



MOLLUSCAN FAUNA FROM THE UPPER DISANG FORMATION OF MANIPUR, INDIA: THEIR BIOSTRATIGRAPHIC IMPLICATIONS

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ABSTRACT

Molluscan fauna have been studied from the Upper Disang Formation of Disang Group of the Imphal valley in Manipur region, India. Altogether 108 taxa have been recorded, in which 80 taxa are of bivalves and 28 taxa belong to gastropods. Some of these taxa are biostratigraphical markers and used here for creating biozones. Based on these taxa, three biozones have been established that characterize Zone-I *Caestocorbula (Parmicorbula) regubiensis*-*Flemingostrea pharaonum* var.-*aviculina* zone, Zone-II *Vulsella pakistanica*-*Corbula (Varicorbula) daltoni* and Zone-III *Callista (Callista) yawensis*-*Lucina (Lucina) yawensis* equivalent to Thanetian-Ypresian, Lutetian-Bartonian and Priabonian ages. This is the first study to demonstrate the applicability of molluscan fauna for detailed stratigraphic set up in the Indo-Myanmar range, India with reference to global time scale.

Keywords: Molluscan fauna; Biostratigraphy; Upper Disang Formation; Imphal valley; India

INTRODUCTION

Imphal valley is confined in the central part of Manipur which belongs to the north-eastern region of India and shares with international border of Myanmar on the eastern and southern sides. The remaining half of this state is neighboured to the states of Nagaland, Assam and Mizoram on the northern, western and south-western sides respectively (Fig. 1). It lies approximately between 23° 50' N - 25° 41' N latitudes and 93° 02' E - 94° 41' E longitudes. Mishra (1990, 1991, 1993); Kachhara *et al.* (2000); Pal and Mishra (2005); Chungkham and Jafar (1998); Chungkham *et al.* (1992); Singh *et al.* (2010); Sijagurumayum *et al.* (2011, 2014); Singh and Meera (2013); Singh *et al.* (2013, 2014, 2015), Sijagurumayum (2015) and Singh *et al.* (2016) have contributed considerably towards fossil wealth including organic matter, palynomorphs, planktonic foraminifers and molluscs from this region. Most of the earlier workers commented on the fauna recovered from Ukhrul and Chandel districts of Manipur region. Besides, few sporadic finds in the Imphal valley, there is no detailed work on the fauna of this area.

The present study is the first detailed molluscan biostratigraphy of Paleogene deposits from Changamdabi area of the Imphal valley. It examines molluscan fauna mainly bivalves and gastropods from three sections of this region. Based on the molluscan fauna recovered from this formation, we recognized three biostratigraphic zones with reference to the global standard time scales.

GEOLOGICAL SETTING

An account on the geology of the Manipur region is given by Theobald (1871); Oldham (1883); Pascoe (1912); Evans (1932); Dayal and Daura (1965); Nandy (1980); Mitra *et al.* (1986); Bhattacharya and Bhattacharya (1987) and Soibam

(1998). The Paleogene rocks are well exposed in the form of scattered outcrops in the Imphal valley where the oldest rocks occur in the eastern part of Manipur which shares international border with Myanmar on the eastern and southern sides and youngest rocks occur in the western side of this region (Fig.2). The Cretaceous and Tertiary sedimentary rocks are dominant in the Manipur state. Here, the Paleogene rocks are represented by the Disang and Barail groups. The Disang Group is subdivided into two formations namely, Lower Disang and Upper Disang formations. The Upper Disang Formation is represented by rhythmic intercalation of shale, siltstone, and greywacke with fossils and that of Lower Disang Formation is made up of shale, greywacke and thin sandstone bands. The Changamdi area is part of the Imphal valley that represents an intermountane depression within the Indo-Myanmar Range (IMR). The Imphal valley is believed to have evolved as a tectonic basin in the later phase of Indo-Myanmar Range tectogenesis (Soibam and Khuman, 2008). Stratigraphically, the Disang and Barail successions are mainly exposed in the Imphal valley where the former is exposed in the study area.

MATERIALS AND METHODS

The systematic collection of bivalves and gastropods for the present paleontological investigation were carried out from three measured stratigraphic sections namely, Canal Section (US₁ Section; GPS N24°41'54.4": E94°06'05.9"), Maning Ching (US₂ Section; GPS 24°41'34"N: 94°05'07"E) and Khongjai Chingkhong Section (US₃ Section; GPS 24°41'42"N: 94°0.5'57"E) located in and around Changamdi, Manipur (Fig. 1). The specimens recorded here are mainly external casts and moulds so the internal bivalve characters could not be studied. All the litho-units were searched for fossils and after a thorough search few fossiliferous beds were delineated i.e. Bed No. 3 in US₃ section, Bed Nos. 4 and 8 in US₂ section and Bed No. 8 in

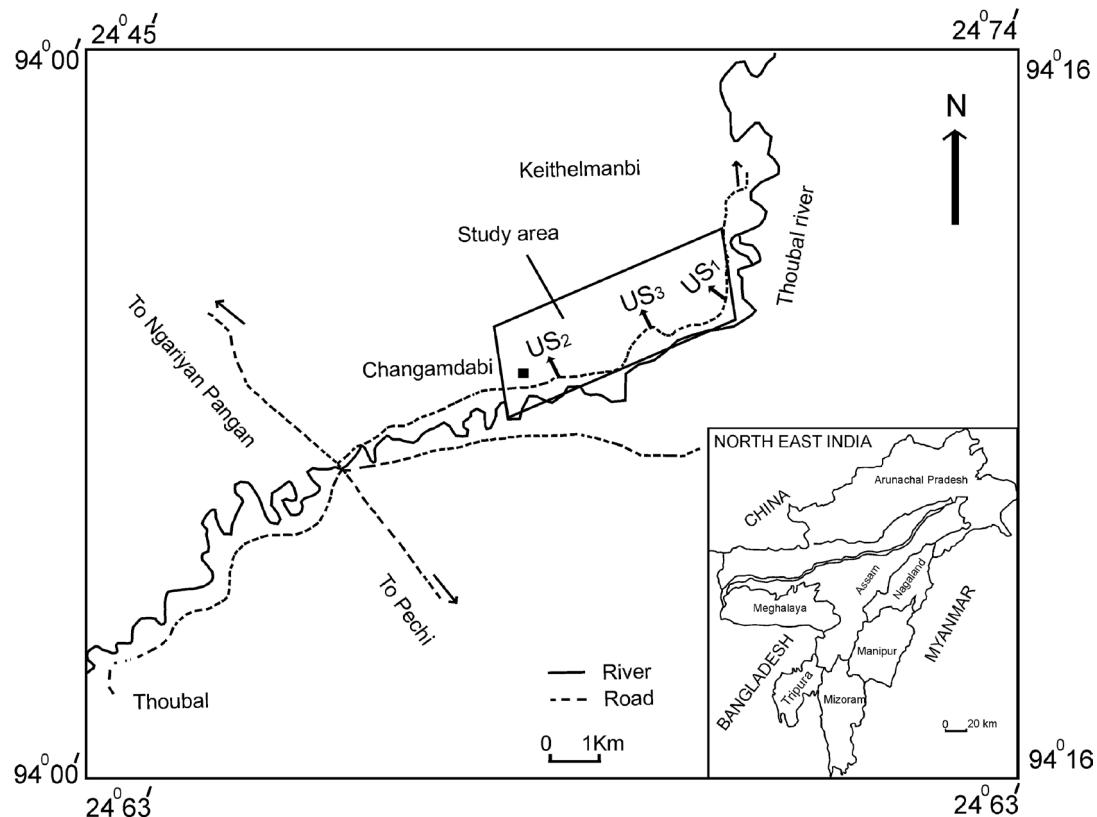


Fig. 1. Location map of the study area showing sample localities.

US₁, section (Figs. 3 & 4). The molluscan fauna has been studied in detail after the samples were prepared for their identification with the help of relevant literature. Identification was confirmed by comparison with type specimens housed at Geological Survey of India, Paleontological Laboratory, Kolkata.

RESULTS

Molluscan assemblage

Fossil collection comprised more than one thousand individuals of which a sizable component was discarded due to very poor preservation or fragmentary nature. In spite of all these hindrances as many as 108 taxa i.e. 80 of bivalves and 28 of gastropods have been identified. Biostratigraphic scale for the area has to be solely on the basis of bivalves due to the insufficient number of the gastropods. These 80 bivalve species belong to 51 genera grouped into 30 families, 7 orders and 4 subclasses. The distribution and range charts of species zone wise are shown in Tables 3, 4, 5. The representative taxa have been shown in Figs. 5, 6.

