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NEOGENE PALAEONTOLOGY OF THE SURMA GROUP, MIZORAM, INDIA. 1- THE ARCOIDA (MOLLUSCA : BIVALVIA)

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ABSTRACT

The sediments of the Bhuban Subgroup in Mizoram contain a diverse fossil assemblage rich in bivalves and gastropods. Fourteen species of bivalves belonging to the order Arcoida are recorded, identified and described systematically from the seven stratigraphic sections of the Middle and Upper Bhuban Formations. Of these, four are described as new. The known forms of the present assemblage that occur in other parts of the Indian Subcontinent, are being reported for the first time from the present area.

These forms, together with other associated bivalves, gastropods, decapods, echinoids and fishes, indicate that the Middle Bhuban Formation and Upper Bhuban Formation are respectively Aquitanian and Aquitanian to Burdigalian in age. A shallow marine (inner-neritic to littoral) environment of deposition is inferred for the fossiliferous sediments yielding the above assemblage.

Key words: Neogene, Systematics, Arcoida (Bivalvia), Surma Group, Bhuban Subgroup, Mizoram.

INTRODUCTION

The Surma Group (Lower to Middle Miocene) in Mizoram is divisible into a lower Bhuban and an upper Boka Bil Subgroups. The Bhuban Subgroup is further divisible into the Lower, Middle and Upper Bhuban formations (Ganju, 1975). This Subgroup consists of the alternations of shale, mudstone, siltstone and sandstone and their admixtures in varying proportions. Besides, a few pockets of shell limestone, calcareous sandstone and intra-formational conglomerates are also present. The detailed general geology of the area has been discussed by Karunakaran (1974), Ganju (1975) and Tiwari and Kumar (1997).

The Bhuban sediments of Mizoram contain a diverse fossil assemblage of bivalves and gastropods. The other fossils of the assemblage belong to decapods, echinoids, fishes and barnacles. The present paper deals with the description of fourteen species of bivalves belonging to the order Arcoida, of which four are described as new. The fossils come from the ten fossiliferous horizons of seven stratigraphic sections in the Middle and Upper Bhuban formations of the Bhuban Subgroup (Surma Group). The forms known from other parts of the Indian Subcontinent, are being reported for the first time from the study area.

The published literature on the bivalves of the Bhuban Subgroup of Mizoram is meagre. Bannerjee and Das Gupta (1978), Das Gupta (1977 in Das Gupta, 1982), Sinha, Chatterjee and Satsangi (1982), Patil (1989, 1990, 1991) and Tiwari (1992) reported a large number of bivalve fauna from the Bhuban succession of Mizoram. These reports, however, are mostly up to generic level and without any description and illustration. Tiwari and Kachhara (2000), for the first time, described and illustrated two new forms of *Apolymetis* (Bivalvia:Tellinidae) from the Bhuban sediments of Mizoram.

The described specimens have been collected from the ten fossil localities, four around Aizawl and six around Lunglei towns of Mizoram (figs. 1 and 2). The stratigraphic and temporal distribution of the fossil localities are shown in the fig. 3. The specimens recorded here are poorly preserved and are usually in the form of external casts and single valves.

The present work follows the

classification of bivalvia as suggested by Newell (in Moore *et al.*, 1969). The identification of the genera and species is based mainly on the external features, though the internal characters have also sometimes been considered wherever possible. All the specimens described and illustrated here are housed in the Palaeontology Museum, Department of Geology, Pachhunga University College, Mizoram University, Aizawl-796 001, Mizoram. The following abbreviations are used in this paper : OD= original designation, SD= subsequent designation, Sp. No.= specimen number, n. sp.= new species, cf.= comparable to, aff.= affinity to, s. str.= sensu stricto, RV= right valve, LV= left valve, BV= both valve, SV= single valve, NR= number of primary ribs, C= computed, GSI= Geological Survey of India, PUC= Pachhunga University College and I= invertebrates.

SYSTEMATIC PALAEONTOLOGY

Phylum **Mollusca** Linné, 1758

Class **Bivalvia** Linné, 1758

Subclass **Pteriomorpha** Beurlen, 1871

Order **Arcoida** Stoliczka, 1871

Superfamily **Arcacea** Lamarck, 1809

Family **Arcidae** Lamarck, 1809

Subfamily **Arcinae** Lamarck, 1809

Genus ***Arca*** Linné, 1758

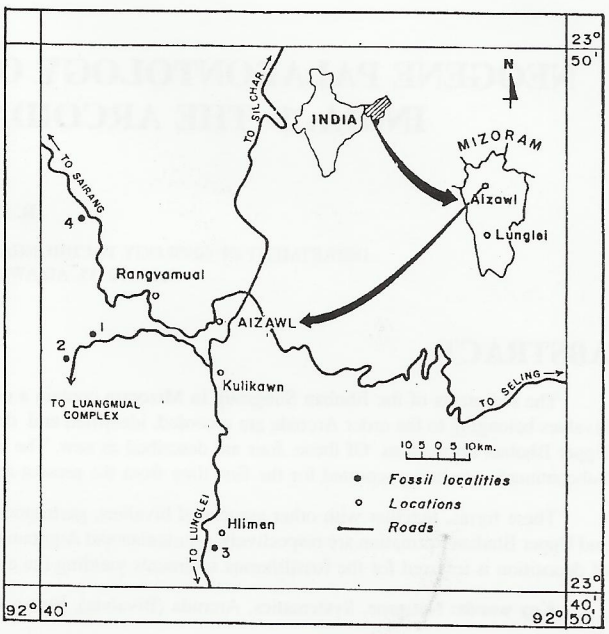


Fig. 1. Fossil localities around Aizwal, Mizoram, India.

Type species: *Arca noae* Linné 1758; SD Schmidt, 1818. Recent; Mediterranean.

Arca feddeni Vredenburg

(Pl. I, fig. 1)

Arca feddeni Vredenburg, 1928, p. 415, Pl. XXXIII, figs. 1-3.

Material: One right valve; specimen no. PUC/I/1.

Horizon and Locality: Upper Bhuban Formation; Hlimen quarry (Locality no. 3).

