

Pteropod preservation profiles in seabed sediments off Middle Andaman Island in Andaman Sea

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Quantitative studies of the major microfauna from 19 gravity cores and 8 grab samples and semi-quantitative studies of 47 surficial sediments, collected between 191m and 2334 m water depths off Middle Andaman Island and around Barren Island shows a characteristic relation of the microfauna with the physiographic domains in the Andaman basin. Craggy domain of volcanic arc zone in Andaman Sea reveals a variation of pteropod preservation profile (PPP) in the seabed sediments. The PPP bears a direct relationship with the nature of sediment, quantity of pyroclastic materials and physiographic configuration of the region. The degree of preservation of the dissolution prone pteropods and its numerical abundance at various water depths in 27 surficial sediments are utilized to examine the PPP in the area. These parameter can be applied to examine and compare different pteropod preservation domains in other parts of Andaman Sea for oceanographic inferences.

[Key words: Andaman Sea, aragonite compensation depth, dissolution indices, pteropod preservation profile, preservation index]

Introduction

Pteropod is an important constituent of pelagic gastropods and shows its usefulness in oceanographic implications in tectonically active Andaman Sea during the Late Quaternary time. It is widely distributed in the open oceans from the polar to the tropical regions^{1,2}. Pteropods show worldwide distribution but their presence is restricted within the limited bathymetric levels due to their highly fragile nature. Their occurrence in ocean floor depends upon the physical, chemical and biological parameters of different water masses^{3,4}. The nature of aragonite compensation depth (ACD) and its variation is directly reflected by the occurrence of the aragonitic pteropod tests in the seabed sediments^{5,6}. Significance of pteropod was realized with the study of seabed samples collected during various ocean expeditions by “Challenger”, “Valdia”, “John–Murry”, “Dana”, “Umika Maru”, “Meteor”, “Wecoma”, “Antarctic” and “International Indian Ocean Expedition”.

Palaeontological importance of Quaternary pteropod has been established by scientific results of IIOE⁷, DSDP^{8,9} and ODP^{10,11} reports. Quaternary seabed samples collected by GSI research vessel “Samudra Manthan” in last two decades revealed important results of pteropod records from the Exclusive Economic Zone (EEZ) of India from

Arabian Sea¹²⁻¹⁵, Bay of Bengal¹⁶⁻¹⁸, Andaman Sea¹⁹⁻²¹ and Indian Ocean²²⁻²⁵ around Carlsberg Ridge. Pteropod studies from the Arabian Sea suggests that they are good indicator of upwelling and bathometers^{26,27}. Pelagic gastropod study is now an internationally recognized branch of oceanographic research, which has significant implication for Late Quaternary marine investigations. The complex physiographic domain of the study area partly covers the Narcondam-Barren basin in the northwestern side, Alcock seamount in the eastern side and continental slope of Middle Andaman island in the western side respectively (Fig. 1). The present study of pteropod preservation profiles (PPP) in the northern Indian Ocean is a maiden attempt in this respect. The PPP study has its importance due to more sensitive nature of pteropods than the calcite skeletal remains of coccoliths and foraminifera for environmental analysis of Quaternary marine sediments.

Materials and Methods

Present work is mainly based on the quantitative studies from the top sediments of 19 gravity cores and 8 grab samples and semi-quantitative studies from tops of 47 gravity cores, collected from an area of about 15000 km² between the latitudes 12°N & 13°N and longitudes 93°15'E & 95°20'E in the northern

part of Andaman Sea (NHO Chart no. 41). The seabed samples, lying between 191 m and 2334 m water depths, have been collected by research vessel “*Samudra Manthan*” (Cruise No.SM-143) within the EEZ of India (Fig. 1) during May, 2000

The seabed samples were processed following the techniques suggested by various workers. About 10 g of oven dried sample was taken in one litter distilled water, 10 ml 6% H_2O_2 solution is added and the sample was kept in the solution for 48 hours for disaggregation. Wet samples were washed through a 230 ASTM sieve and dried in room temperature. The weight % of coarser fraction ($> 63 \mu m$) had been calculated to examine the total number of Pteropods in a gram of dry sample. The processed samples with good number of pteropods were again split with the auto-microsplitter in order to obtain about 250 to 300 specimens of pteropod tests. All the specimens were hand picked, fixed on the micropalaeontological trays and taxonomic classification had been carried out after Tesch²⁸, Hodkinson *et al.*²⁹ and Ujihara³⁰.

