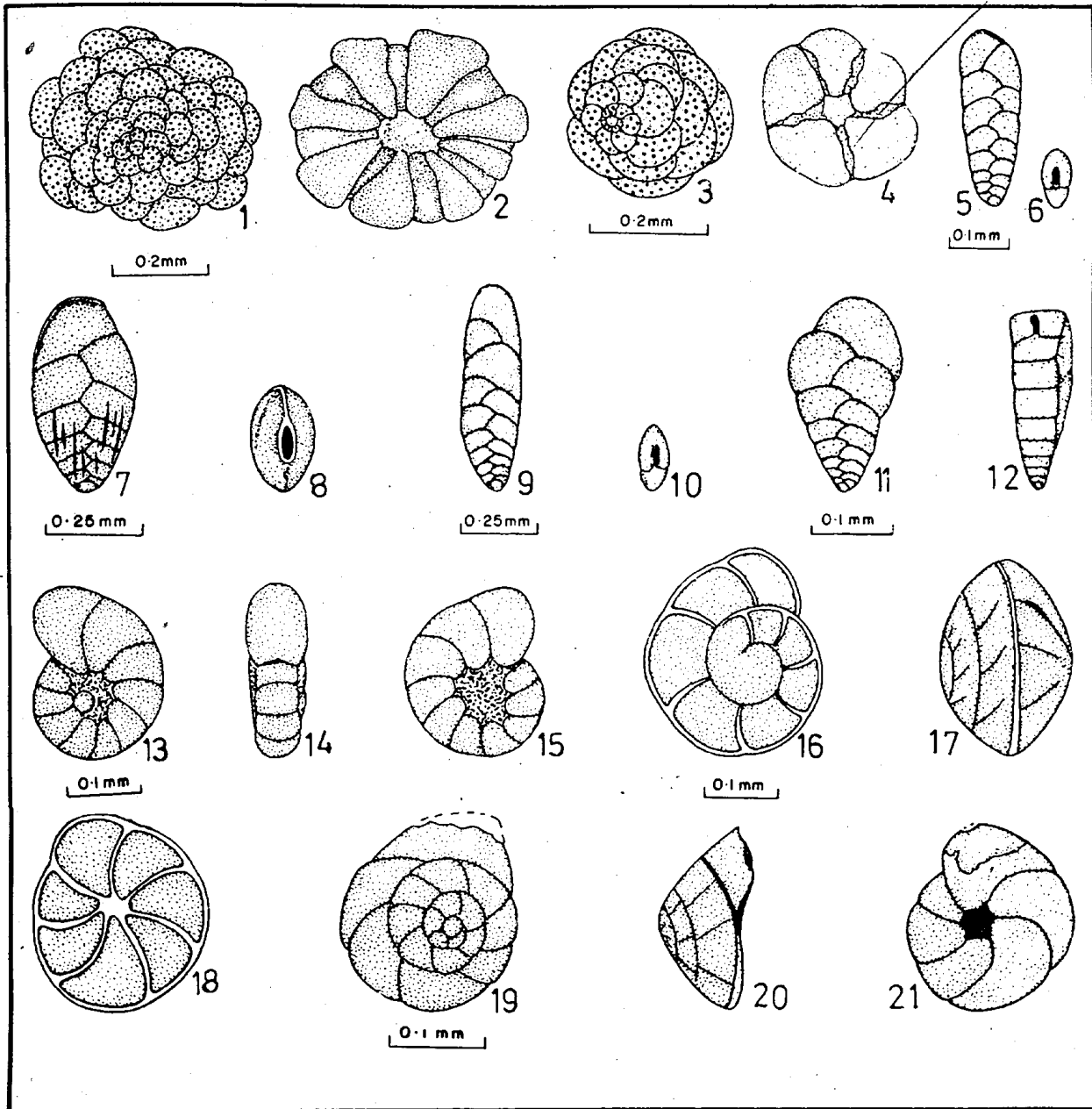


Plate VIII— Foraminiferal species [*Cymbaloporeta bradyi* (Cushman): 1, dorsal view; 2, ventral view. *C. squamosa* (d'Orbigny): 3, dorsal view; 4, ventral view. *Loxostomum limbatum* (Brady): 5, side view; 6, apertural view. *L. limbatum* var. *costulatum* (Cushman): 7, side view; 8, apertural view. *L. rostrum* Cushman: 9, side view; 10, apertural view. *L. truncatum* Phleger and Parker: 11, side view; 12, peripheral view. *Nonion depressulum* (Walker and Jacob): 13, 15, opposite sides; 14, peripheral view. *Oridorsalis umbonatus* (Reuss): 16, dorsal view; 17, peripheral view; 18, ventral view. *Conorboides advena* (Cushman): 19, dorsal view; 20, peripheral view; 21, ventral view.]

inulum, *Triloculina irregularis*, *T. oblonga*, *T. trigonula*, *Miliolinella circularis*, *Peneroplis pertusus*, *Sorites marginalis*, *Amphisorus hemprichii*, *Rosalina bertheloti*, *R. floridana*, *Glabratella tabernacularis*, *Amphistegina lessonii*, *Cymbaloporetta bradyi* and *C. squamosa* (Table 1).

Comparison of the fauna in both the Arabian Sea near Laccadive area⁵ and the lagoons of the present study shows 21 common species and also, it reveals that the fauna is more diverse in the sea than in the lagoons. From the earlier works¹⁰⁻¹² in the inshore waters of Bay of Bengal, it is found that 30 species are common to both Laccadives and Krusadai island. From comparison of these faunal studies, it can be concluded that the fauna of reef ecosystems of the Indian peninsula is quite similar and most of the species reported from the lagoons are also known from the reef areas of tropical Pacific and Atlantic Oceans¹³⁻²⁰.