Bivalves

The checklists of bivalves are given in Table 1. Out of these, 22 genera have not been earlier reported from Manipur such as *Bathyarca*; *Cucullaea*; *Protonoetia*; *Trigonodesma*; *Mytilaster*; *Lithophaga*; *Aviculoperna*; *Vulsella*; *Gryphaeostrea*; *Cubitostrea*; *Flemingostrea*; *Chama*; *Trapezium*; *Venerella*; *Pholas*; *Martesia* and *Pholadomya*. The 5 genera namely *Boeuvia*; *Lentidium*; *Cyrtodaria*; *Laternula* and *Pecchiolia* are not known from Eocene beds of India till date.

The four bivalve taxa *Protonoetia manipurensis*,

Aviculoperna chagamdabiensis, *Venericardia* (*Venericardia spondyliformis*) and *Trachycardium* (*Trachycardium yairipokensis*) have been created by Sijagurumayum et al. (2014). Two taxa *Septifer manipurensis* n. sp. and *Chlamys* (*Chlamys multistriata*) Deshayes var. *bijui* have been newly created. The thirty taxa have been recorded for the first time from Manipur (Table 6). Out of remaining 36 taxa, *Boeuvia pulchella* and *Cyrtodaria rutupiensis* are reported for the first time from the Eocene beds of India (Table 6).

SYSTEMATIC DESCRIPTION

- Order **Mytiloida** Ferussac, 1822
- Superfamily **Mytilacea** Rafinesque, 1815
- Family **Mytilidae** Rafinesque, 1815
- Subfamily **Mytilinae** Rafinesque, 1815
- Genus **Septifer** Recluz, 1848

(Type species: *Mytilus bilocularis* Linné, 1758; SD Stoliczka, 1871, Recent; Indo-Pacific).

Subgenus Septifer s.s.

- Septifer* (*Septifer*) *manipurensis* n. sp.
(Fig. 6 A, B)

Derivation of name: The species is being named after the state of Manipur, India from where the specimens have been done.

Diagnosis: Shell mytiliform with expanded posterior, inflation is maximum along a curved ridge, rectilinear hinge about four-fifth of the length, bifurcating radials at posterior extremity and crenulated margin.

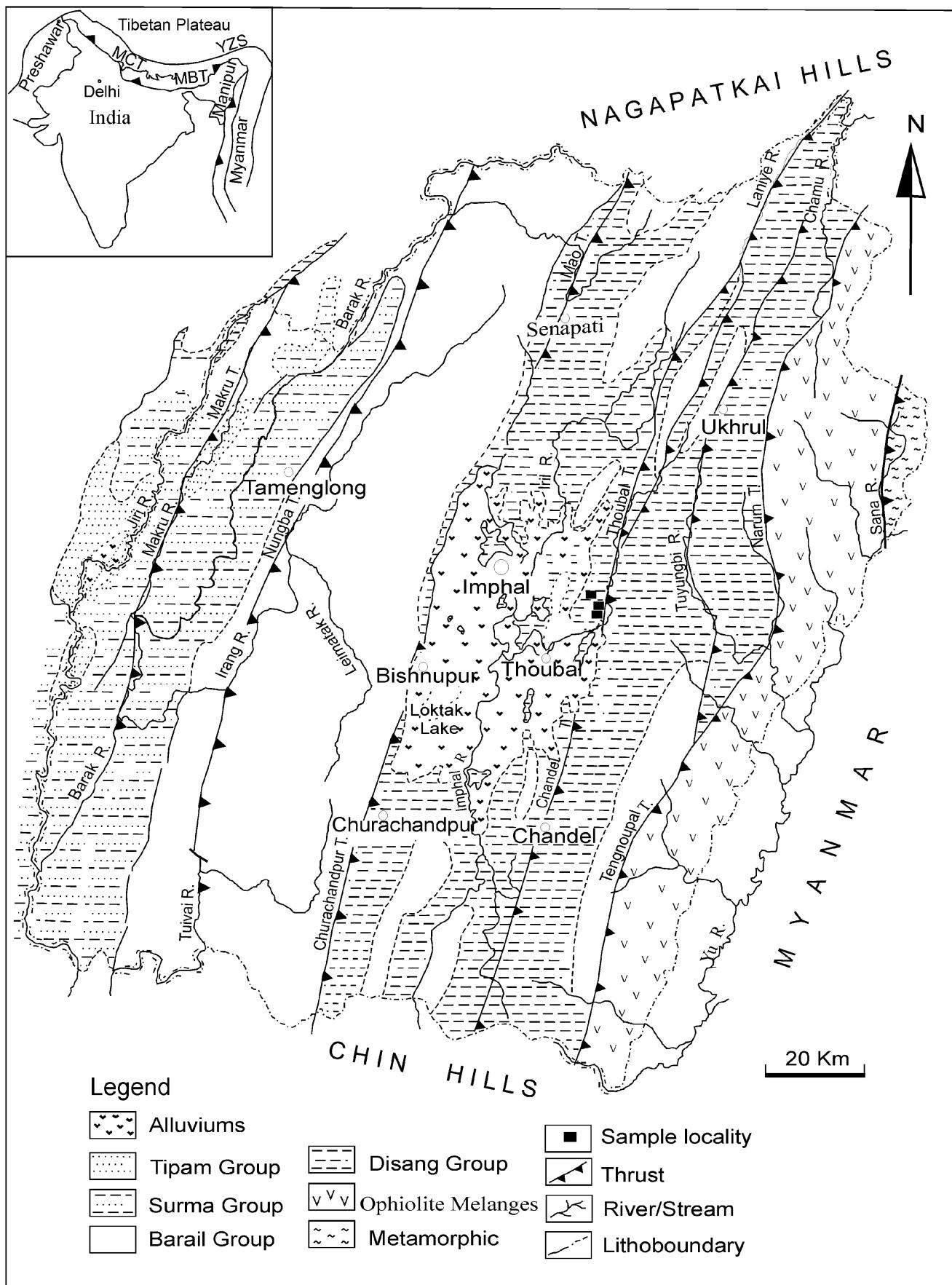
Fig. 2. Geological map of Manipur (After Singh *et al.*, 2013).



Fig. 3. A, Fossiliferous bed 8 of US₁ Section; B-C, Fossiliferous beds 4 and 8 of US₂ Section; D, Fossiliferous bed 3 of US₃ Section.

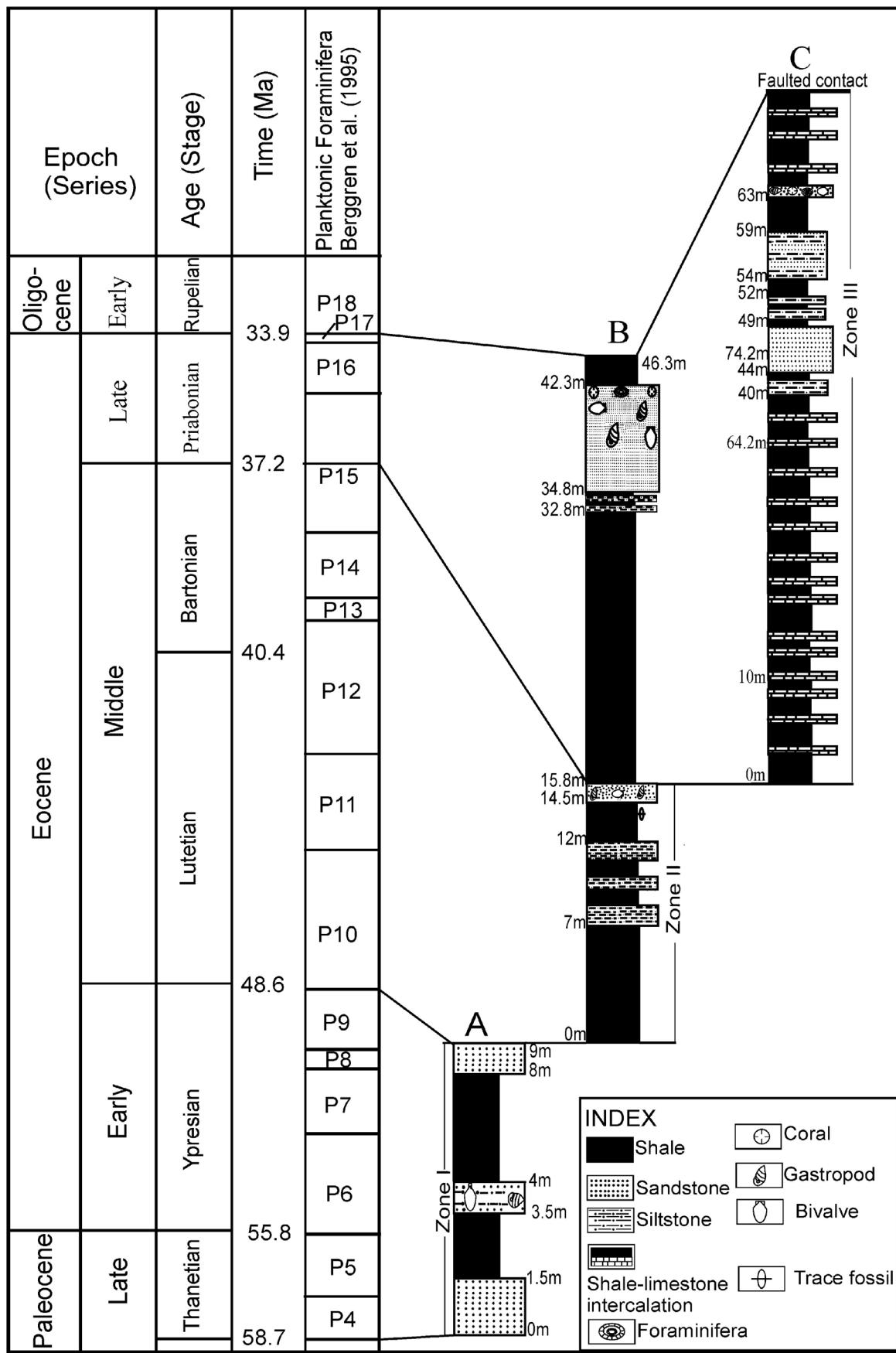


Fig. 4. Biostratigraphic zones of the Upper Disang Formation at the fossil localities (A, US₃, Khongjai Chingkhong Section; B, US₂, Maning Ching and C, US₁, Canal Section). Standard time-scale is given in the left.