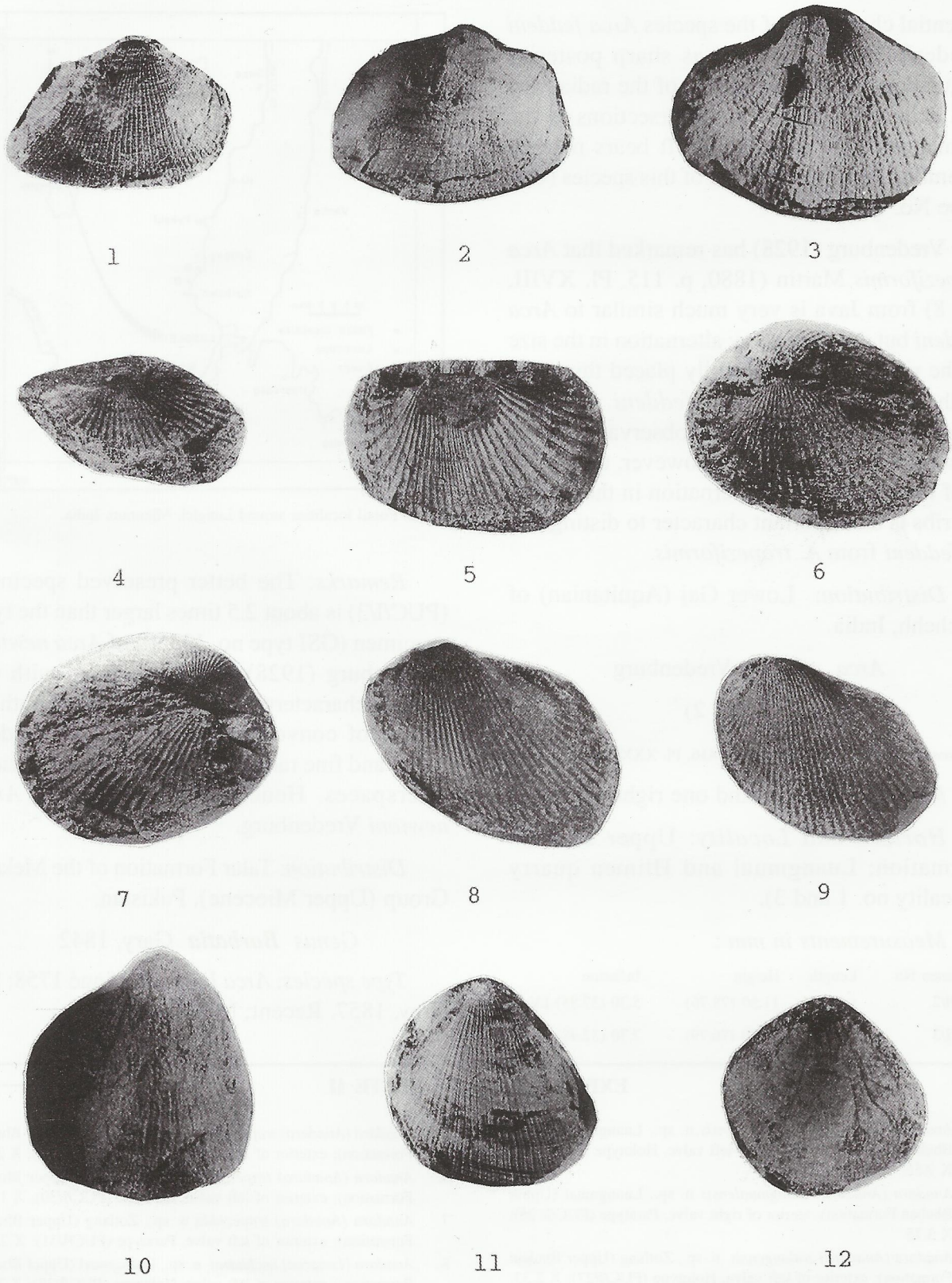
Measurements in mm:

Length- 26.00; Height- 17.30; Inflation- 5.00 (19.23%, SV).

Remarks: The specimen exhibits all the

EXPLANATION OF PLATE I

1. *Arca fedenni* Vredenburg, Hlimen (Upper Bhuban Formation); exterior of right valve (PUC/I/1); X 1.77.
2. *Arca newtoni* Vredenburg, Hlimen (Upper Bhuban Formation); exterior of right valve (PUC/I/3); X 1.69.
3. *Barbatia* (*Barbatia*) *costellata* n. sp., Hlimen (Upper Bhuban Formation); exterior of left valve, Paratype (PUC/I/5); X 2.65.
4. *Trisidos* cf. *semitorta* (Lamarck), Lunglawn (Middle Bhuban Formation); exterior of left valve (PUC/I/6); X 1.44.
5. *Anadara craticulata* (Nyst), Lunglawn (Middle Bhuban Formation); exterior of left valve (PUC/I/12); X 2.00.
6. *Anadara daviesi* Mukerjee, Serkawn (Upper Bhuban Formation); exterior of left valve (PUC/I/7); X 1.33.
7. *Anadara daviesi* Mukerjee, Serkawn (Upper Bhuban Formation); exterior of right valve (PUC/I/7); X 1.33.
8. *Anadara garoensis* Mukerjee, Luangmual (Upper Bhuban Formation); exterior of left valve (PUC/I/17); X 2.22.
9. *Anadara garoensis* Mukerjee, Luangmual (Upper Bhuban Formation); exterior of left valve (PUC/I/20); X 1.85.
10. *Anadara* cf. *gourae* Dey, Luangmual (Upper Bhuban Formation); exterior of right valve (PUC/I/23); X 2.15.
11. *Anadara* sp., Hlimen (Upper Bhuban Formation); exterior of left valve (PUC/I/24); X 1.25.
12. *Glycymeris sindiensis* Vredenburg, Lunglawn (Middle Bhuban Formation); exterior of left valve (PUC/I/36); X 3.36.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essential characters of the species *Arca feddeni* Vredenburg (1928), such as sharp posterior angulation, alternation in size of the radial ribs and delicate granules over intersections of the former with the concentrics. It bears marked resemblance to the holotype of this species (GSI Type No. 13348).