Five families of Foraminifera, viz. Soritidae, Spirillinidae, Calcarinidae, Miliolidae, and Amphisteginidae are present at all atolls. Among them, last 3 families are significant as they are most abundant. The highest number of families (27) is present at Suhelipar, followed by Agatti (20), Kavaratti (18) and the least number (8) at Minicoy. Species belonging to Textulariidae, Fischerinidae, Nubeculariidae, Bolivinitidae, Discorbidae, Glabratellidae, Elphidiidae, Eponididae, Planorbulinidae, and Cymbaloporidae are observed at Agatti, Kavaratti, and Suhelipar and Ataxophragmiidae are represented at Kavaratti and Suhelipar, while Foraminifera of the families Buliminidae and Globigerinidae at Agatti and Suhelipar, individuals of the families Rotaliidae and Cibicidiidae at Agatti, Suhelipar, and Minicoy and those of Nummulitidae at Agatti, Kavaratti and Minicoy. The families Alveolinidae, Uvigerinidae, Siphoninidae, Acervulinidae, Loxostomidae, Nonionidae, and Alabaminidae occur at Suhelipar atoll and Ceratobuliminidae at Kavaratti atoll.

It is evident from the above distribution of families of Foraminifera that the fauna of Marshall islands¹³ in the Pacific Ocean differs from that of Laccadives in the greater abundance of Amphisteginidae, Camerinidae, and lesser concentration of Miliolidae, Nonionidae, and Rotaliidae. Out of 30 families reported from Ontoa atoll, Gilbert islands¹⁵, 9 families are known from the area investigated. Species of the Bahama Banks¹⁶ included under 10 families are known from Laccadive lagoons, but this region is characterized by a family—Homotrematidae. Though Calcarinidae is not represented in the Florida Keys¹⁷, this area shows faunal similarity with Laccadives in the domin-

ance of Miliolidae. Davis¹⁸ reported 17 families from the fauna of Alacran reef, Campeche Bank, Mexico, of which only 4 families are not known from Laccadives. Cebulski^{19,20} recorded 69 species from the barrier reef, British Honduras and among them, 19 species occur in the lagoons of the present study. In general, the fauna studied here are similar in the tropical Indo-Pacific and Atlantic Oceans.

