



MOLLUSCAN BIOSTRATIGRAPHY OF THE TERTIARY SEDIMENTS OF MIZORAM, INDIA

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ABSTRACT

Good exposures of the Tertiary sediments ranging from Oligocene to early Pliocene are available in Mizoram, India. These are classified into the Barail Group (Oligocene), the Surma Group (upper Oligocene to middle Miocene) and the Tipam Group (late Miocene to early Pliocene) in the ascending order. The Surma Group is divisible into a lower, Bhuban Subgroup and an upper, Boka Bil Subgroup. The Bhuban Subgroup is further divisible into Lower, Middle and Upper Bhuban Formations.

Five zones in all have been established in the sediments of the Barail and the Surma Groups. These zones are based on the molluscan species having a more or less restricted range in the zones and correspond to the referred ages in the Indo-Pacific regions. These, in the ascending order, are *Meretrix agrestis* Zone (1) of upper Eocene to Oligocene age, *Glycymeris sindiensis* - *Nuculana virgo* Zone (2) of Aquitanian age, *Ostrea latimarginata*-*Natica pellis tigrina* Zone (3) of Aquitanian-Burdigalian age, *Pecten* (*Oopecten*) *gigas* Zone (4) of Burdigalian age and *Pecten* sp. Zone (5) of Helvetian age. The Zone 1 lies in Barail Group, the Zone 2 in the Lower and Middle Bhuban Formations whereas the Zones 3, 4 and 5 lie in the lower, the middle and the upper parts respectively of the Upper Bhuban Formation. The Boka Bil Subgroup is devoid of any age diagnostic fauna, whereas the Tipam Group yielded fossil wood only.

Key words: Mollusca, Biostratigraphy, Barail Group, Surma Group, Mizoram, India.

INTRODUCTION

Good outcrops of the sediments of the Tertiary period especially of Oligocene to early Pliocene are available in Mizoram, India. These, in the ascending order, are arranged into the Barail (Oligocene), the Surma (upper Oligocene to middle Miocene) and the Tipam Groups (late Miocene to early Pliocene). The main rock types in the area are sandstones, siltstones, shales, mudstones and their admixtures in various proportions besides a few pockets of shell limestones, calcareous sandstones and intraformational conglomerates. These sediments are overall monotonous and are characterised by widespread litho-facies variations, absence of marker horizons, and are traversed by numerous transverse faults. The contacts between various stratigraphic units are also transitional in nature. Hence solely on the lithostratigraphic basis, it is difficult to identify isolated outcrops of different formations in the area and correlate them. In this situation, biostratigraphic tools are of immense value to subdivide such monotonous sequences of huge thickness. Furthermore, these sediments are surprisingly devoid of planktonic foraminifers and nanno-planktons, at least in the exposed sections, which have been used world over for biozonations and correlations of Palaeogene and Neogene sequences.

In the course of palaeontological investigations in Mizoram, large numbers of individuals of molluscs have been collected and their precise horizons and age are recorded. These are mostly benthic bivalves, gastropods and scaphopods. Besides, a few echinoids, decapods, shark teeth and barnacles have also been collected. Therefore, a humble attempt has been made to erect biostratigraphic zones in the Tertiary sequences of Mizoram based on molluscan taxa. These seem to be helpful in local as well as regional correlations of the strata.

GENERAL GEOLOGY OF THE AREA

Mizoram, geologically, is a part of the Tripura-Mizoram sedimentary basin. Argillaceous and arenaceous sediments occur here in alternation. These form N-S trending and longitudinally plunging anticlines and synclines (Ganju, 1975 and Ganguly, 1983). The strata generally trend N-S with dips either eastward or westward and amount varying from 20° to 50° (Karunakaran, 1974). Main rock facies in the area are sandstone, siltstone, shale, mudstone and their admixture in various proportions and a few pockets of shell limestone, calcareous sandstone and intraformational conglomerate. Sequentially, these are arranged into the Barail, the Surma and the Tipam Groups. The stratigraphic succession as worked out

Table 1: Stratigraphic Succession in Mizoram (Karunakaran, 1974 and Ganju, 1975).

Age	Group	Subgroup	Formation	Generalised Lithology
Recent	Alluvium			Silt, clay and gravel
Unconformity				
Early Pliocene to late Miocene	TIPAM (+900m)			Friable sandstone with occasional clay bands
Conformable and transitional contact				
Miocene	S	BOKA BIL (+950m)		Shale, siltstone and sandstone
Conformable and transitional contact				
to	U	B	Upper Bhuban (+1100m)	Arenaceous predominating with sandstone, shale and siltstone
upper	R	H		
Conformable and transitional contact				
		U	Middle Bhuban (+3000m)	Argillaceous predominating with shale, siltstone-shale alternations and sandstone
	M	B		
Conformable and transitional contact				
Oligocene		A	Lower Bhuban (+900m)	Arenaceous predominating with sandstone and silty- shale
	A	N		
Unconformity obliterated by fault				
Oligocene	Barail (+3000m)			Shale, siltstone and sandstone
Lower contact not seen				

by Karunakaran (1974) and Ganju (1975) is given in table 1.

PREVIOUS WORK

A brief resume of the paleontological and biostratigraphic works carried out so far in the Tertiary sediments of Mizoram is as follows:

La Touche (1891) was the first to report *Schizaster* sp. from the Lunglei area. Later on

Chatterjee (1972) reported ostracodes and foraminifers from the Upper Bhuban Formation near Sairang. Subsequently, Sinha (1973) mentioned the occurrence of a few bivalves, gastropods and echinoids from the Lunglei area and Das Gupta (1977) reported a large number of bivalves, foraminifers and ostracodes from the Lower Bhuban Formation in the Tuipang area and assigned to it the Aquitanian age.

EXPLANATION OF PLATE I

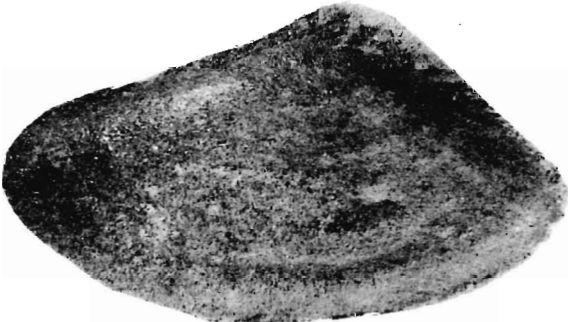
- Nucula warsarensis* Eames: Lunglawn (Middle Bhuban Formation); exterior of right valve (PUC/I/37); X 5.5.
- Nucula warsarensis* Eames: Lunglawn (Middle Bhuban Formation); exterior of left valve (PUC/I/37); X 5.5.
- Yoldia (Yoldia)* sp.1; Luangmual (Upper Bhuban Formation, middle part); exterior of right valve, (PUC/I/38); X 5.3.
- Nuculana virgo* (Martin); Lunglawn (Middle Bhuban Formation); exterior of right valve (PUC/I/39); X 5.5.
- Anadara (Anadara) zotlangensis* Tiwari; Zotlang (Upper Bhuban Formation, middle part); exterior of left valve (PUC/I/27), X 2.33.
- Anadara (Lunarca) kachharai* Tiwari; Luangmual (Upper Bhuban Formation, middle part); exterior of left valve, (PUC/I/34), X 3.26.
- Arca feddeni* Vredenburg; South Hlimen (Upper Bhuban Formation, lower part); exterior of right valve (PUC/I/1); X 1.77.
- Glycymeris sindiensis* (Vredenburg); Lunglawn (Middle Bhuban Formation); exterior of left valve (PUC/I/36); X 3.36.



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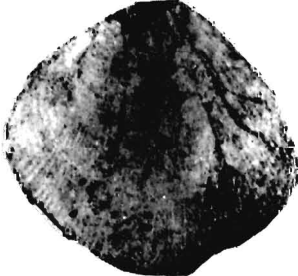
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Das Gupta (1982), while reviewing the faunal records from the Surma basin, referred to the occurrence of a few genera of bivalves, gastropods, foraminifers and ostracodes from different parts of Mizoram. He commented that the Surma fauna bears close resemblance with the Kama and Pyalo faunas of Myanmar and the Lower Bhuban Formation may be of Oligocene age. Sinha, Chatterjee and Satsangi (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 sediments of Mizoram. Similarly, Patil (1990, 1991) has also reported bivalves, gastropods, echinoids, crabs and shark teeth from the Surma Group of Mizoram. However, these reports are mostly up to generic level and without any descriptions and illustrations.

Tiwari and Satsangi (1988), for the first time, described a crab, namely, *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. Tiwari, Barman and Satsangi (1997) reported four genera and five species of decapod crustacea from the Upper Bhuban Formation and assigned to it Aquitanian-Burdigalian to Burdigalian age. Tiwari, Mishra and Lyngdoh (1998) also reported eight species of fish teeth from the Middle and Upper Bhuban Formations. Tiwari and Kachhara (2000) described two new species of

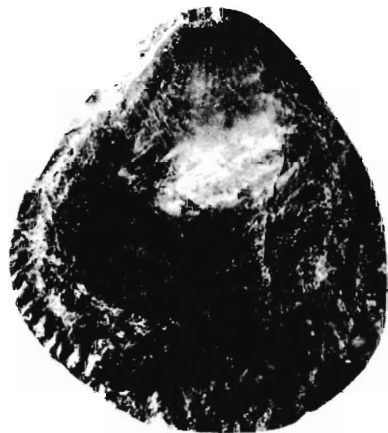
Apolymetis (Bivalvia:Tellinidae) from the Upper Bhuban Formation of Mizoram. Tiwari and Mehrotra (2000) described 5 species including a new species of woods from the Tipam Group of Mizoram and suggested prevalence of warm and humid climate during its deposition. Mandaokar (2000) reported palynoflora from the Bhuban Subgroup in Aizawl and suggested the existence of brackish water swamp and prograding delta complex with fresh water influx. Mehrotra, Mandaokar, Tiwari and Rai (2001) reported an ichnogenus *Teredolites clavatus* from the Upper Bhuban Formation in Aizawl and inferred shallow marine transgressive phase of deposition for it. Tiwari and Bannikov (2001) described three new species of early Miocene marine fishes from the Upper Bhuban Formation in Aizawl and Buarpui and inferred a near-shore, shallow water, probably estuarine, marine environment of deposition for it. Tiwari (2001) described 14 species of bivalves from the Bhuban Subgroup in Mizoram and inferred a shallow marine (inner neritic to littoral) environment of deposition for it. Tiwari and Mehrotra (2002) reported an interesting assemblage of leaf and seed impressions from the Barail sediments of the Champhai area. The assemblage indicates the occurrence of tropical forest under warm and humid climate in the nearby area during the time of deposition.