Vredenburg (1928) has remarked that *Arca trapeziformis* Martin (1880, p. 115, Pl. XVIII, fig. 8) from Java is very much similar to *Arca feddeni* but does not show alternation in the size of the ribs. He has doubtfully placed this form in the synonymy of *Arca feddeni*. It is not possible to comment on this observation since Java form is not available. However, the author is of the view that the alternation in the size of the ribs is an important character to distinguish *A. feddeni* from *A. trapeziformis.*

Distribution: Lower Gaj (Aquitanian) of Kachchh, India.

Arca newtoni Vredenburg

(Pl. I, fig. 2)

Arca newtoni Vredenburg, 1928, p. 416, Pl. XXXIII, figs. 5-6.

Material: One left and one right valves.

Horizon and Locality: Upper Bhuban Formation; Luangmual and Hlimen quarry (Locality no. 1 and 3).

Measurements in mm :

Specimen No.	Length	Height	Inflation
PUC/I/2	14.60	11.50 (78.76)	5.30 (37.85) LV
PUC/I/3	23.70	18.20 (76.79)	7.70 (32.48) RV

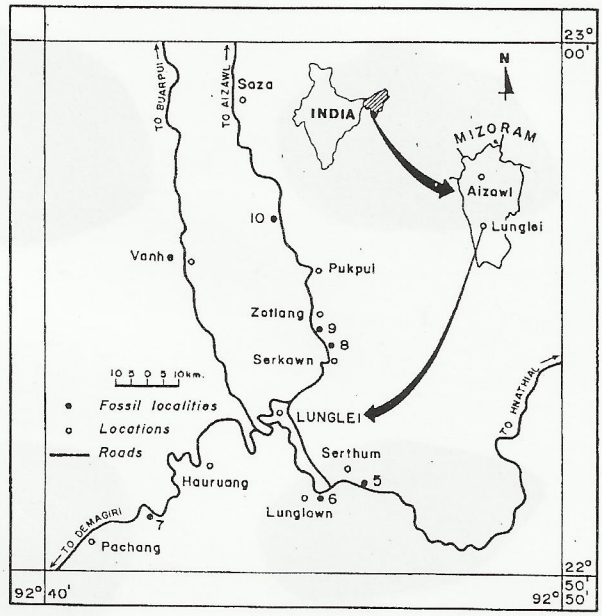


Fig. 2. Fossil localities around Lunglei, Mizoram, India.

Remarks: The better preserved specimen (PUC/I/3) is about 2.5 times larger than the type specimen (GSI type no. 13350) of *Arca newtoni* Vredenburg (1928) and agrees well with the same in characters such as relatively tall outline, degree of convexity, short hinge, submedian umbo and fine radiating ribs separated by wider interspaces. Hence, it is assigned to *Arca newtoni* Vredenburg.

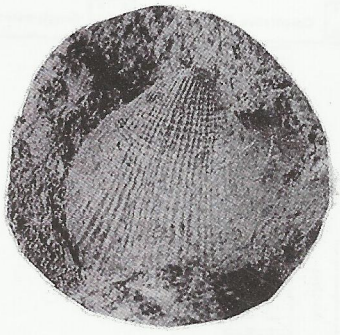
Distribution: Talar Formation of the Mekran Group (Upper Miocene), Pakistan.

Genus **Barbatia** Gary, 1842

Type species: *Arca barbatia* Linné 1758; SD Gray, 1857. Recent; Mediterranean

EXPLANATION OF PLATE II

1. *Anadara (Anadara) luangmualensis* n. sp., Luangmual (Upper Bhuban Formation); exterior of left valve, Holotype (PUC/I/25); X 3.55
2. *Anadara (Anadara) luangmualensis* n. sp., Luangmual (Upper Bhuban Formation); xterior of right valve, Paratype (PUC/I/ 26); X 3.75.
3. *Anadara (Anadara) zotlangensis* n. sp., Zotlang (Upper Bhuban Formation); exterior of left valve, Holotype (PUC/I/27); X 2.33.
4. *Anadara (Anadara) zotlangensis* n. sp., Zotlang (Upper Bhuban Formation); exterior of left valve, Paratype (PUC/I/ trapezoida 28); X 1.76.
5. *Anadara (Anadara) trapezoida* n. sp., Luangmual (Upper Bhuban Formation); exterior of left valve, Holotype (PUC/I/29); X 2.15.
6. *Anadara (Anadara) trapezoida* n. sp., Serthum (Upper Bhuban Formation); exterior of left valve, Paratype (PUC/I/30); X 1.75.
7. *Anadara (Anadara) trapezoida* n. sp., Zotlang (Upper Bhuban Formation); exterior of left valve, Paratype (PUC/I/31); X 2.0.
8. *Anadara (Lunarca) kachharai* n. sp., Luangmual (Upper Bhuban Formation); exterior of left valve, Holotype (PUC/I/33); X 3.33.
9. *Anadara (Lunarca) kachharai* n. sp., Luangmual (Upper Bhuban Formation); exterior of left valve, paratype (PUC/I/34); X 3.26.



