FORAMINIFERAL BIOSTRATIGRAPHY, PALEOECOLOGY AND THE BOUNDARY EVENTS OF PALEOGENE SEDIMENTS FROM PARTS OF KOHIMA AND PHEK DISTRICTS, NAGALAND

A THESIS SUBMITTED

TO

NAGALAND UNIVERSITY

FOR THE AWARD OF DEGREE OF DOCTOR OF PHILOSOPHY IN GEOLOGY

BY

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KOHIMA

2005

Ph.D. Regd. No. 89/2000

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CERTIFICATE

This is to certify that Ms. **Kapesa Lokho**, M.Sc., Scientist-'B', Wadia Institute of Himalayan Geology, Dehra Dun, has worked under my supervision on the research work entitled ***"Foraminiferal Biostratigraphy, Paleoecology and the Boundary Events of Paleogene Sediments from parts of Kohima and Phek Districts, Nagaland"***, in the Department of Geology, Nagaland University, Kohima. She has completed the research work for the full period as prescribed under University Ordinances (Clause 9.5 of the Ph.D. Ordinances) and the thesis embodies the results of her investigations conducted during the period she worked as research scholar.

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DECLARATION

I, **Kapesa Lokho**, hereby declare that the thesis entitled ***"Foraminiferal Biostratigraphy, Paleoecology and the Boundary Events of Paleogene Sediments from parts of Kohima and Phek Districts, Nagaland"*** submitted by me for the *Degree of Doctorate of Philosophy* in Geology is a record of research work done by me during September 2000 to June 2005 and that the thesis has not formed the basis for the award of any Degree, Diploma, Associateship, Fellowship or other similar title to me.

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ACKNOWLEDGEMENT

I express my deep sense of gratitude to Dr. R. Venkatachalapathy, Senior Lecturer, Department of Geology, Nagaland University, Kohima for suggesting to me the research problem, giving me invaluable guidance, advices and encouragements and also for the major DST Project entitled "*Biostratigraphy, Paleoecology, Boundary Events and Sea Level Changes of Tertiary Sediments from Nagaland State, India*", through which I initiated my research career.

I am very much grateful to Dr. D. S. N. Raju, ONGC Consultant, KDMIPE, Dehradun who has inspired me with a vast ocean of knowledge, valuable advices, constant guidance and to Mrs. Dr. D. S. N. Raju for all her care and encouragements all throughout my work.

I am also very much indebted to the Heads, Department of Geology, Nagaland University, Kohima- Prof. Glenn Thomas Thong (Present) and Prof. N. Pandey (Former), and the authorities of Nagaland University for providing the necessary facilities available in the Department.

I am thankful to Prof. R. P. Kachhara for his valuable suggestions and discussions during the course of research work. I also thank Dr. B. V. Rao for his encouragements and to all the Faculty members and Non-Teaching Staff of the Department of Geology, Nagaland University, Kohima for their cooperation and help extended in various ways.

I am also grateful to the Directors of the Wadia Institute of Himalayan Geology (WIHG), Dehradun- Dr. B. R. Arora (Present) and Dr. N. S. Virdi (Former) for granting me permission to work for my Doctorate Degree and for providing various facilities available in the Institute and constant encouragements.

I am grateful to Dr. R. J. Azmi (WIHG, Dehra Dun) for carefully going through the manuscript of the thesis and making valuable suggestions. I also thank my senior colleagues at WIHG, Dehradun, especially Dr. N. S. Mathur and Dr. K. P. Juyal for making valuable suggestions and advices.

I sincerely thank Prof. M. S. Srinivasan of BHU, Varanasi for providing me valuable study materials in the course of my research work.

I also express my sincere thanks to Shri P. Ramesh and Shri Prabhakaran, Chief Geologists, KDMIPE, Dehradun for extending their help in identification of some foraminifera and sedimentary analysis.

I am also indebted to the Librarians of WIHG & KDMIPE, Dehradun and the Geological Survey of India, Shillong for their full cooperation and valuable help. Mr N. K. Juyal of WIHG is duly acknowledged for the help extended for SEM photography facilities.

I am also very much indebted to all my friends especially Mr Kezhakielie Whiso, Mr David Lhoupenyi, Mr Temsulemba Walling, Mr Jayajit Lukram, Ms Yanbeni Humtsoe, Ms Chonchibeni Ezung, Ms Abeni Odyuo, Ms Mezhalhouno, Ms Kezhaleno Kirha, Ms Rokokhono Nagi, Mr Merangsoba, Mr Ranjit Nayak and Ms Lolenrenla from Nagaland University, Kohima and Mr Kaihe Kemas, Mr Metenol Angami, Ms G. Martha and Mr Nokmatongba Jamir and Mr Kaprosang Joute (Geologists, ONGC) for the help extended to me in various forms. Dr. Khayingshing Luirie, Dr. Trilochan Singh and Dr. Krishnakanta Singh and Dr. (Mrs.) Mrinalinee Devi of WIHG, NE unit are thanked for their help and support.

Special thanks are duly acknowledged to the Post Graduate (Women) hostellers (Ms Imlinungla Walling, Ms Lanuinla Aier, Ms Throngpila Sangtam and Ms Atokili Achumi) of the Department of Geology, Nagaland University, Kohima for their care and hospitality extended to me during my stay in the hostel during the submission of my thesis.

I sincerely acknowledge the help and valuable time extended to me by Mr Ravi for the computer works.

I acknowledge Mr Kekhrozülo Ritse of Pfutsero for his help and guidance during my many field trips to Pfutsero and its adjoining areas. I also thank the authorities of Pfutsero Guest House and Chetheba Guest House for providing accommodation during the course of my field works. Thanks also goes to the authorities of Sacred Heart School, Chizami, St. Xavier's School, Meluri and St. Andrew's School, Chetheba for rendering help during my field work.

I am also indebted to all my friends at WIHG, Dehradun especially Mr. B. P. Singh, Dr. Indu Pant, Dr. Deepak Joshi, Dr. Jaishree Bhatt, Mr. Senthil Kumar, Mr. Subhijit Sinha, Mr Sandeep Nandeep and Dr. Preety for their help rendered to me in various forms.

The financial support from DST-New Delhi in the initial years of my research work in the form of DST Project Assistant is thankfully acknowledged. Thanks are also due to the Geological Society of India, Bangalore for their encouragement in providing me a "B.L. Rama Rao Research Grant" in the year 2000.

Lastly, I am unable to adequately acknowledge my parents and family members for their support, financial assistance and constant encouragement rendered to me during the course of this work.

Above all I thank the Almighty for His continuous blessings in bringing this work to a successful and satisfying completion.

ABSTRACT

The Disang Group of rocks comprises mainly shale, siltstone and fine-grained sandstone. It is divided into Lower and Upper Disang. The former consists of dark grey shales interbedded with thin bands of grey siltstone or fine-grained sandstone. In general, the frequency and thickness of siltstone/sandstone bands increases towards the top of this group (Upper Disang). The shales are argillaceous and carbonaceous in Lower Disang and more arenaceous in Upper Disang. In few places the shales and silty beds yielded micro-gastropods, bivalves and foraminifers.

The purpose of the present study is to locate the fossiliferous strata, to establish the age of sediments, set a zonal scheme and correlate the same with those of the northeast region, other parts of India and of the world; to discuss the paleoenvironmental set-up of the Disang Group, Nagaland.

To fulfill the above-mentioned objectives, investigations for locating microfossil-bearing horizons were carried out in different areas falling between the latitude 25°30′ and 25°45′ and longitude 94°00′ and 94°45′. These areas are covered in the Survey of India toposheet No. 83 K/2 and No. 83 K/6. They fall under Phek and Kohima Districts. The localities in Phek District yielded a good number of foraminifera while those in Kohima District did not yield fauna.

56 foraminiferal species belonging to 29 genera, 23 families, 17 superfamilies and 5 suborders have been systematically identified. Of the total species, 16 are planktic forms and 40 are benthic forms. Among the planktonic foraminifers *Chiloguembelina cubensis, C. martini, C.* cf. *tenuis, Gobigerinatheka semiinvoluta*, *Hantkenina liebusi, Pseudohastigerina naguewichiensis, Turborotalia cerroazulensis cerroazulensis, Turborotalia cerroazulensis cocoaensis* and *T. c. pomeroli* have been reported for the first time from Nagaland.

In the study area, 3 biozones in Late Eocene are recognized. They are based on the first appearances and last occurrences of marker species (planktic foraminifera) and their ranges. In the present study, the classification proposed by Loeblich and Tappan (1988) is followed. The zones are proposed in accordance with the code of stratigraphic nomenclature of India. The zonation used in the present study is based on Berggren *et al.* (1995). The proposed zonal scheme is primarily intended for the purpose of correlation within Disang Group of Nagaland. At the same time, this planktic foraminiferal zonal scheme for the Upper Disang Group (Late Eocene) helps in correlation with the works of Raju (1971) for Cauvery Basin, South India and

Samanta (1973) for Assam, Northeast India. The correlation is based on the ranges of species of *Globigerinatheka semiinvoluta*, *Cribrohantkenina inflata* and *Turborotalia cerroazulensis* within the regions concerned.

Correlations of planktic foraminiferal zones between the studied sections show that Chobama 1 section has three biozones namely *Globigerinatheka semiinvoluta* Zone (P14), *Cribrohantkenina inflata* Zone (P15) and *Turborotalia cerroazulensis* Zone (P16). Chobama 2 section has no zonal marker. Therefore, no zone has been assigned to it. Chobama 3 section has been assigned two zones, namely *Cribrohantkenina inflata* Zone and *Turborotalia cerroazulensis* Zone

Pfutsero 1 and 2 sections are assigned *Turborotalia cerroazulensis* Zone due to the presence of the zonal marker *Turborotalia cerroazulensis*.

Leshemi section is assigned as Taptian (Priabonian) stage due to the presence of *Hantkenina alabamensis* and no zone is assigned as no zonal marker foraminifera was encountered.

Published data on the stratigraphy of the Disang Group of Nagaland suggested a geosynclinal and/or deep marine set-up but direct evidences of foraminifera and other paleontological and sedimentological data have not been documented so far. The present study on Uvigerinids and smaller benthic foraminifera from the south-central part of Nagaland (around Pfutsero), planktic foraminifera and published data from outcrops from the Western and Northern part suggest:

1) Inner shelf facies at Tehai Reu Section and Lotsu Village ection in the western part based on reported occurrence of *Pellastispira, Nummulites* and *Discocyclina*.
2) Middle to outer shelf set-up by an association of larger benthic and planktic foraminifera and some Uvigerinids (*U.* cf. *jacksonensis*) from a locality of Heina Reu section.
3) Lower part of upper bathyal set-up for the localities of Pfutsero 1 & 2, Chobama and Leshemi, supported by dominant *Uvigerina* facies consisting *Uvigerina cocoaensis, U. continuosa, U.* cf. *eocaena, U. glabrans, U. jacksonensis, U. longa, U. moravia, U.* cf. *steyeri and U. vicksburgensis*. In the absence of fauna on the level above the *Turborotalia cerroazulensis* Zone in the study area and elsewhere in Nagaland, we are unable to establish Eocene-Oligocene boundary.

SIGNIFICANCE OF PRESENT STUDY

1) (a) Confirms a deeper marine (lower part of upper bathyal) environmental set-up for the Upper Disang Group of central part of Nagaland at Leshemi section, Chobama 1, 2, 3 sections, Pfutsero 1 and Pfutsero 2 sections. Presence of abundant Miliolids and some *Nummulites pengaronensis* and *Nummulites chavanennsi* in association with *Osangularia* sp., *Cyclammina* sp. and *Uvigerina jacksonensis* at Leshemi section suggest that the larger foraminifera along with microgastropods from lagoonal- shallow marine was transported to bathyal condition. Studies by Raju *et al.* (1996) on morphological variation of Uvigerinids along Bay of Bengal support a paleobathymetry deeper than 350m.

(b) Shallow marine conditions during Late Eocene in western part of Nagaland at Champang, Chumukedima and Tynyphe wells, Heningkunglwa and Lotsu indicate paleo-shelf edge/margin is along a belt in western Nagaland.

2) Haq *et al.* (1988) suggested a global drop of sea-level around 80m during Late Eocene. The deeper part of upper bathyal set up during Disang was due to rapid subsidence.

3) The foraminiferal criteria employed to infer anoxic conditions are based on the approach of a paleontologists by the name of Robertson Reuach (see Chandra *et al.*, 1993). The criteria pertinent to our study are:

i) localized occurrence of thick "Uvigerinids";

ii) presence of pteropods and,

iii) pyritised tests.

4) Very high percentage of Uvigerinids with pyritised tests indicate anoxic conditions, suggesting of possible source rocks.

5) Although local/regional variations are known, some of the species of Uvigerinids from Nagaland support open sea connection but had a restricted circulation at times to deep marine.

6) Confirms Late Eocene age for the Upper Disangs from the present work with the findings of Late Eocene markers of *Cribrohantkenina inflata*, *Globigerinatheka semiinvoluta* and *Turborotalia cerroazulensis*.

CHAPTER 1

INTRODUCTION

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1.1 INTRODUCTION

The State of Nagaland is located in the northeastern part of India and has a mountainous topography. It is bounded by Assam in the west, Arunachal Pradesh in the north, Manipur in the south and by Myanmar in the east. It lies between 25°60′ and 27°40′ latitudes north of the equator and between the longitudinal lines E 93°20′ and E 95°15′ having an area of 16,579 sq. km.

The geological setting and stratigraphy of this area matches in its broad aspects with that of Upper Assam. Except the alluvial plains, Ophiolite and metamorphic complexes occurring along the Indo-Myanmar border, the whole area within Nagaland is occupied by Tertiary sediments. The Tertiary sediments occur in the Central flysch zone and the Schuppen Belt. The Schuppen Belt, a highly thrusted zone is known for harboring oil and gas. The famous Digboi oil field is located within the Tertiary succession of the northeastern extremity of the Naga Hills. The presence of oil and gas in Champang and near Chumukedima in Nagaland was located by ONGC and exploration was on for a short period.

The Tertiary succession of Assam, Kutch, Cambay and Cauvery Basins has been the subject of detailed studies in view of rich oil fields found in these areas, whereas the studies pertaining to Tertiary sediments of Nagaland have received scanty attention. It may be because of the remoteness of the area and also by other factors like road, transport etc.

1.2 PHYSIOGRAPHY AND CLIMATE

The state has a picturesque landscape endowed with an enchanting landscape of green hills, valleys and rivers flowing along deep gorges. A rugged mountainous terrain characterizes most parts of the state. The Barail range in the southwest and the Patkai range in the north are the two major mountain ranges in the state. The Patkai range boasts of Mt. Saramati (3840m above MSL) which is the highest mountain peak in the state. The ridges usually trend NE-SW. The Barail range enters the state at the SW corner and runs in a northeasterly direction almost up to Kohima. Japfu peak (3015m above MSL) located southwest of Kohima town is the highest point in the Barail range. The Barail range forms the watershed of the state, while the Patkai range forms the watershed in the easternmost part of the state bordering Myanmar. Most of the rivers emerging from these ranges drain into the Brahmaputra, except the Barak and Tizu, which drain into the Chindwin in Myanmar. The major rivers in the state are Dhansiri, Doyang, Dikhu, Tizit and Tizu.

Kohima district is basically a hilly region occupying the south-west part of the state. The town of Kohima, which is also the headquarters of the state, is located at a height of 1444.12m above MSL. It is 74 km southeast of the nearest railway station and airport of the state, which are located in Dimapur District. The exotic Dzukou Valley in the south of the district is one of the most picturesque places in the state.

Phek, one of the eleven districts of the state, lies in the south and southeastern part of the state. It forms part of the Patkai range with roughly N-E trending ridges. Pfutsero, the highest town in the state, elevated at a height of 2133m above MSL is an important town of the district. Laniye, Tizu and Sidzu are the main rivers in the district. Kaku, Kheli and Thiza are the other streams/rivers that discharge their load to Laniye and Sedzu.

The climate of the state is typical of subtropical with rather heavy rainfall. The maximum temperature during summer is 31° C and minimum is 16° C. During winter, maximum temperature is 24° C and minimum is 2° C. The monsoon starts from mid-May with an average rainfall of about 240cm.

1.3 LOCATION AND ACCESSIBILITY

The present investigation deals with the foraminiferal biostratigraphy, paleoecology and the boundary events of the Paleogene sediments of Nagaland. The present area of study is located in the extreme south of Nagaland state bordering the state of Manipur. It lies between latitude 25°30′ and 25°45′ and longitude 94°00′ and 94°45′ in the Survey of India toposheet No. 83 K/2 and No. 83 K/6 (Fig 1.1). Pfutsero, the sub-divisional headquarter of Phek district is 70 km from state capital Kohima and is about 150 km from the nearest railway station, which is at Dimapur, and it is about 144 km from the District Headquarter Phek. For the present study the samples have been collected from different localities at Khulazu Bawe, Khulazu Basa, Phesachodu, Chobama, Zamei, Pfutsero, Pfutseromi, Glory Peak, Mesulumi, Chizami, Meluri of Phek District and Jotsoma, Kohima, New Secretariat Complex, Lalmati, Zubza, Pherima, Kigwema and Jakhama of Kohima District. The localities in Phek District yield a good number of foraminifera, whereas the locations in Kohima District are not yielding

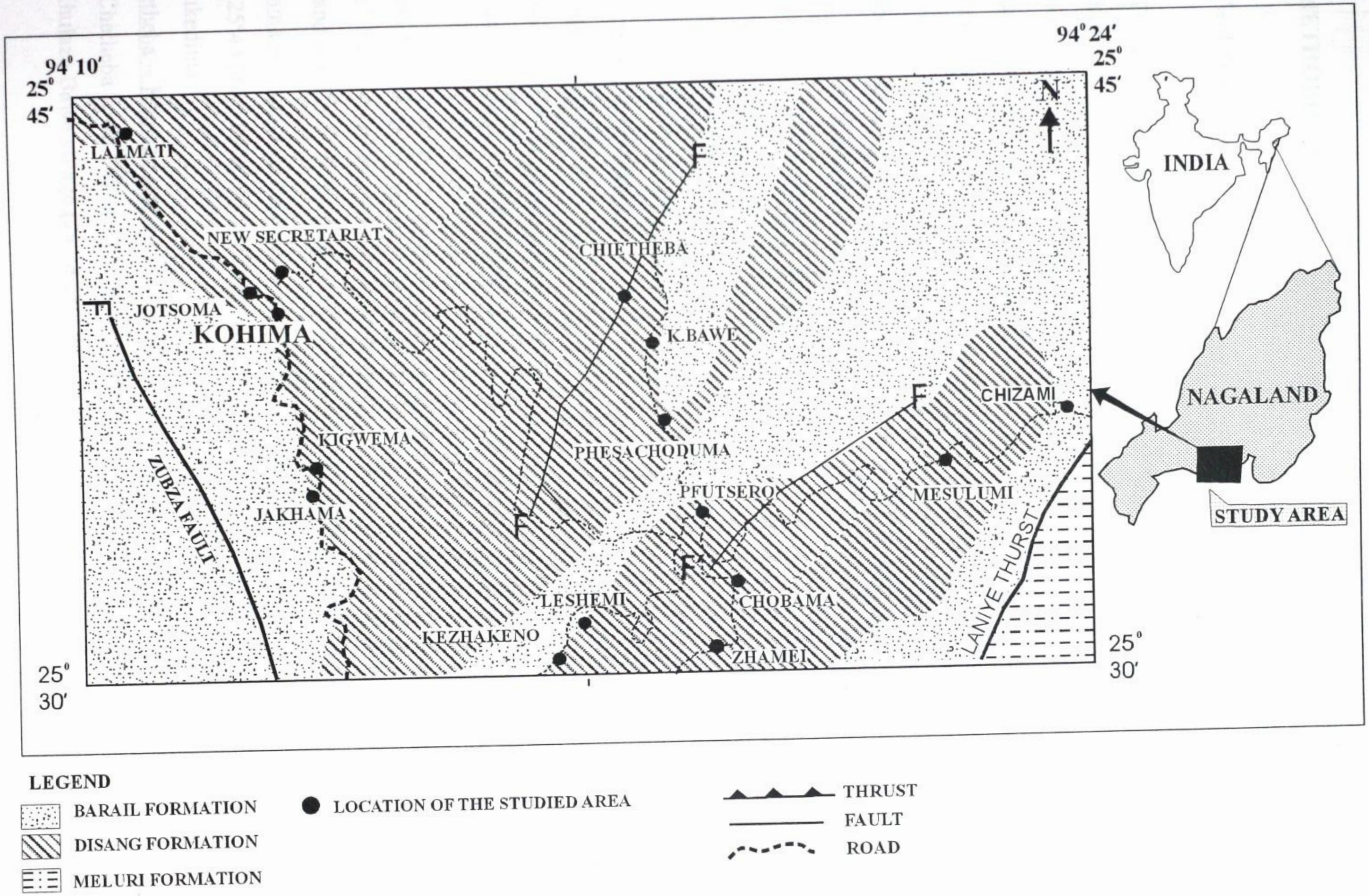

FIGURE 1.1 **LOCATION MAP OF THE STUDY AREA**

fauna. Hence, study has been concentrated in the fossiliferous localities of Phek District. Most of the study areas in and around Pfutsero are accessible by unmetalled road.

