ABSTRACT

Rock succession of Surma Group Miocene are well exposed in Mizoram. This entire sedimentary column is a repetitive succession of arenaceous and argillaceous rocks comprising sandstone, silty-sandstone, siltstone, shale, shaly-sandtones, silty-shale, mudstone and their admixtures in varying proportions along with random pockets of shell-limestone and Intraformational conglomeratic bands. The palaeontological wealth of the Surma Group rocks in Mizoram is yet to be fully explored. Therefore, present study was taken-up in order to carry out detailed palaeontological investigations some of the unexplored areas in and around Aizawl in a view to assign ages to the fossiliferous beds, evolve biostratigraphic framework and reconstruct the depositional environment. The findings of the study are presented in seven chapters excluding references, alphabetical list of the genera and species.

Rock succession of the study area belong to upper part of Middle Bhuban Unit and lower part of Upper Bhuban unit of the Bhuban Subgroup of Surma Group. Systematic collection of fauna has been made from all the lithic units exposed in the area *i. e.* brown sandstone bed, dark brown sandstone bed, brownish grey sandstone bed, grey silty sandstone bed, grey sandstone bed and Intraformational conglomeratic bed. These lithic units are not uniformly fossiliferous. In spite of several visit to the site, only about three hundred individuals could be collected from the area (Chapter 2). The fauna so collected have been prepared for study after necessary cleaning and about two hundred specimens were found suitable for systematic study. Preservation

of fauna is not so good. Original bivalve shells are rarely preserved and in most cases casts of single valves are available.

The collection has yielded 49 forms out of which 44 are bivalves, 3 are gastropod, 1 is scaphopod and 2 echinoids. Bivalves are represented by 22 genera that are grouped into 16 families, 13 superfamilies and 6 orders belonging to 4 subclasses. Gastropods belong to 3 superfamilies, 3 families and 3 genera. *Dentalium is* the sole representative of class scaphopoda. Echinoids are represented by genera *Coelopleurus* and *Shizaster*. Among the total faunal assemblage form the present collection, *Tellina* (*Oudardia*) sp. and *Tellina* (*Perodina*) sp**.** are being reported for the first time from the Miocene succession of Mizoram as well as North East (Chapter 3).

Locality-wise occurrence of fossils with their age range as well as the overall age of the succession in the study area has been discussed in the chapter 4. By and large, the Bhuban successions of the study area are inferred to be of Aquitanian - Burdigalian age.

Based on some age diagnostic fauna, three Biozones have been proposed in the Upper Bhuban unit of Bhuban Formation in the study area (Chapter 5). The lower one, *i. e.* Zone-I, is named as *Pecten* (*Pecten*) *mathuri* Zone of Aquitanian to Burdigalian (more towards Aquitanian) age; the middle one, Zone-II, as *Paphia* (*Paphia*) *rotundata* - *Paphia (Paphia) jhai* Zone of Aquitanian to Burdigalian (more towards Burdigalian) age whereas the upper one, *i. e.* Zone-III, as *Crassostrea gajensis* Zone of Burdigalian age.

These biozones are prove to be very useful in correlation of Miocene succession of the study area with other areas of Mizoram as well as the Indian sub-continent (Chapter 5). It has been found out that Zone I of the study area is correlatable with Zone II (*Glycymeris sindiensis* - *Nuculana virgo* Zone), Zone III (*Ostrea latimarginata* - *Natica pellis tigrina* Zone) and Zone IV [*Pecten* (*Oopecten*) *gigas* Zone] of Tiwari and Kachhara (2003), Zone IIA(a) and Zone IIB of Mazumder (2004), Subzone IB *Barbatia* (*Barbatia*) *bataviana* var. *carinata*- *Neptunussindensis* Zone of Aquitanian – Burdigalian to Burdigalian age of Ralte (2009), Zone I of Lalchawimawii (2013), Zone IA of Lyngdoh (2004), Gaj of Kachchh (Vredenburg, 1925, 1928), Gaj of Kathiawar (Jain, 1997; Vredenburg, 1925 and 1928) and Miocene Succession of Myanmar (Noetling, 1895, 1901). Zone II of the area is correlatable with Zone III (*Ostrea latimarginata* - *Natica pellis tigrina* Zone) and Zone IV [*Pecten* (*Oopecten*) *gigas* Zone] of Tiwari and Kachhara (2003), Zone IIB of Mazumder (2004), Subzone IA and IB of Ralte (2009), Zone II of Lalchawimawii (2013), Lower Miocene succession of Garo Hills, Meghalaya (Mukherjee, 1939), Zone IB of Lyngdoh (2004), Gaj of Sind (Vredenburg, 1925, 1928), Gaj of Kachchh (Vredenburg, 1925, 1928), Gaj of Kathiawar (Jain, 1997; Vredenburg, 1925 and 1928) and Miocene Succession of Myanmar (Noetling, 1895, 1901). Zone III of the study area can be correlate with Zone II and III of Tiwari and Kachhara (2003), Zone II and III of Lalchawimawii (2013), Zone IB of Lyngdoh (2004), Gaj of Kathiawar (Jain, 1997; Vredenburg, 1925 and 1928) and Miocene Succession of Myanmar (Noetling, 1895, 1901).

Palaeoecology and depositional environment of the succession based on gross lithology and fossils contents has been dealt with in Chapter 6. Bhuban Formation

comprises a hybrid association of sandstone, shale, siltstone, mudstone and their admixtures in various proportions. The shales and siltstones grade into mudstones and argillaceous alternations consisting of interlaminations of shales, ripple laminated siltstones and silty-sandstones. Sandstones are usually hard, ill sorted and fine grained, immature and richly micaceous. The characteristic feature of Bhuban succession is rhythmic alternations of argillaceous and arenaceous strata.

All the infaunal elements are compressed which indicates unconsolidated substrate. Based on the composition of the molluscan fauna, it may be assumed that the fauna grew in the shallow sea water region mainly in the shelf with the influence of warm water environment. Most of the bivalves occur as detached valves proposing that the assemblage is an allochthonous one. Several shells are disarticulated as very few of the fossils retain their original shell covering. The fauna consists of infaunal, epifaunal, swimming and sessile forms, the majority of which are known to live in the inter-tidal to lower tidal zones and even though their bathymetric distribution extends down to greater depth, most of the identified species are shallow water forms. Dwarfed forms and unusually thickened forms are missing from the present specimen collection which indicates faunal association lived in water under normal salinity.

Considering all the observations it can be inferred that an open shallow, warm sea with fluctuations from inner neritic to littoral water with depth less than 45m meter existed during deposition of these sediments. The substrate was soft but firm at places to support epifaunal byssate forms. So, the overall picture from this assemblage comes to be of inner-shelf sand and silt representing a fluctuating shoreline because of the presence of cross-bedding and disarticulated bivalve shells.

At the same time, it can also be inferred that fossils were perhaps intra-basinally transported by the bottom currents from a variety of communities of the inter-tidal to near shore shelf, evidenced by infaunal elements characteristics of soft substratum occurring in sandy bottom.

PALAEONTOLOGICAL STUDY OF BHUBAN FORMATION (SURMA GROUP) IN AIZAWL, MIZORAM

C. LALCHHANHIMA

DEPARTMENT OF GEOLOGY
MIZORAM UNIVERSITY

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BY

C. LALCHHANHIMA

DEPARTMENT OF GEOLOGY

Submitted in partial fulfilment of the requirement of the Degree of Doctor of Philosophy in Geology of Mizoram University, Aizawl

DEPARTMENT OF GEOLOGY

MIZORAM UNIVERSITY

(A Central University established by an Act of Parliament)

भौमिकी विभाग, मिज़ोरम विश्वविद्यालय

Mizoram : Aizawl - 796 004

Prof. K. Srinivasa Rao

E-mail: *ksrao@mzu.edu.in*

Mobile: 9436352394

CERTIFICATE

This is to certify that **C. Lalchhanhima, Ph. D Scholar, Department of Geology, Mizoram University, Regn. No. MZU/Ph.D/446 of 15.05.2012** has written his thesis titled **'Paleontological Study of Bhuban Formation (Surma Group) in Aizawl'** under my guidance and supervision. In preparing the thesis Mr. C. Lalchhanhima has complied with all the requirement laid down in the Pd. D Regulation of the University. The thesis is the original work of the scholar and has not been submitted for any degree to any other University.

(Prof. R.P. TIWARI)
Joint Supervisor

(Prof. K. SRINIVASA RAO)
Supervisor

MIZORAM UNIVERSITY

AIZAWL: MIZORAM – 796004

Month: December **Year: 2019**

DECLARATION

I, C. Lalchhanhima, hereby declare that the subject matter of this thesis is the record of work done by me, that the contents of this thesis did not form basis of the award of any previous degree to me or to the best of my knowledge to anybody else, and that the thesis has not been submitted by me for any research degree in any other University/Institute.

This is being submitted to the Mizoram University for the degree of Doctor of Philosophy in Geology.

(C. LALCHHANHIMA)
Candidate

(Prof. Shiva Kumar)
Head

Prof. K. Srinivasa Rao
Supervisor

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Dated Aizawl
The 19th December, 2019

(C. LALCHHANHIMA)
Department of Geology
Mizoram University

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CHAPTER 1: INTRODUCTION

1. INTRODUCTION

1.1. GENERAL REMARKS

Mizoram is the easternmost state of India. It is sandwiched between Myanmar and Bangladesh. It covers an area of about 21,081 square kilometers and exposes huge thickness of Tertiary sequences of ~ 8000m. Mizoram succession has been grouped into Barail, Surma and Tipam Groups and has been considered as the southern extension of Surma basin.

Mizoram lies between latitudes 21°26′N and 24°30′N to longitudes 92°16′E to 93°26′E. It has aerial dimensions of 115Km from east to west and 285Km from north to south (Pachuau, 1994). It was the district of the Assam State till 1972, when it became Union Territory with capital at Aizawl. It became a full-fledged state in 1986. The state is bounded by The Chin Hills of Myanmar to the east, Arakan Hill Tracts to the south, Tripura and Chittagong Hill Tracts of Bangladesh to the west, Cachar Valley of Assam to the north, and Manipur to the northeast. Tropic of cancer passes through the state which divides it into almost two equal parts, Mizoram is connected with Assam by NH-54 that connects Silchar (Assam) with Aizawl, the capital of Mizoram. State Transpor, private maxi cab and buses ply regularly between Aizawl and Guwahati. Aizawl is also connected by air with Imphal, Guwahati and Kolkata. Inner Line Permit is necessary for entry into Mizoram, which can be obtained from various Mizoram Houses located in Delhi, Kolkata, Guwahati and Silchar.

Mizoram enjoys a mild climate because of its location in the tropical region which has a humid climate with short winter and long summer with heavy rainfall. The temperature ranges from 20 to 29 C in summer, but progressively warmer due to climate change with temperature crossing 30 C, and 7 to 22 C in winter. The state has an annual average rainfall of 245 centimeters. Maximum rainfall generally takes place in the months of July and August while December and January are the driest months of the year.

1.2. STUDY AREA

The study area is around Aizawl and falls under the Survey of India Topographic Sheet no. Nos. 84 A/13 and 84 A/14 and coordinates of the study area is (GPS) N23^0 44' 53" – N 23^0 43' 46'' and E 92^0 47' 7" - – E 92^0 46' 40''.

1.3. GENERAL GEOLOGY

Geologically, Mizoram is a part of the Tripura - Mizoram sedimentary basin of Cenozoic age (Evans, 1964). It has been considered as the southern extension of Surma Valley. The sedimentary column of the entire area is a repetitive succession of Paleogene and Neogene argillaceous and arenaceous succession in alternation. Structurally, N-S trending and longitudinally plunging anticlines and synclines occur in the state (Ganju, 1975, Nandy, 1982 and Ganguly, 1983; Fig. 1.1). The rock formations trend generally N-S with dips varying from 20º to 50º either towards east or west (Karunakaran, 1974; Main rock types exposed in the area are sandstone, siltstone, shale, mudstone and their admixture in various proportions and a few pockets of shell limestone, calcareous sandstone and intra-formational

conglomerates. Sequentially, these are grouped into the Barail, the Surma and the Tipam Groups in the ascending order. The stratigraphic succession in the state as worked out by Karunakaran (1974) and Ganju (1975) is given in Table 1.1.

Presence of the Barail succession in Mizoram is rather controversial. Geologists of the Geological Survey of India like Munshi (1964), Nandy (1972, 1982) and Nandy *et al.* (1983) have shown the occurrence of Barail succession in the eastern part of the State around Champhai. Geologists of the Oil and Natural Gas Corporation of India, namely, Ganju (1975), Ganguly (1975), Shrivastava *et al.* (1979), Jokhan Ram and Venkataraman (1984), on the other hand, are of the opinion that the Barails do not occur in Mizoram and the rocks around Champhai should be included in the Surma Group only.

The spatial distributions of various lithounits indicate that Lower Bhuban succession are exclusively confined to the anticlinal cores of high amplitude folds. The Middle Bhuban succession is generally exposed on limbs of folds and they also occupy the cores of low amplitude anticlines. The Upper Bhuban rocks form anticlines in western Mizoram but are confined to the synclinal cores in central and eastern Mizoram. Bokabil rocks *vis-à-vis* Tipams are limited within the cores of synclines in the western and northwestern parts of the State (Ram and Venkataraman, 1984).

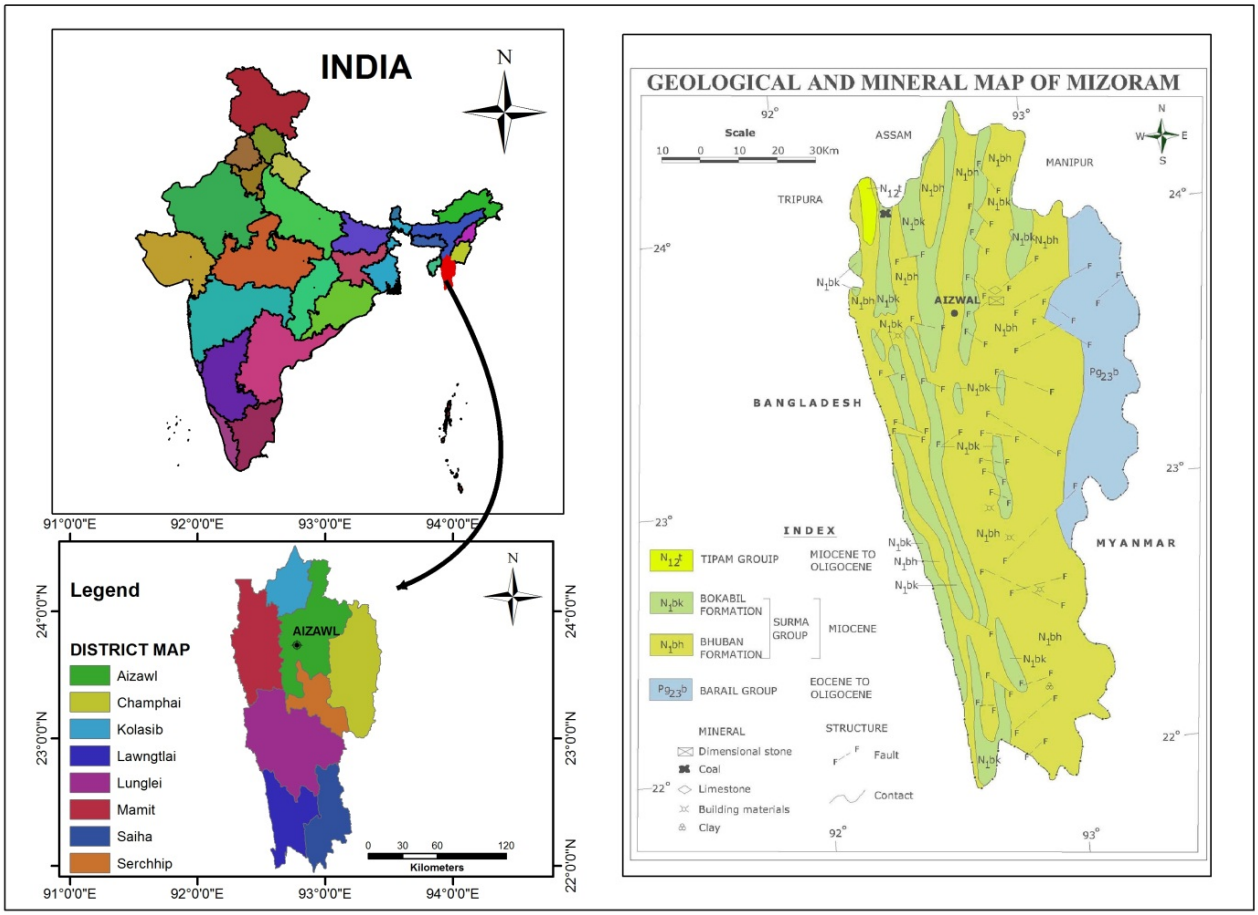

Figure 1.1. Geological and mineral map of Mizoram (after GSI, 2011)

Table 1.1. Geological Succession of Mizoram (Modified after Karunakaran, 1974; Ganju, 1975; Tiwari & Kachhara, 2003; Mandaokar, 2000; and Duhawma, 2016)

Age	Group / Formation		Thickness	Gross Lithology	Depositional Environment
Recent	-		-	Gravel, silts and clays	Fluvial and alluvial
----------Unconformity----------					
Early Pliocene to Late Miocene	Tipam		+ 900 m.	Friable sandstone with occasional clay bands	Fluvial
----------Conformable and transitional contact ----------					
Miocene	S U R M A	B o k a b i l	+ 950 m.	Shale, siltstone and sandstone	Shallow marine
		----------Conformable and transitional contact ----------			
To		B H U B A N	Upper (+1100 m.)	Arenaceous predominating with sandstone, shale and siltstone	Shallow marine, near shore to lagoonal
			----------Conformable and transitional contact --------		
Upper Oligocene			Middle (+1000m.)	Argillaceous predominating with shale alterations and sandstone	Deltaic
			--------Conformable and transitional contact --------		
			Lower (+900 m.)	Arenaceous predominating with sandstone, silty shale	Shallow marine
----------Unconformity obtained by faults----------					
Oligocene	B a r a i l		(+ 3000 m)	Shale, siltstone and sandstone	Shallow marine
---------- Lower contact not exposed ----------					

1.4. FLORA AND FAUNA

The state has a very rich and diversified flora and fauna since northeastern India is a meeting place of eastern floral and faunal species besides the North Indian ones. The entire State abounds in subtropical trees, bushes, plants, grasses and variety of bamboos. The hills are covered with green plantations throughout the year. Ferns and allies, soft stemmed herbaceous plants; orchids and other epiphytes make a long list of plants endemic to this area with a unique assemblage of non-tree floral species.

The forest of Mizoram is inhabited by swamp deer, tiger, elephant, leopard, sambhar, hoolock gibbon, bear, wild pig, mountain goat, mithun, monkey, flying squirrel, snakes and other reptiles.

1.5. GEOMORPHOLOGY

The terrains of Mizoram are rugged and highly undulated with an aerial extent of 21,081 sq. km. The Mizo Hills (=Lushai Hills) are consisting of alternating ridges and valleys which are trending approximately N-S to NNE-SSW with a tendency to taper at both ends. The terrains are of first order topography. The elevation ranges from 40m at Bairabi to 2157m at Phawngpui (Blue Mountain) with average elevation of about 900m. The elevation increases towards the east. Hills are generally steep with relatively compact and older rock units exposed in the anticlinal crest and younger and softer formations exposed in the synclinal troughs (Ganguly, 1983). Hills are trending approximately N-S, separated by river valleys flowing either towards north or south forming deep gorges.

The area exhibits angular, sub-parallel, parallel and dendritic drainage patterns. Lower order streams run both parallel and across topographic 'highs' and 'depressions'. Sonai (Tuirial), Dhaleswari (Tlawng), and Tuivawl are important rivers that flow towards north. They are originate in the central part of the state and flows towards the Barak Valley of Assam. The important southerly flowing rivers are Koladyne (Chhimtuipui) and Karnafuli. Koladyne, the main river in the state, which originates from Myanmar and flows southerly with a distance of about 500 km in Mizoram and enters again in Myanmar. Karnafuli River originates at the southern tip of Mizoram, flows northerly up to middle of the state, then takes turn towards west and enters into Bangladesh.

Topographic features in the state show prominent relief, as the terrain is immature due to recent tectonics. The major geomorphic features of the area are the structural and topographic 'highs' and 'depressions', 'flats' and 'slopes' that are arranged in linear fashion. Topographic 'depressions' are, in all cases, in accordance with the normal first order structural elements but topographic 'highs' are recorded both in structural 'highs' and 'depressions'. Physiographic expression of the state is characterised by approximately north-south trending steep, mostly anticlinal, longitudinal, and parallel to sub-parallel hill ranges and synclinal narrow valleys. The anticlines and synclines are intersected by transverse faults.

1.6. REVIEW OF LITERATURE

The geological studies of Mizoram is not at par with other geological terrains of the country because of its remote location, undulated topography, inaccessibility, highly rugged terrains coupled with dense vegetation cover. No exhaustive work has

been done in Mizoram until 1980s in case of palaeontological studies. A brief resume of the palaeontological and biostratigraphic studies carried out by various workers in the Tertiary succession of Mizoram are as follows:

La Touche (1891) was the first to report *Schizaster* sp. from the Lunglei area. Thereafter, we have a long period of quiescence, then it was only after 1970s, that the pace of detailed investigation on various geological aspects of the Tertiary succession of Mizoram was accelerated by several workers *viz*., Das Gupta (1977, 1984), Ganju (1971, 1972, 1974, 1975), Ganguly (1974, 1975, 1983), Ganguly *et al.* (1973), Jokhan Ram *et al.* (1983), Nandy (1972, 1980, 1982), Nandy *et al.* (1983), Ranga Rao (1983), Sarkar *et al.* (1977), Shrivastava *et al.* (1979), Tiwari *et al.* (1989), John *et al.* (1990), Bhaskar *et al.* (1990), Purushottaman *et al.* (1990).

Chatterjee (1972) reported foraminifers and ostracods from the Upper Bhuban Formation near Sairang. Subsequently, Sinha (1973) recorded the occurrence of a few bivalves, echinoids and gastropods from Lunglei area and Das Gupta (1977) reported a large number of bivalves, foraminifers and ostracods from the Lower Bhuban Formation in Tuipang area and assigned them to Aquitanian. Das Gupta (1982), while reviewing the faunal records from the Surma basin, referred to the occurrence of a few genera of bivalves, gastropods, foraminifers and ostracods from different parts of Mizoram. He commented that the Surma faunas bear close resemblance with the form of Kama and Pyalo beds of Myanmar thereby the Lower Bhuban Formation may belong to Oligocene. Sinha *et al.* (1982), while writing on the status of palaeontological researches in the northeast, mentioned the presence of a few bivalves, gastropods and echinoids in the Surma succession of Mizoram. Similarly, Patil (1990, 1991) too, reported bivalves, gastropods, echinoids, crabs and

2shark teeth from the Surma Group of Mizoram. However, these reports are mostly up to generic level and without any descriptions and illustrations. Satsangi and Mehrotra (1983) reported the occurrence of selachians (*Hemipristis serra*, *Carcharodon* cf. *carcharias*, *Carcharhinus* sp., *Odontaspis cuspidata*, *Negaprion* sp., ? *Isurus* sp.), batoid (*Dasyatis* sp.) and teleost (siluroid tooth) from the Bhuban rocks of Kolasib area. Similarly, Mehrotra (1984) reported *Alopias* sp., *Odontaspis* cf. *contortidens*, *Carcharhinus nicaraguensis* (sharks) and *Sparus cintus* (teleost) from the calcareous sandstone of Kolasib area. Satsangi (1985) reported larger and smaller foraminifers along with isolated teeth and spines of sharks and ray fishes from Bhuban Formation, South Hlimen, ~5 km south of Aizawl, and suggested shallow marine environment of deposition for the beds. However, these earlier records especially of fossil fish teeth from the Tertiary sediments of Mizoram are in the form of reporting in the News Letters of Geological Survey of India. These reports are mostly up to generic level and are without systematic descriptions, therefore detailed comparison of the earlier reported invertebrates and vertebrates from the state could not be made with the present collections due to lack of details. Satsangi and Mehrotra (1986) recorded the occurrence of echinoderms and arthropods in the collection of Mishra *et al.* (1986) from Upper Bhuban Formation in Aizawl District. Satsangi and Patil (1988) identified bivalves, gastropods, echinoids, corals, decapods and shark teeth from the sandstone - siltstone and mud-pellet conglomerate horizons of Upper Bhuban Formation of Aizawl and Chhimtuipui Districts. They inferred that invertebrate fauna, on the whole, shows a good resemblance to the Aquitanian – Burdigalian fauna of the Garo Hills, Meghalaya.

Tiwari and Satsangi (1988), for the first time described a crab, *Portunus* sp., from the Upper Bhuban Formation in Lunglei. Later, Tiwari (1992) described and illustrated 125 species of bivalves, gastropods, echinoids, crabs, shark teeth and scaphopods in decreasing order of abundance from the Surma Group in Aizawl and Lunglei. He proposed three assemblage zones - one within the Middle and two within the Upper Bhuban Formations and assigned Aquitanian age for the former and Aquitanian-Burdigalian to Burdigalian age for the latter. Hait and Banerjee (1994) reported rich and diverse tropical and subtropical palynoassemblage indicating coastal and brackish environment. They assigned Bhuban Formation to Lower Miocene and Tipam Group to Upper Miocene. Tiwari *et al.* (1997) reported four genera and five species of decapod crustaceans from the Upper Bhuban Formation and assigned them Aquitanian-Burdigalian to Burdigalian age. In subsequent year Tiwari *et al.* (1998) recorded eight species of fish teeth in the Middle and Upper Bhuban Formations. Tiwari and Kachhara (2000) described two new species of *Apolymetis* (Bivalvia: Tellinidae) from the Upper Bhuban Formation of Mizoram. Tiwari and Mehrotra (2000) illustrated five species including a new species of wood from the Tipam Group of Mizoram and inferred prevalence of warm and humid climate during the time of deposition of these rocks. Mandaokar (2000) reported palynomorphs from the Bhuban Subgroup of Aizawl and opined the existence of brackish water swamp and prograding delta complex with fresh water influx. Mehrotra *et al.* (2001) recorded an ichnospecies, *viz. Teredolites clavatus* Leymerie from the Upper Bhuban Formation of Aizawl and inferred shallow marine transgressive phase of deposition for it. Tiwari and Bannikov (2001) with three new species of early Miocene marine fishes from the Upper Bhuban Formation of Aizawl

and Buarpui, inferred a near-shore, shallow water, probably estuarine, marine environment of deposition. Tiwari (2001) while describing 14 species of bivalves from the Bhuban Subgroup in Mizoram inferred a shallow marine (inner neritic to littoral) environment of deposition. Tiwari and Mehrotra (2002) came across an interesting assemblage of leaf and seed impressions from the Barail succession of the Champhai area. The assemblage reflects the occurrence of tropical forest under warm and humid climate in the nearby area during the time of deposition. Mehrotra *et al.* (2003) illustrated a *Nypa* plant fossil from Kolasib of Mizoram and are of the opinion that the Bay of Bengal was extended northward during Miocene than its present day boundary. Tiwari and Kachhara (2003) established five biozones in the succession (Barail and Surma Groups) of Mizoram. These Zones are: I. *Meretrix agrestis* Zone of Late Eocene to Oligocene age, II. *Glycymeris sindiensis* - *Nuculana virgo* Zone of Aquitanian age, III. *Ostrea latimarginata* - *Natica pellis tigrina* Zone of Aquitanian to Burdigalian age, IV. *Pecten* (*Oopecten*) *gigas* Zone of Burdigalian age and V. *Pecten* sp. Zone of Helvetian age. Tiwari (2006) has described a few species of genus *Tellina* from the area in and around Aizawl and Lunglei. Thus, it is evident that the detailed study of mega-biota from this locality is yet to be carried out. It is in this context that the present study is significant.

Jauhri *et al*. (2003) reported an interesting assemblage of corals, foraminifers and echinoids from Upper Bhuban sediments from a locality near Zemabawk, Aizawl. Mazumder (2004), while working for his doctoral degree, identified 153 forms of which 118 belong to bivalves, 21 to gastropods, 8 to decapods, 5 to echinoids and one to scaphopods from the Surma rocks in and around Kolasib, Mizoram. He proposed two bio-zones in Surma rocks. These are Zone-1. *Nucula*

(*Lamellinucula*) aff. *pulchra* - *Nuculana* (*Nuculana*) *virgo* of Aquitanian age in the Middle Bhuban, and Zone - 2 *Chlamys* (*Argopecten*) *senatoria* - *Tellina* (*Tellinella*) *pseudohilli* of Aquitanian – Burdigalian to Burdigalian in the Upper Bhuban. He further proposed two subzones within Zone - 2 (Subzone 2A: *Clementia* (*Clementia*) *papyracea* of Aquitanian to Burdigalian in the Upper Bhuban and Subzone 2B: *Callista* (*Costacallista*) *erycina* - *Antigona granosa* - *Trisidos semitorta* of Burdigalian in Upper Bhuban). Subzone 2A has two Zonules (Zonule 2A(a): *Conus* (*Lithoconus*) *ineditus* - *Diplodonta* (*Diplodonta*) *incerta* of Aquitanian - Burdigalian), and (Zonule 2A(b): *Conus* (*Dendroconus*) *loroisii* - *Archimediella* (*Torculoidella*) *angulata* of Burdigalian). The assemblage reported here points to a shallow marine to coastal depositional environment. Palaeogeographically, the basin around Kolasib was a part of the Indo - Pacific zoogeographic province. A good number of fauna endemic to this province are recorded from the area. For example, *Fragum*, *Donax*, *Antigonia*, *Trisidos*, *Lutraria*, *Cultellus*, *Apolymetis*, *Solecurtus*, *Corbula*, *Natica*, *Conus* (*Dendroconus*), *Conus* (*Lithoconus*), *Tellina* (*Tellinella*), *Clementia* and *Architectonica* are typical faunas of the Indo - Pacific Province. Even at species level, the typical Indo - Pacific taxa, e.g. *Clementia papyracea* (Gray) (Davies, 1975; Tiwari *et al.*, 1998b), are present in the area leaving no doubt that this area was a part of palaeozoographical Indo - Pacific Province of Miocene Epoch.

Srivastava *et al*. (2008) described two echinoid genera namely, *Coelopleurus* (*Keraiophorus*) Michelin, 1862 (an arbacioid echinoid) and *Schizaster* L. Agassiz, 1836 (a spatangoid echinoid) for the first time, from the rocks of the Upper Bhuban Unit, Bhuban Formation, Surma Group (lower to middle Miocene) exposed in the study area.

Ralte (2009) described 98 taxa comprising mega-invertebrates, foraminfers, fishes and crocodylidae? From Upper Bhuban Unit of Bhuban Formation, Surma rocks in and around Aizawl, Mizoram. The assemblage comprises 44 bivalve species, 8 gastropod species, 6 species of decapods. He proposed one biozone with two subzones in the Bhuban Formation. Zone – 1 is named as *Paphia* (*Paphia*) *rotundata* - *Palaeocarpilius rugifer* Zone and the two subzones are *Gari* (*Gari*) *natensis* Subzone (1A) and *Barbatia* (*Barbatia*) *bataviana* var. *carinata* - *Neptunus sindensis* Subzone (1B).

Mazumder and Tiwari (2009) reported six species of the genus *Meiocardia* from the upper part of the Bhuban Formation, Surma Group, Assam.

Ralte *et al*., (2009) described six genera and five species of decapod fossils viz., *Calappa protopustulosa* Noetling, *Ebalia tuberculata* Noetling, *Typilobus granulosus* Stoclizka, *Neptunus sindensis* Stoliczka, *Xantho* sp. and *Palaeocarpilius rugifer* Stoliczka from Aizawl area. These decapods and the associated bivalves, gastropods, echinoids and fish teeth indicate Aquitanian - Burdigalian age for the fossil yielding beds and the existence of an open shallow, warm sea with fluctuations from inner neritic to littoral water with depth <45m meter.

Lalmuankimi *et al*. (2010) reported a foraminiferal fauna comprising planktic and benthic assemblages. This includes *Globigerinoides trilobus* (Reuss), *Globigerinoides subquadratus* Bronnimann and *Miogypsina* sp. suggesting equivalence with planktic foraminifera zones N5 - N6, *i. e.* early Miocene.

Ralte *et al.* (2011) reported an interesting selachian fish assemblage having stratigraphic and palaeoecological significance from the two intraformational calcareous conglomeratic horizons within the Upper Bhuban unit of Bhuban

Formation, Surma Group (Lower to Middle Miocene) from east of Aizawl. The assemblage consists of eighteen species of selachian fishes including two new ones, namely, *Carcharhinus bhubanicus* and *Hemipristis unidenticulata*. The fish fauna and the associated mega-invertebrates suggest Lower Miocene (Aquitanian – Burdigalian) age for the Upper Bhuban unit of Bhuban Formation. These further suggest that the fish yielding horizons were deposited under a warm shallow marine set-up near to the shoreline in a high-energy environment.

A detailed ichnological study performed on the Bhuban Formation, Surma Group (Lower to Middle Miocene) of Mizoram by Tiwari *et al.* (2011) reveals the occurrence of rich and diverse trace fossil assemblage. These ichnogenera indicate foreshore to shoreface - offshore zone of shallow marine environment for the deposition of the rocks of the Bhuban Formation of Mizoram. Tiwari *et al*. (2012) described eleven species of fossil woods from a petrified wood forest of north-western part of Mizoram from Tipam Group. The modern environmental tolerances of the above taxa indicate the existence of a tropical warm and humid climate in Mizoram during the depositional period. Tiwari and Ralte (2012) described dental plates and a caudal spine belonging to two species of *Myliobatis*, one of *Aeteobatus* (batoids) and four of *Diodon* (teleosts) from Upper Bhuban unit of Mizoram. These fish remains together with associated selachians and mega-invertebrates suggest the existence of a tropical to subtropical climate and a warm shallow marine set-up near to the shoreline in a high-energy environment during the deposition of the fossiliferous horizon. Three species of the genus *Periploma* (*Aelga*), namely *Periploma* (*Aelga*) sp. 1, *P*. (*A*.) sp. 2, and *P*. (*A*.) sp. 3 were described from the grey sandstone and calcareous sandstone beds of the Bhuban Formation, Surma Group

(Lower to Middle Miocene), Kolasib, Mizoram by Mazumder and Tiwari (2012). Seven bivalve taxa of the family Pectinidae are identified recorded by Mazumder and Tiwari (2012) from Bhuban Formation of Kolasib area.

Chinmoy *et al*. (2013) described a well preserved and diversified trace fossil assemblage consisting of 13 ichnospecies from the Middle Bhuban unit of the Bhuban Formation, Surma Group (Lower to Middle Miocene) exposed along the Bawngkawn - Durtlang road section, Aizawl, Mizoram. These together with sedimentological attributes suggests that Middle Bhuban succession was deposited under fluctuating energy conditions in foreshore to shoreface/offshore zones of shallow marine environment.

Lalchawimawii (2013), while studying Upper Bhuban Unit of Bhuban Formation from Hlimen quarry reported 103 bivalve forms along with a number of gastropods, scaphopod, decapods and echinoid. She suggested that the Upper Bhuban fauna grew in the shallow sea water region mainly in the shelfal set-up under the influence of warm water referring to the shallowing of the basin with water depth during the deposition of this bed was probably ranging from 10-15m.

1.7. OBJECTIVES

The objectives of the proposed study are follows:

1. To establish fossil assemblage stratigraphy of the Bhuban Formation (Surma Group) in the study area.
2. To attempt stratigraphic correlation.
3. To decipher depositional environment

1.8. METHODOLOGY

The litho-column of the rocks exposed in the study area has been prepared based on the extensive data collected from the field. Fossiliferous horizons have been delineated and marked in the litho-column. Bed by bed collections of mega-biota from the study area has been made. The mega-biota thus collected have been thoroughly-studied group-wise up to species level for their systematic palaeontological descriptions with the help of type material and available literature in the laboratory. Age of the fossiliferous horizons has been deciphered based on the common occurrence of fossils species in the rock successions of equivalent age. Bio-zones have been worked out based on the restricted occurrence of short-range taxa. The Bhuban succession of the study area has been correlated with the Miocene succession of the other areas based on the extent to which fossil fauna are common. The data regarding the distribution pattern of fossils in the rocks (*viz*. orientation, density, sorting and state of preservation), their association, mode of occurrence, relationship with the enclosing sediments and forms has helped to decipher palaeoecology of the fossil species. This data along with the bathymetry of the studied taxa has been used to work out the depositional history of the associated rocks and palaeogeography of the study area.

CHAPTER 2: GEOLOGICAL SETTING

2. GEOLOGICAL SETTING

2.1. GEOLOGY OF THE STUDY AREA

Geologically, the rocks exposed are belong to Middle and Upper Bhuban Formation, Surma Group of lower - middle Miocene age. The rock types in the study comprises of dark to light brown sandstones, repetitive alteration of sandstones, shale, silty-sandstones and siltstones along with intraformational conglomerates and pockets of calcareous sandstones. The trend of the rocks formations here is roughly N-S with and the general dip is towards west with varying amount ranging from 40^0 - 60^0 dip due west. Geological map of Aizawl and its surrounding areas is given in Figure 2.1. The collection of fossils comes from eight localities. The detail lithological characteristics and faunal contents of each fossil locality in the study area are given below:

LOCALITY 1: Near Amawii Tyre Works, Bawngkawn, Aizawl.

This locality is the oldest and alongside Bawngkawn – Lunglei road, Aizawl (N23^0 44’ 53” and E 92^0 47’ 7”). The fossiliferous rocks are presented by medium grained brown and grey silty sandstone (Plate I A). Fossil preservation is excellent though the variety is scarce as there are only two species of fossils. Following is the list of fauna identified from this bed. The litho column of the rock exposed in this area is shown in Figure. 2.2A.