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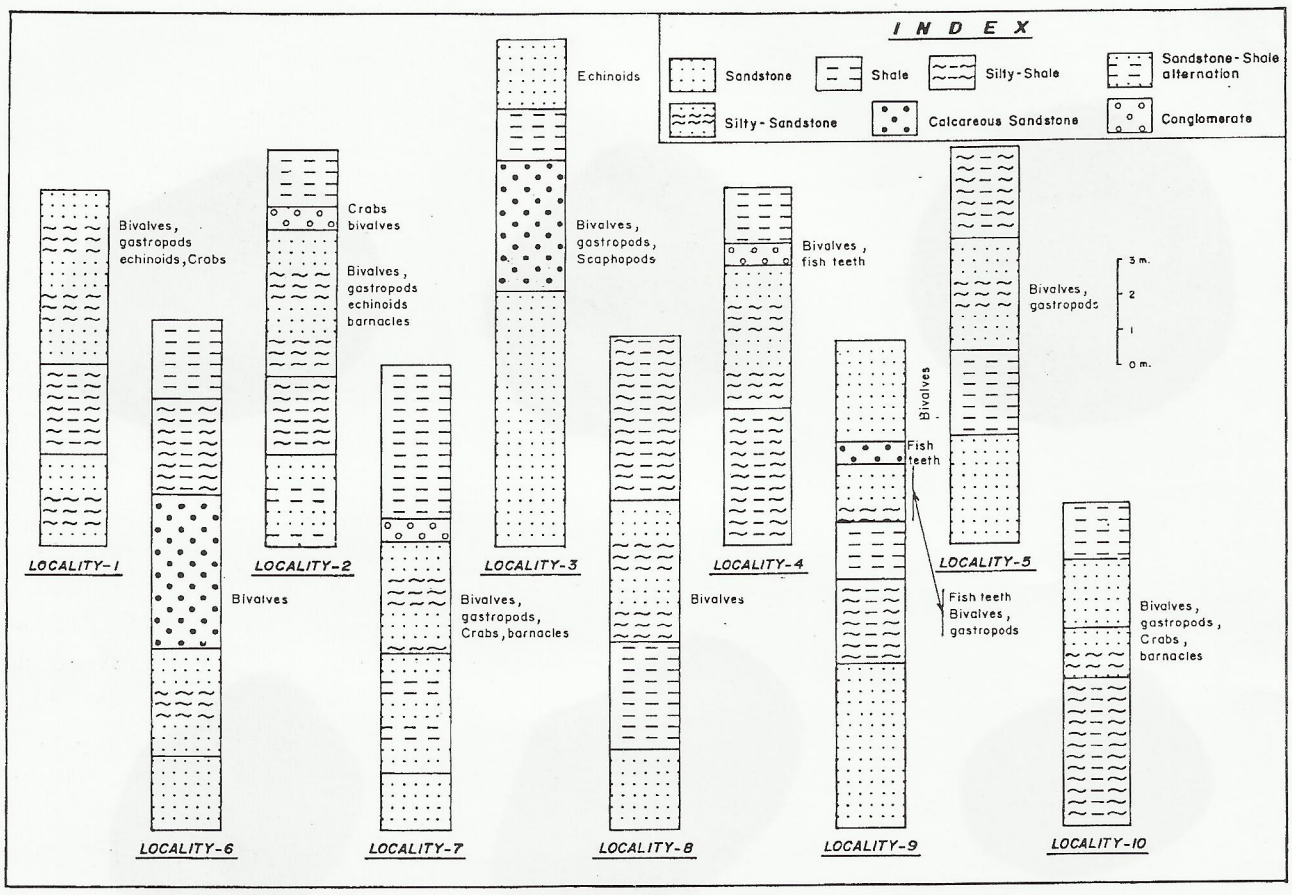

Fig. 3. Measured litho-columns in the middle (6) and Upper Bhuban Formations (1, 2, 3, 4, 5, 7, 8, 9, and 10) at the fossil localities.

Subgenus ***Barbatia*** s. str.

Barbatia (Barbatia) costellata n. sp.

(Pl. I, fig. 3)

Etymology: The species has been named after the paired radial costellae which are characteristic of the species.

Material: Two left valves.

Type Horizon and Locality : Upper Bhuban Formation; Hlimen Quarry (locality no 3).

Measurements in mm:

Specimen No.	Length	Height	Inflation
Holotype PUC/I/4	21.50	16.50 (76.14)	5.10 (23.72) LV
Paratype PUC/I/5	17.00	13.00 (76.47)	4.50 (27.47) LV

Diagnosis: Paired radial costellae with narrow interspaces and the antero-dorsal corner as the farthest anterior point.

Description: Valves small, subtrapezoidal, moderately inflated, inequilateral with height about three-fourth of the length. Umbo fairly prominent and situated at anterior-third of valve length. Antero-dorsal margin short and straight while postero-dorsal one long and inclined at about 25° from the horizontal. Anterior margin broadly rounded, steep and meeting antero-dorsal margin at right angles, the angulation so formed is the extreme anterior part. Posterior margin short and rounded. Ventral margin almost flat and sinuous medially.

A broad, shallow and median groove runs from umbo towards ventral margin. Cardinal area narrow.

Surface sculptured with paired radial

costellae separated by the narrow interspaces. The radials are crossed over by the fine concentrics which inturn produce granules over the ribs.

Internal characters not accessible.

Remarks : The christened species is quite different from the hitherto known forms of *Barbatia* owing to its paired radial costellae with narrow interspaces, and the antero-dorsal corner as the farthest anterior point. However, the comparison is made with the following:

i) *Barbatia kayalensis* Dey (1962, p. 38, Pl. III, fig. 14; GSI collection no. K-24/185) from the Quilon Beds approaches the present form in respect of prosogyrate and anterior-third umbo, vague median depression and radials crossed over by the fine concentrics, but its oblique posterior margin and absence of paired radials distinguish it from the latter.

ii) *Barbatia bataviana* Martin var. *carinata* Noetling (Mukerjee, 1939, p. 25, Pl. I, figs. 12-13; no. K-22/832 of GSI collection), recorded from the sediments of the same age from the Garo Hills of Meghalaya, is distinguished from the described species by its very large size, altogether different configuration and ornamentation.

Genus ***Trisidos*** Roeding, 1798

Type species : *Arca tortuosa* Linné, 1758; OD. Recent; Philippines.

Trisidos cf. *semitorta* (Lamarck)

(Pl. I, fig. 4)

References for the typical *Trisidos semitorta* (Lamarck) are as follows:

Arca semitorta Lamarck, 1819, p. 37.

Arca tortuosa! Sowerby, 1840, Pl. XXV, fig. 13.

Arca kurracheensis d' Archiac and Haime, 1853, p. 263, Pl. XXII, fig. 4.

Arca (*Trisis*) *semitorta* Lamarck: Smith, 1891, p. 432.

Arca (*Parallelepipedum*) *semitorta* Lamarck: Noetling, 1901, p. 151.