1.4 METHODOLOGY

1.4.1 Field Work

The geological maps prepared by Geological Survey of India, Oil and Natural Gas Commission and Directorate of Geology and Mining of Nagaland formed the basis for sample collections. Samples were collected from various litho-units and concentration was made in collecting samples from calcareous shales, siltstones, black shales and thin parting of claystone and also the sediments containing mega fossils. Very close and systematic sampling has been carried out to establish the stratigraphy of the sedimentary sequence. The standard micropaleontological techniques were adopted in the collection of samples. Very close sampling of 10-30 cm gap was carried out in the field. A total of about 500 samples were collected and studied from 10-11 sections.

Based on the absence or presence of foraminifera, the sections studied were broadly classified into two categories. They are:

A) Sections without Foraminifera

1) Kohima – Kigwema – Jakhama: Random spot sampling was carried out in this section, which lies along the Kohima-Imphal road on the National Highway No. 39. The bearings of these areas are as follows-Kigwema village (25°36′08″), Jakhama village (25°35′39″, 94°3′ 33″).

2) In an around Kohima town: Samples were collected near Naga Students' Federation Martyrs' Park (25°39′23″, 94°6′11″), along the Kohima Science College road (25°40′11″, 94° 4′33″) and at the New Secretariat site (25°42′24″, 94°6′31″) and processed.

3) Kohima – Chumukedima section: Random spot sample collection was carried out at Lalmati cliff (25°44′08″, 94°00′48″), Pherima village and near the Patkai Christian College, Chumukedima.

4) Chetheba – Khulazu Bawe - Phesachodu section: A traverse was made along the road that links Chetheba town (25°40′13″, 94°16′ 08″) and Pfutsero town and samples were collected near Khulazu Bawe village (25°38′28″, 94°16′56″).

5) Pfutsero – Meslumi - Yoseba – Chizami section: A traverse along the state highway (Phek road) was made from Chizami to Pfutsero via Yoseba and Mesulumi. Samples were collected from every possible exposure and processed.

6) Meluri - Akhegwo section: A traverse of 12 km was taken from Meluri town (N 25° 41'23″ and E 94°38′18″) towards Akhegwo. Samples of siltstone and shale were collected and processed.

B) Sections with foraminifera

1) Pfutsero 1 section: This section is along the state highway that links Kohima with Pfutsero town. It is located about 200 m from Pfutseromi Village gate towards Pfutsero town. The section bears Latitude 25°34′03″ and Longitude 94°17′43″.

2) Pfutsero 2 section: This section is located about 2 kms from Pfutsero town towards Phek and lies opposite to Rikuzu colony. The bearings of this section are as follows: Latitude 25°34′02″, Longitude 94°18′23″.

3) Leshemi Village section: This section lies above the village of Leshemi on the road towards Khezhakeno village. The bearings of this section are: Latitude 25°32′10″, Longitude 94°14′05″.

4) Chobama 1 and 2 fault section: The Chobama 1and 2 sections are separated by a local fault and is about 100 m from Chobama 3 section toward Chobama village. This section bears Latitude 25°33′43″and Longitude 94°19′27″.

5) Chobama 3 apple tree section: This section is located along the road that links Pfutsero and Zamai Village. It is two kms from Chobama village towards Pfustero. The bearings of this section are: Latitude 25°33′42″ and Longitude 94°19′27″.

1.4.2 Laboratory Work

Standard micropaleontological techniques were adopted in the processing and preparation of the samples. A precise methodology of the laboratory works engaged in studying foraminifers is given below:

1) 50 gm weight of each sample was processed. Weighing was done using a digital balance of Aman Scales (P) Limited.

2) Hydrogen peroxide (H_2O_2) and Ammonium solution (NH_4) were used for the disintegration of the samples, which were soaked from a few hours to overnight depending on the state of compaction of the sediments.
3) Disintegrated samples were washed using sieve of ASTM 230 and dried in a Hot Air Oven.
4) Sieving was carried out using ASTM mesh nos. 20, 40, 60,100,120.
5) Picking of foraminifera from processed samples was carried out using Stereozoom microscope (Leica $MZ7_5$). Photographs of the specimens were taken using a Scanning Electron Microscope (Phillips).
6) Taxonomic and morphological study of foraminifera was carried out using stereozoom microscope.
7) Taxonomy and species description of planktic and benthic foraminifera were described referring Loeblich and Tappan (1988), Bolli *et al.* (1986), Catalogue of Foraminifera by Ellis *et al.* (1940), Boersma (1985), Zwaan *et a*l. (1986) and other selected references.
8) The abundance of foraminifera is expressed as; rare (5 specimens or less), few (6 to 10 specimens) and common (11 and above specimens).
9) The illustrated foraminiferal species are deposited in Wadia Institute of Himalayan Geology, Dehradun.

1.5 SCOPE OF THE PRESENT WORK

During the course of mapping in Nagaland, the workers of GSI and ONGC reported few fossiliferous horizons from Disang and Barail Groups. They stressed the need for the systematic sampling in this area to establish a detailed biostratigraphy based on microfossils. A survey of literature, field and laboratory observations by Dr. R. Venkatachalapathy (Supervisor) shows the possibility of locating many more fossil (microfossil) bearing horizons in parts of Nagaland. The absence or rarity of megafossils in some horizons has underscored the need for an alternative, if complementary, zonal scheme based on microfossils which are numerous, recurrent and can be recovered with equal facility from surface and subsurface sections. Foraminifers are ideal tool to meet such requirements.

Foraminifers are globally used for biostratigraphic subdivision and correlation of sedimentary strata. A limited work on planktic foraminiferal biostratigraphy of Nagaland has been carried out in some parts of the state on surface and subsurface (Sinha and Chatterjee, 1982, Singh *et al.*, 1986, Baruah *et al.*, 1987 and Bhatia and Dave, 1996). Though the benthic foraminifera are good indicators of paleoenvironment, so far, in this area, paleoenvironmental significance has not been satisfactorily studied. The present research work is therefore, made to carry out the detailed investigation on the occurrence of foraminifera, leading to the detailed biostratigraphy, paleoecology and the boundary events of the Paleogene sediments of Nagaland.

1.6 PREVIOUS WORK

A survey of literature reveals that considerable amount of work has been done on foraminifera and on other microfossils of Tertiary rocks of Assam, Kutch, Cambay, Cauvery Basin and also in Northwestern Himalayas. However, no significant work on microfauna has been carried out in Nagaland. It may be because of the remoteness of this area and by other factors like road and transport etc. Before dealing with the present investigation it would be desirable to give a chronological review of the work done by previous workers. The stratigraphy of Nagaland has been worked by the Geologists of the Geological Survey of India, Directorate of Geology and Mining, Nagaland and Oil and Natural Gas Corporation Limited.

Detailed foraminiferal biostratigraphy of the Barail and Disang Groups of all the tectonic blocks of Nagaland has not been carried out so far perhaps due to difficulty in accessibility.

Mallet (1876) was the first to work on Disang rocks on account of the coalfields of the Naga Hills and first named it as Disang series. He proposed the name Disang Group for dark grey shales and minor sandstones exposed along Disang (Dilli) river section (23°5′ N: 95°23′ E). Later Oldham (1883) correlated the Disang with Axials of Arakan Yoma. Maclaren (1904) followed by Pascoe (1912) considered that the 'bulk of the Disangs has more in common with the Negrais bed of Arakan Yoma'.

Hayden (1910) suggested that the Disangs may be made up of great flysch formation and might extend up even into the Tertiary. Based on the reported find of an *Ammonite* by Hayden, the Disangs may range in age from Cretaceous to Middle Eocene (Evans, 1932). Subsequently, Evans (1932) found *Nummulites* and opined 'that Disangs will eventually be shown to be a more altered and practically unfossiliferous equivalent of the Laungshe shales of Burma', which are believed to range from Paleocene to Eocene. He further described Disang shales as 'very like those of Kopili Formation' and suggested that the Disangs include a deeper water facies of the Jaintia Group and perhaps lower horizons equivalent to Ranikot , Laki and Kirthar and possibly the upper most Cretaceous.

Since the inception of biostratigraphy work nearly a century ago, only a few selected sections and a few deep wells have been studied in Nagaland.

The previous workers mainly reported the occurrence of foraminifera (except Baruah *et al.*, 1986 & Bhatia *et al.*, 1996) from various parts of Nagaland. As the biostratigraphy data published by few authors particularly with reference to paleoenvironment is different, the present study presents a detail work of each of the previous work in detail according to different parts of Nagaland.

NORTH NAGALAND:

Location: North of Damchara

Nagappa (1959) recorded smaller arenaceous foraminifera *Ammobaculites* sp. *Ammodiscus* sp., *Bathysiphon* sp., *Cyclammina* sp., *Gaudryina* sp. and *Haplophragmoides* sp. from the topmost bed of the Disang Group exposed at a locality, north of Damchara, suggesting deposition under shallow marine environment.

Location: Changtongka

Micropaleontological studies carried out by Sinha (1974), have yielded reticulate *Nummulites* in Disang Group exposed at Changtongka (GSI, vol. 112, 1982). Reticulate *Nummulites* range from late Middle Eocene to Early Oligocene, but exact age cannot be given without specific identification.

Location: Champang well

Borholla field extends eastwards below the Naga thrust and that part of the structure in Nagaland is designated as Champang field (Rao and Prasad, 1982). The oil and gas pools at Champang field are in basement, Basal Sandstone, Sylhet and Kopili units and also in Tipam.

According to Singh *et al.* (1986) in Champang well the representative core samples from Basal Sandstone unit have not yielded foraminifera (Fig. 1.2). Hence, considering the unfossiliferous nature of the sediments and lithological association, deposition of this unit seems to have taken place in fluvial condition. The fossiliferous Sylhet Formation and lower part of the Kopili Formation seem to have been deposited in an open marine environment. In the upper part of Kopili Formation, the larger benthonic foraminifers are eliminated and in turn are taken over by smaller benthonic foraminifer.

A gradual reduction of foraminiferal assemblage is observed in this well, which indicates considerable shallowing of the sea and deposition in marginal marine environment towards the Kopili-Barail boundary the calcareous benthonic foraminifera totally disappear and a sharp reduction of faunal population is observed, suggesting setting in of regressive phase and deposition under brackish water environment.

Biostratigraphy of this well was built and published by Bhatia and Dave in 1996. The litho-column, faunal frequency, stratigraphic unit, biozones, age and paleoecology as given by Bhatia and Dave is reproduced here. There are four biozones. These are described in detail from younger to older in order as follows:

1) Barren zone: The dark grey splintery shale sequence of the upper part of Kopili Formation and the Barail Group of sandstone are devoid of foraminifera. The zone conformably overlies *N.* cf. *N. wemmellensis* Zone of Late Eocene without any sedimentation break, besides the palynofloral assemblage of Late Eocene age has been recorded from this interval. Hence, Late Eocene age has been assigned to this zone.

2) *N.* cf. *W. wemmellensis* Zone: This zone has been recorded in lower to middle part of Kopili Formation and lies above the *N. discorbinus-Assilina* sp. Zone. Discontinuance occurrence of foraminifera is noticed on the top part of the zone. In this zone, *Nummulite* sp. A occurs commonly. Ostracodes, *N.* cf. *N. wemmellensis, Quinqueloculina* sp. are infrequent and microgastropods, *Operculina* sp, *Rotalia* sp., *Elphidium* sp. and *Cibicides* sp. are rare.

3) *N. discorbinus-Assilina* sp. Zone: This zone has been recognized in upper part of Sylhet Formation. It conformably overlies *N. acutus* Zone. The top of the zone is marked by the discontinuance of *N. pengaronensis, N. discorbinus, Nummulites sp.* B, *A. praespira* and

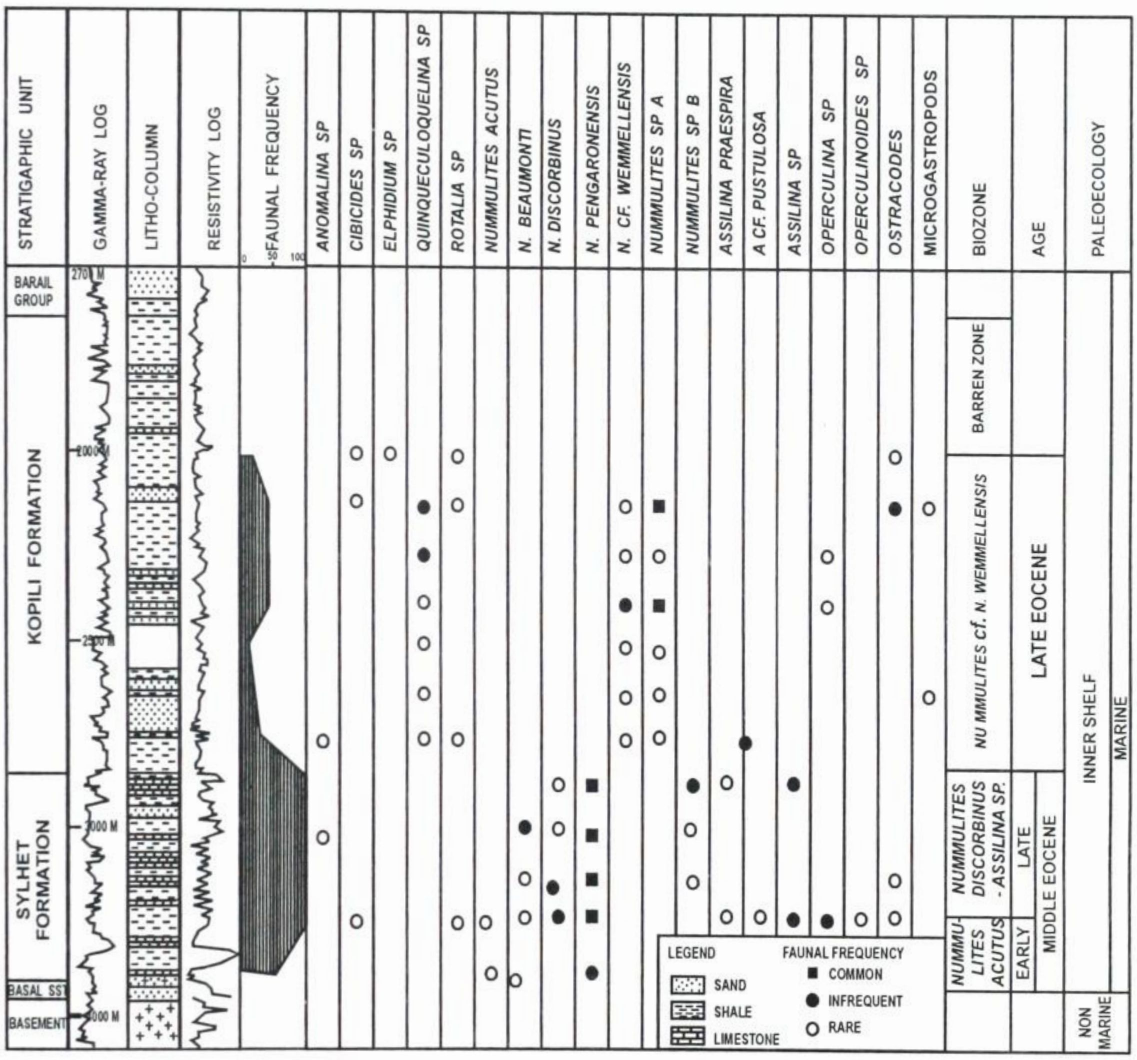

Figure 1.2 **Faunal Distribution, Age and Paleoecology of Champang Well.** (After Singh et al., 1986)

Assilina sp. B, *A. praespira* and *Assilina* sp. In this zone, occurrence of *N. pengaronsis* is common and *Assilina* sp., *Nummulites* sp. B, *N. discorbinus, N. beaumonti* infrequently occurs. Ostracodes, *A. praespira* and *Anomalina* sp. are rare. The foraminiferal assemblage recorded in this zone, indicates a late Middle Eocene age.

4) *Nummulites acutus* Zone: This zone lies in the lower part of Sylhet Formation unconformably overlying the basal sandstone. The base of the zone is marked by the first appearance of *N. Pengaronensis*, *N. beaumonti* and *N. acutus*. In this assemblage zone , presence of rare ostracodes, *Operculinoids* sp. *A.* cf. *pustulosa, A. praespira*, *N. beaumonti, N. acutus, Rotalia* sp., *Cibicides* sp., infrequent occurrence of *Operculina* sp., *Assilina* sp., *N. discorbinus* sp. and common occurrence of *N. pengaronesis* is recorded. The foraminiferal assemblage recorded in this zone indicates early Middle Eocene age.

SOUTH-WEST NAGALAND:

Location: Chumukedima well

It is a part of Dhansiri valley and lies in the South west of Nagaland. The thickness of the Paleogene sequence is considerably reduced in the northeastern part of Dhansiri valley at Barpathar, where it unconformably overlies the Gondwanas. However, it attains maximum thickness at Chumukedima, suggesting a basinal slope towards Southwest (Bhatia and Dave, 1996) as in shown in Figure 1.3.

The detail biostratigraphy of this well studied by Bhatia and Dave (1996) is discussed below. The Formations encountered here are; Basal Sandstone, Sylhet, Kopili and Barail Group. Bhatia and Dave recognized five 5 biozones, which are described in detailed from top to bottom.

1) Poorly fossiliferous Zone: This zone is represented at the depth of between 3700m and 4015m. It conformably overlies the *N. pengaronensis Zone*. The foraminiferal assemblage of upper Kopili consists of rare occurrence of arenaceous foraminifers, *Trochammina* sp., *Haplophragmoides* sp., *Osangularia* sp., *Rotalia* sp., *Nummulites* sp. and common occurrence of *Operculina* sp. The upper part of Barail Group in this well is devoid of foraminifera. No age is assigned to this zone.