Foraminiferal assemblages-- Arenaceous: They are of little significance in the lagoons of Lakshadweep as they form very low percentage range (0.3 to 2.3) of total fauna (Fig.2) and are represented by 5 species belonging to 3 genera and 2 families — Textulariidae and Ataxophragmiidae. Though they are sparsely present in the lagoons owing to coarse nature of the lagoonal sediments, they are entirely lacking in Minicoy. Of the 5 species, *Textularia agglutinans* is somewhat better represented in distribution in Agatti, Kavaratti and also at 1 location in Suhelipar. All other species, viz. *T. candeiana*, *T. cuneiformis*, *Valvulina oviedoiana* and *Clavulina difformis* occur at 1 location only in Suhelipar.

Porcelaneous: Foraminifera with porcelaneous tests belong to 5 families, 15 genera, and 43 species (Table 1). Of 5 families of Foraminifera, Miliolidae is constituted by the greatest number of species (32), followed by Nubeculariidae and Soritidae with 4 species each, while Fischerinidae and Alveolinidae are represented separately by a single species. *Quinqueloculina* and *Triloculina* are the most dominant genera and 4 species, viz. *Wiesnerella auriculata*, *Hauerina miocenica*, *Spirulina arietina* and *Borelis pulchra* are very rare species found in the lagoonal deposits. Porcelaneous tests range in percentage from 2.7 to 30.9 of total fauna and their average percent occurrence in the order of abundance for different lagoons — Kavaratti (26.2), Suhelipar (18.7), Agatti (14.2), and Minicoy (6.7) — shows they are most abundant in Kavaratti and relatively sparse in Minicoy.

Hyaline: As they form bulk of the fauna in the lagoons of Lakshadweep, they contribute largely to the number of species next to porcelaneous foraminiferal assemblage and comprise 59 species belonging to 30 genera and 22 families. Two species, which are most abundant and found at all locations in the lagoons are *Calcarina calcar* and *Amphistegina radiata*. Others with a wide spectral range in distribution include *Rosalina bertheloti*, *R. floridana*, *Glabratella tabernacularis*, *Amphistegina lessonii*, *Cymbaloporetta bradyi* and *C. squamosa*. Of 59 species of hyaline Foraminife-

ra, 29 are found at only 1 location and they are very poor in abundance (Table 1). Mean percent of hyaline tests in total fauna of different lagoons shows that the highest abundance (93.2) is found at Minicoy, followed by Agatti (85.2), Suhelipar (80.3) and the lowest abundance (72) in Kavaratti.

Planktonic: They are represented by 3 species - *Globigerinoides ruber*, *G. sacculifer* and *Globigerinita glutinata* in the lagoon deposits. As they prefer open sea, their presence in the lagoons is due to transport by water currents through openings of the reef.

Reef ecology— As Lakshadweep is situated 200-300 km away from the west coast of India, there can not be any influence of the river discharge from the coastal waters on salinity conditions of the waters of reef area and it can be inferred that the Lakshadweep waters are typical of a tropical ocean. The investigation of Sankaranarayanan²¹ provides ecological data and conditions for the waters within a typical lagoon of Kavaratti atoll. Salinity varies from 34.3 to 34.5 $\times 10^{-3}$ and temperature from 30.2°-32.4°C, while in the open sea it ranges from 29.1° to 31°C. Variation of pH is from 7.9 to 8.2. Oxygen contents are 4.48-10.24 ml.l⁻¹.