Bivalves: *Apolymetis grimesi* Noetling

Echinoids: *Schizaster alveolatus* Duncan and Sladen

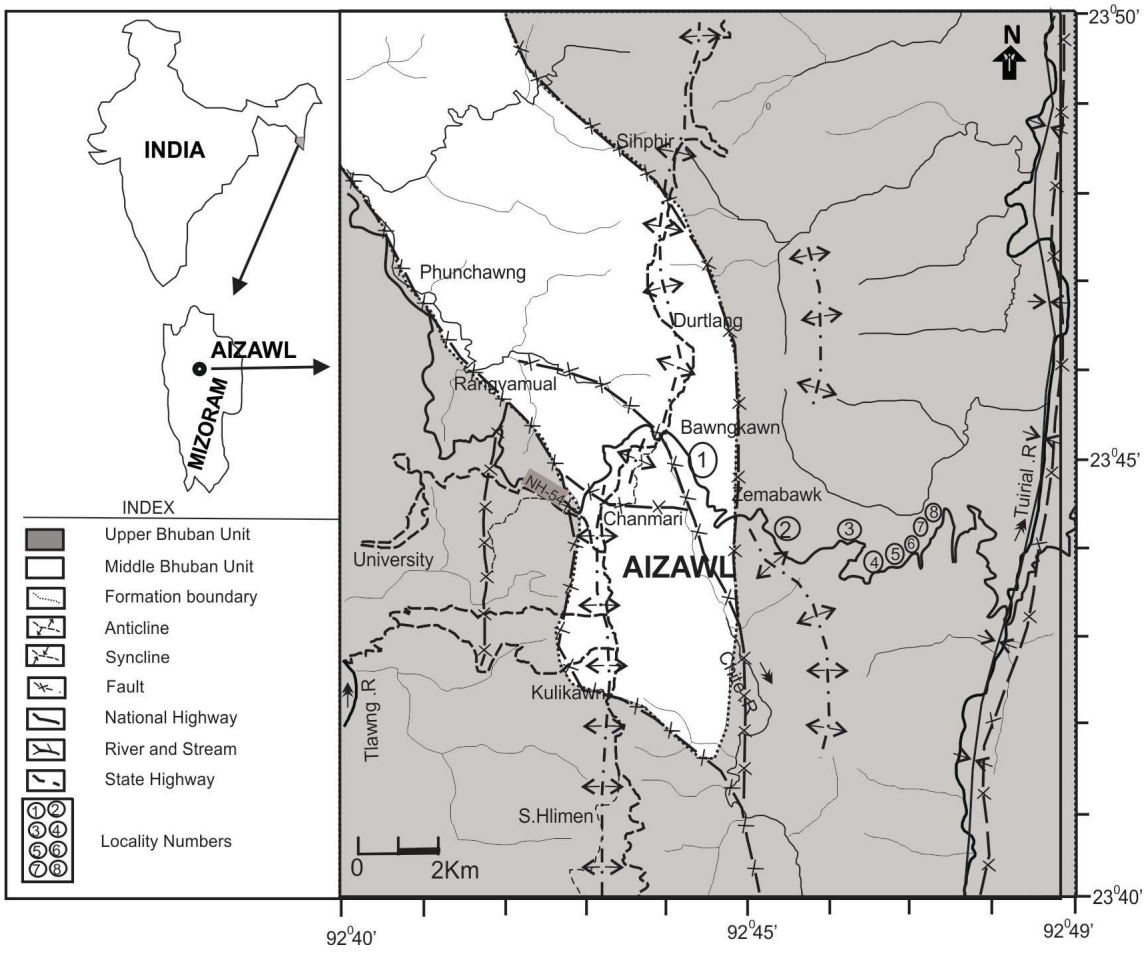

Figure 2.1. Geological map of Aizawl showing the location of the studied areas. (modified after Malsawma *et al*., 2010).

PLATE I

A. Locality 1: Near Amawii Tyre Works, Bawngkawn, Aizawl.

B. Locality 2: Near Vara Workshop, Bawngkawn, Aizawl.

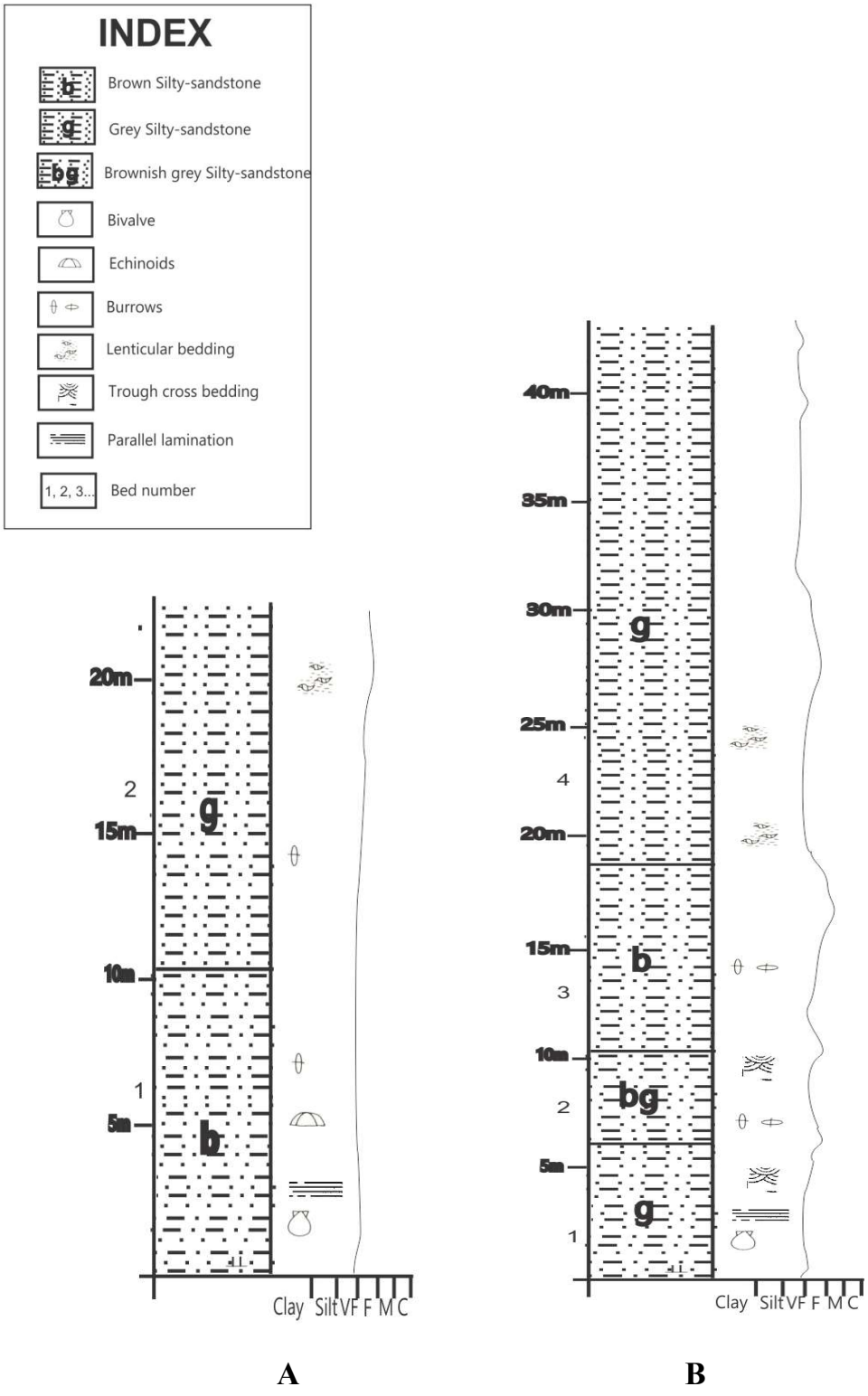

Figure 2.2. A - Litho-column at Fossil Locality-1 (near Amawii Tyre works, Bawngkawn, Aizawl)

B - Locality-2 (Near Vara workshop, Zemabawk, Aizawl).

LOCALITY 2: Near Vara Workshop, Zemabawk, Aizawl.

This locality is at near Vara Workshop (Plate I B), Zemabawk, Tuirial Road (N 23^0 43' 49'' – E 92^0 45' 25''). The litho column of the rocks exposed at this site is given in Figure. 2.2 B. There is only one fossiliferous horizon in this locality even though the exposed rock unit is more than 40 meters in thickness. The only fossiliferous horizon was found at the lower bed which is about 0.5m in thickness. It is medium to fine grained grey silty-sandstone bed. The check list of fauna from this locality is as follows:

Bivalves: *Anadara daviesi* Mukerjee

Echinoids: *Coelopleurus* (*Keraiophorus*) sp.

LOCALITY 3: **Prayer Point, Tuirial Road.**

This section (N 23^0 44' 09'' – E 92^0 45' 93'') is located at about 11 kms from Aizawl, eastern side (Plate II A). The exposed rock unit is about 24 meters, containing brown and brownish grey sandstone bed. Fossils are dispersed on the top 5-meter range. This section is well bedded, moderately hard and compact in nature. The lithocolumn is shown in Figure 2.3A. The faunal list from this bed is given below.

Bivalves: *Tellina* (*Eurytellina) pilgrimi* Cox*., Tellina maubawka* Tiwari*, Tellina Perodina* sp*. Gari* (*Gari*) *natensis* Noetling*, Paphia* (*Callistotapes*) *pseudoliratus Vredenburg, Paphia* sp*.,* and *Corbula* (*Corbula*) *tunicosulcata* Vredenburg

LOCALITY 4: **Khawlthangi Quarry, Tuirial Road.**

A quarry (N 23^0 43' 72'' – E 92^0 46' 40'') at about 15kms from Aizawl, on the right side of Aizawl-Tuirial road exposes fossiliferous rocks belonging to Upper Bhuban Formation (Plate II B). The total thickness of the exposed litho unit is about 50 meters, though the fossiliferous horizons are found on the lowest dark brown sandstone bed (0.5m), the lower brown sandstone (3 m), scattered on the middle grey silty-sandstone bed and upper brown sandstone bed (Figure 2.3B). The following fossil species are identified from this locality.

Bivalves*: Anadara* (*Anadara*) *elongata* Lalchawimawii, *Chlamys* (*Argopecten*) *senatoria* (Gmelin), *Chlamys* (*Chlamys*) *quilonensis* Dey, *Chlamys* sp*., Pecten* (*Pecten*) *mathuri* Tiwari MS, *Placuna* (*Indoplacuna*) sp*., Crassostrea gajensis* (Vredenburg), *Diplodonta* (*Diplodonta*) *incerta* d'Archiac, *Ostrea* sp., *Astarte* (*Astarte*) *trigonalis* Lalchawimawii, *Cultellus* (*Cultellus*) *zulloi* Tiwari, *Tellina maubawka* Tiwari, *Tellina* (*Angulus*) sp., *Tellina* (*Tellinella*) *hilli* Noetling*, Callista* sp*., Callista* (*Macrocallista*) *florida* (Lamarck), *Callista* (*Macrocallista*) *cf. lilacina* (Lamarck), *Paphia* (*Paphia*) *jhai* Tiwari MS, *Paphia* (*Paphia*) *persica* Cox, *Paphia* (*Paphia*) *rotundata* (Linné), *Paphia* (*Callistotapes*) *pseudoliratus* Vredenburg and *Paphia* sp.

LOCALITY 5: **Mafaki Quarry, Tuirial Road.**

This locality is the extension of locality 4 (N 23^0 43' 71'' – E 92^0 46' 47''), the fossiliferous horizons are characterized by the brown sandstone and grey silty-sandstone bed (Plate III A). The check list of fauna is given below. The detailed lithocolumn is shown in Figure 2.4A.

PLATE II

A. Locality 3: Prayer Point, Tuirial Road, Aizawl

B. Locality 4: Khawlthangi Quarry, Tuirial Road, Aizawl

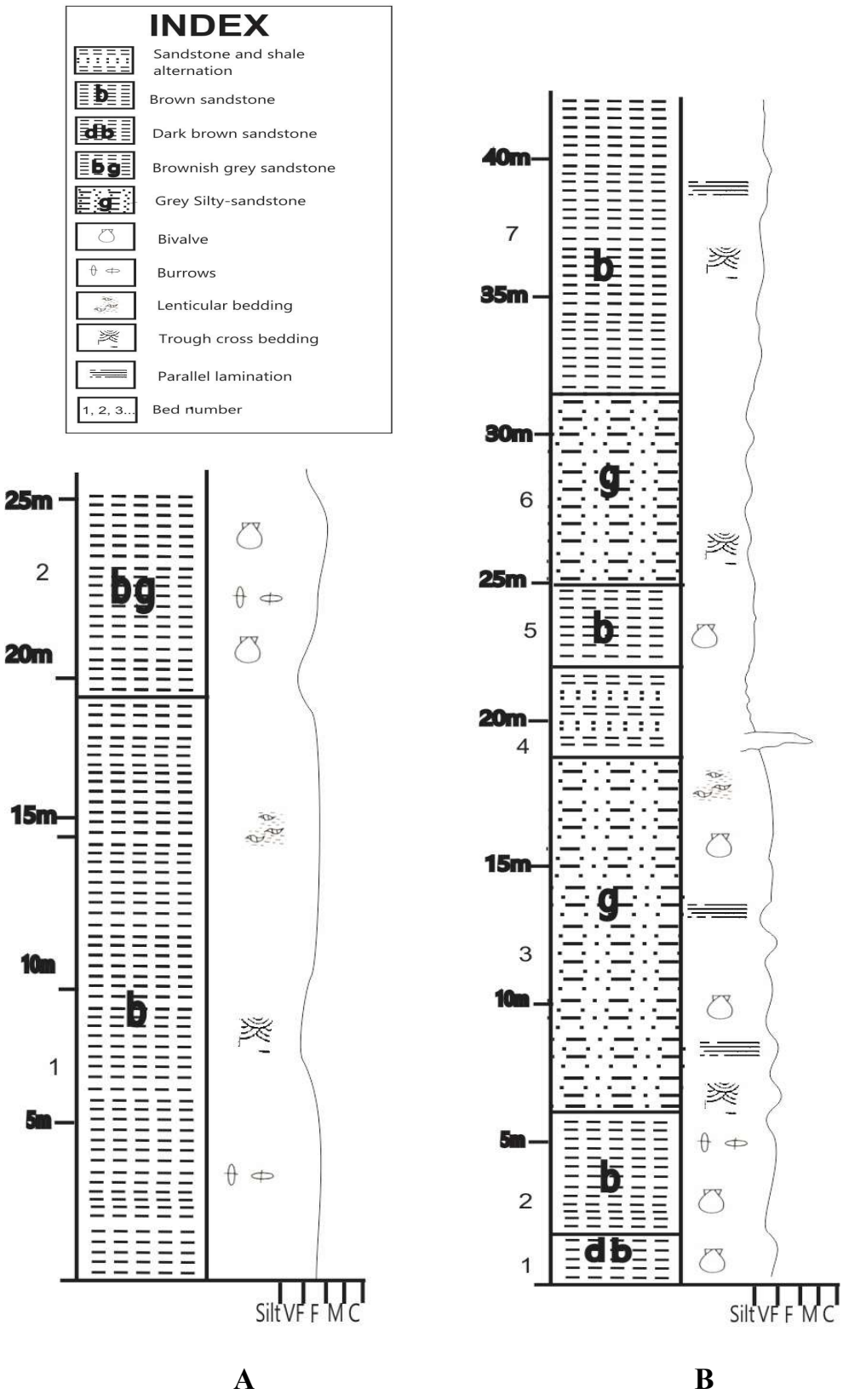

Figure 2.3. A - Litho-column at Fossil Locality-3 (Prayer Point, Tuirial Road)

B - Locality-4 (Khawlthangi quarry, Tuirial Road), Aizawl

Bivalves: *Nucula warsarensis* Eames, *Anadara* (*Anadara*) *trapezoida* Tiwari, *Anadara* (*Anadara*) *elongata* Lalchawimawii, *Chlamys* (C*hlamys*) *jamviniensis* Cox, *Chlamys* sp., *Pecten* (*Pecten*) *mathuri* Tiwari MS, *Placuna* (*Indoplacuna*) sp., *Astarte (Astarte) trigonalis* Lalchawimawii, *Cultellus* (*Cultellus*) *zulloi* Tiwari, *Tellina compressa* Tiwari, *Tellina* (*Eurytellina*) *pilgrimi* Cox, Noetling, *Tellina* (*Oudardia*) sp., *Arctica islandica* (Linné), *Callista* sp., *Paphia* (*Paphia*) *jhai* Tiwari MS, *Paphia* (*Paphia*) *persica* Cox, *Paphia* (*Paphia*) *rotundata* (Linné) Vredenburg, *Paphia* (*Callistotapes*) *pseudoliratus* Vredenburg and *Paphia* sp.

LOCALITY 6: **Tuirial Road.**

An exposure at about 15.5kms from Aizawl on the right side of Aizawl-Tuirial road (Plate III B) constitutes locality 6 (N 23^0 43'47'' – E 92^0 46' 55''). The detail litho-column of this section is shown in Figure 2.4 B. The fossiliferous bed at this locality is represented by about 2.5m thick medium grained brown sandstone bed. The fossil preservation is quite good though fossil variety is low. The faunal check-list is given below.

Bivalves: *Anadara* (*Anadara*) *elongata* Lalchawimawii, *Chlamys* (*Argopecten*) *senatoria* (Gmelin), *Chlamys* (C*hlamys*) *jamviniensis* Cox, *Chlamys* (*Chlamys*) *quilonensis* Dey, *Chlamys* sp, *Cultellus* (*Cultellus*) *zulloi* Tiwari, *Tellina maubawka* Tiwari, *Paphia* (*Paphia*) *jhai* Tiwari MS, *Paphia* (*Paphia*) *rotundata* (Linné), *Paphia* (*Callistotapes*) *pseudoliratus* Vredenburg and *Paphia* sp.

PLATE III

A. Locality 5: Mafaki Quarry, Tuirial Road, Aizawl

B. Locality 6: Tuirial Road, Aizawl

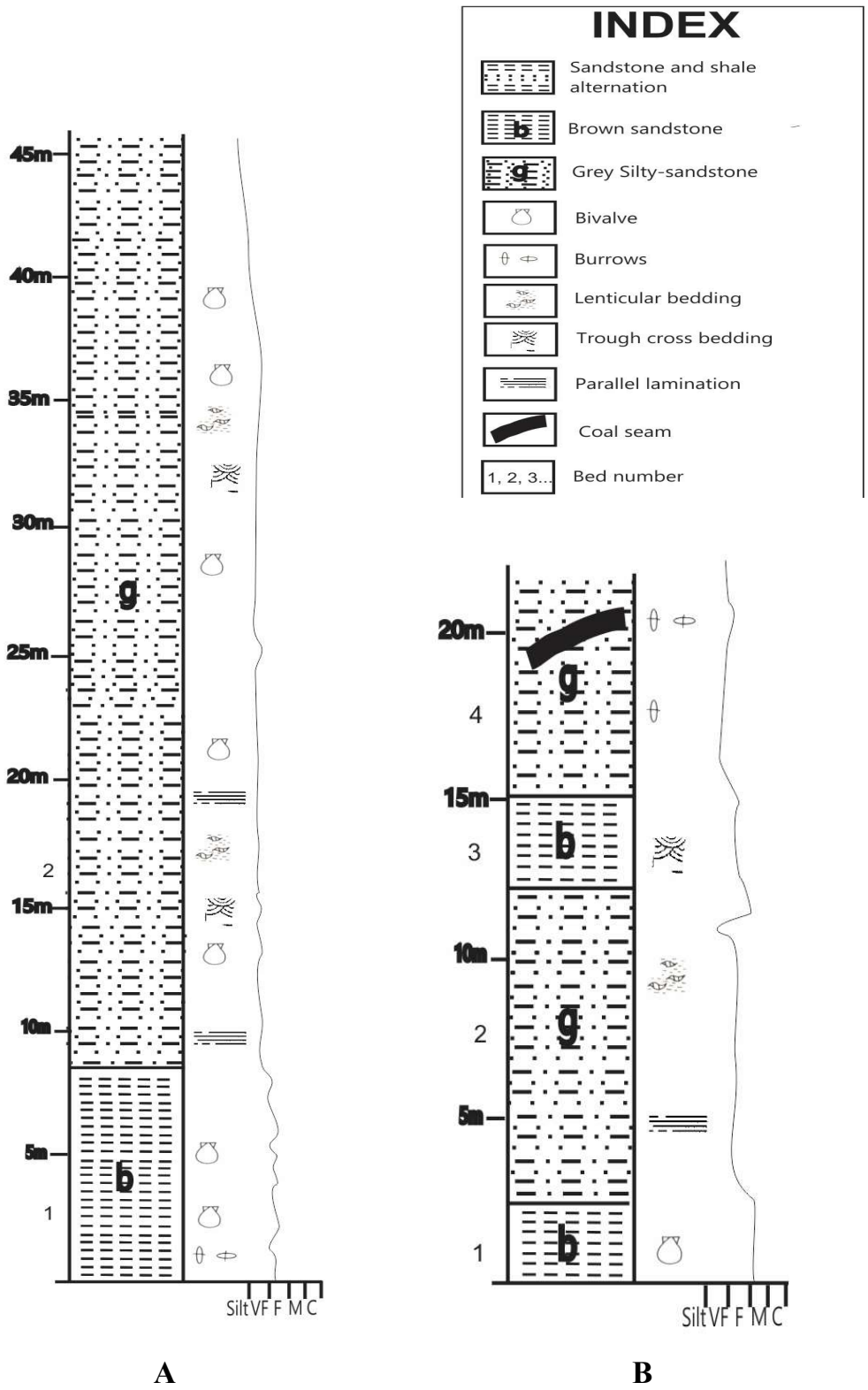

Figure 2.4. **A** - Litho-column at Fossil Locality-5 (Mafaki quarry, Tuirial road)
B - Locality-6 (Tuirial Road), Aizawl

LOCALITY 7: Bung Bangla Quarry 2, Tuirial Road.

This locality (Plate IV A) is a continuation of locality 6 (N 23^0 43' 46'' – E 92^0 46' 37''). The detailed lithocolumn is shown in Figure. 2.5 A. Fossiliferous beds are characterized by two grey sandstone beds at the lower and upper section. The following fossil species are identified from this locality:

Bivalves: *Anadara* (*Anadara*) *elongata* Lalchawimawii, *Pecten* (*Pecten*) *mathuri* Tiwari MS, *Astarte (Astarte) trigonalis* Lalchawimawii, *Cultellus (Cultellus) zulloi* Tiwari, *Arctica islandica* (Linné), *Callista* sp., *Callista* (*Macrocallista*) *florida* (Lamarck), *Callista* (*Macrocallista*) *cf. lilacina* (Lamarck), *Paphia* (*Paphia*) *jhai* Tiwari MS, *Paphia* (*Paphia*) *persica* Cox, *Paphia* (*Callistotapes*) *pseudoliratus* Vredenburg, *Paphia* sp., *Timoclea* (*Timoclea*) *arakanensis* Nevill and *Timoclea* (*Timoclea*) *scabra* (Hanley).

LOCALITY 8: **Bung Bangla Quarry 1, Tuirial Road**

The locality (Plate IV B) is at about 16 kms from Aizawl on Aizawl – Tuirial road (N 23^0 43' 46'' – E 92^0 46' 40''). The rock type exposed are shown in Figure. 2.5 B. There are two fossiliferous horizons in this locality i.e. the upper intraformational conglomeratic bed and the lower brown sandstone bed. Fossil variety is abundant though preservation is very poor in this section. Check-list of fauna is given below.

Bivalves: *Anadara* (*Anadara*) *trapezoida, Pinna* sp. *Chlamys (Argopecten*) *senatoria* (Gmelin), *Chlamys* (C*hlamys*) *jamviniensis* Cox, *Chlamys* (*Chlamys*) *quilonensis* Dey, *Chlamys* sp., *Placuna* (*Indoplacuna*) sp., *Crassostrea gajensis* (Vredenburg), *Cultellus*

(*Cultellus*) *zulloi* Tiwari, *Timoclea* (*Timoclea*) *subspadicea* (Cossmann) and *Periploma* (*Aelga*) *elliptica* Lalchawimawii.

Gastropods: *Turritella* (*Turritella*) *pseudobandongensis* Vredenburg, *Natica obscura* Sowerby and *Conus* (*Leptoconus*) *bonneti* Cossmann.

Scaphopods: *Dentalium junghuhni* Martin.

PLATE IV

A. Locality 7: Bung Bangla Quarry 2, Tuirial Road, Aizawl.

B. Locality 8: Bung Bangla Quarry 1, Tuirial Road, Aizawl.

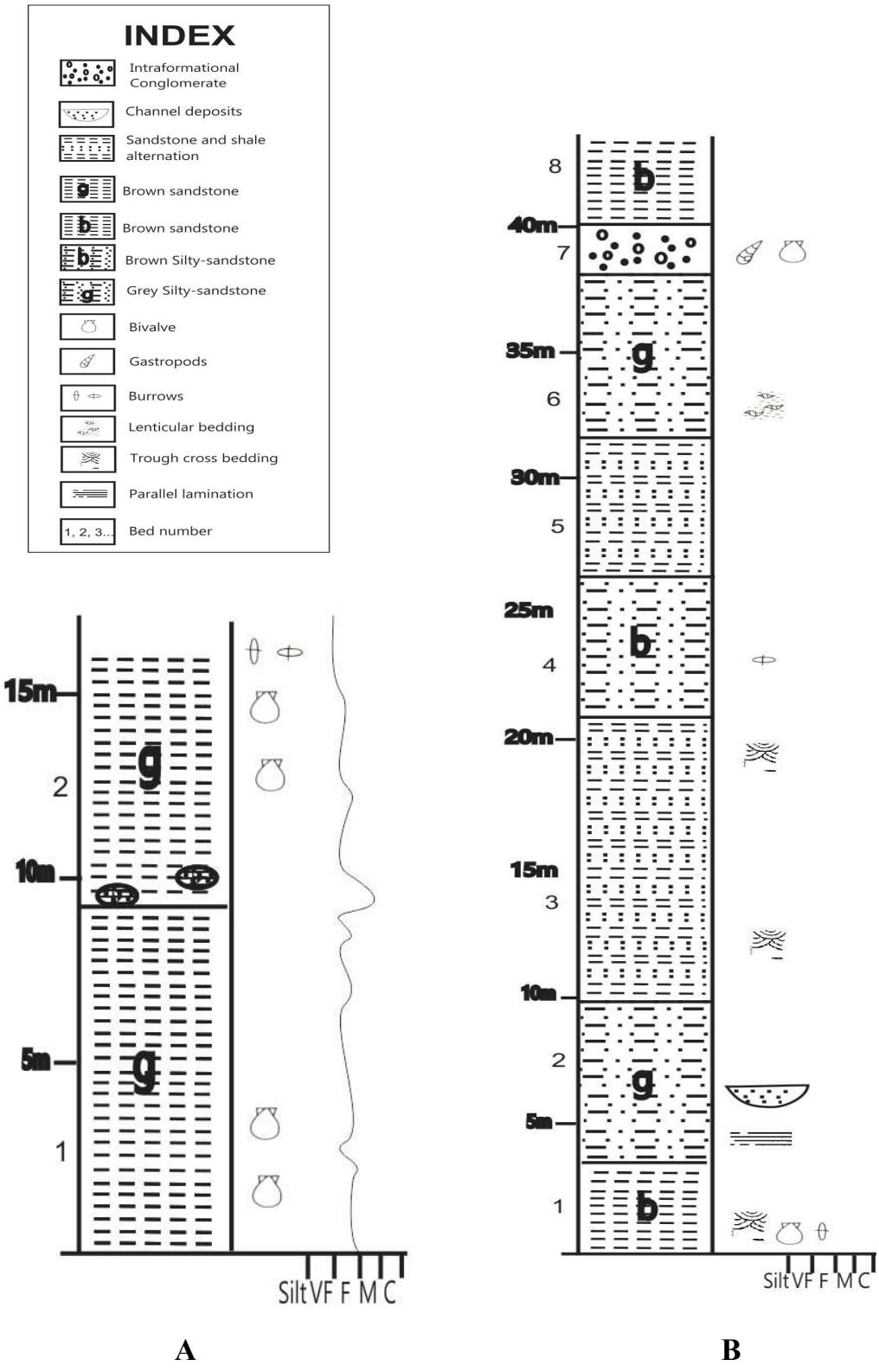

Figure 2.5. **A** - Litho-column at Fossil Locality-7 (Bung Bangla Quarry 2, Tuirial Road)

B - Locality-8 (Bung Bangla Quarry 1, Tuirial Road), Aizawl.

CHAPTER 3: SYSTEMATIC DESCRIPTION OF INVERTEBRATES

3. SYSTEMATIC DESCRIPTION OF INVERTEBRATES

3.1. SYSTEMATIC DESCRIPTION OF BIVALVIA

Bivalves represent the most abundant group of fossils in the study area. Though, the preservation is not very satisfactory and these generally occur as isolated valves, moulds and casts, the essential external features are observable enough for the identification upto species level.

The classification scheme of the Bivalvia suggested by Newell has been adopted for the purpose of systematic (see Moore R. C. *et al.*, 1969). The identification of genera and species is mainly based on the external morphological characters and comparision with the type specimens. The internal characters have also been considered wherever available. Measurements of the specimens are given in millimetres. Besides using their location abbreviation which is given below, the specimens are labeled with alphabetical A to L and X which denotes different beds. The following abbreviations have been used in the description:

Sp. No. - specimen number	mm - millimetre(s)
RV - right valve	h – height
LV - left valve	l – length
BV - both valves	t - thickness
sp. - species	w - width
s. s. - *sensustricto*	SD - subsequent designation
cf. - comparable to	OD - original designation
aff. - affinity to	M - monotypy

loc. cit. – locality cited above op. cit. – reference cited above

PP – Prayer Point TR- Tuirial Road

BC - Bawngkawn

The specimen photographs have mostly been taken in natural light with orientation in the reading positions. Magnification of the photographps may not tally with the actual figures given in the text due to parallax effect during photography.

The figured specimens are housed in the Paleontology Laboratory of the Department of Geology, Mizoram University, Aizawl, India.

The classification scheme of the Bivalvia as suggested by Newell has been adopted for the purpose of systematics (see Moore R. C. *et al.*, 1969). The identification of genera and species is mainly based on the external features but internal characters, wherever available, have also been considered.

Phylum - MOLLUSCA Linné, 1758

Class - BIVALVIA Linné, 1758

Subclass - PALAEOTAXODONTA Korobkov, 1954

Order - NUCULOIDA Dall, 1889

Super family - NUCULACEA Gray, 1824

Family - NUCULIDAE Gray, 1824

Genus - *Nucula* Lamarck, 1799

Type species: *Arca nucleus* Linné, 1758; M. Recent; France.

***Nucula warsarensis* Eames**

(Pl. V, fig. 1)

1928. *Nucula cancellata* Vredenburg, p. 420, Pl. XXXIII, figs. 4, 8, 10, 11, 12 and 13 (non Meek and Hayden).

1933. *Nucula cancellata* Vredenburg: Kumar and Pichamuthu, p. 96.

1950. *Nucula warsarensis* Eames, p. 243.

1962. *Nucula warsarensis* Eames: Dey, p. 25.

1992. *Nucula warsarensis* Eames: Tiwari, p. 34, Pl. III, figs. 2a, b.

2003. *Nucula warsarensis* Eames: Tiwari, p. 60, Pl. I, figs. 1 – 2.

2013 *Nucula warsarensis* Eames: Lalchawimawii, p. 22, Pl. III, figs. 1 a, b, c – 2.

Material: One right valve.

Location: Locality 5 (Mafaki Quarry, Tuirial Road, Aizawl, Mizoram).

Horizon: Brown sandstone of Upper Bhuban Formation (bed no. 1).

Dimensions:

Sp. No.	Length	Height	Inflation	
C18	21.1	14.6	5.5	RV

Remarks: The specimen is closely similar to *Nucula cancellata* Vredenburg (1928) in general outline, shape and positions of umbones. It has been compared with *Nucula warsarensis* Eames of Tiwari's collection no. LS/5/1 (1992) and Lalchawimawii's collection (B/CH/183 and B/CH/184) and found to match well. Hence, the specimen is unhesitatingly assigned to this form.

Subclass - PTERIOMORPHIA Buerlen, 1944

Order - ARCOIDA Stoliczka, 1871

Superfamily - ARCACEA Lamarck, 1809

Family - ARCIDAE Lamarck, 1809

Subfamily - ANADARINAE Reinhert, 1935

Genus - *Anadara* Gray, 1847

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

Subgenus - *Anadara* (*s. s.*)

***Anadara* (*Anadara*) *trapezoida* Tiwari**

(Pl. V, figs. 2 - 3)

2001. *Anadara* (*Anadara*) *trapezoida* Tiwari, p. 147 - 160, Pl. II, figs. 5 - 7.

2003. *Anadara* (*Anadara*) *trapezoida* Tiwari: Tiwari, p. 66, Pl. IV, fig. 31.

2004. *Anadara* (*Anadara*) *trapezoida* Tiwari: Mazumder, p. 49, Pl. III, fig. 3.

2009. *Anadara* (*Anadara*) *trapezoida* Tiwari: Ralte, p. 36, Pl. 3, figs. 14.

2013 *Anadara* (*Anadara*) *trapezoida* Tiwari: Lalchawimawii, p. 31, Pl. IV, figs. 11-12.

Material: One right valve and one left valve.

Location: Locality 5 (Mafaki Quarry, Tuirial Road) and Locality 8 (Bung Bangla Quarry 1, Tuirial Road)

Horizon: Brown sandstone of Upper Bhuban Formation of Locality 5 and 8 (bed no. 1).

Dimensions:

Sp. No.	Length	Height	Inflation	
C36	25	14.5	6.2	RV
D9	22.1	15.3	6.5	LV

Remarks: Tiwari (2001) described the diagnostic characters of the species *Anadara (Anadara) trapezoida,* as obliquely trapezoidal outline, terminal umbo, angular and very prominent posterior carina, and oblique ventral margin parallel to postero-dorsal margin. The present collections are well match with these characters. Further these have also been compared with the holotype of the species from Tiwari collection (2001) and are found to match well. Hence, they are assigned to this form without any reservation.

Anadara daviesi Mukerjee

(Pl. V, fig. 4)

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

1992. *Anadara daviesi* Mukerjee: Tiwari, p. 54, Pl. V, figs. 5a and b, 6, 7.

2004. *Anadara daviesi* Mukerjee: Mazumder, p. 47, Pl. III, fig. 6.

2004. *Anadara daviesi* Mukerjee: Lyngdoh, p. 36, Pl. II, fig. 11.

2009. *Anadara daviesi* Mukerjee: Ralte, p. 33, Pl. 3, figs. 10 - 11.

2013. *Anadara daviesi* Mukerjee: Lalchawimawii, p. 33, Pl. IV, figs. 1 a, b, c.

Material: One right valve.

Location: Locality 2 (near Vara workshop, Zemabawk) Aizawl, Mizoram.

Horizon: Grey silty sandtone of Upper Bhuban Formation (bed no. 1).

Dimensions:

Sp. No.	Length	Height	Inflation	
K4	22.1	12.9	4.1	RV

Remarks: Though the specimen under examination is poorly preserved and not complete, it shows the essential character like elongate and sub-ovate outline, height (about 60 – 65% of length), moderate inflation, oblique posterior margin, broad and flattened radial ribs and distinct granulations towards anterior-third. These have also been directly compared with Lalchawimawii's collection of the same species (2013) and are found to match well. Hence, the assignment is beyond doubt

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***Anadara* (*Anadara*) *elongata* Lalchawimawii**

(Pl. V, figs. 5 - 6)

2013. *Anadara* (*Anadara*) *elongata* Lalchawimawii, p.35, Pl. V, figs. 4-6

Material: Five right valves and one left valve.

Location: Locality 4 (Khawlthangi Quarry, Tuirial Road); Locality 5 (Mafaki Quarry, Tuirial Road); Locality 6 (Tuirial Road) and Locality 7 (Bung Bangla Quarry 2, Tuirial Road) Aizawl, Mizoram.

Horizon: Upper brown sandstone of Upper Bhuban Formation of Locality 4 (bed no. 5); grey silty-sandstone of Upper Bhuban Formation of Locality 5 (bed no. 2); brown sandstone of Upper Bhuban Formation of Locality 6 (bed no. 1); upper grey sandstone of Upper Bhuban Formation of Locality 7 (bed no. 2).

Dimensions:

Sp. No.	Length	Height	Inflation	NR
A11	22.3	13	4.7	LV
D31	24.4	12.5	4.8	RV
E6	22.8	14.2	5.5	RV
E7	20.6	12	5	RV

I3	21	10.5	3.4	RV
J7	13.3	5.9	2.8	RV

Remarks: Diagnostic characteristic of the species *Anadara* (*Anadara*) *elongata,* as reported by Lalchawimawii (2013) are, shell small and transversely elongate. Height about half of the length and inflation moderate to strong. Umbones prosogyrate, prominent, incurved and situated at about anterior- third of the shell-length. Antero-dorsal margin short and straight; postero-dorsal long and straight; anterior margin broadly rounded and merges smoothly with the long and flat ventral margin; posterior margin oblique in the upper half and meets smoothly with the ventral margin in the later half. Shallow and broad median sulcus runs from umbo towards ventral margin. Hinge margin long, slightly less than the shell length and straight. Teeth not exposed. Shell surface bears about 34 bifurcating radial ribsseparated by the interspaces wider than the ribs. All these characters are well marked in the collection. They have also been compared with holotype of the species from Lalchawimawii's collection (2013). Thus, they are assigned to this form.

Order - MYTILOIDA Ferussac, 1822

Superfamily - PINNACEA Leach, 1819

Family - PINNIDAE Leach, 1819

Genus - *Pinna* Linné, 1758

Type species: *Pinna rudis* Linné, 1758: SD. Children, 1823; Recent; Barbados.

Subgenus - *Pinna* (*s. s.*)

***Pinna* sp.**

(Pl. V, fig. 7)

Material: Two fragmental species.

Location: Locality 8 (Bung Bangla Quarry 1, Tuirial Road) Aizawl, Mizoram.

Horizon: Grey intraformational conglomeratic band of Grey sandstone of Upper Bhuban Formation (bed no. 7).

Dimensions:

Sp. No.	Length	Height	Inflation
TC1	52.3	26.9	
TC9	23.4	14.2	

Description and Remarks: The specimens are characterized by a broad and convex nature of the surface. The internal features are not visible and external surface is covered with numerous radial ribs only and oblique folds found in *Pinna* (*Pinna*) *choudhuryi* Tiwari and *Pinna* (*Pinna*) *vermai* Tiwari are altogether missing as well as median ridge. On these counts, these specimens cannot be merged with the previously described species of *Pinna* by Tiwari (1992). Hence, they are left to open nomenclature.

Order - PTERIOIDA Newell, 1965

Suborder - PTERIINA Newell, 1965

Superfamily - PECTINACEA Rafinesque, 1815

Family - PECTINIDAE Rafinesque, 1815

Genus - *Chlamys* Roeding, 1798.

Type species: *Pecten islandicus* Mueller, 1776; SD. Herrmannsen, 1847; Recent; North-Atlantic.

Subgenus - *Argopecten* Monterosato, 1899

Type species: *Pecten solidulus* Reeve, 1853; OD. Recent; Unknown locality.

***Chlamys* (*Argopecten*) *senatoria* (Gmelin)**

(Pl V, fig. 8.)

1791. *Ostrea senatoria* Gmelin, p. 3327.

1840. *Pecten articulates* J. de C. Sowerby, Pl. XXV, fig. 15.

1853. *Pecten favrei* d' Archiac and Haime, p. 270, Pl. XXIV, fig. 5.

1927. *Chlamys senatoria* (Gmelin): Cox, p. 45. Pl. VII, figs. 1 - 3; p. 75, Pl. XV, fig. 3; Pl. XXVII, fig. 10.

1928. *Pecten* (*Chlamys*) *senatoria*var. *Soomrowensis* Sowerby: Vredenburg, p. 434.

1928. *Chlamys senatoria* (Gmelin): Douglas, p. 2, Pl. VIII, figs. 3 - 5.

1929-30. *Chlamys senatoria* (Gmelin): Cox, p. 191.

1930. *Chlamys senatoria* (Gmelin): Cox, p. 108, Pl. XIII, fig. 21; p. 122, 52.

1936. *Chlamys senatoria* (Gmelin): Cox, p. 54, Pl. V, fig. 18; Pl. IV, fig. 9.

1939. *Chlamys senatoria* (Gmelin): Mukerjee, p. 31, Pl. I, fig. 2; Pl. II, figs. 9, 10.

1974. *Chlamys senatorius* (Gmelin): Dance, p. 234.