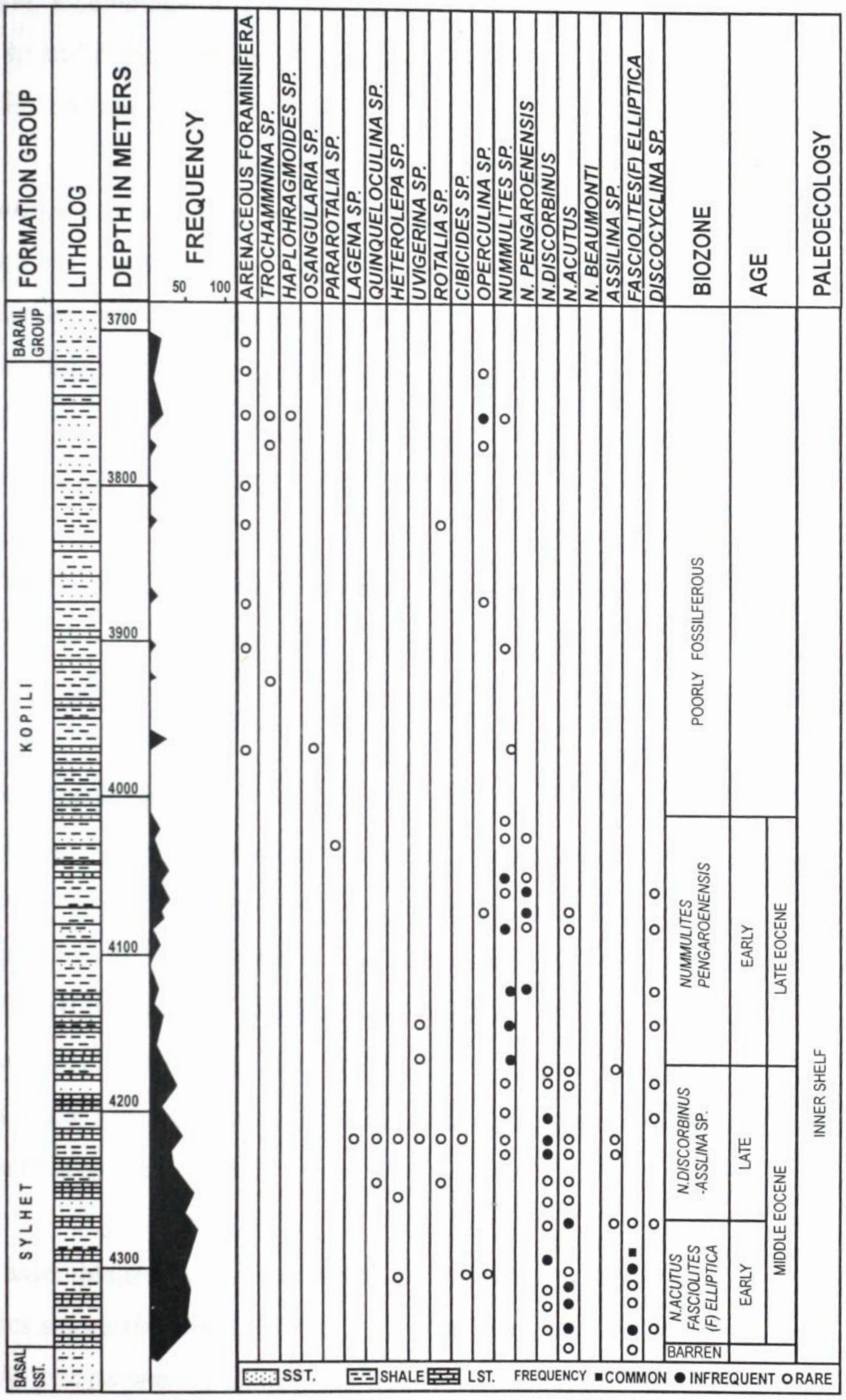

Figure 1.3 Biostratigraphy of the Pre-Barail Sequence in Chumukedima Well
(After Singh et al., 1986 and Bhatia & Dave, 1996)

2) *N. pengaronensis* Zone: This zone is marked by the common occurrence of *Nummulites* sp. The zone is characterized by the dominance of *N. pengaronensis.* The other rare occurrence of foraminiferal assemblage is *Discocyclina* sp., *Assilina* sp., *N. acutus* sp., *Operculina* sp., *Uvigerina* sp and *Pararotalia* sp. The occurrence of *N. Pengaronensis* in this zone suggests an early Late Eocene age.

3) *N. discorbinus-Assilina* sp. Zone: The assemblage recorded from this zone includes rare *Discocyclina* sp., *Assilina* sp., *N. acutus*, *Cibicides* sp., *Rotalia* sp., *Uvigerina* sp., *Heterolepa* sp., *Quinqueloculina* sp., *Lagena* sp. and common occurrence of *N. discorbinus.* A gradual reduction of fauna towards the top of this zone is observed. At Chumukedima well, this zone is recorded from the upper part of Sylhet Formation where it overlies the *N. actus-F. elliptica* Zone. This zone is assigned as late Middle Eocene.

4) *N. acutus-F. elliptica* Zone: This zone is characterized by the first appearance of *F. elliptica* and *N. acutus* at the base. *Discocyclina* sp., *Assilina* sp., *Operculina* sp., *Cibicides* sp., *Heterolepa* sp. occurs rarely. Of common occurrence are *F. elliptica*, *N. acutus* and *N. discorbinus*. Due to the presence of *F. elliptica* (Madan Mohan, 1972), this zone is assigned early Middle Eocene age.

The Basal Sandstone which unconformable overlies the basement has been found to be unfossiliferous. The lithological association along with the occurrence of palynofossils suggests deposition in fluvial environment. The overlying Sylhet and Kopili Formations have yielded rich assemblage of larger benthic foraminifera comprising *Nummulites* sp., *Discocyclina* sp and *Assilina* sp. along with smaller benthics. The occurrence of larger benthic foraminifera in the lower part of Sylhet Formation indicates the initiation of Paleogene marine transgression (Singh *et al*., 1986).

The assemblage zone of *N. acutus-F. elliptica* is characterized by an abundance of larger benthics suggesting deposition in inner shelf environment. Further upward, in the Kopili Formation (*N. pengaronensis* Zone), the frequency of larger foraminifera is again increased, indicating a shallowing of sea and the deposition in inner shelf environment. The transition from Kopili to Barail is marked by the elimination of calcareous benthics and sporadic presence of arenaceous foraminifera. This indicates setting in of regressive phase and the deposition of Barails in brackish water environment.

Location: Tynyphe well

This well lies in the South West of Nagaland. The section given by Bhatia and Dave (1996) showing lithology, faunal distribution, age and paleoecology is shown in Fig. 1.4.

The three biozones of this well are described in detail from top to bottom.

1) Poorly fossiliferous Zone: The poorly fossiliferous zone in Tynyphe well is represented between 3270m and 3800m. This zone is characterized by rare occurrence of *Trochammina* sp., *Cyclammina* sp., and *Ammodiscus* sp. Since this zone unconformably overlies the *N. pengaronensis* Zone of Late Eocene age without a sedimentation break and some of the arenaceous foraminiferal species recorded from this zone extend up into the Barail Group of Oligocene age, this zone is assigned as Late Eocene to Oligocene. The upper part of Barail Group of this well is devoid of foraminifera.

2) *N. pengaronensis* Zone: The dominance of *N. pengaronensis* characterizes this zone. The foraminiferal assemblage of this zone includes rare *Cyclammina* sp., arenaceous foraminifera, *Cibicides* sp., *Quinqueloculina* sp., *Operculina* sp., *Discocyclina* sp., *N. acutus* and common occurrence of *N. pengaronensis* and *Nummulites* sp. Age: The occurrence of *N. pengaronensis* suggests an early Late Eocene age for this zone.

3) N. *acutus*- *F. elliptica* Zone: The base of this zone is marked by the first occurrence level of larger benthics and the top is marked by the disappearance of *F. elliptica, A. praespira* and *N. discorbinus.* The foraminiferal assemblage of this zone are rare occurrence of *Quinqueloculina* sp, *Operculina* sp, *Assilina* sp, *A. praespira,* infrequent occurrence of *Discocyclina* sp, *A. praespira, N. Pengaronensis, N. discorbinus, N. beaumonti* and common occurrence of *Nummulites* sp., *N. acutus and F. elliptica.*

The basal Tura Sandstone unconformably overlying the basement has been found unfossiliferous. The overlying Sylhet and Kopili Formations have yielded good assemblage of

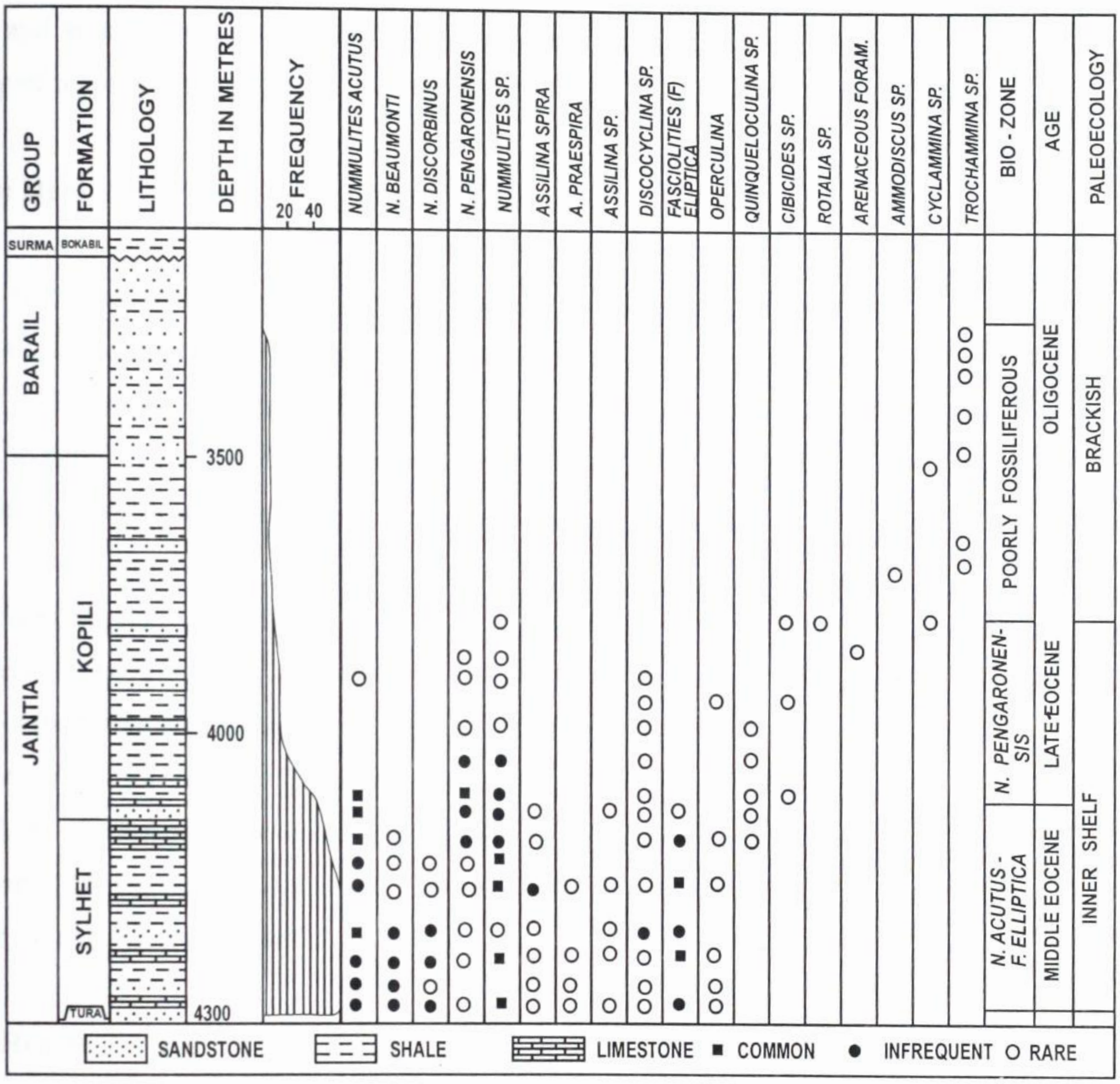

Figure 1.4 **Faunal distribution, age and paleoecology in Tynyphe well**
(After Bhatia, M.L. and Dave, Alok, 1996)

larger benthic foraminifera comprising *N. discorbinus, N. acutus, N. beaumonti, N. discorbinus, N. pengaronensis, Nummulites* sp. *Discocyclina sp* and *F. elliptica* indicating the initiation of Paleogene marine transgression and deposition in inner shelf environment.

The transition from Kopili to Barail is marked by the elimination of calcareous benthics and sporadic presence of *Trochammina* sp, *Cyclammina* sp, and *Ammodiscus* sp. indicating of regressive phase and the deposition of Barails in brackish water environment.

Location: Heningkunglwa (Southwest of Dimapur)

A rich foraminiferal assemblage has been recorded by Baruah et al. (1987) from an argillaceous sequence (Fig. 1.5) outcropping near Heningkunglwa village (N 93°47'2": E 25°31'41"). The study of Baruah et al. showing the litho columns, faunal distribution is discussed in detail. The foraminiferal assemblages recorded by them in the Disang rocks near Heningkunglwa are reproduced below section wise (from i through iii).

1) Tehai Reu Section: The siltstone sequence in this section contains mostly larger benthic foraminifera. *Nummulites sp., Discocyclina sp.* and *Pellatispira* sp. are common, whereas planktic foraminifers are rare and poorly preserved. The important larger foraminifera are *N. pengaronensis* (Verbeek), *N. discorbinus* (Schlotheim), *D. dispansa* (Sowerby), *D. eamesi* (Samanta), *P. madaraszi* (Hantken) and *P. inflata* (Umbgrove). The planktic foraminifera are *H. alabamensis* Cushman, *Globorotalia centralis* Cushman and Bermudez, *G. cerroazulensis* (Cole) and *G. ampliapertura* (Bolli).

2) Heina Reu Section: A rich planktic foraminiferal assemblage has been recovered from dark grey splintery shales. Only few species of larger foraminifera are found, which include *Nummulites* and *Pellatispira.* Planktic foraminifers include *G. pseudoampliapertura* Blow and Banner, *G. yeguaensis* Weinzierl and Applin, *G. tripartita* Koch, *G. ouchitaensis* Home and Wallace, *G. cerroazulensis* (Cole) *G. centralis* (Cushman and Bermudez), *G. increbescens* (Bandy), *G. insolita* (Jenkins), *H. alabamensis* (Cushman) *C. inflata* (Howe) and *P. barbadoensis* (Blow). Few smaller benthic foraminifera viz. *Uvigerina* sp., *Marginulina* sp., *Cibicides* sp., *Dentalina* sp., *Bulimina* sp. and a few corals have been reported.

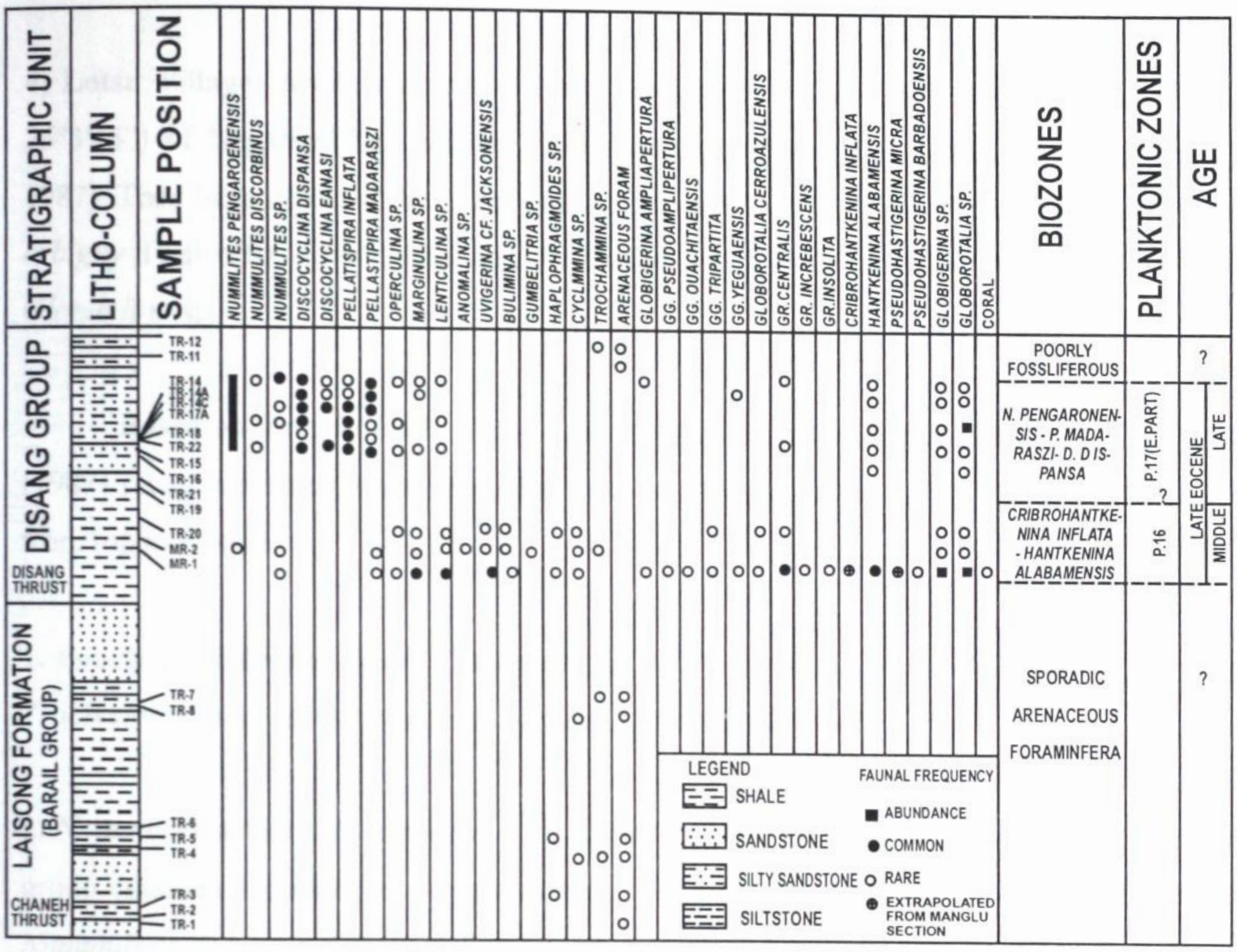

Figure 1.5 **Faunal distribution and Biozones of Tehai - Heina nala section** (After Baruah *et al.*, 1986)

3) Manglu River Section: In this section, a rich planktic foraminiferal assemblage has been reported from dark grey silty shales but there is no report of larger foraminifera. The assemblage is similar to that of Heina Reu section except for the common occurrence of *C. inflata* and absence of *P. barbadoensis*.

4) Lotsu Village: Another outcrop of silty sandstone, exposed near Lotsu village (94°5'25": 26°3'45") of Nagaland has yielded similar larger foraminiferal assemblage (Baruah *et al.*, 1987). They have reported the larger benthic foraminifera of *P. madaraszi*, *Nummulites* sp. *N. orbigny* (Galeotti), *Operculina* sp., *Cibicides* sp., *Quinqueloculina* sp., *Lagena* sp. and *Glandulina* sp.

Based on foraminiferal assemblages recorded in the above four sections, Baruah et al. (1987) recognized four zones including two assemblage zones. These are reproduced below from top to bottom:

1. Poorly fossiliferous Zone: The upper part of Disang Group consists of rare occurrence of *Trochammina* sp., arenaceous foraminifera. Age is not assigned.

2. *N. pengaronensis* – *P. madraszi* – *D. dispansa* Zone: The middle and lower part of Disang group contains abundant *N. pengaronensis, P. inflata, P. madraszi,* common occurrence of *Nummulites* sp., *D. dispansa, D. eamesi* and *Globorotalia* sp. and rare occurrence of *N. discorbinus, Operculina* sp., *Marginulina* sp., *Lenticulina* sp., *G. amplipertura, G. yeguaensis, G. centralis, H. alabamensis* and *Globigerina* sp. The foraminiferal assemblage indicates Late Eocene age for this zone.

3. *C. inflata* – *H. alabamensis* Zone: This zone is recognized on the basis of the occurrence of *C. inflata* and *H. alabamensis* on the lower boundary and the upper limit is delineated on the basis of poor frequency of planktic foraminifera. The other foraminifers include an abundant occurrence of *Globorotalia* sp. and *Globigerina* sp. and common occurrence of *Gr. centralis, Uvigerina* cf. *jacksonensis, Lenticulina* sp. and *Marginulina* sp. and rare occurrence of coral, *P.barbadoensis, H. alabamensis, Gr. insolita, Gr. increbescens, G. cerroazulensis, GG. yeguaensis, GG tripartita, GG ouachitaeensis, GG. amplipertura, G. amplipertura, Trochammina* sp., *Cyclammina sp., Haplophragmoides sp., Gumbelitria sp., Bulimina* sp., *Anomalina* sp., *Operculina* sp., *P. madraszi* and *N. pengaronensis*. They assigned middle part of Late Eocene age to this zone.