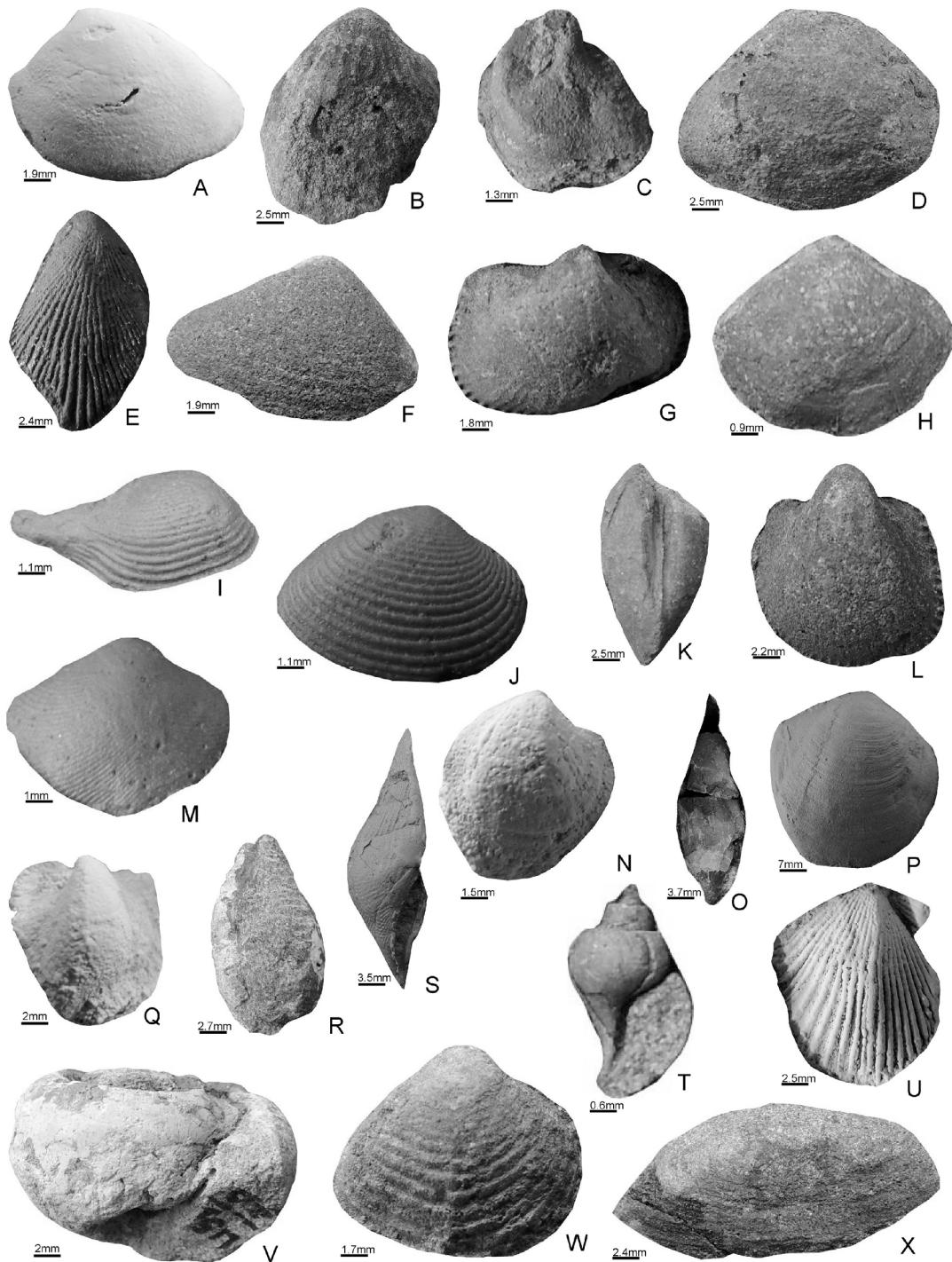


Fig. 5. A, *Nucula (Leionucula) baboensis*, Specimen No. US₃/806, internal mould of right valve; B, *Venericardia (Venericardia) gilli*, Specimen No. US₃/482, external mould of left valve; C, *Flemingostrea pharaonum* Oppenheim var. *aviculina*, Specimen No. US₃/722, external mould of left valve; D, *Tellina (Tellina) pakistanica*, Specimen No. US₂-5/592, external mould of left valve; E, *Septifer (Septifer) cf. denticulatus*, Specimen No. US₃/805, external mould of left valve; F, *Corbula (Varicorbula) daltoni*, Specimen No. US₂-8/610, external mould of left valve; G, *Venericardia (Venericardia) hollandi*, Specimen No. US₂-5/476, external mould of left valve; H, *Venerella parva*, Specimen No. US₃/710, external mould of left valve; I, *Caestocorbula (Parmicorbula) regulbiensis*, Specimen No. US₃/811, external mould of right valve; J, *Astarte (Astarte) filigera*, Specimen No. US₃/727, external mould of left valve; K, *Callista (Costacallista) punjabensis*, Specimen No. US₂-8/907, external mould of right valve; L, *Vepricardium (Hedecardium) sharpei*, Specimen No. US₂-5/927B, external mould of left valve; M, *Boeuvia pulchella*, Specimen No. US₃/875, external mould of left valve; N, *Glycymeris (Glycymeris) brevirostris*, Specimen No. US₃/695, internal mould of left valve; O, *Terebellum fusiformopse*, Specimen No. US₂-5/1, apertural view; P, *Lucina (Lucina) yawensis*, Specimen No. US₁/923B, external mould of left valve; Q, *Noetia (Noetia) harudiensis*, Specimen No. US₂-5/570, external mould of right valve; R, *Volvaria* cf. *birmanica*, Specimen No. US₂-5/382; S, *Rimella pakistanica*, Specimen No. US₂-5/73, apertural view; T, *Clavilithes songoensis*; Specimen No. US₃/660, U, *Chlamys (Chlamys) soriensis*, Specimen No. US₂-5/20, external mould of left valve; V, *Galeodea archiaci*, Specimen No. US₂-5/12, apertural view; W, *Meretrix agrestris*, Specimen No. US₂-5/303, external mould of left valve; X, *Cyrtodaria rutupiensis*, Specimen No. US₂-5/87, external mould of right valve. Scale bars represent 1.9 mm (A, F); 2.5 mm (B,D,K,U); 1.3 mm(C); 2.4mm (E, X); 1.8mm (G); 0.9mm (H); 1.1mm (I-J); 2.2mm (L); 1mm (M); 1.5mm (N); 3.7mm (O); 7mm (P); 2mm (Q, V); 2.7mm (R); 3.5mm (S); 0.6mm (T) and 1.7mm (W).