Water depth at the stations covered in the lagoons varies from 1 to 6 m and as evident from Fig.2, it has no effect on the distribution of foraminiferal fauna. Lakshadweep lagoons are not only very shallow, but also characterized by the absence of raised reefs in comparison with those in the Pacific Ocean where average range of depth is from 40 to 80 m. Due to shallowness of the lagoon it is well illuminated. It has been experimentally demonstrated in corals that there is a definite relationship between light and the deposition of calcium²². Perhaps, this may be the reason why tests of some genera of forams are larger and thicker in the lagoon samples.

The lagoon sediment is coarse and composed of skeletal components like fragmented corals, molluscs, coralline algae, echinoids, ostracods, and foraminifers. The bottom surface is not smooth because of the presence of pinnacles and knolls with depressions in between. This nature of the substratum affects the distribution of agglutinated Foraminifera as they are rare in the coarse sand (Fig.2). However, they are supplanted dominantly by calcareous fauna.

Environmental implications of some Foraminifera are important in providing clues to the nature of an ecosystem especially in restricted areas. Typical coral-reef species from Laccadives are *Valvulina oviedoiana*, *Quinqueloculina parkeri*, *Q.*

reticulata, *Schlumbergerina alveoliniformis*, *Peneroplis pertusus*, *Spirolina arietina*, *Sorites marginalis*, *Amphisorus hemprichii*, *Calcarina calcar*, *Heterostegina depressa*, *Amphistegina lessonii*, *A. madagascariensis*, *A. radiata*, *Planorbulina mediterraneensis*, *Planorbulinella larvata*, *Sphaerogypsina globulus*, *Cymbaloporella bradyi*, and *C. squamosa*. Observations on ecological conditions of larger foraminiferids suggest that they live in association with aquatic plants scattered as smaller patches on the lagoon floor in the atolls of Lakshadweep. The flora consists mostly of turtle grass, *Thalassia hemprichii* and manatee grass, *Cymodocea isoetifolia*. The sea grasses and the coralline alga, *Halimeda*, in the lagoons offer these forams not only protection against strong water currents, but also from desiccation due to exposure for a short interval during low-tide. Such observations are also made by others²³⁻²⁵ in the reef areas. In general, the distribution of larger foraminiferids like *Peneroplis*, *Spirolina*, *Sorites*, *Amphisorus*, *Calcarina*, *Heterostegina*, and *Amphistegina* encountered with macroflora in the lagoons of Laccadives is same as that of living corals, which are confined chiefly in the tropical belt of the world oceans. However, in Persian Gulf where extreme environmental conditions like high temperatures and high salinities prevail, all these genera are absent with the exception of *Peneroplis*. *Amphistegina* is found to occur in the reef areas as well as in sediments elsewhere with high percentage of CaCO₃²⁶⁻²⁸. As the lagoonal deposits are rich in CaCO₃ content mainly above 90%, they are dominated by calcareous fauna and arenaceous Foraminifera are rare.

Reef formation— Coral reefs abound in shallow waters of tropical seas and they contain two naturally occurring abundant minerals, viz. calcite and dolomite. Of the various reef-producing organisms, Foraminifera contribute chiefly calcite.

Reef-building is the result of biological precipitation of calcium from seawater by certain calcareous organisms, which include foraminifers. In environs like coral reefs, precipitation of carbonates (calcite) is effected by microorganisms by the removal of CO₂ from the water through photosynthesis²⁹, while in certain deep-sea sediments it is due to fragmentation of the shells of Foraminifera and not from precipitation *in situ*. In the lagoons of Laccadives, the sea grasses *Thalassia hemprichii* and *Cymodocea isoetifolia* and the alga, *Halimeda* present abundantly seem to have a major role in photosynthesis instead of phytoplankton and microorganisms. Therefore, besides lime-extracting organisms that participate in the

Table 1 — Percentage Occurrence of Foraminiferal Species in Total Population at Different Atolls