Pteropod dissolution indices were calculated as per method given by Almogi-Labin *et al.*³¹, Peterson & Prell³², den Dulk *et al.*³³, and Haddad & Droxler³⁴. In this work, three dissolution indices viz. total number of pteropod tests per gram of dry sediment (C1), Percentage of whole pteropod specimens to whole and fragmented pteropod tests (C2) and Percentage of pteropod to pteropod and planktonic foraminiferal tests (C3) show the variation of these indices in different seabed samples at various depths (Table 1).

Results

The spatial distribution pattern of pteropod, foraminifera and radiolarian in surficial sediments is

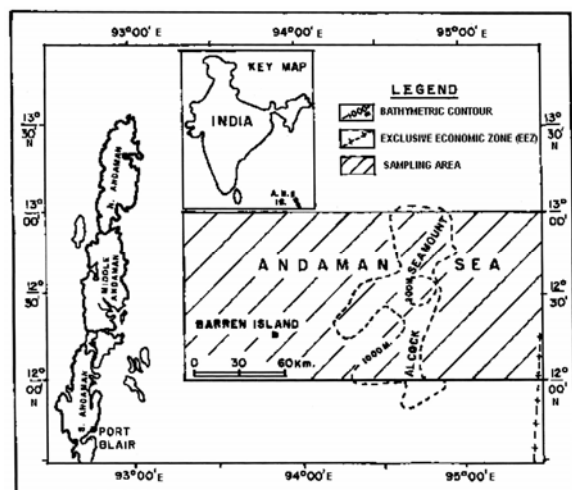


Fig. 1—Location map.

shown in Fig. 2 and Table 2 on the basis of their relative abundance. Pteropod and foraminifera rich sediments occur in the western part of the area as a north-south trending elongated patch and over the upper part of the Alcock Seamount along NNE-SSW direction. The sediments also contain minor proportion of ostracod, microgastropod, bivalve, echinoid spines, bryozoa and coral fragments. The eastern and the western flanks of the Alcock Seamount and the middle bathyal zone off Middle Andaman island are mainly floored by planktonic foraminifera with some radiolarian and very little pteropods. This unit also contains some diatoms, sponge spicules, dinoflagellates and minor ostracods. The deeper part of Narcondam-Barren basin below 1800 m depth is covered by foraminifera and radiolaria but is devoid of pteropods. An appreciable quantity of sponge spicules and dinoflagellates was commonly noticed in this sediment. Some pteropods occur in benthic foraminifera rich sediments around the conical peaks of the Alcock Seamount. Percentage of the above microfauna in different physiographic domains of the study area is briefly shown in Table 2.

Twenty four pteropod species namely *Limacina inflata* (d'Orbigny), *L. trochiformis* (d'Orbigny), *L. bulimoides* (d'Orbigny), *L. lesueuri* (d'Orbigny), *Creseis acicula* (Rang), *C. chierchiae* (Boas), *C. virgula* (Rang), *C. virgula virgula* (Rang), *C. virgula constricta* (Chen & Be), *C. virgula conica* Eschscholtz, *Clio convexa* (Boas), *C. pyramidata* Linne, *C. cuspidata* (Bosc), *Cavolinia longirostris* (de Blainville), *C. globulosa* (Gray), *C. tridentata* Niebur, *C. inflexa* (Lesueur), *Dicria trispinosa* (de Blainville), *D. quadridentata* (de Blainville), *Cuvierina columnella* (Rang), *Styliola subula* Quoy & Gaimard, *Hyalocylis striata* (Rang), *Peraclis reticulata* (d'Orbigny) and *P. depressa* Meisenheimer were recorded in the sediments. They belong to nine genera of three families and comes under two sub-orders, Pseudothecosomata and Euthecosomata of the order Thecosomata. Brief taxonomic description of pteropod taxa is given below.