BIOSTRATIGRAPHIC ZONATION

The sediments of the Barail Group and the Bhuban and the Boka Bil Subgroups in Mizoram contain a number of fossiliferous horizons. Fossil collection has been made from 31 fossil localities (fig. 1). The distribution of these is given in the table 2:

EXPLANATION OF PLATE II

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| <p>9. <i>Pecten</i> (<i>Pecten</i>) sp.1; South Hlimen (Upper Bhuban Formation, lower part); exterior of right valve, (PUC/I/40); X 2.5.</p> <p>10. <i>Chlamys</i> (<i>Chlamys</i>) <i>senatoria</i> (Gmelin); Hauruang (Upper Bhuban Formation, upper part); exterior of left valve, (PUC/I/41); X 2.8.</p> <p>11. <i>Ostrea latimarginata</i> Vredenburg; South Hlimen (Upper Bhuban Formation, middle part); exterior of left valve, (PUC/I/42); X 2.0.</p> <p>12. <i>Pinna</i> (<i>Pinna</i>) sp.1; Luangmual (Upper Bhuban Formation, middle part); dorsal surface, (PUC/I/43), X 0.85.</p> | <p>13. <i>Maetra</i> (<i>Maetra</i>) <i>protoreevesii</i> Noetling; Luangmual (Upper Bhuban Formation, middle part); exterior of right valve, (PUC/I/44); X 2.0.</p> <p>14. <i>Tellina salinensis</i> Cotter; Luangmual (Upper Bhuban Formation, middle part); exterior of right valve, (PUC/I/45); X 1.75.</p> <p>15. <i>Pinna</i> (<i>Pinna</i>) sp.2; Vanhne (Upper Bhuban Formation, middle part); exterior of right valve, (PUC/I/46); X 2.0.</p> <p>16. <i>Maetra</i> (<i>Maetra</i>) <i>protoreevesii</i> Noetling; Luangmual (Upper Bhuban Formation, middle part); exterior of left valve, (PUC/I/47); X 2.0.</p> |
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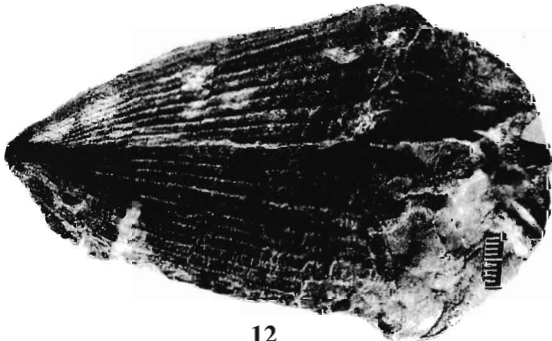
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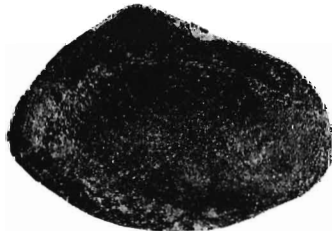
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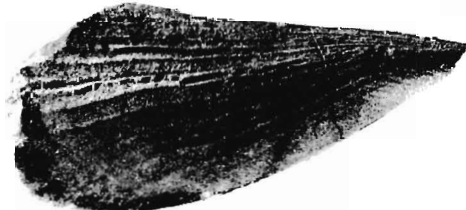
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Table 2: Spatial and temporal distribution of fossil localities.

Group	Sub-group	Formation	No. of localities	No. of beds
Tipam			2	2
Surma	Boka Bil		1	1
		Bhuban	20	32
	Bhuban	Upper Bhuban	4	5
		Middle Bhuban	1	1
Barail			3	3

The collection includes several species of bivalves (121) and gastropods (29), and a few of scaphopods (2), decapods (5), echinoids (5) and fish teeth (8). Although majority of the taxa have long range, few have restricted ranges suitable for biozonation. The Boka Bil Subgroup entombed the long ranging taxa and the Tipam Group has yielded some wood logs only.

Five molluscan informal zones are recognized in the Barail Group and Surma Group (table 3). They are (1) *Meretrix agrestis* Zone, (2) *Glycymeris sindiensis-Nuculana virgo* Zone, (3) *Ostrea latimarginata – Natica pellis tigrina* Zone, (4) *Pecten (Oopecten) gigas* Zone and (5) *Pecten* sp. Zone in ascending order. These are based on the molluscan species having a more or less restricted range and correspond to the referred ages in the Miocene sediments of the Indo-Pacific regions, viz., Garo Hills, Cachar Valley, Baripada beds, Quilon beds, Kachchh and Kathiawar (in India); Sind and Mekran beds (Pakistan); Persia; Myanmar, Sri Lanka and South East Asia. The geological ranges of the taxa are mainly based on the work published by Davies (1975).

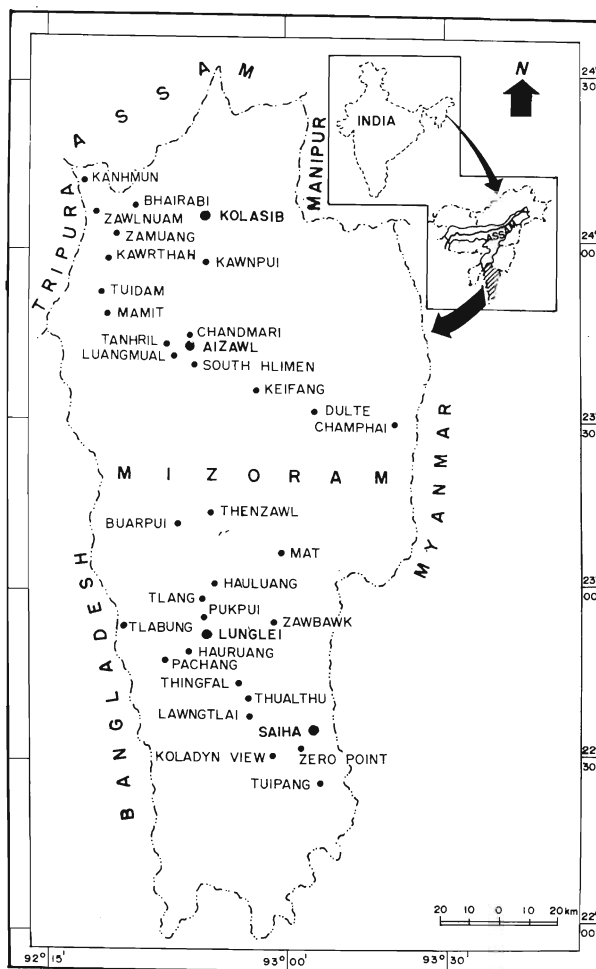


Fig. 1. Map of Mizoram showing the fossil localities.

ZONE 1: *Meretrix agrestis* Zone

This zone is confined to the Barail Group. The section is exposed at near 5km of the Champhai-Aizawl road on the left cutting. It is 11.50m thick and composed of thick bedded, hard, compact, brown

EXPLANATION OF PLATE III

17. *Lucina (Lucina)* sp.; Luangmual (Upper Bhuban Formation, middle part); exterior of right valve, (PUC/I/48); X 2.3.
18. *Conus (Leptoconus) bonneti* Cossmann; Luangmual (Upper Bhuban Formation, middle part); Abapertural view (PUV/I/49); X 1.25.
19. *Diplodonta rotundatus* (Montagu); Luangmual (Upper Bhuban Formation, middle part); exterior of left valve, (PUC/I/50); X 3.0.
20. *Diplodonta incerta* d' Archiac; Zotlang (Upper Bhuban Formation, middle part); exterior of right valve, (PUC/I/51); X 3.0.
21. *Diplodonta incerta* d' Archiac; South Hlimen (Upper Bhuban Formation, lower part); exterior of left valve, (PUC/I/52); X 3.5.
22. *Clementia (Clementia) papyracea* (Gray); Luangmual (Upper Bhuban Formation, middle part); exterior of left valve, (PUC/I/53); X 2.5.
23. *Clementia (Clementia) papyracea* (Gray); Luangmual (Upper Bhuban Formation, middle part); exterior of right valve, (PUC/I/53); X 2.5.
24. *Corbula tunicosulcata* Vredenburg; Luangmual (Upper Bhuban Formation, middle part); exterior of left valve, (PUC/I/54); X 4.2.
25. *Corbula mekranica* Vredenburg; Pukpui (Upper Bhuban Formation, upper part); exterior of right valve, (PUC/I/55); X 4.5.



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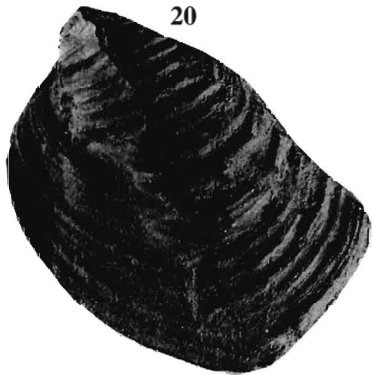
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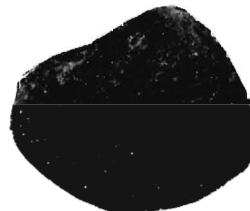
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to grey coloured silty-sandstone (fig. 2.). In the upper part, it is highly fossiliferous and mainly yields bivalves along with a few shark teeth, echinoids and wood streaks. The younger litho units near 8km and 10km yield leaf impressions and ichnogenus *Palaeophycus striatus* Hall and *P. annulatus* n. inchnosp. (Mehrotra *et al.*, 2002).