4. Sporadic arenaceous foraminiferal Zone: This zone is confined to Laisong Formation (Barail Group). Foraminiferal assemblage in this zone includes a sporadic occurrence of arenaceous foraminifera, *Trochammina* sp., *Cyclammina* sp. and *Haplophragmoides* sp. Age is not assigned to this zone.

The paleoecology of Disang and Barail Groups studied by Baurah et al. is reproduced here. The foraminiferal assemblage recorded from the Disang and Barail Group represents deposition in shallow marine environment with oscillations in bathymetry. Heina Reu and Manglu sections are rich in planktic foraminiferal assemblage with *Uvigerina* sp. and *Bulimmina* sp., corresponding to middle to outer shelf zones and indicating bathymetry between 100 to 150m. Scanty occurrence of arenaceous foraminiferal assemblage on top part of Disang Group and in Barail Group suggests a brackish water environment of deposition.

Location: Manglu River, Tehai Heina Reu and Lotsu village

Singh and Rao (1998) reported the occurrence of foraminifera from Manglu River, Tehai Heina Reu and Lotsu village sections of Nagaland and Homo Nala section of Assam. The samples have yielded a rich microfaunal assemblage, which includes both planktic and benthic foraminifera. The larger foraminifera constitute the dominant element of the fauna and are widely distributed in the area. The detailed study of the assemblage led to recognition of thirteen species of the genera *Biplanispira, Pellatispira, Nummulites, Discocyclina* and *Heterostegina.*

The rich presence of *Biplanispira mirabils* (Umbgrove), a rare occurring species, in the above assemblage was noted to be interesting. Based on larger benthic foraminifera *N. pengaronensis- P. madaraszi* biozone has been recognized out of the above assemblage which could be dated Middle – Late Eocene equivalent to Zone P16 on planktic scale.

Location: South East Nagaland

Sinha *et al*. (1982) recorded the occurrence of *Nummulites* sp. and *Dictyoconoides* sp. from the Disang Group of rocks exposed around Pfutsero and Meluri in Phek districts.

The list of fossils reported are Bivalves: *Barbatia* sp., *Corbula* sp., *Nemocardium* sp., Solen sp., *Tellina* sp., *Venericardia* sp.; Gastropods: *Lymnaea* sp., *Turritella* sp.
Foraminifera: *Nummulites* sp.

The above assemblage together with the fauna recorded at various times consist of molluscan taxa, which are cosmopolitan in nature, long ranging i.e., upper Cretaceous to Recent and indicative of marine shallow water deposition.

The presence of characteristic bivalves suggests the lower age limit of the fossiliferous members of the Upper Formation of the Disang Group as Paleocene. They have also further confirmed by the presence of larger foraminifera cf. *Nummulites* sp., which first appears in Paleocene. They reported that the record of Eocene index form *Dictyoconoides* suggests the age of the Disang Group may extend at least up to Middle Eocene.

CHAPTER 2

REGIONAL GEOLOGICAL SETTING

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2.1 GENERAL GEOLOGY AND STRATIGRAPHY

2.1.1 Introduction

Almost the whole of the Nagaland State is covered by Tertiary sediments, except the alluvial plains and Ophiolite and metamorphic complex occurring along Myanmar border. The Cenozoic sequence of this region consists of shelf and geosynclinal, (flysch/molasses) sediments. The stratigraphic succession of Nagaland is shown in the Table I. In this section, an attempt is made to provide a brief description of each of the Groups/Formations.

2.1.2 Disang Group

Mallet (1876) proposed the name Disang Group for dark grey shales and minor sandstone exposed along Disang (Dilli) river section (23°5′ N, 95°23′ E) some 24 km south of the Naharkotiya oil field. Evans (1932) later named it Disang Series and opined that owing to great spatial extent of these rocks it would be convenient to have several typical sections, rather than a few formally designated ones.

The Disang Group is made up of dark grey and black, fissile, splintery shales with minor sandstones. Mitra *et al.* (1974) recognized three distinct units within the Disang as lower dark grey, splintery shales, siltstones and silty sandstones; middle dark grey, splintery shales; and upper concretionary shale, sandy silts and sandstone unit.

The total thickness of Disang varies considerably from around 1600m in type section to over 3000m in the mobile belt. Towards the top, sediments of Barail group with a normal gradational contact overlie the Disang Group (Ganju *et al.*, 1986).

In a few places, the shales and silty sand beds are yielding micro-gastropods, bivalves and foraminifera. Marine foraminiferal assemblages from Disang Group have been reported from time to time. These include *Nummulite sp., Discocyclina sp., Dictyoconoides sp.,* and *G. cerroazulensis* etc (Evans, 1932; Rao & Prasad, 1982). On the basis of these fossil assemblages, Cretaceous to Late Eocene age is assigned to the Disang Group.

AGE	GROUP/SUB GROUP	FORMATION AND THICKNESS (in m)	LITHOLOGY
Pleistocene to Holocene	Alluvium	Alluvium	Gravels, silts and clays.
Pleistocene	Dihing	Dihing (300- 1600m)	Pebbles, cobbles and boulders of sandstone in ferruginous coarse sandy matrix.
Pliocene to Pleistocene	Dupitila	Namsang (800m)	Sandstone, coarse occasionally pebbly and gritty with mottled clay bands.
Miocene to Pliocene	Tipam	Girujan Clay	Mottled clays, shales of varied colours with medium to fine grained sandstone.
		Tipam Sandstone	Massive sandstone, medium to coarse grained with current bedded structures.
Miocene	Surma	Bokabil (400m)	Alternations of shales with siltstone and sandstone.
		Upper Bhuban (400m)	Alternation of sandstone and shale.
		Middle Bhubhan (450m)	Silty shale with sand lenticles, sandstone medium-grained, soft with current ripples.
Late Eocene to Oligocene	Barail	Renji (900m)	Sandstone medium to thick bedded, fine-grained, well-sorted. Occasional carbonaceous shales.
		Jenam (850m)	Shales with subordinate sandstone. Sandstones occur as lenticular bodies and as thin bands.
		Laisong (1750m)	Sandstone with minor silty shale. Sandstone thin to thick bedded.
Cretaceous to Eocene	Disang	Upper (1800-3000m)	Dark grey, splintery shale with non-calcareous siltstone and silty sandstone
		Lower	Epimetamorphosed sediments of slates, phyllites with lenticular limestone beds. Ophiolites

Table I. Generalized stratigraphic succession of Nagaland, NE Himalaya.

(Compiled after Evans, 1932 and Ranga Rao, 1983)

2.1.3 Barail Group

The rock association included in this group was studied first by Mallet (1876) in Namsang river section of Makum coalfield (27°15′ N: 95°42′ E) and designated as coal measures. He regarded them as questionable *Nummulitic* and/or middle Tertiary age. Later, Evans (1932) proposed the name Barail and accorded the status of a series of similar rock association exposed in Barail range. This Group is subdivided into three Formations viz. Laisong Formation, Jenam Formation and Renji Formation. The Barails are usually light to brownish grey, fine to medium-grained sandstone, often interbedded with brown to dark grey shales.

The rocks of Barail Group form a series of discontinuous/continuous linear patches in the Kohima-Patkai folded zone, the inner belt of Disang and Barail (Mathur and Evans, 1964, Das Gupta, 1977). They are mostly confined to synclinal parts and occur topographically as mere capping on synclinal hills. In the Schuppen zone of imbricate slices, they occupy long linear tracts of strips and wedges, overriding younger sediments.

Sarmah (1989) studied clay minerals (kaolinite) in the Barail sediments and suggested a continental or near-shore depositional environment for them. Presence of kaolinite with subordinate amount of illite in the Barail sediments may also indicate marine transgression/regression suggesting a possibility of admixture of marine water in the continental or near-shore environment, which ultimately resulted in the transformation of some kaolinite into illite. Mandal (1996) suggested a warm and humid climate due to the presence of *Notothyrites* and *Phragmothyrites. Striatriletes,* one of the major elements of *Marginipollis* suggests swampy environment of deposition. The presence of coal-bands also supports the same. The lower contact with Disang Group is gradational, while the upper contact with Surma group is regarded as unconformable, Evans (op. cit.). The thickness of Barail group in Naga-Patkai belt is estimated as over 6000m (Das Gupta, 1977). Ranga Rao *et al.* (1983) collected *Nummulites chavannesi*, reticulate *Nummulites, Nummulites* sp. and *Operculina* sp. from the base of the formation of Kiphire-Sirire road, near Chizami and near Lalmati on Kohima-Dimapur road. The foraminiferal faunа is very poor and the general aspect of the fauna is of Late Eocene.

Lithostratigraphically, the sediments of Barail Group of Assam and neighboring areas of Nagaland are dated as Oligocene. The presence of Eocene marker taxa in the assemblage suggests a close similarity with the Middle to Late Eocene assemblages and the appearance of *Polyadopollenites* indicate Late Eocene age of the sediments of Barail Group exposed along Mariani-Mokokchung Road (Mandal, 1996).

2.1.4 Surma Group

A thick sequence of shales, sandy shales, mudstones, shaly sandstones, sandstones and thin conglomerates lies above the Barails with a stratigraphic break of regional magnitude and importance. It is known as Surma Group. The term was first introduced by Evans (1932) adopting the name from the Surma valley where it is best exposed. The Surma is divided into 3 Formations viz. Middle Bhuban, Upper Bhuban and Bokabil Formation. In Nagaland, the Middle Bhuban consists of mainly shale and minor sandstone, whereas Upper Bhuban is mainly arenaceous. The Bokabil Formation is dominated by grey laminated shales with a few sandstone beds towards top.

In the Naga Hills Surma Group of rocks are exposed as long linear strips among imbricate thrust slices of schuppen zone. They comprise of alternation of shale, sandstone, siltstone beds, characterized by their susceptibility to change within short space.

The section near Changki (94°23′26″ E: 26°25′20″ N) in Mariani-Mokokchung sector and around Kimpar nala are considered as typical sections in Naga Hills. A conformable contact with Barail group in early uplifted area is suggested (Evans 1932). Its junction with overlying Tipam Group appears conformable. Estimates of over 900m have been made for Surma equivalents in Naga-Patkai belt while in Surma valley it exceeds 5500m. Faunal evidences and polospore data indicate a Mio-Pliocene and alternatively a questionable early Miocene age (Ganju *et al.*, 1986).

2.1.5 Tipam Group

The term was first coined by Mallet (1876). Evans (1932) subdivided the Group into 2 Formations viz. Tipam sandstone and Girujan clay. This Group is exposed over a vast area in northeast India.

The Tipam sandstone is predominantly made up of coarse grained to gritty ferruginous sandstone. The sandstone is often marked by partings of shale. The Tipam sandstone Formation is characterized by ferruginous sandstone in the Naga Hills. At places, fossil wood is found and thin lignite bands are quite common. Gritty beds and conglomerates and shale conglomerate occur in various localities.

The Tipam sandstone is overlain by a very distinctive group of rocks predominantly composed of mottled clay. This is known as Girujan clay and named after a river near Digboi. In Naga Hills, the overlying Girujan Clay Formation is characterized by typical blue and mottled clays with argillaceous sandstone beds, which gradually thin out. At places it shows a thickness of 600m.

The Tipam Group is divisible into two distinct units viz. a lower sandy unit and an upper clay unit. The distinction is clear and pronounced all along the exposed tracts in Naga Hills. A total thickness of over 4000m is estimated for the group in the Naga-Patkai belt. No specific paleontological data is available for age determination and the group is dated as ranging from Middle Miocene to Pliocene from order of super-position and regional geological considerations (Ganju *et al.*, 1986).

2.1.6 Dupitila Group

The term Dupitila was first described by Evans (1932) after a type section of hills between Chargola and Langai valleys. They overlie the Girujan Formation unconformably. The type section exposes 500 m sandy shale, and sandstones in almost equal proportion.

The Dupitila Group is poorly exposed. The sediments are generally loose and friable and lack bedding. It comprises variegated, mottled, friable, ferruginous and medium to coarse grained and poorly sorted sandstones rich in chocolate red to pink ferruginous clay matrix. Based on order of super-position and dating of tectonic events, a Mio-Pliocene age is suggested for it in the absence of any faunal criterion (Ganju *et al.*, 1986).

2.1.7 Dihing Group

Mallet (1876) named the pebble beds exposed in the Dihing river section (27°15′-16′ N: 95°24′-25′ E) and designated them as type section for Dihing Group. Its lower contact with Namsang Formation is marked by an angular unconformity. The outcrops are mostly confined to the synclinal areas. In general, the sequence comprises alternations of pebble beds, light grey sands, mottled sands, mottled sandy clays and coarse grits (Ganju *et al.*, 1986). In the absence of any precise data on dating, a tentative Plio-Pleistocene age for the Dihing Group is suggested (Das Gupta, 1977).

2.1.8 Alluvial beds

This alluvial sequence includes gravels, silts and clays of sub-recent to recent origin, overlying the Dihing Group with unconformable junction in the Naga-Patkai belt and an apparent gradational interface in present clay shelf and basin areas (Ganju *et al.*, 1986). The older alluvium, comprising of clay, coarse sand gravel and boulders deposits occurs at the northwestern flanks of the Naga-Patkai ranges. The newer lower level alluvium comprising of clay, sand, silt and shingle covers vast areas bordering the Naga Hills.

2.2 STRUCTURAL AND TECTONIC SET UP OF NORTH EAST INDIA

The tectonic features of Northeastern India have many unsolved problems. It is termed as a polyhistory type basin, which has more than one phase of sedimentation and tectonism. The evolution of the basin is influenced by three plates, viz. Indian, Eurasian and Burmese plates (Mehrotra, 2002). Fig. 2.1.

The complex evolutionary trend of the northern India, i.e., continental rifting-drifting-convergence collision might have provided the requisite thermo-kinetic conditions for the generation of hydrocarbons in geologic time.

According to Bastia *et al.* (1993), the Assam-Arakan Basin (including the Assam plains, Cachar, Meghalaya, Nagaland, Mizoram, Manipur, Tripura and parts of Arunachal Pradesh) evolved in four phases (Fig. 2.2). They are as follows;

Phase-I (Cretaceous): The Assam-Arakan Basin came into existence during the Early Cretaceous time due to Continental rifting. Subsequent drifting of the Indian plate from the Indo-Australian plate (Sub Gondwana) took place during the Upper Cretaceous. This resulted in the formation of several horst and graben features.

Phase–II (Paleocene-Eocene): The northward movement of the Indian plate caused subduction of this plate beneath the Burmese plate. This resulted in the formation of the Indo-Burmese trench system east of the Assam shelf. Further east, the peripheral arc continues and merges into the Shan volcanic arc system. The Indo-Burmese trench became the locus of deposition of deep marine sediments i.e. Disang shale. Simultaneously, the Assam shelf part received continental to shallow marine sediments belonging to the Jaintia Group.

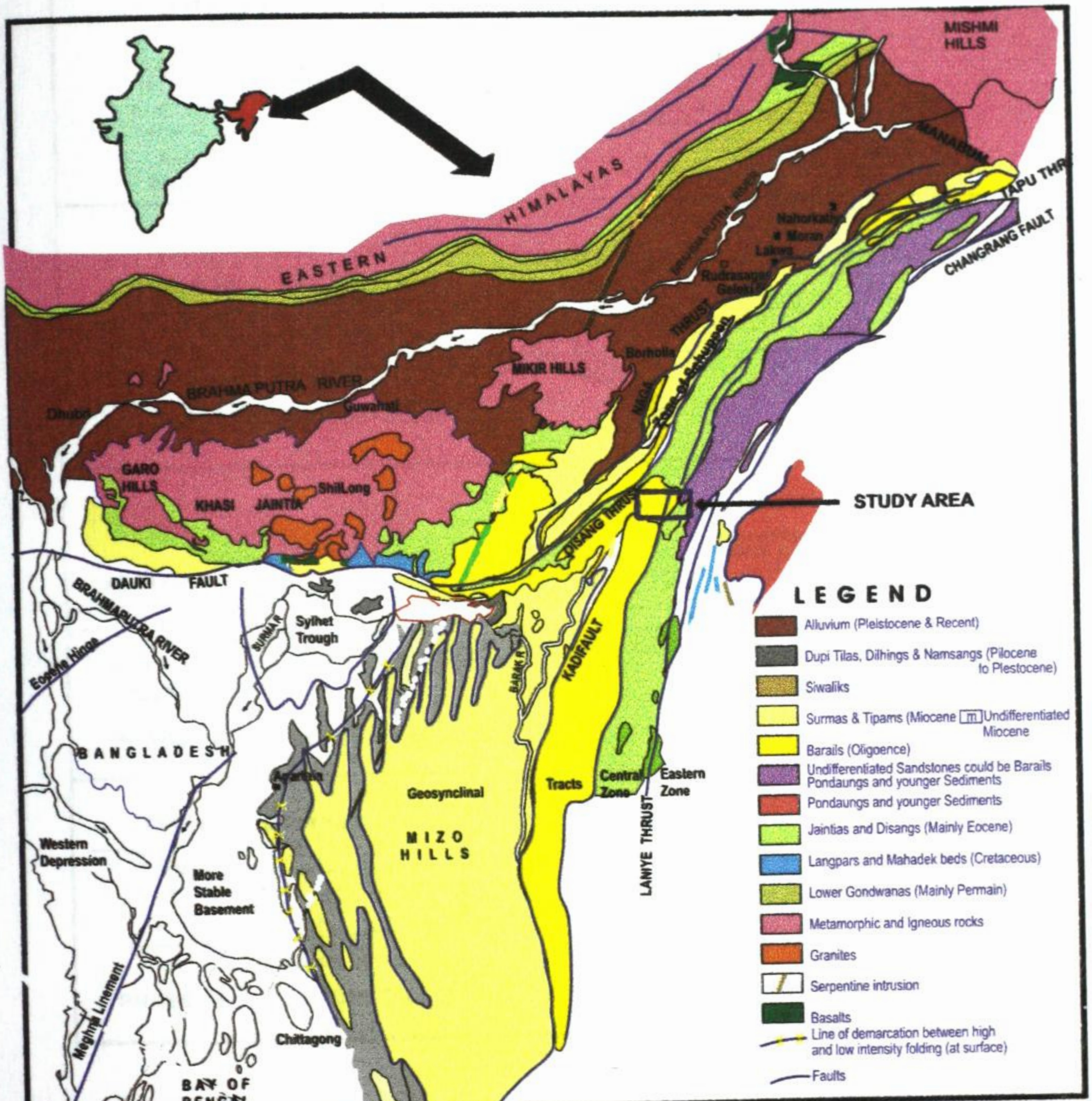

Figure 2.1 Geological map of Assam and surroundings (After Das Gupta, 1977)

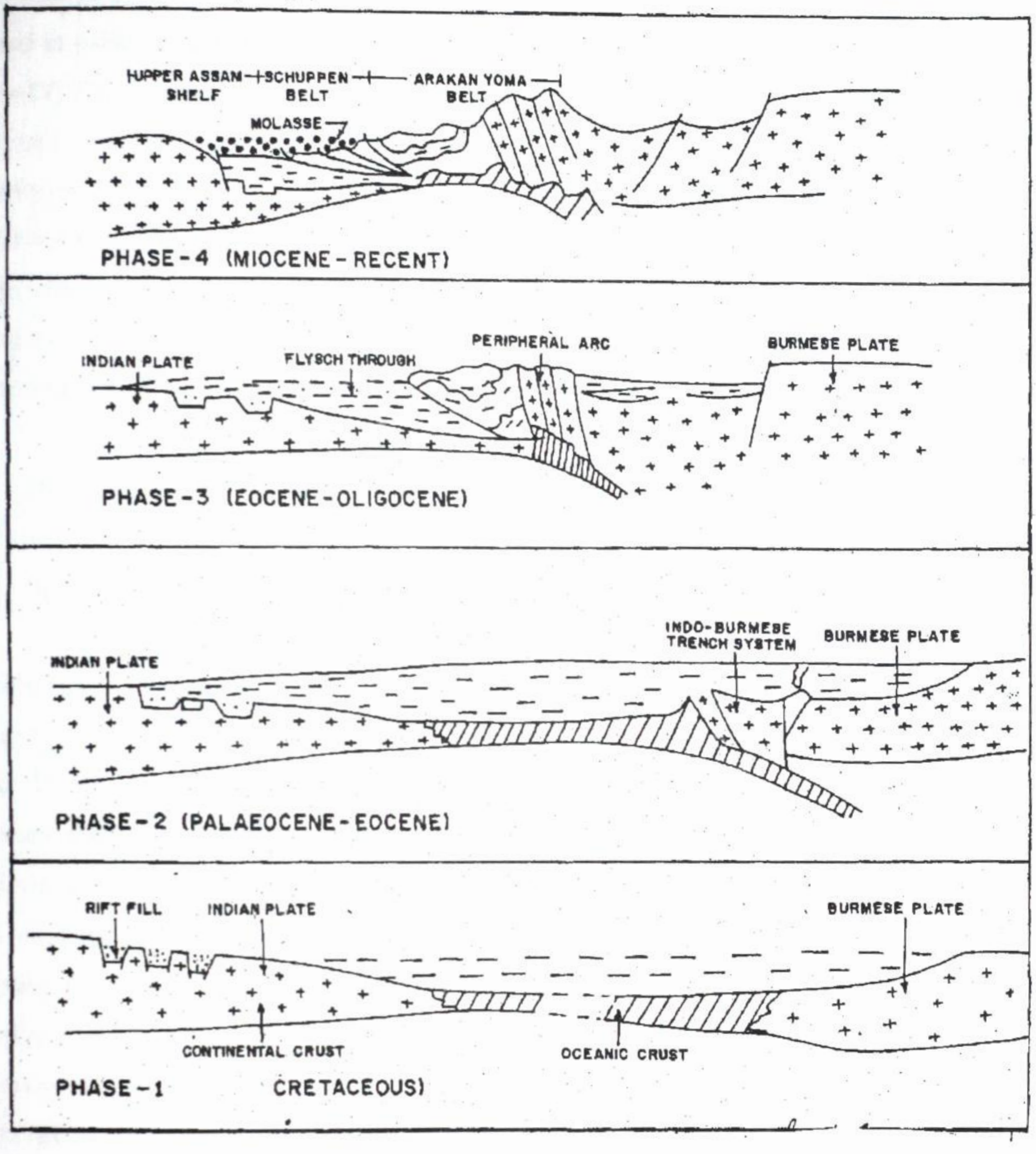

Figure 2.2 **Tectonic evolution of Assam-Arakan basin. (In Bastia et al., 1993)**

Phase-III (Eocene-Oligocene): Continued convergence resulted in further rift of the peripheral arc system and narrowing of the intervening sea. Upper Assam foreland basin was evolved in which the Barail deltaic sediments were deposited.