Families, species and varieties	Station Number: 1	Agatti								Kavaratti								Subellipar								Minicoy	
		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24			
ARENACEOUS																											
Textulariidae																											
<i>Textularia agglutinans</i>	-	-	-	2.3	1.0	-	-	1.0	-	2.3	2.0	-	-	-	-	-	-	-	-	-	0.7	-	-	-	-	-	
<i>T. candeiana</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>T. cuneiformis</i>	-	-	-	-	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	
Ataxophragmiidae																											
<i>Valvulina ovoidiana</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.3	-	-	-	-	-	-	-	-	-	-	-	
<i>Clavulina difformis</i>	-	-	-	-	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	
PORCELLANEOUS																											
Fischeriidae																											
<i>Cyrtogira involvens</i>	1.3	1.3	-	-	-	-	-	1.3	1.3	2.3	1.7	1.3	-	-	1.3	1.0	1.0	-	-	-	-	-	-	-	-	-	
Nubeculariidae																											
<i>Wuellerstorfi auriculata</i>	-	-	-	-	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Spiroloculina antillarum</i>	-	-	1.3	1.7	-	-	-	0.3	-	0.7	-	-	0.3	0.3	-	-	1.0	-	-	-	-	-	-	-	-	-	
<i>S. antillarum</i> d'Orbigny var <i>angulata</i>	0.7	-	-	-	-	-	-	0.3	-	1.0	-	-	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Vertebrulina striata</i>	-	-	-	-	-	-	-	0.7	-	1.0	-	-	-	-	0.7	4.3	-	-	-	-	-	-	-	-	-	-	
Miliolidae																											
<i>Massilina annectens</i>	3.0	2.3	-	2.3	11.0	-	1.3	1.7	-	11.3	4.0	5.0	6.0	-	1.0	5.0	4.0	3.3	-	-	-	-	-	-	-	4.0	
<i>Quinqueloculina agglutinans</i>	-	-	-	5.0	-	-	-	-	0.3	-	-	-	-	-	-	-	-	0.7	-	-	-	-	-	-	-	-	
<i>Q. agglutinata</i>	-	0.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.3	1.3	-	-	-	-	-	-	-	
<i>Q. berthelotiana</i>	-	-	-	1.0	-	-	-	-	-	-	-	-	-	-	-	0.7	-	-	-	-	-	-	-	-	-	-	
<i>Q. bradyana</i>	-	0.3	-	3.7	1.0	-	0.3	0.7	0.7	-	0.3	0.3	1.0	-	2.0	2.0	1.7	-	-	-	-	-	-	-	-	-	
<i>Q. crassa</i> d'Orbigny var. <i>subcuneata</i>	0.7	-	-	-	-	-	0.3	0.3	2.0	0.3	-	-	0.7	0.3	0.3	1.0	2.3	-	-	-	-	-	-	-	-	-	
<i>Q. curta</i>	-	0.3	-	-	-	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Q. cuvieriana</i>	-	-	-	-	-	-	-	-	-	-	-	-	0.7	-	-	-	-	0.3	-	-	-	-	-	-	-	-	
<i>Q. laevigata</i>	0.3	-	-	-	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Q. lamarciana</i>	-	-	-	-	-	-	-	-	-	-	0.3	0.3	-	-	-	-	-	-	0.3	0.3	-	-	-	-	-	-	
<i>Q. oblonga</i>	-	-	-	-	-	-	-	-	-	-	0.3	-	-	-	-	0.3	0.7	2.7	-	-	-	-	-	-	-	-	
<i>Q. parkeri</i>	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	0.3	0.7	2.7	-	-	-	-	-	-	-	-	
<i>Q. polygona</i>	-	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Q. reticulata</i>	1.0	-	-	1.3	-	-	-	0.7	1.0	2.0	3.0	-	-	0.7	-	0.3	-	-	-	-	-	-	-	-	-	2.3	
<i>Q. rhodiensis</i>	4.3	0.3	-	-	-	-	-	0.3	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	1.0	
<i>Q. semnulium</i>	4.0	6.3	-	-	-	-	1.0	1.7	0.7	-	1.3	4.3	1.0	5.3	-	3.0	-	-	-	-	-	-	-	-	-	1.7	
<i>Q. sulcata</i>	-	-	-	-	-	-	1.3	-	-	-	2.3	-	-	2.3	-	-	2.3	-	-	-	-	-	-	-	-	-	
<i>Trifarina angulosa</i>	-	-	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>T. fichteliana</i>	-	-	-	-	-	-	-	-	-	0.3	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>T. insignis</i>	-	-	-	-	-	-	-	-	0.3	0.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>T. irregularis</i>	0.3	1.7	-	1.0	-	-	1.3	1.3	-	0.7	-	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-	1.3	
<i>T. oblonga</i>	2.3	2.3	1.3	-	-	-	0.7	1.7	0.3	1.3	0.7	6.0	4.0	2.3	0.3	5.0	-	-	-	-	-	-	-	-	-	4.3	
<i>T. planicosta</i>	-	-	-	-	-	-	-	0.3	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>T. rotunda</i>	0.3	-	-	1.0	0.3	-	0.7	-	-	-	-	0.3	-	-	-	0.3	-	-	-	-	-	-	-	-	-	0.7	