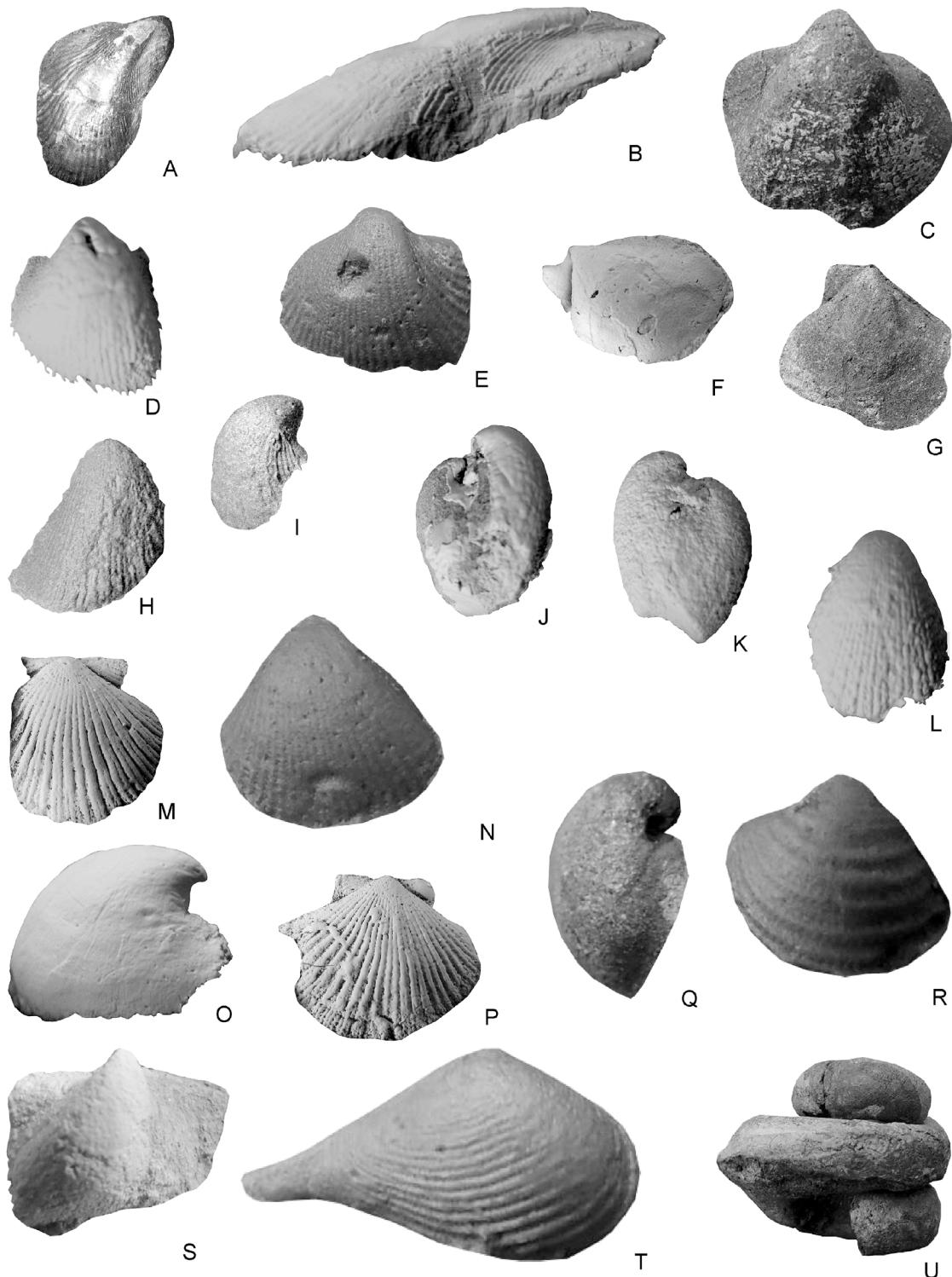


Fig. 6. A. B. *Septifer (Septifer) manipurensis* n. sp., Specimen No. US₂-5/74; (A), external mould of right valve X 1, (B), external mould of right valve X 3; C, *Loxocardium kanlegnum*, Specimen No. US₂-5/913, external mould of right valve X 3; D, E. *Protonoetia manipurensis*, Specimen No. US₂-5/853, US₃-1/1000; (D), external mould of left valve X 3; (E), external mould of left valve X 4; F, G. *Aviculoperna changamdbiensis*, Specimen No. US₂-8/7, US₂-8/736; (F), internal cast of left valve X 1.5; (G), internal cast of left valve X 1; J. *Trachycardium (Trachycardium) yairipokensis*, Specimen No. US₂-5/4, side view of both valves X 2; H, I. *Venericardia (Venericardia) spondyliformis*, Specimen No. US₂-5/52; (H), exterior of right valve; X 1.5; (I), exterior of right valve X 1; K, L. *Trachycardium (Trachycardium) yairipokensis*, Specimen No. US₂-5/4; (K), side view of both valves X 2; (L), exterior of right valve X 2; M, *Chlamys (Chlamys) wynnei*, Specimen No. US₂-5/745, external mould of left valve X 1.4. N. *Venericardia (Venericardia) mutabilis*, Specimen No. US₃-727, external mould of right valve X 5.4; O, *Nucula (Nucula)* sp., Specimen No. US₂-5/2, side view of left valve X 2; P, *Chlamys (Chlamys) multistriata* (Deshayes) var. *bijui* n. var., Specimen No. US₂-5/589, external mould of left valve X 1.4. Q, *Martesia (Martesia)* sp., Specimen No. US₃-936C, side view of right valve 2.5; R, *Lucina (Lucina) exquisite*, Specimen No. US₃-748, external mould of left valve X 6; S, *Noetia (Noetia) harudiensis*, Specimen No. US₂-5/528, external mould of left valve X 2.5; T, *Nuculana (Saccella) ukhrulensis*, Specimen No. US₃-742, external mould of right valve X 5; U, *Vermetus cf. hanguensis*, Specimen No. US₃-943C, X 2.

Material: Two right valves (US₂-5/74 and US₂-5/68)

Horizon and locality: Bed No.4 of US₂ Section, Upper Disang Formation; Changamdabi.

Description: Shell mytiliform with narrow anterior and expanded posterior. Length is slightly in excess of height. Inflation moderate, maximum along an oblique ridge running from umbo to postero-ventral corner. This ridge is narrow at anterior end and widening towards posterior. Umbo pointed, almost terminal and anteriorly placed. Hinge rectilinear is about four-fifth of the length. Anterior margin is very short and sub-vertical. In anterior region there is a small and oval antero-ventral bulge separated by a shallow groove from the ridge. Surface ornamented with radial ribs which are very fine on the antero-ventral bulge and little coarser on the remaining surface. These seem to cross over by commarginal lines which are more conspicuous at the antero-ventral bulge. Few radials are bifurcating near the posterior extremity. Inner margin is crenulated. Interior characters are unknown.

Measurement in mm:

Sp. no.	Length	Height	Inflation
US ₂ -5/74	27.2	25.7 (94%)	9.6 (35%)
US ₂ -5/68	11	6 (54.5%)	3 (27%)

Remarks: In respect of overall configuration, length-height ratio, it is quite close to the living genotype *Septifer bilocularis* (Linné) thrived in the Indo-Pacific region (Soot-Ryen 1959, p. N274, figs. C18, 2) but the recorded form can be differentiated immediately on the basis of fewer bifurcating radials, longer hinge lines, and in having comparatively less elongate posterior margin.

The Upper Eocene species from Myanmar namely *Septifer* cf. *denticulatus* Lamarck (Cotter, 1923, p. 38, Pl. VII, fig. 9; GSI type No. 12389) and *Septifer* sp. indet. recorded by Bhatia and Khosla (1978, p. 227, pl. III, fig 10) from the lower Eocene beds of Rajasthan is easily distinguishable by its elongate sub-elliptical outline with the height much less than the length and many ribs are repeatedly bifurcating.

Superfamily Pectinacea Rafinesque, 1815

Family Pectinidae Rafinesque, 1815

Genus Chlamys Röding, 1798

(*Type species:* *Pecten islandicus* Muller, 1776; SD Herrmannsen, 1847. Recent; North Atlantic)

Subgenus Chlamys s.str.

Chlamys (Chlamys) multistriata (Deshayes) var. *bijui* n. var. (Fig. 6 P)

Diagnosis: 27-29 ribs and few ribs are bifurcated and most of the ribs have simple radials separated by equally spaced interval and crossed by scale like growth wrinkles, equal size auricles sculptured with 6 radials in left valve.

Material: Ten specimens (US₂-5/74, US₂-5/236(LV), US₂-5/589 (LV), US₂-5/58, US₂-5/59A (LV), US₂-5/59 (LV), US₂-5/221 (RV), US₂-5/902A (RV), US₂-5/913A (LV), US₂-5/187 (RV)).

Horizon and Locality: Bed No.4 of US₂ Section, Upper Disang Formation; Changamdabi.

Description: Shell is slightly triangular, compressed, left valve slightly more inflated than right valve sculptured with 27-29 rounded ribs, many of which split into groups two and three riblets; crossed by scale like growth wrinkles, auricles unequal,

anterior one larger bearing about five scaly to nodulose radial riblets, left valve with narrower, sharper ribs.