Arca semitorta Lamarck: Lamy, 1907, p. 109. - Vredenburg, 1928, p. 417. - Mukerjee, 1939, p. 24, Pl. I, fig. 19. - Kanno *et al.*, 1982, p. 57, Pl. XIV, figs. 5-6.

Material: An ill-preserved left valve.

Horizon and Locality: Middle Bhuban Formation; Lunglawn (locality no. 6).

Measurements in mm:

Specimen (no. PUC/I/6) has: Length- 24.30; Height- 10.50 (43.20); Inflation- 3.50 (14.40, SV).

Remarks: The size of the referred species is quite variable. The example from Dalu, Garo Hills of Meghalaya (GSI no. K-22/895) measures 14.00 mm in length and 7.00 mm in height and the one from Sind 47.00 mm and 21.40mm in length and height respectively. Thus, the present specimen is of intermediate size. The characters such as the narrow cardinal area, prominent radial ribs crossed over by fine concentric lines (clear at places in the posterior part) indicate closeness with *Trisidos semitorta* (Lamarck). But in the absence of well-marked twisting and concentric ornamentation throughout, it is being described as *Trisidos* cf. *semitorta* (Lamarck).

Distribution: Garo Hills (Aquitanian-Burdigalian) of Meghalaya; Gaj of Kachchh, Kathiawar and Sind; Kama Formation (Aquitanian) of Myanmar and Tartaro Formation (Upper Miocene) of Philippines.

Subfamily **Anadarinae** Reinhart, 1935

Genus ***Anadara*** Gray, 1847

Type species: *Arca antiquata* Linné, 1758; OD. Recent; Madagaskar.

Anadara daviesi Mukerjee, 1939

(Pl. I, figs. 6-7)

Anadara garoensis Mukerjee, 1939, p. 28, Pl. I, fig. 14; Pl. II, fig. 1.

Material: One bivalved (opened) specimen, three left valves and a right valve.

Horizon and Localities: Upper Bhuban Formation; Luangmual, Serkawn and Pukpui (Localities nos. 1, 2, 8 and 10).

Measurements in mm :

Specimen No.	Length	Height	Inflation
PUC/I/7	31.50	18.10 (57.46)	7.60 (24.12) LV of bivalved specimen
PUC/I/8	13.50	7.70 (57.03)	3.30 (24.44) LV
PUC/I/9	16.90	9.00 (56.25)	4.00 (25.00) RV
PUC/I/10	10.90	6.40 (58.71)	2.50 (22.93) LV
PUC/I/11	11.20	6.50 (58.03)	2.70 (24.10) LV

Remaks: The diagnostic characters of *Anadara daviesi* Mukerjee such as elongate sub-ovate outline, height about 55-60 per cent of the length, moderate inflation, oblique posterior margin, broad and flattened radial ribs and distinct granulations towards anterior to anterior-third of the umbo are well marked in all the studied specimens. Particularly, the illustrated specimen (no PUC/I/7) of the present collection, agrees well with the type specimen (GSI no. 16380) from Baghmara, Garo Hills. The species is said to bear 38 ribs; however, in the present collection these vary in number from 22-35. It is observed that the smaller the size of the specimen, lesser the number of the ribs and vice versa.

Distribution: Garo Hills (Aquitanian-Burdigalian) of Meghalaya, India.

Anadara craticulata (Nyst)

(Pl. I, fig. 5)

Arca clathrata Reeve, 1844 (non Defrance, 1816), p. 44. - Nyst, 1847, p. 22

Arca burnesi d' Archiac & Haime, 1853, p. 264, Pl. XXII, fig. 5.

Scapharca pygmaea Adams, 1857, p. 2, Pl. III, fig. 5

Arca burnesi d' Archiac & Haime: Martin, 1885, p. 245, Pl. XII, fig. 50. - d' Archiac & Haime: Noetling, 1901, p. 131, Pl. V, figs. 6-10.

Arca clathrata Reeve: Lamy, 1907, p. 229.

Arca (Scapharca) burnesi d' Archiac & Haime: Tesch, 1920, p. 97, Pl. CXXXVIII, fig. 258.

Arca clathrata Reeve var. *burnesi* d' Archiac & Haime: Vredenburg, 1928, p. 241.

Anadara craticulata (Nyst): Cox, 1930, p. 150. - Mukerjee, 1939, p. 26, Pl. I, figs. 7, 15. - Dey, 1962, p. 39.

Anadara (Anadara) burnesi d' Archiac & Haime: Shuto, 1973, p. 20, Pl. II, figs. 7,8,14.

Material: One left and three right valves.

Horizon and Locality: Middle and Upper Bhuban Formations; Luangmual, Hlimen Quarry and Lunglawn (Locality nos. 1, 2, 3 and 6).

Measurements in mm:

Specimen No.	Length	Height	Inflation
PUC/I/12	22.00	14.30 (65.00)	5.50 (25.00) LV
PUC/I/13	18.30	12.00 (65.57)	4.70 (25.73) RV
PUC/I/14	17.50	10.80 (61.71)	4.40 (25.14) RV
PUC/I/15	10.60	7.00 (66.03)	3.00 (28.30) RV

Remarks: The specimens are well preserved and are referable to *Anadara craticulata* (Nyst) in view of their broadly elliptical outline, moderate inflation, unequal radial ribs with granulation on anterior side, umbonal position and close resemblance to its representatives from the Garo Hills (GSI type no. K-20/830; Mukerjee, 1939).

Distributions: Garo Hills (Aquitanian-Burdigalian) of Meghalaya; Lower Gaj (Aquitanian) of Kachchh (Vredenburg, 1928); Quilon Beds (Vindobonian) of Kerala (Dey, 1962) and Neogene of Panay Island, Philippines (Shuto, 1973).

Anadara garoensis Mukerjee

(Pl. I, figs. 8-9)

Anadara garoensis Mukerjee, 1939, p. 26, Pl. I, figs. 6,16; Pl. II, figs. 2-3

Material: Five left and two right valves.

Horizon and Locality: Upper Bhuban Formation; Luangmual, Rangvamual and Hauruang (Locality nos. 1, 2, 4 and 7).