Meretrix agrestis Cotter of late Eocene to Oligocene from Myanmar is restricted to this zone. Other taxa of the same geological range occurring in this zone only are: *Cardium kanleanum* Cotter, *Cardium thetregyinense* Cotter, *Venus pasokensis* Cotter and *Sunetta yethama* Cotter. A long-ranging shark tooth *Isurus spallanzanii* Bonaparte is also recovered from this zone. The other taxa from this zone which are left to open nomenclature at the specific level are: *Yoldia* sp., *Cardium* sp., *Ostrea* sp., *Tellina* sp. and *Cidaris* sp.

Hence this zone is of late Eocene to Oligocene in age. However, the Barail Group of the Surma basin is assigned to Oligocene based on its stratigraphic position, age of the pre and post-barail (Disang and Surma Groups) sediments, and its considerable thickness (Baksi, 1974).

ZONE 2: *Glycymeris sindiensis* – *Nuculana virgo* Zone

This zone extends into the Lower and Middle Bhuban Formations of the Bhuban Subgroup. The Litho-unit of this zone crops out near Tuipang (Lower

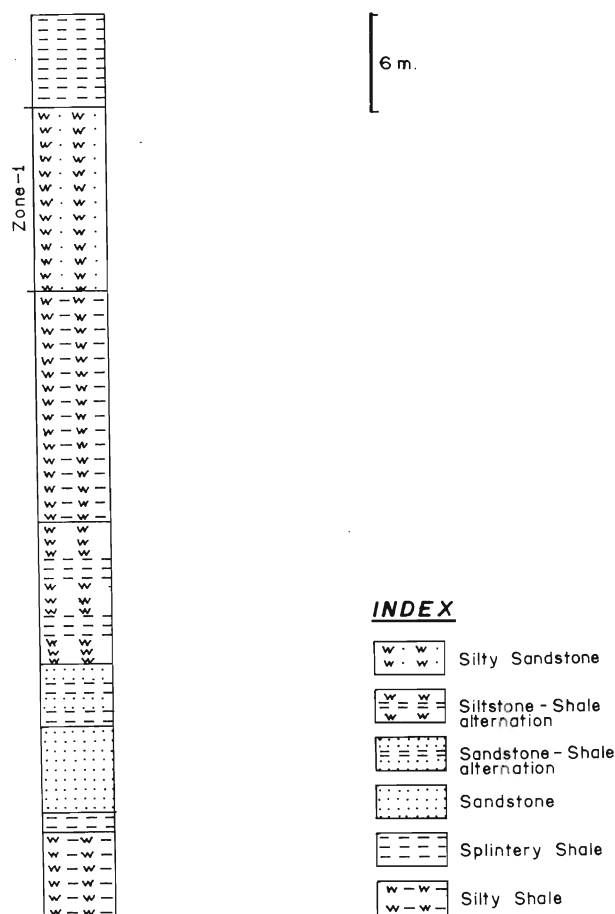


Fig. 2. Lithocolumn of the Barail Group between 5-11 km. mile stones on Chaphai-Aizaal road (Mizoram) showing Zone - 1 (*Meretrix agrestis* Zone).

EXPLANATION OF PLATE IV

26. *Nucula alcocki* Noetling; Luangmual (Upper Bhuban Formation, middle part); exterior of left valve, (PUC/I/56); X 4.25.
27. *Nucula alcocki* Noetling; Luangmual (Upper Bhuban Formation, middle part); exterior of right valve, (PUC/I/56); X 4.25.
28. *Nucula alcocki* Noetling; Luangmual (Upper Bhuban Formation, middle part); dorsal view, (PUC/I/56); X 4.25.
29. *Anadara* sp., Luangmual (Upper Bhuban Formation, middle part), exterior of left valve, (PUC/I/24); X 1.25.
30. *Anadara (Anadara) luangmualensis* Tiwari; Luangmual (Upper Bhuban Formation middle part); exterior of left valve, (PUC/I/25); X4.75.
31. *Anadara (Anadara) trapezoida* Tiwari; Luangmual (Upper Bhuban Formation, middle part); exterior of left valve, (PUC/I/29); X4.75.
32. *Antigona granosa* (Sowerby); Hauruang (Upper Bhuban Formation, upper part); exterior of right valve (PUC/I/57); X1.66.
33. *Chlamys (Chlamys) quilonensis* Dey; Luangmual (Upper Bhuban Formation, middle part); exterior of right valve (PUC/I/58); X1.75.
34. *Chlamys cf. jamviniensis* Cox; Pukpui (Upper Bhuban Formation, upper part); exterior of left valve (PUC/I/59); X1.66.
35. *Astarte (Astarte)* sp.1; Luangmual (Upper Bhuban Formation, middle part); exterior of left valve (PUC/I/60); X3.33.
36. *Astarte (Astarte)* sp.1; Luangmual (Upper Bhuban Formation, middle part); dorsal view (PUC/I/60); X3.33.
37. *Astarte (Bathiamina)* sp.1; Hauruang (Upper Bhuban Formation, upper part); exterior of right valve (PUC/I/61); X 2.40.



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Bhuban Formation) and Koladyne View, Lunglawn and Dulte (Middle Bhuban Formation). Near Tuipang, it is confined to 3.8m thick brown coloured and fine grained silty-sandstone (fig. 3). At Koladyne View, it is represented in 4.6m thick, deep brown coloured and relatively unconsolidated silty-sandstone. A 3.9m thick grey coloured calcareous sandstone constitutes this zone near Lunglawn (a locality in Lunglei town), whereas 1.8m thick dark grey silty-sandstone represents it near Dulte village on the Aizawl–Champhai road (fig. 4). This zone is mostly common in bivalves and a few gastropods and echinoids.

The species *Glycymeris sindiensis* Vredenburg and *Nuculana virgo* (Martin) of Aquitanian age are exclusively confined to this zone and justify its name. *Nucula warsarensis* Eames, *Anodontia* sp., *Tellina salinensis* Cotter and *Hemipristis serra* Agassiz are also restricted to this zone. The checklist of the other associated long ranging taxa together with the ones left to open nomenclature is given in table 4.

This zone is of Aquitanian age.

ZONE 3: *Ostrea latimarginata* – *Natica pellis tigrina* Zone

This zone represents the lower part of the Upper Bhuban Formation. It is discernible in South Hlimen, Thenzawl and Theiriat areas of Mizoram. Near

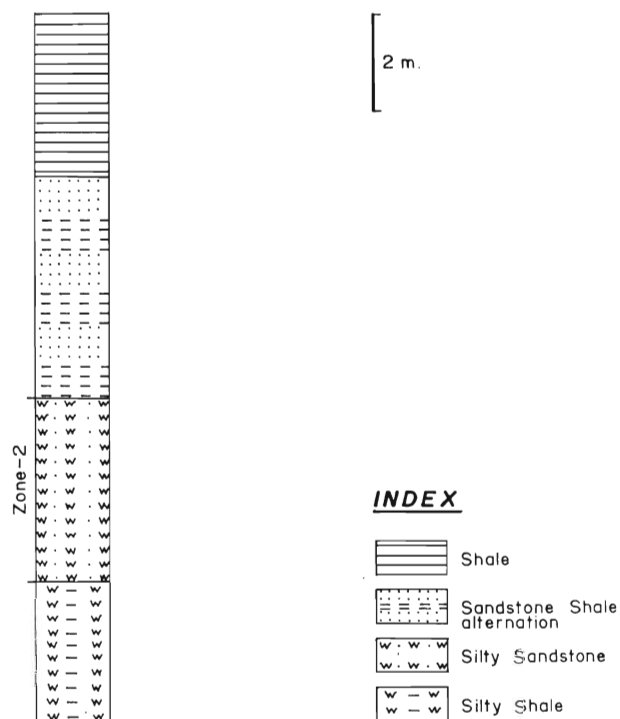
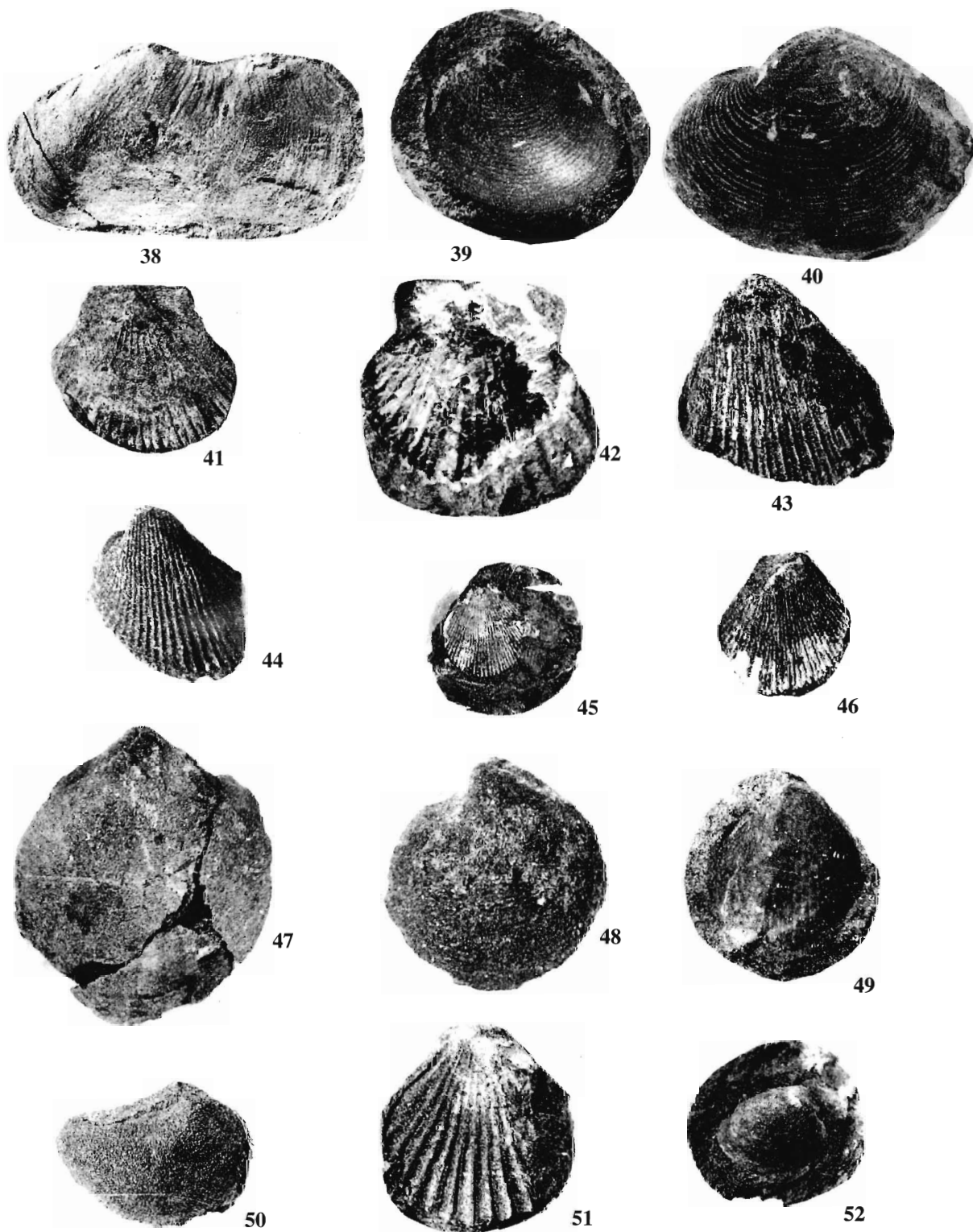


Fig. 3. Lithocolumn of the Lower Bhuban Formation near Tuipang, Mizoram showing Zone-2 (*Glycymeris sindensis*-*Nuculana virgo* Zone).