Contd

Table 1 — Percentage Occurrence of Foraminiferal Species in Total Population at Different Atolls — Contd

Station Number:	Agatti					Kavaratti					Subhalepar					Minticoy									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
Families, species and varieties																									
Miliolidae - Continued																									
<i>T. transversistriata</i>	-	-	-	-	-	-	-	-	-	-	0.3	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>T. tricerinata</i>	0.3	-	-	1.3	0.3	-	-	-	-	0.3	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-
<i>T. trigonula</i>	-	-	-	1.3	0.3	-	-	-	0.7	1.0	0.3	0.3	-	-	4.0	-	-	-	0.3	-	-	-	-	-	-
<i>Miliolinella circularis</i>	0.3	0.3	-	-	-	-	0.7	1.0	-	-	-	-	1.0	1.0	0.3	-	-	0.3	-	1.3	-	-	-	-	-
<i>M. labiosa</i>	-	-	0.3	-	-	-	-	0.3	1.7	3.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>M. labiosa d'Orbigny sparsicosata</i>	-	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Hauerina miocenica</i>	-	-	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>H. pacifica</i>	-	-	-	-	-	-	-	-	-	0.3	0.3	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-
<i>Schlumbergerina alveoliformis</i>	-	-	-	-	-	-	-	-	-	-	1.0	-	0.3	-	-	-	-	-	0.3	-	-	-	-	-	-
Sorbitidae																									
<i>Peneroplis pertusus</i>	.7	3.3	2.0	-	-	-	-	-	0.3	-	4.3	2.0	-	1.3	4.3	5.0	4.0	-	-	-	-	-	3.0	-	-
<i>Spirulina arietina</i>	-	-	-	-	-	-	-	-	-	-	-	0.7	0.3	-	-	-	-	-	-	-	-	-	-	-	-
<i>Sorites marginalis</i>	-	-	-	-	3.3	-	3.0	-	-	1.7	1.7	-	-	-	0.7	1.0	2.0	4.0	-	2.3	3.3	-	-	2.0	-
<i>Amphisorus hemprichii</i>	0.3	1.0	-	2.3	2.3	2.7	6.7	8.7	2.0	1.3	2.7	5.3	3.0	3.3	3.0	4.3	-	2.3	1.7	3.0	5.0	3.3	2.3	3.3	
Alveolinidae																									
<i>Borelis pulchra</i>	-	-	-	-	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-
HYALINE																									
Bolivinitidae																									
<i>Bolivinita quadrilatera</i>	-	-	-	-	-	-	-	-	0.3	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Bolivina abbreviata</i>	-	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>B. cf. paula</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-
<i>B. compacta</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.7	-	-	-	-	-	-	-	-	-
<i>B. rhomboidalis</i>	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>B. fortuosa</i>	-	-	-	1.3	-	-	-	-	-	-	-	-	-	-	-	2.7	-	-	-	-	-	-	-	-	-
Buliminidae																									
<i>Bulimina marginata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.7	-	-	-	-	-	-	-	-	-	-
<i>Reussella spinulosa</i>	1.3	1.0	-	-	-	-	-	-	-	-	-	-	2.0	-	-	2.0	-	-	-	-	-	-	-	-	-
Uvigerinidae																									
<i>Uvigerina porrecta</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-
Siphoninidae																									
<i>Siphonina reticulata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	-	0.3	-	-	-	-
Discorbidae																									
<i>Neonorbina crustata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Discorbis parisiensis</i>	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Contd																									