Measurements in mm:

Sp. No.	Length	Height	Inflation	NR
PUC/I/16	12.40	11.00 (88.68)	4.40 (31.14) RV	30
PUC/I/17	18.00	14.90 (83.33)	6.00 (33.33)LV	30
PUC/I/18	14.00	11.00 (78.57)	3.90 (27.85) LV	29

PUC/I/19	17.00	14.00 (82.11)	6.00 (32.29) LV	30
PUC/I/20	19.00	17.00 (89.47)	7.00 (36.84) LV	31
PUC/I/21	15.20	12.00 (78.93)	4.50 (29.60) LV	30
PUC/I/22	13.60	10.00 (72.72)	4.00 (29.41) RV	29

Remarks: All the specimens referred here agree well with the representatives of *Anadara garoensis* Mukerjee (1939) from the Garo Hills, Meghalaya, housed in GSI, Calcutta (no. 16376, 16377-79) in respect of sub-rhomboidal outline, number (around 30) and nature of radial ribs and inflation. However, the present specimens have relatively sharper carina which may possibly fall within the range of variation.

Distribution: Garo Hills (Aquitanian - Burdigalian) of Meghalaya.

Anadara cf. *gourae* Dey

(Pl. I, fig. 10)

Anadara cf. *gourae* Dey, 1962, p. 40, Pl. I, fig. 10; Pl. IX, fig. 6.

Material: An ill-preserved right valve.

Horizon and Locality: Upper Bhuban Formation, Luangmual (locality no. 1)

Measurements in mm:

Lone specimen (PUC/I/23) measures 20.00 in length, 19.00 (95.00) in height and 6.50 (32.50) in the inflation of right valve.

Description: Valve small, obliquely trapezoidal, highest near the posterior end, moderately inflated, maximum inflation being along the carina. Umbo salient and situated at about the anterior-fourth of the length; cardinal area narrow but shallow. Anterior margin rounded; posterior truncated and steeply inclined; antero-dorsal part short; postero-dorsal long and gently inclined; ventral margin oblique and parallel to the postero-dorsal one.

An obtusely angular carina runs from umbo to the postero-ventral corner separating a large and slightly concave posterior area. Flank is moderately sloping.

Surface sculpture is in the form of radial ribs which are discernible on the flank along the ventral margin adjacent to the carina.

Interior not visible.

Remarks: The present example from the Luangmual, Aizawl, on comparison, is found to match well with the Quilon species, viz., *Anadara* cf. *gourae* Dey (1962) in all respects and shows a good resemblance to the GSI type specimen (no. 16415) described under the same name.

Dey (1962) remarked that *Anadara* cf. *gourae* differs from the typical *Anadara gourae* Dey (1962, p. 39, Pl.I, figs. 4-8; Pl. IX, fig. 4) in having higher degree of convexity and its postero-dorsal end extending beyond the postero-ventral corner. However, the inadequate material and poor preservation do not allow to describe it as a new species.

Distribution: Quilon Beds (Vindobonian) of Kerala.

Anadara (*Anadara*) *luangmualensis* n. sp.

(Pl. II, figs. 1-2)

Etymology: The trivial name is derived after the type locality, i.e. Luangmual, Aizawl.

Material: One left and a posteriorly broken right valves.

Type Horizon and Locality : Upper Bhuban Formation; Luangmual (Locality no. 2).

Measurements in mm:

Sp. No.	Length	Height	Inflation
Holotype PUC/I/25	9.00	8.00 (88.88)	5.00 (55.55)LV
Paratype PUC/I/26	12.00 (c)	11.00 (91.66)	6.80 (56.66)RV

Diagnosis: Subquadrilateral outline, height about ninety per cent of the length, strongly and evenly convex flank, steeply inclined posterior area with wing-like posterior end, and thin and closely spaced radials crossed over by fine

concentric lines producing a reticulate pattern.

Description : Valves small for the genus, subquadrilateral, height a little less than the length, strongly inflated, maximum inflation being along the carina. Umbo small, curved, pronouncedly prosogyrous and anterior to the median portion. Antero-dorsal and anterior margins evenly rounded; postero-dorsal part slightly broken but appears to be truncated; ventral margin feebly arched.

Cardinal area short, narrow and deep. Hinge straight and slightly less than the length.

A slightly curved carina runs from umbo to the postero-ventral corner. It is sharp and angular in the dorsal half and gradually becomes rounded in ventral one. Flank is strongly but evenly convex. Posterior area is concave and steeply inclined with the wing- like posterior end. Flank as well as posterior area bear thin and closely spaced radials which are crossed over by fine concentric lines producing a reticulate pattern.

Dentition not exposed.

Remarks : Height to length ratio and rounded anterior margin of the proposed new species are similar to *Anadara garoensis* Mukerjee (1939, p. 26, Pl. I, figs. 6, 16; Pl. II, figs. 2-3; GSI type no. 16376) but the latter differs in having sub-rhomboidal outline and coarse radial ribs.

Anadara (*Anadara*) *tambacana* (Martin), known from the Neogene beds of Panay Island, Phillippines, described and illustrated by Shuto (1973, p. 11 and 14, Pl. II, figs. 9,11,12,; Pl. III, figs. 14 17), also has an elevated, incurved and anteriorly directed umbo but can be distinguished from the present one by its rhomboid-orbicular outline and obliquely truncated anterior and posterior margins.

Regularly rounded anterior margin and nature of posterior area of the species *Anadara* (*Anadara*) *verbeeki* (Woodward), described and figured by Shuto (1982, p. 106, Pl. XVII, figs 1-24; Pl. XIX, figs. 5, 8, 9, 20 and 21) from the Miocene beds of Negros Island, express similarity with the new species. But the Negros Island form differs in respect of elongate-ovate outline and in bearing finely crenulated radial ribs.

Anadara (*Anadara*) *zotlangensis* n. sp.

(Pl. II, figs. 3-4)

Etymology: The trivial name is derived after its occurrence in Zotlang, Lunglei, Mizoram.

Material: Two left valves.

Type Horizon and Locality: Upper Bhuban Formation; Zotlang (Locality no. 9).