Phase-IV: The convergence finally led to the collision of the Indian plate with the Burmese plate and resulted in complete closure of part of the Indian Ocean and a regional unconformity at the top of the Barail. The collision gave rise to imbricate thrust faults and upliftment as well as over riding of the older sediments, which were finally stacked adjacent to the Assam shelf. Foreland basin was subsequently filled with molassic sediments belonging to Tipam and younger sequences. The synchronous sedimentation further south was dominated by shallow to deep marine facies belonging to the Surma Formation.

2.3 MAJOR STRUCTURAL FEATURES OF NAGALAND

2.3.1 Kohima-Patkai folded zone

East of the Disang thrust is a zone of anticlinal and synclinal reversals named as the Kohima-Patkai folded zone. This includes what has been referred to as Naga folded zone and central Flysch zone (Ganju and Khar, 1985) and also an inner zone of Disang and Barail (Das Gupta, 1977). A characteristic feature of this zone is the reversal in topography with the anticlines forming valleys and synclines those of hills (Ganju *et al.*, 1986). Most of the anticlinal valleys expose older sediments of Disang Group while the Barail is restricted to mere capping of synclinal hills. A number of thrusts viz. Dikhu, Tapu, Yangmun and Yimpang straddle through this zone. The most prominent amongst them is the Tapu thrust that affects the thrust-faulted Mao anticline in south and runs through the entire zone with successive increase in magnitude of overriding movement towards north. The Dikhu thrust affects the western limb of the Longchang syncline and unites with the Disang thrust to form a separate strip. The Yangmun and Yimpang thrust unite south of Tuensang and their unified trace merges with Laniye thrust, which together with Changrang-Zungki thrust alignment forms the eastern limit of Kohima-Patkai folded zone.

Between Laniye and Laruri thrusts is a zone of imbricate thrust slices, which is named as Zungki imbricate zone. These thrusts, namely Changrang, Zungki, Laniye, Moya and Laruri etc. diverge and unite in much the same as brow zone to form individual strips or wedges. The western outline of these strips collectively known as Changrang-Zungki-Laniye thrust alignment thrust defines the western limit of Zungki imbricate zone. To the east, it is limited by the Laruri thrust, which brings the constituents of the Naga metamorphic complex to override the strips of the Ophiolite suite and epi-metamorphic slates, phyllites and greywackes of Zungki imbricate zone (Ganju *et al.*, 1987).

The Kohima Synclinorium lies in the southwest of the Naga Hills. It occupies an area where the colliding plates were bringing the Indian continental mass at an angle towards Myanmar. Initially, it constituted a funnel shaped wide expanse of the intervening sea, narrowing towards the northeast. As the collision progressed, successive movements narrowed it down further to its present configuration (Gupta and Biswas, 2000).

2.3.2 Ophiolite Belt of Naga Hills

The Ophiolites of northeast India are rootless and of various dimensions, floating in a matrix which belongs to the Upper Cretaceous-Lower Tertiary Disang Group. They consist of a diverse mixture of igneous, sedimentary and metamorphic rocks, of which ultramafics are the main component. They do not constitute a continuous sheet but are made up of units haphazardly juxtaposed along faults or they consist of lensoid slices interbedded with Disang Group of rocks (Bhattacharjee, 1991).

The age of the radiolaria in the cherts indicates that the development of a trench along the western margin of the Burma plate took place during the Middle Cretaceous. This may therefore be taken as the period of time during which the subduction zone between the Indian and Burmese land masses was established. The Burmese plate was most probably welded to the Eurasian plate by the time it came into tectonic contact with the Indian plate (Bhattacharjee, 1991).

2.3.3 Naga Over thrust Belt (Schuppen Belt)

The belt of Schuppen, juxtaposed to the Assam plain is a wide zone of imbricate thrusts. The zone is bounded by the Naga thrust in the west, Disang thrust in the east, Mishmi thrust in the north and Haflong-Dauki compartmental fault in the south. Sediments ranging in age from the Cretaceous to Recent have been encountered in Schuppen belt (Bastia *et al.*, 1993).

According to Rao and Prasad (1982), the 'Schuppen Belt' between Naga and Disang thrusts is about 4500 sq. km. in area. The schuppen belt constitutes part of the mobile belt of the Assam-Arakan geosyncline. The belt is sliced by 4-5 prominent thrusts and consequently, units above Barail, totaling about 5500 m thickness are repeated. All the thrusts are of the same general shape, each repeats the strata and all dip in the same general direction. This type of thrust system was described as Schuppen structure (Rao and Samanta, 1987) or in modern usage as an imbricate zone and the rock sequence overlying each thrust as a thrust sheet.

Rao and Prasad (1982) stated that the 'Schuppen Belt' is characterized by folding to a much lesser degree than by faulting. Folding is mostly confined to selected places in the brow zone immediately east of the Naga thrust. According to Bastia *et al.*, 1993, 'The tectonic evolution of the Schuppen belt has been synthesized with structural complexity, which is closely related to the hydrocarbon potential. The convergence of Indian and Burmese plates resulted in a zone of high crustal mobility leading to major vertical and lateral movements of rock units. Continued convergence of Indian and Burmese plates resulted in the imbricate thrust faults giving rise to the upliftment and over riding of the older sediments, which were finally stacked adjacent to the Assam shelf. Often, earlier formed imbricate thrusts are truncated by younger thrusts forming duplexes which are favourable locales for hydrocarbon entrapment'.

In the area between Dimapur and Kanjang, Ganju *et al.* (1986) recognized seven major longitudinal thrust faults. Naga thrust is the westernmost thrust, which divides geographically the plains of Dimapur area and the mountain ranges towards East.

CHAPTER 3

SYSTEMATIC PALEONTOLOGY

CHAPTER 3

SYSTEMATIC PALEONTOLOGY

3.1 CLASSIFICATION

In the present work, the classification of Loeblich and Tappan (1988) entitled "Foraminiferal Genera and their Classification" is followed. Although numerous other publications in recent years have emphasized planktic genera and their classification, agglutinated taxa, or other selected groups from limited geographic regions or geologic periods, the most recent compilation of all described genera was that of Loeblich and Tappan (1988).

In this foraminiferal classification, they gave importance in denoting relationships-the genetically controlled test composition, mineralogy, ultrastructure, and method of test formation; hence these characteristics delimit the suborders.

The unilocular, bilocular or multilocular character of the test, presence or absence of wall perforations, canaliculi, alveoli or canal systems and major apertural features rank next in importance and separate superfamilies.

The free or attached nature of the foraminifer, mode of chamber addition, simple or undivided chamber, interior and apertural modifications separate families.

Subfamilies are also recognized in some but not all families.

According to Loeblich and Tappan (1988), "Wall composition and ultra structural modifications appear more fundamental than number and arrangement of chambers, both of which may change during ontogeny; hence evolutionary relationships appear to be best indicated by such a hierarchial classification. Although individual species are not discussed in this book, even surface ornamentation may show phyletic importance at the species level". As regards to planktic foraminifera the work of Toumarkine & Luterbacher entitled "Paleocene & Eocene planktic foraminifera" in Bolli *et al.*, 1985 has been adopted.

For the classification, identification and description of Uvigerinids, "Handbook of common Tertiary *Uvigerina*" by Boersma (1984), "Atlantic-European Oligocene to Recent *Uvigerina* taxonomy, paleoecology and paleogeography" by Zwann *et al.* (1986) is followed.

For taxonomic descriptions the available published literatures from different parts of the world have been referred.

In this chapter, 56 species belonging to 29 genera, 23 families, 17 superfamilies and 5 suborders are described and illustrated.

Of the total species, 16 are planktic forms and 40 are benthic forms. Ranges for each species of planktic forms are given. Benthic forms' ranges are not given as they are long ranging. Identifications for each species were carried out with the comparisons of faunas reported by previous workers from Nagaland, Assam, Meghalaya, Cauvery Basin and Cambay Basin and other parts of the world.

All the illustrated foraminiferal species are lodged in Wadia Institute of Himalayan Geology, Dehradun.

3.2 SYSTEMATIC DESCRIPTIONS

Order FORAMINIFERIDA Eichwald, 1830

Suborder TEXTULARIINA Delage and Hérouard, 1896

Superfamily LOFTUSIACEA Brady, 1884

Family CYCLAMMINIDAE Marie, 1941

Subfamily CYCLAMMININAE Marie, 1941

Genus *Cyclammina* Brady, 1879

Cyclammina sp.

pl. 6, figs. 4-5.

Description: Test planispirally coiled and involute, somewhat flattened, numerous broad and low chambers per whorl, whorls increasing rapidly in height, sutures nearly radial, periphery broadly rounded; wall agglutinated, with very thin imperforate outer layer; aperture is a curved slit at the base of the apertural face, supplementary pores indistinct.

Remarks: The specimen from the Disang Group of Nagaland is not preserved satisfactorily. Few specimens are encountered in the present study area at Leshemi section

Suborder MILIOLINA Delage and Hérouard, 1896
Superfamily MILIOLACEA Ehrenberg, 1839
Family HAUERINIDAE Schwager, 1876
Subfamily MILIOLINELLINAE Vella, 1957
Genus ***Pyrgo*** Defrance, 1824

Pyrgo sp.
pl. 7, figs. 7-8

Description: Test is ovate in outline, compressed through the midpoint of the opposing chambers, periphery angular to carinate, chambers one-half coil in length, microspheric generation with early quinqueloculine to cryptoquinqueloculine arrangement, adult biloculine; wall calcareous, imperforate porcellaneous, aperture at the end of the final chamber, ovate with a short bifid tooth.

Remarks: The specimen from the Disang Group of Nagaland has an ovate test, periphery sub- rounded, chambers one-half coil in length, wall calcareous, imperforate. Aperture at the end of final chamber and the bifid tooth is not seen due to ill preservation. Few specimens have been recovered from Chobama 1 section.

Genus ***Triloculina*** (d'Orbigny, 1826)

Triloculina sp.
pl. 9, figs. 9, 10

Description: Test ovate in outline, equilaterally triangular or sub-triangular in section, chambers one-half coil in length, only three chambers visible from the exterior; wall calcareous, imperforate, porcellaneous, aperture rounded at the end of the final chamber.

Remarks: The specimen from the present study is not well preserved. Moderate amount of specimens are found at Chobama 1 and Leshemi section.

Family MILIOLIDAE Ehrenberg, 1839
Subfamily MILIOLINAE Ehrenberg, 1839
Genus ***Miliola*** Lamarck, 1804

Miliola sp.

pl. 9, figs.7-8.

Description: Test narrow and elongate fusiform, chambers one-half coiled in length, quinqueloculine, wall calcareous, porcellaneous, surface pitted by numerous pseudopores and has longitudinal costae, aperture terminal on the final chamber.

Remarks: Only a few specimens are observed in the present study. The preservation is not satisfactory and sediments have filled most of the pits; a few specimens have been found at Chobama 2 section.

Suborder LAGENINA Delage and Hérouard, 1896

Superfamily NODOSARIACEA Ehrenberg, 1838

Family NODOSARIIDAE Ehrenberg, 1838

Subfamily NODOSARIINAE Ehrenberg, 1838

Genus ***Dentalinoides*** Marie, 1941

Dentalinoides sp.

pl. 8, fig. 9

Description: Test elongate, straight to slightly arcuate, uniserial, circular in section, sutures horizontal; wall calcareous, perforate, surface smooth; aperture terminal, slightly eccentric in position and opening toward the concave side of the test.

Remarks: The specimen from the Disang Group, Nagaland is badly preserved and few specimens are found at Chobama 1 section.

Genus ***Pseudonodosaria*** Boomgaart, 1949

Pseudonodosaria sp.

pl. 6, fig. 6

Description: Test elongate, cylindrical , base broadly rounded , sutures straight , horizontal , flush with the surface, wall calcareous , surface smooth ; aperture terminal , radiate.

Remarks: Due to poor preservation, no characteristic features are clearly definable. Few specimens are found at Chobama 1 section.

Family VAGINULINIDAE Reuss, 1860

Subfamily LENTICULININAE Chapman, Parr and Collins, 1934

Genus ***Lenticulina*** Lamarck, 1804

Lenticulina sp.

Pl. 7 fig. 6

Description: Test planispiral, lenticular, biumbonate, periphery angled to carinate, chambers increase slowly in size as added, sutures straight to curved; wall calcareous, hyaline, perforate radial, surface smooth other than the sutural nodes; aperture radiate or slit like at the peripheral angle.

Remarks: The specimen from Disang Group of rocks in Nagaland is not satisfactorily preserved. It occurs at Pfutsero 1 section.

Family LAGENIDAE Reuss, 1862

Genus ***Lagena*** Walker and Jacob, 1798

Lagena acuticosta Reuss var. ***proboscidialis*** Bandy, 1951

pl. 7, fig. 1

Description: Test unilocular, globular to ovate, base rounded, aperture terminal with a shoulder and short cylindrical neck, surface ornamented with 10-12 costae, which blend into the shoulder at the apertural end and extend to the basal apex at the other end. Neck short and cylindrical.

Selected reference and locality:

1993 *Lagena acuticosta* Reuss, Boltovskoy and Watanabe, p. 11, pl. 1, fig. 24, DSDP Site 25, South Atlantic

Remarks: The present specimen has an ovate, sub-globular test, a short cylindrical neck, surface ornamented with 10-12 costae. Since the apertural part is not preserved well, it cannot be described in detail. It is found at Chobama 1 section.

Lagena striata (d'Orbigny)

pl. 7, fig. 2

Description: Test unilocular, spherical; wall calcareous, finely perforate with many delicate longitudinal striae from the base of the test to the neck; aperture rounded on a surface with numerous longitudinal striae or costae.

Selected references and localities:

1992 *Lagena striata* (d'Orbigny), Kaiho, p. 377, pl. 2, fig. 7, Hokkaido, Japan

1996 *Lagena striata* (d'Orbigny), Dave, p. 25, pl.1, fig. 9; Cauvery and Krishna-Godavari Basins, India

Remarks: The specimens referred by Kaiho from the Upper Eocene of Hokkaido, Japan have the same characters with the present specimen from the Disang Group; a spherical test with 18-20 longitudinal striae. Necks of specimens are generally broken. The specimen is recorded from Chobama1 & 3 sections.

Lagena sulcata (Walker and Jacobs) var. ***spicata***

Cushman and McCulloch, 1950

pl. 7, fig. 4

Description: Variety differing from the typical *Lagena sulcata*, in having the basal end drawn out into a stout spine, the apertural end with a tapering cylindrical neck with a phialine lip, usually without other ornamentation, body of the test with numerous longitudinal costae as in the typical form.

Selected reference and locality:

1950 *Lagena sulcata* (Walker and Jacob) var. *spicata* Cushman and McCulloch, no. 6, p. 360; Los Angeles, California, North America.

Remarks: The specimen from Disang Group of Nagaland is poorly preserved. The basal end drawn out into a stout spine is prominent with numerous longitudinal costae. This variety is fairly common in the Pacific in fairly deep water. One or two specimens are encountered at Chobama 1 section.

Lagena sp.

pl. 7, figs. 3 and 5

Description: Test unilocular, globular to ovate; wall calcareous, hyaline, surface with numerous delicate longitudinal striae; aperture terminal, rounded produced on a short neck.

Remarks: Only few specimens are encountered at Leshemi section.

Family ELLIPSOLAGENIDAE A. Silvestri, 1923

Subfamily PARAFISSURININAE R.W. Jones, 1984

Genus ***Parafissurina*** Parr, 1947

Parafissurina sp.

pl. 10, figs. 7-9

Description: Test unilocular, peripheral margin rounded, wall calcareous, surface smooth, aperture crescentic, sub-terminal.

Remarks: Few specimens are found at Chobama 1 and Leshemi sections. The preservation is poor.

Suborder GLOBIGERININA Delage and Hérouard, 1896

Superfamily HETEROHELICACEA Cushman, 1927

Family CHILOGUEMBELINIDAE Reiss, 1963

Genus ***Chiloguembelina*** Loeblich and Tappan, 1956

***Chiloguembelina* sp.**

pl. 3, fig. 4

Description: Test sub-triangular in outline, narrow to flaring, chambers slightly inflated and compressed, biserial throughout with a tendency to be slightly twisted, sutures distinct, depressed; wall calcareous, finely perforate, surface granulate, aperture a simple and arched opening, with inturned narrow narrow bordering rim.

Remarks: The genus *Chiloguembelina* was described by Loeblich and Tappan (Nov, 1956) to include those Tertiary species, originally referred to *Guembelina* Egger, which were characterized by the absence of an early coiled stage, the presence of neck-like aperture extensions and the tendency to develop a twisted test and an asymmetrical aperture. The genus was placed in the family Heterohelicidae. *Guembelina venezuelana* Nuttal, one of the several Tertiary species of *Guembelina* included by Loeblich and Tappan in their genus *Chiloguembelina*, had earlier been placed in the genus *Virgulina* d'Orbigny by Hofker (1954), who stated that he observed a tri-serially arranged initial part of the test and a well-developed tooth plate in Nuttall's form. In July 1956, Hofker transferred Nuttall's form to his newly erected genus *Stainforthia*. Beckmann (1957), in the course of his detailed study on the genus *Chiloguembelina* from Trinidad, remarked (p.83): "The presence of a tri-serial stage *in Guembelina venezuelana* Nuttall, recorded by Hofker (1954), could not be confirmed". He regarded *Chiloguembelina* as a valid genus (Samanta, 1969). Few specimens are found at Chobama 1 and 3 sections. In the study area, about four species of *Chiloguembelina* are found. Most of them have the general characters of *Chiloguembelina* with some variations for individual species. Hence, only remarks are presented for each species.