1992. *Chlamys* (*Chlamys*) *senatoria*(Gmelin): Tiwari MS, p. 73, Pl. VII, figs. 10, 11; Pl. VIII, figs. 1 - 3.

1997. *Chlamys* (*Argopecten*) *senatoria* (Gmelin): Jain MS, p. 72, Pl. XI, figs. 15 - 18.

2004. *Chlamys* (*Argopecten*) *senatoria* (Gmelin): Mazumder, p. 69, Pl. VIII, fig. 5.

2004. *Chlamys* (*Argopecten*) *senatoria* (Gmelin): Lyngdoh, p. 52, Pl. V, fig. 1.

2009. *Chlamys* (*Argopecten*) *senatoria* (Gmelin): Ralte, p. 38, Pl. 3, figs. 17 - 19.

2013. *Chlamys* (*Argopecten*) *senatoria* (Gmelin): Lalchawimawii, p. 40, Pl. VI, figs. 2-5

Material: Three right valves and one left valve

Location: Locality 4 (Khawlthangi Quarry, Tuirial Road) and Locality 6 (Tuirial Road) Aizawl, Mizoram.

Horizon: Dark brown sandstone of Upper Bhuban Formation of Locality 4 (bed no. 1); brown sandstone of Upper Bhuban Formation of Locality 6 (bed no. 1).

Dimensions:

Sp. No.	Length	Height	Inflation	
A4	28.6	34	5.3	RV
A8	22.1	26.8	3.3	RV
B1	22.2	21	5	RV
B2	36.6	31.3	6.6	LV

Description and Remarks: The species in question is highly variable in dimensional ratios and intervening spaces. Besides, it is a long ranging one from Miocene to Recent having wide geographical distribution in Asia and Africa.

The specimens at hand agree with all the essential characters of the species *Chlamys* (*Argopecten*) *senatoria* (Gmelin) and are referred to it. Both specimen resembles very well with Tiwari's collection (Specimen No. HPQ/8/17) and Lalchawimawii`s collection (B/CH/380) from Mizoram under the same name. Hence, the reference.

Subgenus - *Chlamys* (*s. s.*)

***Chlamys* (*Chlamys*) *jamviniensis* Cox**

(Pl. V, figs. 9 - 10)

1927. *Chlamysjamviniensis* Cox, p. 44, Pl. V, fig. 4.

1939. *Chlamysjamviniensis* Cox: Mukerjee, p. 32, Pl. I, fig. 3.

1992. *Chlamys* (*Chlamys*) *jamviniensis* Cox: Tiwari, p. 76, Pl. VII, fig. 9.

2013. *Chlamys* (*Chlamys*) *jamviniensis* Cox: Lalchawimawii, p. 42, Pl. VI, figs. 6-11.

Material: Six left valves and one right valve.

Location: Locality 5 (Mafaki Quarry, Tuirial Road), Locality 6 (Tuirial Road) and Locality 8 (Bung Bangla Quarry 1, Tuirial Road) Aizawl, Mizoram.

Horizon: Brown sandstone bed of Upper Bhuban Formation of Locality 5, 6 and 8 (bed no. 1).

Dimensions:

Sp. No.	Length	Height	Inflation	NR
A7	26.5	29.1	4.4	LV
A7B	13.2	13.4	4.3	LV
C6	23.6	20.2	5.5	LV
C9	20.5	23.3	3.5	LV
C10	24.3	25	4.5	RV
D12A	19.4	22.6	3.7	LV
D14	22.6	23	4.6	LV

Remarks: The specimens are characterized by ovate-trigonal, height a little in excess of length, unbranched and regularly distributed primary ribs. The radial ribs are varied in number *i.e* 32 – 36. Hence, the specimens are provisionally identified as *Chlamys* (*Chlamys*) *jamviniensis* Cox.

***Chlamys* (*Chlamys*) *quilonensis* Dey**

(Pl.VI, figs.1 & 2)

1962. *Chlamys* (*Chlamys*) *quilonensis*Dey, p. 43, Pl. II, figs. 8, 9.

1992. *Chlamys* (*Chlamys*) *quilonensis*Dey: Tiwari MS, p. 75, Pl. VII, figs. 7, 8.

2004. *Chlamys* (*Chlamys*) *quilonensis*Dey: Mazumder, p. 67, Pl. VIII, figs. 4, 6.

2013. *Chlamys* (*Chlamys*) *quilonensis*Dey: Lalchawimawii, p. 42, Pl. VI, fig. 12, Pl. VII, fig. 1

Material: Seven right valves and four left valves.

Location: Locality 4 (Khawlthangi Quarry, Tuirial Road), Locality 6 (Tuirial Road) and Locality 8 (Bung Bangla Quarry 1, Tuirial Road) Aizawl, Mizoram.

Horizon: Dark brown sandstone and upper brown sandstone of Upper Bhuban Formation of Locality 4 (bed no. 1 and 5); brown sandstone of Upper Bhuban Formation of Locality 6 (bed no. 1); grey intraformational conglomeratic band and brown sandstone of Upper Bhuban Formation of Locality 8 (bed no. 7).

Dimensions:

Sp. No.	Length	Height	Inflation	NR
A6	23.7	26.7	2.9	RV
A6b	9	11.6	2.3	LV
D17	19	23.8	4.7	RV
D18	23.8	30	7.2	LV
D21	18	20	2.8	LV
D12B	14.6	19.3	3.2	LV
L2	11.4	10.9	1.2	RV
TC6	16.4	18.1	5.2	RV
TC8	14.2	15.2	3.3	RV
TC9	17.4	22	6	RV
TC11	13.93	14.3	3.4	RV

Description and Remarks: The specimens at hand are thin, small, rather oblique and feebly convex, higher than wide with around 16 rounded ribs, which are squamose near the margin separated by interspaces have the same width as the ribs. Above description tallies well with the *Chlamys* (*Chlamys*) *quilonensis* Dey (1962, op. cit.), Hence, it is named accordingly.

***Chlamys* sp.**

(Pl. VI, figs. 3 & 4)

Material: Twelve right valves and nine left valves and five fragmentary species.

Location: Locality 4 (Khawlthangi Quarry, Tuirial Road), Locality 5 (Mafaki Quarry, Tuirial Road), Locality 6 (Tuirial Road), Locality 7 (Bung Bangla Quarry 2,

Tuirial Road) and Locality 8 (Bung Bangla Quarry 1, Tuirial Road) Aizawl, Mizoram.

Horizon: Dark drown and lower brown sandstone of Upper Bhuban Formation of Locality 4 (bed no. 1 and 2); brown sandstone and grey silty-sandstone of Upper Bhuban Formation of Locality 5 (bed no. 1 and 2); brown sandstone of Upper Bhuban Formation of Locality 6 (bed no. 1); brown sandstone and grey intraformational conglomeratic band of Upper Bhuban Formation of Locality 8 (bed no. 1 and 7).

Dimensions:

Sp. No.	Length	Height	Inflation	NR
A5	25.2	24.4	2.1	RV
A10	13.2	14.1	1.6	RV
C2	18.4	19.3	3.7	RV
C3	21.4	23.9	4.3	LV
C5	15.3	16	3	LV
C7	25.8	24.7	8	RV
C8A	26.1	27.6	5.3	LV
C8B	19.2	20.2	4.4	RV
C11	28	26.7	7	LV
D11	29.6	32.6	5.9	RV
D13	23.2	27.3	6.2	RV
D19	24.6	23.7	2.7	RV
D15	26.3	22.6	3.1	RV
D20	21.7	19.8	2.4	-

D22	23.3	23.5	3.1	-
I1	22.2	23.3	2.4	LV
I5	20.6	23.2	4.2	-
J3	25.3	26	3.8	-
D16	27.2	26.1	3.8	RV
E3	28.3	29.4	3	LV
L3	16.7	18.7	3.9	LV
L4	9.7	11.2	1.9	RV
TC7A	16.7	15.7	6.1	LV
TC7	21.9	18	5.1	RV
TC10	14.6	13.6	2.6	LV
TC13	17.9	18.1	3.3	-

Description and Remarks: The specimen at hand differ in size and inflation. The valves seem to be in trigonal to trapezoidal in shape.The external features are poorly preserved especially the auricles. The number of radial ribs cannot be counted in some specimen because of poor preservation. Some specimen yields too much variation in the number of radial ribs, so they cannot be assigned to any known species.

Genus - *Pecten* Mueller, 1776

Type species: *Ostrea maxima* Linné, 1758; SD. Schmidt, 1818. Recent; English Channel.

Subgenus - *Pecten* (*s. s.*)

***Pecten* (*Pecten*) *mathuri* Tiwari MS**

(Pl. VI, figs. 5 a, b, c & 6)

1992. *Pecten* (*Pecten*) *mathuri* Tiwari MS, p. 78, Pl. VIII, figs. 5 - 8.

2004. *Pecten* (*Pecten*) *mathuri* Tiwari MS: Mazumder, p. 70, Pl. VIII, fig. 8.

2009. *Pecten* (*Pecten*) *mathuri* Tiwari MS: Ralte, p. 39, Pl. 3, figs. 20 a – b and Pl. 4, fig. 1.

2013. *Pecten (Pecten) mathuri* Tiwari MS: Lalchawimawii, p. 44, Pl. VII, figs. 5-8

Material: One complete valve**,** three left valves and three fragmentary species.

Location: Locality 4 (Khawlthangi Quarry, Tuirial Road), Locality 5 (Mafaki Quarry, Tuirial Road) and Locality 7 (Bung Bangla Quarry 2, Tuirial Road) Aizawl, Mizoram.

Horizon: Middle grey sandstone of Upper Bhuban Formation of Locality 4 (bed no. 3); brown sandstone of Upper Bhuban Formation of Locality 5 (bed no. 1); lower grey sandstone bed of Upper Bhuban Formation of Locality 7 (bed no. 1).

Dimensions:

Sp. No.	Length	Height	Inflation	NR
E1	20	18.3	2.4	-
E2	25	21.4	3.8	-
E4	27.8	29.6	6.4	BV
E5	22	29.3	5.5	LV
G2	19.6	24.9	4.5	LV
J1	30.8	26.9	3.4	
H1	20.6	27.7	3.4	LV

Remarks: Tiwari (1992) described *Pecten* (*Pecten*) *mathuri* for the first time in having sub-orbicular in outline, having nearly flat left valves, small umbo, straight postero-dorsal concave antero-dorsal with evenly distributed and equally prominent 30 radial ribs. In all these characters, they approach the species christened by Tiwari. Hence, the present assignment.

Superfamily - ANOMIACEA Rafinesque, 1815

Family - ANOMIIDAE Rafinesque, 1815

Genus - *Placuna* Lightfoot, 1786

Type species: *Anomia placenta* Linné, 1758; SD Schmidt, 1818. Recent; Ceylon.

***Placuna* (*Indoplacuna*) sp.**

(Pl. VI, fig. 7)

Material: Three right valves and one fragmental species.

Location: Locality 4 (Khawlthangi Quarry, Tuirial Road) and Locality 5 (Mafaki Quarry, Tuirial Road) Aizawl, Mizoram.

Horizon: Middle grey sandstone and upper brown sandstone of Upper Bhuban Formation of Locality 4 (bed no. 3 and 5); Brown sandstone and grey silty-sandstone of Upper Bhuban Formation of Locality 5 (bed no. 1 and 2).

Dimensions:

Sp. No.	Length	Height	Inflation	
C35	26.2	33	8.5	-
D7	37.7	34.2	6.8	RV
G1	38.4	43.1	11.9	RV
J2	28.2	26.7	8.8	RV

Description and Remarks: The specimens at hand are medium to large in size, moderately thick, somewhat orbicular, the external suface of the specimen at hand are covered with numerous minute radial thread. They are match well with the *Placuna* (*Indoplacuna*) *sindiens*is Vredenburg in these characters. However, they do not exhibit other characters of this species like muscle scar, crescentic depression and pairs of crura. Hence, they are left to open nomenclature under the genus *Placuna* (*Indoplacuna*) sp.

Suborder - OSTREINA Ferussac, 1822

Superfamily - OSTREACEA Rafinesque, 1815

Family - OSTREIDAE Rafinesque, 1915

Subfamily - OSTRENAE Rafinesque, 1815

Genus - *Ostrea* Linné, 1758

Type species: *Ostrea edulis* Linné, 1758; SD. Gray, 1847, Living; England.

Crassostrea gajensis (Vredenburg)

(Pl. VI, fig. 8)

1928. *Ostrea gajensis* Vredenburg, p. 423, Pl. XXIV, fig. 1.

1997. *Crassostrea gajensis* (Vredenburg): Jain, p. 100, Pl. XVIII, figs. 3 - 7.

2004. *Crassostrea gajensis* (Vredenburg): Lyngdoh, p. 57, Pl. VI, figs. 5 and 6.

2013. *Crassostrea gajensis* (Vredenburg): Lalchawimawii, p. 46, Pl. VII, figs. 1-3.

Material: One left valve.

Location: Locality 8 (Bung Bangla Quarry 1, Tuirial Road) Aizawl, Mizoram.

Horizon: Grey intraformational conglomeratic bed of Upper Bhuban Formation (bed no. 7).

Dimensions:

Sp. No.	Length	Height	Inflation	
D24	34.2	36.9	5.2	LV

Remarks: The specimen has external sculpture in the form of fine concentric lamellae and has ridge shaped granulations all around the margin. The specimen at hand agree with all the essential characters of the species *Crassostrea gajensis* (Vredenburg) and referred to it. The specimen resembles very well Lalchawimawii`s collection from Mizoram under the same name. Hence, the reference.

Ostrea sp.

(Pl. VII, fig. 1)

Material: One right valve.

Location: Locality 4 (Khawlthangi Quarry, Tuirial Road) Aizawl, Mizoram.

Horizon: Middle grey sandstone of Upper Bhuban Formation (bed no. 3).

Dimensions:

Sp. No.	Length	Height	Inflation	
G4	25.6	24.3	4	RV

Remarks: Rounded to oval shape, ridge shaped granulations at the margins remind at once the genus *Ostrea.* The specimen is thus assigned to this genus. Due to poor preservation and incomplete valve, further description is not possible.

Subclass - HETERODONTA Neumayr, 1884

Order - VENEROIDA H. Adams and A. Adams, 1856

Family - UNGULINIDAE Adams and Adams, 1857

Genus - *Diplodonta* Bronn, 1831.

Type species: *Venus lipinis* Brochhi, 1814; SD. Hermannsen, 1846; Recent; Mediterranean.

Subgenus - *Diplodonta* (*s. s.*)

***Diplodonta (Diplodonta) incerta* d'Archiac**

(Pl.VI, figs. 2 & 3)

1850. *Diplodanta incerta* d' Archiac, p. 259.

1853. *Lucina inflata* d'Archiac: d'Archiac and Haime, p. 240, Pl. XVI, figs. 15 - 16; Pl. XXXVI, figs. 7 - 8.

1853. *Lucina inflata* d'Archiac: d'Archiac and Haime, p. 355.

1928. *Diplodonta incerta* d'Archiac: Vredenburg, p. 441.

1939. *Taras* (*Diplodonta*) *incerta* d'Archiac: Mukerjee, p. 9, Pl. II, fig. 6.

1992. *Diplodonta incerta* d' Archiac: Tiwari, p. 86, Pl. IX, figs. 4 - 7.

2004. *Diplodonta* (*Diplodonta*) *incerta* d' Archiac: Mazumder, p. 79, Pl. IV, figs. 8.

2004. *Diplodonta* (*Diplodonta*) *incerta* d' Archiac: Lyngdoh, p. 62, Pl. VIII, figs. 4 - 5.

2009. *Diplodonta* (*Diplodonta*) *incerta* d' Archiac: Ralte, p. 41, Pl. IV, figs. 2 - 3.

2013. *Diplodonta* (*Diplodonta*) *incerta* d' Archiac: Lalchawimawii, p. 4, Pl. VIII, figs. 8 - 12.

Material: Two right valves and three left valves.

Location: Locality 4 (Khawlthangi Quarry, Tuirial Road) Aizawl. Mizoram.

Horizon: Dark brown sandstone and upper brown sandstone of Upper Bhuban Formation (bed no. 1 and 5).

Dimensions:

Sp. No.	Length	Height	Inflation	
D30	18.6	16.1	2.3	RV
D39	19	18.5	5	RV
D47	27.4	20	3.6	LV
L9	14.4	14.4	3.1	LV
L11	17.3	16.4	1.7	LV

Remarks: The external characters of the ornamentation and general portion of the specimen collected are compared with *Diplodonta incerta* d'Archiacreported by Mukerjee (1939, p. 9, Pl. II, fig. 6) to which they are found to match well. Hence, the assignment.

Suborder - ASTARTEDONTINA

Superfamily - CRASSATELLACEA Ferussac, 1822

Family - ASTARTIDAE d' Orbigny, 1844

Subfamily - ASTARTINAE d' Orbigny, 1844

Genus - *Astarte* J. Sowerby, 1816.

Type species: *Venus scotica* Maton and Rackettm 1807 (= *Pectunculus sulcatus* Da Costa, 1778); OD. Recent; Scotland.

Subgenus - *Astarte* (*s. s.*)

***Astarte* (*Astarte*) *trigonalis* Lalchawimawii**

(Pl. VII, fig. 4)

2013. *Astarte* (*Astarte*) *trigonalis* Lalchawimawii, p. 51, Pl. IX, fifs 6 a,b,c-&a,b,c

Material: One right valve.

Location: Locality 5 (Mafaki Quarry, Tuirial Road) Aizawl, Mizoram.

Horizon: Brown sandstone of Upper Bhuban Formation (bed no. 1).

Dimensions:

Sp. No.	Length	Height	Inflation	
C30	21.2	17.7	5.3	RV

Description and Remarks: Lalchawimawii (2013) described the diagnostic characters of the species *Astarte* (*Astarte*) *trigonalis,* as medium sized, highly inequilateral, trigonally-ovate height about fourth-fifth of the shell, strongly inflated, having prominent and elevated umbo, strongly prosogyrous and situated at about anterior-fifth of the shell-length. Short antero-dorsal margin and long postero-dorsal which inclined at an angle of 35^{o}. Small and shallow lunule small, elongated and

escavated escutchean.Ligament external and opisthodetic.The present collections are well match with these characters.Hence, the assignment.

Astarte ovalis Lalchawimawii

(Pl. VII, figs. 5a, b, c)

2013. *Astarte ovalis* Lalchawimawii, p.52, Pl. X, figs 1-2

Material: One complete bivalve and one left valve.

Location: Locality 5 (Mafaki Quarry, Tuirial Road) and Locality 7 (Bung Bangla Quarry 2, Tuirial Road) Aizawl, Mizoram.

Horizon: Brown sandstone of Upper Bhuban Formation of Locality 5 (bed no. 1); upper grey sandstone of Upper Bhuban Formation of Locality 7 (bed no. 2).

Dimensions:

Sp. No.	Length	Height	Inflation	
C34	31.8	25.9	12.4	LV
E23	27.3	22.5	5.7	BV

Description and Remarks: The specimen**s** at hand tally well with the holotype of *Astarte ovalis* **(**Lalchawimawii, 2013) in view of medium sized valve, oval in shape, height nearly equal to the length, small, pointed and prosogyrate umbo that are situated at about middle of the valve-length, concave antero-dorsal which merge smoothly with broadly rounded posterior margin, flat ventral margin and external surface traversed by fine concentric undulations with narrower interspaces. Hence, their assignment is beyond doubt.

Subfamily - LUTRARIINAE Adams and Adams, 1956

Genus - *Lutraria* Lamarck, 1759.

Type species: *Mya lutraria* Linné, 1758; Tautonomy. Recent, Mediterranean.

Subgenus - *Lutraria* (*s. s*.)

***Lutraria* cf. *philippinarum* Reeve**

(Pl. VII, fig. 8)

1854. *Lutraria philippinarum* Deshayes; Reeve, conch. Icon, VIII, *Lutraria* sp. 4.

1928. *Lutraria philippinarum*, Melvill, *Proc.* Malac. *Soc. London,* XVIII, p. 116.

1932. *Lutraria philippinarum*, Prashad, *Siboga-Exped Monogr*., L III c, p. 211(with Synonymy)

1936. *Lutratria* cf. *philippinarum,* Reeve: Cox, p. 65, Pl. VIII, fig. 1.

2004. *Lutraria* cf. *philippinarum* Reeve: Mazumder, p. 98, Pl. XI, fig. 9.

2009. *Lutraria philippinarum* Reeve: Ralte, p. 47, Pl. 4, fig. 12 - 14.

2009. *Lutraria philippinarum* Reeve: Lalchawimawii, p. 57, Pl. X, fig. 10 and 12.

Material: Two right valves and one left valve.

Location: Locality 4 (Khawlthangi Quarry, Tuirial Road) and Locality 6 (Tuirial Road) Aizawl, Mizoram.

Horizon: Upper brown sandstone of Upper Bhuban Formation of Locality 4 (bed no. 5); brown sandstone of Upper Bhuban Formation of Locality 6 (bed no. 1).

Dimensions:

Sp. No.	Length	Height	Inflation	
A1A	49.2	18.6	4.4	RV
A1B	57.8	18.5	3.2	LV
D6	34	13.9	2.6	RV

Remarks: The specimens are comparable to those of *Lutraria* cf. *philippinarum* figured by Cox (1936), loc. cit. from Vindobonian of Persia in terms of compressed in nature, elongate-ovate and somewhat arcuate in shape. Hence, they are assigned under the species *Lutraria* cf. *philippinarum* Reeve.

Superfamily - SOLENACEA Lamarck, 1809

Family - SOLENIDAE Lamarck, 1809

Genus - *Solena* Mörch, 1853

Type species: *Solen obliquus* Spengler, 1794; SD Stoliczka, 1871. Recent; Carribeans.

Subgenus - *Plectosolen* Conrad, 1866

Type species: *Solen gracilis* Sowerby, 1844; SD Stoliczka, 1871. Lower Eocene to Middle Eocene. England.

***Solena* (*Plectosolen*) sp.**

(Pl. VII, fig. 7)

Material: One right valve.

Location: Locality 4 (Khawlthangi Quarry, Tuirial Road) and Locality 7 (Bung Bangla Quarry 2, Tuirial Road) Aizawl, Mizoram.

Horizon: Upper brown sandstone of Upper Bhuban Formation of Locality 4 (bed no. 5); upper grey sandstone of Upper Bhuban Formation of Locality 7 (bed no. 2).

Dimensions:

Sp. No.	Length	Height	Inflation
D8	30.2	6.9	5.2

TR E8A	31.4	9.6
TR E8B	25.1	5.1

Description and Remarks: Posterior margin is straight while anterior one is oblique. The dorsal and ventral margins are straight and parallel to each other. There is a carina which runs from umbo to antero-ventral corner forming a small anterior area. Surface appears to be smooth though internal characters are unobservable. Since the preservation of the specimen is poor, most of the defined characteristics cannot be observed and its specific identifications comparisons with other known forms is not possible.

Family - CULTELLIDAE Davies, 1935

Genus - *Cultellus* Schumacher, 1817

Type species: *Cultellus magmus* (=*Solen lacteus* Spengler, 1794); by monotype. Recent; East Indies.

Subgenus - *Cultellus* (*s. s*.)

***Cultellus* (*Cultellus*) *zulloi* Tiwari**

(Pl. VIII, figs. 1a, b, c and 2a, b, c)

1992. *Cultellus (Cultellus) zulloi* Tiwari, p. 105, Pl. XI, figs. 3, 6.

2004. *Cultellus (Cultellus) zulloi* Tiwari: Mazumder, p. 99, Pl. XI, fig. 10.

2009. *Cultellus (Cultellus) zulloi* Tiwari: Ralte, p. 48, Pl. 4, fig. 16.

2013. *Cultellus (Cultellus) zulloi* Tiwari: Lalchawimawii, p. 60, Pl. XI, figs. 1 a,b,c and 3 a,b,c.

Material: Five bivalves, three right valves and two left valves.

Location: Locality 4 (Khawlthangi Quarry, Tuirial Road), Locality 5 (Mafaki Quarry, Tuirial Road), Locality 6 (Tuirial Road) and Locality 7 (Bung Bangla Quarry 2, Tuirial Road) Aizawl, Mizoram.

Horizon: Upper brown sandstone of Upper Bhuban Formation of Locality 4 (bed no. 5); brown sandstone of Upper Bhuban Formation of Locality 5 and 6 (bed no. 1); upper grey sandstone of Upper Bhuban Formation of Locality 7 (bed no. 2).

Dimensions:

Sp. No.	Length	Height	Inflation	
A2A	36.9	12	3.3 (total)	BV
A3	36.1	18.3	2.3	LV
C1	31.7	15.3	7.4	BV
D1A	48.2	18.6	1.8	RV
D1B	45.2	17.7	3.1	LV
D2	50.3	18	5	RV
D3	40	20.2	11.3	BV
D4	37.6	20.3	3.9	RV
D5	32.8	16.3	6.2	BV
E9	45.3	16	4.7 (single)	BV

Remarks: The collections at hand show perfectly elliptical outline excepting near umbonal region. There are fine concentric lamellae on the surface which are conspicuous towards the ventral margin. The specimens show gapping at both the ends and length is about 2 to 2.5 times to the height. A shallow groove is present on either side of umbo all along the dorsal margin in all the specimens. Umbones are small and low, placed anterior-fourth of the shell-length. These characters are tally

well with *Cultellus* (*Cultellus*) *zulloi* Tiwari (1992). Further, on direct comparison these are found to match well with the type material of Tiwari from the Upper Bhuban of Mizoram. Hence, the assignment.

Superfamily - TELLINACEA de Blainville, 1814

Family - TELLINIDAE de Blainville, 1814

Subfamily - TELLININAE de Blainville, 1814

Genus - *Tellina* Linné, 1758.

Type species: *Tellina radiata* Linné, 1758; SD. Children, 1823. Recent; West Indies.

***Tellina compressa* Tiwari**

(Pl. VIII, fig. 3)

2006. *Tellina compressa* Tiwari, p. 37, Pl.II, figs. 2 – 3.

2013. *Tellina compressa* Tiwari: Lalchawimawii, p. 62, Pl.XI, figs. 6 – 10.

Material: One right valve.

Location: Locality 5 (Mafaki Quarry, Tuirial Road) Aizawl, Mizoram.

Horizon: Brown sandstone of Upper Bhuban Formation (bed no. 1).

Dimensions:

Sp. No.	Length	Height	Inflation	
C37	41	22.5	2.3	RV

Remarks: In ovate-trigonal outline, laterally compressed, height slightly in excess of half of the length, surface ornamented with fine concentric lines, equal antero-and postero-dorsal margins, the specimen at hand well match *Tellina compressa*

described by Tiwari (2006) from the Bhuban Formation, Surma Group of Luangmual, Mizoram. Hence the identification is confirmed.

Tellina maubawka Tiwari

(Pl. VIII, fig. 4)

2006. *Tellina maubawka* Tiwari, p. 34, Pl. II, fig. 5.

2013. *Tellina maubawka* Tiwari: Lalchawimawi, p. 63, Pl. XII, fig. 5.

Material: One right valve and three left valves.

Location: Locality 3 (Prayer Point, Turial Road), Locality 4 (Khawlthangi Quarry, Tuirial Road) and Locality 6 (Tuirial Road) Aizawl, Mizoram.

Horizon: Brownish grey sandstone of Upper Bhuban Formation of Locality 3 (bed no. 2); upper brown sandstone of Upper Bhuban Formation of Locality 4 (bed no. 5); brown sandstone of Upper Bhuban Formation of Locality 6 (bed no. 1).

Dimensions:

Sp. No.	Length	Height	Inflation	
A14	25.6	11.7	3	LV
D35	31.1	16.8	3.3	RV
D36	36	21.9	5.5	LV
PP1	26.3	16.2	2.6	LV

Description and Remarks: The specimens at hand are characterized by ovate-truncate outline, obliquely rounded anterior margin, sinuous ventral margin, height is about two-third of the length. There is a prominent furrow from umbo towards postero-ventral. The specimen has fine but sharp concentric growth lines but the total surface sculpture could not be ascertained because of worn out surfaces. These

characters are very well matched with the description done by Tiwari on *Tellina maubawka*. Hence merged with the Tiwari's specimens (2006, op.cit.)

Subgenus - *Angulus* Megerle Von Muehlfeld, 1811.

Type species: *Tellina lanceolata* Gmelin, 1791; SD. Gray, 1847. Recent; East Indies.

***Tellina* (*Angulus*) sp.**

(Pl. VIII, fig. 5)

1992. *Tellina* (*Angulus*) Tiwari, p. 106.

2004. *Tellina* (*Angulus*) Tiwari: Mazumder, p. 101, Pl. XII, fig. 1

2009. *Tellina* (*Angulus*) Tiwari: Ralte, p. 50, Pl. 5, figs. 2 – 3.

2013. *Tellina* (*Angulus*) Tiwari: Lalchawimawii, p. 63, Pl. XII, figs. 2a,b,c

Material: One right valve.

Locality: Locality 4 (Khawlthangi Quarry, Tuirial Road) Aizawl, Mizoram.

Horizon: Middle grey sandstone of Upper Bhuban Formation (bed no. 3).

Dimensions:

Sp. No.	Length	Height	Inflation	
F5	27.5	16.3	4.5	RV

Description and Remarks: The specimen at hand is small, compressed and slightly in-equilateral, sub-elliptical with acuminated posterior. Its height is more than half of the length. Antero and postero-dorsal margins are making elliptical outline with anterior and posterior margins. The shell surface is covered with fine and closely spaced concentric growth lines with flat ventral margin. Hence, the specimen is

identified as *Tellina (Angulus*) sp. though because of poor preservation, assignment under new species is not feasible.

Subgenus - *Eurytellina* Fischer, 1887

Type species: *Tellina punicea* Born, 1790; M. Recent; West Indies.

***Tellina* (*Eurytellina*) *pilgrimi* Cox**

(Pl.VIII , fig. 6)

1936. *Tellina pilgrimi* Cox, p. 37, Pl. IV, figs.11, 12 a - b.

1992. *Tellina* (*Eurytellina*) *pilgrimi* Cox: Tiwari, p. 108. Pl. XI, figs. 4, 5, 7, 8, 9, 10,11; Pl. XIII, figs. 8a and b.

2004. *Tellina* (*Eurytellina*) *pilgrimi* Cox: Mazumder, p. 103. Pl. XII, fig. 4.

2009. *Tellina* (*Eurytellina*) *pilgrimi* Cox: Ralte, p. 51. Pl. 5, fig. 4.

2013. *Tellina* (*Eurytellina*) *pilgrimi* Cox: Lalchawimawii, p. 64. Pl. XII, figs. 11, 12 a-b.

Material: One complete bivalve, two right valves and one left valve.

Locality: Locality 3 (Prayer Point, Turial Road and Locality 5 (Mafaki Quarry, Tuirial Road) Aizawl, Mizoram.

Horizon: Brownish grey sandstone and brown sandstone of Upper Bhuban Formation of Locality 3 and 5 (bed no. 2 and 1).

Dimensions:

Sp. No.	Length	Height	Inflation	
C4	30	26.4	3.6	BV
C27A	22.7	20	3.1	LV
C27B	26.1	17.5	4.2	RV
PP4	29.7	18.7	3.2	RV

Description and Remarks: This species have variable dimensions (Cox, 1936). For example, the paratypes have almost median umbones and slightly more height to length ratio (75%), while holotype (G.S.I. No. 17375) is more elongate (height-length ratio is 69%) with umbones little posterior to median. Likewise the specimen have similarities and resemblance with 62.9% ratio, though it is a bit low compared to the holotypes and paratypes, it is acceptable and hence assigned to *Tellina* (*Eurytellina*) *pilgrimi* (Cox, 1936).

Subgenus - *Oudardia* Monterosato, 1884

Type species: *Tellina oudardii* Payraudeau, 1826 (= *Tellina compressa* Brocchi, 1814, OD.

***Tellina (Oudardia)* sp.**

(Pl.IX , fig. 1)

Material: One left valve.

Locality: Locality 5 (Mafaki Quarry, Tuirial Road), Aizawl, Mizoram.

Horizon: Brown sandstone of Upper Bhuban Formation (bed no. 1).

Dimensions:

Sp. No.	Length	Height	Inflation	
C17	25.4	16.7	3.4	LV

Description and Remarks: Shell small, compressed, height is more than half of the length. Surface is covered with fine oblique lines. It resemble T. Moerella in form but with a thick internal rib, radiating from beak to ventral margin in front of mid line; surface covered partly with fine oblique lines of sculpture. Since the specimen

is poorly preserved, comparision with other species of *Tellina* and assigning a new name is not possible.

Subgenus - *Perodinia* Dall, 1900

Type species: *Tellina albicans* Gmelin, 1826; OD.

***Tellina* (*Perodina*) sp.**

(Pl.IX , fig. 2)

Material: One left valve.

Locality: Locality 3 (Prayer Point, Turial Road) Aizawl, Mizoram.

Horizon: Brownish grey sandstone of Upper Bhuban Formation (bed no. 1)

Dimensions:

Sp. No.	Length	Height	Inflation	
PP01	37.8	20.3	4.6	LV

Description and Remarks: Shell elongate, solid and compressed. sub equivalve, without lunule, escutcheon long, narrow; shell with fine concentric grooves, stronger anteriorly; lateral teeth weak. This form is distince from other species of *Tellina* but the identification is left to open nomenclature for more and better preserved material.

Subgenus - *Tellinella* Mörch, 1853

Type species: *Tellina virgata* Linné, 1758; SD Stoliczka, 1870. Recent; East Indies.

Tellina (*Tellinella*) *hilli* Noetling

(Pl. IX, fig. 3)

1898. *Tellina* (*Tellinella*) *hilli* Noetling, p. 13, Pl. III, figs. 5 - 6.

1901. *Tellina* (*Tellinella*) *hilli* Noetling, p. 223, Pl. XIV, figs. 7a - d.

1992. *Tellina* (*Tellinella*) *hilli* Noetling: Tiwari, p. 115, Pl. XII, fig. 4; Pl. XIII, fig. 10.

2004. *Tellina* (*Tellinella*) *hilli* Noetling: Lyngdoh, p. 88, Pl. XI, figs. 5 - 7.

2013. *Tellina* (*Tellinella*) *hilli* Noetling: Lalchawimawii, p. 66, Pl. XIII, figs. 1a,b,c - 2.

Material: One right valve and one left valve

Locality: Locality 4 (Khawlthangi Quarry, Tuirial Road), Aizawl, Mizoram.

Horizon: Middle grey sandstone of Upper Bhuban Formation of Locality 4 (bed no.3).

Dimensions:

Sp. No.	Length	Height	Inflation	
D37	29.3	16.4	1.9	RV
D49	28.7	17	2.5	LV

Remarks: The specimens show essential characters of *Tellina* (*Tellinella*) *hilli* in respect size, configuration, nature of carina, and ornamentation. Thus, the identity is unquestionable.

Subfamily - MACOMINAE Olsson, 1961

Genus - *Apolymetis* Salisbury, 1929

Type species: *Tellina meyeri* Phillipi, 1846, ex Dunker, MS; by Monotypy. Recent; East Indies.

***Apolymetis grimesi* (Noetling)**

(Pl. IX, figs. 4a, b, c)

1901. *Tellina* (*Metis*) *grimesi* Noetling, p. 216, Pl. 14, figs. 4 - 6.

1939. *Apolymetis grimesi* (Noetling): Mukerjee, p. 11, Pl. I, fig. 18.

1997. *Apolymetis grimesi* (Noetling): Jain, p. 131-132, Pl. XXIII, figs. 10 - 20.

2004. *Apolymetis grimesi* (Noetling): Lyngdoh, p. 90, Pl. XI, fig. 10.

2009. *Apolymetis grimesi* (Noetling): Ralte, p. 54, Pl. 5, figs. 10 - 12.

Material: Three bivalve specimens.

Locality: Locality 1 (near Amawii Tyre Works, Bawngkawn) Aizawl, Mizoram.

Horizon: Brown sandstone of Middle Bhuban Formation (bed no.1).

Dimensions:

Sp. No.	Length	Height	Inflation	
BC1	31.4	25.5	8.2	BV
BC2	11.7	11.1	2.9	BV
BC7	15.4	14.7	6	BV

Remarks: The specimens at hand resembles very closely with *Apolymetis grimesi* described by Noetling from Myanmar (1901) and by Mukerjee (1939) from Miocene of Garo Hills in respect of nature of valve ornamentation, general configuration, dimentional ratios and low inflation. The species has also been reported by Ralte (2009) from Aizawl and Lalchawimawii (2013) from Hlimen Quarry, Aizawl. The

collections are found to match well with them. Hence, the assignment of the present specimen is under the species *Apolymetis grimesi* is justifiable.

Family - PSAMMOBIIDAE Fleming, 1828

Subfamily - PSAMMOBIINAE Fleming, 1828

Genus - *Gari* Schumacher, 1817

Type Species: *Gari vulgaris* (= *Solen amethystus* Wood, 1815); SD Children, 1823. Recent; East Indies.

Subgenus - *Gari* (*s. s*.)

***Gari* (*Gari*) *natensis* Noetling**

(Pl. IX, fig. 5)

1901. *Gari natensis* Noetling, p. 228. Pl. XV, figs. 6a - e.

1992. *Gari* (*Gari*) *natensis* Noetling: Tiwari, p. 125, Pl. XII, fig. 7

2004. *Gari* (*Gari*) *natensis* Noetling: Lyngdoh, p. 91, Pl. XI, figs. 12 - 13.

2009. *Gari* (*Gari*) *natensis* Noetling: Ralte, p. 55, Pl. 5, fig. 13.

2013. *Gari* (*Gari*) *natensis* Noetling: Lalchawimawii, p. 68, Pl. XIII, fig. 4.

Material: One right valve.

Locality: Locality 3 (Prayer Point, Turial Road) Aizawl, Mizoram.

Horizon: Brownish grey sandstone of Upper Bhuban Formation (bed no.2).

Dimensions:

Sp. No.	Length	Height	Inflation	
PP3	29.3	11.9	3.3	RV

Description and Remarks: The overall outline, ornamentation and posterior region of the present specimen resembles *Gari natensis* Noetling (1901), particularly the holotype no. 7629 and hence the assignment.

Superfamily - ARCTICACEA Newton, 1891

Family - ARCTICIDAE Newton, 1891

Subfamily - ARCTICINAE Newton, 1891

Genus - *Arctica* Schumacher, 1817

Type species: *Arctica vulgaris* (=*Venus islandica* Linné, 1767); M. Pliocene; England; Lower Cretaceous to Recent; Europe, North America.

***Arctica islandica* (Linné)**

(Pl. IX, fig. 6)

1959. *Arctica islandica* (Linné): White, p. 98, Pl. XXXV, figs. 4 and 5.

1969. *Arctica islandica* (Linné): Myra Keen (in Moore *et al*.,), p. N646, figs. E127, 1a and b.

1971. *Arctica islandica* (Linné): Davies, p. 242, figs. 549a and b.

1992. *Arctica islandica* (Linné): Tiwari, p. 129, Pl. XIV, figs. 1a and b, 2 and 3.

2013. *Arctica islandica* (Linné): Lalchawimawii, p. 69, Pl. XIII, figs. 6-7.

Material: One right valve and one left valve.

Location: Locality 7 (Bung Bangla Quarry 2, Tuirial Road) Aizawl, Mizoram.