Measurements in mm:

Specimen No.	Length	Height	Inflation
Holotype PUC/I/27	21.00	16.00 (76.19)	9.00 (42.85) LV
Paratype PUC/I/28	21.00	16.50 (77.57)	8.50 (44.76) LV

Diagnosis: Outline sub-ovate, height about three-fourth of the length, strongly inflated, umbo situated anterior-fourth of the valve length, carina elongated and obtusely rounded and posterior area moderately sloping and slenderly concave.

Description: Valves medium sized, sub-ovate, height about three-fourth of the length and strongly inflated. Maximum inflation is below the umbo at about mid-height. Umbo small, incurved, salient, situated at about anterior-fourth of the valve length; umbonal ridges meeting at a moderately acute angle. Dorsal margin more or less straight and slightly less than the length of the valve. Both anterior and posterior margins are rounded but the former is slightly shorter than the latter. Ventral margin slightly oblique and inclined downwardly towards the posterior end.

Cardinal area small.

Anterior carina is steep and smaller than the posterior one which is elongate and obtusely rounded, surface between these two is gently convex. Anterior area is much smaller than the moderately sloping and slenderly concave posterior area.

Surface bears 35 strong and evenly spaced radial ribs with a shallow groove on each one. The ribs are curved outwardly in both the areas.

Interior could not be exposed.

Remarks: The largest example from Meghalaya recorded under the name *Anadara craticulata* (Nyst) (Mukerjee, 1939, p. 26, Pl. I, figs 7 and 15) is, size-wise and in length to height ratio, close to the present form but its broad, elliptical outline and unequal radial ribs do not allow its merger with the latter.

Anadara (*Anadara*) *nodifera* (Martens), an Upper Miocene species described and illustrated by Kanno *et al.* (1982, p. 60, Pl. XIV, figs. 2a-b) from the Tartaro Formation of Luzon, Phillippines has similar disposition of radial ribs as in the present form but can be distinguished by its strong granulations all over the ribs and ovately rounded outline.

The example at hand has configuration more or less similar to that of the Oligocene species *Anadara chichibuensis* Hatai and Nishiyama (Oyama *et al.*, 1960, p. 109, Pl. XXIV, figs. 3, a-b), which, however, differs from the new species in its tall stature and umbonal position with reference to the valve length. In *A. chichibuensis,* the umbo is situated at about anterior third of the valve length.

Anadara (*Anadara*) *trapezoida* n. sp.

(Pl. II, figs. 5-7)

Etymology: The trivial name is derived from its trapezoidal outline.

Material: Three left valves and one right valve.

Type Horizon and Locality: Upper Bhuban Formation; Luangmual, Serthum and Zotlang (Locality nos 2, 5 and 9).

Measurements in mm:

Specimen No.	Length	Height	Inflation
Holotype PUC/I/29	22.00	14.10 (64.09)	8.00 (36.36)LV
Paratypes PUC/I/30	20.30	14.00 (68.96)	7.70 (37.93)LV
PUC/I/31	—	22.50	9.20 LV
PUC/I/32	21.00	14.00 (66.66)	7.80 (37.10) RV

Diagnosis: Umbo subterminal, outline obliquely trapezoidal, posterior carina angular, posterior margin steeply sloping, becoming almost flat at its extreme end and postero-dorsal and ventral margins almost parallel.

Description: Valves small to medium sized, obliquely trapezoidal, height about two-thirds of length and strongly inflated, maximum inflation being at about mid-height along a ridge from the umbo. Umbo subterminal, acute, incurved and slightly prosogyrous. Cardinal area small and narrow. Anterior margin near the umbo is concave and becomes feebly convex in ventral half. Postero-dorsal margin long, more or less straight and parallel to slightly arched ventral margin. Posterior margin truncated.

There are two umbonal ridges, of which the anterior one is short, steeply sloping and almost vertical, whereas the posterior one is long, angular and runs from umbo to postero-ventral corner. Surface posterior to the ridge is steeply sloping but becomes flat at the posterior extremity. Flank between the ridges is evenly convex but falls rapidly towards ventral.

Shell surface between anterior extremity and posterior umbonal ridge is ornamented with 20 radial ribs, of which seven anterior and six

posterior ribs are bifurcating. The radial ribs have tendency to fade out towards posterior margin; therefore, posterior area bears indistinct radials. Flank as well as areas are crossed over by fine, closely spaced concentric lines producing granulations over the ridge which is well marked between the two umbonal ridges.

Internal characters not observable.

Remarks : The species in question is quite distinct from the rest because of its almost terminal umbo, obliquely trapezoidal outline and tendency of radial ribs to fade out gradually towards posterior margin. However, its comparison is made with *Anadara garoensis* Mukerjee (1939, p. 26, Pl. I, figs 6, 16; Pl. II, figs. 2-3; GSI type no. 16376) in view of similar type of posterior umbonal ridge, but the latter can be separated by its equally prominent radial ribs throughout the shell surface and anterior-third umbonal position.

Anadara sp.

(Pl. I, fig. 11)

Material: One left valve.

Horizon and Locality: Upper Bhuban Formation; Hlimen quarry (Locality no. 3).

Measurements in mm:

The specimen (PUC/I/24) measures: Length-28.00(c); Height-24.00(85.71); Inflation- 11.50 (41.71, SV)

Description and Remarks: The valve at hand is slightly broken posteriorly and partly covered under matrix anteriorly; therefore, detail descrption and comparison is not possible. However, ornamentation is well preserved and consists of 32 radial ribs inclusive of both primaries and secondaries. The primaries have tendencies to bifurcate due to presence of a groove on each rib. A few tertiaries are also present in the anterior side which persist on lower part only and do not continue up to the dorsal side and give an impression as if primaries are trifurcating. Ribs thin out from flank towards the posterior area.

Furcation of the ribs and strong inflation suggest closeness with *Anadara gourae* Dey (1962) but on account of the secondaries and tertiaries, which are not visible in the typical form, it is not presently possible to suggest its specific status.

Subgenus ***Lunarca*** Gray, 1857

Type species: *Lunarca costata*, Gray, 1857; OD. Recent; USA

Anadara (*Lunarca*) *kachharai* n. sp.