Dimensions (mm):

Sp. No.	Length	Height	Inflation
US ₂ -5/74	26.0	19.0 (73.1%)	5.0 (19.2%)
US ₂ -5/236(LV)	25.0	17.0 (70%)	5.0 (20%)
US ₂ -5/589 (LV)	24.5	21.3 (146.9%)	7.6 (31.8%)
US ₂ -5/58	21.8	19.5 (89.4%)	8.0 (34.6%)
US ₂ -5/59A (LV)	20.0	21.2 (106%)	5.0 (25%)
US ₂ -5/59 (LV)	20.0	22.5 (112.5%)	5.0 (25%)
US ₂ -5/221 (RV)	19.0	20.5 (107.9%)	8.0 (42%)
US ₂ -5/902A (RV)	19.0	17.0 (89.5%)	7.0 (36.8%)
US ₂ -5/913A (LV)	16.0	17.0 (106.2%)	5.0 (31.2%)
US ₂ -5/187 (RV)	14.6	11.0 (75.3%)	3.0 (20.5%)

Remarks: These differ from *Chlamys* cf. *multistriata* (Deshayes) in having less number of ribs i.e. 27-29 instead of 37, few ribs are bifurcating instead of entirely simple one and in possession of auricles of equal size sculptured with 6 radials in left valve. In view of these conspicuous differences the recorded specimens are placed into a new variety namely *Chlamys multistriata* (Deshayes) var. *bijui* n.var.

Gastropods

The Gastropod taxa include 28 species assigned to 26 genera falling into 16 families (13 subfamilies) grouped into 10 superfamilies, 4 orders and 2 subclasses. Among 26 genera, 20 are not earlier known to occur in Manipur. These are *Patella*; *Turbo*; *Vermetus*; *Vermicularia*; *Batillaria*; *Rimella*; *Tibia*; *Terebellum*; *Natica* (*Cochlis*); *Cassis*; *Galeodea*; *Fusinus*; *Latirus*; *Tetrasomella*; *Euthriofusus*; *Clavilithes*; *Volutocorbis*; *Volvaria*; *Roxania* and *Turbanilla*. Of these, the *Patella* and *Volvaria* are not known from Eocene beds of India till date. Out of 28 gastropod species, the following 16 hitherto has not been reported from the Manipur by earlier workers (Table 6). The following one taxa has been newly designated i.e., *Natica (Cochlis) manipurensis* (Sijagurumayum et al., 2014) whereas eight are indeterminate. A mention may be made that three species already reported from Manipur are also encountered in the present work: *Turritella (Stiracolpus) harnaiensis*; *Globularia brevispira* and *Seila stracheyi* and remaining eight are indeterminate. The checklists of gastropods with their abundance are given in Table 2.

DISCUSSION

Biostratigraphy

Worldwide biozonation of Palaeogene sequences (Fig. 4) is mainly based on planktonic foraminifera (Blow, 1969; Berggren and Miller, 1988; Berggren et al., 1995; Berggren and Pearson, 2005); calcareous nannoplankton (Martini, 1971; Bukry, 1973, 1975), and larger foraminifera (Serra-Kiel et al., 1998). Unfortunately, in the study area planktonic foraminifera, larger foraminifera and calcareous nannoplankton are either rare or completely absent. Thus, there is only scope left to work out such biozonation on the basis of molluscs. Molluscan fauna have sufficiently distinctive taxonomic composition or characters (common species groups and the like) that they provide a key for at least gross international correlation, especially for the early Tertiary (Nicol, 1953; Sohl, 1977). Therefore, one can easily

Table 1. Checklist of bivalves, their geographical and zone wise distributions.

Subclass/Order/Superfamily/ Family/Tribe	Genera, Subgenera and species	No. of Species			
		US ₃ -3 Zone I	US ₂ -4 Zone II	US ₂ -8 Zone III	US ₁ -8 Zone III
Palaeotaxodonta Korobkov, 1954	<i>Nucula</i> (<i>Leionucula</i>) <i>baboensis</i> Sowerby, 1839	2	1	1	
Nuculoida Dall, 1889	<i>Nucula</i> (<i>Leionucula</i>) <i>rakhiensis</i> Eames, 1951	3			
Nuculacea Gray, 182	<i>Nucula</i> (<i>Nucula</i>) sp.			1	
Nuculidae Gray, 1824					
Nuculanacea Adams and Adams, 1858	<i>Nuculana</i> (<i>Sacella</i>) <i>ukhrulensis</i> Lukhram, 2005	2			
Nuculanidae Adams and Adams, 1858					
Pteriomorphia Beurlen, 1944					
Arcoida Stoliczka, 1871					
Arcacea Lamarck, 1809					
Arcidae Lamarck, 1809					
Arcinae Lamarck, 1809					
Anadarinae Reinhart, 1935	<i>Bathyarca</i> sp.		1		
Cucullaeidae Stewart, 1930	<i>Cucullaea</i> (<i>Cucullaea</i>) sp.			1	
Noetidae Stewart, 1930	<i>Noetia</i> (<i>Noetia</i>) <i>harudiensis</i> Devi et al. 2010			2	
Noetinae Stewart, 1930	<i>Noetia</i> (<i>Noetia</i>) <i>magnifica</i> Eames, 1951			1	
	<i>Noetia</i> (<i>Noetia</i>) <i>pondaungensis</i> Cotter, 1923			1	
	<i>Noetia</i> sp.				1
	<i>Protoñoetia manipurensis</i> Sijagurumayum et al. 2014			4	
Striarcinae Mac Neil, 1938	<i>Trigonodesma</i> sp.			1	
Limopsacea Dall, 1895	<i>Glycymeris</i> (<i>Glycymeris</i>) <i>brevirostris</i> (Sowerby)		1		
Glycymerididae Newton, 1922	White, 1959				
Glycymeridinae Newton, 1922	<i>Glycymeris</i> (<i>Glycymeris</i>) sp.			1	
Mytilida Ferussac, 1822	<i>Mytilaster</i> sp.		1		
Mytilacea Rafinesque, 1815	<i>Septifer</i> (<i>Septifer</i>) cf. <i>denticulatus</i> (Lamarck) Cotter, 1923		2	1	
Mytilidae Rafinesque, 1815	<i>Septifer</i> (<i>Septifer</i>) sp.			1	
Mytilinae Rafinesque, 1815	<i>Septifer</i> (<i>Septifer</i>) <i>manipurensis</i> n. sp.			2	
Lithophaginae Adams and Adams, 1857	<i>Lithophaga</i> (<i>Lithophaga</i>) sp.			1	
Pterioida Newell, 1965	<i>Aviculoperna changamdabiensis</i> Sijagurumayum et al. 2014				7
Pteriina Newell, 1965					
Pteriacea Gray, 1847					
Bakevellidae King, 1850					
Malleidae Lamarck, 1819	<i>Vulsella pakistanica</i> Eames, 1951			4	
Pectinacea Rafinesque, 1815	<i>Chlamys</i> (<i>Chlamys</i>) <i>pakistanica</i> Eames, 1951			5	
Pectinidae Rafinesque, 1815	<i>Chlamys</i> (<i>Chlamys</i>) <i>soriensis</i> Eames, 1951			1	
	<i>Chlamys</i> (<i>Chlamys</i>) <i>wynnei</i> Cox, 1931			2	
	<i>Chlamys</i> (<i>Chlamys</i>) <i>multistriata</i> Deshayes var. <i>bijui</i> n.var.			10	
Ostreina Ferussac, 1822	<i>Gryphaeostrea</i> sp.				1
Ostreacea Rafinesque, 1815					
Gryphaeidae Vyalov, 1936					
Exogyrinae Vyalov, 1936					
Gryphaeostreini Stenzel, 1971					
Ostreidae Rafinesque, 1815	<i>Ostrea</i> (<i>Ostrea</i>) <i>velata</i> White, 1959				2
Ostreinae Rafinesque, 1815	<i>Cubitostrea perplicata</i> (Dall) Stenzel, 1971				3
Flemingostreini Stenzel, 1971	<i>Flemingostrea haydeni</i> Cossmann and Pissarro, 1927			1	
	<i>Flemingostrea pharaonum</i> Oppenheim var. <i>aviculina</i> (Mayer – Eymer) Cossmann and Pissarro, 1927		4		
Heterodontia Neumayr, 1884	<i>Lucina</i> (<i>Lucina</i>) <i>exquisita</i> Eames, 1952		2		
Veneroida Adams and Adams, 1856	<i>Lucina</i> (<i>Lucina</i>) <i>yawensis</i> Cotter, 1923				2
Lucinacea Fleming, 1828					
Lucinidae Fleming, 1828					
Lucininae Fleming, 1828					
Divaricellinae, Glibert, 1967	<i>Boeuvia pulchella</i> (Agassiz) Moore et al. 1969		2		
Ungulinidae Adams and Adams, 1857	<i>Diplodonta</i> (<i>Diplodonta</i>) <i>pakistanica</i> Eames, 1951			1	
Chamacea Lamarck, 1809	<i>Chama</i> (<i>Chama</i>) <i>brimonti</i> d'Archiac and Haime, 1854				1
Chamidae Lamarck, 1809					
Carditacea Fleming, 1820	<i>Venericardia trachycardiiformis</i> Eames, 1951			1	
Carditidae Fleming, 1828	<i>Venericardia</i> (<i>Venericardia</i>) <i>dufrenoyi</i> (d' Archiac and Haime), Eames, 1951		1	2	
Venericardiinae Chavan 1969	<i>Venericardia</i> (<i>Venericardia</i>) <i>hollandi</i> Cossmann and Pissarro, 1927			3	
	<i>Venericardia</i> (<i>Venericardia</i>) <i>gilli</i> Mathur, 1975			3	
	<i>Venericardia</i> (<i>Venericardia</i>) <i>mutabilis</i> (d' Archiac and Haime) Mathur and Juyal, 2000		3		
	<i>Venericardia</i> (<i>Venericardia</i>) <i>spondyliformis</i> Sijagurumayum et al. 2014			3	