Horizon: Upper grey sandstone of Upper Bhuban Formation (bed no.2)**.**

Dimensions:

Sp. No.	Length	Height	Inflation	
TR 21	23.8	19.6	7.6	RV
TR E22	22.6	17.1	7.8	LV

Remarks: Shell thick, sub orbicular outline, beak strongly prosogyrate, strong inflation. The overall character, umbo and ornamentation very well match with the characters of *Arctica islandica* (Linné) and thus assigned to this form.

Superfamily - VENERACEA Rafinesque, 1815

Family - VENERIDAE Rafinesque, 1815

Subfamily - VENERINAE Rafinesque, 1815

Genus - *Venus* Linné, 1758

***Venus* sp.**

(Pl. IX, fig. 7)

Material: One left valve.

Location: Locality 4 (Khawlthangi Quarry, Tuirial Road) Aizawl, Mizoram.

Horizon: Middle grey sandstone of Upper Bhuban Formation of Locality 4 (bed no.3).

Dimensions:

Sp. No.	Length	Height	Inflation	
TR F11	25.9	20.3	6.4	LV

Description and Remarks: The collection at hand is small and ovate-elongate with moderate inflation. Umbo is prosogyrous, sharp and pointed and situated at about

one-third of the shell-length. The specimen has short antero-dorsal with flat ventral margin. There is a thick concentric bands which becomes more conspicuous towards ventral margin. These bands are crossed over by fine radial threads. Internal characters assessment is not possible. Specific identification is deferred because of wanting for better presercation.

Genus - *Callista* Poli, 1791

Type species: *Venus chione* Linné, 1758; SD. Meek, 1876. Recent; Mediterranean.

***Callista* sp.**

(Pl. IX, fig. 8

Material: One left valve and two fragmental species.

Locality: Locality 5 (Mafaki Quarry, Tuirial Road) and Locality 7 (Bung Bangla Quarry 2, Tuirial Road) Aizawl, Mizoram.

Horizon: Brown sandstone of Upper Bhuban Formation of Locality 5 (bed no.1); upper grey sandstone of Upper Bhuban Formation of Locality 7 (bed no.2).

Dimensions:

Sp. No.	Length	Height	Inflation	
C30	18	13.9	1.9	-
E11	26.7	20.9	6.6	-
E24	14.3	9.6	2	LV

Description and Remarks: The specimen at hand are small in size, trigonally ovate and moderately inflated. Umbo is pointed and small, situated at about the anterior

third of shell length. Faint ridge runs from umbo to postero-ventral. There are flat and concentric ridges which are separated by narrow interstices.

All these characters are well tally with the genus *Callista* sp. except the internal characters are not accessible. Due to the want of better preservation, it is left to open nomenclature.

Subgenus - *Macrocallista* Meek, 1876

Type species: *Venus gigantea* Gmelin, 1791 (= *Venus nimbosa* Lightfoot, 1786). Recent; Carribeans.

***Callista* (*Macrocallista*) *florida* (Lamarck)**

(Pl. X, fig. 1)

1818. *Cytherea florida* Lamarck, p. 565.

1864. *Dione florida* Reeve, conch. Icon., XIV.

1880. *Cytherea* (*Callista*) *florida* v. Martens, p. 325.

1900. *Callista florida* Newton, p. 554.

1928. *Cytherea* (*Callista*) *florida* Lamarck: Vredenburg, p. 449.

1930. *Macrocallista florida* (Lamarck): Cox, p. 129 and 156.

1962. *Macrocallista* (*Costacallista*) *florida* (Lamarck): Dey, p. 33, Pl. III, fig. 3.

2004. *Callista* (*Macrocallista*) *florida* (Lamarck): Mazumder, p. 117, Pl. XIII, fig. 2.

2004. *Callista* (*Macrocallista*) *florida* (Lamarck): Lyngdoh, p. 100, Pl. XIII, fig. 8.

2013. *Callista* (*Macrocallista*) *florida* (Lamarck): Lalchawimawii, p. 76, Pl. XIV, figs. 5 - 8.

Material: Two left valves.

Location: Locality 7 (Bung Bangla Quarry 2, Tuirial Road) Aizawl, Mizoram.

Horizon: Upper grey sandstone of Upper Bhuban Formation (bed no.2)**.**

Dimensions:

Sp. No.	Length	Height	Inflation	
E10	31.9	19.3	6	LV
E19	32.9	19.8	5.4	LV

Remarks: The collections at hand matches very well with *Macrocallita* (*Costacallista*) *florida* (Lamarck) described by Dey (1962) in respect of outline, umbonal positions, dimensional ratios, nature of margins and nature of ornamentation. The collections are well matched with Lalchawimawiis's collection and hence the assignment.

***Callista* (*Macrocallista*) cf. *lilacina* (Lamarck)**

(Pl. X, fig. 2)

1962. *Macrocallista* (*Costacallista*) cf. *lilacina* (Lamarck): Dey, p. 33, Pl. II, fig. 7.

2004. *Macrocallista* (*Costacallista*) cf. *lilacina* (Lamarck): Mazumder, p. 118, Pl. XIII, fig. 3.

2004. *Macrocallista* (*Costacallista*) cf. *lilacina* (Lamarck): Lyngdoh, p. 99, Pl. XIII, fig. 3 - 7.

2013. *Macrocallista* (*Costacallista*) cf. *lilacina* (Lamarck): Lalchawimawii, p. 77, Pl. XIV, fig. 9a, b, c.

Material: Two right valves.

Location: Locality 7 (Bung Bangla Quarry 2, Tuirial Road) Aizawl, Mizoram.

Horizon: Upper grey sandstone of Upper Bhuban Formation (bed no.2)**.**

Dimensions:

Sp. No.	Length	Height	Inflation	
E12	28	15.7	5.1	RV
X1	25.1	16.4	4	RV

Remarks: Dey (1962, op. cit.) explained that the species differs from *Callista* (*Costacallista*) *erycina*(Linné) by its closely spaced and more distinct concentric grooves. The collections at hand matched very well with specimen no.K24/173 recorded by Dey (1962, p.33-34, Pl. II, fig.7) from Quilon as *Macrocallista* (*Costacallista*) cf. *lilacina* (Lamarck). Therefore, its assignment is justifiable.

Subfamily - TAPETINAE Adams and Adams.

Genus - *Paphia* Roeding, 1798

Type species: *Paphia alapapilionis* (=*Venus rotundata* Linné, 1758); SD. Dall, 1902; Recent; Western Pacific.

Subgenus - *Paphia* (*s. s*.)

***Paphia* (*Paphia*) *jhai* Tiwari MS**

(Pl. X, figs. 3 & 4)

1992. *Paphia* (*Paphia*) *jhai* Tiwari MS, p. 146, Pl. XV, figs. 8, 9 and 12.

2004. *Paphia* (*Paphia*) *jhai* Tiwari MS: Mazumder, p. 125, Pl. XIV, figs. 8.

2009. *Paphia* (*Paphia*) *jhai* Tiwari MS: Ralte, p. 64, Pl. 6, figs. 14 - 15.

2013. *Paphia* (*Paphia*) *jhai* Tiwari MS: Lalchawimawii, p. 81, Pl. XV, figs. 5-6.

Material: One bivalve specimen, four right valves and two left valves.

Locality: Locality 4 (Khawlthangi Quarry, Tuirial Road), Locality 5 (Mafaki Quarry, Tuirial Road), Locality 6 (Tuirial Road) and Locality 7 (Bung Bangla Quarry 2, Tuirial Road) Aizawl, Mizoram.

Horizon: Upper brown sandstone of Upper Bhuban Formation of Locality 4 (bed no.5); brown sandstone of Upper Bhuban Formation of Locality 5 (bed no.1); brown sandstone of Upper Bhuban Formation of Locality 6 (bed no.1); upper Grey sandstone of Upper Bhuban Formation of Locality 7 (bed no.2).

Dimensions:

Sp. No.	Length	Height	Inflation	
A17	23.7	14.2	5.7	RV
C13	17.5	12.2	4.6	RV
C14	13.9	16.3	6.9	RV
D28	32.4	21.8	4.7	RV
E17	28.6	17.7	5.8	LV
G5	24.6	13.1	2.8	BV
J6	28.1	15.6	4.7	LV

Remarks: Valve small to medium size, inequilateral, elongate-ovate and moderately inflated. Umbo is small prosogyrous and anterior-fourth. It has a short and concave antero-dorsal, a long and gently sloping postero-dorsal, narrow rounded anterior and acutely rounded posterior margins and long and feebly arched ventral margin. Flat topped concentric growth lines on the surface are separated by much narrower interspaces. These characters tally well with the description of *Paphia* (*Paphia*) *jhai*

Tiwari (1992, op. cit.). Moreover, it matches very well with the holotype no. RL/6/3 of Tiwari. Hence, the assignment to this species is unquestionable.

***Paphia* (*Paphia*) *persica* Cox**

(Pl. X , figs.5 & 6)

1936. *Paphia persica* Cox, p. 62, Pl. VII, figs. 10 and 11.

1992. *Paphia* (*Paphia*) *persica* Cox: Tiwari, p. 145, Pl. XV, figs. 10 and 11.

2013. *Paphia* (*Paphia*) *persica* Cox: Lalchawimawii, p. 83, Pl. XV, figs. 7-8.

Material: Eight right valves and three left valves.

Location: Locality 4 (Khawlthangi Quarry, Tuirial Road), Locality 5 (Mafaki Quarry, Tuirial Road) and 7 (Bung Bangla Quarry 2, Tuirial Road), Aizawl, Mizoram.

Horizon: Dark brown sandstone, middle grey sandstone and upper brown sandstone of Upper Bhuban Formation of Locality 4 (bed no.1,3 and 5); brown sandstone of Upper Bhuban Formation of Locality 5 (bed no.1); lower Grey sandstone of Upper Bhuban Formation of Locality 7 (bed no.1).

Dimensions:

Sp. No.	Length	Height	Inflation	
B5	19.2	11.4	2.1	RV
C20	21.8	11.3	3.9	LV
D26	33.7	19.2	5	RV
D27	24.7	13.2	4.7	RV
D29	22.6	13.3	3.1	LV
D48	28.8	13	6.1	RV

E14	22	10.1	4.2	RV
F2	18.8	11.5	2.9	LV
I2	19.7	10.3	2.5	RV
J5	24.8	15.5	2.9	RV
J9	13.5	8.2	2.7	RV

Description and Remarks: The specimen have sub-median umbone, elongated valve and fine concentric sculpture.It has been compared with the specimens assigned to the same species by Tiwari (1992) from Upper Bhuban Formation of Mizoram to which these exhibit close similarity. The specimen approach *Paphia* (*Paphia) persica* Cox in its characteristics. Hence, the identification is confirmed.

***Paphia* (*Paphia*) *rotundata* (Linné)**

(Pl.X, figs. 7 & 8)

1969. *Paphia* (*Paphia*) *rotundata*(Linné):Myra Keen, p. 256, figs. E 149 and 2a - c.

1971. *Paphia* (*Paphia*) *rotundata* (Linné): Davies, p. 256, fig. 587c.

1992. *Paphia* (*Paphia*) *rotundata* (Linné): Tiwari, p. 144, Pl. XV, figs. 13, 14, 15; Pl. XVI, figs. 1a, b and c.

2009. *Paphia* (*Paphia*) *rotundata* (Linné): Ralte, p. 63, Pl. 6, figs. 10 – 13.

2013. *Paphia* (*Paphia*) *rotundata*(Linné): Lalchawimawii, p. 84, Pl. XV , figs. 9 – 12.

Material: One right valve, three left valves and one fragmental species.

Location: Locality 4 (Khawlthangi Quarry, Tuirial Road)**,** Locality 5 (Mafaki Quarry, Tuirial Road) and Locality 6 (Tuirial Road) Aizawl, Mizoram

Horizon: Upper brown sandstone of Upper Bhuban Formation of Locality 4 (bed no. 5); brown sandstone of Upper Bhuban Formation of Locality 5 (bed no.1); brown sandstone of Upper Bhuban Formation of Locality 6 (bed no.1).

Dimensions:

Sp. No.	Length	Height	Inflation	
A13	34.5	17.8	6	LV
B4	19.6	12.9	4.2	LV
C12	39.3	20.3	4.5	LV
C26	27.9	21.1	5	-
D42	28.4	15.9	4.3	RV

Description and Remarks: The specimens have been assigned to *Paphia* (*Paphia*) *rotundata* (Linne') owing to similarity in respect of general outline, nature and positions of umbo, dimensional ratios and in surface ornamentation. Hence, these are assignment to the Linne' species. The identification has further been confirmed by the direct comparison with Tiwari's collection (1992).

Subgenus - *Callistotapes* Sacco, 1900

Type species: *Venus ventula* Basterot, 1825; OD. Oligocene to Recent; Europe, Asia and New Zealand.

***Paphia* (*Callistotapes*) *pseudoliratus* Vredenburg**

(Pl. X, figs. 9 - 11)

1928. *Tapes* (*Callistotapes*) *pseudoliratus* Vredenburg, p. 457, Pl. XXXI, figs. 2 - 5.

1992. *Paphia* (*Callistotapes*) *pseudoliratus* Vredenburg: Tiwari, p. 148, Pl. XVI, figs. 2, 3 and 4.

2004. *Paphia* (*Callistotapes*) *pseudoliratus* Vredenburg: Lyngdoh, p. 107, Pl. XIV, figs. 1 - 2.

2009. *Paphia* (*Callistotapes*) *pseudoliratus* Vredenburg: Ralte, p. 64, Pl. 6, figs. 16 - 17.

2013. *Paphia* (*Callistotapes*) *pseudoliratus* Vredenburg: Lalchawimawii, p. 85, Pl. XV , figs. 13- 14. Pl. XVI, fig 1.

Material: Six right valves and seven left valves.

Location: Locality 3 (Prayer Point, Turial Road), Locality 4 (Khawlthangi Quarry, Tuirial Road), Locality 5 (Mafaki Quarry, Tuirial Road), Locality 6 (Tuirial Road) and Locality 7 (Bung Bangla Quarry 2, Tuirial Road) Aizawl, Mizoram.

Horizon: Brownish grey sandstone of Upper Bhuban Formation of Locality 3 (bed no.2); Lower brown sandstone, middle grey sandstone and upper brown sandstone of Upper Bhuban Formation of Locality 4 (bed no.2, 3 and 5); brown sandstone of Upper Bhuban Formation of Locality 5 and 6 (bed no.1); upper Grey sandstone of Upper Bhuban Formation of Locality 7 (bed no.2).

Dimensions:

Sp. No.	Length	Height	Inflation	
A1	28	15.5	4.3	LV
A2B	27.9	17	5.2	LV
A15	26.6	17	7.5	RV
A19	20.3	13.7	3.5	RV
B3	16.9	9.1	2.6	RV
C32	18.3	13.6	1.9	RV
D33	28.8	18.7	4.8	LV

D44	20.7	13.1	2.6	LV
E15	26.7	17.3	5.8	RV
F4	26.8	19.8	6.3	RV
F4A	27.2	18.4	6.6	LV
F7	25	16.9	2.9	LV
PP5	18	10.8	3.9	LV

Description and Remarks: The specimen are compressed and elongate in nature medium size, ovate outlin narrowly rounded anterior an posterior margins fine concentric sculpture which are separated by narrow interstices. This characters wll match the species *Tapes* (*Callistotapes*) *pseudoliratus*, described by Vredenburg (1928). Hence the specimens at hand are assigned to this species. Tiwari (1992) has included *Callistotapes* under the genus *Paphia* following Myra Keen (in Moore *et al.,* 1969, p. N 685). In accordance, the author also prefers to assign this species as *Paphia* (*Callistotapes*) *pseudoliratus* Vredenburg.

***Paphia* sp.**

(Pl. XI, fig. 1 & 2)

Material: Ten right valves and thirteen left valves.

Location: Locality 3 (Prayer Point, Turial Road), Locality 4 (Khawlthangi Quarry, Tuirial Road), Locality 5 (Mafaki Quarry, Tuirial Road), Locality 6 (Tuirial Road) and Locality 7 (Bung Bangla Quarry 2, Tuirial Road) Aizawl, Mizoram.

Horizon: Brownish grey sandstone of Upper Bhuban Formation of Locality 3 (bed no.2); dark brown sandstone, lower brown sandstone and middle grey sandstone of

Upper Bhuban Formation of Locality 4 (bed no.1, 2 and 3); brown sandstone of Upper Bhuban Formation of Locality 5 and 6 (bed no.1); lower and upper grey sandstone of Upper Bhuban Formation of Locality 7 (bed no.1 and 2).

Dimensions:

Sp. No.	Length	Height	Inflation	
A16	17.3	11.6	3.9	LV
A18	22.1	17.7	4	LV
A20	7.1	5.7	1.8	LV
A21	9	6.6	2.8	RV
B6	23.5	16.1	2.8	RV
B7	18.8	14.7	2.8	LV
B8	20.7	16.3	3.7	RV
B9	28.5	2.6	4.6	LV
C25	17.5	15.4	5.8	RV
C29	18.6	14.4	7.4	RV
D32	23.9	15.9	5.5	RV
D32	19.4	14.5	5	LV
D34	10.3	8	2.3	RV
D41	21.6	12.8	4.8	LV
D38	17.7	12	4.3	RV
D40	13.8	9.5	1.8	LV
D30	24.1	20.2	5.2	LV
D46	10.2	8.6	2.6	LV
E16	25.6	18.2	7	LV

F3	23.3	15.8	5	LV
H5	17.3	13.5	4.4	LV
PP8	23.4	17.1	5.1	RV
PP9	21.2	17.2	4.3	RV

Description and Remarks: The specimens are small, elongate-ovate and moderately inflated. Umbo prosogyrous and at about one-third of the shell. Concentric ribs are prominent wih narrow interstices. Since the preservation of the specimen is poor, most of the defined characteristics cannot be observed and comparision of its specific identifications with other known forms is not possible.

Subfamily - CHIONINAE Frizzel, 1936

Genus - *Timoclea* Brown, 1827

Type species: *Venus ovata* Pennant, 1777; M. Late Miocene-Recent; Europe, Mediterranean, India, Central America, Western Pacific.

Subgenus - *Timoclea* (*s. s*.)

***Timoclea* (*Timoclea*) *arakanensis* Nevill**

(Pl. XI, fig. 3)

1974. *Timoclea arakanensis* Nevill: Dance, p. 270.

2004. *Timoclea* (*Timoclea*) *arakanensis* Nevill: Mazumder, p. 126, Pl. XIV, fig. 1.

2013. *Timoclea* (*Timoclea*) *arakanensis* Nevill: Lalchawimawii, p. 87, Pl. XVI, fig. 6.

Material: Two right valves.

Location: Locality 5 (Mafaki Quarry, Tuirial Road) and Locality 7 (Bung Bangla Quarry 2, Tuirial Road) Aizawl, Mizoram.

Horizon: Grey silty-sandstone of Upper Bhuban Formation of Locality 5 (bed no.2); upper grey sandstone of Upper Bhuban Formation of Locality 7 (bed no.2).

Dimensions:

Sp. No.	Length	Height	Inflation	
TR E21	9.3	6.5	1.9	RV
J8	8.8	5.9	2.1	RV

Remarks: The specimen at hand resembles *Timoclea arakanensis* Nevill illustrated by Mazumder (2004) in the outline, moderately compression, surface ornamentation and shell structures. Hence, these are assigned to this form.

***Timoclea* (*Timoclea*) *scabra* (Hanley)**

(Pl. XI, fig. 4)

1844. *Antigona scabra* Hanley, p. 161, 361, Pl. 16, fig. 24.

1853. *Venus scabra* (Hanley): Sowerby, p. 718, Pl. 157, figs. 101 and 102.

1864. *Venus scabra* (Hanley): Reeve, Vol. 14.

1960. *Veremolpha scabra* (Hanley): Shuto, p. 144, text fig. 10.

1974. *Timoclea scabra* (Hanley): Dance, p. 271.

2004. *Timoclea* (*Timoclea*) *scabra* (Hanley): Mazumder, p. 127, Pl. XIV, figs. 2, 3.

2009. *Timoclea* (*Timoclea*) *scabra* (Hanley): Ralte, p. 65, Pl. 6, fig. 18; Pl. 7, fig. 1

2013. *Timoclea* (*Timoclea*) *scabra* (Hanley): Lalchawimawii, p. 88, Pl. XVI, figs. 7-9

Material: One left valve.

Location: Locality 7 (Bung Bangla Quarry 2, Tuirial Road) Aizawl, Mizoram.

Horizon: Upper grey sandstone of Upper Bhuban Formation (bed no.2).

Dimensions:

Sp. No.	Length	Height	Inflation	
E 18	7.7	6.5	2	LV

Remarks: The diagnostic characters of *Timoclea scabra* (Hanley) described by are Shuto (1960, op. cit.) are ovate trigonal outline with moderate inflation, rounded posterior and ventral margins, radial ribs are stronger on the anterior than the posterior slope. The specimen at hand showed these characters very well. The specimen is also compared and match well with same species reported by Mazumder (2004, op. cit). Therefore,it can be merged with the species *Timoclea* (*Timoclea*) *scabra* Hanley.

***Timoclea* (*Timoclea*) *subspadicea* (Cossmann)**

(Pl. XI, figs. 5 & 6)

1825. *Venus radiata* Bast., p. 89.

1836. *Venus radiata* Bast.: Moulins, p. 169.

1838. *Venus radiata* Bast.: Grat., p. 66.

1873. *Venus ovata* Benoist, p. 37.

1895. *Venus subspadicea* Cossmann, p. 5, Pl. IV, figs. 11 - 12.

1910. *Timoclea subspadicea* (Cossmann): Cossmann, p. 337, Pl. XIII, fig. 29; Pl. XIV, figs. 36 - 40.

1939. *Timoclea subspadicea* (Cossmann): Mukerjee, p. 19, Pl. II, fig. 7.

2004. *Timoclea subspadicea* (Cossmann): Mazumder, p. 128, Pl. XVI, fig. 4.

2004. *Timoclea subspadicea* (Cossmann): Lyngdoh, p.109, Pl. XIV, figs. 6 - 7.

2013. *Timoclea subspadicea* (Cossmann): Lalchawimawii, p.89, Pl. XVI, figs. 10 - 11.

Material: One right valve and two left valves

Location: Locality 8 (Bung Bangla Quarry 1, Tuirial Road) Aizawl, Mizoram.

Horizon: Grey intraformational conglomeratic bed of Grey sandstone of Upper Bhuban Formation (bed no. 7).

Dimensions:

Sp. No.	Length	Height	Inflation	
E20A	8.5	5	1	LV
E20B	7.7	4.2	1.3	LV
E20C	6.5	5	1.6	RV

Remarks: The specimen at hand have been assigned to *Timoclea subspadicea* (Cossmann) owing to similarity with this species in respect of general outline, nature and position of umbo, dimentional ratios and surface ornamentation. The identification has been further confirmed by comparision with Lalchawimawii's collection (2013).

Order	MYOIDA Stoliczka, 1870
Suborder	MYINA Stoliczka, 1870
Superfamily	MYACEA Lamarck, 1809
Family	CORBULIDAE Lamarck, 1818
Subfamily	CORBULINAE Gray, 1823
Genus	*Corbula* Bruguiere, 1797

Type species: Corbula sulcata Lamarck, 1801; SD.Schmidt, 1818. Recent; Senegal (West Africa).

Corbula* (*Corbula*) *tunicosulcata Vredenburg

(Pl. XI, fig. 7)

1928. *Corbula tunicosulcata* Vredenburg, p. 460, Pl. XXXI, figs. 10 - 19.

1992. *Corbula tunicosulcata* Vredenburg: Tiwari, p. 150, Pl. XVI, fig. 12.

2004. *Corbula tunicosulcata* Vredenburg: Mazumder, p. 131, Pl. XIII, fig. 13.

2004. *Corbula tunicosulcata* Vredenburg: Lyngdoh, p.113, Pl. XIV, figs. 13 - 14.

2004. *Corbula tunicosulcata* Vredenburg: Lalchawimawii, p.46, Pl. VI, fig. 6.

2008. *Corbula tunicosulcata* Vredenburg: Ralte, p.67, Pl. 7, figs. 3 - 4.

Material: One right valve.

Location: Locality 3 (Prayer Point, Turial Road), Aizawl, Mizoram

Horizon: Brownish grey sandstone of Upper Bhuban Formation (bed no. 2)

Dimensions:

Sp. No.	Length	Height	Inflation	
PP10	25.5	20.8	13.5	RV

Remarks: Vredenburg (1928) christened a new species by the name *Corbula* (*Corbula*) *tunicosulcata* considering the dignostic characters like broadly triangular, flattened and moderately incurved umbo, high inflation, elongated and contracted posterior portion with a prominent curvilinear ridge and surface with broadly spaced angular costae. All these characters are clearly marked in all the specimens at hand. Hence, the assignment. Vredenburg (1928) considered this form as an intermediate

form of *Corbula tunicata* (Hinds) and *Corbula sulcata* Lamarck because his collections showed the characters of both these species.

Subclass - ANOMALODESMATA Dall, 1889

Order - PHOLADOMYOIDA Newell, 1965

Superfamily - PANDORACEA Rafinesque, 1815

Family - PERIPLOMATIDAE Dall, 1895

Genus - *Periploma* Schumacher, 1817

Type species: *Periploma inequivalvis* Schumacher, 1817 (= *Corbula margaritacea* Lamarck, 1801); M. Recent; West Indies.

Subgenus - *Aelga* Slodkevich, 1935

Type species: *Tellina besshoensis* Yokoyama, 1924; OD. Miocene; Japan.

***Periploma* (*Aelga*) *elliptica* Lalchawimawii**

(Pl. XI, fig. 8)

Material: One right valve and one left valve.

Location: Locality 8 (Bung Bangla Quarry 1, Tuirial Road) Aizawl, Mizoram.

Horizon: Intraformational conglomeratic bed of Upper Bhuban Formation of Locality 8.

Dimensions:

Sp. No.	Length	Height	Inflation	
TC2	50.8	46.8(92.1)	11	LV
TC3	41.7	37.6 (90.1)	7.2	RV

Description and Remarks: The collections at hand are medium sized, inequilateral, elliptical in outline; low inflation, the inflation of the right valve slightly more than that of the left one. Umbo prominent, beak opisthogyrous, placed slightly posterior to the midline, and with a slit. Lunule small, depressed and escutcheon long and lanceolate. Dorsal margin of the shell slightly arched, antero-dorsal margin arched, postero-dorsal almost straight, anterior and posterior margins well rounded, ventral margin convex; antero-dorsal, anterior, posterior and ventral margin form a continuous curve; ventral view of the shell with a sinuate ventral margin. Both anterior and posterior areas depressed and marked off from the rest of the shell surface by folds and flexures; anterior area of left valve with a fold, and a corresponding flexure present in the right valve; posterior area of right valve with a fold, and a corresponding flexure present in the left valve. Surface covered with sub-equally spaced, finely striated growth wrinkles. Internal characters are unobservable.

3.2. SYSTEMATIC DESCRIPTION OF GASTROPODA

The Bhuban rocks of the study area have yielded only a few gastropods. Overall, preservation is poor, and in majority of the cases only whorls are found. Classification given by Davies (1971, pp. 280 - 444) has been followed in this work. Dimensions are given in millimeters.

Class - GASTROPODA Cuvier, 1797

Subclass - PROSOBRANCHIA Milne Edward, 1848

Order - MESOGASTROPODA Cox, 1959

Superfamily - CERITHIACEA Fleming, 1822

Family - TURRITELLIDAE Woodward, 1851

Subfamily - TURRITELLINAE Woodward, 1815

Genus - *Turritella* Lamarck, 1799

Type species: *Turbo terebra* Linné, 1758; M. Recent; Western Pacific.

Turritella (*s. s.*)

Turritella* (*Turritella*) *pseudobandongensis Vredenburg

(Pl. XI, fig. 129

1928. *Turritella pseudobandongensis* Vredenburg, p. 376, Pl. XIX, figs. 3-5, 7.

1992. *Turritella* cf. *pseudobandongensis* Vredenburg: Tiwari MS, p. 156,

Pl. XVII, fig. 1.

2004. *Turritella pseudobandongensis* Vredenburg: Mazumder, p. 139, Pl. XV, fig. 5.

Material: Two specimens, base and apex broken.

Location: Locality 8 (Bung Bangla Quarry 1, Tuirial Road) Aizawl, Mizoram.

Horizon: Grey intraformational conglomeratic band of Grey sandstone of Upper Bhuban Formation (bed no. 7).

Dimensions:

Sp. No.	Height	Diameter
TC23	12.4	7.4
TC27	10	5

Remarks: The specimen at hand is medium in size, conch is slender and height of the whorl is about half of its width. Numerous fine threads cover whorls. Moreover, its shape coincides with *Turritella pseudobandongensis* Vredenburg (1928, *op. cit.*). Hence, the identification.

Superfamily - NATICACEA Gray, 1847

Family - NATICIDAE Forbes, 1838

Subfamily - NATICINAE Forbes, 1838

Genus - *Natica* Scapoli, 1777

Type species: *Nerita vitellus* Linné, 1758; SD Harris, 1897. Living, Indo-Pacific.

***Natica obscura* Sowerby**

(Pl. XI, figs. 10a & b)

1840. *Natica obscura* Sowerby, Pl. XXVI, fig. 2.

1895. *Natica obscura* Sowerby: Noetling, p. 22, Pl. V, fig. 6, 7.

2004. *Natica obscura* Sowerby: Noetling, Mazumder, p. 144, Pl. XV, fig. 8.

2004. *Natica obscura* Sowerby: Noetling, Lyngdoh, p. 139, Pl. XVII, figs. 6 - 8.

2013. *Natica obscura* Sowerby: Lalchawimawii, p. 99, Pl. XVIII, figs. 4 - 6.

Material: One shell with aperture.

Location: Locality 8 (Bung Bangla Quarry 1, Tuirial Road) Aizawl, Mizoram.

Horizon: Grey intraformational conglomeratic band of Grey sandstone of Upper Bhuban Formation (bed no.7).

Dimensions:

Sp. No.	Height	Diameter at the base
TC16	16.2	17.8

Remarks: The present specimen shows all the essential characters of the species *Natica obscura* Sowerby described by Mazumder (2004) such as globular shell, depressed spires, sharp and well defined sutures. Surface smooth except some striae of growth and a very shallow depression runs alongside the suture on the upper end of whorls. Outer lip is sharp, broadly rounded but inner lip cannot be seen. Noetling (1895, op. cit.) illustrated this form from the Miocene of Myanmar to which the present collection tally well in all respect. Hence, the assignment is done with least reservation.

Superfamily CONACEA Rafinesque, 1815

Family CONIDAE Rafinesque, 1815

Genus *Conus* Linne', 1758

Type species: *Conus marmoreus* Linne'; SD Children, 1823. Recent; Indo-Pacific.

Subgenus *Leptoconus* Swainson, 1840

Type species: Conus amadis Martini; SD Herrmannsen, 1847. Recent; Indo-Pacific.

Conus* (*Leptoconus*) *bonneti Cossmann, 1900

(Pl XII, figs. 1a & b)

1900. *Conus* (*Leptoconus*) *bonneti* Cossman, p. 59, Pl. IV, figs. 15 - 16.

1901. *Conus hanza* Noetling, p. 364, Pl. XXIII, figs. 24 - 26.

1921. *Conus* (*Leptoconus*) *hanza* (Noetling): Vredenburg, p. 279.

1925. *Conus* (*Leptoconus*) *bonneti* Cossman: Vredenburg, p. 285.

1939. *Conus* (*Leptoconus*) *bonneti* Cossman: Mukerjee, p. 85.

1988. *Conus* (*Leptoconus*) *bonneti* Cossman: Mathur, p. 48.

1992. *Conus* (*Leptoconus*) *bonneti* Cossman: Tiwari, p. 171, Pl. XVII, fig. 12.

2004. *Conus* (*Leptoconus*) *bonneti* Cossman: Lyngdoh, p. 174, Pl. XXII, figs. 2 and 4.

2008. *Conus* (*Leptoconus*) *bonneti* Cossman: Ralte, p. 75, Pl. 7, figs. 13 - 14.

Material: Two poorly preserved specimens.

Location: Locality 8 (Bung Bangla Quarry 1, Tuirial Road) Aizawl, Mizoram.

Horizon: Grey intraformational conglomeratic bed of Upper Bhuban Formation (bed no. 7).

Dimensions:

Sp. No.	Height of conch	Diameter of conch
TC22	11.2	11.6
TC 24	9.9	9.6

Remarks: The collections at hand show all the essential characters of the species *Conus* (*Leptoconus*) *bonneti* Cossmann figured by Tiwari (1992). As such, the assignment is beyond question.

3.3. SYSTEMATIC DESCRIPTION OF SCAPHOPODA

Class Scaphopoda is represented only by one genera and one species having one specimen. The specimen belongs to Genus *Dentalium*. Systematic description of this species is as follows:

Class - SCAPHOPODA Bronn, 1862

Order - DENTALIOIDA Palmer, 1974

Family - DENTALIIDAE Gray, 1834

Genus - *Dentalium* Linné, 1758

Type species: *Dentalium elephantinum* Linné, 1758; SD Montfort, 1810. Recent; Phillippines Islands.

***Dentalium junghuhni* Martin**

(Pl. XII, fig. 3)

1879-80. *Dentalium junghuhni* Martin, p. 87, Pl. XII, fig. 11.

1879-81. *Dentalium junghuhni* Martin, p. 87, Pl. XII, fig. 11.

1882. *Dentalium junghuhni* Martin: Boettger, p. 141, Pl. XII, figs. 6a - d and 8.

1883-87. *Dentalium junghuhni* Martin, p. 135, Pl. X, figs. 182 - 183.

1901. *Dentalium junghuhni* Martin: Noetling, p. 250, Pl. XVII, figs. 1a - b, 2 and 3a - b.

1939. *Dentalium junghuhni* Martin: Mukerjee, p. 2.

1992. *Dentalium junghuhni* Martin: Tiwari, p. 173, Pl. XVIII, fig. 2.

2013. *Dentalium junghuhni* Martin: Lalchawimawii, p. 108, Pl. XIV, figs. 10 - 12.

Material: One broken specimen.

Location: Locality 8 (Bung Bangla Quarry 1, Tuirial Road) Aizawl, Mizoram.

Horizon: Grey intraformational conglomeratic band of Grey sandstone of Upper Bhuban Formation (bed no. 7).

Dimensions:

Sp. No.	Length	Height
TC19	21.4	5.1

Remarks: The Martin (1879) described the species *Dentalium junghuhni*as a shell surface having fine and raised longitudinal ribs crossed over by flat, widely spaced and equidistant concentrics. These characters are well-marked in the specimen at hand, hence its identity as *Dentalium junghuhni* Martin, 1879. Further, identification is also confirmed by comparison of the present specimen with the one reported by Lalchawimawii (2013), which are found to match well.

3.4. SYSTEMATIC DESCRIPTION OF ECHINOIDEA

Class Echinoidea is represented only by two genus having four specimens. The specimens belongs to Genus *Coelopleurus* and *Schizaster*. Its systematic description is as follows:

Class	-	ECHINOIDEA Leske, 1778
Superorder	-	ECHINACEA Claus, 1876
Order	-	ARBACIOIDA Gregory, 1900
Family	-	ARBACIIDAE Gray, 1855
Genus	-	*Coelopleurus* L. Agassiz, 1840
Subgenus	-	*Keraiophorus* Michelin, 1862

***Coelopleurus* (*Keraiophorus*) sp.**

(Pl. XII, figs. 3a & b)

Material: One specimen.

Location: Locality 2 (near Vara workshop, Zemabawk, Aizawl) Mizoram.

Horizon: Grey silty sandtone of Upper Bhuban Formation (bed no. 1).

Dimensions:

Sp. No.	Length	Height
D10	36.1	24.3

Remarks: The studied specimen is placed under the genus *Coelopleurus* L. Aggassiz, 1840 based on the preserved morphological characters, and the specific identification of this specimen is not possible. However, in the Indian subcontinent, the genus is known from the Eocene succession of Sind (d'Archaic and Haime, 1853), Kachchh (Wynne,

1872): Oligocene succession of Sind (Blanford, 1876, 1879: Duncan and Sladen, 1882-1886) and Miocene succession of Sind (Duncan and Sladen, 1882-1886), Kachchh (Duncan and Sladen, 1883) and Kathiawar (Jain, 1997)

Class - ECHINOIDEA Leske, 1778

Subclass - PERISCHOECHINOIDEA M'Coy, 1849

Order - SPATANGOIDA Claus, 1876

Suborder - HEMIASTERINA Fischer, 1966

Family - SCHIZASTERIDAE Lambert, 1905

Genus - *Schizaster* Agassiz, 1836

Type species: *Schizaster studeri* Agassiz, 1836. SD ICZN opinion-209, 1948. Eocene; France.

Schizaster alveolatus Duncan and Sladen

(Pl. XII, figs. 3a & b – 4a & b)

1882-86. *Schizaster alveolatus* Duncan and Sladen, p. 87, Pl. XX, figs. 10-14.

1970. *Schizaster alveolatus* Duncan and Sladen: Sastri and Sinha, p. 62.

1973. *Schizaster alveolatus* Duncan and Sladen: Pascoe, p. 1650.

1992. *Schizaster alveolatus* Duncan and Sladen: Tiwari MS, p. 175, Pl. XVIII, fig. 6.

Material: Three specimens.

Location: Locality 1 (near Amawii Tyre works, Bawngkawn) Aizawl, Mizoram.

Horizon: Brown sandstone of Middle Bhuban Formation (bed no.1).

Dimensions:

Sp. No.	Length	Height	Thickness
BC1	31.4	25.5	8.2
BC2	11.7	11.1	2.9
BC7	15.4	14.7	6

Remarks: The specimen matches well with *Schizaster alveolatus* Duncan and Sladen (1882-86, *op. cit*., GSI type no. 2585) with respect to their shape and nature of oculo-genital system, which is eccentric and posteriorly shifted. Hence, the identification is beyond doubt.