(Pl. II, figs. 8-9)

Etymology: The species name is named in honour of Professor R. P. Kachhara of Nagaland University for his contribution to Palaeontology.

Materail: Two left and one right valves.

Type Horizon and Locality: Upper Bhuban Formatiom; Luangmual (locality no.1 and 2).

Measurements in mm:

Sp.	No.	Length	Height	Inflation	NR
Holotype	PUC/I/33	7.20	5.80 (80.55)	2.30 (31.94) LV	23
Paratypes	PUC/I/34	13.00	10.10 (77.60)	4.00 (30.77) LV	30+
	PUC/I/35	16.00	13.50 (84.37)	5.20 (32.00) RV	30

Dignosis: Outline suborbicular to subovate, umbo forwardly directed, submedian to anterior-third, postero-umbonal ridge mild and long, feebly arched posterior series of converging teeth with increasing size outwardly.

Description: valves small, outline suborbicular to subovate, height more than three-quarters and moderately inflated. Umbo forwardly directed and submedian to anterior-third of the shell length. Cardinal area inconspicuous. Antero-dorsal margin short; postero-dorsal margin long and gently arched; anterior, ventral and posterior margins are merging with each other without any angulation.

Valve surface is more or less convex except

for the presence of a mild posterior umbonal ridge. The ridge runs from the umbo to mid-height, gradually broadens afterwards and ultimately dies out.

Surface sculpture consisting of 23-30 radial ribs, their number increasing with size. Ribs are in the form of strong costae and correspond to interlocking crenulations of the valve margins.

Dentition consists of a long feebly arched posterior series of converging teeth which increase in size outwardly. Anterior series short and irregular. Other internal characters are not exposed.

Remarks: This may be the first record of the subgenus from the Miocene sediments of India. As compared to the genotype *Anadara* (*Lunarca*) *costata* Gray, Newell (in Moore *et al.*, p. N254, figs C3, 5,a-b), a Recent species, the present form agrees well in overall configuration, surface sculpture and dentition. The pronouncedly forward umbo and large size, however, differentiate it from the described one. No other form is available for comparison.

Superfamily **Limopsacea** Dall, 1895

Family **Glycymeridae** Newton, 192

Genus ***Glycymeris*** da Costa, 1778

Type species: *Arca orbicularis* da Costa, 1778(=*Arca glycymeris*, 1758); Tautonomy. Recent; Mediterranean.

Glycymeris sindiensis (Vredenburg)

(Pl. I, fig. 12)

Non *Pectunculus pecten* J. de C. Sowerby, 1840, Pl. XXIV, fig. 4.

Pectunculus pecten J. de C. Sowerby: d' Archiac & Haime, 1853 p. 266, Pl. XXIV, fig. 13.

Pectunculus pectiniformis Lamarck: Martin, 1885, p. 237, Pl. XII, fig. 241.

Pectunculus sindiensis Vredenburg, 1928, p. 419.

Glycymeris sindiensis (Vredenburg): Pascoe, 1973, p. 1644.

Material: One left valve.

Horizon and Locality: Middle Bhuban Formation; Lunglawn (Locality no.6).

Measurements in mm:

Specimen (PUC/I/36) is 12.50 in length and 13.00 (104.00) in height.

Remarks: The recorded specimen satisfactorily shows all the essential characters of *Pectunculus sindiensis* described by Vredenburg (1928) from the Lower Gaj of Sind. Hence, it is named accordingly. It differs from *Glycymeris pecten* (Sowerby) described and figured by Dey (1962, p. 36, Pl. I, figs, 16-17) from the Quilon Beds of Kerala in possessing a large numbers of radial ribs.

Distrubution: Lower Gaj (Aquitanian) of Kachchh, Gujarat.

DISCUSSION

Tiwari and Kachhara (2000) proposed three bivalve zones in the Bhuban sediments of Mizoram. These in the ascending order are: *Glycymeris sindiensis- Nuculana virgo* Zone (1) of Aquitanian age; *Chlamys senatotia-Pinna* Zone (2) of Aquitanian-Burdigalian age (2A. *Mactra protoreevisii* Subzone and 2B. *Diplodonta incerta-Diplodonta rotundatus* Subzone) and *Pecten pascoei* Zone (3) of Burdigalian age. The distribution of the above described fossil assemblage in these zones is as follows:

Trisidos cf. *semitorta* (Lamarck) and *Glycymeris sindiensis* (Vredenburg) belong to zone 1; *Arca feddeni* Vredenburg, *Arca newtoni* Vredenburg, *Barbatia* (*B.*) *costellata*, n. sp., *Anadara* cf. *gourae* Dey and *Anadara* sp. belong to zone 2A and *Anadara* (A.) *luangmualensis* n. sp., *Anadara* (*A.*) *zotlanglensis* n. sp. and *Anadara* (A.) *trapezoida* n. sp. to zone 2B. *Anadara* (*Lunarca*) *kachharai* n. sp. range from zone 2A to 2B; *Anadara craticulata* (Nyst) from zone 1 to 2B, whereas *Anadara daviesi* Mukerjee and *Anadara garoensis* Mukerjee

from zone 2A- zone 3.

The present fossil assemblage, therefore, indicates the Aquitanian age for the Middle Bhuban Formation, and Aquitanian-Burdigalian to Burdigalian age for the Upper Bhuban Formation of the Bhuban Subgroup. The other associated bivalves, gastropods, echinoids and fishes also support these ages for the Bhuban sediments (Tiwari *et al.*, 1998).

Barbatia sp. is a suspension feeder, byssate nestler among stones and branching corals and lives in the transition zone at 10-45m depth. *Anadara* sp. and *Trisidos* sp. are also byssate nestles. *Glycymeris* sp. rolls over the substrate, whereas *Arca* sp. inhabits relatively deeper zone (Bera *et al.*, 1996). The present assemblage is, therefore, dominated by byssate nestlers and indicates deposition of the fossiliferous horizons in the inner-neritic to littoral zones.

Majority of the specimens are single valved and may not be autochthonous.

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