Family Limacinidae Gray, 1847.

Species *Limacina inflata*, *L. trochiformis*,
L. bulimoides & *L. lesueuri*

Family Cavoliniidae Fischer, 1883.

Species *Creseis acicula*, *C. chierchiae*, *C. virgula*, *C. virgula virgula*, *C. virgula constricta*, *C. virgula conica*, *Clio convexa*, *C. pyramidata*, *C. cuspidata*, *Cavolinia longirostris*, *C. globulosa*, *C. tridentata*,

Table 1—Occurrence of pteropod in sea bed sediments off Middle Andaman and Barren island in Andaman Sea

Table 1—Occurrence of pteropod in sea bed sediments off Middle Andaman and Barren island in Andaman Sea										
Sl. No.	Sample No.	Location				Depth (m)	Pteropod (no/g.)	%Whole Pteropod Test	%Pteropod/ (Pteropod+ Pl. Foram.)	Lithology
		Latitude N		Longitude E						
1	SM143/GC1/T	12°	59.88'	93°	14.91'	567	350-400	72	18.95	Sandy silt
2	SM143/GC12/T	13°	0.29'	94°	37.61'	1108	500-600	45	9.86	Clay with foraminifera.
3	SM143/G15	13°	0.21'	95°	0.47'	1071	180- 200	35	11.76	Clay with pyroclasts
4	SM143/GC25/T	12°	50.08'	94°	52.3'	593	100-150	65	5.13	Medium sand
5	SM143/GC27/T	12°	50.11'	94°	37.31'	910	800-900	72	21.05	Sandy clay
6	SM143/GC38/T	12°	50.12'	93°	14.72'	514	300-380	70	24	Clay silt
7	SM143/GC39/T	12°	40.02'	93°	15.81'	405	300-320	55	17.13	Biogenic sand
8	SM143/G47	12°	39.99'	94°	16.04'	752	600-700	75	23.08	Sticky clay
9	SM143/GC49/T	12°	40.02'	94°	30.37'	1055	40-60	42	6.66	Clay with pyroclast.
10	SM143/GC50/T	12°	39.91'	94°	37.91'	956	800-900	70	20	Sandy clay
11	SM143/GC52/T	12°	40.06'	94°	52.8'	1022	600-800	60	18.46	Sandy clay
12	SM143/G64	12°	29.88'	94°	52.8'	567	200-300	62	20	Biogenic sand
13	SM143/GC65/T	12°	30.06'	94°	37.44'	1035	500-600	50	14.16	Clay
14	SM143/GC66/T	12°	30.06'	94°	29.89'	969	700-750	70	18.92	Sandy clay
15	SM143/GC67/T	12°	30.12'	94°	22.32'	837	100-140	30	8.8	Clay with pyroclast.
16	SM143/G72	12°	30.07'	93°	15.08'	303	40-50	25	8.12	Biogenic sand
17	SM143/G73	12°	19.99'	93°	15.62'	471	60-70	30	5.55	Biogenic sand
18	SM143/GC93/T	12°	9.94'	94°	52.78'	784	750-800	73	16.25	Clayey sand
19	SM143/G96	12°	10.48'	94°	29.89'	510	900-950	85	29.49	Sandy clay
20	SM143/GC97/T	12°	10.33'	94°	22.19'	1147	100-150	30	6.84	Clayey sand
21	SM143/GC98/T	12°	10.4'	94°	14.93'	851	150-200	40	15	Sand with pyroclasts
22	SM143/G103	12°	9.91'	93°	15.01'	204	40-50	52	20	Coarse sand
23	SM143/GC104/T	11°	59.8'	93°	15.55'	514	300-350	62	22.89	Biogenic sand
24	SM143/GC107/T	12°	0.14'	93°	37.49'	686	850-900	80	27.85	Clayey sand
25	SM143/GC111/T	12°	0.32'	94°	7.59'	831	200-300	60	14	Silty sand with pyroclast
26	SM143/GC114/T	12°	0.11'	94°	29.83'	973	700-800	65	19.44	Foraminiferal clay
27	SM143/G120	12°	32.12'	94°	47.1'	191	15-20	50	18.18	Biogenic sand