EXPLANATION TO PLATE V

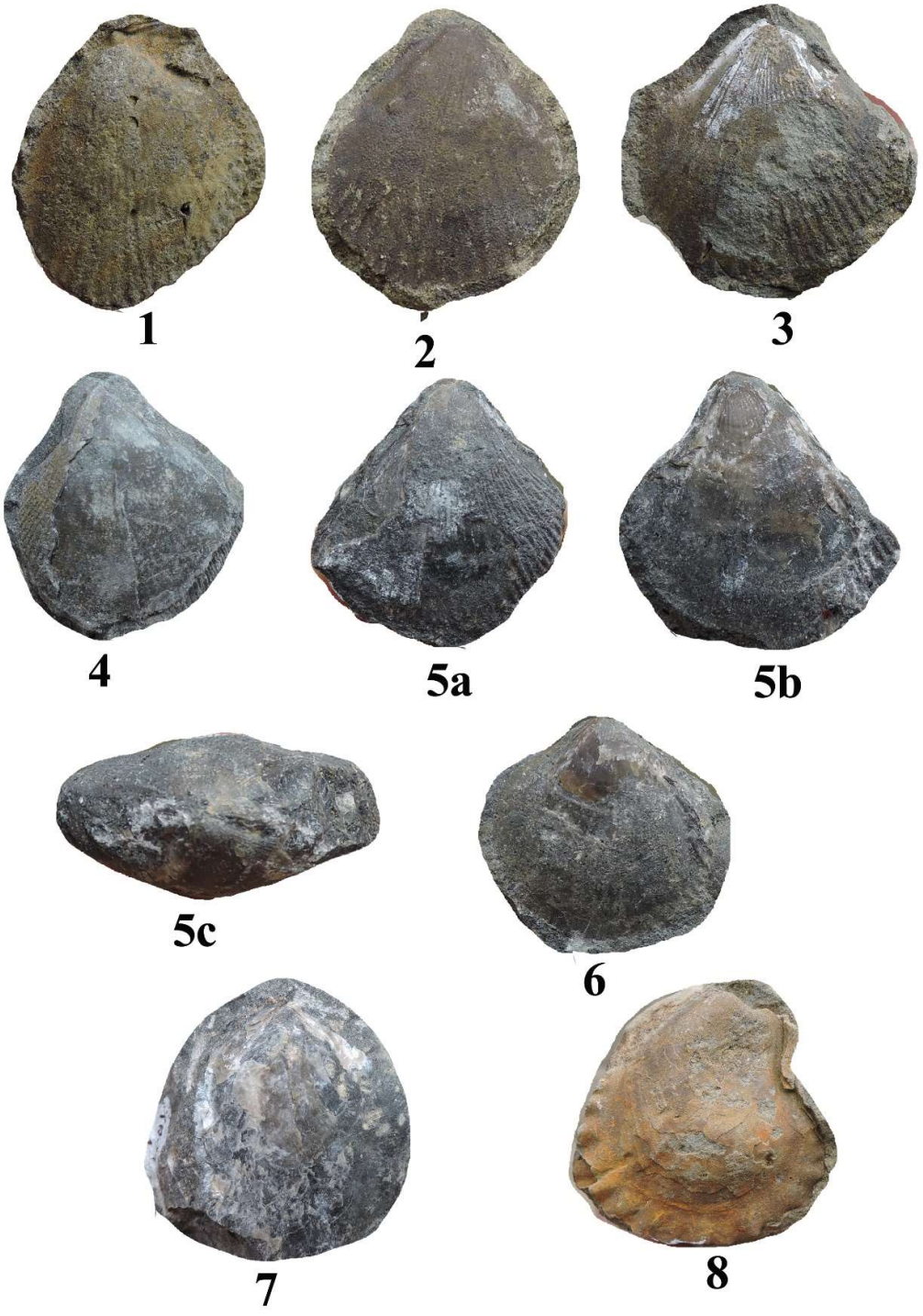
Figure	Explanation	Page
1	*Nucula* (*Nucula*) *warsarensis* Eames, Brown sandstone bed of Upper Bhuban Formation. Locality 5 (Mafaki Quarry, Tuirial Road, Aizawl, Mizoram). (Sp. No. C18). External of right valve.	34
2	*Anadara (Anadara) trapezoida* Tiwari, Brown sandstone bed of Upper Bhuban Formation of Locality (Bung Bangla Quarry 1, Tuirial Road). (Sp.No. C36). External of right valve.	35
3	*Anadara (Anadara) trapezoida* Tiwari, Grey silty sandtone of Upper Bhuban Formation of Locality 2 (near Vara workshop, Zemabawk, Aizawl). (Sp.No. D9). External of right valve.	35
4	*Anadara daviesi* Mukerjee, Grey silty sandtone of Upper Bhuban Formation of Locality 2 (near Vara workshop, Zemabawk, Aizawl). (Sp.No. D9). External of right valve.	36
5	*Anadara* (*Anadara*) *elongata* Lalchawimawii, Brown sandstone bed of Upper Bhuban Formation of Locality 6 (Tuirial Road). (Sp.No. A11). External of right valve.	37
6	*Anadara* (*Anadara*) *elongata* Lalchawimawii, Upper grey sandstone bed of Upper Bhuban Formation of Locality 7 (Bung Bangla Quarry 2, Tuirial Road, Aizawl). (Sp.No. E7A). External of right valve.	37
7	*Pinna sp.,* Grey intraformational conglomeratic band of Grey sandstone bed of Upper Bhuban Formation, Locality 8 (Bung Bangla Quarry 1, Tuirial Road) Aizawl. (Sp.No. TC1).	39
8	*Chlamys (Argopecten) senatoria* (Gmelin), Brown sandstone bed of Upper Bhuban Formation of Locality 6 (Tuirial Road) Aizawl (Sp.No. A4). External of right valve.	40
9	*Chlamys* (C*hlamys*) *jamviniensis* Cox, Brown sandstone bed of Upper Bhuban Formation of Locality 6 (Tuirial Road, Aizawl). (Sp.No. A7). External of left valve.	42
10	*Chlamys* (C*hlamys*) *jamviniensis* Cox, Brown sandstone bed of Upper Bhuban Formation of Locality 8 (Bung Bangla Quarry 2, Tuirial Road, Aizawl). (Sp.No. D14). External of left valve.	42

PLATE V

EXPLANATION TO PLATE VI

Figure	Explanation	Page
1	*Chlamys* (*Chlamys*) *quilonensis* Dey, Brown sandstone bed of Upper Bhuban Formation of Locality 6 (Tuirial Road, Aizawl). (Sp.No. A6). External of left valve.	43
2	*Chlamys* (*Chlamys*) *quilonensis* Dey, Brown sandstone bed of Upper Bhuban Formation of Locality 8 (Bung Bangla Quarry 2, Tuirial Road, Aizawl) (Sp.No. D21) External of left valve.	43
3	*Chlamys* sp., Brown sandstone bed of Upper Bhuban Formation of Locality 8 (Bung Bangla Quarry 2, Tuirial Road, Aizawl) (Sp.No. D16) External of right valve.	44
4	*Chlamys* sp., Grey silty-sandstone bed of Upper Bhuban Formation of Locality 5 (Mafaki Quarry, Tuirial Road, Aizawl). Sp. No. I5.	44
5a	*Pecten* (*Pecten*) *mathuri* Tiwari MS, Lower grey sandstone bed of Upper Bhuban Formation of Locality 7 (Bung Bangla Quarry 2, Tuirial Road, Aizawl), (Sp. No. E4). External of right valve.	47
5b	*Pecten (Pecten) mathuri* Tiwari MS, Lower grey sandstone bed of Upper Bhuban Formation of Locality 7 (Bung Bangla Quarry 2, Tuirial Road, Aizawl), (Sp. No. E4). External of left valve.	47
5c	*Pecten (Pecten) mathuri* Tiwari MS, Lower grey sandstone bed of Upper Bhuban Formation of Locality 7 (Bung Bangla Quarry 2, Tuirial Road, Aizawl), (Sp. No. E4). Dorsal view.	47
6	*Pecten (Pecten) mathuri* Tiwari MS, Lower grey sandstone bed of Upper Bhuban Formation of Locality 7 (Bung Bangla Quarry 2, Tuirial Road, Aizawl), (Sp. No. J1). External of left valve.	47
7	*Placuna* (*Indoplacuna*) sp., Middle grey sandstone bed of Upper Bhuban Formation of Locality 4 (Khawlthangi Quarry, Tuirial Road, Aizawl). (Sp. No. G1). External of right valve	48
8	*Crassostrea gajensis* (Vredenburg), Grey intraformational conglomeratic bed of Upper Bhuban Formation of Locality 8 (Bung Bangla Quarry 2, Tuirial Road, Aizawl). (Sp. No. D24). External of left valve.	50

PLATE VI



EXPLANATION TO PLATE VII

Figure	Explanation	Page
1	*Ostrea* sp., Middle grey sandstone bed of Upper Bhuban Formation of Locality 4 (Khawlthangi Quarry, Tuirial Road, Aizawl). (Sp. No. G4). External of right valve.	50
2	*Diplodonta (Diplodonta) incerta* d'Archiac, Upper brown sandstone bed of Upper Bhuban Formation of Locality 4 (Khawlthangi Quarry, Tuirial Road,Aizawl). (Sp. No. D30). External of right valve.	51
3	*Diplodonta (Diplodonta) incerta* d'Archiac, Upper brown sandstone bed of Upper Bhuban Formation of Locality 4 (Khawlthangi Quarry, Tuirial Road,Aizawl). (Sp. No. D30). External of left valve.	51
4	*Astarte* (*Astarte*) *trigonalis* Lalchawimawii, Brown sandstone bed of Upper Bhuban Formation of Locality 5 (Mafaki Quarry, Tuirial Road, Aizawl). (Sp. No. C30). External of right valve	53
5a	*Astarte ovalis* Lalchawimawii, Upper grey sandstone bed of Upper Bhuban Formation of Locality 7 ((Bung Bangla Quarry 2, Tuirial Road, Aizawl). (Sp. No. E23). External of left valve.	54
5b	*Astarte ovalis* Lalchawimawii, Upper grey sandstone bed of Upper Bhuban Formation of Locality 7 ((Bung Bangla Quarry 2, Tuirial Road, Aizawl). (Sp. No. E23). External of right valve.	54
5c	*Astarte ovalis* Lalchawimawii, Upper grey sandstone bed of Upper Bhuban Formation of Locality 7 ((Bung Bangla Quarry 2, Tuirial Road, Aizawl). (Sp. No. E23). Dorsal view.	54
6	*Lutraria cf. philippinarum* Reeve, Brown sandstone bed of Upper Bhuban Formation of Locality 6 (Tuirial Road, Aizawl). (Sp. No. A1B). External of left valve.	55
7	*Solena (Plectosolen)* sp., Upper grey sandstone bed of Upper Bhuban Formation of Locality 7 (Bung Bangla Quarry 2, Tuirial Road, Aizawl). (Sp. No. EA8).	56

PLATE VII

EXPLANATION TO PLATE VIII

Figure	Explanation	Page
1a	*Cultellus (Cultellus) zulloi* Tiwari, Brown sandstone bed of Upper Bhuban Formation of Locality 6 (Tuirial Road, Aizawl). (Sp. No. A2A). External of right valve	57
1b	*Cultellus (Cultellus) zulloi* Tiwari, Brown sandstone bed of Upper Bhuban Formation of Locality 6 (Tuirial Road, Aizawl). (Sp. No. A2A). External of left valve.	57
1c	*Cultellus (Cultellus) zulloi* Tiwari, Brown sandstone bed of Upper Bhuban Formation of Locality 6 (Tuirial Road, Aizawl). (Sp. No. A2A). Dorsal view.	57
2a	*Cultellus (Cultellus) zulloi* Tiwari, Brown sandstone bed of Upper Bhuban Formation of Locality 5 ((Mafaki Quarry, Tuirial Road, Aizawl). (Sp. No. C1). External of left valve.	57
2b	*Cultellus (Cultellus) zulloi* Tiwari, Brown sandstone bed of Upper Bhuban Formation of Locality 5 ((Mafaki Quarry, Tuirial Road, Aizawl). (Sp. No. C1). External of right valve.	57
2c	*Cultellus (Cultellus) zulloi* Tiwari, Brown sandstone bed of Upper Bhuban Formation of Locality 5 ((Mafaki Quarry, Tuirial Road, Aizawl). (Sp. No. C1). Dorsal view.	57
3	*Tellina compressa* Tiwari, Brown sandstone bed of Upper Bhuban Formation of Locality 5 (Mafaki Quarry, Tuirial Road, Aizawl). (Sp. No. C37). External of right valve.	59
4	*Tellina maubawka* Tiwari, Brown sandstone bed of Upper Bhuban Formation of Locality 6 (Tuirial Road, Aizawl). (Sp. No. A14). External of left valve.	60
5	*Tellina (Angulus)* sp., Middle grey sandstone bed of Upper Bhuban Formation of Locality 4 (Khawlthangi Quarry, Tuirial Road, Aizawl). (Sp. No.F5). External of right valve.	61
6	*Tellina* (*Eurytellina*) *pilgrimi* Cox, Brown sandstone bed of Upper Bhuban Formation of Locality 5 (Mafaki Quarry, Tuirial Road, Aizawl). (Sp. No. C27). External of left valve	62

PLATE VIII

1a

1b

1c

2a

2b

2c

3

4

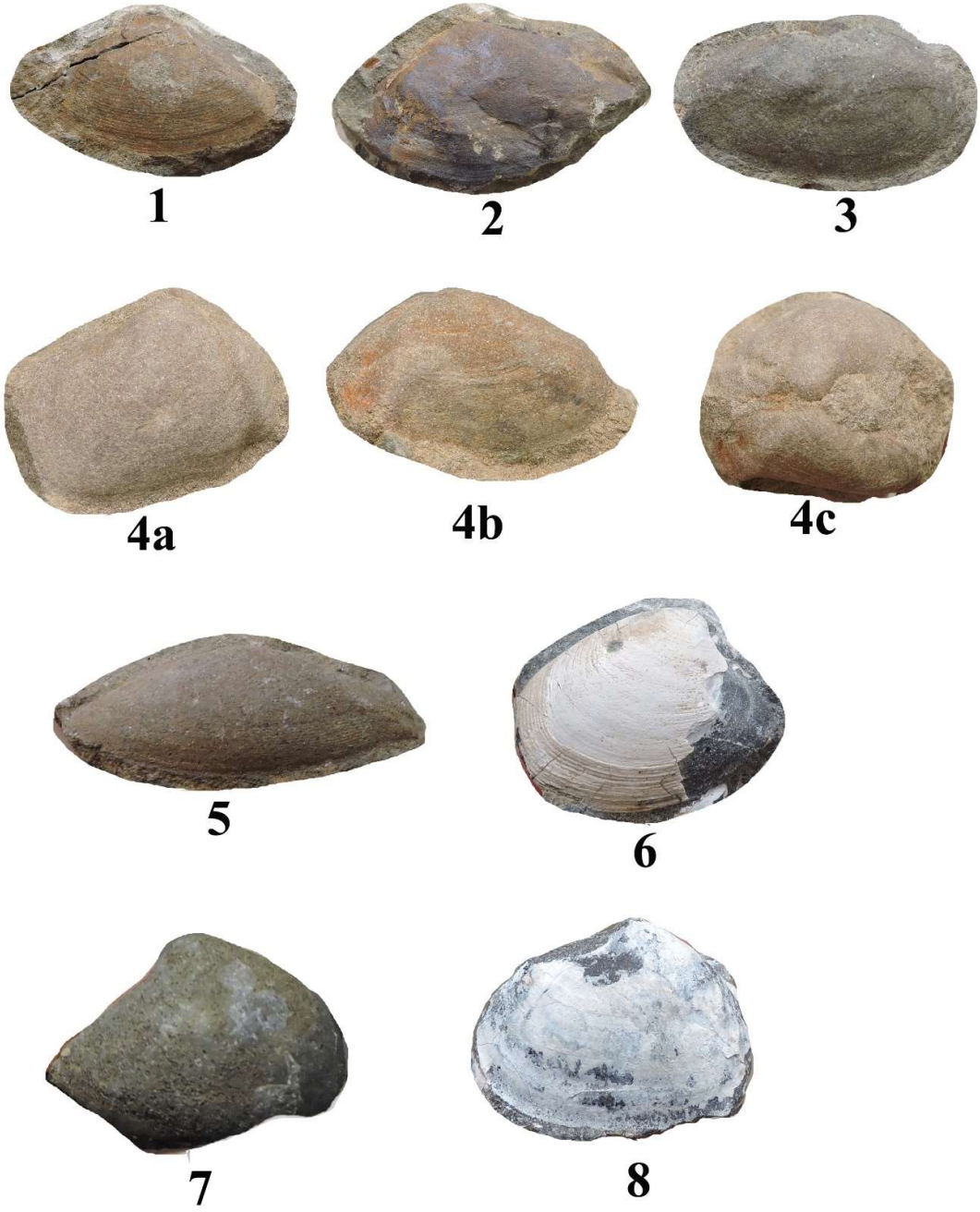
5

6

EXPLANATION TO PLATE IX

Figure	Explanation	Page
1	*Tellina (Oudardia)* sp., Brown sandstone bed of Upper Bhuban Formation of (Mafaki Quarry, Tuirial Road, Aizawl). (Sp. No. C17). External of left valve.	63
2	*Tellina* (*Perodina*) sp., Brownish grey sandstone bed of Upper Bhuban Formation of Locality 3 (Prayer Point, Turial Road, Aizawl). (Sp. No. PP01). External of left valve.	64
3	*Tellina* (*Tellinella*) *hilli* Noetling, Middle grey sandstone bed of Upper Bhuban Formation of Locality 4(Khawlthangi Quarry, Tuirial Road, Aizawl). (Sp. No. D37). External of right valve.	65
4a	*Apolymetis grimesi* (Noetling), Brown sandstone bed of Middle Bhuban Formation of Locality 1 (near Amawii Tyre Works, Bawngkawn, Aizawl). (Sp. No. BC1A). External of right valve.	66
4b	*Apolymetis grimesi* (Noetling), Brown sandstone bed of Middle Bhuban Formation of Locality 1 (near Amawii Tyre Works, Bawngkawn, Aizawl). (Sp. No. BC1A). External of left valve.	66
4c	*Apolymetis grimesi* (Noetling), Brown sandstone bed of Middle Bhuban Formation of Locality 1 (near Amawii Tyre Works, Bawngkawn, Aizawl). (Sp. No.BC1A). Dorsal view.	66
5	*Gari* (*Gari*) *natensis* Noetling, Brownish grey sandstone bed of Upper Bhuban Formation of Locality 3 (Prayer Point, Turial Road, Aizawl). (Sp. No. PP3). External of right valve.	67
6	*Arctica islandica* (Linné), Upper grey sandstone bed of Upper Bhuban Formation of Locality 7 (Bung Bangla Quarry 2, Tuirial Road, Aizawl). (Sp. No. TR 21). External of right valve.	68
7	*Venus* sp., Middle grey sandstone bed of Upper Bhuban Formation of Locality 4 (Khawlthangi Quarry, Tuirial Road, Aizawl). (Sp. No. TR F11). External of left valve.	69
8	*Callista* sp., Upper grey sandstone bed of Upper Bhuban Formation of Locality 7 (Bung Bangla Quarry 2, Tuirial Road, Aizawl). (Sp. No. E11). External of right valve.	71

PLATE IX



EXPLANATION TO PLATE X

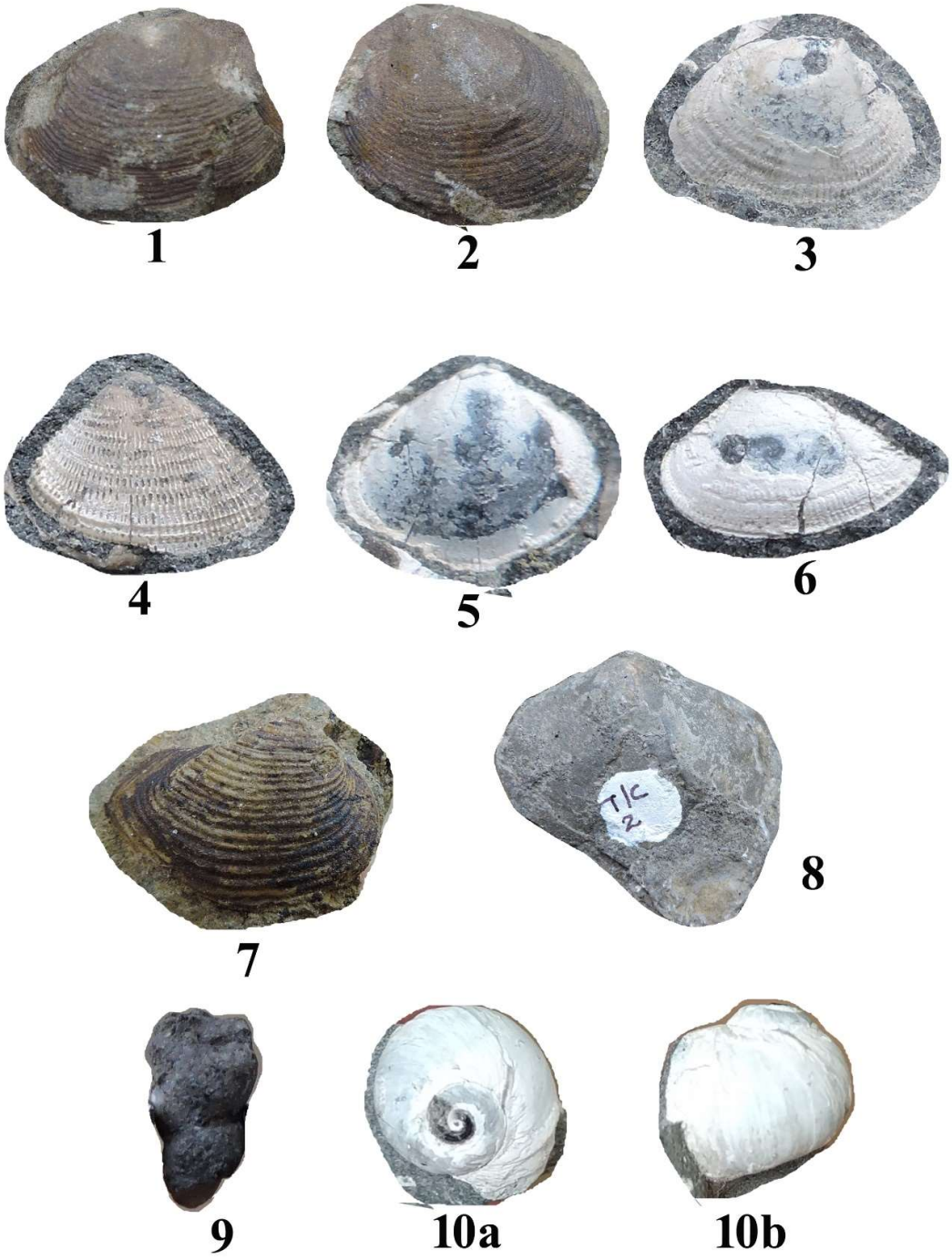
Figure	Explanation	Page
1	*Callista* (*Macrocallista*) *florida* (Lamarck), Upper grey sandstone bed of Upper Bhuban Formation of Locality 7 (Bung Bangla Quarry 2, Tuirial Road, Aizawl). (Sp. No. E1). External of left valve.	71
2	*Callista* (*Macrocallista*) cf. *lilacina* (Lamarck), Upper grey sandstone bed of Upper Bhuban Formation of Locality 7 (Bung Bangla Quarry 2, Tuirial Road, Aizawl). (Sp. No. E12). External of right valve.	72
3	*Paphia* (*Paphia*) *jhai* Tiwari MS, Brown sandstone bed of Upper Bhuban Formation of Locality 5 (Mafaki Quarry, Tuirial Road, Aizawl). (Sp. No. C14). External of right valve.	73
4	*Paphia* (*Paphia*) *jhai* Tiwari MS, Upper grey sandstone bed of Upper Bhuban Formation of Locality 7 (Bung Bangla Quarry 2, Tuirial Road, Aizawl). (Sp. No. E17). External of left valve.	73
5	*Paphia* (*Paphia*) *persica* Cox, Upper brown sandstone bed of Upper Bhuban Formation of Locality 4 (Khawlthangi Quarry, Tuirial Road, Aizawl). (Sp. No. D26). External of right valve.	75
6	*Paphia* (*Paphia*) *persica* Cox, Middle grey sandstone bed of Upper Bhuban Formation of Locality 4 (Khawlthangi Quarry, Tuirial Road, Aizawl). (Sp. No. F2). External of left valve.	75
7	*Paphia* (*Paphia*) *rotundata* (Linné), Brown sandstone bed of Upper Bhuban Formation of Locality 6 (Tuirial Road, Aizawl). (Sp. No. A13). External of left valve.	76
8	*Paphia* (*Paphia*) *rotundata* (Linné), Brown sandstone bed of Upper Bhuban Formation of Locality 5 ((Mafaki Quarry, Tuirial Road, Aizawl). (Sp. No. C12). External of left valve.	76
9	*Paphia* (*Callistotapes*) *pseudoliratus* Vredenburg, Brown sandstone bed of Upper Bhuban Formation of Locality 6 (Tuirial Road, Aizawl). (Sp. No. A1). External of left valve	77
10	*Paphia* (*Callistotapes*) *pseudoliratus* Vredenburg, Lower brown sandstone bed of Upper Bhuban Formation of Locality 4 (Khawlthangi Quarry, Tuirial Road, Aizawl). (Sp. No. D33). External of left valve.	77
11	*Paphia* (*Callistotapes*) *pseudoliratus* Vredenburg, Middle grey sandstone bed of Upper Bhuban Formation of Locality 4 (Khawlthangi Quarry, Tuirial Road, Aizawl). (Sp. No. F7). External of left valve.	77

PLATE X

EXPLANATION TO PLATE XI

Figure	Explanation	Page
1	*Paphia* sp., Lower brown sandstone bed of Upper Bhuban Formation of Locality 4 (Khawlthangi Quarry, Tuirial Road, Aizawl). (Sp. No. D33). External of left valve.	79
2	*Paphia* sp., Lower grey sandstone bed of Upper Bhuban Formation of Locality 7 (Bung Bangla Quarry 2, Tuirial Road, Aizawl). (Sp. No. H5). External of left valve.	79
3	*Timoclea* (*Timoclea*) *arakanensis* Nevill, Upper grey sandstone bed of Upper Bhuban Formation of Locality 7 (Bung Bangla Quarry 2, Tuirial Road, Aizawl). (Sp. No. E21). External of right valve.	81
4	*Timoclea* (*Timoclea*) *scabra* (Hanley), Upper grey sandstone bed of Upper Bhuban Formation of Locality 7 (Bung Bangla Quarry 2, Tuirial Road, Aizawl). (Sp. No. E18). External of left valve.	82
5	*Timoclea* (*Timoclea*) *subspadicea* (Cossmann), Grey intraformational conglomeratic bed of Grey sandstone bed of Upper Bhuban Formation 8 (Bung Bangla Quarry 2, Tuirial Road, Aizawl). (Sp. No. E20A). External of left valve.	83
6	*Timoclea* (*Timoclea*) *subspadicea* (Cossmann), Grey intraformational conglomeratic bed of Grey sandstone bed of Upper Bhuban Formation 8 (Bung Bangla Quarry 2, Tuirial Road, Aizawl). (Sp. No. E20C). External of right valve.	83
7	*Corbula* (*Corbula*) *tunicosulcata* Vredenburg, Brownish grey sandstone bed of Upper Bhuban Formation of Locality 3 (Prayer Point, Turial Road, Aizawl). (Sp. No. PP01). External of right valve.	85
8	*Periploma* (*Aelga*) *elliptica* Lalchawimawii, Intraformational conglomeratic bed of Upper Bhuban Formation of Locality 8 (Bung Bangla Quarry 1, Tuirial Road, Aizawl). (Sp. No. TC2). External of left valve.	86
9	*Turritella* (*Turritella*) *pseudobandongensis* Vredenburg, Intraformational conglomeratic bed of Upper Bhuban Formation of Locality 8 (Bung Bangla Quarry 1, Tuirial Road, Aizawl). (Sp. No. TC27). Abapertural view.	88
10a	*Natica obscura* Sowerby, Intraformational conglomeratic bed of Upper Bhuban Formation of Locality 8 (Bung Bangla Quarry 1, Tuirial Road, Aizawl). (Sp. No. TC16). Apical view.	89
10b	*Natica obscura* Sowerby, Intraformational conglomeratic bed of Upper Bhuban Formation of Locality 8 (Bung Bangla Quarry 1, Tuirial Road, Aizawl). (Sp. No. TC16). Abapertural view.	89

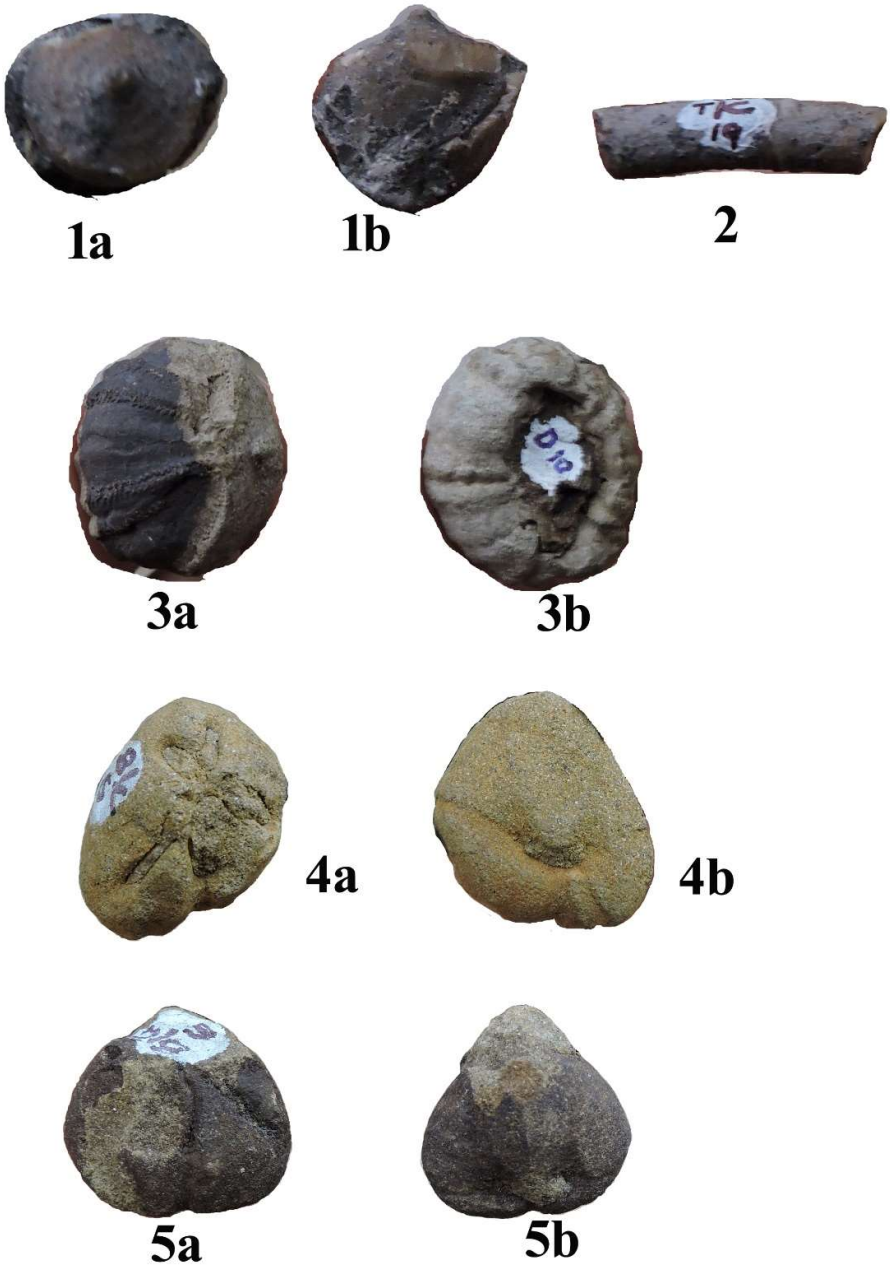
PLATE XI



EXPLANATION TO PLATE XII

Figure	Explanation	Page
1a	*Conus* (*Leptoconus*) *bonneti* Cossmann, 1900, Intraformational conglomeratic bed of Upper Bhuban Formation of Locality 8 (Bung Bangla Quarry 1, Tuirial Road, Aizawl). (Sp. No. TC22). Apical view.	91
1b	*Conus* (*Leptoconus*) *bonneti* Cossmann, 1900, Intraformational conglomeratic bed of Upper Bhuban Formation of Locality 8 (Bung Bangla Quarry 1, Tuirial Road, Aizawl). (Sp. No. TC22). Abapertural view.	91
2	*Dentalium junghuhni* Martin, Intraformational conglomeratic bed of Upper Bhuban Formation of Locality 8 (Bung Bangla Quarry 1, Tuirial Road, Aizawl). (Sp. No. TC19). External of a shell.	92
3a	*Coelopleurus* (*Keraiophorus*) sp., Grey silty sandstone bed of Upper Bhuban Formation of Locality 2 (near Vara Workshop, Zemabawk, Aizawl). (Sp. No. D10). Apical view.	94
3b	*Coelopleurus* (*Keraiophorus*) sp., Grey silty sandstone bed of Upper Bhuban Formation of Locality 2 (near Vara Workshop, Zemabawk, Aizawl). (Sp. No. D10). Oral view.	94
4a	*Schizaster alveolatus* Duncan and Sladen, Brown sandstone bed of Middle Bhuban Formation of Locality 1 (near Amawii Tyre works, Bawngkawn, Aizawl). (Sp. No. BC5). Apical view.	95
4b	*Schizaster alveolatus* Duncan and Sladen, Brown sandstone bed of Middle Bhuban Formation of Locality 1 (near Amawii Tyre works, Bawngkawn, Aizawl). (Sp. No. BC5). Oral view.	95
5a	*Schizaster alveolatus* Duncan and Sladen, Brown sandstone bed of Middle Bhuban Formation of Locality 1 (near Amawii Tyre works, Bawngkawn, Aizawl). (Sp. No. BC6). Apical view.	95
5b	*Schizaster alveolatus* Duncan and Sladen, Brown sandstone bed of Middle Bhuban Formation of Locality 1 (near Amawii Tyre works, Bawngkawn, Aizawl). (Sp. No. BC6). Oral view.	95

PLATE XII



CHAPTER 4: ANALYSIS OF FAUNA AND AGE OF BEDS

4. ANALYSIS OF FAUNA AND AGE OF BEDS

4.1. INTRODUCTION

Rock succession of the study area belong to upper part of Middle Bhuban Unit and lower part of Upper Bhuban unit of the Bhuban Subgroup of Surma Group. Systematic collection of fauna has been made from all the lithic units exposed in the area *i. e.* brown sandstone bed, dark brown sandstone bed, brownish grey sandstone bed, grey silty sandstone bed, grey sandstone bed and intraformational conglomeratic bed. These lithic units are not uniformly fossiliferous. In spite of several visit to the site, only about four hundred individuals could be collected from the area. The fauna so collected have been prepared for study after necessary cleaning and about two hundred and twenty were found suitable for systematic study. Preservation of fauna is not so good. Original bivalved shells are rarely preserved and in most cases casts of single valves are available.

4.2. ANALYSIS OF FAUNA

The collection has yielded 49 forms out of which 44 are bivalves, 3 are gastropod, 1 is scaphopod and 2 echinoids. Bivalves are represented by 22 genera that are grouped into 16 families, 13 superfamilies and 6 orders belonging to 4 subclasses. Gastropods belong to 3 superfamilies, 3 families and 3 genera. *Dentalium is* the sole representative of class scaphopoda. Echinoids are represented by genera *Coelopleurus* and *Shizaster*. Family-wise, veneridae of the class bivalvia contains largest number of genera, *i. e.* 4, namely, *Venus*, *Callista*, *Paphia* and *Timoclea*. Species-wise *Tellina* have maximum number of taxa, *i. e.* 6, closely followed by

Paphia - 4, *Anadara* and *Chlamys* and *Timoclea* – 3 each and *Astarte* and *Callista*– 2 each. All other genera are represented by one species only. Individual-wise the following genera are abundant: *Paphia* – 72, *Chlamys* – 56, *Tellina* – 15, *Cultellus* – 10, *Anadara* – 9, *Pecten* – 7, *Callista* – 7, *Diplodonta* – 5, *Timoclea* – 5, *Placuna* – 4, *Solena* – 4, *Shizaster* – 4, *Astarte* – 3, *Apolymetis* – 3, *Arctica* – 3, *Lutraria* – 3, *Pinna* – 2, *Periploma* – 2, *Ostrea* – 2, *Turritella* – 2, *Nucula* – 1, *Gari* – 1, *Venus* – 1, *Corbula* - 1, *Natica* – 1, *Conus* – 1, *Dentalium* – 1, *Coelopleurus* – 1.

Percentage composition of faunal assemblage in the study area (Fig. 4.1), Genera-wise relative abundance of mega-invertebrates species in the study area (Fig. 4.2), Locality-wise distribution of fauna in the study area (Fig. 4.3) and Locality-wise distribution of fauna in the study area (Fig. 4.4) is shown below. Locality-wise occurrence of fossils from the study area showing age range and bed wise occurrence of fossils is given in Table 4.1 and 4.2. Bedwise distribution of forms is given below.

4.2.1. Brown Sandstone Bed

These beds are exposed in Locality 1 (near Amawii Tyre Works, Bawngkawn, Aizawl), Locality 4 (Khawlthangi Quarry, Tuirial Road), Locality 5 (Mafaki Quarry, Tuirial Road), Locality 6 (Tuirial Road) and Locality 8 (Bung Bangla Quarry 1, Tuirial Road).

Bivalves: *Nucula warsarensis* Eames, *Anadara* (*Anadara*) *trapezoida* Tiwari, *Anadara* (*Anadara*) *elongata* Lalchawimawii, *Chlamys* (*Argopecten*) *senatoria* (Gmelin), *Chlamys* (C*hlamys*) *jamviniensis* Cox, *Chlamys* (*Chlamys*) *quilonensis* Dey, *Chlamys* sp., *Placuna* (*Indoplacuna*) sp., *Diplodonta* (*Diplodonta*) *incerta* d'Archiac, *Astarte* (*Astarte*) *trigonalis* Lalchawimawii, *Lutraria* cf. *philippinarum*

Reeve, *Cultellus* (*Cultellus*) *zulloi* Tiwari, *Tellina compressa* Tiwari, *Tellina* (*Eurytellina*) *pilgrimi* Cox, *Tellina* (*Tellinella*) *hilli* Noetling, Tellina (*Oudardia*) sp. *Apolymetis grimesi* Noetling, *Gari* (*Gari*) *natensis* Noetling, *Arctica islandica* (Linné), *Callista* sp., *Paphia* (*Paphia*) *jhai* Tiwari MS, *Paphia* (*Paphia*) *persica* Cox, *Paphia* (*Paphia*) *rotundata* (Linné), *Paphia* (*Callistotapes*) *pseudoliratus* Vredenburg and *Paphia* sp.

Echinoids: *Schizaster alveolatus* Duncan and Sladen

4.2.2. Dark Brown Sandstone Bed

This bed is exposed in Locality 4 (Khawlthangi Quarry, Tuirial Road).

BIVALVES: *Chlamys (Chlamys) quilonensis* Dey and *Chlamys* sp.

4.2.3. Brownish Grey Sandstone Bed

This bed is exposed in Locality 3 (Prayer Point, Tuirial Road).

Bivalves: *Tellina* (*Eurytellina) pilgrimi* Cox*., Tellina maubawka* Tiwari*, Tellina Perodina* sp*. Gari* (*Gari*) *natensis* Noetling*, Paphia* (*Callistotapes*) *pseudoliratus Vredenburg, Paphia* sp*.,* and *Corbula* (*Corbula*) *tunicosulcata Vredenburg*

4.2.4. Grey Silty Sandstone Bed

These beds are exposed in Locality 2 (near workshop, Zemabawk, Aizawl) and locality 5 (Mafaki Quarry, Tuirial Road).

Bivalves: *Anadara daviesi* Mukerjee, *Anadara* (*Anadara*) *elongata* Lalchawimawii, *Chlamys* sp., *Pecten* (*Pecten*) *mathuri* Tiwari MS, *Placuna* (*Indoplacuna*) sp*., Paphia* (*Paphia*) *jhai* Tiwari MS, *Paphia* (*Paphia*) *persica* Cox and *Paphia* sp.

Echinoids: *Coelopleurus (Keraiophorus)* sp.