***Chiloguembelina cubensis* (Palmer, 1934)**

pl. 3, fig. 2

References and localities:

1968 *Chiloguembelina cubensis* (Palmer), Raju, pl. 1, Figs. 4a, b; Cauvery Basin, South India.

1974	*Chiloguembelina cubensis* (Palmer), Fleisher, p. 1016, pl. 4, Fig. 8; Arabian Sea, Deep Sea Drilling Project (DSDP), LEG 23A.
1991	*Chiloguembelina cubensis* (Palmer), Qianyu and Radford, fig. 12 (*C. cubensis* is one of the few omnipresent Chiloguembelinids).
1991	*Chiloguembelina cubensis* (Palmer), Spezzaferri and Silva, p. 253, pl. 10, figs. 5a, 6a, 7a, 8a, 9a-b; Hole 538A, DSDP LEG 77, Gulf of Mexico.
2002	*Chiloguembelina cubensis* (Palmer), Galeotti *et al.*, pl. 3, fig. 5, pl. 5, fig. 15, Agulhas Ridge, South Africa.
2003	*Chiloguembelina cubensis* (Palmer), Mukhopadhyay, p. 84, pl. 3, Fig. 11-13, Cambay Basin, India.

Remarks: The *Chiloguembelina cubensis* from Disang Group of Nagaland are small in size (Length 0.02mm and width 0.01mm). It occurs in few numbers at Chobama 1 and 2 and Leshemi sections. The slowly expanding elongate test, rough surface and a low basal aperture characterizes the species.

Stratigraphic range: Beckmann (1957) gave the range of this species from *Porticolulasphaera mexicana* Zone to *G. opima opima* Zone in Trinidad. The species has also been reported from various parts of the world in sections of Upper Eocene to Oligocene. Blow (1969) gave the range of *Chiloguembelina* ex group *cubensis* from Zone P13 to be very close to the Zone N4/Zone N3 (=P22) boundary. In Cauvery basin, this species is common from the *G. mexicana* Zone to *G. ampliapertura* Zone (Raju, 1971, p.39).

Chiloguembelina martini (Pijpers, 1933)

pl. 3 fig.1

References and localities:

1968	*Chiloguembelina martini* (Pijpers), Raju, pl. 1, fig. 12, Cauvery Basin, India.
1969	*Chiloguembelina martini* (Pijpers), Mohan and Soodan, pl. 1, fig. 3, Kutch, India.
1981	*Chiloguembelina martini* (Pijpers), Nath and Choubey, p. 100, pl. 2, figs. 19a, b, Cambay Basin, Gujarat.

Remarks: The small specimen of *Chiloguembelina martini* has 0.2mm length and 0.1 mm width, with slowly expanding elongate test, rough surface and a low basal aperture characterizes the species. This species is encountered at Chobama 1 and 3 sections.

Stratigraphic range: Beckmann (1957) gave the range of this species from the *Globorotalia aragonensis* Zone to the top *of G. cocoaensis* Zone (= *G. cerroazulensis* Zone) in Trinidad. In Cauvery Basin, this species is recorded from the *Globorotalia spinuloinflata* subzone (Lower Eocene) to the top of *G. cerroazulensis* Zone (Raju, 1971).

Chiloguembelina* cf. *tenuis (Todd, 1957)

pl.3, fig.3

Selected references and localities:

1969 *Chiloguembelina tenuis* (Todd), Samanta, p. 329, pl. 1, figs. 8a-b; Garo Hills, Assam, India

1970 *Chiloguembelina* sp. cf. *C. tenuis* (Todd), Samanta, p. 189, pl. 1, figs. 8-9; Lakhpat, Cutch, Western India

Remarks: With their small elongate compressed test 5-6 pairs of inflated chambers between depressed inclined sutures, finely perforate smooth surface. The specimens from Nagaland are comparable with *Chiloguembelina tenuis* (Todd) of Samanta (1970) from Cutch. The outer surfaces of the specimens are generally corroded or damaged may be due to transportation and the slit-like apertures are filled with matrix. In the present study, it occurs at Leshemi, Chobama 1 and Pfutsero 2 sections.

Stratigraphic range: The upper limit of the range of the genus is not well established. Loeblich and Tappan (1956) described it as a Paleocene and Eocene genus.

Superfamily GLOBOROTALIACEA Cushman, 1927

Family GLOBOROTALIIDAE Cushman, 1927

Genus ***Turborotalia*** Cushman and Bermudez, 1949

Turborotalia cerroazulensis cerroazulensis (Cole), 1928

pl. 2, figs.7-9

Description: Test globose to inflated, trochospiral, closely coiled, chambers ovate, somewhat flattened on the slightly convex spiral side, umbilical side strongly convex, suture radial, slightly depressed, periphery broadly rounded without a keel; wall calcareous, finely perforate, surface smooth, aperture a curved low interiomarginal arch, umbilical-extraumbilical, with bordering lip.

References and localities:

1968 *Turborotalia cerroazulensis* (Cole), Raju, pl. 3, figs. 7a-c, Cauvery Basin, South India

1969 *Turborotalia cerroazulensis* (Cole), Samanta, p. 333, pl. 2, fig. 1a-c, Garo Hills, Assam

1974 *Turborotalia cerroazulensis cerroazulensis* (Cole), Fleisher, p.1035, pl. 19, fig. 1; Arabian Sea, Deep Sea Drilling Project, Leg 23A

1985 *Turborotalia cerroazulensis cerroazulensis;* Toumarkine and Luterbacher, p. 137, Fig. 34, 3-4.

1988 *Turborotalia cerroazulensis cerroazulensis* (Cole); Nocchi *et al.*, pl. 3, figs. 6, 7, Se Umbria, Italy.

2003 *Turborotalia cerroazulensis cerroazulensis* (Cole); Warraich and Nishi, p. 228, pl. 2, 3a-c, Sulaiman range, Indus Basin, Pakistan.

2003 *Turborotalia cerroazulensis cerroazulensis* (Cole); Mukhopadhyay, pl. 1, fig. 1, Cambay Basin, India.

Remarks: *Turborotalia cerroazulensis cerroazulensis* differs from *T. cerroazulensis pomeroli* by its flattened spiral side, which gives a more angular aspect in lateral view. The aperture is higher; it tends to migrate towards the umbilicus and does not reach the periphery. However, the two sub-species are linked by an uninterrupted series of intermediate forms (Toumarkine and Luterbacher, 1985). In the present study it is found at Chobama 3 and Pfutsero 1, 2 sections

Stratigraphic range: Toumarkine and Luterbacher, (1985) placed the range of *Tuborotalia cerroazulensis cerroazulensis* to a probable range from upper part of Zone P12 to P13 and definite range from Zone P14 to P17.

Turborotalia cerroazulensis cocoaensis (Cushman, 1928)

pl. 2, figs. 3 and 5

Description*:* *Turborotalia cerroazulensis cocoaensis* shares the general characters of the subspecies *cerroazulensis* on the flat spiral side, but in lateral view, its periphery is considerably more acute. The aperture is a high arch between the umbilicus and the periphery but does not reach the latter.

References and localities:

1987 *Globorotalia (Turborotalia) cerroazulensis* (Cole), Baruah *et al.*, fig. 6 (5-7), Nagaland

1988 *Turborotalia cerroazulensis cerroazulensis* (Cole); Nocchi *et al.*, pl. 3, figs. 10, Se Umbria, Italy

2002 *Turborotalia cerroazulensis cocoaensis* (Cushman), Abdelghany, p. 214, pl. 1, figs. 1-2, Dammam Formation, west of Northern Oman Mountains

Remarks: The specimen from Disang Group of Nagaland is very much comparable with the figures of *T .c. cocoaensis* of Toumarkine & Luterbacher (1985). It is found at Chobama 3 section.

Stratigraphic range: In Toumarkine and Luterbacher, 1985 probable range starts from Zone P14 and definite range starts from Zone P15 to P17.

Turborotalia cerroazulensis pomeroli (Toumarkine and Bolli, 1970)

pl. 2, figs. 1-2 and 4.

Description: *Turborotalia cerroazulensis pomeroli* differs from its ancestor *Turborotalia cerroazulensis possagnoensis* by the larger number of chambers in the last whorl (4-6 instead of 3½), and by its larger size and more rounded periphery.

Selected references and localities:

1974 *Turborotalia cerroazulensis pomeroli* (Toumarkine and Bolli), Fleisher, p.1035, pl. 19, figs. 2, 3, Arabian Sea, Deep Sea Drilling Project, LEG 23 A.

1980 *Turborotalia cerroazulensis pomeroli* (Toumarkine and Bolli), Benjamini, p. 355, pl. 5, fig. 17-20., Avedat Group in the Northern Negev, Israel.

1981 *Turborotalia cerroazulensis pomeroli* (Toumarkine and Bolli), Couvering *et al.*, pl. 1 figs. 8, 9, 12, Carpathian Mountains, Poland, Europe.

1988 *Turborotalia cerroazulensis pomeroli* (Toumarkine and Bolli), Nocchi *et al.*, p. 190, 192, pl. 3, figs. 4, 5, Se Umbria, Italy.

2003 *Turborotalia cerroazulensis pomeroli* (Toumarkine and Bolli), Warraich and Nishi, pl. 2, figs. 2a-c, Sulaiman Range, Indus Basin, Pakistan.

Remarks: The specimen from Nagaland has 5 chambers and rounded periphery. The spiral side has a flat surface. The surface is ornamented with pores. *Turborotalia cerroazulensis pomeroli* is probably the most abundant and widely distributed sub-species of the *Turborotalia cerroazulensis* lineage, since it is generally very well represented in assemblage from tropical as well as temperate regions. *Turborotalia cerroazulensis pomeroli* occurs in fair numbers at Chobama 1 and Pfutsero 2 sections.

Stratigraphic range: The probable range of *Turborotalia cerroazulensis pomeroli* starts from upper part of Zone P11 (upper part of early Middle Eocene) and the actual range starts from upper part Zone P12 (upper part of Middle Eocene) to Zone P17 (late Late Eocene).

Superfamily HANTKENINACEA Cushman, 1927

Family GLOBANOMALINIDAE Loeblich and Tappan, 1984

Genus ***Pseudohastigerina*** Banner and Blow, 1959

Pseudohastigerina barbadoensis Blow, 1969

pl. 1, fig. 9

Description: *P. nauguewichiensis* and *P. barbadoensis* are very close in appearance (Toumarkine and Luterbacher, 1985 p.119, Fig. 21.17). *P. nauguewichiensis* has possibly a more lobate equatorial outline and is less tightly coiled than *P. barbadoensis*. As the two species have the same stratigraphic range, Toumarkine and Luterbacher, (1985) included *P. barbadoensis* in the variability of *P. nauguewichiensis*.

References and localities:

1969 *Pseudohastigerina barbadoensis* Blow; Raju, p. 35, fig. 12-14, Cauvery Basin, India.

1971 *Pseudohastigerina barbadoensis* Blow; Raju, p. 35, figs. 12-14, Cauvery Basin, India.

1985 *Pseudohastigerina barbadoensis;* Toumarkine and Luterbacher, p. 119, fig. 21.17a-b.

1991 *Pseudohastigerina barbadoensis* Blow; Spezzaferri and Silivia, p. 253, pl. 14, fig. 3a-b, Hole 538A, DSDP Leg 77, Gulf of Mexico.

2003 *Pseudohastigerina barbadoensis*; Mukhopadhyay, p. 82-83, pl. 2, fig. 6.

Remarks: With its small size and six chambers, the specimen from Disang Group of Nagaland is very well comparable with illustrations and description of the type. In the present study, it occurs in Chobama 1 section.

Stratigraphic range: In Cauvery Basin, this species is very common in *G. gortanii* Zone and very rare in the *G. cerroazulensis* Zone (Raju, 1971). According to Toumarkine and Luterbacher (1985) *P. naguewichiensis* range from Zone P16 to P17. As *P. naguewichiensis* and *P. barbadoensis* have the same stratigraphic range, it has the range have from Zone P16 to Zone P17.

Pseudohastigerina micra (Cole, 1927)

pl. 1, fig. 8

Description: This planispiral, bi-umbilicate, rather small species is more laterally compressed. The periphery of *P. micra* is generally rounded but it becomes sub-acute in larger specimens.

References and localities:

1968 *Pseudohastigerna micra* (Cole), Raju, p. 36, pl. 13, Fig. 9 a, b; Cauvery Basin, South India

1969 *Pseudohastigerna micra;* Samanta, p. 342, pl. 1, Fig. 6 a, b, Garo Hills, Assam, India.

1970 *Pseudohastigerna micra* (Cole), Mohan and Soodan, pl. 2, fig. 9, Kutch, India

1981 *Pseudohastigerna micra* (Cole), Nath and Choubey, p. 101, pl. 2, figs. 20a-c, Cambay Basin, Gujarat

1985 *Pseudohastigerna micra* (Cole), Toumarkine and Luterbacher, p.118, figs. 21(1-8)

1987 *Pseudohastigerna micra* (Cole), Baruah *et al.*, fig. 6 (12, 13), Nagaland

1988 *Pseudohastigerna micra* (Cole), Nocchi *et al.*, p. 190, 193, pl. 4, fig. 7, Se Umbria, Italy

1991 *Pseudohastigerna micra* (Cole), Spezzaferri and Silva, p. 253, pl. 14, figs. 4a, b, Hole 538A, Deep sea drilling project (DSDP) Leg 77, Gulf of Mexico.

1997 *Pseudohastigerna micra* (Cole), Mukhopadhyay, p. 220, pl. 2, figs. 24-25; Kotadru nala section, Bharuch District, Gujarat.

2003 *Pseudohastigerina micra* (Cole), Mukhopadhyay, p. 82-83, pl. 2, figs. 1-3; Cambay Basin, India.

Remarks: This apparently fragile species is in fact very resistant to bad ecologic conditions and is a dominant species in the study area. With its small size and six chambers, the specimen from Disang Group of Nagaland is very well comparable with the illustrations and description of *P. micra* of Toumarkine and Luterbacher. It is found in fairly large numbers at Pfutsero 1, 2 and Chobama 1, 3 sections.

Stratigraphic range: In Cauvery Basin, this species is very common in *G. gortanii* Zone and very rare in the *G. cerroazulensis* Zone (Raju, 1971). Toumarkine and Luterbacher gave the range of *P. naguewichiensis* to the Zone of P16 to P17. As *P. naguewichiensis* and *P. barbadoensis* have the same stratigraphic range, *P. barbadoensis* have the range from Zone P16 to P17.

Pseudohastigerina naguewichiensis (Myatliuk, 1950)

pl. 1 Fig. 7

Remarks: *Pseudohastigerina naguewichiensis* has more lobate equatorial outline with numerous chambers in the last whorl (often 8), sutures straight, periphery rounded. It is found at Chobama 1 and Pfutsero 2 sections.

References and localities:

1985 *Pseudohastigerina naguewichiensis* (Myatliuk) Toumarkine & Luterbacher, p. 119, figs. 10-16.

1991 *Pseudohastigerina naguewichiensis* (Myatliuk), Spezzaferri and Silvia, p. 253, pl.10, figs. 1a-c, 2a-b, 5a-c, Hole 538A, DSDP Leg 77, Gulf of Mexico.

1997 *Pseudohastigerina naguewichiensis* (Myatliuk), Mukhopadhyay, pl. 2, fig. 26, Kotardu Nala Section, Bharuch District, Gujarat.

Stratigraphic range: It starts from Zone P16 and continues to Oligocene.

Family HANTKENINIDAE Cushman, 1927

Genus ***Cribrohantkenina*** Thalmann, 1942

Cribrohantkenina inflata (Howe, 1928)

pl. 1, figs.5-6

Description: This species is readily recognized by its 4-6 inflated chambers, each carrying a stout spine in the last whorl and by its peculiar accessory areal apertures. The primary aperture is trilobate as in *Hantkenina* whereas the accessory areal apertures are tuberculate holes (Toumarkine and Luterbacher, 1985, p.125).

Selected references and localities:

1968 *Cribrohantkenina inflata* (Howe), Raju, pl. 1, fig. 7; Cauvery Basin, South India.

1969 *Cribrohantkenina inflata* (Howe), Samanta, p. 337, pl. 1, fig. 11a, b; Garo Hills, Assam, India.

1971 *Cribrohantkenina inflata* (Howe), Raju, p. 37, pl. 13, figs. 2, 3, 4, 5, 6, 7, 8a, b; Cauvery Basin, South India.

1985 *Cribrohantkenina* inflata (Howe), Toumarkine and Luterbacher, p.125.

1987 *Cribrohantkenina inflata* (Howe), Baruah *et al*., p. 317, fig. 6, 3-4; Disang and Barail Groups, Nagaland.

2002 *Cribrohantkenina inflata* (Howe), Abdelghany, p. 215, pl. 2, fig. 3-6; Damman Formation, west of the Northern Oman Mountains.

2003 *Cribrohantkenina inflata* (Howe), Coxall, p. 87, fig. 2; Ocean Drilling Project (ODP) site 865.

Remarks: The genus *Cribrohantkenina* with its peculiar cribrate aperture is thought to be monospecific. With its large planispirally coiled involute test, 4-5 strongly inflated rapidly enlarging chambers in the last whorl, one short tubulospine in each chamber and multiple aperture, *Cribrohantkenina inflata* (Howe) is a distinctive planktonic foraminifera in the study area. According to Toumarkine and Luterbacher (1985 p.121), the evolutionary trends within the genus *Hantkenina* lead from strongly stellate forms to more and more compact tests and to a narrowing of the initially rather wide triradiate aperture and finally to transitional form to *Cribrohantkenina*. The specimens from the study area are not well preserved. The spines are either partially or completely broken. In the present study, it is found at Chobama 1 and 3 sections.

Stratigraphic range: This species is known to be an important worldwide index fossil of Upper Eocene. This species is common throughout the *G. cerroazulensis* in Cauvery Basin (Raju, 1971). Toumarkine and Luterbacher, 1985, placed the range of this species to upper most part of Zone P15 to P17.

Genus ***Hantkenina*** Cushman, 1924

Hantkenina alabamensis Cushman 1925

pl. 1, figs.1-2.

Description: Test planispirally enrolled, involute, biconvex, and biumbilicate, chambers are globular, most chambers of the final whorl characterized with a single long hollow tubulospine arising slightly anterior to the chamber mid point on the periphery and in the plane of coiling, tubulospines with tiny distal opening, sutures depressed, radial, (Loeblich and Tappan 1988, p. 487). Wall calcareous, hyaline, finely perforate, except for the apertural flanges and tubulospines. *Hantkenina alabamensis is* the most advanced representative of the genus *Hantkenina*. Its chambers increase slowly in size and are closely pressed against each other. The contour of the periphery is rounded (Toumarkine and Luterbacher, 1985).

Selected references and localities:

1959	*Hantkenina alabamensis* Cushman; Nagappa, pl. 2, fig. 14, Garo Hills, Assam, India.
1968	*Hantkenina alabamensis* Cushman; Raju, p. 291, pl. 1, fig. 11; Cauvery Basin, South India.
1969	*Hantkenina alabamensis* Cushman; Samanta, p. 338, pl. 3, Fig. 3a, b; Garo Hills, Assam, India.
1971	*Hantkenina alabamensis* Cushman; Raju, p. 36, pl. 11, figs. 8, 9a, b; Cauvery Basin, South India.
1985	*Hantkenina alabamensis* Cushman; Toumarkine and Luterbacher, p. 123, fig. 25, 1-10.
1987	*Hantkenina alabamensis* Cushman; Baruah *et al.*, fig. 6 (1-2), Nagaland.
1988	*Hantkenina* cf. *alabamensis* Cushman; Nocchi *et al.*, p. 190-193, pl. 4, figs. 9-10; Se Umbria, Italy.
1997	*Hantkenina* cf. *alabamensis* Cushman; Mukhopadhyay, p. 220, pl. 2, fig. 21; Kotadru nala section, Bharuch district, Gujarat.
2003	*Hantkenina alabamensis* Cushman; Mukhopadhyay, pl. 1, fig. 5; Cambay Basin, India.