C. inflexa, *Dicria trispinosa*, *D. quadridentata*, *Cuvierina columnella*, *Styliola subula* & *Hyalocylis striata*

Family Peraclididae Tesch, 1913.

Species *Peracliis reticulata* & *P. depressa*

Differential dissolution susceptibility of different taxa has been noticed in the above pteropod assemblage. It is observed that the differential dissolution of pteropod tests depends on thickness, size, shape and surface ornamentation of the individual taxon³⁵⁻³⁷. Shell thickness appears to be the most important factor in this assemblage³⁸⁻⁴⁰. An attempt has been made to quantify the mode of preservation of different pteropod taxa on the basis of the fragmentation of the specimens. The mode of preservation of pteropod shells of the above three

families varies considerably. Test preservation was very good for Limaciniidae, moderate to good for Cavoliniidae and moderate for Peraclididae. Well preserved forms generally possess complete tests and were mostly opaque-white in colour. Good preserved specimens were less broken or partly broken with white to transparent tests. The moderately preserved tests were commonly broken and show pitted surface. The tests of *Limacina inflata*, *L. bulimoides*, *D. quadridentata* and *L. trochiformis* were well preserved. Good mode of preservation was seen in the specimens of *S. subula*, *C. pyramidata*, *C. virgula* and *C. columnella*. However, the tests of *C. acicula*, *C. inflexa*, *P. reticulata* and *H. striata* were moderately preserved. A list of 10 taxa from high to low preservation index had been identified and shown