Crassatellacea Féussac, 1822	<i>Astarte (Astarte) filigera</i> (Wood) White, 1959	10		
Astartidae d'Orbigny, 1844				
Astartinae d'Orbigny, 1844				
Crassatellidae Ferussac, 1822	<i>Crassinella blandfordi</i> (Cossmann and Pissarro)	2		
Scambulinae Chavan, 1952	Lukhram, 2005			
Cardiacea Lamarck, 1809	<i>Cardium subfragile</i> (Bottger) Cotter, 1923		1	1
Cardiidae Lamarck, 1809	<i>Acanthocardia (Schedocardia) sp.</i>		1	
Cardiinae Lamarck, 1809	<i>Loxocardium kanleqnum</i> Cotter, 1923		3	
	<i>Loxocardium thetregynense</i> Cotter, 1923		11	
	<i>Vepriocardium (Hedecardium) sharpei</i> (d'Archiac and Haime) Devi, 2011		3	
Trachycardiinae Stewart, 1930	<i>Trachycardium (Trachycardium) sp. juv. cotteri</i> (Cox) Devi, 2011			1
	<i>Trachycardium (Trachycardium) yairipokensis</i> Sijagurumayum et al., 2014		3	
Protocardiinae Keen, 1951	<i>Nemocardium (Discors) bunburyi</i> d'Archiac and Haime, 1854			1
Solenacea Lamarck, 1809	<i>Solen manensis</i> Cotter, 1923	1	2	
Solenidae Lamarck, 1809				
Tellinacea de Blainville, 1814	<i>Tellina (Tellina) pakistanica</i> Eames, 1951		1	
Tellinidae de Blainville, 1814	<i>Tellina (Lyratellina) cf. lyra</i> (Hanley)	1		
Tellininae de Blainville, 1814	<i>Tellina (Peroniida) sp.</i>			1
Psammobiidae Fleming, 1828	<i>Macrosolen cyclopeus</i> (Brongniart) Eames, 1951	1		
Psammobiinae Fleming, 1828				
Arcticacea Newton, 1891	<i>Trapezium daviesi</i> Cox, 1930		1	
Trapeziidae Lamy, 1920				
Veneracea Rafinesque, 1815	<i>Venus (Venus) pasokensis</i> Cotter, 1923		2	
Veneridae Rafinesque, 1815				1
Venerinae Rafinesque, 1815				
Meretricinae Gray, 1847	<i>Meretrix agrestis</i> Cotter, 1923		8	4
Pitarinae Stewart, 1930	<i>Pitar (Calpitaria) pseudosubcyrenoides</i> Eames, 1951		1	
	<i>Pitar (Calpitaria) rakhensis</i> Eames, 1951		1	1
	<i>Callista (Callista) yawensis</i> Cotter, 1923			2
	<i>Callista (Costacallista) punjabensis</i> Eames, 1951	1	1	
	<i>Callista (Macrocallista) sp.</i>		1	
Tapetinae Adams and Adams, 1857	<i>Venerella parva</i> Eames, 1951		11	
Myoida Stoliczka, 1870	<i>Corbula (Corbula) paukensis</i> Cotter, 1923		1	1
Myina Stoliczka, 1870	<i>Corbula (Bicorbula) subexarata</i> d'Archiac and Haime, 1854	1		
Myacea Lamarck, 1809				
Corbulidae Lamarck, 1818	<i>Corbula (Bicorbula) subexarata</i> d'Archiac and Haime var. <i>lituus</i> Cotter, 1923			2
Corbulinae Gray, 1823	<i>Corbula (Varicorbula) daltoni</i> Cotter, 1923		3	
	<i>Corbula (Varicorbula) harpa</i> (d'Archiac and Haime) Lukhram, 2005	2		
Caestocorbulinae Vokes, 1945	<i>Caestocorcula (Parmicorbula) regulbiensis</i> (Morris) Lukhram and Kachhara, 2010	5		
Lentidiinae Vokes, 1945	<i>Lentidium (Lentidium) sp.</i>	1		
Gastrochaenacea Gray, 1840	<i>Kummelia americana</i> (Gabb) Moore et al., 1969	2		
Gastrochaenidae Gray, 1840				
Hiatellacea Gray, 1824	<i>Cyrtodaria rutupiensis</i> (Morris) White, 1959		1	
Hiatellidae Gray, 1824				
Pholadina Adams and Adams, 1858	<i>Pholas (Pholas) sp.</i>		1	
Pholadacea Lamarck, 1809				
Pholadidae Lamarck, 1809				
Pholadinae Lamarck, 1809				
Martesiinae Grant and Gale, 1931	<i>Martesia (Martesia) sp.</i>	1		
Anomalodesmata Dall, 1889	<i>Pholadomyia (Pholadomyia) sp.</i>		1	
Pholadomyoida Newell, 1965				
Pholadomyacea Gray, 1847				
Pholadomyidae gray, 1847				
<i>Pholadomyia</i> G.B. Sowerby, 1823	<i>Laternula (Laternula) sp.</i>		1	
Pandoracea Rafinesque, 1815	<i>Pecchiolia</i> sp.		1	
Laternulidae Hedley, 1918				

Table 2. Checklist of gastropods, their geographical and zone wise distributions.

Subclass/Order/Superfamily/ Family/Tribe	Genera, Subgenera and species	No. of Species			
		US ₃ -3 Zone I	US ₂ -4 Zone II	US ₂ -8 Zone III	US ₁ -8 Zone III
Prosobranchia Milne Edwards, 1848 Archaeogastropoda Thiele, 1925 Patellina Von Ihering, 1876 Patellacea Rafinesque, 1815 Patellidae Rafinesque, 1815 Patellinae Rafinesque, 1815	<i>Patella</i> sp.	1			
Trochina Trochacea Turbinidae Turbininae	<i>Turbo</i> sp. indet.	1			
Caenogastropoda Cox, 1959 Cerithiacea Fleming, 1822 Turritellidae Woodward, 1851 Turritellinae	<i>Turritella (Stiracolpus) harnaiensis</i> Cox, 1931 <i>Turritella subathooensis</i> d' Archiac and Haime, 1854		1		
Vermitidae	<i>Vermetus</i> cf. <i>hangensis</i> Cox, 1930	2			
	<i>Vermicularia</i> sp.	1			
Potamididae Batillariinae	<i>Batillaria coronata</i> Cox, 1930	1			
Cerithiidae Cerithiinae	<i>Seila stracheyi</i> (d' Archiac and Haime) Vokes, 1937	1			
Campanilinae	<i>Serratocerithium</i> sp.				1
Strombacea Strombidae	<i>Rimella pakistanica</i> Eames, 1952		9	3	
	<i>Rimella fissurrella</i> (Linné) Davies, 1971		1		
	? <i>Tibia</i> sp.		1		
	<i>Terebellum fusiformopse</i> (de Gregorio) Eames, 1952		3		
Naticacea Naticidae Naticinae	<i>Natica (Cochlis) manipurensis</i> Sijagurumayum et al., 2014			5	
Polinilinae	<i>Polinices</i> sp.		1		
Ampullospirinae	<i>Globularia brevispira</i> (Leymerie) Lukhram, 2005		1		1
Tonnacea Cassididae	<i>Cassis</i> sp.		3	1	
	<i>Galeodea archiaci</i> Cossmann and Pissarro, 1909			11	
Buccinacea Fusinidae Fusininae (fusinae)	<i>Fusinus buddhaicus</i> Vredenburg, 1923	1			
Fasciolariinae	<i>Latirus</i> sp. indet.		1		
Pyrenidae	? <i>Tetrastomella pseudohumilis</i> Eames, 1952		1		
	<i>Euthrio fuscus malcomsoni</i> (d' Archiac and Haime) Mathur and Juyal, 2000	1			
	<i>Clavilithes songensis</i> Martin, 1923	3	1		
Volutacea Volutidae Athletinae	<i>Volutorbis daviesi</i> Cox, 1930	1			
Strepsiduridae	<i>Strepsidura tipperi</i> Cox, 1930	2			
Mitridae Cylindromitrinae	<i>Volvaria</i> cf. <i>birmanica</i> Noetling, 1895		1		
Euthyneura Cephalaspidea Acteonacea Scaphandridae	<i>Roxania pseudosemistriata</i> Eames, 1952			1	
Entomotaeniata Pyramidellacea Pyramidellidae	<i>Turbanilla soriensis</i> Eames, 1951		1		

Table 3. Range chart of known species from US₃-3 locality, Zone-I (Paleo=Paleocene; Eo=Eocene; Oligo=Oligocene; Mio=Miocene; Plio=Pliocene; Pleisto=Pleistocene; R=Recent; E=Early; M=Middle and L=Late).