Table 1 — Percentage Occurrence of Foraminiferal Species in Total Population at Different Atolls — Contd

Families, species and varieties	Agatti					Kavaratti					Suhelipar					Minicoy									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
Discorbidae - Continued																									
<i>Rosalina bertheloti</i>	-	-	-	-	-	-	-	0.7	-	-	-	-	-	1.0	1.0	1.7	-	-	-	2.7	4.0	-	-	-	-
<i>R. bradyi</i>	-	-	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>R. floridana</i>	-	-	-	-	-	-	-	-	-	1.7	1.3	3.0	-	-	2.0	4.7	6.0	3.0	-	-	1.7	4.0	-	-	-
<i>R. globularis</i>	-	-	0.7	-	-	-	-	-	-	1.3	0.3	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>R. vilardobona</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Gavelinopsis praegeri</i>	-	-	-	-	-	-	-	-	-	-	-	-	0.3	0.3	-	-	-	-	-	-	-	-	-	-	-
Elabratellidae																									
<i>Elabratella tabernacularis</i>	0.7	0.3	0.7	-	-	-	-	-	-	0.3	-	-	0.7	0.3	2.7	1.7	-	-	0.3	-	-	-	-	-	-
Spirillinidae																									
<i>Spirillina decorata</i>	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>S. lateoplata</i>	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	-
<i>S. limbata</i> H. B. Brady, var. <i>denticulata</i>	-	-	-	-	-	-	-	-	-	1.7	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>S. limbata</i> H. B. Brady, var. <i>papillosa</i>	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rotaliidae																									
<i>Ammonia beccarii</i> (Linné) - variant	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
" <i>Rotalia</i> " <i>translucens</i>	-	-	0.3	-	-	-	-	-	-	-	-	0.3	-	-	-	4.0	-	-	-	-	-	-	-	-	1.0
Calcarinidae																									
<i>Calcarina calcar</i>	48.7	56.7	48.7	72.3	47.3	31.3	27.3	28.3	40.0	52.7	37.7	64.0	44.0	34.0	40.0	28.0	28.3	43.3	66.7	69.3	43.3	66.0	72.7	60.7	
Elphidiidae																									
<i>Elphidium craticulatum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	-
<i>E. crispum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	-
<i>E. jenseni</i>	-	-	-	1.3	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>E. poeyanum</i>	-	-	-	-	-	-	-	-	-	3.0	-	0.3	-	-	-	-	-	-	-	-	2.7	-	-	-	-
<i>E. cf. reticulosum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	-	-
<i>E. simplex</i>	-	-	-	-	-	-	-	-	-	-	-	0.7	-	-	-	-	1.7	-	-	-	-	-	-	-	-
Nummulitidae																									
<i>Heterosfegina depressa</i>	-	-	-	-	-	-	-	-	0.7	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0
Globigerinidae																									
<i>Globigerinoides ruber</i>	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	0.7	-	-	-	-	-	-	-	-	-	-
<i>G. sacculifer</i>	-	-	-	-	-	-	-	-	-	-	-	-	2.0	-	-	-	-	-	-	-	-	-	-	-	-
<i>Globigerinita glutinata</i>	0.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eponididae																									
<i>Eponides antillarum</i>	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>E. broeckhianus</i>	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Contd