South Hlimen, 5km south of Aizawl, it groups together three litho-units, namely, grey coloured hard calcareous sandstone (3.5m), deep brownish unconsolidated shale (1.4m) and medium-grained brown coloured sandstone (2.3m). Near Thenzawl,

EXPLANATION OF PLATE V

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| <p>38. <i>Solecurtus</i> sp.; Hauruang (Upper Bhuban Formation, upper part); exterior of left valve (PUC/I/62); X 2.0.</p> <p>39. <i>Salaputinium</i> sp.; Luangmual (Upper Bhuban Formation, middle part); exterior of left valve (PUC/I/63); X 3.0.</p> <p>40. <i>Callista</i> (<i>Costacallista</i>) <i>pseudoumbonella</i> Vredenburg; South Hlimen (Upper Bhuban Formation, lower part); exterior of left valve (PUC/I/64); X 1.5.</p> <p>41. <i>Pecten</i> (<i>Oopecten</i>) <i>gigas</i> (Schlotheim); Kawrthah (Upper Bhuban Formation, middle part), exterior of left valve (PUC/I/65); X 1.0.</p> <p>42. <i>Pecten</i> (<i>Oopecten</i>) <i>gigas</i> (Schlotheim); Kawrthah (Upper Bhuban Formation, middle part); exterior of left valve (PUC/I/66); X 1.2.</p> <p>43. <i>Cardium kanleanum</i> Cotter; Near Champhai (Barail Group); exterior of left valve (PUC/I/70); X 3.0.</p> <p>44. <i>Cardium thetregyinense</i> Cotter; Near Champhai (Barail Group); exterior of left valve (PUC/I/69); X 1.3.</p> | <p>45. <i>Pecten</i> sp.; Pukpui (Upper Bhuban Formation, upper part); exterior pf left valve (PUC/I/67); X 1.5.</p> <p>46. <i>Pecten</i> sp.; Pukpui (Upper Bhuban Formation, upper part); exterior of left valve (PUC/I/68); X 1.0.</p> <p>47. <i>Dosinia</i> (<i>Dosinia</i>) <i>peralta</i> Vredenburg; Tuipang (Lower Bhuban Formation); exterior of right valve (PUC/I/71); X 1.5.</p> <p>48. <i>Dosinia</i> (<i>Dosinia</i>) <i>peralta</i> Vredenburg; Buarpui-B (Upper Bhuban Formation, middle part); exterior of right valve (PUC/I/72); X 1.5.</p> <p>49. <i>Anadara gourae</i> Dey; Zotlang (Upper Bhuban Formation, middle part); exterior of right valve (PUC/I/76); X 1.9.</p> <p>50. <i>Yoldia</i> sp.; Champhai (Barail Group); exterior of right valve (PUC/I/74); X 1.8.</p> <p>51. <i>Chlamys</i> sp.; Champhai (Barail Group); exterior of right valve (PUC/I/75); X 2.2.</p> <p>52. <i>Meretrix agrestis</i> Cotter; Champhai (Barail Group); exterior of right valve (PUC/I/73); X 1.2.</p> |
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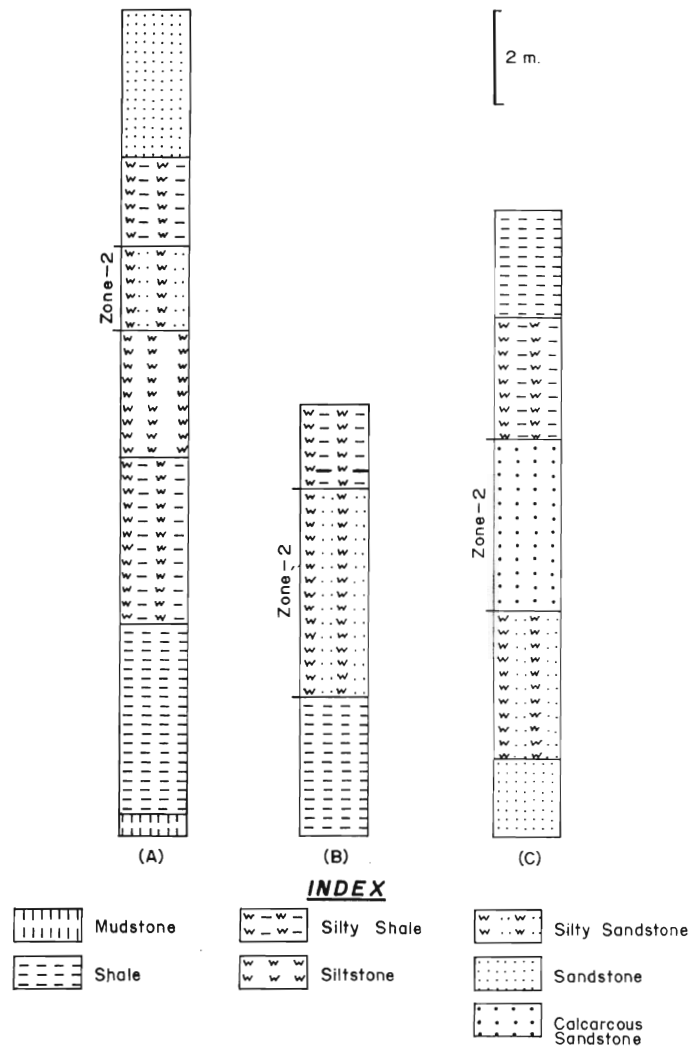


Fig. 4. Lithocolumns of the Middle Bhuban Formation near Dulte (A), Koladyne view (B) and Lunglawn (C), Mizoram showing Zone -2 (*Glycymeris sindensis* - *Nuculana virgo* Zone).

EXPLANATION OF PLATE VI

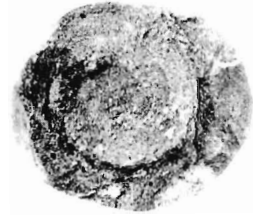
53. *Natica pellis tigrina* Chemnitz; South Hlimen (Upper Bhuban Formation, lower part); abapertural view (PUC/I/77); X 3.0.
54. *Architectonica affinis* (Sowerby); South Hlimen (Upper Bhuban Formation, lower part); apical view (PUC/I/78); X 2.5.
55. *Architectonica affinis* (Sowerby); Buarpui-A (Upper Bhuban Formation, middle part); apical view (PUC/I/79); X 2.5.
56. *Conus (Dendroconus) lorisii* Keiner; Buarpui-A (Upper Bhuban Formation, middle part); apertural view (PUC/I/80); X 1.4.
57. *Conus (Dendroconus) lorisii* Keiner; Buarpui-A (Upper Bhuban Formation, middle part); apical view (PUC/I/81); X 1.4.
58. *Globularia callosa* (Sowerby); Buarpui-A (Upper Bhuban Formation, middle part); abapertural view (PUC/I/82); X 3.0.
59. *Ficus conditus* (Brongniart); Luangmual (Upper Bhuban Formation, middle part); abapertural view (PUC/I/83); X1.7.
60. *Ficus* sp.; Luangmual (Upper Bhuban Formation, middle part); abapertural view (PUC/I/84); X 1.8.
61. *Turritella (Torculoidella) angulata* Sowerby; Luangmual (Upper Bhuban Formation, middle part); abapertural view (PUC/I/85); X2.0.
62. *Turritella cf. pseudobandongensis* Vredenburg; Pukpui (Upper Bhuban Formation, upper part); abapertural view (PUC/I/86); X1.5.
63. *Nassaria birmanica* (Vredenburg); Luangmual (Upper Bhuban Formation, middle part); abapertural view (PUC/I/87); X1.7.
64. *Xenophora birmanica* Noetling; Luangmual (Upper Bhuban Formation, middle part); apical view (PUC/I/88); X2.0.



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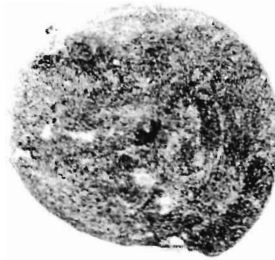
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64

This zone is assigned Aquitanian-Burdigalian age.

ZONE 4: *Pecten (Oopecten) gigas* Zone

This zone is restricted to the middle part of the Upper Bhuban Formation and otherwise most widespread of all the zones. It occurs in around 12 localities, viz. Thenzawl, Buarpui (B and C), Luangmual, Kawrthah, Tuidam (B and D), Thualthu, Zotlang, Serkawn, Rahsiveng (including Vanhne) and Lawngtlai areas of Mizoram. The fossiliferous horizons in these localities are: 1.3m silty-sandstone;

4.8m sandstone and 0.15m conglomerate (B); 1.5m silty-sandstone and 0.5m conglomerate (C); 4.0m sandstone and 0.6m conglomerate; 4.9 m sandstone and 0.7m calcareous sandstone; 0.5m calcareous sandstone (B); 4.1m silty-sandstone (D); 2.9m silty-sandstone; 1.4m silty-sandstone, 0.35m conglomerate and 2.2m sandstone; 3.2m silty-sandstone; 4.2m sandstone and 4.9m silty-sandstone (figs. 6, 7 and 8).