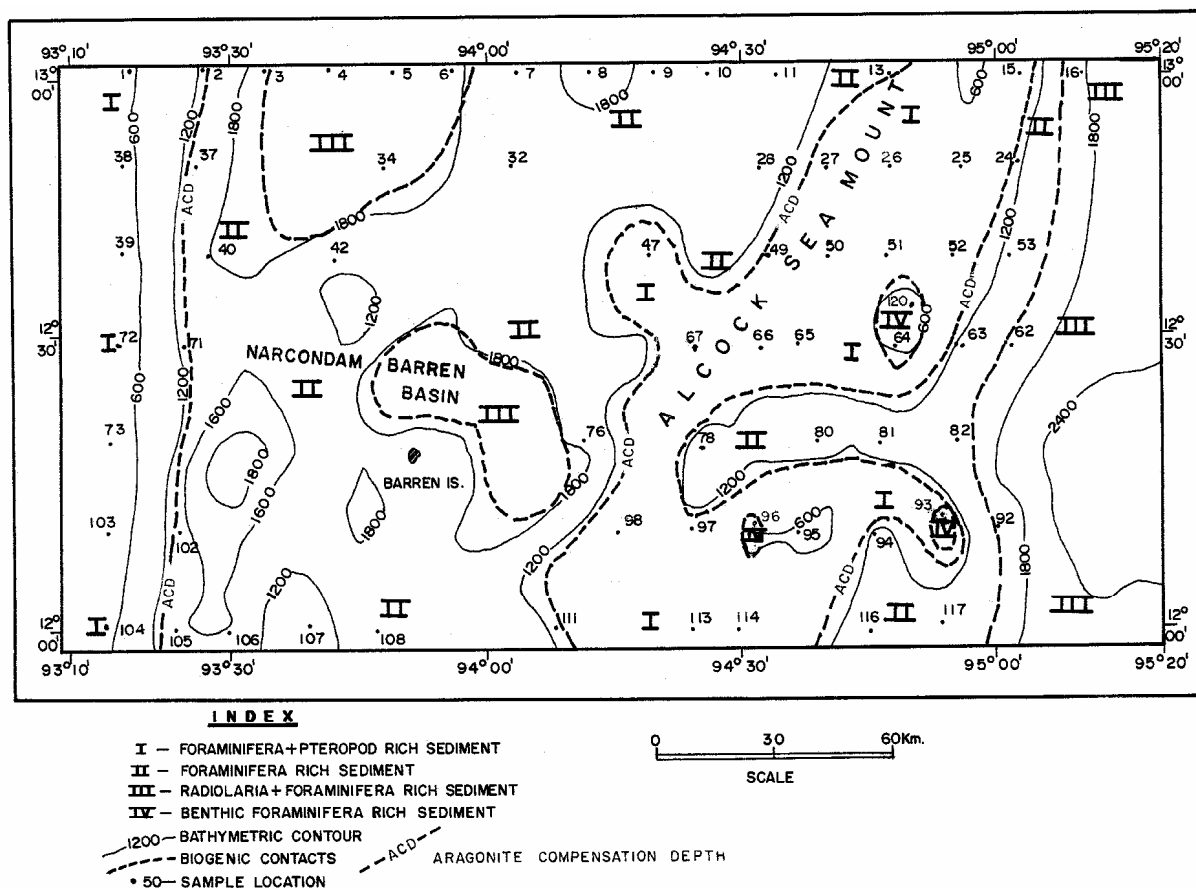


Fig. 2—Distribution of major microfauna in seabed sediments, around Barren island and over Alcock seamount, Andaman Sea.

in serial order. This series shows decreasing in preservation ability from 1 to 10 as follow.

1. *Limacina inflata* 2. *L. bulimoides* 3. *Dicria quadridentata* 4. *Styliola subula* 5. *Clio pyramidata* 6. *Creseis. virgula virgula* 7. *C. acicula* 8. *Cavolinia inflexa* 9. *Peraclis reticulata* and 10. *H. striata*

It is important to note that mode of preservation of pteropod is good in silty clay and clay silt, moderate to good in fine to medium sand, moderate to poor in sediments with pyroclastic materials and poor in coarse biogenic sand containing concretions and relict biota.

Five clayey sediment samples (GC-98, 67, 49, 111 and G-15) over the Alcock Seamount show moderate presence (50 to 200) of pteropod tests. These samples lie between 839 and 1071 m water depth and contain good amount of pyroclastic materials. Presence of total pteropod specimens in the pyroclastic sediment depends on the amount and the size of volcanic material. Ten samples from biogenic sand (G-120, 103, 72, 73, 64 and GC-38, 39, 25, 1, 104) over

Alcock Seamount and eastern continental slope of the Middle Andaman island between 191 and 600 m isobaths contain poor to moderate (15 to 400) pteropod specimens. Fine to medium biogenic sand contain high number (200 to 400) pteropod tests but coarse to very coarse biogenic sand with relict biota show poor (15 to 30) presence of pteropod in the sediments. The occurrence of pteropod gradually increases from 500 m to 1108 m water depths in fine clayey silt and silty clay sediments (Table 1, 2, Fig. 3). Pteropod preservation profile was delineated with the help of best fit line of pteropod number in one gram of dry seabed sample versus the water depth in different sample locations (Fig. 3). Higher number (400 to 950) of pteropods were observed in 12 samples collected from 510 to 1108 m water depths. Below this bathymetric level, it is considerably reduced. Plotting of C1 data of the above 27 samples represents three different geological set up in this region as shown in Fig. 3. It is observed that the C1 values of pyroclastic sediments and coarser biogenic