4.2.5. Grey Sandstone Bed

These beds are exposed in Locality 4 (Khawlthangi Quarry, Tuirial Road) and Locality 7 (Bung Bangla Quarry 2).

Bivalves: *Anadara* (*Anadara*) *elongata* Lalchawimawii, *Chlamys* sp., *Pecten* (*Pecten*) *mathuri* Tiwari MS, *Placuna* (*Indoplacuna*) sp., *Ostrea* sp., *Astarte* (*Astarte*) *trigonalis* Lalchawimawii, *Cultellus* (*Cultellus*) *zulloi* Tiwari, *Tellina* (*Angulus*) sp., *Callista* (*Macrocallista*) cf. *lilacina* (Lamarck), *Callista* (*Macrocallista*) *florida* (Lamarck), *Callista* sp., *Paphia* (*Paphia*) *jhai* Tiwari MS, *Paphia* (*Paphia*) *persica* Cox, *Paphia* (*Callistotapes*) *pseudoliratus* Vredenburg, *Paphia* sp, *Timoclea* (*Timoclea*) *arakanensis* Nevill and *Timoclea* (*Timoclea*) *scabra* (Hanley).

4.2.6. Grey Intraformational Conglomeratic Bed

This bed is exposed in Locality 8 (Bung Bangla Quarry 1, Tuirial Road).

Bivalves: *Anadara* (*Anadara*) *trapezoida* Tiwari, *Pinna* sp., *Chlamys* (*Argopecten*) *senatoria* (Gmelin), *Chlamys* (C*hlamys*) *jamviniensis* Cox, *Chlamys* (*Chlamys*) *quilonensis* Dey, *Chlamys* sp., *Placuna* (*Indoplacuna*) sp., *Crassostrea gajensis* (Vredenburg), *Solena* (*Plectosolen*) *sp. Cultellus* (*Cultellus*) *zulloi* Tiwari, *Timoclea* (*Timoclea*) *subspadicea* (Cossmann) and *Periploma* (*Aelga*) *elliptica* Lalchawimawii.

Gastropods: *Turritella* (*Turritella*) *pseudobandongensis* Vredenburg, *Natica obscura* Sowerby and *Conus* (*Leptoconus*) *bonneti* Cossmann.

Scaphopods: *Dentalium junghuhni* Martin.

The following two forms are being reported for the first time from the Miocene succession of Mizoram:

1. *Tellina (Oudardia)* sp.
2. *Telina (Perodina)* sp.

The following two forms are being reported for the first time from the Miocene rocks of Northeast India:

3. *Tellina (Oudardia)* sp.
4. *Telina (Perodina)* sp.

4.3. OVERALL AGE

The ratio of living to fossil component of the assemblage has been considered successfully as the basis by many workers for classifying the Tertiary strata of the Indo-Pacific region. Lyell (see Dey 1962) first proposed a method for classifying the Tertiary rocks on the basis of per cent composition of Recent species in the fossil records. Dall (1904) opined that the Miocene succession contain about 17 to 20 per cent of species which are surviving to the Recent. Martin (Van Der Vlerk 1931 p. 291) established the following percent component of existing taxa among the Tertiary faunas of the Indo-Pacific:

Pliocene	-	50 to 70 %
Upper Miocene	-	20 to 50 %
Lower Miocene	-	8 to 20 %
Eocene	-	0 %

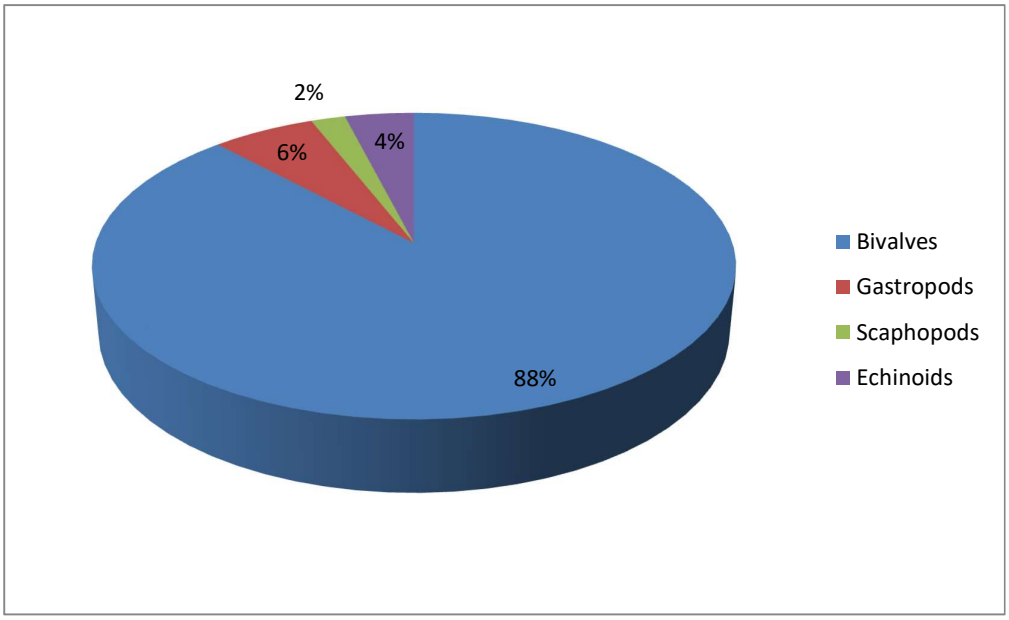


Figure 4.1. Percentage composition of faunal assemblage in the study area

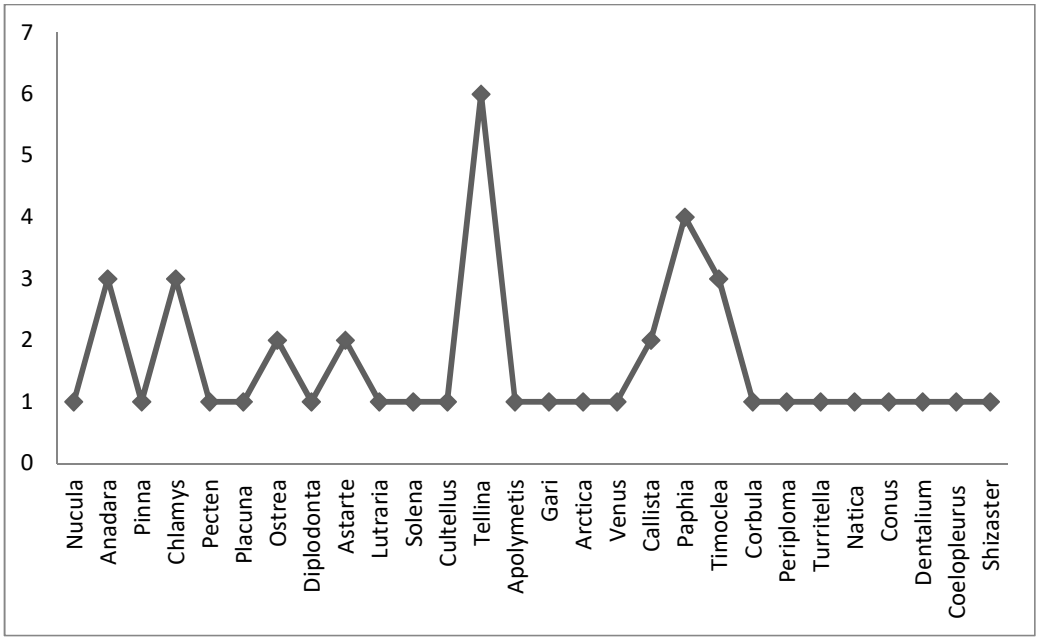
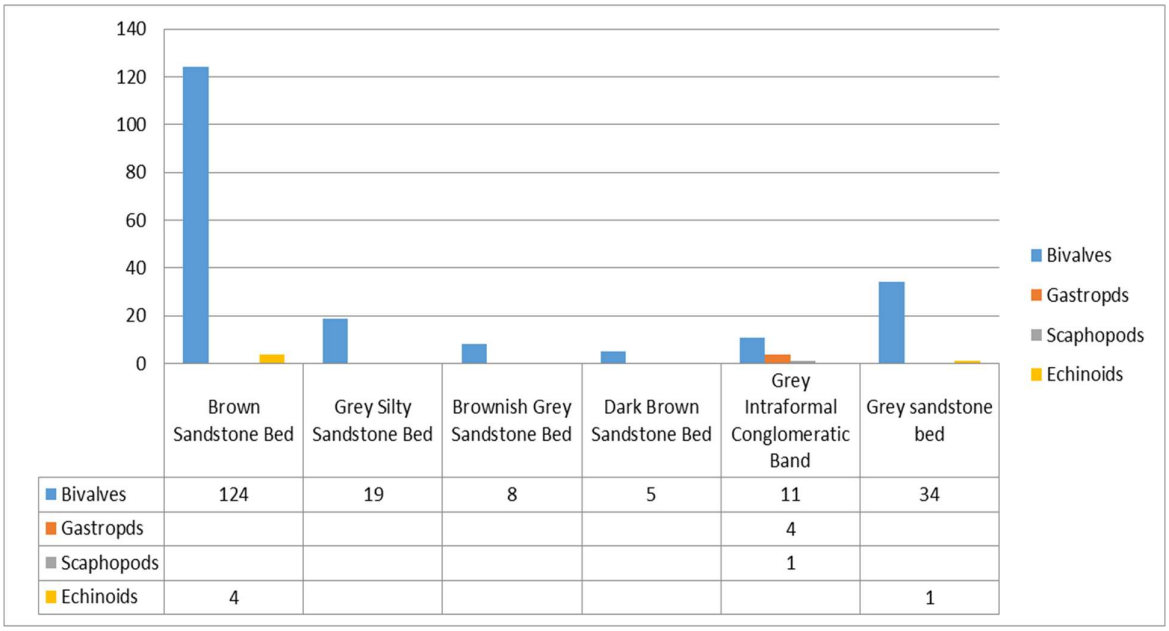
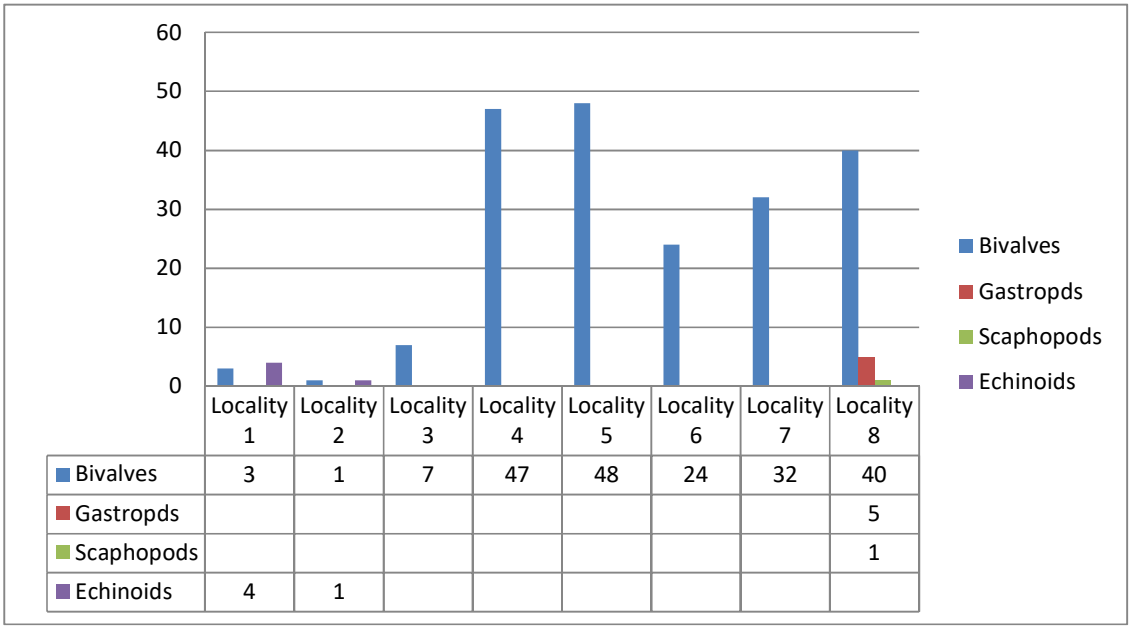


Figure 4.2. Genera-wise relative abundance of mega-invertebrates species in the study area



	Brown Sandstone Bed	Grey Silty Sandstone Bed	Brownish Grey Sandstone Bed	Dark Brown Sandstone Bed	Grey Intraformal Conglomeratic Band	Grey sandstone bed
Bivalves	124	19	8	5	11	34
Gastropds					4	
Scaphopods					1	
Echinoids	4					1

Figure 4. 3. Locality-wise distribution of fauna in the study area



	Locality 1	Locality 2	Locality 3	Locality 4	Locality 5	Locality 6	Locality 7	Locality 8
Bivalves	3	1	7	47	48	24	32	40
Gastropds								5
Scaphopods								1
Echinoids	4	1						

Figure 4. 4. Bed-wise distribution of fauna in the study area

Vredenburg (1921) was of the view that Upper and Lower Gaj of Northwestern India (Lower Miocene) together have 17.30 per cent of composition of the living fauna. Mukerjee (1939) estimated that the percent living component of Lower Miocene molluscan faunas of Myanmar, Western India and Java vary from 7 to 25 depending on the horizon, facies and generic constitution. Further, he worked out 21 per cent composition of Recent molluscs for Lower Miocene sediments of the Garo Hills, Meghalaya.

In the present context out of 49 molluscan taxa 6 range up to the Recent and constitute 12.24 per cent as a living component. This figure is in conformity with the Martin's figure for the Lower Miocene hence the Bhuban succession are also of the same age.

Amongst the recorded species from the present area 46 (Tiwari 1992, 2001 and 2006), (Mazumder 2004), (Ralte 2009) and (Lalchawimawii, 2013) are respectively common to the Lower Miocene of Aizawl Kolasib and Lunglei. 14 species are common to the Aquitanian-Burdigalian succession of the Garo Hills of Meghalaya, 6 to Kama Formation of Myanmar and 2, 7 and 3 are common to Gaj (Lower Miocene) of Kachchh Kathiawar and Sind respectively (Table 4.3). All these confirm a Lower Miocene (Aquitanian-Burdigalian) age for the Bhuban succession and is in conformity with the age as envisaged by the earlier workers. A mention may be made here that Eames (in Davies 1975) considered Aquitanian as Lower Miocene and Burdigalian as Middle Miocene. However in the present work both are taken as Lower Miocene.

4.3.1. AGE OF FOSSILIFEROUS BEDS BASED ON RECORDED TAXA

4.3.1.1. GENERAL REMARKS

Miocene succession of the Indian Subcontinent have been studied in reasonable detail by the various workers. These studies have shown that few taxa could be considered as index fossils. The index fossils as shown for each subdivision are found to be quite suitable for dating the beds in the present area especially *Diplodonta* (*Diplodonta*) *incerta* d'Archiac and *Diplodonta* (*Diplodonta*) *rotundatus* (Montagu) of Gaj Beds (Aquitanian to Burdigalian). The latter is also known to occur in the Garo Hills, Mekran Bed and Iran (Persia) (Aquitanian-Burdigalian). Besides *Ostrea latimarginata* has also been considered as an index fossil of Aquitanian-Burdigalian age. Tiwari (2003) while working out the molluscan biostratigraphy of Tertiary succession of Mizoram has considered the following forms as time indicator of the periods mentioned against them.

Aquitanian to Recent

1. *Chlamys* (*Argopecten*) *senatoria* (Gmelin)
2. *Arctica islandica* (Linné)
3. *Callista* (*Macrocallista*) *florida* (Lamarck)
4. *Timoclea* (*Timoclea*) *arakanensis* Nevill
5. *Timoclea* (*Timoclea*) *scabra* (Hanley)

Aquitanian to Pliocene

1. *Paphia* (*Callistotapes*) *pseudoliratus* Vredenburg

Aquitanian to Upper Miocene (Vindobonian)

1. *Chlamys* (*Chlamys*) *quilonensis* Dey
2. *Paphia* (*Paphia*) *persica* Cox

Aquitanian to Helvetian

1. *Nucula warsarensis* Eames
2. *Anadara daviesi* Mukerjee
3. *Chlamys* (C*hlamys*) *jamviniensis* Cox
4. *Tellina compressa* Tiwari
5. *Corbula* (*Corbula*) *tunicosulcata* Vredenburg

Rupelian to Helvetian

Tellina (*Eurytellina*) *pilgrimi* Cox

Burdigalian

1. *Crassostrea gajensis* (Vredenburg)
2. *Timoclea* (*Timoclea*) *subspadicea*(Cossmann)

Aquitanian to Burdigalian

1. *Anadara* (*Anadara*) *trapezoida* Tiwari
2. *Pecten* (*Pecten*) *mathuri* Tiwari MS
3. *Diplodonta* (*Diplodonta*) *incerta* d'Archiac
4. *Cultellus* (*Cultellus*) *zulloi* Tiwari
5. *Tellina maubawka* Tiwari
6. *Tellina* (*Moerella*) *indifferens* Noetling
7. *Natica obscura* Sowerby
8. *Tellina* (*Tellinella*) *hilli* Noetling
9. *Apolymetis grimesi* Noetling
10. *Gari* (*Gari*) *natensis* Noetling
11. *Dentalium junghuhni* Martin
12. *Paphia* (*Paphia*) *jhai* Tiwari MS

13. *Paphia* (*Paphia*) *rotundata* (Linné)

14. *Turritella* (*Turritella*) *pseudobandongensis* Vredenburg

15. *Natica obscura* Sowerby

4.3.1.2. Brown Sandstone Bed near Amawii Tyre Works, Bawngkawn, Aizawl.

Only two forms, one bivalve and one echinoid have been identified from this bed. *Apolymetis grimesi* (Noetling) range from Aquitanian to Burdigalian (more towards Aquitanian) while *Schizaster alveolatus* Duncan and Sladen range from Burdigalian – Helvetian. Even though the number of fossil have been very few, we may assign this bed Aquitanian to Burdigalian (more towards Aquitanian).

4.3.1.3. Brownish grey sandstone Bed at Prayer Point, Tuirial Road.

A total of seven bivalve forms have been identified from this bed of which three range from Aquitanian to Burdigalian. These are: *Tellina maubawka* Tiwari, *Corbula* (*Corbula*) *tunicosulcata* Vredenburg and *Gari* (*Gari*) *natensis* Noetling as the last one is of Aquitanian to Burdigalian (more towards Aquitanian) respectively. One form namely, *Tellina* (*Eurytellina*) *pilgrimi* Cox range from Rupelian to Helvetian while the remaining one *Paphia* (*Callistotapes*) *pseudoliratus* Vredenburg ranges from Aquitanian to Pliocene. Therefore, this bed has a strong affinity to Aquitanian to Burdigalian and assigned accordingly.

4.3.1.4. Dark brown sandstone bed at Khawlthangi quarry.

Since there are only two taxa available on this bed, assigning age is not attempted.

4.3.1.5. Brown sandstone bed at Khawlthangi quarry, Tuirial Road

There are two brown fossiliferous bed at this locality, the lower one consists of long ranging fossils as the age cannot be ascertained. The upper bed has yielded 8 forms of bivalves. Out of these, one form is left to open nomenclature. There are 3 forms which range from Aquitanian to Burdigalian, namely, *Anadara* (*Anadara*) *elongata* Lalchawimawii, *Diplodonta* (*Diplodonta*) incerta d'Archiac and *Tellina maubawka* Tiwari. *Paphia* (*Paphia*) *jhai Tiwari MS* and *Paphia* (*Paphia*) *rotundata* (Linné) has specific age of Aquitanian to Burdigalian (more towards Burdigalian). *Paphia* (*Paphia*) *persica* Cox has an age range of Aquitanian to Vindobonian while *Paphia* (*Callistotapes*) *pseudoliratus* Vredenburg is of Aquitanian to Pliocene age. We can assign this bed as Aquitanian to Burdigalian (more towards Burdigalian).

4.3.1.6. Grey Sandstone bed at Khawlthangi quarry, Tuirial Road

A total of 7 bivalve forms have been identified from this bed. Out of which 4 are left to open nomenclature. Two forms are Aquitanian to Burdigalian (more towards Aquitanian), which are *Pecten* (*Pecten*) *mathuri* Tiwari MS and *Tellina* (*Tellinella*) *hilli* Noetling while the remaining one form, *Paphia* (*Callistotapes*) *pseudoliratus* Vredenburg has an age range of Aquitanian to Pliocene. As such, this bed may be assigned as Aquitanian to Burdigalian (more towards Aquitanian).

4.3.1.7. Grey Silty Sandstone bed at Mafaki quarry, Tuirial Road

Three out of six bivalve species reported from this bed, namely, *Anadara* (*Anadara*) *elongata* Lalchawimawii, *Paphia* (*Paphia*) *jhai* Tiwari MS and *Paphia* (*Paphia*) *rotundata* (Linné) range form Aquitanian to Burdigalian and the latter two has specific range of Aquitanian to Burdigalian (more towards Burdigalian). The remaining one form *Paphia* (*Paphia*) *persica* Cox is long ranging from Aquitanian to Vindobonian while two forms are left to open nomenclature. Therefore, this bed has a very strong affinity to Aquitanian to Burdigalian (more towards Burdigalian) and is assigned to this age accordingly.

4.3.1.8. Brown sandstone bed at Mafaki quarry, Tuirial Road

This bed has yielded 16 forms of bivalves, out of which, 4 are left to open nomenclature. Of the remaining 12 forms, five forms namely *Anadara* (*Anadara*) *trapezoida* Tiwari and *Pecten* (*Pecten*) *mathuri* Tiwari MS has an age range of Aquitanian to Burdigalian (more towards Aquitanian), *Cultellus* (*Cultellus*) *zulloi* Tiwari has an age of Aquitanian to Burdigalian. The remaining forms are long ranging as three forms have been considered to range from Aquitanian to Helvetian, which are *Nucula warsarensis* Eames, *Chlamys* (*Chlamys*) *jamviniensis* Cox and *Tellina compressa* Tiwari. This bed has also yielded Aquitanian to Recent species *Arctica islandica* (Linné), Aquitanian to Vindobonian species *Paphia* (*Paphia*) *persica* Cox, Aquitanian to Pliocene species *Paphia* (*Callistotapes*) *pseudoliratus* Vredenburg and Rupelian to Helvetian species *Tellina (Eurytellina) pilgrimi* Cox. This bed is assigned to Aquitanian to Burdigalian (more towards Aquitanian).

4.3.1.9. Brown Sandstone bed at Tuirial Road

Five out of ten bivalve forms reported from this bed has an age range of Aquitanian to Burdigalian, which are, *Anadara* (*Anadara*) *elongata* Lalchawimawii, *Cultellus* (*Cultellus*) *zulloi* Tiwari, *Paphia* (*Paphia*) *jhai* Tiwari MS, *Paphia* (*Paphia*) *rotundata* (Linné) and *Tellina maubawka* Tiwari. There is one form namely *Chlamys* (*Chlamys*) *jamviniensis* Cox range from Aquitanian to Helvetian, another one form *Paphia* (*Callistotapes*) *pseudoliratus* Vredenburg range from Aquitanian to Pliocene while *Chlamys* (*Argopecten*) *senatoria* (Gmelin) has an age range of Aquitanian to Recent. Two forms are left to open nomenclature. Since *Paphia* (*Paphia*) *jhai* Tiwari MS and *Paphia* (*Paphia*) *rotundata* (Linné) has an age range of Aquitanian to Burdigalian (more towards Burdigalian), this bed can be assigned as Aquitanian to Burdigalian (more towards Burdigalian).

4.3.1.10. Grey Sandstone bed at Bung Bangla quarry 2, Tuirial Road

There are two fossiliferous grey sandstone bed in this locality. 16 forms of bivalves have been reported from this bed out of which 5 range range from Aquitanian to Burdigalian, which are: *Anadara* (*Anadara*) *elongata* Lalchawimawii, *Astarte* (*Astarte*) *trigonalis* Lalchawimawii, *Cultellus* (*Cultellus*) *zulloi* Tiwari, *Pecten* (*Pecten*) *mathuri* Tiwari MS and *Paphia* (*Paphia*) *jhai* Tiwari MS. Four forms range from Aquitanian to Recent, namely, *Arctica islandica* (Linné), *Callista* (*Macrocallista*) *florida* (Lamarck), *Timoclea* (*Timoclea*) *arakanensis* Nevill and *Timoclea* (*Timoclea*) *scabra* (Hanley). *Paphia* (*Paphia*) *persica* Cox range from Aquitanian to Vindobonian while *Paphia* (*Callistotapes*) *pseudoliratus* Vredenburg range from Aquitanian to Pliocene. There are two forms which appear at Burdigalian

i.e. *Callista* (*Macrocallista*) *cf. lilacina* (Lamarck) which range from Burdigalian to Recent. 4 forms are left to open nomenclature. The overall bed can safely be assigned as Aquitanian to Burdigalian while Aquitanian to Burdigalian (more towards Aquitanian) form *Pecten* (*Pecten*) *mathuri* Tiwari MS is found at the lower bed and Aquitanian to Burdigalian (more towards Burdigalian) form *Paphia* (*Paphia*) *jhai Tiwari* MS is found at the upper bed. So. The lower bed may be assigned as Aquitanian to Burdigalian (more towards Aquitanian) while the upper one as Aquitanian to Burdigalian (more towards Burdigalian).

4.3.1.11. Brown sandstone at Bung Bangla quarry 1, Tuirial Road

Out of 8 forms, 3 are left to open nomenclature. The remaining 5 forms appeared at Aquitanian but only two forms, namely *Anadara* (*Anadara*) *trapezoida* Tiwari, with an age of Aquitanian to Burdigalian (more towards Aquitanian) and *Cultellus* (*Cultellus*) *zulloi* Tiwari range upto Burdigalian. *Chlamys* (*Chlamys*) *jamviniensis* Cox continue upto Helvetian while *Chlamys* (*Chlamys*) *quilonensis* Dey is found upto Vindobonian. The remaining one range upto recent i.e. *Chlamys* (*Argopecten*) *senatoria* (Gmelin). Therefore, we may assign this bed as Aquitanian to Burdigalian (more towards Aquitanian).

4.3.1.12. Intraformational conglomeratic bed at Tuirial quarry 1, Tuirial Road

A total of 9 forms have been described from this bed out of which 5 are bivalves, 3 are gastropods and 1 scaphopod. There are 4 forms which have an age range of Aquitanian to Burdigalian, namely, *Periploma* (*Aelga*) *elliptica* Lalchawimawii, *Natica obscura* Sowerby, *Turritella* (*Turritella*)

pseudobandongensis Vredenburg and *Dentalium junghuhni* Martin. One form *Chlamys* (*Chlamys*) *quilonensis* Dey has an age range of Aquitanian to Vindobonian while *Conus* (*Leptoconus*) *bonneti* Cossmann has a range of Aquitanian to Lower Pliocene. Two forms namely, *Crassostrea gajensis* (Vredenburg) and *Timoclea* (*Timoclea*) *subspadicea* (Cossmann) are of Burdigalian age. The remaining 2 forms are left to open nomenclature. Therefore, this bed can be assigned to Burdigalian age.

Table 4.1: Locality-wise occurrence of fossils from the study area showing age range.

Sl. No	Name of species	Localities								Age
		1	2	3	4	5	6	7	8	
	A. Bivalves									
1	*Nucula warsarensis* Eames					x				Aquitanian - Helvetian
2	*Anadara* (*Anadara*) *trapezoida* Tiwari					x			x	Aquitanian - Burdigalian (more towards Aquitanian)
3	*Anadara daviesi* Mukerjee		x							Aquitanian to Helvetian (more towards Aquitanian-Burdigalian)
4	*Anadara* (*Anadara*) *elongata* Lalchawimawii				x	x	x	x		Aquitanian to Burdigalian
5	*Pinna* sp.								x	
6	*Chlamys* (*Argopecten*) *senatoria* (Gmelin)				x		x			Aquitanian to Recent
7	*Chlamys* (C*hlamys*) *jamviniensis* Cox					x	x		x	Aquitanian to Helvetian
8	*Chlamys* (*Chlamys*) *quilonensis* Dey				x		x		x	Aquitanian to Upper Miocene (Vindobonian)
9	*Chlamys* sp.				x	x	x	x	x	
10	*Pecten* (*Pecten*) *mathuri* Tiwari MS				x	x		x		Aquitanian to Burdigalian (more towards Aquitanian)
11	*Placuna* (*Indoplacuna*) sp.				x	x				
12	*Crassostrea gajensis* (Vredenburg)								x	Burdigalian
13	*Ostrea* sp.				x					
14	*Diplodonta* (*Diplodonta*) *incerta* d'Archiac				x					Aquitanian to Burdigalian
15	*Astarte* (*Astarte*) *trigonalis* Lalchawimawii					x				Aquitanian to Burdigalian
16	*Astarte ovalis* Lalchawimawii					x		x		Aquitanian to Burdigalian
17	*Lutraria* cf. *philippinarum* Reeve				x		x			Burdigalian to Vindhobonian

Sl. No	Name of species	Localities								Age
		1	2	3	4	5	6	7	8	
18	*Solena* (*Plectosolen*)sp.				x			x		
19	*Cultellus* (*Cultellus*) *zulloi* Tiwari				x	x	x	x		Aquitanian to Burdigalian
20	*Tellina compressa* Tiwari					x				Aquitanian - Helvetian
21	*Tellina maubawka* Tiwari			x	x		x			Aquitanian to Burdigalian
22	*Tellina* (*Angulus*) sp.				x					Aquitanian to Burdigalian
23	*Tellina* (*Eurytellina*) *pilgrimi* Cox			x		x				Rupelian to Helvetian
24	*Tellina (Oudardia)* sp.					x				
25	*Tellina* (*Perodina*) sp.			x						
26	*Tellina* (*Tellinella*) *hilli* Noetling				x					Aquitanian to Burdigalian (more towards Aquitanian)
27	*Apolymetis grimesi* Noetling	x								Aquitanian to Burdigalian (more towards Aquitanian)
28	*Gari* (*Gari*) *natensis* Noetling			x						Aquitanian to Burdigalian (more towards Aquitanian)
29	*Arctica islandica* (Linné)							x		Aquitanian to Recent
30	*Venus* sp.				x					
31	*Callista sp.*					x		x		
32	*Callista* (*Macrocallista*) *florida* (Lamarck)							x		Aquitanian to Recent
33	*Callista* (*Macrocallista*) cf. *lilacina* (Lamarck)							x		Burdigalian to Recent
34	*Paphia* (*Paphia*) *jhai* Tiwari MS				x	x	x	x		Aquitanian to Burdigalian (more towards Burdigalian)

Sl. No	Name of species	Localities								Age
		1	2	3	4	5	6	7	8	
35	*Paphia* (*Paphia*) *persica* Cox				x	x		x		Aquitanian to Vindobonian
36	*Paphia* (*Paphia*) *rotundata* (Linné)				x	x	x			Aquitanian to Burdigalian (more towards Burdigalian)
37	*Paphia* (*Callistotapes*) *pseudoliratus* Vredenburg			x	x	x	x	x		Aquitanian to Pliocene
38	*Paphia* sp.			x	x	x	x	x		
39	*Timoclea* (*Timoclea*) *arakanensis* Nevill					x		x		Aquitanian to Recent
40	*Timoclea* (*Timoclea*) *scabra* (Hanley)							x		Aquitanian to Recent
41	*Timoclea* (*Timoclea*) *subspadicea* (Cossmann)								x	Burdigalian **Table**
42	*Corbula* (*Corbula*) *tunicosulcata* Vredenburg			x						Aquitanian to Helvetian
43	*Periploma* (*Aelga*) *elliptica* Lalchawimawii								x	Aquitanian to Burdigalian
	B. Gastropods:									
44	*Turritella* (*Turritella*) *pseudobandongensis* Vredenburg								x	Aquitanian to Burdigalian
45	*Natica obscura* Sowerby								x	Aquitanian to Burdigalian
46	*Conus (Leptoconus) bonneti* Cossmann, 1900								x	Aquitanian to Lower Pliocene
	C. Scaphopods:									
47	*Dentalium junghuhni* Martin								x	Aquitanian to Burdigalian (more towards Aquitanian)
	D. Echnoids:									
48	*Coelopleurus* (*Keraiophorus*) sp.		x							
49	*Schizaster alveolatus* Duncan and Sladen	x								Burdigalian to Helvetian

Table 4.2: Bed-wise occurrence of fossils from the study area.

Sl. No.	Name of species	Brown Sandstone Bed	Dark Brown Sandstone Bed	Brownish Grey Sandstone Bed	Grey Silty Sandstone Bed	Grey Sandstone Bed	Grey Intraformational Conglomeratic Bed
	A. Bivalves						
1	*Nucula warsarensis* Eames	x					
2	*Anadara* (*Anadara*) *trapezoida* Tiwari	x					x
3	*Anadara daviesi* Mukerjee	x			x	x	
4	*Anadara* (*Anadara*) *elongata* Lalchawimawii	x			x	x	
5	*Pinna* sp.						x
6	*Chlamys* (*Argopecten*) *senatoria* (Gmelin)	x	x				x
7	*Chlamys* (*Chlamys*) *jamviniensis* Cox	x					
8	*Chlamys* (*Chlamys*) *quilonensis* Dey	x	x				x
9	*Chlamys* sp.	x	x		x		x
10	*Pecten* (*Pecten*) *mathuri* Tiwari MS	x				x	
11	*Placuna* (*Indoplacuna*) sp.	x			x	x	
12	*Crassostrea gajensis* (Vredenburg)						x
13	*Ostrea* sp.					x	
14	*Diplodonta* (*Diplodonta*) *incerta* d'Archiac	x	x				
15	*Astarte* (*Astarte*) *trigonalis* Lalchawimawii	x					
16	*Astarte ovalis* Lalchawimawii	x				x	
17	*Lutraria* cf. *philippinarum* Reeve	x					

Sl. No.	Name of species	Brown Sandstone Bed	Dark Brown Sandstone Bed	Brownish Grey Sandstone Bed	Grey Silty Sandstone Bed	Grey Sandstone Bed	Grey Intraformational Conglomeratic Bed
18	*Solena* (*Plectosolen*)sp.	x				x	
19	*Cultellus* (*Cultellus*) *zulloi* Tiwari	x				x	
20	*Tellina compressa* Tiwari	x					
21	*Tellina maubawka* Tiwari	x		x			
22	*Tellina* (*Angulus*) sp.					x	
23	*Tellina* (*Eurytellina*) *pilgrimi* Cox	x		x			
24	*Tellina (Oudardia)* sp.	x					
25	*Tellina* (*Perodina*) sp.			x			
26	*Tellina* (*Tellinella*) *hilli* Noetling					x	
27	*Apolymetis grimesi* Noetling	x					
28	*Gari* (*Gari*) *natensis* Noetling			x			
29	*Arctica islandica* (Linné)					x	
30	*Venus* sp.					x	
31	*Callista sp.*	x				x	
32	*Callista* (*Macrocallista*) *florida* (Lamarck)					x	
33	*Callista* (*Macrocallista*) cf. *lilacina* (Lamarck)					x	
34	*Paphia* (*Paphia*) *jhai* Tiwari MS	x				x	
35	*Paphia* (*Paphia*) *persica* Cox	x				x	

Sl. No.	Name of species	Brown Sandstone Bed	Dark Brown Sandstone Bed	Brownish Grey Sandstone Bed	Grey Silty Sandstone Bed	Grey Sandstone Bed	Grey Intraformational Conglomeratic Bed
36	*Paphia* (*Paphia*) *rotundata* (Linné)	x					
37	*Paphia* (*Callistotapes*) *pseudoliratus* Vredenburg	x		x		x	
38	*Paphia* sp.	x	x	x		x	
39	*Timoclea* (*Timoclea*) *arakanensis* Nevill				x	x	
40	*Timoclea* (*Timoclea*) *scabra* (Hanley)					x	
41	*Timoclea* (*Timoclea*) *subspadicea* (Cossmann)						x
42	*Corbula* (*Corbula*) *tunicosulcata* Vredenburg			x			
43	*Periploma* (*Aelga*) *elongata* Lalchawimawii						x
	B. Gastropods:						
44	*Turritella* (*Turritella*) *pseudobandongensis* Vredenburg						x
45	*Natica obscura* Sowerby						x
46	*Conus (Leptoconus) bonneti* Cossmann, 1900						x
	C. Scaphopods:						
47	*Dentalium junghuhni* Martin						x
	D. Echnoids:						
48	*Coelopleurus* (*Keraiophorus*) sp.				x		
49	*Schizaster alveolatus* Duncan and Sladen				x		

Table 4.3: Check list, geographic distribution and age range of mega-invertebrate species from the study area.