This zone yields a large number of bivalves and gastropods and a few crabs, echinoids, fish teeth and balanoid barnacles. *Pecten (Oopecten) gigas* (Schlotheim) is a most widely occurring form with

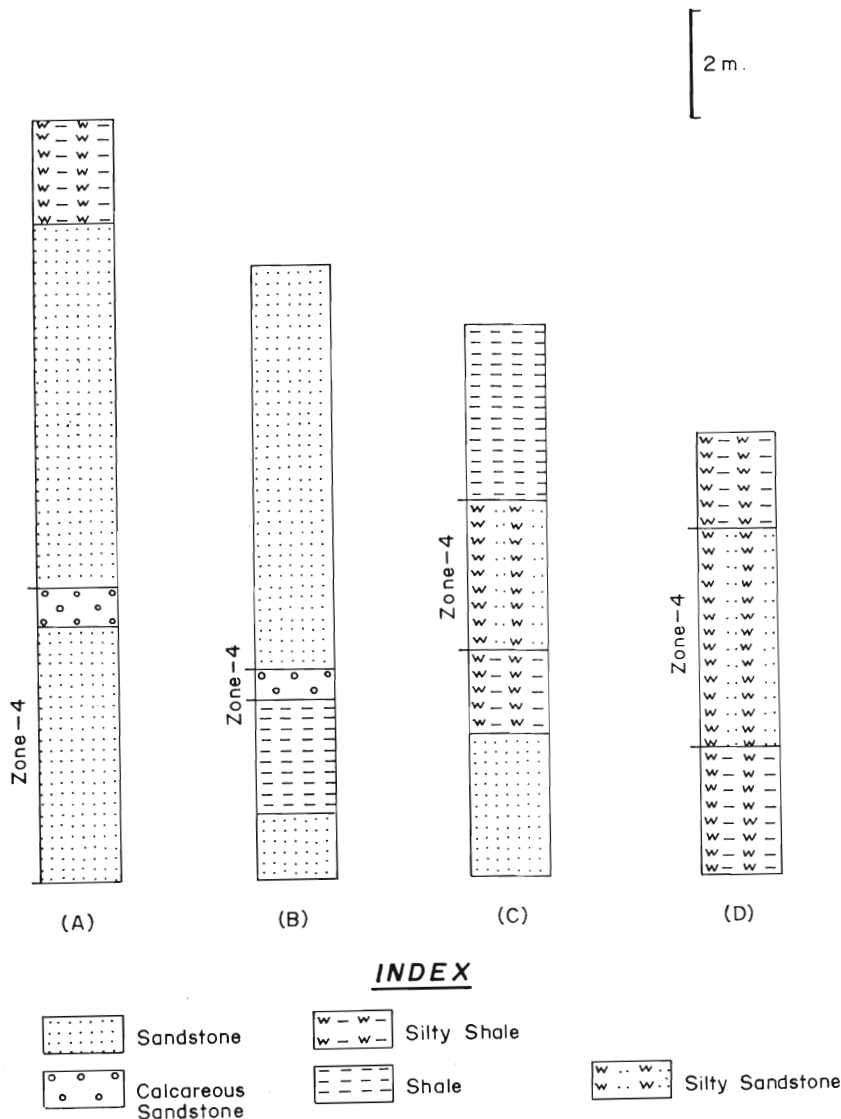


Fig. 6. Lithocolumns of the Upper Bhuban Formation (middle part) near Kawrthah (A) Tuidam (B and D) and Thualthu (C) in Mizoram showing Zone - 4 (*Pecten (Oopecten) gigas* Zone).

the restricted range of Burdigalian. The checklist of other taxa confined to this zone is: *Nucula alcocki* Noetling, *Nucula* sp. 2., *Nucula* sp. 3., *Anadara dichotoma* Deshayes, *Anadara* (A) *luangmualensis* Tiwari, *Anadara* (Lunarca) *kachharai* Tiwari, *Scapharca ferruginea* Reeve, *Pecten pilgrimi* Cox, *Limaria* (*Limatulella*) sp., *Astarte* (A.) sp., *Salaputinium* sp.1, *Cardium*

quilonense Dey, *Turritella narica* Vredenburg, *Turris* (*Lophistoma*) *quilonica* Dey, *Clavatula tipperi* Cox, *Charonia davidsoni* Noetling, *Bursa elegans* (Becks), *Xenophora birmanica* Noetling, *Nassaria birmanica* (Vredenburg), *Volvaria birmanica* Noetling, *Conus* (*Leptoconus*) *bonneti* Cossman, *Conus* (*Dendroconus*) *loroisii* Kiener, *Ebalia tuberculata* Noetling, *E. spinosa* Tiwari et

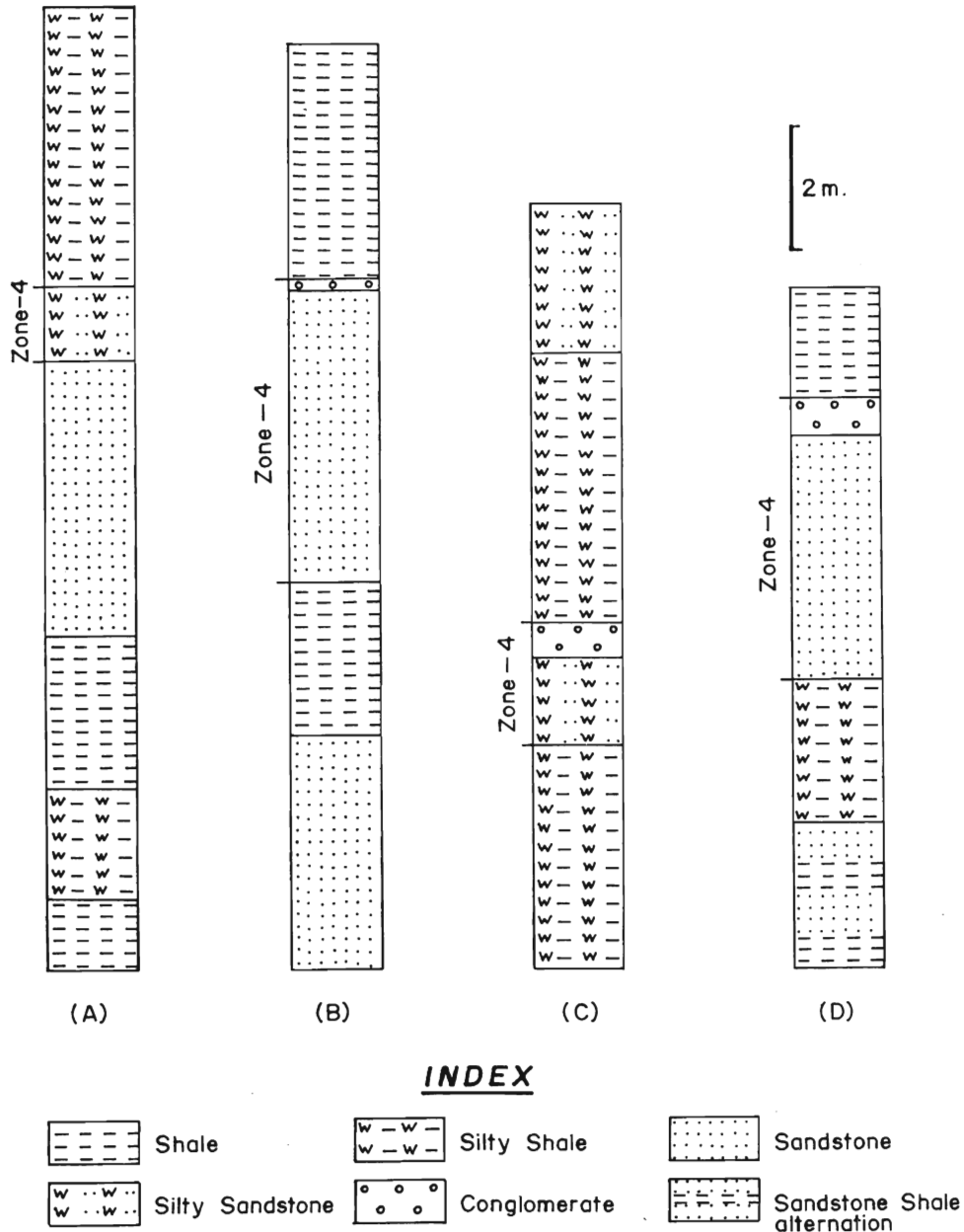


Fig. 7. Lithocolumns of the Upper Bhuban Formation (middle part) near Thenzawl (A), Buarpui (B) and d(C) in Lunglei district, and Luangmual in Aizawl district, Mizoram showing Zone-4 (*Pecten* (*Oopecten*) *gigas* Zone).

al., *Sphyrna zygaena* Linne and *Pristiophorus suevicus* Jackel. The checklist of the long ranging taxa from this zone is given in Table 4.