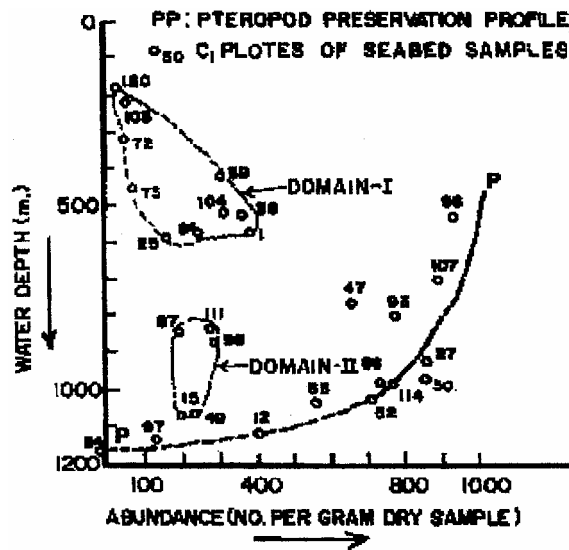


Fig. 3—Occurrence of pteropods in seabed sediments with depth.

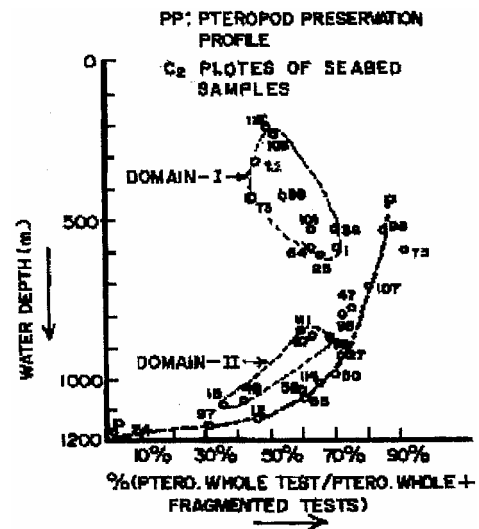


Fig. 4—Variation of (Pteropod whole test / pteropod whole test + Pteropod fragmented test) % with depth.

Table.2—Percentage of different micofauna in sea bed sediments off Middle Andaman and Barren island in Andaman Sea

Sl. No.	> 63 μ m	Radiolaria (%)	Planktonic foram (%)	Benthonic. foram (%)	Pteropod (%)	Mollusc (%)	Others (%)
1	25.58	6 to 8	57 to 59	8 to 10	10 to 11	5 to 6	9 to 10
2	23.92	20 to 22	60 to 62	3 to 4	9 to 10	1 to 2	3 to 4
3	19.87	22 to 24	58 to 60	4 to 5	5 to 7	1 to 2	5 to 7
4	76.13	10 to 12	55 to 57	9 to 10	5 to 6	6 to 8	10 to 11
5	48.56	12 to 14	60 to 62	3 to 4	15 to 17	2 to 3	3 to 5
6	34.07	10 to 12	54 to 56	9 to 10	8 to 9	5 to 6	10 to 12
7	84.21	7 to 9	54 to 56	10 to 12	7 to 8	5 to 6	8 to 10
8	22.98	16 to 18	58 to 60	4 to 5	12 to 14	2 to 3	4 to 5
9	24.36	32 to 34	52 to 54	2 to 3	3 to 5	1 to 2	6 to 7
10	48.5	11 to 12	60 to 61	2 to 3	18 to 19	2 to 3	4 to 6
11	46.24	13 to 14	60 to 62	2 to 3	15 to 17	1 to 2	5 to 6
12	82.36	10 to 12	40 to 42	22 to 24	6 to 8	6 to 8	10 to 12
13	23.97	22 to 24	58 to 60	3 to 4	9 to 10	2 to 3	4 to 6
14	47.84	28 to 30	52 to 54	1 to 2	13 to 15	0	3 to 4
15	22.88	28 to 30	50 to 52	2 to 3	4 to 5	2 to 3	8 to 10
16	78.94	18 to 20	54 to 56	8 to 10	2 to 3	3 to 4	10 to 11
17	80.13	20 to 22	54 to 56	7 to 8	3 to 4	3 to 4	9 to 10
18	62.48	12 to 14	42 to 44	20 to 22	16 to 17	4 to 5	2 to 3
19	49.86	8 to 10	58 to 60	5 to 6	18 to 20	3 to 4	4 to 5
20	58.42	28 to 30	60 to 62	2 to 3	4 to 5	1 to 2	2 to 3
21	78.56	30 to 32	56 to 58	3 to 4	5 to 6	1 to 2	2 to 3
22	80.23	6 to 8	50 to 52	16 to 18	2 to 3	9 to 10	11 to 13
23	90.11	10 to 12	60 to 62	8 to 10	6 to 8	4 to 5	5 to 7
24	72.69	16 to 18	55 to 57	4 to 5	14 to 16	2 to 4	3 to 5
25	54.93	24 to 26	60 to 62	3 to 4	5 to 6	2 to 3	2 to 4
26	40.23	14 to 16	60 to 62	2 to 3	18 to 20	1 to 2	1 to 2
27	76.89	15 to 17	38 to 40	26 to 28	1 to 2	7 to 8	9 to 10