Sl. No	Name of species	Mizoram (Tiwari, 1992, 2001, 2006; Tiwari and Kachhara, 2003; Mazumder, 2004;Victor, 2009 and Lalchawimawii, 2013)	Garo Hills (Mukherjee, 1939 and Lyngdoh, 2004)	Gaj Beds (Vredenburg, 1925, 1928 and Jain, 1997)			Myanmar (Noetling, 1895, 1901)			Quilon Bed (Dey, 1960)	Persian Bed (Cox, 1936)	Eocene			Oligocene				Miocene				Pliocene			Recent
				Kachchh	Kathiawar	Sind	(Oigocene)	Kama Formation	Pyalo Formation			Lower Eocene	Middle Eocene	Upper Eocene	Sannoisian	Rupelian	Chattian	Stampian	Aquitanian	Burdigalian	Helvetian	Tortonian	Plaisancian	Astian	Sicilian	
	A. Bivalves																									
1	*Nucula warsarensis* Eames	√								√									-	-	-					
2	*Anadara (Anadara) trapezoida Tiwari*	√																	-	-						
3	*Anadara daviesi Mukerjee*	√	√																-	-	-					
4	*Anadara* (*Anadara*) *elongata* Lalchawimawii	√																	-	-						
5	*Pinna* sp.	√																								
6	*Chlamys* (*Argopecten*) *senatoria* (Gmelin)	√	√	√	√	√		√			√								-	-	-	-	-	-	-	
7	*Chlamys* (C*hlamys*) *jamviniensis* Cox	√	√																-	-	-					
8	*Chlamys* (*Chlamys*) *quilonensis* Dey	√								√									-	-	-	-				-

Sl. No	Name of species	Mizoram (Tiwari, 1992, 2001, 2006; Tiwari and Kachhara, 2003; Mazumder, 2004;Victor, 2009 and Lalchawimawii, 2013)	Garo Hills(Mukherjee, 1939 and Lyngdoh, 2004)	Gaj Beds (Vredenburg, 1925, 1928 and Jain, 1997)			Myanmar (Noetling, 1895, 1901)			Quilon Bed (Dey, 1960)	Persian Bed (Cox, 1936)	Eocene			Oligocene				Miocene				Pliocene			Recent
				Kachchh	Kathiawar	Sind	Singu (Oigocene)	Kama Formation	Pyalo Formation			Lower Eocene	Middle Eocene	Upper Eocene	Sannoisian	Rupelian	Chattian	Stampian	Aquitanian	Burdigalian	Helvetian	Tortonian	Plaisancian	Astian	Sicilian	
9	*Chlamys* sp.																								
10	*Pecten* (*Pecten*) *mathuri* Tiwari MS	√																	-	-					
11	*Placuna* (*Indoplacuna*) sp.	√																							
12	*Crassostrea gajensis* (Vredenburg)	√	√		√															-					
13	*Ostrea* sp.	√																							
14	*Diplodonta* (*Diplodonta*) *incerta* d'Archiac	√	√		√	√													-	-					
15	*Astarte* (*Astarte*) *trigonalis* Lalchawimawii	√																	-	-					
16	*Astarte ovalis* Lalchawimawii	√																	-	-					
17	*Lutraria* cf. *philippinarum* Reeve	√			√						√									-	-	-			
18	*Solena* (*Plectosolen*) sp.	√																							
19	*Cultellus* (*Cultellus*) *zulloi* Tiwari	√																	-	-					
20	*Tellina compressa* Tiwari	√																	-	-	-				

Sl. No	Name of species	Mizoram (Tiwari, 1992, 2001, 2006; Tiwari and Kachhara, 2003; Mazumder, 2004;Victor, 2009 and Lalchawimawii, 2013)	Garo Hills(Mukherjee, 1939 and Lyngdoh, 2004)	Gaj Beds (Vredenburg, 1925, 1928 and Jain, 1997)			Myanmar (Noetling, 1895, 1901)			Quilon Bed (Dey, 1960)	Persian Bed (Cox, 1936)	Eocene			Oligocene				Miocene				Pliocene			Recent
				Kachchh	Kathiawar	Sind	Singu (Oigocene)	Kama Formation	Pyalo Formation			Lower Eocene	Middle Eocene	Upper Eocene	Sannoisian	Rupelian	Chattian	Stampian	Aquitanian	Burdigalian	Helvetian	Tortonian	Plaisancian	Astian	Sicilian	
21	*Tellina maubawka* Tiwari	√																	-	-						
22	*Tellina* (*Angulus*) sp.	√																	-	-						
23	*Tellina* (*Eurytellina*) *pilgrimi* Cox	√									√					-	-	-	-	-	-					
24	*Tellina (Oudardia)* sp.																									
25	*Tellina (Perodina)* sp.																									
26	*Tellina* (*Tellinella*) *hilli* Noetling	√	√					√											-	-						
27	*Apolymetis grimesi* Noetling	√	√					√											-	-						
28	*Gari* (*Gari*) *natensis* Noetling	√	√					√											-	-						
29	*Arctica islandica* (Linné)	√																	-	-	-	-	-	-	-	-
30	*Venus* sp.	√																								
31	*Callista sp.*	√																								
32	*Callista* (*Macrocallista*) *florida* (Lamarck)	√	√		√					√									-	-	-	-	-	-	-	-

Sl. No	Name of species	Mizoram (Tiwari, 1992, 2001, 2006; Tiwari and Kachhara, 2003; Mazumder, 2004;Victor, 2009 and Lalchawimawii, 2013)	Garo Hills(Mukherjee, 1939 and Lyngdoh, 2004)	Gaj Beds (Vredenburg, 1925, 1928 and Jain, 1997)			Myanmar (Noetling, 1895, 1901)			Quilon Bed (Dey, 1960)	Persian Bed (Cox, 1936)	Eocene			Oligocene				Miocene				Pliocene			Recent
				Kachchh	Kathiawar	Sind	Singu (Oigocene	Kama Formation	Pyalo Formation			Lower Eocene	Middle Eocene	Upper Eocene	Samoisian	Rupelian	Chattian	Stampian	Aquitanian	Burdigalian	Helvetian	Tortonian	Plaisancian	Astian	Sicilian	
33	*Callista* (*Macrocallista*) cf. *lilacina* (Lamarck)	√								√										-	-	-	-	-	-	
34	*Paphia* (*Paphia*) *jhai* Tiwari MS	√																	-	-						
35	*Paphia* (*Paphia*) *persica* Cox	√									√								-	-	-	-				
36	*Paphia* (*Paphia*) *rotundata* (Linné)	√																	-	-						
37	*Paphia* (*Callistotapes*) *pseudoliratus* Vredenburg	√	√																-	-	-	-	-	-	-	
38	*Paphia* sp.	√																								
39	*Timoclea* (*Timoclea*) *arakanensis* Nevill	√																	-	-	-	-	-	-	-	-
40	*Timoclea* (*Timoclea*) *scabra* (Hanley)	√																	-	-	-	-	-	-	-	-
41	*Timoclea* (*Timoclea*) *subspadicea* (Cossmann)	√	√																	-						
42	*Corbula* (*Corbula*) *tunicosulcata* Vredenburg	√																		-	-					
43	*Periploma* (*Aelga*) Lalchawimawii	√																	-	-						

Sl. No	Name of species	Mizoram (Tiwari, 1992, 2001, 2006; Tiwari and Kachhara, 2003; Mazumder, 2004;Victor, 2009 and Lalchawimawii, 2013)	Garo Hills(Mukherjee, 1939 and Lyngdoh, 2004)	Gaj Beds (Vredenburg, 1925, 1928 and Jain, 1997)			Myanmar (Noetling, 1895, 1901)			Quilon Bed (Dey, 1960)	Persian Bed (Cox, 1936)	Eocene			Oligocene				Miocene				Pliocene			Recent
				Kachchh	Kathiawar	Sind	(Oigocene)	Formation	Formation			Lower	Middle	Upper	Sannoisian	Rupelian	Chattian	Stampian	Aquitanian	Burdigalian	Helvetian	Tortonian	Plaisancian	Astian	Sicilian	
	B. Gastropods:																									
44	*Turritella (Turritella) pseudobandongensis* Vredenburg	√	√		√	√													-	-						
45	*Natica obscura* Sowerby	√	√	√	√			√											-	-						
46	*Conus (Leptoconus) bonneti* Cossmann, 1900	√	√					√											-	-	-	-	-			
	C. Scaphopods:																									
47	*Dentalium junghuhni* Martin	√																	-	-						
	D. Echnoids:																									
48	*Coelopleurus* (*Keraiophorus*) sp.	√																								
49	*Schizaster alveolatus* Duncan and Sladen	√																			-	-				

CHAPTER 5: BIOSTRATIGRAPHY AND CORRELATION

5. BIOSTRATIGRAPHY AND CORRELATION

5.1. BIOSTRATIGRAPHY

5.1.1. INTRODUCTION

The concept of molluscan biostratigraphy was first introduced by Lyell (1830-33). He was the first to divide the Cenozoic Era into Eocene, Miocene, Pliocene and Recent on the basis of the ratio of extinct versus living molluscan forms. Oligocene epoch in the Tertiary period was originated much later using the same criterion by Beyrich (1854). Nicol (1953) studied the lifespan of several bivalves and proposed that a bivalve species has an average lifespan of 6.5 million years while the duration of a short-lived species is 1 to 2 million years(s). The species either become extinct or change into a distinct form after crossing over this period. There are considerable examples where molluscs are successfully used for local biostratigraphy as well as regional correlation. This clearly manifest wherever microfossils are absent molluscs can be used as an alternative tool for biostratigraphy. The mega invertebrates have been successfully used by earlier workers (Tiwari, 1992, 2001: Mazumder, 2004; Lalchawimawii, 2004, 2013; Ralte, 2008) in stratigraphic correlation and biostratigraphic classification of Tertiary succession in Mizoram. Therefore, molluscan biostratigraphy has been attempted for Bhuban succession of the study area.

5.1.2. BIOSTRATIGRAPHIC ZONATION

Three molluscan zones have been proposed in the Bhuban Formation of Surma Group exposed in the study area. The lower one, *i. e.* Zone-I, is named as

Pecten (*Pecten*) *mathuri* Zone, the middle one, Zone-II, as *Paphia* (*Paphia*) *rotundata* - *Paphia* (*Paphia*) *jhai* Zone whereas the upper one, *i. e.* Zone-III, as *Crassostrea gajensis* Zone (Table 5.1). The distribution of the species in these zones are given in Table 5.2.

ZONE I. *Pecten* (*Pecten*) *mathuri* Zone

Pecten (*Pecten*) *mathuri* Tiwari MS of Aquitanian to Burdigalian (more towards Aquitanian) is confined to this subzone, hence the name. This zone consists of the Upper Bhuban unit of Bhuban Formation at Locality 4 (Khawlthangi Quarry, Tuirial Road), Locality 5 (Mafaki Quarry, Tuirial Road) and Locality 7 (Bung Bangla Quarry 2, Tuirial Road). This bed is the oldest among all fossiliferous beds in the study area. At Locality 4, it is found at about 13m grey sandstone bed (bed no. 3) which consists of bivalves. This zone at Locality 5 consists of 8m thick brown sandstone bed (bed no. 1) containing bivalves while this zone is represented by 9m thick lower grey sandstone bed (bed no. 1) yielding bivalves at Locality 7. This zone is devoid of echinoids, decapods and scaphopods thus the age assigned to it is based on molluscan assemblage.

The other fossil species having restricted age range of Aquitanian to Burdigalian (more towards Aquitanian) found in this zone is *Tellina* (*Tellinella*) *hilli* Noetling. The forms that also have restricted age range of Aquitanian to Burdigalian (more towards Aquitanian) but found in other areas are *Apolymetis grimesi* Noetling (Locality 1, bed no.1) and *Gari* (*Gari*) *natensis* Noetling (Locality 3, bed no. 2). The

Table 5.1: Biostratigraphic Zonations in the study area.

Epoch	Age	Formation	Faunal Zone
M I O C E N E	Burdigalian	Upper Bhuban Formation	**Zone III.** *Crassostrea gajensis* Zone
	Aquitanian to Burdigalian (more towards Burdigalian)	Upper Bhuban Formation	**Zone II.** *Paphia (Paphia) rotundata* - *Paphia (Paphia) jhai* Zone
	Aquitanian to Burdigalian (more towards Aquitanian)	Upper Bhuban Formation	**Zone I.** *Pecten* (*Pecten*) *mathuri* Zone

remaining 18 species that occur in this zone are long temporal and spatial distribution.

This Zone is assigned to Aquitanian to Burdigalian (more towards Aquitanian).

ZONE II. *Paphia* (*Paphia*) *rotundata* - *Paphia* (*Paphia*) *jhai* Zone

This zone is confined to the four localities i.e. Locality 4 (Khawlthangi Quarry, Tuirial Road), Locality 5 (Mafaki Quarry, Tuirial Road), Locality 6 (Tuirial Road) and Locality 7 (Bung Bangla Quarry 2, Tuirial Road) Aizawl, Mizoram.

At Locality 4, it is represented by 3m thick of brown sandstone bed (bed no. 5) containing fossil assemblage of bivalves. This zone is represented by 8m thick grey silty sandstone bed (bed no. 2) in Locality 5 while at Locality 6, it consists of 2m thick brown sandstone bed (bed no. 1). About 5m thick of grey sandstone bed (bed no.2) represent this zone at Locality 7. Fossil assemblages in these localities are represented by bivalve community.

Paphia (*Paphia*) *rotundata* (Linné) and *Paphia* (*Paphia*) *jhai* Tiwari MS are the only forms with age range of Aquitanian to Burdigalian (more towards Burdigalian) from this zone as well as the total study area.

The following species, though long ranging elsewhere are also found in this zone: (*Anadara*) *elongata* Lalchawimawii, *Chlamys* (*Argopecten*) *senatoria* (Gmelin), *Chlamys* (*Chlamys*) *jamviniensis* Cox, *Chlamys* (*Chlamys*) *quilonensis* Dey, *Diplodonta* (*Diplodonta*) *incerta* d'Archiac, *Astarte* (*Astarte*) *trigonalis* Lalchawimawii, *Cultellus* (*Cultellus*) *zulloi* Tiwari, *Tellina maubawka* Tiwari,

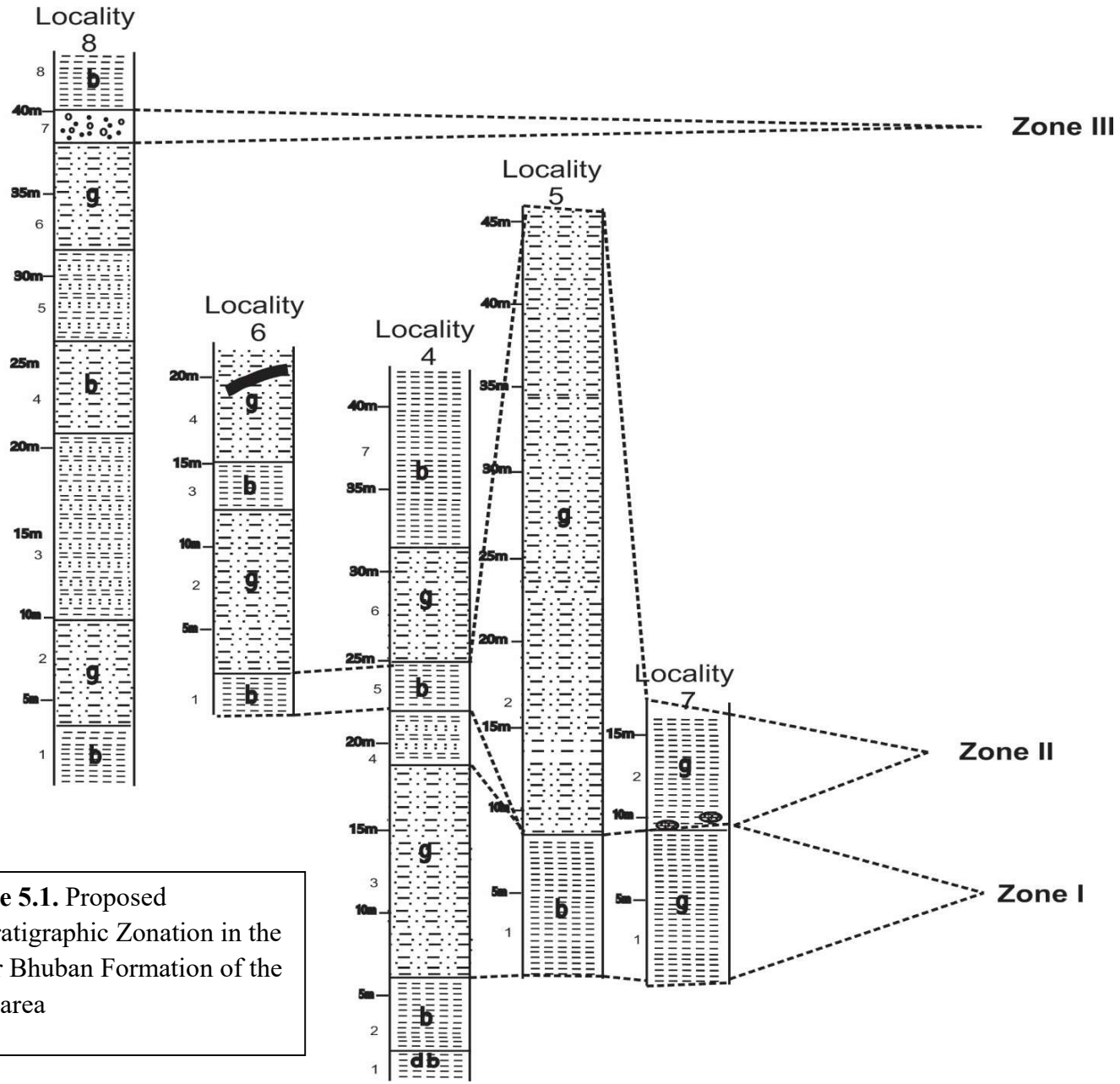
Arctica islandica (Linné), *Callista* (*Macrocallista*) *florida* (Lamarck), *Callista* (*Macrocallista*) *cf. lilacina* (Lamarck), *Paphia* (*Paphia*) *persica* Cox, *Paphia* (*Callistotapes*) *pseudoliratus* Vredenburg, *Timoclea* (*Timoclea*) *arakanensis* Nevill and *Timoclea* (*Timoclea*) *scabra* (Hanley).

This Zone is assigned to Aquitanian to Burdigalian (more towards Burdigalian).

ZONE III. *Crassostrea gajensis* Zone

Crassostrea gajensis (Vredenburg) of Burdigalian age is confined to this zone, hence the name. This zone is exposed at Locality 8 (Bung Bangla quarry 2), Tuirial road (bed no.7) and is represented by intraformational conglomeratic bed yielding bivalves, gastropods and scaphopods. *Timoclea (Timoclea) subspadicea* (Cossmann) is another fossil species with an age range of Burdigalian found in this zone.

Seven species, which are of long ranging are discovered from this zone which are: *Chlamys (Chlamys) quilonensis* Dey, *Periploma* (*Aelga*) *elliptica* Lalchawimawii, *Natica obscura* Sowerby, *Dentalium junghuhni* Martin, *Conus* (*Leptoconus*) *bonneti* Cossmann and *Turritella* (*Turritella*) *pseudobandongensis* Vredenburg.



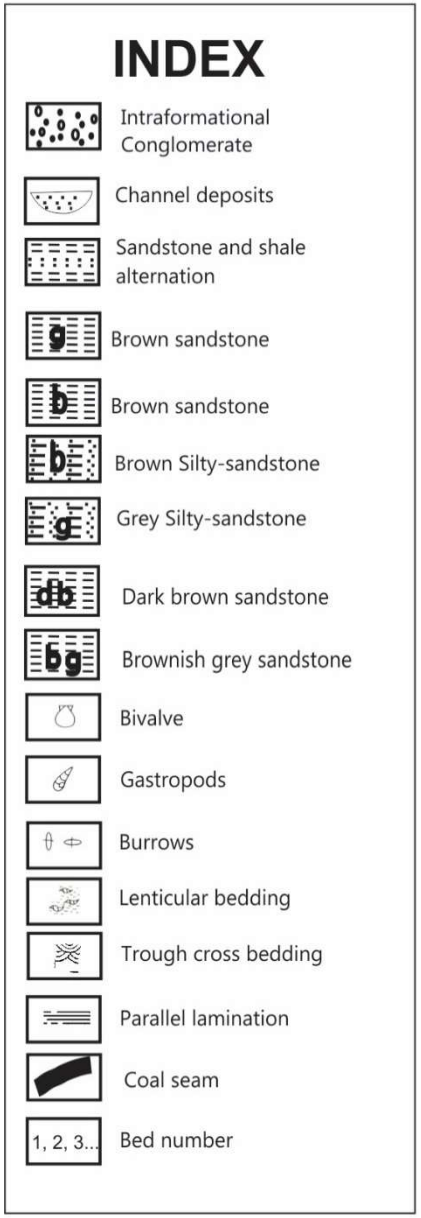


Figure 5.1. Proposed Biostratigraphic Zonation in the Upper Bhuban Formation of the study area

5.2. CORRELATION OF BEDS

Conventionally, biostratigraphic zones together with entombed faunal assemblage have been extensively used for local as well as regional correlations. Correlation of the present sequence is attempted in two step. First attempt is made to establish the relationship among various fossiliferous horizons of different localities in the study area is with a view to know the local composite faunal and stratigraphic sequences. The correlation of the local sequence is then done with those of other areas of the Indo-Pacific province where Lower Miocene fossiliferous strata have been studied in detail.

5.2.1. CORRELATION OF LOCAL SEQUENCE WITH OTHER AREAS

The mega-invertebrates from fossiliferous rocks of Lower Miocene age have been studied form several locations, which are: Aizawl and Lunglei, Mizoram (Tiwari, 1992, 2000, 2001 and 2003; Mazumder, 2004 and Ralte, 2009; Lalchawimawii, 2013), Kanchanpur, Assam (Mukerjee, 1929; Das Gupta, 1982), Garo Hills, Meghalaya (Vredenburg, 1921; Mukerjee, 1939; Lyngdoh, 2004), Sind (Pakistan), Kachchh and Kathiawar in Gujarat (Vredenburg, 1925, 1928; Jain, 1997) and in Myanmar (Noetling, 1895, 1901; Vredenburg, 1921 and Pascoe, 1973). An attempt has been made here to correlate the Bhuban rocks of the study area with the above-mentioned Lower Miocene localities from the Indian sub-continent.

Table 5.2: Zonal distribution and frequency of occurrence of species in the study area.

Sl. no.	FREQUENCY / SPECIES / ZONE	A = Abundant F = Frequent R = Rare		
		ZONE- I	ZONE- II	ZONE- III
	Bivalves			
1	*Nucula warsarensis* Eames	R		
2	*Anadara* (*Anadara*) *trapezoida* Tiwari	R		
3	*Anadara daviesi* Mukerjee			
4	*Anadara* (*Anadara*) *elongata* Lalchawimawii		A	
5	*Pinna* sp.			R
6	*Chlamys* (*Argopecten*) *senatoria* (Gmelin)		R	
7	*Chlamys* (*Chlamys*) *jamviniensis* Cox		F	
8	*Chlamys* (*Chlamys*) *quilonensis* Dey			F
9	*Chlamys* sp.	A	F	F
10	*Pecten* (*Pecten*) *mathuri Tiwari* MS	A		
11	*Placuna* (*Indoplacuna*) sp.	R	R	
12	*Crassostrea gajensis* (Vredenburg)			R
13	*Ostrea* sp.	R		
14	*Diplodonta* (*Diplodonta*) *incerta* d'Archiac		F	
15	*Astarte* (*Astarte*) *trigonalis* Lalchawimawii	R	R	
16	*Astarte ovalis* Lalchawimawii			
17	*Lutraria cf. philippinarum* Reeve			
18	*Solena* (*Plectosolen*) sp.		R	
19	*Cultellus* (*Cultellus*) *zulloi* Tiwari	R	A	
20	*Tellina compressa* Tiwari	R		
21	*Tellina maubawka* Tiwari		F	
22	*Tellina* (*Angulus*) sp.	R		
23	*Tellina* (*Eurytellina*) *pilgrimi* Cox	F		
24	*Tellina* (*Oudardia*) sp.	R		
25	*Tellina* (*Perodina*) sp.			
26	*Tellina* (*Tellinella*) *hilli* Noetling	R		
27	*Apolymetis grimesi* Noetling			
28	*Gari* (*Gari*) *natensis* Noetling			
29	*Arctica islandica* (Linné)	R	R	

Sl. no.	FREQUENCY / SPECIES / ZONE	A = Abundant F = Frequent R = Rare		
		ZONE- I	ZONE- II	ZONE- III
	Bivalves			
30	*Venus* sp.			
31	*Callista* sp.		R	
32	*Callista* (*Macrocallista*) *florida* (Lamarck)		R	
33	*Callista* (*Macrocallista*) cf. *lilacina* (Lamarck)		F	
34	*Paphia* (*Paphia*) *jhai* Tiwari MS		A	
35	*Paphia* (*Paphia*) *persica* Cox	R	A	
36	*Paphia* (*Paphia*) *rotundata* (Linné)		R	
37	*Paphia* (*Callistotapes*) *pseudoliratus* Vredenburg	F	A	
38	*Paphia* sp.	A	A	
39	*Timoclea* (*Timoclea*) *arakanensis* Nevill		R	
40	*Timoclea* (*Timoclea*) *scabra* (Hanley)		R	
41	*Timoclea* (*Timoclea*) *subspadicea* (Cossmann)			F
42	*Corbula* (*Corbula*) *tunicosulcata* Vredenburg			
	Periploma (*Aelga*) *elliptica* Lalchawimawii			R
43	**Gastropods:**			
44	*Turritella* (*Turritella*) *pseudobandongensis* Vredenburg			R
45	*Natica obscura* Sowerby			R
	Conus (Leptoconus) bonneti Cossmann, 1900		R	
46	**Scaphopods:**			
47	*Dentalium junghuhni* Martin			R
	Echnoids:			
48	*Coelopleurus* (*Keraiophorus*) sp.			
49	*Schizaster alveolatus* Duncan and Sladen			

5.2.2. Miocene Succession of Mizoram

5.2.2.1. Biostratigraphic Zonations of Tiwari and Kachhara (2003)

Tiwari and Kachhara (2003) erected five bio-zones zones (Zone I - Zone V) in the Barail and Surma for Aizawl and Lunglei area. These are: Zone I: *Meretrix agrestis* Zone within the Barail Group and is assigned to Late Eocene-Oligocene; Zone II: *Glycymeris sindiensis* - *Nuculana virgo* Zone of Aquitanian age and lies within the Lower and Middle units of Bhuban Formation; Zone III: *Ostrea latimarginata* - *Natica pellis tigrina* Zone of Aquitanian to Burdigalian age within the lower part of Upper Bhuban Formation; Zone IV: *Pecten* (*Oopecten*) *gigas* Zone of Burdigalian age within middle part of the Upper Bhuban unit; and Zone V: *Pecten* sp. Zone of Helvetian age which lies within the upper part of Upper Bhuban unit of Bhuban Formation

Detailed comparison of Zone I with zones of Tiwari and Kachhara (2003) revealed that six taxa from the Zone I of the study area are known to occur in Zone II of Tiwari and Kachhara (2003), these are: *Nucula warsarensis* Eames, *Diplodonta* (*Diplodonta*) *incerta* d'Archiac, *Tellina* (*Eurytellina*) *pilgrimi* Cox, *Tellina* (*Tellinella*) *hilli* Noetling, *Arctica islandica* (Linné) and *Paphia* (*Paphia*) *persica* Cox. Five forms, namely *Anadara* (*Anadara*) *trapezoida* Tiwari, *Tellina* (*Eurytellina*) *pilgrimi* Cox, *Arctica islandica* (Linné), *Paphia* (*Paphia*) *persica* Cox and *Paphia* (*Callistotapes*) *pseudoliratus* Vredenburg from Zone I of the study area are also known to occur in Zone III of Tiwari and Kachhara (2003). Six forms from Zone I of the study area are also present in Zone IV of Tiwari an Kachhara (2003), which are: *Anadara* (*Anadara*) *trapezoida* Tiwari, *Tellina* (*Eurytellina*) *pilgrimi* Cox, *Tellina* (*Tellinella*) *hilli* Noetling, *Arctica islandica* (Linné), *Paphia* (*Paphia*) *persica*

Cox and *Paphia* (*Callistotapes*) *pseudoliratus* Vredenburg. Correlation between Zone I of the study area with Zone V of Tiwari and Kachhara is limited to only three forms, which are *Tellina* (*Eurytellina*) *pilgrimi* Cox, *Tellina* (*Tellinella*) *hilli* Noetling and *Arctica islandica* (Linné). Hence, this zone is broadly correlatable with Zone II (*Glycymeris sindiensis* - *Nuculana virgo* Zone), Zone III (*Ostrea latimarginata* - *Natica pellis tigrina* Zone) and Zone IV [*Pecten* (*Oopecten*) *gigas* Zone] of Tiwari and Kachhara (2003).

Only three taxa from Zone II of the study are known to occur in Zone II of Tiwari and Kachhara, which are *Diplodonta* (*Diplodonta*) *incerta* d'Archiac, *Arctica islandica* (Linné) and *Paphia* (*Paphia*) *persica* Cox whereas zonal taxa *Paphia* (*Paphia*) *rotundata* (Linné) along with other six forms namely *Chlamys* (*Argopecten*) *senatoria* (Gmelin), *Chlamys* (*Chlamys*) *quilonensis* Dey, *Diplodonta (Diplodonta) incerta* d'Archiac, *Arctica islandica* (Linné), *Paphia* (*Paphia*) *persica* Cox and *Paphia* (*Callistotapes*) *pseudoliratus* Vredenburg from Zone II of the study area also occur in Zone III of Tiwari and Kachhara (2003). Zonal taxa *Paphia* (*Paphia*) *rotundata* (Linné) of Zone II of the study area is also present in Zone IV of Tiwari and Kachhara (2003) along with the folling six forms: *Chlamys* (*Argopecten*) *senatoria* (Gmelin), *Chlamys* (*Chlamys*) *quilonensis* Dey, *Diplodonta (Diplodonta) incerta* d'Archiac, *Arctica islandica* (Linné), *Paphia* (*Paphia*) *persica* Cox and *Paphia* (*Callistotapes*) *pseudoliratus.* Only two forms *Chlamys* (*Argopecten*) *senatoria* (Gmelin) and *Arctica islandica* (Linné) from Zone II of the study area occur in Zone V of Tiwari and Kachhara (2003). Therefore, it is evident from the above that Zone II of the study area is correlatable with Zone III (*Ostrea*

latimarginata - *Natica pellis tigrina* Zone) and Zone IV [*Pecten* (*Oopecten*) *gigas* Zone] of Tiwari and Kachhara (2003).

Detailed study showed that only one taxa each from Zone III of the study area is known to occur in Zone II (*Dentalium junghuhni* Martin), Zone III [*Chlamys* (*Chlamys*) *quilonensis* Dey] and Zone IV [*Chlamys* (*Chlamys*) *quilonensis* Dey] of Tiwari and Kachhara (2003). So, this Zone may be correlatable with Zone II and III of Tiwari and Kachhara (2003).

5.2.2.2. Biostratigraphic Zonations of Mazumder (2004)

Mazumder (2004) studied the Bhuban succession of Kolasib area and proposed two molluscan zones. Zone I is *Nucula* (*Lamellinucula*) aff. *pulchra* - *Nuculana* (*Nuculana*) *virgo* Zone of Aquitanian age within Middle Bhuban Unit, whereas Zone-II of *Chlamys* (*Argopecten*) *senatoria* - *Tellina* (*Tellinella*) *pseudohilli* Zone is Aquitanian to Burdigalian age within Upper Bhuban unit. He further proposed two subzones within Zone II, both of them are within Upper Bhuban Unit of Bhuban Formation, namely *Clementia* (*Clementia*) *papyracea* (Subzone IIA) of Aquitanian – Burdigalian age and *Callista* (*Costacallista*) *erycina* - *Antigona granosa* - *Trisidos semitorta* (Subzone IIB) of Burdigalian age. Zone IIA has been further divided into *Conus* (*Lithoconus*) *ineditus* - *Diplodonta* (*Diplodonta*) *incerta* [Zonule IIA(a)] of Aquitanian to Burdigalian age and *Conus* (*Dendroconus*) *loroisii* - *Archimediella* (*Torculoidella*) *angulata* [Zonule IIA(b)] of Burdigalian age.

The detailed comparisons of the fauna from proposed Zone I of the study area indicates that three taxa are also present in Zone IIA(a) of Mazumder (2004) namely *Anadara* (*Anadara*) *trapezoida* Tiwari, *Cultellus* (*Cultellus*) *zulloi* Tiwari and *Tellina*

(*Eurytellina*) *pilgrimi* Cox. Zonal taxa of Zone I of the study area *i.e Pecten* (*Pecten*) *mathuri* Tiwari MS is also known to occur in Zone IIB of Mazumder (2004). Besides three forms *Anadara* (*Anadara*) *trapezoida* Tiwari, *Cultellus* (*Cultellus*) *zulloi* Tiwari and *Tellina* (*Eurytellina*) *pilgrimi* Cox are also present in Zone IIB of Mazumder (2004). Hence, Zone I of the study area is correlated with Zone IIA(a) and Zone IIB of Mazumder (2004).

Comparisons of Zone II of the study area with Mazumder (2004) indicates that three, two and seven forms from this zone are also present in Zone IIA(a), Zone IIA(b) and Zone IIB respectively including zonal taxa of Zone II of the study area *Paphia* (*Paphia*) *jhai* Tiwari MS is found to occur at Zone IIB of Mazumder (2003). Therefore, Zone II of the study area can be correlated with Zone IIB of Mazumder (2004).

Only one form each *Natica obscura* Sowerby and *Chlamys* (*Chlamys*) *quilonensis* Dey from Zone III of the study area are present in Zone IIA(b) Zone IIB of Mazumder (2004). Since the correlatable taxa are few and no zonal taxa form Zone III of the study area does not occur in any of the zones proposed by Mazumder (2004), correlation is not attempted with any zones of Mazumder (2004).

5.2.2.3. Biostratigraphic Zonations of Ralte (2009)

Ralte (2009) proposed only one biozone in the Bhuban Formation of Aizawl area *i. e. Paphia* (*Paphia*) *rotundata* - *Palaeocarpilius rugifer* Zone. He further proposed two subzones within this zone. These are Subzone (1A) *Gari* (*Gari*) *natensis* of Aquitanian - Burdigalian age and Subzone (1B) *Barbatia* (*Barbatia*)

bataviana var. *carinata- Neptunussindensis* of Aquitanian – Burdigalian to Burdigalian age.

Zonal taxa of Zone I of the study area *i. e. Pecten* (*Pecten*) *mathuri* Tiwari MS is known to occur in Subzone 1A and Subzone 1B of Ralte (2009). Besides only one form *Paphia* (*Callistotapes*) *pseudoliratus* Vredenburg from Zone I of the sudy area is also present in Subzone 1A of Ralte (2009) and four forms *Anadara* (*Anadara*) *trapezoida* Tiwari, *Cultellus* (*Cultellus*) *zulloi* Tiwari, *Apolymetis grimesi* (Noetling) and *Paphia* (*Callistotapes*) *pseudoliratus* Vredenburg from Zone I of the study area are known to occur in Subzone IB of Ralte (2009). Therefere, Zone I of the study area can be correlated with Subzone IB *Barbatia* (*Barbatia*) *bataviana* var. *carinata- Neptunussindensis* Zone of Aquitanian – Burdigalian to Burdigalian age of Ralte (2009).

Detailed study shows that five forms each from Zone II of the study area are also present in Subzone IA [*Chlamys* (*Argopecten*) *senatoria* (Gmelin), *Diplodonta (Diplodonta) incerta* d'Archiac, *Paphia* (*Callistotapes*) *pseudoliratus* Vredenburg and *Timoclea (Timoclea) scabra* (Hanley)] and Subzone IB [*Chlamys* (*Argopecten*) *senatoria* (Gmelin), *Diplodonta (Diplodonta) incerta* d'Archiac, *Cultellus (Cultellus) zulloi* Tiwari and *Paphia* (*Callistotapes*) *pseudoliratus* Vredenburg] of Ralte (2009). One zonal taxa *Paphia* (*Paphia*) *rotundata* (Linné) Vredenburg is present in Zone IA of Ralte (2009) while both zonal taxa *Paphia* (*Paphia*) *jhai* Tiwari MS and *Paphia* (*Paphia*) *rotundata* (Linné) Vredenburg are also occur in Zone IB of Ralte (2009). Therefore, proposed Zone II of the study area can be correlated with Subzone IA and IB of Ralte (2009).

No taxa from Zone III of the study area are found to occur in any one of the zones proposed by Ralte (2009). Hence correlation cannot be attempted.

5.2.2.4. Biostratigraphic Zonations of Lalchawimawii (2013)

Lalchawimawii (2013) studied the Lower Miocene rocks of Hlimen quarry and established three biozones within these successions. The lowermost, Zone I: *Anadara* (*Anadara*) *trapezoida* - *Pecten* (*Pecten*) *mathuri* Zone of Aquitanian to Burdigalian age, the middle, Zone II: *Crassostrea gajensis*- *Timoclea* (*Timoclea*) *subspadicea* Zone of Burdigalian age and the uppermost, Zone III: *Anadara garoensis* Zone of Burdigalian to Helvetian age. All of them lies within the Upper Bhuban unit of Bhuban Formation.

Detailed comparisons of Zone I of the study area revealed that zonal taxa *Pecten* (*Pecten*) *mathuri* Tiwari MS is also present in Zone I of Lalchawimawii (2013) along with eleven taxa. These are: *Anadara* (*Anadara*) *trapezoida* Tiwari, *Chlamys* (C*hlamys*) *jamviniensis* Cox, *Astarte* (*Astarte*) *trigonalis* Lalchawimawii, *Cultellus* (*Cultellus*) *zulloi* Tiwari, *Tellina compressa* Tiwari, *Tellina* (*Eurytellina*) *pilgrimi* Cox, *Tellina* (*Tellinella*) *hilli* Noetling, *Apolymetis grimesi* Noetling, *Arctica islandica* (Linné), *Paphia* (*Paphia*) *persica* Cox and *Paphia* (*Callistotapes*) *pseudoliratus* Vredenburg. Six forms from Zone I of the study area also present in Zone II of Lalchawimawii (2013), namely *Nucula warsarensis* Eames, *Chlamys* (C*hlamys*) *jamviniensis* Cox, *Cultellus* (*Cultellus*) *zulloi* Tiwari, *Tellina* (*Eurytellina*) *pilgrimi* Cox, *Paphia* (*Paphia*) *persica* Cox and *Paphia* (*Callistotapes*) *pseudoliratus* Vredenburg whereas five forms from Zone I of the study area are also known to occur in Zone II of Lalchawimawii (2013). These are: *Chlamys* (C*hlamys*)

jamviniensis Cox, *Cultellus (Cultellus) zulloi* Tiwari, *Tellina compressa* Tiwari, *Tellina* (*Eurytellina*) *pilgrimi* Cox and *Paphia* (*Paphia*) *persica* Cox. Therefore, Zone I of the study is correlatable with Zone I of Lalchawimawii (2013).

Zonal taxa of Zone II of the study area, namely *Paphia* (*Paphia*) *jhai* Tiwari MS and *Paphia* (*Paphia*) *rotundata* (Linné) are also present in Zone I of Lalchawimawii (2013). Besides eight forms *Anadara* (*Anadara*) *elongata* Lalchawimawii, *Chlamys* (*Argopecten*) *senatoria* (Gmelin), *Chlamys* (C*hlamys*) *jamviniensis* Cox, *Chlamys* (*Chlamys*) *quilonensis* Dey, *Diplodonta* (*Diplodonta*) *incerta* d'Archiac, *Astarte* (*Astarte*) *trigonalis* Lalchawimawii, *Cultellus* (*Cultellus*) *zulloi* Tiwari and *Tellina maubawka* Tiwari form Zone II also occur in Zone I of Lalchawimawii (2013). Zonal taxa of Zone II of the study area, namely *Paphia* (*Paphia*) *jhai* Tiwari MS and *Paphia* (*Paphia*) *rotundata* (Linné) are also present in Zone II of Lalchawimawii (2013) along with other 11 forms, these are: *Anadara* (*Anadara*) *elongata* Lalchawimawii, *Chlamys* (*Argopecten*) *senatoria* (Gmelin), *Chlamys* (C*hlamys*) *jamviniensis* Cox, *Chlamys* (*Chlamys*) *quilonensis* Dey, *Diplodonta* (*Diplodonta*) *incerta* d'Archiac, *Cultellus* (*Cultellus*) *zulloi* Tiwari, *Tellina maubawka* Tiwari*, Callista* (*Macrocallista*) *florida* (Lamarck), *Paphia* (*Paphia*) *persica* Cox, *Paphia* (*Callistotapes*) *pseudoliratus* Vredenburg and *Timoclea* (*Timoclea*) *scabra* (Hanley). Detailed comparison shows that Zonal taxa of Zone II of the study area *Paphia* (*Paphia*) *jhai* Tiwari MS and *Paphia* (*Paphia*) *rotundata* (Linné) also occur in Zone III of Lalchawimawii (2013) including these 5 forms, *Chlamys* (C*hlamys*) *jamviniensis* Cox, *Cultellus* (*Cultellus*) *zulloi* Tiwari, *Callista* (*Macrocallista*) *cf. lilacina* (Lamarck), *Paphia* (*Paphia*) *persica* Cox and *Timoclea* (*Timoclea*) *scabra* (Hanley). Since maximum number of common taxa

from Zone II of the study area are in Zone II of Lalchawimawii (2013), hence the correlation.