Remarks: The specimens from the study area are comparable with the illustrations and description of Toumarkine and Luterbacher, 1985. Successive chambers are progressively larger and are closely pressed against each other. The contour of the periphery is rounded. The specimens are characterised by the presence of a thin tubulospine at the forward margin of each chamber. The present specimens are similar to the specimen identified by Samanta (1969, pl. 3, Fig. 3a, b) from Garo Hills, Assam in which the spines are not preserved and the aperture is filled with matrix. In the present study, it is found at Chobama 3 and Leshemi sections.

Stratigraphic range: In Cauvery basin typical forms of this species are recorded so far from the *G. mexicana* Zone and *G. cerroazuleasis* Zone (Raju, 1971). Toumarkine and Luterbacher, 1985 gave the range of this species from upper part of Zone P12 to P17.

Hantkenina liebusi Shokhina, 1937

pl. 1, figs. 3-4.

Description: The test of *H. liebusi* is characterized by four to five clearly separated chambers with slender spines situated close to anterior suture with triangular chamber morphology, and planispiral coiling, is quite distinctive, and easily recognized (Coxall *et al.*, 2003, p. 239).

Selected references and localities:

1969 *Hantkenina liebusi* (Shokhina), Samanta, p. 339, pl. 1, fig. 10a, Garo Hills. Assam, India.

1970 *Hantkenina liebusi* (Shokhina), Mohan and Soodan, pl. 2, figs. 6, 7, 8, Kutch, India

1993 *Hantkenina liebusi* (Shokina), Pearson *et al.*, pl. 3, figs. 8-10; Deep Sea Drilling Project (DSDP) Site 523

2000 *Hantkenina liebusi* (Shokhina), Coxall *et al.*, p. 87, fig. 2; Ocean drilling project (ODP) Site 865

2003 *Hantkenina liebusi* (Shokhina), Coxall *et al.*, pl. 4, figs. 1-3, 7-9, Helvetikum section of Austria

Remarks: The small tests of *Hantkenina liebusi,* characterized by four to five clearly separated chambers with slender spines situated much below the anterior sutures, are quite distinctive and easily recognized, although the preservation of the material is not completely satisfactory. The aperture is filled with matrix and the details cannot be described. The slender spines are in most cases partly broken. In the present study, it occurs at Chobama 1 and 3 sections.

Stratigraphic range: *H. liebusi* was established on specimens from the Middle Eocene of the Caucasus, U.S.S.R. Earlier, Liebus (1911) reported it as *Pullenia Kochj* (Hantken) from the Middle Eocene of North Dalmatia. The reported stratigraphic range of *H. liebusi* in

Assam is Middle and Upper Eocene (Samanta, 1969). In Coxall, 2003 gave the range of *H. liebusi* from Zone P11 early Middle Eocene to lower part of P14 late Middle Eocene.

Superfamily GLOBIGERINACEA Carpenter, Parker and Jones, 1862

Family GLOBIGERINIDAE Carpenter, Parker and Jones, 1862

Subfamily GLOBIGERININAE Carpenter, Parker and Jones, 1862

Genus ***Globigerina*** d'Orbigny 1826

Globigerina sp.

pl. 3, figs. 7-9

Description: Test globose, trochospirally coiled, chambers spherical to ovate, enlarging rapidly as added, commonly only three to five chambers in the final whorl, sutures distinct, depressed, umbilicus open, periphery rounded; wall calcareous, perforate; primary aperture a high umbilical arch that may be bordered by an imperforate rim, no secondary apertures.

Stratigraphic range: Upper Eocene to Holocene (Loeblich and Tappan, 1988). It is found in moderate amount in all the studied sections.

Subfamily PORTICULASPHAERINAE Banner, 1982

Genus ***Globigerinatheka*** Bronnimann 1952

Globigerinatheka semiinvoluta Keijzer, 1954

pl. 3, figs. 5-6

Description: Test globular, early chamber spherical to ovate, trochospirally coiled, later chambers with changed directions with of coiling so that the final chamber completely cover the foramen umbilical side of the test. Suture distinct, depressed; wall calcareous perforate aperture interiomarginal.

References and localities:

1968 *Globigerapsis semiinvoluta* (Keijzer); Raju, pl. 2, figs. 4-5, Cauvery Basin, South India.

1985 *Globigerinatheka semiinvoluta* (Keijzer); Toumarkine and Luterbacher, p. 144-145, fig. 39, 1-17

1988 *Globigerinatheka semiinvoluta* (Keijzer); Nocchi *et al.*, pl. 4, fig. 11, Se Umbria, Italy

2002 *Globigerinatheka* cf. *semiinvoluta* (Keijzer); Galeotti *et al.*, pl. 3, fig. 3, Agulhas Ridge, South Africa

Remarks: The main character of *G. semiinvoluta* is the final hemispherical chamber, which embraces nearly half of the earlier test and the high-arched to circular sutural apertures with distinct rims. The specimen from Disang Group of Nagaland is very well comparable with the description and illustration of the Toumarkine and Luterbacher (1985). In the present study, it occurs at Chobama 1 section.

Stratigraphic range: Toumarkine and Luterbacher (1985) gave the range of the species from Zone P15 to lower part of Zone P16.

Suborder ROTALIINA Delage and Hérouard, 1896

Superfamily BOLIVINACEA Glaessner, 1937

Family BOLIVINIDAE Glaessner, 1937

Genus ***Bolivina*** d'Orbigny, 1839

Bolivina sp.

pl. 8, fig.7

Description: Test elongate, ovate to triangular in outline, compressed, biserial throughout; septa flush to slightly depressed, wall calcareous, hyaline, perforate. Surface ornamented with imperforate costae. Aperture a narrow loop at the base of the apertural face. With the mentioned characters, the present specimen is identified as *Bolivina* sp. Due to ill preservation of the specimen; it is not identifiable to species level. It occurs at Chobama 2 section in few numbers.

Superfamily TURRILINACEA Cushman, 1927

1985 *Globigerinatheka semiinvoluta* (Keijzer); Toumarkine and Luterbacher, p. 144-145, fig. 39, 1-17

1988 *Globigerinatheka semiinvoluta* (Keijzer); Nocchi *et al.*, pl. 4, fig. 11, Se Umbria, Italy

2002 *Globigerinatheka* cf. *semiinvoluta* (Keijzer); Galeotti *et al.*, pl. 3, fig. 3, Agulhas Ridge, South Africa

Remarks: The main character of *G. semiinvoluta* is the final hemispherical chamber, which embraces nearly half of the earlier test and the high-arched to circular sutural apertures with distinct rims. The specimen from Disang Group of Nagaland is very well comparable with the description and illustration of the Toumarkine and Luterbacher (1985). In the present study, it occurs at Chobama 1 section.

Stratigraphic range: Toumarkine and Luterbacher (1985) gave the range of the species from Zone P15 to lower part of Zone P16.

Suborder ROTALIINA Delage and Hérouard, 1896

Superfamily BOLIVINACEA Glaessner, 1937

Family BOLIVINIDAE Glaessner, 1937

Genus ***Bolivina*** d'Orbigny, 1839

Bolivina sp.

pl. 8, fig.7

Description: Test elongate, ovate to triangular in outline, compressed, biserial throughout; septa flush to slightly depressed, wall calcareous, hyaline, perforate. Surface ornamented with imperforate costae. Aperture a narrow loop at the base of the apertural face. With the mentioned characters, the present specimen is identified as *Bolivina* sp. Due to ill preservation of the specimen; it is not identifiable to species level. It occurs at Chobama 2 section in few numbers.

Superfamily TURRILINACEA Cushman, 1927

Family TURRILINIDAE Cushman, 1927

Genus ***Praebulimina*** Hofker, 1953

Praebulimina reussi Morrow, 1934; Hofker, 1953

pl. 7, fig. 9

Description: Test is fusiform, sub-circular in cross section; periphery rounded, chambers are tri-serially arranged, rapidly flaring from the more or less pointed initial part; sutures slightly depressed; aperture sub-terminal, comma shaped; wall calcareous and smooth.

Selected references and localities:

2001 *Praebulimina reussi* (Morrow), Alegret and Thomas, p. 311, pl. 10, fig. 2, Mexico

Remarks: *Praebulimina reusssi* (Morrow) is distinguished from *Sitella cushmani* (Sandidge) by its triserial test and, when visible, by its comma –shaped aperture. The variability in this species in expressed in the degree of elongation of the tests, ranging from low and globular to elongate and fusiform. The specimen of Alegret and Thomas from northeastern Mexico and my specimen from Nagaland have the same characters with its fusiform test and comma shape aperture. The specimen has recorded from Pfutsero 1 section in few numbers.

Genus ***Turrilina*** Andreae, 1884

Turrilina robertsi (Howe and Ellis, 1939)

pl. 10, figs. 1-2

Description: Test elongate, trochospirally enrolled in the early stage, later triserial, with rapidly enlarging and inflated chambers strongly overlapping those preceding, spiral nearly horizontal, intercameral sutures nearly vertical, depressed; wall calcareous, finely perforate, surface smooth; aperture ovate bordered by an elevated narrow lip.

Selected references and localities:

1991 *Turrilina robertsi (*Howe and Ellis, 1939), Müllar-Merz and Oberhänsli, p. 161-162, pl. 2, figs. 23-24, South Atlantic transect at 20-30^0 S.

Remark: The specimen of Müller-Merz from Atlantic transect and my specimen from Disang Formation of Nagaland have the same characters with an elongate test with rapidly enlarging and inflated chambers strongly overlapping those proceeding. Wall calcareous, finely perforate; aperture an ovate opening, wider near the midpoint and bordered by an elevated narrow lip. The species is recorded from Chobama 1 and 3 sections.

Turrilina sp.

pl.10, figs. 3-6

Description: Test elongate with rapidly enlarging and inflated chambers strongly overlapping those preceding, spiral nearly horizontal, intercameral sutures nearly vertical, depressed; wall calcareous; aperture an ovate opening, wider near the midpoint, a part of the lip bends downward joining the aperture to the previous foramen. Moderate amount of specimen is encountered at Chobama 1, 2 and 3 sections.

Superfamily BULIMINACEA Jones, 1875

Family SIPHOGENERINOIDIDAE Saidova, 1981

Subfamily SIPHOGENERINOIDINAE Saidova, 1981

Genus ***Rectobolivina*** Cushman, 1927

Rectobolivina sp.

pl. 8, fig.8

Description: Two broken fragments of *Rectobolivina* sp. are found at Leshemi section. The specimen has an incomplete elongate, oval test, chambers broad and low; sutures straight in juvenile stage and later ones arched, depressed, wall calcareous. The other characters are not seen due to ill preservations of the specimen. It is found at Pfutsero 1 section.

Family UVIGERINIDAE Haeckel, 1894

Subfamily UVIGERININAE Haeckel, 1894

Genus ***Uvigerina*** d'Orbigny, 1826

Uvigerina cocoaensis Cushman, 1925

pl. 12, fig. 1

Description: Elongate test medium in size, test about 2 times as long as broad in 3 to 3½ whorls; sides sub-parallel so test is somewhat rectangular; coiling triserial, with some specimens developing a tendency toward uniserial coiling; chambers increase in size very regularly; sutures only distinct on unornamented chambers; periphery slightly lobulate; porous walls ornamented with platy, longitudinal costae, costae reduced in height and number on the final whorl or usually absent in the final few chambers; neck terminal set into a slight depression in the final chamber.

References:

1980 *Uvigerina cocoaensis* (Cushman), Tipton, fig. 8, California, USA.

1984 *Uvigerina cocoaensis* (Cushman), Boersma, p.33; pl. 1, fig. 1-4; pl.2, figs.1-4.

Remarks: Elongate test, almost rectangular in shape chambers increase in size; porous wall ornamented with longitudinal costae; costae altogether absent on the final whorl; neck terminal. In the present study, it is found at Pfutsero 1 and 2 sections.

Stratigraphic range: In Boersma (1984), stratigraphic range of *Uvigerina cocoaensis* is from Zone P16 to P22.

Ecology: It occurs in the upper bathyal zone in lower to middle latitudes. It demonstrates a tendency towards uniserial chamber arrangement in both clay and carbonate rich areas, but this trend is most frequently found in sediment of Late Eocene age.

Uvigerina continuosa Lamb, 1964

pl. 11, figs. 1, 4

Description: Test large, elongate fusiform; about 2½ to 3 times as long as broad with greatest breadth in the mid portion of the test; chambers gradually increase in size, coiling triserial, chambers mildly inflated, sutures indistinct, periphery not lobulate; porous wall ornamented with a few, continuous longitudinal costae, about 2 to 4 per chambers; short neck terminal, situated in slightly round depression in the final chamber.

References:

1984 *Uvigerina continuosa (*Lamb), Boersma, p. 36-38, figs. 1-4.

Remarks: The present specimen is very well comparable with the description and illustrations of the type species except that my specimen is shorter in length and breadth i.e. 0.5 mm and 0.3 mm respectively. In the present study, it occurs at Chobama 3 section and Pfutsero 1, 2 sections.

Stratigraphic range: The stratigraphic range of *Uvigerina continuosa* given by Boersma (1984) is from Zone P14 to P20.

Ecology: *Uvigenina continuosa* is an upper bathyal species most frequently found in lower latitude carbonate marls where it develops a larger number of costae per chamber and more costae, which traverse only two chambers rather than the entire length of the test. In clay, quartz and organic-rich sediments it tends to add more uniserial final chambers.

Uvigerina cf. ***eocaena*** Guembel, 1870

pl. 11 figs. 2-3 and 5-6

Description: Stout costae *Uvigerina*. The aperture has a very distinct, smooth neck, and a lip, and is situated in a slight depression. The basal part of the costae may be connected with the costae of earlier chambers. The individual chambers are often obscured by the ornamentation.

References:

1976 *Uvigerina eocaena* (Guembel), Berggren and Aubert, p. 316-317, pl. 3, 15-18, Rockall Bank (Deep Sea Drilling Project Site 117) and Hatton-Rockall Basin (DSDP Site 116).

1984 *Uvigerina eocaena* (Guembel), Boersma, p. 52-55, figs. 1-4.

1986 *Uvigerina eocaena* (Guembel), Zwann *et al.*, p. 130, pl. 1, figs. 1-6.

Remarks: The specimen from Disang Group of Nagaland is similar to the specimens illustrated by Boersma (1984) in all the characters except it is smaller in size. It has a length of 0.4mm and about 0.2mm breadth. In the area studied, it occurs at Pfutsero 2 section.

Stratigraphic range: *Uvigerina eocaena* has been identified from the late Eocene Zone P15 through the Oligocene. It may range further back in the Eocene.

Ecology: *Uvigerina eocaena* occurs in planktic foraminiferal marls and clays rich in benthic foraminifera in the lowermost-upper to upper-middle bathyal zone.

Uvigerina glabrans Cushman, 1933

pl. 12, figs. 7-8

Description: Test medium to large, twice as long as broad, chambers relatively few, in 3 to 4 whorls; chambers increase in size gradually, so greatest breadth in the mid portion of the test is greatest; coiling triserial throughout; chambers slightly inflated, periphery very slightly lobulate; porous wall unornamented and appearing smooth; final chamber rounded, terminal neck ends in a reverted lip.

References:

1984 *Uvigerina glabrans* (Cushman) Boersma, p. 65-66, fig. 1-4.

Remarks: The specimen from Disang Formation of Nagaland is comparatively small in length and width, i.e. 0.4mm and 0.3mm respectively. The other characteristic features of the specimen are comparable with the illustrations and description of Boersma, 1984. It occurs at Pfutsero 1 section.

Stratigraphic Range: Boersma 1984 gave the range of this species from Zone P16-18.

Ecology: *Uvigerina glabrans* occurs in carbonate rich upper bathyal foraminiferal sands and marls with a large percentage of the benthic rather than planktonic foraminifera. It is not typical in sediments rich in clay or glauconite.

Uvigerina jacksonensis Cushman, 1925

pl. 12, figs. 5, 6

Description: Test large, stout, broadly fusiform with the greatest width at the middle; chambers increasing gradually in size, final chamber often smaller than those in penultimate whorl; coiling compact and tri-serial throughout; chambers are inflated; sutures somewhat depressed; periphery lobulate to robust, wall ornamented with longitudinal costae, most of which are restricted to individual chambers; final chambers somewhat rounded; aperture ends in a terminal neck with reverted lip.

References:

1984 *Uvigerina jacksonensis* (Cushman), Boersma, p. 88-89, pl. 1, figs 1-5, pl. 2, figs 1-4.

1986 *Uvigerina jacksonensis* (Cushman), Zwann *et al*; p .194.

Remarks: The present specimen is smaller than the specimen described by Boersma (1984) having a length of 0.4mm and a breadth of 0.2mm. Wall ornamented with 7 costae per whorl. Aperture ends in a terminal neck with a reverted lip. In the present study it occurs at Pfutsero 2 section.

Stratigraphy range: *Uvigerina jacksonensis* ranges from Early Eocene Zone P7 through Late Oligocene Zone P22. It is found first in the Early Eocene of North Africa and the Middle East. In early Eocene Zone P7, it occurs in Russia. Not until the Late Eocene has it been found in the American Gulf Coast, Mexico and the American West Coast. It continues into the Oligocene of the Caribbean area and Mexico and the American West Coast.

Ecology: *Uvigerina jacksonensis* is found in upper bathyal marls and clays representing marginal bays and in carbonate shelf sediments. These facies contains some planktic foraminifera, but benthics are much more abundant. Land- derived materials such as mica are often abundant. In more carbonate-rich sediments, *Uvigerina jacksonensis* is accompanied by a plexus of coarsely costae forms such as *Uvigerina cocoaensis, Uvigerina multistriata* and at the shallowest end of its depth spectrum, *U. nuttalli* Cushman and Edward. In more

Uvigerina jacksonensis Cushman, 1925

pl. 12, figs. 5, 6

Description: Test large, stout, broadly fusiform with the greatest width at the middle; chambers increasing gradually in size, final chamber often smaller than those in penultimate whorl; coiling compact and tri-serial throughout; chambers are inflated; sutures somewhat depressed; periphery lobulate to robust, wall ornamented with longitudinal costae, most of which are restricted to individual chambers; final chambers somewhat rounded; aperture ends in a terminal neck with reverted lip.

References:

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Ecology: *Uvigerina jacksonensis* is found in upper bathyal marls and clays representing marginal bays and in carbonate shelf sediments. These facies contains some planktic foraminifera, but benthics are much more abundant. Land- derived materials such as mica are often abundant. In more carbonate-rich sediments, *Uvigerina jacksonensis* is accompanied by a plexus of coarsely costae forms such as *Uvigerina cocoaensis*, *Uvigerina multistriata* and at the shallowest end of its depth spectrum, *U. nuttalli* Cushman and Edward. In more organic- rich, shallow water or lagoonal or bay facies, *U. jacksonensis* may be accompanied by *Uvigerina vicksburgensis.*

Uvigerina longa Cushman and Bermudez, 1937

pl. 11, figs. 7-8

Description: *Uvigerina longa* has most of the characters of *Uvigerina* sp. It is elongate with a tendency towards uniseriality, ornamented with plate-like costae.

Reference:

1996 *Uvigerina longa* (Cushman and Bermudez), Raju and Dave, p. 197, pl. 3, figs. 3, 7, Cauvery Basin, South India.

Remarks: The present specimen measures a length of 0.5mm and a breadth of 2mm. It has 7-10 costae per chamber. Aperture ends in a terminal neck with a reverted lip. In the present work, *U. longa* is found at Chobama 3 section.

Stratigraphic range: It ranges from Late Eocene through Oligocene (Boersma, 1984).