Species	Paleo		Eo			Oligo		Mio		Plio	Pleisto	Recent
	E	L	E	M	L	E	L	E	L			
<i>Nucula (Leionucula) baboensis</i>				M								
<i>Nucula (Leionucula) rakhiensis</i>	E			M								
<i>Nucula (Saccella) ukhrulensis</i>		L	E									
<i>Glycymeris (Glycymeris) brevirostris</i>			E									
<i>Septifer (Septifer) cf. denticulatus</i>				M								
<i>Flemingostrea pharaonum</i> Oppenheim var. <i>aviculina</i>		L	E									
<i>Lucina (Lucina) exquisita</i>			E									
<i>Boeuvia pulchella</i>				M								
<i>Venericardia (Venericardia) dufrenoyi</i>			E	M								
<i>Venericardia (Venericardia) mutabilis</i>			E	L								
<i>Astarte (Astarte) filigera</i>		L	E									
<i>Crassinella blandfordi</i>	E		E									
<i>Solen manensis</i>		L										
<i>Tellina (Lyratellina) cf. lyra</i>											R	
<i>Macrosolen cyclopeus</i>	E											
<i>Callista (Costacallista) punjabensis</i>	E	L										
<i>Venerella parva</i>				M								
<i>Corbula (Bicorbula) subexarata</i>	E	L										
<i>Corbula (Varicorbula) harpa</i>	E		E									
<i>Caestocorbula (Parmicorbula) regulbiensis</i>	E	L										
<i>Kummelia americana</i>	E	L										
<i>Turritella subathooensis</i>	E			M								
<i>Vermetus cf. hanguensis</i>	E	L										
<i>Batillaria coronata</i>	E		E									
<i>Seila stracheyi</i>	E			M								
<i>Fusinus buddhaicus</i>	E	L										
<i>Euthriofusus malcomsoni</i>	E			M								
<i>Clavilithes songoensis</i>	L											
<i>Volutocorbis daviesi</i>	E	L										
<i>Strepsidura tipperi</i>	E	L										

envise that bivalves and gastropods can also be used for the purpose of biostratigraphy.

Even for local biostratigraphy in different Tertiary sequences of India, a number of workers (Mathur, 1975; Lyngdoh *et al.*, 1999; Mathur and Juyal, 2000; Tiwari and Kachhara, 2003; Lukhram and Kachhara, 2010; Kachhara *et al.*, 2011) have used bivalves and gastropods successfully. In the present study, the biostratigraphic zones have been named after bivalve taxa which had more or less restricted geologic ranges and zones. For each zone, time span was deduced mainly on the basis of their reported occurrence in various sections, especially the Indian subcontinent by earlier workers (Vredenburg, 1921, 1923; Cossmann and Pissarro, 1927; Cox, 1930; Eames, 1951, 1952; Mathur, 1975; Bhatia and Khosla, 1978; Bhatia and Singh, 1984; Mathur and Juyal, 2000; Lukhram and Kachhara, 2010; Singh *et al.*, 2016). Systematically identified taxa are in the form of 108 species (80 bivalves and gastropods) belonging to 51 and 26 genera, respectively. Based on their geological and

geographical distribution, majority of the taxa are observed to be long ranging, in spite of that a few are found to be suitable for biozonation because of their short geologic range. After a thorough study, three bivalves assemblage zones are recognised in the study area (Tables 1, 7). The details of the zones are given below:

Zone I: Caestocorbula (Parmicorbula) regulbiensis-Flemingostrea pharaonum var. aviculina

This zone characterizes the lower part of the Upper Disang Formation. Related stratum is very well outcropped in US₃, Section (Khongjai Chingkhong Section; Fig. 4). Altogether, 41 taxa of molluscan fauna are recorded from this zone.

Restricted to zone I: The *Caestocorbula (Parmicorbula) regulbiensis* (Morris) is common and is restricted to Palaeocene and *Flemingostrea pharaonum aviculina* (Mayer-Eymer) is a typical form of late Palaeocene to early Eocene, hence, name of the zone. The other restricted taxa are in Table 1.

Table 4. Range chart of known species from US₂-4 locality, Zone-II (short forms in Table 3).

Species	Paleo		Eo			Oligo		Mio		Plio	Pleisto	Recent
	E	L	E	M	L	E	L	E	L			
<i>Nucula (Leionucula) baboensis</i>				M								
<i>Noetia (Noetia) harudiensis</i>				M								
<i>Noetia (Noetia) magnifica</i>				M	L							
<i>Noetia (Noetia) pondaungensis</i>				M	L							
<i>Septifer (Septifer) denticulatus</i>				M								
<i>Vulsella pakistanica</i>				M								
<i>Chlamys (Chlamys) pakistanica</i>					L							
<i>Chlamys (Chlamys) soriensis</i>				M								
<i>Chlamys (Chlamys) wynnei</i>			E	M								
<i>Chlamys multistriata</i> Deshayes				M	L							
var. <i>bijui</i> n. var.												
<i>Cubitostrea perplicata</i>				M								
<i>Flemingostrea haydeni</i>	E			M								
<i>Diplodonta (Diplodonta) pakistanica</i>				M								
<i>Venericardia trachycardiiformis</i>		L										
<i>Venericardia (Venericardia) dufrenoyi</i>			E	M								
<i>Venericardia (Venericardia) hollandi</i>	E	L										
<i>Venericardia (Venericardia) gilli</i>	E											
<i>Cardium subfragile</i>					L							
<i>Loxocardium kanleqnum</i>					L							
<i>Loxocardium thetregyinense</i>					L							
<i>Vetricardium (Hedocardium) sharpei</i>	E		E									
<i>Solen manensis</i>					L							
<i>Tellina (Tellina) pakistanica</i>			E		L							
<i>Trapezium daviesi</i>			E		L							
<i>Venus (Venus) pasokensis</i>					L							
<i>Meretrix agrestris</i>					L							
<i>Pitar (Calpitaria) pseudosubcyrenoides</i>				M								
<i>Pitar (Calpitaria) rakhensis</i>			E	M								
<i>Callista (Costacallista) punjabensis</i>			E		L							
<i>Corbula (Corbula) paukensis</i>					L							
<i>Corbula (Varicorbula) daltoni</i>				M	L							
<i>Cyrtodaria rutupiensis</i>			E									
<i>Turritella (Stiracolpus) harnaiensis</i>			E	M								
<i>Rimella pakistanica</i>				M								
<i>Rimella fissurrella</i>				M								
<i>Terebellum fusiformopse</i>			E									
<i>Globularia brevispira</i>	E			M								
<i>Galeodea archiaci</i>			E									
? <i>Tetrastomella pseudohumilis</i>												
<i>Clavilithes songoensis</i>					L							
<i>Volvaria cf. birmanica</i>						E						
<i>Roxania pseudosemistriata</i>					L							
<i>Turbonilla soriensis</i>					L							

Table 5. Range chart of known species from US₂-8 and US₁-8 localities, Zone-III (Short forms in Table 3).

Species	Paleo		Eo			Oligo		Mio		Plio	Pleisto	Recent
	E	L	E	M	L	E	L	E	L			
<i>Nucula (Leionucula) baboensis</i>				M								
<i>Chlamys (Chlamys) multistriata</i>				M	L							
Deshayes var. <i>bijui</i>												
<i>Ostrea (Ostrea) velata</i>				M		E						
<i>Cubitostrea perplicata</i>				M								
<i>Cardium subfragile</i>					L							
<i>Trachycardium (Trachycardium)</i>					L							R
sp. juv. <i>cotteri</i>												
<i>Nemocardium (Discors) bunburyi</i>		L		M								
<i>Meretrix agrestris</i>					L							
<i>Pitar (Calpitaria) rakhensis</i>			E	M								
<i>Callista (Callista) yawensis</i>					L							
<i>Corbula (Corbula) paukensis</i>					L							
<i>Corbula (Bicorbula) subexarata</i> var. <i>lituus</i>					L							
<i>Corbula (Varicorbula) daltoni</i>				M	L							
<i>Rimella pakistanica</i>				M								
<i>Lucina (Lucina) yawensis</i>					L							
<i>Chama (Chama) brimonti</i>			E		L							
<i>Venus pasokensis</i>					L							
<i>Globularia brevispira</i>		L		M								

Majority of the taxa, leaving aside a few, have restricted range of late Palaeocene, early Eocene, Palaeocene-early Eocene, Palaeocene and Eocene, (Table 3). Hence, this zone is assigned the Late Palaeocene-Early Eocene, i.e. Thanetian-Ypresian age (Table 7). Seven of them are of younger age, i.e. middle or late Eocene but it is not a point of concern as these are recorded by earlier workers only from one locality and with more occurrences there is possibility that range may be restricted. Therefore, their ranges are to be adjusted as per present record.