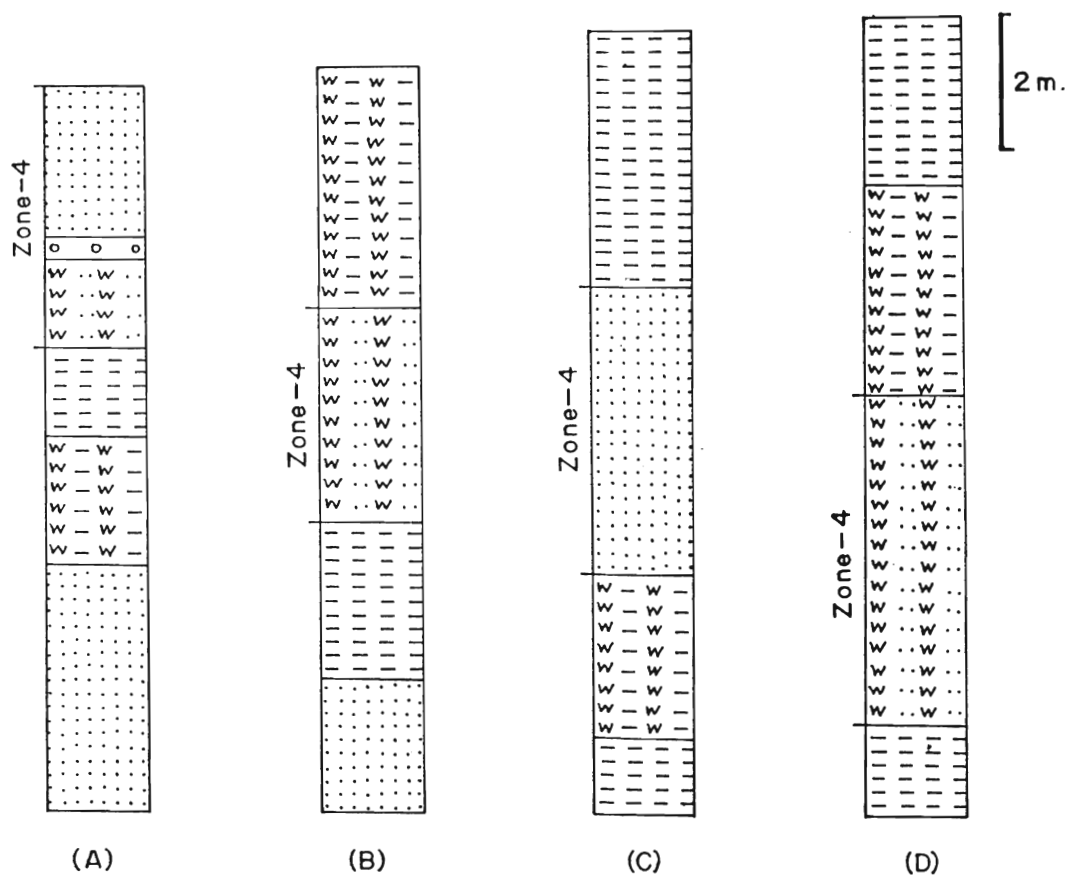
This zone is possibly of Burdigalian age.

ZONE 5: *Pecten* sp. Zone

This zone is a part of the upper portion of the Upper Bhuban Formation. It is present around Hauruang, Pukpui and Mat River in Lunglei district of Mizoram. A 2.8m silty-sandstone and 0.5m conglomerate forms this zone at Hauruang. The

thickness of the first unit decreases to 1.0m, and of second unit increases to 1.5m around Pukpui. The conglomeratic unit is missing near the Mat River section and the zone occurs in 3.1m silty-sandstone (fig. 9).

The zone yields mostly bivalves, few gastropods, crabs, echinoids and barnacles. *Pecten* sp. characterise this zone. *Arca* sp. 2, *Anadara* (*Tegillaria*) *nodifera* (Martens), *Chlamys* cf. *jamviensis* Cox, *Astarte* (*Bathiamena*) sp.2, *Tellina* (*Phylloda*) cf. *foliacea* Reeve, *Solecurtus* sp.,



INDEX

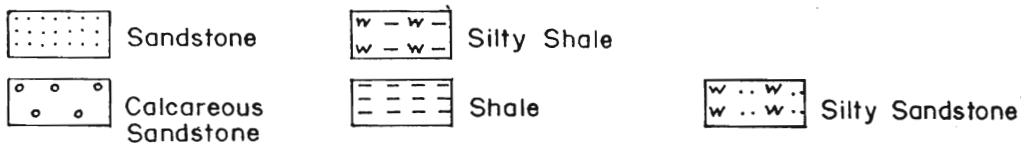


Fig. 8. Lithocolumns of the Upper Bhuban Formation (middle part) near Zotlang (A), Serkawn (B), Rashiveng (C) and Lawngtlai (D) Lunglei district Mizoram showing Zone-4 (*Pecten* (*Oopecten*) *gigas* Zone).

Antigona granosa (Sowerby), *Pitar altombonata* (Nagao), *Turritella pseudobandongensis* Vredenburg, *Calappa protopustulosa* Noetling and *Typilobus granulosus* Stoliczka are also confined to this zone. The checklist of other associated long ranging taxa is given in Table 4.

This zone is possibly of Helvetian age.

BOKA BIL SUBGROUP

Only one fossiliferous unit could be traced in the Boka Bil Subgroup. This occurs at Zamuang and is composed of 1.0m thick grey coloured shale (fig.10).

It yields long ranging molluscan taxa, *Chlamys senatoria* (Gmelin), *Astarte (Bathiamena) sp.*, *Tellina (Tellinella) sp.*, and *Calyptrea chinensis* (Linne) besides chela of crabs. In the absence of age-diagnostic taxa, it is not possible to recognize any biozone in the Boka Bil Subgroup.

TIPAM GROUP

The Tipam Group contains a large number of wood logs in the northwestern corner of Mizoram particularly near Zawlnuam and Kanhmun (fig. 11). These are found embedded in the feldspathic sandstone. Five species of fossil woods have been

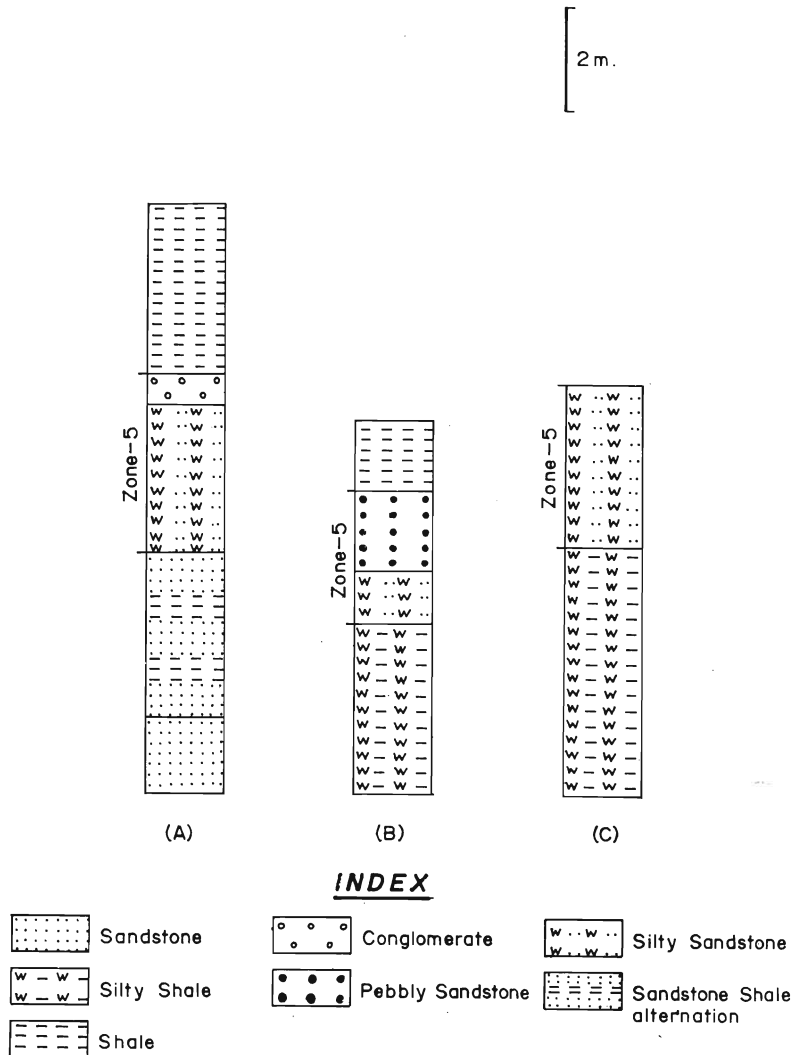


Fig. 9. Lithocolumns of the Upper Bhuban Formation (upper part) near Hauruang (A), Pukpui (B) and Mat River (C) in Mizoram showing Zone-5 (*Pecten* sp. Zone).

identified in the collection, one of these being a new one (Tiwari and Mehrotra, 2000). These are: *Dipterocarpoxydon premacrocarpum* Prakash, *Glutoxydon cuddalorensis* Awasthi, *Millettioxydon palaeopulchra* Awasthi, *Lagerstroemioxydon eoflosreginum* Prakash and Tripathi, and *Laurinoxydon dilcheri* Tiwari and Mehrotra. Based on these, late Miocene to early Pliocene age is assigned to the Tipam Group.

TAXONOMIC NOTES ON THE ZONAL FOSSILS

1. *Meretrix agrestis* Cotter

(Pl. V, fig. 52)

Shell sub-trigonal, inequilateral, height about fourth-fifth and thickness about half of the length. Umbones indistinct, depressed, prosogyrate and situated at about anterior-third of the shell

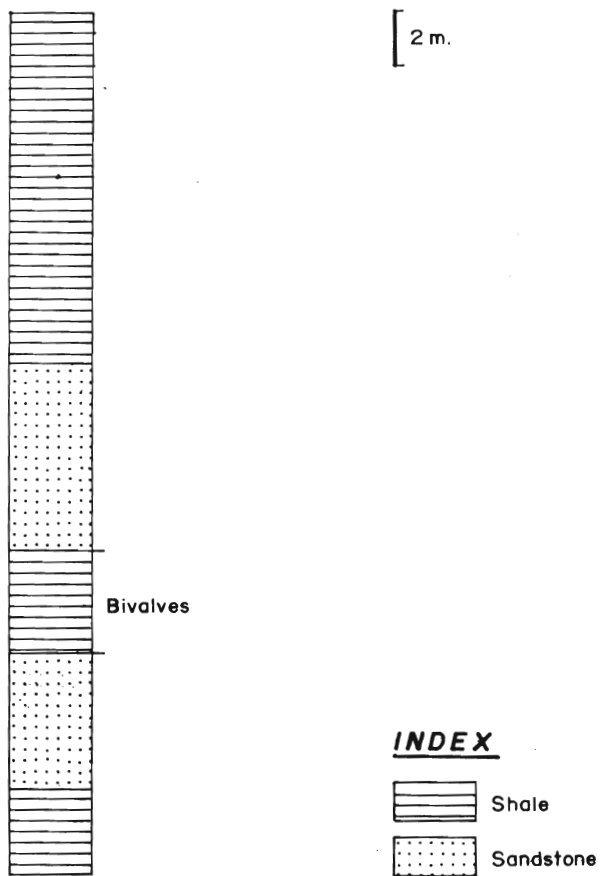


Fig. 10. Lithocolumn of the Boka Bil Subgroup at 6 Km. Milestone on Zamuang - Bairabi road, Mizoram showing fossiliferous horizon.