sand show deviation from the normal path of preservation profile (PP) and this plotting comes in two separate clusters as Domain I and II (Fig. 3).

The percentage of the whole of pteropod tests³² to whole and fragmented pteropod tests in the above 27 samples is plotted to understand the degree of pteropod dissolution. This measure shows the gradual decrease of C2 value at higher depth (Fig. 4). This index varies between 85% and 45% within the 510 to 1108 m water depths and from 45% to 30% within 1108 to 1147 m depths in fine clayey silt to silty clay sediments. The degree of pteropod whole test preservation versus water depth curves for the biogenic sand and pyroclastic sediment do not match well with the same curve for fine sediment. Rather the C2 value for the pyroclastic sediments and coarser biogenic sediments show localized clustering in Domain I and II respectively. It is important to note that pteropod whole test preservation becomes zero below 1150 m water depth in all types of sediments. Increase of pyroclastic and terrigenous materials as well as shell fragments and abraded tests of other invertebrates in seabed sediments reduces the percentage of pteropod whole tests. Wide variation (30% to 85%) of whole pteropod specimen percentage was observed in three domains of this region as shown in (Fig. 4).

The percentage of pteropod to pteropod plus planktonic foraminifera has been measured (C3) and shown in Tables 1 and 2. This measure indicates a proxy of the degree of aragonite versus calcite preservation (Berger⁴⁰). A pteropod dissolution profile has been drawn with these data against the water depth (Fig. 5). Preservation of pteropods and planktonic foraminifera is good at 510 to 1108 m water depth. Sharp decline of pteropods against planktonic foraminifera is noted between 1108 and 1147 m water depth. However, well preserved planktonic foraminifera tests remain in high number below 1150 m water depth as shown in Table 2. This factor shows low value in biogenic sand (6% to 15%), low to moderate (5 to 25%) in pyroclast containing sediments and moderate in fine silty clay and clay sediments respectively. The plotting of C3 values in respect of pyroclast bearing sediments and coarser biogenic sediments also show two separate cluster domains like C1 and C2 values (Fig. 5).