Zone II: *Vulsella pakistanica* - *Corbula (Varicorbula) daltoni*

This zone characterizes the lower portion of the middle part of Upper Disang Formation with concerning strata well exposed in a hill section (Maning Ching- US₂ Section; Fig. 4). It has yielded molluscan fossils of bivalves and gastropods with rare occurrence of echinoids, solitary corals, crab chela, pollens and ichnofossils.

Restricted to zone II: Both *Vulsella pakistanica* and *Corbula (Varicorbula) daltoni* are quite common and the former is typical middle Eocene whereas latter with range of middle-late Eocene, thus, the name of the zone. The other restricted taxa to this zone are in Table 4.

Out of sixty one taxa from this zone, component-wise, seventeen are restricted to middle Eocene or may be of Palaeocene but not extending beyond middle Eocene, four are of middle-late Eocene whereas twelve are confined to late Eocene and two are occurring throughout Eocene. Twenty six taxa are certainly favouring the range of middle-late Eocene. Therefore, this zone has been assigned as the late-middle Eocene, i.e.

Lutetian - Bartonian in age (Table 7). The taxa, *Protonoetia manipurensis* is interesting as the genus itself has a restricted range of middle Eocene. Amongst the indeterminate twelve forms, a mention may be made of a subgenus *Schedocardia*, which has a range from Palaeocene to Eocene. Among others, four forms are of early Eocene, two of Palaeocene and another one of early Oligocene. For such species, comments put forward earlier while discussing Zone-I, are valid here also.

Zone III: *Callista (Callista) yawensis* - *Lucina (Lucina) yawensis* Zone

Both the taxa *Callista (Callista) yawensis* and *Lucina (Lucina) yawensis* are quite common and have restricted range of late Eocene, hence the name of this zone. This uppermost zone III is occurring in the upper two-third of the sequence of the Maning Ching Section (US₂ Section; Fig. 4) and covering the whole Canal section (US₁ Section; Fig. 4). The brown silty sandstone bed is quite fossiliferous and shows representatives of mega-invertebrates like bivalves, gastropods, large foraminifers and solitary corals.

Restricted to zone III: The other restricted taxa are given in Table 5.

From analysis of geological ranges of all the species occurring in this zone, it falls in late Eocene interval. Out of 23 taxa reported in this zone, nine are of Late Eocene, two ranges from Middle-Late Eocene and two throughout Eocene. However, five taxa are confined presumably to Middle Eocene are also occupying a place in associated long ranging taxa. The occurrence of foraminifer taxon of *Nummulites fabiani* (Prever) is also supporting the Late Eocene age. Hence, this zone has been assigned the late Eocene, i.e. Priabonian age (Table 7).

Table 6: The species recorded for the first time from the study area, Eocene beds of the Indian subcontinent and created as new.

The species recorded for the first time from the study area	The species recorded for the first time from Eocene beds of the Indian subcontinent	The species created as new
<i>Nucula (Leionucula) baboensis</i> ; <i>Noetia (Noetia) harudiensis</i> ; <i>Vulsella pakistanica</i> ; <i>Chlamys (Chlamys) pakistanica</i> ; <i>Chlamys (Chlamys) soriensis</i> ; <i>Chlamys (Chlamys) wynnei</i> ; <i>Ostrea (Ostrea) velata</i> ; <i>Cubitostrea perpicata</i> ; <i>Flemingostrea haydeni</i> ; <i>Flemingostrea pharaonum</i> Oppenheim var. <i>aviculina</i> ; <i>Lucina (Lucina) exquisita</i> ; <i>Boeuvia pulchella</i> ; <i>Diplodonta (Diplodonta) pakistanica</i> ; <i>Chama (Chama) brimonti</i> ; <i>Venericardia (Venericardia) dufrenoyi</i> ; <i>Venericardia (Venericardia) gilli</i> ; <i>Astarte (Astarte) filigera</i> ; <i>Cardium subfragile</i> ; <i>Loxocardium kanleqnum</i> ; <i>Vetricardium (Hedecardium) sharpei</i> ; <i>Trachycardium (Trachycardium) sp. juv. cotteri</i> ; <i>Nemocardium (Discors) bunburyi</i> ; <i>Tellina (Lyratellina) cf. lyra</i> ; <i>Macrosolen cyclopeus</i> ; <i>Trapezium daviesi</i> ; <i>Venerella parva</i> ; <i>Corbula (Bicorbula) subexarata</i> ; <i>Corbula (Varicorbula) daltoni</i> ; <i>Kummelia americana</i> ; <i>Cyrtodaria rutupiensis</i> ; <i>Proto noetia manipurensis</i> ; <i>Aviculoperna changamdabiensis</i> ; <i>Venericardia (Venericardia) spondyliformis</i> ; <i>Trachycardium (Trachycardium) yairipokensis</i> ; <i>Turritella subathoensis</i> ; <i>Vermetus cf. hangensis</i> ; <i>Batillaria coronata</i> ; <i>Seila stracheyi</i> ; <i>Rimella pakistanica</i> ; <i>Rimella fissurrella</i> ; <i>Terebellum fusiformopse</i> ; <i>Galeodea archiaci</i> ; <i>Fusinus buddhaicus</i> ; <i>?Tetrasstromella pseudohumilis</i> ; <i>Euthriofusus malcomsoni</i> ; <i>Clavilithes songoensis</i> ; <i>Volutocorbis daviesi</i> ; <i>Volvaria cf. birmanica</i> ; <i>Roxania pseudosemistriata</i> and <i>Turbonilla soriensis</i> .	<i>Boeuvia pulchella</i> ; <i>Cyrtodaria rutupiensis</i>	<i>Septifer (Septifer) manipurensis</i> n. sp.; <i>Chlamys (Chlamys) multistriata</i> Deshayes var. <i>bijui</i>

Table 7: Biostratigraphic biozonation of the study area.

Epoch	Age	Formation	Indian Stage	Biostratigraphic Assemblage Zone
Late Eocene	Priabonian	Upper Disang	Tarapurian	<i>Callista (Callista) yawensis-Lucina (Lucina) yawensis</i> Zone III
Middle Eocene- Late Eocene	Lutetian- Bartonian	Upper Disang	Kakdian-Babian	<i>Vulsella pakistanica</i> - <i>Corbula (Varicorbula) daltoni</i> Zone II
Late Palaeocene- Early Eocene	Thanetian-Ypresian	Upper Disang	Khasian-Kakdian	<i>Caestocorbula (Parmicorbula) regulbiensis</i> - <i>Flemingostrea pharaonum</i> var. <i>aviculina</i> Zone I

REPOSITORY

All the illustrated specimens are housed in the museum of the Department of Earth Sciences, Manipur University, Canchipur, Imphal (India).

CONCLUSIONS

The present study is mainly confined to the Upper Disang Formation exposed around Changamdabi area of Imphal Valley, India. This study is confined to three sections, namely Canal Section (US₁ Section), Maning Ching (US₂ Section) and Khongjai Chingkhong Section (US₃ Section). The four fossiliferous horizons have been identified in these sections. Altogether, 80 species of bivalves referable to 51 genera and 28 species of gastropods belonging to 26 genera are recovered from the Upper Disang Formation in the study area.

Three biostratigraphic assemblage zones are recognized in the study area based on their geological and geographical distribution. Analysis of the molluscan fauna of the Upper Disang Formation has led to the recognition of three biozones. They are Zone III *Callista (Callista) yawensis*- *Lucina (Lucina) yawensis*, Zone II *Vulsella pakistanica*-*Corbula (Varicorbula) daltoni* and Zone I *Caestocorbula (Parmicorbula) regulbiensis*-*Flemingostrea pharaonum* var. *aviculina* in the descending order of stratigraphy. The Zones I, II and III range from late Palaeocene-early Eocene (Thanetian to Ypresian) in age, middle

to late Eocene (Lutetian to Bartonian) in age and late Eocene (Priabonian) in age, respectively.

ACKNOWLEDGMENTS

We thank Prof. K. P. Kachhara (Retd.), Udaipur for help in identification of the specimens. One of the authors (SU) thanks the Council of Scientific and Research Institute and Manipur University for financial support in the form of Senior Research Fellowship. She also thanks the Geological Society of India for L. Ramarao Research Grant 2010-2011. Authors (YRS and BPS) are also thankful to DST (Project No. SR/S4/ES-577/2011), New Delhi for financial assistance in form of research project. Author (YRS) also is thankful to UGC, New Delhi for financial assistance in the form of Major Research Project (F. No. 41-1024/2012 SR). The authors sincerely acknowledge Ksh. Atamajit Singh, Mr. Venus Guruaribam and Miss Reshma Naorem (Research Scholars), Department of Earth Sciences, Manipur for their support during the field work.

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Manuscript received May 2016

Revised Manuscript accepted January 2017