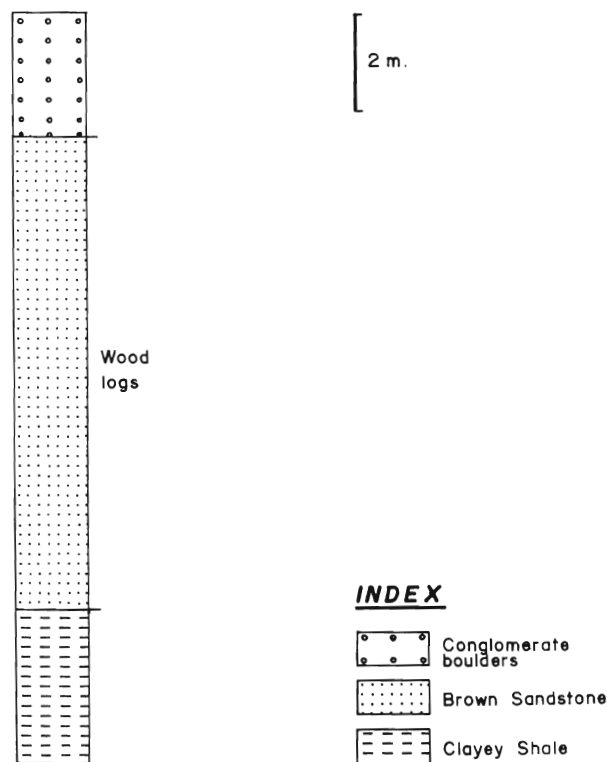


Fig. 11. Lithocolumn of the Tipam Group near Zawlpui Aizawl district, Mizoram showing horizon containing Wood log.

length. Antero-dorsal margin is slightly concave near the umbo and merges with broadly rounded anterior margin. Posture-dorsal margin is feebly convex for a short length and then merges with straight and inclined (at about 45°) posterior margin that in turn meets the ventral margin in a narrow and rounded curve. Ventral margin is slightly convex. Lunule small, moderately deep and cordiform. Escutcheon indistinct. Shell surface bears fine concentric ornamentation that is more distinct towards the ventral.

This species was originally described by Cotter (1923, p. 10) from the Eocene of Myanmar.

2. *Nuculana virgo* (Martin)

(Pl. I, fig. 4)

Specific characters of this species have been defined by Noetling (1901, p.160) that include less swollen shell, much acuminate and rostrate posterior region and coarser and fewer concentric costae of growth.

Solitary specimen of this species from Mizoram resembles very closely with the one from the Miocene of Meghalaya (Mukerjee, 1939, pp. 6-7), Myanmar (Noetling, 1901, p. 160) and Java (Martin, 1879, p. 113), the only difference being that the former is somewhat larger in size than the latter but length-height ratio is the same.

However, the Meghalaya and Myanmar examples have regularly and uniformly distributed costae all over the surface and in this respect they differ from Mizoram and Java examples which have widely distributed costae near the umbonal region.

3. *Glycymeris sindiensis* (Vredenburg)

(Pl. I, fig. 8)

Shell orbicular, nearly equilateral with moderate and regular convexity. Hinge line narrow. Shell surface bears about 35 rounded and regularly distributed radial ribs that are separated by narrower interspaces towards the anterior. Radials ribs are crossed over by several fine growth lines.

This species was originally described by Vredenburg (1928, p. 419) under the name *Pectunculus sindiensis* from the Lower Gaj of Sind. Lator, Pascoe (1973, p. 1644) renamed it as *Glycymeris sindiensis*.

4. *Ostrea latimarginata* Vredenburg

(Pl. II, fig. 11)

Specific characters of this species have been defined by Vredenburg (1908, p. 317) and by Douglas (1927, pp. 3-5). Present specimen, though not very well preserved, exhibits most diagnostic character of the species *i. e.* large sub-orbicular left valve bearing radial ribs that are narrow, sinuous and branching and have tendency to fade away, and extraordinarily developed broad flange like expansion surrounding the small visceral cavity internally.

5. *Natica pellis tigrina* Chemnitz

(Pl. VI, fig. 53)

Small conch with short spire (one-sixth of the height) of four whorls with convex sides. Body whorl much convex, maximum convexity being at

about mid-height then narrowing down anteriorly very rapidly. Aperture semi-oval, somewhat expanded, slightly oblique and extending up to three-fourth of the height of the body whorl.

Whorls ornamented with oblique lines of growth.

6. *Pecten (Oopecten) gigas* (Schlotheim)

(Pl. V, figs. 41-42)

Two left valves represent this species. Valves fan-shaped and nearly flat. The length (40mm and 34mm) slightly exceeds the height (38mm and 32mm). Dorsal margins somewhat concave and forming shoulder like angles with the anterior and posterior margins. Hinge margin is straight and elongate. Auricles are long and narrow.

Valves are covered with 14-15 depressed flat-topped radial costae separated by interspaces which are usually of the same width. Very fine regularly spaced concentric threads cross over both the ribs and the interspaces.

This European species was also reported by Cox (1936, pp. 53-54) from the Asmari Limestone of Burdigalian age from Iran.

Table 3 : Biostratigraphic zones in the Tertiary of Mizoram.

Age	Formation	Zones
Late Miocene to early Pliocene	Tipam Group	-
Middle Miocene	Boka Bil	-
Helvetian	Upper Bhuban Formation (upper part)	<i>Pecten</i> sp. Zone (5)
Burdigalian	Upper Bhuban Formation (middle part)	<i>Pecten (Oopecten) gigas</i> Zone (4)
Aquitanian Burdigalian	Upper Bhuban Formation (lower part)	<i>Ostrea latimarginata-Natica pellis tigrina</i> zone (3)
Aquitanian	Lower and Middle Bhuaban Formations	<i>Glycymeris sindiensis</i> – <i>Nuculana virgo</i> Zone (2)
Late Eocene to Oligocene	Barail Group	<i>Meretrix agrestis</i> Zone (1)

<i>Tellina (Tellinella) hilli</i> Noetling	R		F	R	<i>Corbula (Tunicosulcata)</i> sp.				R
<i>Tellina (Tellinella)</i> <i>pseudohilli</i> Noetling				R	<i>Pholadomia</i> sp. 1			A	A
<i>Tellina (Tellinella)</i> sp.	R	R	R		<i>Pholadomia</i> sp. 2			F	A
<i>Tellina (Telliangulus)</i> sp.				R	B. GASTROPODA:				
<i>Tellina salinensis</i> Cotter		F			<i>Turritella narica</i> Vredenburg				R
<i>Tellina</i> sp.	A		A		<i>Turritella</i> cf.				R
<i>Apolymetis aizawlensis</i> Tiwari & Kachhara				A	<i>pseudobandonensis</i> Vredenburg				
<i>Apolymetis lungleiensis</i> Tiwari & Kachhara			F		<i>Turritella (Torculoidella)</i> <i>angulata</i>			F	F
<i>Apolymetis</i> sp.			R	R	Sowerby				
<i>Gari (Gari) natensis</i> Noetling			R	R	<i>Turris</i> sp.				R
<i>Gari (Psammobia) aff.</i> <i>kingi</i> Noetling			R		<i>Turris (Lophistoma)</i> <i>quilonica</i> Dey				R
<i>Solecurtus</i> sp.					<i>Architectonica Buddha</i> (Noetling)			R	
<i>Arctica islandica</i> (Linne)	R	F	F	R	<i>Architectonica affinis</i> (Sowerby)			R	R
<i>Arctica</i> cf. <i>islandica</i> (Linne)			A	F	<i>Architectonica</i> sp.				R
<i>Antigona granosa</i> (Sowerby)					<i>Scala</i> cf. <i>irregularis</i> (Noetling)			R	
<i>Venus pasokensis</i> Cotter	F				<i>Clavatula tipperi</i> Cox				R
<i>Meretrix persica</i> Cox			F	A	<i>Charonia davidsoni</i> Noetling				R
<i>Meretrix</i> sp. juv. <i>meretrix</i> (Linne)			F	A	<i>Bursa elegans</i> (Becks)				R
<i>Meretrix agrestis</i> Cotter	F				<i>Calyptrea chinensis</i> (Linne)	Boka	Bil		
<i>Pitar altoumbonata</i> (Nagao)					<i>Cassispira</i> sp.				R
<i>Sunetta yethama</i> Cotter	A				<i>Oliva</i> sp.				R
<i>Timeclea</i> cf. <i>subspadicea</i> (Cossmann)		F		F	<i>Xenophora birmanica</i> Noetling				R
<i>Callista (Callista)</i> <i>pseudoumbonella</i> Vredenburg			R		<i>Natica coxi</i> Mukerjee			F	F
<i>Callista</i> sp.				R	<i>Natica pellis tigrina</i> Chemnitz			R	
<i>Callista (Costacallista)</i> <i>erycina</i> (Linne)			A	A	<i>Globularia callosa</i> (Sowerby)			R	R
<i>Dosinia (Dosinia) peralta</i> Vredenburg	R		F	R	<i>Sinum protoneritodeum</i> (Vredenburg)			R	R
<i>Clementia (Clementia)</i> <i>papyracea</i> (Gray)			F	F	<i>Nassaria birmanica</i> (Vredenburg)				R
<i>Clementia (Clementia)</i> <i>protopapyracea</i> Vredenburg				R	<i>Ficus conditus</i> (Brongniart)		R	F	F
<i>Clementia</i> sp.				R	<i>Ficus</i> sp.		R	R	R
<i>Paphia (Paphia) rotundatus</i> (Linne)			A	F	<i>Murex maegillivrayi</i> Dohrn				R
<i>Paphia (Paphia)</i> sp.			A	F	<i>Murex</i> sp.				R
<i>Paphia (Paphia) persica</i> Cox	F		A	R	<i>Volvaria birmanica</i> Noetling				R
<i>Paphia (Callistotapes)</i> <i>pseudoliratus</i> Vredenburg			F	F	<i>Conus (Lithoconus)</i> <i>ineditus</i> Michelotti				F
<i>Corbula tunicosulcata</i> Vredenburg	R	R	R	R	<i>Conus (Leptoconus)</i> <i>bonneti</i> Cossmann				F
<i>Corbula mekranica</i> Vredenburg				R	<i>Conus (Dendroconus)</i> <i>loroisii</i> Keiner				F
<i>Corbula harpa</i> d' Archias				R	C. SCAPHOPOD:				
				R	<i>Dentalium boettgeri</i> Noetling			R	
				R	<i>Dentalium junghuhni</i> Martin			R	