Discussion

The complex physiographic domain in the northern part of Andaman basin which lies in the volcanic arc

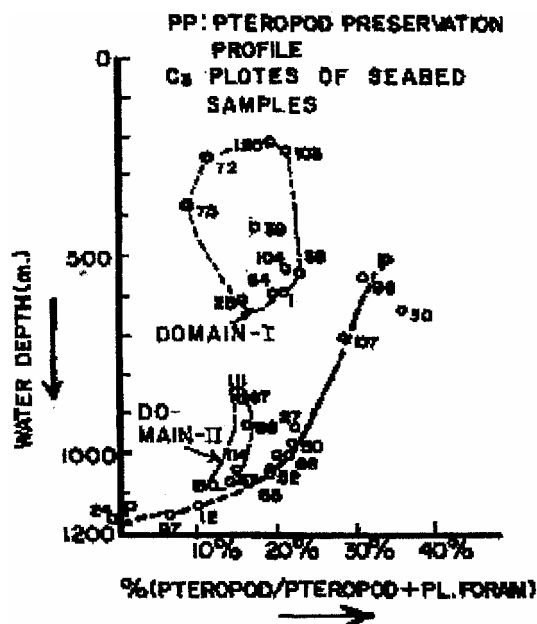


Fig. 5—Variation of (Pteropod/Pteropod+Planktonic foraminifera) % with depth.

zone off the Middle Andaman island suggests a changing pteropod preservation trend in the Recent sediments. The Aragonite Compensation depth (ACD) is noted by high dissolution or disappearance of pteropod tests in the seabed sediments because pelagic gastropod shells are made up of aragonite skeleton. The factor of dissolution depends on the depth of water column and nature of bottom water mass. On the basis of the above pteropod preservation profile it can be stated that the seabed sediments above and below 1150 m isobath show the evidence of preservation and dissolution of pteropod tests respectively. Below 1150 m water depth only a few fragments of robust pteropods were rarely noticed at places. Hence ACD has been demarcated at about 1150 m water depth in this region.

Eruption of volcanic materials from Barren volcano during the recent time resulted in supply of a lot of pyroclastic materials that are distributed in different physiographic domains and mixed up with seabed sediments. These pyroclastic substances reduce the occurrence of delicate pteropod tests as well as pteropod numbers in per gram of sediment. Pteropod preservation in seabed sediment with pyroclastic materials depends on the quantity and size of volcanic constituents in the sediments. The degree of preservation of pteropods and its numerical abundance along bathymetric transect reveal a remarkable difference from the normal pteropod

preservation profile of this region. Concretionary pebbles, grits and relict biota occur in some samples within the biogenic sand. These materials also immensely reduced the pteropod frequency in the ocean floor. Skeletal and non skeletal grains of relict sediments in coarser biogenic sand damage the delicate tests of pteropod skeletons and decline pteropod preservation index. This phenomenon is well documented by the plotting of C1, C2 and C3 values in respect of pyroclastic bearing sediments and coarser biogenic sands that show clustering in two separate domains, instead of following the normal preservation profiles. Increase of gritty –pebbly concretions and reworked tests of bivalve, gastropod, shallow water benthic foraminifera, bryozoa and coral fragments severely depletes the percentage of pteropods in biogenic sand. The above observations reveal that the nature of the seabed sediments also play an important role on the preservation of pteropod profile in Andaman Sea.

Distribution of pteropods and ACD in different parts of the world has been studied by various workers⁴⁰⁻⁴³. Present ACD off Krishna-Godavari delta in Bay of Bengal, around Narcondam island⁴⁴ in Andaman Sea, over the Carlsberg Ridge⁴⁵ in Indian Ocean and around Car Nicobar²⁰ island in Andaman Sea lies at about 1000 m, 1150 m, 2400 m and 1500 m water depths respectively. Hence, a decline of ACD value from northern part of the Andaman Sea (around Narcondam-Barren basin) to the southern part of Andaman Sea (off Car Nicobar island) is observed. The raise of the ACD level in the former domain is due to high influx of water by the Irrawaddy river system in the proximal area near the Narcondam-Barren islands. The pteropod data in this work has been used as a new proxy for demarcating the aragonite preservation in the Andaman Sea and therefore is of appropriate scientific application.

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