Detailed comparison shows that four taxa from Zone III of the study area are occur in Zone I of Lalchawimawii (2013). These are: *Chlamys* (*Chlamys*) *quilonensis* Dey, *Periploma* (*Aelga*) *elliptica* Lalchawimawii, *Natica obscura* Sowerby and *Dentalium junghuhni* Martin whereas two forms *Chlamys* (*Chlamys*) *quilonensis* Dey and *Timoclea* (*Timoclea*) *subspadicea* (Cossmann) are also present in Zone II of Lalchawimawii (2013). Hence, Zone III of the study area can be correlated with Zone II and III of Lalchawimawii (2013).

5.2.3. Miocene Succession of Garo Hills, Meghalaya

5.2.3.1. Garo Hills (Mukherjee, 1939)

Pinfold (1919) discovered two fossil localities and collected few mega invertebrates near Dalu and Baghmara of Garo Hills, Meghalaya. His collections were studied by Vredenburg (1921). Mukherjee (1939) collected a vast amount of taxa from these two localities and based on his findings, he assigned these rocks Aquitanian – Burdigalian age of Lower Miocene.

Only two taxa namely *Chlamys* (C*hlamys*) *jamviniensis* Cox and *Apolymetis grimesi* Noetling of Zone I of the study area are common with Mukherjee (1939). Two forms from Zone II of the study area are also present in the assemblage presented by Mukherjee (1939), namely *Chlamys* (*Argopecten*) *senatoria* (Gmelin), *Chlamys* (C*hlamys*) *jamviniensis* Cox and *Diplodonta* (*Diplodonta*) *incerta* d'Archiac whereas only one taxa *Dentalium junghuhni* Martin is common between the study area and Miocene assemblage from Garo Hills. Therefore, Zone II of the

study area may be correlatable with the Lower Miocene succession of Garo Hills, Meghalaya (Mukherjee, 1939).

5.2.3.2. Biostratigraphic Zonations of Lyngdoh (2004)

Lyngdoh (2004) established two bio-zones from the Lower Miocene of Garo Hills Meghalaya *i.e*. Zone I: *Ostrea latimarginata* Zone and Zone II: *Crassostrea gajensis*- *Conus* (*Dendroconus*) *loroisii*. Zone I is divided into two subzones, Subzone 1A: *Larkinia submultiformis – Turritella narica baluchistanensis* and Subzone 1B*: Harvella* (*Mactrinula*) *protoreevesii –Turritella pinfoldi* Zone. Subzone 1A is of Aquitanian – Burdigalian age and occurs within Baghmara Formation while Subzone 1B is of Burdigalian age which lies near the base of Chengapara Formation. Zone II is within the Chengapara Formation of Burdigalian to Helvetian age.

Only one form *Tellina* (*Tellinella*) *hilli* Noetling from proposed Zone I of the study area is occur in Zone IA of Lyngdoh (2004) while two forms *Apolymetis grimesi* Noetling and *Paphia* (*Callistotapes*) *pseudoliratus* Vredenburg are occur in Zone IB of Lyngdoh (2004). As such, these are correlatable.

One form namely *Diplodonta* (*Diplodonta*) *incerta* d'Archiac from Zone II of the study area is also occur in Zone IA of Lyngdoh (2004) while four forms are common between Zone II of the study area and Zone IB of Lyngdoh (2004), which are *Chlamys* (*Argopecten*) *senatoria* (Gmelin), *Diplodonta* (*Diplodonta*) *incerta* d'Archiac, *Callista* (*Macrocallista*) *florida* (Lamarck) and *Paphia* (*Callistotapes*) *pseudoliratus* Vredenburg. Hence, it is evident that Zone II of the study area is correlatable with Zone IB of Lyngdoh (2004).

Detailed study revealed that only one form *Natica obscura* Sowerby is common between proposed Zone III of the study area and Zone I of Lyngdoh (2004) while two forms are common between Zone III of the study area and Zone IB of Lyngdoh (2004), which are *Natica obscura* Sowerby and *Timoclea* (*Timoclea*) *scabra* (Hanley). Hence, they are correlatable.

5.2.4. Miocene Succession of Gaj

Gaj Beds (Lower Miocene) are exposed in Sind (Pakistan), Kachchh and Kathiawar (Gujarat). The fauna of these successions were studied by Stoliczka (1871), Duncan and Sladen (1882-86), Duncan, Sladen and Blanford (1883); Fedden (1884), Vredenburg (1906, 1908, 1921, 1925 and 1928), Sen Gupta (1964), Biswas (1965), Chatterjee and Mathur (1966), Mathur (1988) and Jain (1997).

5.2.4.1. Gaj of Sind (Vredenburg, 1925 and 1928)

Only *Diplodonta* (*Diplodonta*) *incerta* d'Archiac is common between Zone II of the study area with Gaj of Sind (Vredenburg, 1925, 1928). Hence, it may be correlatable.

5.2.4.2. Gaj of Kachchh (Vredenburg, 1925 and 1928)

Only one form each from Zone I and Zone II of the area [*Nucula warsarensis* Eames and *Chlamys* (*Argopecten*) *senatoria* (Gmelin)] are common with Gaj of Kachchh (Vredenburg, 1925, 1928). Hence, they are correlatable.

5.2.4.3. Gaj of Kathiawar (Jain, 1997; Vredenburg, 1925 and 1928)

The following one, two and one taxa of the present Zone I, Zone II and Zone III are common with Gaj of Kathiawar (Jain, 1997; Vredenburg, 1925, 1928).

Zone I : *Apolymetis grimesi* Noetling.

Zone II : *Chlamys* (*Argopecten*) *senatoria* (Gmelin) and *Diplodonta* (*Diplodonta*) *incerta* d'Archiac.

Zone III : *Natica obscura* Sowerby.

Hence, a good degree of correlation exists between the two.

5.2.5. Miocene Succession of Myanmar (Noetling, 1895, 1901)

This formation has been assigned Burdigalian age (Pascoe, 1973). The main litho-units of this formation are sandstone, shale and pebble beds. *Tellina (Tellinella) hilli* Noetling and *Apolymetis grimesi* Noetling from Zone I of the study area and *Natica obscura* Sowerby and *Dentalium junghuhni* Martin from Zone II of the study area are comment with taxa reported by Noetling (1898, 1901) from Kama and Pyalo Formation of Myanmar

Hence, these two successions are correlatable.

Table 5.3: Correlation of Bhuban rocks with the other Miocene exposures:

Study area	Upper Bhuban Unit		
	Zone I	**Zone II**	**Zone III**
Aizawl and Lunglei, Mizoram Tiwari and Kachhara, 2003	Zone II, III and IV	Zone III and IV	Zone II and III
Kolasib, Mizoram Mazumder, 2004	Zonule IIA(a) and Subzone IIB	Subzone IIB	
Aizawl, Mizoram Ralte, 2009	Subzone 1B	Subzone 1A and 1B	Subzone 1B
Aizawl, Mizoram Lalchawimawii, 2013	Zone I	Zone II	Zone II and III
Garo Hills, Meghalaya Lyngdoh, 2004	Subzone 1A and IB	Subzone 1B	Subzone 1B
Garo Hills Mukerjee, 1939			
Gaj of Sind Vredenburg, 1925, 1928			
Gaj of Kachchh Vredenburg, 1925, 1928			
Gaj of Kathiawar Jain, 1997; Vredenburg, 1925, 1928			
Myanmar Noetling, 1901, 1895			

Table 5.4: Geographical distribution of species in the Miocene of Indian Sub-continent (Mizoram, Garo Hills, Kathiawar, Sind, Kachchh and Myanmar)

Sl. No	Name of the Species	Mizoram (Tiwari and Kachhara, 2003)					Mizoram (Mazumder, 2004)				Mizoram (Ralte, 2009)		Mizoram (Lalchawimawii, 2013)			Mizoram (Present work)			Garo Hills (Mukerjee, 1939)	Garo Hills (Lyng-doh, 2004)			Gaj Beds			Myanmar (Noetling, 1901, 1895)
		I	II	III	IV	V	I	IIA (a)	IIA (b)	IIB	1A	IB	I	II	III	I	II	III		IA	IB	II	Gaj of Sind (Vredenburg, 1925, 1928)	Gaj of Kachchh (Vredenburg, 1925, 1928)	Gaj of Kathiawar (Jain 1997; Vredenburg, 1925, 1928)	
1	*Nucula warsarensis* Eames		X											X		X								X		
2	*Anadara* (*Anadara*) *trapezoida* Tiwari			X	X			X		X		X	X			X										
3	*Anadara daviesi* Mukerjee			X	X	X		X			X	X	X	X					X		X					
4	*Anadara* (*Anadara*) *elongata* Lalchawimawii												X	X			X									
5	*Pinna* sp.																	X								
6	*Chlamys* (*Argopecten*) *senatoria* (Gmelin)			X	X	X		X	X	X	X	X	X	X			X		X		X			X	X	
7	*Chlamys* (*Chlamys*) *jamviniensis* Cox												X	X	X	X	X		X							
8	*Chlamys* (*Chlamys*) *quilonensis* Dey			X	X					X			X	X			X	X								

Sl. No	Name of the Species	Mizoram (Tiwari and Kachhara, 2003)					Mizoram (Mazumder, 2004)				Mizoram (Ralte, 2009)		Mizoram (Lalchawimawii, 2013)			Mizoram (Present work)			Garo Hills (Mukerjee, 1939)	Garo Hills (Lyng-doh, 2004)			Gaj Beds			Myanmar (Noetling, 1901, 1895)
		I	II	III	IV	V	I	IIA (a)	IIA (b)	IIB	1A	IB	I	II	III	I	II	III		IA	IB	II	Gaj of Sind (Vredenburg 1925, 1928)	Gaj of Kachchh (Vredenburg, 1925, 1928)	Gaj of Kathiawar (Jain. 1997; Vredenburg, 1925, 1928)	
9	*Chlamys* sp.												X	X	X	X	X	X								
10	*Pecten* (*Pecten*) *mathuri* Tiwari MS									X	X	X	X			X										
11	*Placuna* (*Indoplacuna*) sp.												X	X		X	X									
12	*Crassostrea gajensis* (Vredenburg)													X								X			X	
13	*Ostrea* sp.															X										
14	*Diplodonta* (*Diplodonta*) *incerta* d'Archiac		X	X	X			X			X	X	X	X			X		X	X	X		X		X	
15	*Astarte* (*Astarte*) *trigonalis* Lalchawimawii												X			X	X									
16	*Astarte ovalis* Lalchawimawii												X	X												
17	*Lutraria* cf. *philippinarum* Reeve									X			X	X												

Sl. No	Name of the Species	Mizoram (Tiwari and Kachhara, 2003)					Mizoram (Mazumder, 2004)				Mizoram (Ralte, 2009)		Mizoram (Lalchawimawii, 2013)			Mizoram (Present work)			Garo Hills (Mukerjee, 1939)	Garo Hills (Lyng-doh, 2004)			Gaj Beds			Myanmar (Noetling, 1901, 1895)
		I	II	III	IV	V	I	IIA (a)	IIA (b)	IIB	1A	1B	I	II	III	I	II	III		IA	IB	II	Gaj of Sind (Vredenburg, 1925, 1928)	Gaj of Kachchh (Vredenburg, 1925, 1928)	Gaj of Kathiawar (Jain 1997; Vredenburg, 1925, 1928)	
18	*Solena* (*Plectosolen*) sp.												X	X	X	X	X									
19	*Cultellus* (*Cultellus*) *zulloi* Tiwari							X		X		X	X	X	X	X	X									
20	*Tellina compressa* Tiwari												X		X	X										
21	*Tellina maubawka* Tiwari												X	X			X									
22	*Tellina* (*Angulus*) sp.												X			X										
23	*Tellina* (*Eurytellina*) *pilgrimi* Cox		X	X	X	X		X		X			X	X	X	X										
24	*Tellina (Oudardia)* sp.															X										
25	*Tellina (Perodina)* sp.																									
26	*Tellina* (*Tellinella*) *hilli* Noetling		X		X	X							X			X				X						X

Sl. No	Name of the Species	Mizoram (Tiwari and Kachhara, 2003)					Mizoram (Mazumder, 2004)				Mizoram (Ralte, 2009)		Mizoram (Lalchawimawii, 2013)			Mizoram (Present work)			Garo Hills (Mukerjee, 1939)	Garo Hills (Lyng-doh, 2004)			Gaj Beds			Myanmar (Noetling, 1901, 1895)
		I	II	III	IV	V	I	IIA (a)	IIA (b)	IIB	1A	IB	I	II	III	I	II	III		IA	IB	II	Gaj of Sind (Vredenburg, 1925, 1928)	Gaj of Kachchh (Vredenburg, 1925, 1928)	Gaj of Kathiawar (Jain 1997; Vredenburg, 1925, 1928)	
27	*Apolymetis grimesi* Noetling											X	X						X		X				X	X
28	*Gari* (*Gari*) *natensis* Noetling			X	X						X		X							X	X	X				X
29	*Arctica islandica* (Linné)		X	X	X	X							X			X	X									
30	*Venus* sp.												X													
31	*Callista sp.*												X	X		X	X									
32	*Callista* (*Macrocallista*) *florida* (Lamarck)								X				X	X			X				X					
33	*Callista* (*Macrocallista*) cf. *lilacina* (Lamarck)									X			X		X		X									
34	*Paphia* (*Paphia*) *jhai* Tiwari MS									X		X	X	X	X		X									
35	*Paphia* (*Paphia*) *persica* Cox		X	X	X								X	X	X	X	X									

Sl. No	Name of the Species	Mizoram (Tiwari and Kachhara, 2003)					Mizoram (Mazumder, 2004)				Mizoram (Ralte, 2009)		Mizoram (Lalchawimawii, 2013)			Mizoram (Present work)			Garo Hills (Mukerjee, 1939)	Garo Hills (Lyng-doh, 2004)			Gaj Beds			Myanmar (Noetling, 1901, 1895)
		I	II	III	IV	V	I	IIA (a)	IIA (b)	IIB	1A	IB	I	II	III	I	II	III		IA	IB	II	Gaj of Sind (Vredenburg, 1925, 1928)	Gaj of Kachchh (Vredenburg, 1925, 1928)	Gaj of Kathiawar (Jain 1997; Vredenburg, 1925, 1928)	
36	*Paphia* (*Paphia*) *rotundata* (Linné)			X	X						X	X	X	X	X		X									
37	*Paphia* (*Callistotapes*) *pseudoliratus* Vredenburg			X	X						X	X	X	X		X	X				X					
38	*Paphia* sp.															X	X									
39	*Timoclea* (*Timoclea*) *arakanensis* Nevill									X			X		X		X									
40	*Timoclea* (*Timoclea*) *scabra* (Hanley)									X	X		X	X			X									
41	*Timoclea* (*Timoclea*) *subspadicea* (Cossmann)								X	X				X				X	X		X					
42	*Corbula tunicosulcata* Vredenburg		X	X	X	X		X			X	X	X	X						X	X			X	X	
43	*Periploma* (*Aelga*) *elliptica* Lalchawimawii												X					X								

Sl. No	Name of the Species	Mizoram (Tiwari and Kachhara, 2003)					Mizoram (Mazumder, 2004)				Mizoram (Ralte, 2009)		Mizoram (Lalchawimawii, 2013)			Mizoram (Present work)			Garo Hills (Mukerjee, 1939)	Garo Hills (Lyng-doh, 2004)			Gaj Beds			Myanmar (Noetling, 1901, 1895)
		I	II	III	IV	V	I	IIA (a)	IIA (b)	IIB	1A	IB	I	II	III	I	II	III		IA	IB	II	Gaj of Sind (Vredenburg, 1925, 1928)	Gaj of Kachchh (Vredenburg, 1925, 1928)	Gaj of Kathiawar (Jain 1997; Vredenburg, 1925, 1928)	
44	*Turritella* (*Turritella*) *pseudobandongensis* Vredenburg																	X								
45	*Natica obscura* Sowerby								X				X					X		X	X				X	X
46	*Conus (Leptoconus) bonneti* Cossmann, 1900																	X								
47	*Dentalium junghuhni Martin*		X										X					X	X							X
48	*Coelopleurus* (*Keraiophorus*) sp.												X	X												
49	*Schizaster alveolatus* Duncan and Sladen																									

CHAPTER 6: PALAEOECOLOGY AND DEPOSITIONAL ENVIRONMENT

6. PALAEOECOLOGY AND DEPOSITIONAL ENVIRONMENT

6.1. GENERAL REMARKS

Detailed information about modes of life and the habitat preferences of fossils, both autecology and synecology, are necessary for reconstructing palaeo-environment of the depositional basin. These palaeoentological informations, in combination with sedimentological ones, help to create an overall view of the palaeo-environment of the sedimentary basin. The spatial and temporal analysis of sedimentary environments is necessary for understanding basin evolution.

Palaeoecology means studying the habitat of ancient organisms in environmental context. It works on the premise of "Present is the key to Past" implying that palaeoecological interpretations can be made from the data obtained from modern ecology. Palaeoecology thus utilizes the concept and methods of ecology. Though, this concept is often disputed, it remains irreplaceable. It is quite obvious that the degree of probability of the reconstruction decreases with the age. The matter becomes further complicated due to increase in the number of groups without living representatives, and the evolution of communities to which these organisms belong. Since the percentage of living representatives increases in the fossil records of the Cenozoic Era, attempting paleoecology based on the concept of modern ecology becomes fairly accurate.

In the present work, interpretation of paleoecology, sedimentary environment and paleogeography is mainly based on the available fauna. However, lithological characteristics and primary-sedimentary structures have also been considered wherever available.

6.2. PALAEOECOLOGY

6.2.1. Bhuban Formation in General

Tiwari *et al*. (1998, 2011, and 2013), Mazumder (2004), Lalchawimawii (2004 and 2013) and Ralte (2009) worked out the depositional environments of the Bhuban Formation based on the emtombed fauna, primary sedimentary structures and preliminary lithological characteristics. According to them this formation comprises a hybrid association of sandstone, shale, siltstone, mudstone and their admixtures in various proportions. The shales and siltstones grade into mudstones and argillaceous alternations consisting of interlaminations of shales, ripple laminated siltstones and silty-sandstones. Sandstones are usually hard, ill-sorted and fine grained, immature and richly micaceous. The characteristic feature of Bhuban succession is rhythmic alternations of argillaceous and arenaceous strata.

The important primary-sedimentary structures include current and interference ripples, ripple-drift laminations, lenticular and flaser beddings, cross and wavy laminations. Alternately regular and irregular beddings of sand or silt and shales indicates rough water environment. Thin nature of the coset of cross-lamination/stratification indicates shallow depth. Small scale cross-laminations are resulted from rippling of the sand-water interface under faster movement of sediments in slightly higher energy regime with frequent variation in the direction of water current. Parallel laminations in the siltstones or thin beddings results from gradational change in grain size suggesting long term fluctuations in the sedimentary load. Interference ripples are indicative of fluctuations in the current direction. Presence of

pyrite at places points to a reducing environment (Pettijohn, 1963; Collinson and Thompson, 1982).

The entombed bivalves, gastropods, scaphopods, decapods, echinoids, fish teeth and trace fossils inhabit shallow marine environment. Tiwari and Bannikov (2001) reported presence of fish skeleton in a large number in the Upper Bhuban succession which indicates their mass death and rapid burial. Echinoids are mostly irregular shallow burrowers preferring soft substrate and *Cidaris* lives in a rocky floor. Shallow to deep burrowers, semi-infaunal, byssate nestlers, cemented and thick shelled and detritus feeder forms are common among the molluscan community. Bivalve shells are mostly disarticulated and at times broken may be due to strong bottom currents. Preservation of delicate worm trails and similar structures revealed feeble bottom current. Vertical burrows are quite common and point to quick sedimentation. The process of burrowing kept pace with the rate of sedimentation perhaps in deltaic regime. These burrows mostly belong to *Skolitho* and *Cruziana* ichnofacies indicating deposition under fluctuating energy conditions in foreshore to shoreface/offshore zones of shallow marine environment (Tiwari *et al*., 2011 and 2013). They suggest that Bhuban succession were deposited in an unstable quickly subsiding basin with a high rate of sedimentation under rapidly fluctuating conditions of deltaic to inner neritic environment with dominance of fluviatile phases intermittently. This formation then represents a complex interfingering of deltaic to marine environment and interruption in sedimentation has been rare. Thickness of this Formation in Mizoram is about 5000m while in Tripura and Surma Valley, it is less than 3000m. It suggests that the linear Mizo fold belt extending north and southwards

to Manipur and Arakan coast formed the site of a rapidly subsiding furrow within a generally subsiding and tectonically active geosynclinal basin during Miocene Epoch.

6.2.2. Palaeoecology of Bhuban Succession of the study area

The Middle Bhuban Unit of Bhuban Formation of the study area comprise only one fossiliferous horizon *i.e.* Brown sandstone bed. The Upper Bhuban Unit of Bhuban Formation of the study area consist of six fossiliferous litho units, namely brown sandstone bed, dark brown sandstone bed, brownish grey sandstone bed, grey silty sandstone bed, grey sandstone bed and intraformational conglomeratic bed. Dark brown sandstone bed yield only a single taxa and paleoecology cannot be worked out from this bed.

6.2.2.1. Brown Sandstone Bed: This constitutes the lower bed at Locality 1, Locality 5, Locality 6, locality 8 and upper and middle bed at Locality 4. This bed is brown colored with high silt content, it is normally massive and primary sedimentary structures are very few. This bed was deposited in oxygen sufficient environment as indicated by its reddish brown colour.

The collection from this bed consists of bivalves and echinoids.

Bivalve genera *Arca* and *Anadara* belong to family Arcidae and are considered of nestler habitate in crevices. Their presence suggests a temperature of sea water in the range of 20ºC to 25ºC. Among the epifauna, *Chlamys* was there, but the population is mostly dominated by habitats of soft substratum and deeply buried infaunal community with long siphon as *Solena*, *Cultellus*, *Tellina*, *Apolymetis* and *Callista*. *Placuna* along with *Chlamys* lie freely on the substratum and are free

swinging to free swimming. Extant genera like *Callista* and *Corbula* indicate transgressive phase and would most commonly occur today in the seas between 10 - 45m depth (Squires, 1984). *Paphia* is a shallow burrowing suspension feeder genus.

The fossil community indicates a shallow sublittoral habitat with a sandy substrate. The epifaunal animals include scallop *Chlamys*, the deposit feeders *Nucula*, and byssally attached *Anadara*. Shallow burrowers like *Diplodonta* as well as deep burrowers *Cultellus*, *Tellina* and *Apolymetis* are also present. These are characteristically habitat of soft substratum. Stationery burrowers like *Callista* is also found. *Nucula* is a deposit palp feeder and generally used to live on black mud of continental shelf. *Diplodonta* which have semi-permanent burrows connected to the surface by an inhalent tube it is a siphonal suspension feeders, more mobile and prefers to live on soft sediments. *Anadara* is a warm water genus and attached to the substrate by means of byssus situated in the middle, preferring mainly the crevices or debris of dead shells.

The genus *Anadara*, which is a large species group and represents an internationally well-known taxonomic group occurring in the Neogene shallow marine sediments. Since the genus has a wide geographical distribution and short geological range with narrow range of ecological adaptation from tropical to warm temperate and embayment to shallow sea, it has contributed considerably for the stratigraphic correlation and palaeoenvironmental reconstruction (Noda, 1991). *Anadara* is a warm water genus and is attached to the substrate by means of byssus situated in middle, preferring mainly the crevices or debris of dead shells. It, though belongs to byssate nestler arcids, is an exception to adapt partially to wholly infaunal conditions.

Chlamys is inter-tidal genus and lives in depth between inter-tidal to 150 fathoms on gravel bearing rocky bottoms. It can swim easily when disturbed; otherwise it is lie freely on the substratum. The presence of *Chlamys* in the assemblage indicates that it is an indigenous one which is not transported far from its original habitat after death *Cultellus* is inter-tidal to euneritic mollusk (Mesuda, 1989). *Tellina* are frequently found buried shallowly in muddy to sandy bottoms of lower to sub-tidal zones and inhabits inter-tidal to 75 fathoms. *Apolymetis* is the index species for the tropical (20m depth) environment and a mangrove fauna and early Middle Miocene age (Noda, Kikuchi and Nikaido, 1994). Strangely, representatives of *Ostrea* is altogether missing from this bed which are known to bolster strong currents.

All the infaunal elements are compressed which indicates unconsolidated substrate. Based on the composition of the molluscan fauna, it may be assumed that the fauna grew in the shallow sea water region mainly in the shelf with the influence of warm water environment. Most of the bivalves occur as detached valves proposing that the assemblage is an allochthonous one. Several shells are disarticulated as very few of the fossils retain their original shell covering. The fauna consists of infaunal, epifaunal, swimming and sessile forms, the majority of which are known to live in the inter-tidal to lower tidal zones and even though their bathymetric distribution extends down to greater depth, most of the identified species are shallow water forms. Dwarfed forms and unusually thickened forms are missing from the present specimen collection which indicates faunal association lived in water under normal salinity.

Considering all the observations it can be inferred that an open shallow, warm sea with fluctuations from inner neritic to littoral water with depth less than 45m meter existed during deposition of these sediments. The substrate was soft but firm at places to support epifaunal byssate forms. So, the overall picture from this assemblage comes to be of inner-shelf sand and silt representing a fluctuating shoreline because of the presence of cross-bedding and disarticulated bivalve shells. At the same time, it can also be inferred that fossils were perhaps intra-basinally transported by the bottom currents from a variety of communities of the inter-tidal to near shore shelf, evidenced by infaunal elements characteristics of soft substratum occurring in sandy bottom.

6.2.2.2. Brownish Grey Sandstone Bed: This bed is exposed in Locality 3 (Prayer Point, Tuirial Road). It is grey colored, fine grained with silty and friable in nature. So, recovery of fauna from this bed is poor. This bed has yielded five species of bivalves and the assemblage is represented by *Tellina, Gari, Paphia* and *Corbula.*

Infaunal forms, both shallow burrower like *Corbula* and deep burrowers like *Tellina* with long siphons are present. The bivalve community consists of thick-shelled genera like *Corbula*, which reflect shallow water environment. *Tellina* are frequently found buried shallowly in muddy to sandy bottoms of lower to sub-tidal zones and they usually inhabit inter-tidal to 75 fathoms. The genus *Gari* is restricted to subtropical to tropical seas. It generally inhabits sandy bottoms from the inter-tidal zone to 10m depth (Tiwari, 2006). *Paphia* is a shallow burrowing suspension feeders. This assemblage indicates that the basin remained shallow during the deposition of this bed with warm water environment.

6.2.2.3. Grey Silty-Sandstone Bed: This constitutes the lower and upper bed of localities 2 and 5. *Anadara, Chlamys, Placuna* and *Paphia* are the representatives of bivalves. Their paleoecology has already been discussed above. This assemblage indicates that the basin remained shallow during the deposition of this bed.

6.2.2.4. Grey Sandstone Bed: This bed is found at the upper part of locality 4 and locality 7. It is also bioturbated and fossiliferous but the preservation is rather poor since they are scattered. Since th lithology is hard and indurated, extraction of fossils is hard. Grey colour indicates that the bed was deposited in reducing environments but on the other hand, presence of trace fossils (burrows and borings) in clastic sequence substantiate that the sediments constituting this bed must have been deposited in a well aerated condition (Clarkson, 1984). On the basis of lithology, it is possible to suggest that at the time of deposition of this bed, initially the basin was deep enough to support various biota. This bed yielded 10 species of bivalves. *Anadara*, *Chlamys, Pecten, Placuna, Ostrea, Cultellus*, *Tellina* and *Paphia* are the representatives of bivalves.

Ostrea is a cemented bivalve, much irregular in shape and flourished well where the current is rigorous. Presence of *Anadara* indicates a temperature of sea water in the range of 20ºC to 25ºC. *Pecten* is a warm water scallop. *Placuna* along with *Chlamys* lie freely on the substratum and are free swinging to free swimming. Deep burrowers like *Cultellus* and *Tellina* are also present in this bed. *Paphia* is a shallow burrowing suspension feeders. Since the ecology of these assemblage have already discussed in detail, we can infer that the basin was soft and shallow during the deposition of this bed.

6.2.2.5. Grey Intraformational Conglomeratic Bed: This bed occurs at the top of Locality 8 and is about 4m thick. This bed has yielded 4 species of bivalves, 3 species of gastropods and 1 scaphopod. The fossil community indicates a shallow sub-littoral habitat with a silt and sandy substrate. Gastropods from this bed belong to order Mesogastropoda which thrive only in marine water at depth less than 300m. *Natica* is a well-known predator feeding upon other molluscs by drilling holes.. Genus *Dentalium* has been considered as infaunal feeding upon benthic foraminifers living within the sediments. It also used to sort out the sediments by digesting the organic matter along with fine grained material, causing a low content of deposition of these materials around it.

Bivalve assemblage is represented by *Chlamys*, *Ostrea, Timoclea* and *Periploma*. Chlamys and Ostrea are also present in brown sandstone and grey sandtone bed as their paleoecology has already discussed. Periploma is deep burrower which have long siphons. *Timoclea* is a suspension feeder and does not prefer very diverse bottom living at about a depth of 10m (Davies, 1975). The fossil community indicates a shallow sublittoral habitat with a sandy substrate.

CHAPTER 7: SUMMARY AND CONCLUSIONS

7. SUMMARY AND CONCLUSIONS

1. A thick (~8000m) shallow marine sedimentary succession of Paleogene and Neogene are well exposed in Mizoram. This succession is grouped into Tipam, Surma and Barail Groups. The Surma Group rocks of Miocene age are best exposed in Mizoram and they are further divided in a lower Bhuban Formation and an upper Boka Bil Formation. Bhuban Formation is further divisible into Lower, Middle and Upper Bhuban Units (GSI, 1972; Ganju, 1975; Tiwari and Kachhara, 2003). The rocks of upper part of the Middle Bhuban Unit as well as lower part of Upper Bhuban unit are exposed in the study area *i.e.* Bawngkawn and Tuirial Road, Aizawl, Mizoram.

2. Fossil occurrences from the Surma succession of Mizoram are known since 1891 (La Touche), Tiwari (1992, 2001 and 2006), Tiwari *et al.*, (2000; 2001 and 2003), Mazumder (2004), Ralte (2009), Lalchawimawii (2013) and Rajkowar (2013) gave a detailed account of the molluscan taxa of the Surma succession of Mizoram. Thus, from surveying previous literature, it is evident that the palaeontological wealth of the Surma Group rocks in Mizoram is yet to be fully explored. The present study was brought-up in order to carry out detailed palaeontological investigation in some unexplored areas in and around Aizawl with a view to help and up-date the existing palaeontological database of the Bhuban unit of Bhuban Formation.
3. The fossiliferous horizons could be located from Middle and Upper Bhuban rocks are exposed from the study area. During the course of extensive fieldwork,

a number of traverses were made to locate fossiliferous horizons and litho-columns of these fossiliferous localities were prepared. A total of eight fossil localities are delineated in which six fossiliferous horizons were located. The lithology and fossil contents of these beds are described in detail (Chapter - 2). These horizons have yielded a large number of bivalves and a few gastropods, scaphopods and echinoids. Only about four hundred individuals could be collected from the area. The fauna so collected have been prepared for study after necessary cleaning and two hundred and twenty were found suitable for systematic study. Preservation of fauna is not so good. Original bivalved shells are rarely preserved and in most cases casts of single valves are available.

4. The collection has yielded 49 forms out of which 43 are bivalves, 3 are gastropod, 1 is scaphopod and 2 echinoids. Bivalves are represented by 22 genera that are grouped into 16 families, 13 superfamilies and 6 orders belonging to 4 subclasses. Gastropods belong to 3 superfamilies, 3 families and 3 genera. *Dentalium is* the sole representative of class scaphopoda. Echinoids are represented by genera *Coelopleurus* and *Shizaster*.

   Among the total faunal assemblage form the present collection, *Tellina (Oudardia)* sp. and *Tellina* (*Perodina*) sp**.** are being reported for the first time from the Miocene succession of Mizoram as well as North East.

5. Locality-wise occurrence of fossils with their age range as well as the overall age of the succession in the study area has been discussed in the chapter 4. By and large, the Bhuban successions of the study area are inferred to be of Aquitanian - Burdigalian age.

Based on some age diagnostic fauna, three Biozones have been proposed in the Upper Bhuban unit of Bhuban Formation in the study area (Chapter 5). The lower one, *i. e.* Zone-I, is named as *Pecten* (*Pecten*) *mathuri* Zone of Aquitanian to Burdigalian (more towards Aquitanian) age; the middle one, Zone-II, as *Paphia* (*Paphia*) *rotundata* - *Paphia* (*Paphia*) *jhai* Zone of Aquitanian to Burdigalian (more towards Burdigalian) age whereas the upper one, *i. e.* Zone-III, as *Crassostrea gajensis* Zone of Burdigalian age.

These biozones are prove to be very useful in correlation of Miocene succession of the study area with other areas of Mizoram as well as the Indian sub-continent (Chapter 5). It has been found out that **Zone I** of the study area is correlatable with Zone II (*Glycymeris sindiensis* - *Nuculana virgo* Zone), Zone III (*Ostrea latimarginata* - *Natica pellis tigrina* Zone) and Zone IV [*Pecten* (*Oopecten*) *gigas* Zone] of Tiwari and Kachhara (2003), Zone IIA(a) and Zone IIB of Mazumder (2004), Subzone IB *Barbatia* (*Barbatia*) *bataviana* var. *carinata*- *Neptunussindensis* Zone of Aquitanian – Burdigalian to Burdigalian age of Ralte (2009), Zone I of Lalchawimawii (2013), Zone IA of Lyngdoh (2004), Gaj of Kachchh (Vredenburg, 1925, 1928), Gaj of Kathiawar (Jain, 1997; Vredenburg, 1925 and 1928) and Miocene Succession of Myanmar (Noetling, 1895, 1901). **Zone II** of the study area is correlatable with Zone III (*Ostrea latimarginata* - *Natica pellis tigrina* Zone) and Zone IV [*Pecten* (*Oopecten*) *gigas* Zone] of Tiwari and Kachhara (2003), Zone IIB of Mazumder (2004), Subzone IA and IB of Ralte (2009), Zone II of Lalchawimawii (2013), Lower Miocene succession of Garo Hills, Meghalaya (Mukherjee, 1939), Zone IB of Lyngdoh (2004), Gaj of Sind (Vredenburg, 1925, 1928), Gaj of Kachchh

(Vredenburg, 1925, 1928), Gaj of Kathiawar (Jain, 1997; Vredenburg, 1925 and 1928) and Miocene Succession of Myanmar (Noetling, 1895, 1901). **Zone III** of the study area can be correlate with Zone II and III of Tiwari and Kachhara (2003), Zone II and III of Lalchawimawii (2013), Zone IB of Lyngdoh (2004), Gaj of Kathiawar (Jain, 1997; Vredenburg, 1925 and 1928) and Miocene Succession of Myanmar (Noetling, 1895, 1901).

Epoch	Age	Formation	Faunal Zone
M I O C E N E	Burdigalian	Upper Bhuban Formation	**Zone III.** *Crassostrea gajensis* Zone
	Aquitanian to Burdigalian (more towards Burdigalian)	Upper Bhuban Formation	**Zone II.** *Paphia (Paphia) rotundata* - *Paphia (Paphia) jhai* Zone
	Aquitanian to Burdigalian (more towards Aquitanian)	Upper Bhuban Formation	**Zone I.** *Pecten* (*Pecten*) *mathuri* Zone

The total number of common taxa between the study area and other Miocene fossil localities of Indian subcontinent along with their respective formations and areas are shown below:

Area	Formation	Number of common taxa
Aizawl, Lunglei and Kolasib, Mizoram	Bhuban	46
Garo Hills, Meghalaya	Dalu, Baghmara and Chengapara	14
Myanmar	Kama	6
Kachchh, Gujarat	Gaj	2
Kathiawar, Gujarat	Gaj	7
Sind, Pakistan	Gaj	3

6. Palaeoecology and depositional environment of the succession based on gross lithology and fossils contents has been dealt with in Chapter 6. Bhuban Formation comprises a hybrid association of sandstone, shale, siltstone, mudstone and their admixtures in various proportions. The shales and siltstones grade into mudstones and argillaceous alternations consisting of interlaminations of shales, ripple laminated siltstones and silty-sandstones. Sandstones are usually hard, ill-sorted and fine grained, immature and richly micaceous. The characteristic feature of Bhuban succession is rhythmic alternations of argillaceous and arenaceous strata.

All the infaunal elements are compressed which indicates unconsolidated substrate. Based on the composition of the molluscan fauna, it may be assumed that the fauna grew in the shallow sea water region mainly in the shelf with the influence of warm water environment. Most of the bivalves occur as detached valves proposing that the assemblage is an allochthonous one. Several shells are disarticulated as very few of the fossils retain their original shell covering. The fauna consists of infaunal, epifaunal, swimming and sessile forms, the majority of which are known to live in the inter-tidal to lower tidal zones and even though their bathymetric distribution extends down to greater depth, most of the identified species are shallow water forms. Dwarfed forms and unusually thickened forms are missing from the present specimen collection which indicates faunal association lived in water under normal salinity.

Considering all the observations it can be inferred that an open shallow, warm sea with fluctuations from inner neritic to littoral water with depth less than 45m meter existed during deposition of these sediments. The substrate was soft but firm at places to support epifaunal byssate forms. So, the overall picture from this assemblage comes to be of inner-shelf sand and silt representing a fluctuating shoreline because of the presence of cross-bedding and disarticulated bivalve shells. At the same time, it can also be inferred that fossils were perhaps intra-basinally transported by the bottom currents from a variety of communities of the inter-tidal to near shore shelf, evidenced by infaunal elements characteristics of soft substratum occurring in sandy bottom.

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ALPHABETICAL INDEX OF SPECIES

Alphabetical Index of Genera Species

BRIEF BIO-DATA OF CANDIDATE

NAME	:	C. LALCHHANHIMA
MOTHER`s NAME	:	P.C. THANGTHUAMI
DOB	:	12th JULY 1989
ADDRESS	:	H. No. Y-4/4. CHHINGA VENG AIZAWL, MIZORAM
GENDER	:	MALE
RELIGION	:	CHRISTIAN
MARITAL STATUS	:	SINGLE
NATIONALITY	:	INDIAN
PH. D. REGN. No. & DATE	:	MZU/Ph. D/446 OF 15.06.2012
DEPARTMENT	:	GEOLOGY MIZORAM UNIVERSITY
TITLE OF THE THESIS	:	PALAEONTOLOGICAL STUDY BHUBAN FORMATION (SURMA GROUP) IN AIZAWL, MIZORAM

PARTICULARS OF THE CANDIDATE

NAME OF THE CANDIDATE	:	C. LALCHHANHIMA
DEGREE	:	Ph. D
DEPARTMENT	:	GEOLOGY
TITLE OF THESIS	:	PALAEONTOLOGICAL STUDY BHUBAN FORMATION (SURMA GROUP) IN AIZAWL, MIZORAM
DATE OF ADMISSION	:	09-08-2011
APPROVAL OF RESEARCH PROPOSAL	:	1. BPGS (GEOLOGY) : 14-5-2015 2. SCHOOL BOARD : 15-5-2015
REGISTRATION No.	:	MZU/Ph. D/446 OF 15.06.2012
EXTENSION (IF ANY)	:	No. 16-2/Adm-I (Acad)/15/55 up to 12.05.2019
ANY AWARD/FELLOWSHIP	:	NET (LS) CSIR-UGC

(PROF. SHIVA KUMAR)
HOD
Dept. of Geology
Mizoram University