<i>Cidaris</i> sp.	R	R	R		
<i>Schizaster alveolatus</i> Duncun & Sladen				F	F
<i>Schizaster baluchistanensis</i> d'Archiac & Haime				R	R
<i>Schizaster granti</i> Duncun & Sladen			R	F	
<i>Schizaster</i> aff. <i>symmetricus</i> Duncun & Sladen			F	F	
E. DECAPODS					
<i>Calappa protopustulosa</i> Noetling					R
<i>Ebalia tuberculata</i> Noetling				F	
<i>Ebalia spinosa</i> Tiwari et. al.				R	
<i>Typilobus granulosus</i> Stoliczka					R
<i>Xantho</i> sp.					R
F. FISH TEETH					
<i>Hemipristis serra</i> Agassiz		R			
<i>Negaprion</i> sp.					R
<i>Sphyrna zagaena</i> Linne					R
<i>Carcharodon carcharias</i> Linne'					R
<i>Isurus spallanzanii</i> Bonnaparte	F			F	F
<i>Pristiophorus suevicus</i> Jaekel					R
<i>Dasyatis</i> sp.					R
<i>Dentex</i> sp.					R

7. *Pecten* sp.

(Pl. V, figs. 45-46)

Two left valves represent this form. Valves are of small size, orbicular and slightly inequilateral. Length and height are nearly equal. Left valve very feebly convex and becomes flattened towards the ventral margin. It is ornamented with 35 narrow, smooth, rounded radial riblets, four of which diverge at nearly equal angles, are usually slightly more prominent than any other, and the remainder usually alternate in strength.

Cox (1936, pp. 50-51) described a new species under the name *Pecten pascoei* from the Pliocene of Iran (Mekran beds). Our specimens exhibit all the diagnostic characters of *Pecten pascoei* Cox. However, these are much smaller in dimensions (length 17mm, height 16mm) as compared to the Cox's holotype (length and height 34.5mm) and are from the older horizon, i.e. Miocene. They possibly represent a new species which will be described in detail in a separate publication.

CONCLUSION

Analysis of the molluscan fauna of the Tertiary sediments of Mizoram has led to the recognition of the five biozones. The Zone 1 (*Meretrix agrestis* Zone) belongs to the Barail Group and is late Eocene to Oligocene age, while Zone 2 (*Glycymeris sindiensis* – *Nuculana virgo* Zone) belongs to the Lower and Middle Bhuban Formations and is Aquitanian in age. The Zone 3 (*Ostrea latimarginata* – *Natica pellis tigrina* Zone), the Zone 4 (*Pecten (Oopecten) gigas* Zone) and the Zone 5 (*Pecten* sp. Zone) represent respectively the lower, middle and the upper parts of the Upper Bhuban Formation and are of Aquitanian – Burdigalian, Burdigalian and Helvetian age, respectively. No biozone could be recognized in the Boka Bil Subgroup, and the Tipam Group yielded only fossil woods.

ACKNOWLEDGEMENTS

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REFERENCES

- Baksi, S.K., 1974. On Oligocene palynology biostratigraphy of the Assam-Bengal basin, India. *BSIP Spl. Publ. No. 3*: 106-116.
- Chatterjee, B.P., 1972. In Nandy, D.R. and Mukerjee, R.N., Geological mapping in parts of Aizawl district, Mizoram. *Geol. Surv. India. Progress Report, (Unpublished)*.
- Cotter, G. de P. 1923. The Lamellibranchiata of the Eocene of Burma. *Pal. Ind., N. S. 7(2)*: 1-24 (pls. I-VII).
- Cox, L. R. 1936. Fossil Mollusca from Southern Persia (Iran) and Bahrein Island. *Pal. Ind., N. S., 22 (2)*, pp. 1-69 (pls. I-VIII).
- Das Gupta, A.B., 1977. Geology of Assam-Arakan Region. *Quart. Jour. Geol. Min. Met. Soc. India, 49*:1-54.
- Das Gupta, S., 1982. Synthesis and review of faunal records from the Surma basin. *Rec. Geol. Surv. India, 12(IV)*: 31-38.
- Davies, A.M., 1975. *Tertiary Faunas II: The sequence of Tertiary faunas (revised by Eames)* George Allen and Unwin Ltd., London.
- Dey, A.K., 1962. The Miocene mollusca from Quilon, Kerala, India. *Mem. Pal. India, N. S. 36*: 1-119.
- Douglas, J. A. 1927. Contributions to Persian Palaeontology. 1-3

- Ganguli, S.** 1983. Geology and Hydrocarbon prospects of Tripura-Cachar- Mizoram region. *Jour. Petrol. Asia*, **6**(IV): 105-109.
- Ganju, J.L.** 1975. Geology of Mizoram. *Bull. Geol. Min. Met. Soc. India*, **48**: 17-26.
- Karunakaran, 1974.** Geology and Mineral resources of the states of India, *Misc. Publ. Geol. Surv. India*, **30**(IV): 93-101.
- La Touche, 1891.** Note on the geology of Lushai Hills. *Rec. Geol. Surv. India*, **24**(2): 83-141.
- Mandaokar, B. D.** 2000. Palynology and palaeoenvironment of the Bhuban Formation (Early Miocene) of Ramrikawn, near Aizawl, Mizoram, India. *Palaeobot.* **49**: 317-324.
- Martin, K.** 1879. *Die Tertiarschiechten auf Java.*
- Mehrotra, R. C., Mandaokar, B.D., Tiwari, R.P. and Rai, V., 2001.** *Teredolites clavatus* from the Upper Bhuban Formation of Aizawl District, Mizoram, India. *Ichmos*, **8**(1): 63-68.
- Mukerjee, P.N., 1939:** The fossil fauna of the Tertiary of the Garo Hills, Meghalaya. *Pal. Indica. N.S.* **28**: 1-101.
- Noetting, F, 1901:** Miocene fauna of Burma, *Mem. Pal. Ind.*, **1**(2): 1-378.
- Pascoe, E. H. 1989.** A Manual of the Geology of India and Burma. Geological Survey India Publication.
- Patil, R.S., 1990.** Palaeontology of the Upper Bhuban Formation of the Lunglei district, Mizoram. *Rec. Geol. Surv. India*, **123**(IV): 168-169.
- Patil, R.S., 1991.** Palaeontology of the Bhuban Rocks of parts of Lunglei district, Mizoram. *Rec. Geol. Surv. India*. **124**(IV): 227.
- Sinha, N.K., 1973.** Systematic geological mapping in parts of Lunglei district, Mizoram. *Prog. Report. Geol. Surv. India (Unpublished).*
- Sinha, N.K., Chatterjee, B.P., and Satsangi, P.P., 1982.** Status of Palaeontological researches in the north-east states of India. *Rec. Geol. Surv. India*, **112**(IV): 66-88.
- Tiwari, R.P., 1992.** Palaeontological and biostratigraphic studies of the Surma Group rocks around Aizawl and Lunglei, Mizoram, India. *Unpubl. Ph.D Thesis, Gauhati University.*
- Tiwari, R.P. 2001.** Neogene Palaeontology of the Surma Group, Mizoram, India. 1-The Arcoida (Mollusca:Bivalvia). *Jour. Pal. Soc. India*, **46**:147-160.
- Tiwari, R. P. and Bannikov, A.F., 2001.** Early Miocene marine fishes from the Surma Group, Mizoram India. *Bollettino del Museo Civico di Storia Naturale di Verona* **25**:11-26. *Geologia Paleontologia Preistoria.*
- Tiwari, R.P, Barman, G and Satsangi, P.P., 1997.** Miocene crabs from Mizoram, India *Jour. Pal. Soc. India*, **42**: 127-132.
- Tiwari, R.P, and Kachhara, R.P., 2000.** Two new species of *Apolymetis* (Bivalvia: Tellinidae) from the Miocene of Mizoram, India *Tertiary Research*, **20**(1-4): 79-84.
- Tiwari, R.P, and Mehrotra, R.C., 2000.** Study of fossil wood from the Tipam Group (Neogene) of Mizoram. India *Tertiary Research*, **20**(1-4) : 85-94.
- Tiwari, R.P. and Mehrotra, R.C., 2002.** Plant Impressions from the Barail Group of Champhai-Aizawl Road section, Mizoram, India. *Phytomorphology*, **52** (1): 69- 76
- Tiwari, R.P, Mishra, V.P. and Lyngdoh, B.C.,1998.** Lower Miocene fish teeth from Mizoram, India, *Geosci. Jour.* **19**(1): 9-17.
- Tiwari, R.P, and Satsangi, P.P, 1988.** Fossil crab from Mizoram, *Curr. Sci.* **57**(7): 956-958.
- Vredenburg, E. W. 1908.** Preliminary note on the Indian occurrences of *Ostrea latimarginata*. *Rec. Geol. Surv. India.*, **36**(4), pp. 317-324.
- Vredenburg, E.W. 1925.** Description of the Mollusca from the post-Eocene Tertiary Formation of north-west India. *Mem. Geol. Surv. India*, **50**(1): 1-322.
- Vredenburg, E.W 1928.** Description of the Mollusca from the post- Eocene Tertiary Formation of north-west India. *Mem. Geol. Surv. India*, **50**(2): 351-506.