Table 1 — Percentage Occurrence of Foraminiferal Species in Total Population at Different Atolls — *Contd*

Station Number:	Kavaratti										Subellipar										Minicoy				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
Families, species and varieties																									
Eponididae - Continued																									
<i>E. repandus</i>	-	-	-	1.3	-	-	-	-	-	-	-	1.0	-	0.7	-	-	0.3	-	1.0	1.0	-	-	-	-	-
<i>E. (?) tuberculata</i>	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Amphisteginidae																									
<i>Amphistegina lessonae</i>	2.7	-	2.7	-	1.0	3.3	4.3	11.7	4.7	-	0.3	2.0	-	1.3	3.3	3.3	-	-	4.0	6.7	4.3	-	5.0	9.3	
<i>A. madagascariensis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-
<i>A. radiata</i>	15.3	17.0	41.7	4.0	18.7	60.0	54.3	40.3	37.0	17.7	20.3	1.3	20.7	33.0	29.0	21.0	5.3	12.3	18.3	10.3	17.3	16.3	17.0	26.7	
Cibicides																									
<i>Cibicides lobatulus</i>	1.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.0	3.7	-	-	-	-	2.7	-	
<i>C. refulgens</i>	1.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.0	3.0	-	-	-	-	-	-	-	
<i>C. pseudoungerianus</i>	-	0.3	0.3	-	0.3	-	-	-	-	-	-	-	-	0.3	-	1.0	0.3	-	-	-	-	-	-	-	
Planorbulinidae																									
<i>Planorbulina mediterraneensis</i>	0.3	-	0.7	-	0.7	-	-	0.3	1.0	0.3	-	1.0	1.0	-	2.3	3.0	-	-	-	-	-	-	-	-	
<i>Planorbulinella larvata</i>	-	-	-	-	-	-	-	0.7	-	-	1.3	-	-	-	-	-	-	-	-	0.3	-	-	-	-	
Acervulinidae																									
<i>Sphaerogypsina globulus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-	
Cymbaloporidae																									
<i>Cymbaloporella bradyi</i>	2.3	2.7	-	-	3.7	1.7	-	0.3	2.0	0.7	-	4.3	4.3	-	5.7	3.0	5.3	-	-	-	-	-	-	-	
<i>C. squamosa</i>	4.0	-	-	-	-	-	1.0	-	3.0	1.0	0.3	2.3	-	1.0	0.3	3.0	-	-	-	-	3.3	-	-	-	
Loxostomidae																									
<i>Loxostomum limbatum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	
<i>L. limbatum</i> H. B. Brady, var <i>costulatum</i>	-	-	-	-	-	-	-	-	-	-	-	0.3	0.3	-	-	-	-	-	-	-	-	-	-	-	
<i>L. rostrum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	-	-	
<i>L. truncatum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-	
Nonionidae																									
<i>Nonion depressulum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.7	-	-	-	-	-	-	-	
Alabaminidae																									
<i>Oridorsalis umbonatus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	
Ceratalbulinidae																									
<i>Conorboides advena</i>	-	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	

construction of reefs, CO₂ of seawater and precipitation of CaCO₃ have an effect on growth of the reef.

Daniel¹² has emphasized the significance of encrusting forams in their contribution to the reef structure and reported 6 species of encrusting Foraminifera from Krusadai island belonging to 3 families-Planorbulinidae, Rupertiidae, and Homotrematidae and to the genera of *Gypsina*, *Acervulina*, *Planorbulina*, and *Homotrema*. The encrusting forams are rather rare in the lagoonal deposits of Laccadives and this may be due to nature of the substrate since they prefer or encrust normally on surfaces of rocks and larger shells of dead organisms - only 2 species are encountered. In fact, Foraminifera play an important role in the reef formation in two ways: as sediment-producing organisms, they contribute to the growth of the reef as well as being detrimental to the process of growing in corals as they silt up living polyps.

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