Ecology: The species is common in the lower upper bathyal and uppermost middle bathyal depths in Italy, Caribbean, Atlantic and Mediterranean area.

Uvigerina moravia Boersma, 1984

pl. 12, fig. 2

Description: Test medium to large, oblong and broadly fusiform in shape; about twice as long as broad with greatest breadth in upper half of the test; coiling triserial throughout; chambers increase in size gradually; sutures depressed, porous wall ornamented with few longitudinal low costae; Neck, is short in the final chamber, ends in a reverted lip.

Reference:

1984 *Uvigerina moravia* Boersma, p. 114-116, figs. 1-4.

Remarks: The present specimen has 0.5mm length and 0.2-0.3mm breadth. Surface ornamentation has 4-5 costae per chamber. A short neck ends in a reverted lip. In the area studied, it occurs at Pfutsero 2 section

Ecology: *Uvigerina moravia* occurs in clay and quartz rich detrital environments of the upper bathyal zone. Less commonly, it is found in marls with moderate amounts of planktonic foraminifera.

Stratigraphic range: *Uvigerina moravia* ranges from Late Eocene Zone P16 through Zones N4 (and possibly into Zone N5) or the Early Miocene. Its first occurrence is found in Northern Italy, but is most common in Europe in the Early to Mid-Oligocene, and spreads to western South America in the Mid-Oligocene. Its last occurrence is found in the Early Miocene of the Para-Tethys.

Uvigerina steyeri Papp, 1975

pl. 12, fig.4

Description: Test medium-sized, stout and robust, fusiform; coiling triserial throughout, chambers inflated and outline slightly lobulate; sutures indistinct costae restricted to individual chambers; terminal neck thick, short, ending in a reverted lip.

Reference:

1984 *Uvigerina steyeri* (Papp), Boersma, p. 166-168, figs. 1-4.

Remarks: The specimen from our study material has 0.6mm length and 0.3mm breadth and has an asymmetrically fusiform shape. It has about 6 costae per chamber and all the costae are restricted to individual chambers. It has a terminal, thick and short lip. In the present study, it is found at Pfutsero 1 and 2 sections.

Ecology: *Uvigerina steyri* is representative of upper bathyal marly clays and quartz rich clays primarily in the Mediterranean bio-province where it occurs through both lower and middle Latitudes. It is usually associated with large amounts of detrital minerals, dark clays and rich, highly ornamented benthic foraminiferal faunas. It occurs less commonly in marly sediments with moderate numbers of planktonic foraminifera.

Stratigraphic range: *Uvigerina steyeri* ranges from the Early Eocene through the Late Oligocene. It was first found in zone P7 in the Aral Sea region of Russia, then in the Middle Eocene of western Africa. It is most common in the Late Eocene of the Circum-Mediterranean, but persists through Late Oligocene Zone P22 in both North Africa and in the Para-Tethys.

Uvigerina vicksburgensis Cushman and Ellisor, 1931

pl. 12, fig. 3

Description: Test medium to large; chambers enlarging rapidly width near the mid portion of the test is greatest; coiling triserial throughout; chambers slightly inflated, periphery slightly lobulate; finely porous wall ornamented with longitudinal, coarse platy costae, all of which are restricted to individual chambers; neck set into a depression in final Chamber; ends in a reverted lip.

Reference:

1980 *Uvigerina vicksburgensis* (Cushman and Ellisor), Tipton, p.270, fig. 8.

1984 *Uvigerina vicksburgensis* (Cushman and Ellisor), Boersma, p. 186-187, figs. 1-4.

Remarks: In our study material, the specimen has about 7-9 costae per chamber. It is 0.4mm length and 0.3mm breadth. Neck is not visible. It may be broken. In the present study, it is found in Chobama 3 section.

Ecology: *Uvigerina vicksburgensis* occurs in clay and carbonate-rich shallow water sediments deposited at upper bathyal to shelf depths. It is most typical during regression.

Stratigraphic range: *Uvigerina vicksburgensis* ranges from the Middle Eocene into the Early Oligocene. It is first found in Mid-Eocene Zone P9 in Tunisia, but is most common from Late Eocene into Early Oligocene in the southeastern United States, in the Alazan formation of Mexico, and in Venezuela.

Superfamily DISCORBACEA Ehrenberg, 1838

Family BAGGINIDAE Cushman, 1927

Subfamily BAGGININAE Cushman, 1927

Genus ***Baggina*** Cushman, 1926

Baggina cojimarensis Palmer, 1941

pl. 5, figs. 1 and 3

Description: Small test, sub-globular, 4-5 chambers in the final whorl. The chambers increases rapidly in size so that the final one occupies nearly half of the dorsal surface, dorsal sutures gently depressed; periphery broad and rounded, lobate in side view, ventral sutures radial, gently depressed, aperture a narrow slit opening into the umbilical depression. Surface finely; conspicuously perforate with the exception of a large clear area above the aperture on the final chamber.

Selected reference and locality:

1994 *Baggina cojimarensis* (Palmer), Bolli *et al.*, p. 361, pl. 55, figs. 1, 2, South Caribbean region

Remarks: The present specimen from Disang Group of Nagaland is similar to the specimen described by Bolli *et al.* (1994) with 4-5 chambers in the final whorl; the final chamber occupies about half of the dorsal surface, aperture a narrow slit opening into the umbilical depression. It has a perforate surface but the area near the aperture is smooth. It is found at Chobama section in fairly large amount.

Baggina dentata Hagn, 1956

pl. 5, figs. 4-5

Description : Test small, oval in outline, sub-globular, both dorsal and ventral side flat, four chambers in the last whorl, enlarging gradually in size as added, the last chamber comprising about one third of the test, sutures depressed, wall perforate, aperture a narrow slit, opening into the wide umbilical depression.

Selected reference and locality:

1956 *Baggina dentata* Hagn, pl. 15, fig. 7a-b; Lake Garda, Italy

Remarks: The chamber size increases as added; wall perforate and the aperture at the umbilicus depression. It is found at Chobama section. A fair number of Baggina dominicana specimens are found at Chobama1, 2 and 3 sections.

Baggina dominicana Bermudez, 1949

pl. 5, fig. 2

Description: Test small, sub globular, dorsal side flat, ventral side slightly concave; five chambers in the last whorl, inflated , enlarging rapidly in size as added; the last chamber comprising about one-third of the test, sutures depressed, the ventral ones converging toward the umbilical region where the bases of the chambers form low knobs of clear shell material, wall smooth, opaque, finely perforate, except on the ventral side of the last chamber which is vitreous, smooth and imperforate; aperture a narrow slit, opening into the wide umbilical depression.

Selected reference:

1949 *Baggina dominicana* Bermudez, no. 25, p. 260

Remarks: The apertures are not clearly preserved due to ill preservation of the specimen. A fair number of *Baggina dominicana* specimen are found at Chobama sections.

Baggina sp.

pl. 5, fig. 6

Description: Test large, inflated, rotaliform, longer than broad, periphery rounded, chambers distinct, five to six in last formed coil, increasing rapidly in size, last chamber large and flaring with apex extended and rather sharp, sutures distinct, depressed but not strongly, slightly curved, wall smooth, aperture a large opening at base of ultimate chamber near umbilicus than periphery. Few species are recorded from Chobama 1, 2, 3 sections.

Genus ***Cancris*** de Montfort, 1808

Cancris mauryae Cushman & Renz, 1942

pl. 6, fig. 1

Description: Test elongate, articulate in outline, chambers increasing as added, sutures depressed, arched on the spiral side and radial around the umbilicus; wall calcareous and perforate with a peripheral keel.

Selected reference:

1994 *Cancris mauryae* (Cushman and Renz), Bolli *et al.*, p. 240, fig. 55, 3a-c.

Remarks: Typical for the species is its size, strongly elongate test shape, five chambers forming the lost whorl, rapidly increasing in size and the presence of a distinct peripheral keel. In the present study, it is occurring at Chobama 1 section in few numbers.

Stratigraphic range: In Bolli *et al.*, 1994, it is recorded in Trinidad from the Paleocene to Early Eocene Soldado Formation.

Superfamily DISCORBINELLACEA Sigal, 1952

Family PARRELLOIDIDAE Hofker, 1956

Genus ***Cibicidoides*** Thalmann, 1939

Cibicidoides sp.

pl. 5, figs. 7-9; pl. 6, fig. 3

Description: Few specimens of the *Cibicidoides* occur at Chobama section. The specimen has a lenticular, biconvex trochospiral test; periphery is angular and carinate; wall calcareous, coarsely perforate on the spiral side, umbilical sparsely perforate. As the specimens are not satisfactorily preserved, other characters cannot be described and it cannot be identified to the species level.

Superfamily PLANORBULINACEA Schwager, 1877

Family CIBICIDIDAE Cushman, 1927

Subfamily CIBICIDINAE Cushman, 1927

Genus ***Cibicides*** de Montfort, 1808

Cibicides sp.

pl. 6, figs. 7-9

Description: Test trochospiral and planoconvex, spiral side flat to concave, evolute, sutures thickened and may be elevated, strongly convex and involute, umbilical side with depressed sutures, apertural face angular periphery carinate; wall calcareous, spiral side coarsely perforate; aperture a low interiomarginal equatorial opening. Few specimens are found at Chobama 1, 3 sections.

Superfamily NONIONACEA Schultze, 1854

Family NONIONIDAE Schultze, 1854

Subfamily NONIONINAE Schultze, 1854

Genus ***Nonionella*** Cushman, 1926

Nonionellina sp.

pl. 6, fig. 2

Description: The specimen from Disang Group of Nagaland characterizes *Nonionellina* genus with its trochospiral test, chambers increase in size as added with an inflated basal lobe at the umbilicus, periphery sub angular to rounded, wall calcareous, surface smooth. Aperture is not clear due to poor preservation. It is found at Chobama section in few numbers.

Superfamily CHILOSTOMELLACEA Brady, 1881

Family OSANGULARIIDAE Loeblich and Tappan, 1964

Genus ***Osangularia*** Brotzen, 1940

Osangularia plummerae Brotzen, 1940

pl. 8, figs. 2-3 and 6

Description: Test trochospiral, planoconvex, sub-circular in outline, periphery a thin prominent keel; dorsal side flat to slightly convex, chambers not clearly visible; sutures broad, curved and slightly elevated, ventral side convex, 8 chambers visible in the last whorl, sutures radial and curved , depressed between the chambers; aperture a short interiomarginal slit on ventral side; wall calcareous.

Selected reference and locality:

2001 *Osangularia plummerae* Brotzen, Alegret and Thomas, p. 292, pl. 9, fig. 11a, b, c, Northeastern Mexico.

Remarks: The present specimen from Disang Group of Nagaland is similar with the specimen reported by Alegret and Thomas from northeastern Mexico with its plane convex test, keeled periphery and number of chambers in the last whorl. The specimen is found at Chobama 1 section in large amount.

Osangularia sp. Brotzen, 1940

pl. 8, figs. 1 and 4-5

Description: Test trochospiral, lenticular, biumbonate, spiral side evolute, whorls enlarging gradually, sutures thickened, oblique and curved; umbilical side involute, sutures radial and depressed, periphery carinate; wall calcareous, finely perforate, surface smooth; aperture areal, at an acute angle to the base of the chamber. Few specimens are encountered at Leshemi and Chobama 1, 2, 3 sections in the study area.

Superfamily ROTALIACEA Ehrenberg, 1839

Family ELPHIDIIDAE Galloway, 1933

Subfamily ELPHIDIINAE Galloway, 1933

Genus ***Elphidiella*** Cushman, 1936

***Elphidiella* sp.**

pl. 9, figs. 1-6

Description: Test large, planispiral, involute and bilaterally symmetrical, from ten to twenty chambers in the final whorl, no true ponticuli or fossettes but may have retral processes; wall calcareous, perforate, optically radial or less commonly optically granular, aperture and foramina interiomarginal, single or multiple; and may also have multiple areal openings. Moderate number of specimens is found at Leshemi and Chobama 1, 2, 3 sections.

Superfamily NUMMULITACEA de Blainville, 1827

Family NUMMULITIDAE de Blainville, 1827

Genus *Nummulites* Lamarck, 1801

Nummulites pengaronensis Verbeek, 1871

pl. 4, figs. 5-8

Description: Test globular, lenticular or discoidal, commonly large, up to about 12cm in diameter, planispirally enrolled, commonly involute but may be evolute in the later stage. Proloculus and deuteroconch separated by an imperate common wall with a single central round pore and with a row of pores at the base of the septum, septa curved back at the periphery and may be sigmoidal, distinct marginal cord on the periphery, directed obliquely backward and forward on both sides of the septa, pillars may be interspersed between septal filaments and appear at the surface as pustules; aperture in all post-procular chambers consists of a row of pores at the base of the face.

Selected references and localities:

1959 *Nummulites pengaronensis* Verbeek; Nagappa, pl. 10, figs. 3-5, Jaintia Hills, Assam, India.

1987 *Nummulites pengaronensis* Verbeek; Baruah *et al.*, fig. 7 (7-9), fig. 8 (1-2), Nagaland.

1996 *Nummulites pengaronensis* Verbeek; Matsumaru, p. 84, pl. 21, figs. 3-5, Ogasawara Islands, Japan

2003 Nummulites *pengaronensis* Verbeek; Mukhopadhyay, p. 90, pl. 6, fig. 5, Cambay Basin, India.

Remarks: The present form is characterized by striated and radial septal sutures in the ornamentation of the bi-conical test, the development of a central plug, nearly straight and radial septa, except near their distal ends, tight coiling of a spiral wall and small embryonic chambers. Thus the present form is referred to *Nummulites pengaronensis* Verbeek, 1871. Nagappa (1959) described those *Nummulites pengaronensis* (Verbeek) from the Khirthar Stage evolved from *N. atacicus* Leymerie from the Laki to Lower Khirthar Stages, whereas *N. beaumonti* d'Archiac and Haime from the Khirthar Stage evolved from *N. pinfoldi* Davies, 1940, from the Laki to lower Khirthar Stage, which evolved from *N. atacicus* Leymerie from the lower Laki Stage. Therefore, both .*N pengaronensis* and *N. beaumonti* could be regarded as descendent species from *N. atacicus*. In the studied sections, it occurs only at Leshemi village section.

Stratigraphic range: Loeblich and Tappan (1988) recorded as Paleocene to Holocene.

Nummulites chavannesi De La Harpe, 1878

pl. 4, figs. 1-4

Selected reference and locality:

1972 *Nummulites chavannesi* (De La Harpe), Blondeau, p. 146, pl. 22, figs.1-3.

Remarks: The present specimen is characterized in hand specimen by a swollen test at center and flat at margin, septal filaments radial, spots in polar region, spine small, septa close and arcuate. In thin section it is characterized by tight coiling of a spiral wall, all the septa projecting backward. Therefore, the present specimen is referred as *N. chavannesi*. In the present study, it is found at Leshemi section.

Stratigraphic range: Blondeau, 1972 recorded the range as from the top of Lutetian to Upper Priabonian.

CHAPTER 4

BIOSTRATIGRAPHY

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4.1 INTRODUCTION

Stratigraphy has been succinctly defined as the "descriptive science of strata". It involves the form, structure, composition, areal distribution, succession and classification of rock strata in normal sequence. Biostratigraphy is that aspect of stratigraphy which involves the direct observation of paleontologic events in superposition. A biostratigraphic unit is a paleontologic characteristic. The evolution of organisms through time has provided the framework for a system of zonations by which discrete units of time represented by material accumulation of sediments can be recognized (Berggren, Haq & Boersma, 1978).

The last 35 years have been of vital importance in the history of the use of planktic microfossils for the dating of Mesozoic and Cenozoic marine sediments. As the oceans occupy 71% of the surface of the globe, the results were bound to have a profound effect on geologic thinking (Bolli *et al.*, 1985).

Planktic foraminiferal species were almost entirely ignored as markers until the 1940s because morphological differences between species were not appreciated, leading to the description of relatively few, mostly long ranging taxa. A change in attitude was forecast by Grimsdale (1951) who compared the ranges of 41 Tertiary planktic species from the Gulf of Mexico and the Caribbean with their equivalents in the Middle East. This was the beginning of a strong commitment by micropaleontologists first in oil companies but soon also in Universities and Geological Surveys, to the zonation of Cretaceous and Tertiary rock sequences using planktic foraminifera.

According to Toumarkine and Luterbacher in Bolli *et al.* (1985), the subdivisions of the Paleogene were developed initially in two widely separated geographic areas. In the eastern hemisphere, it was mainly in the northern foothills of the Caucasus Mountains that planktic foraminifera were already used to solve stratigraphic problems in oil and gas exploration during the 1930s.

A first comprehensive resume of the use of Paleogene planktic foraminifera as a stratigraphic tool was given by Subbotina (1953). In the western hemisphere, the first detailed subdivision of the Paleogene based on planktic foraminifera was established in Trinidad by Bolli (1957a, b). Blow (1969), Blow (1979), Berggren and Miller (1988), Stott and Kennett (1990), Raju *et al.* (1991), Berggren *et al.* (1995), based on sections of on-land, deep wells and deep sea drilling sites at many parts of the world, developed some of the important Paleogene planktic foraminiferal zonal schemes.

The most outstanding events in planktic foraminiferal biostratigraphy over the past five decades are: (1) documentation of foraminifera by Subbotina (1953) from Russia; (2) description of zonal schemes-an initiation towards further developments by Bolli and others (1957) and (3) the advent of JOIDES Deep Sea Drilling Programmes a result of which a number of Cenozoic sequences ranging from tropical to temperate regions were recovered which provided a large opportunity to study the ranges, phylogeny and phenotypic variations within various groups of planktic foraminifera. Zonal schemes based on planktic foraminifera are well established and proved in many land sections, both surface and subsurface, by the time the DSDP began in 1968.

Painstaking researches by several workers during the last few decades in describing the species, collection of data on their lateral distribution and stratigraphic ranges, and the attempts towards clarification of the lineages and classification of planktic foraminifera from different continents have helped in solving several biostratigraphic and taxonomic problems (Raju, 1968).

Nagappa (1957, 1959) emphasized the use of planktic foraminifera in solving certain stratigraphic problems of correlation of early Tertiary beds in the Indian subcontinent. Rajagopalan (1965), for the first time attempted the planktic foraminiferal zonation. Raju (1968) worked on Eocene-Oligocene planktic foraminiferal biostratigraphy of Cauvery Basin, South India and recognized 7 zones. In 1971, Raju worked on Upper Eocene to Early Miocene planktic foraminifera from the subsurface sediments in Cauvery Basin, South India and proposed seven planktic foraminiferal zones for the Upper Eocene to early Miocene sequence.

4.2 BIOSTRATIGRAPHIC STUDIES IN NORTHEAST INDIA

Nagappa (1959), for the first time, recorded the presence of foraminifera from the Disang Group of rocks in Nagaland. He reported the occurrence of reticulate *Nummulites* and some arenaceous foraminifera, such as *Ammobaculites, Ammodiscus, Bathysiphon, Cyclammina, Gaudryina and Haplophragmoides.* Based on the assemblages of these foraminifers, Nagappa (1959) suggested that the top of the Disang Group of rocks are probably not younger than the Upper Eocene.

According to Samanta (1973), the Tertiary rocks in India are best developed in Northeast India. A study of these rocks of Assam by Evans (1932) has indicated that the Tertiary rocks in Assam and its surroundings are developed in two different facies. The Tertiary rocks in Surma Valley and Upper Assam represent the geosynclinal facies while those in Central Assam range were deposited as shelf sediments. In the Eocene part of the succession the difference between the sediments of geosynclinal and shelf facies is remarkable. The geosynclinal facies consisting of mainly grey shales and sandstones, outcrops south and southeast of the Haflong-Disang and Naga thrust is poorly fossiliferous. The shelf facies, on the other hand, occurring north and northwest of the Haflong-Disang and Naga thrusts along the southern foothills of the Garo, Khasi-Jaintia and Mikir-North Cachar Hills is dominantly of calcareous sediments. These shelf sediments are richly fossiliferous and contain both floral and faunal elements. Of these, foraminifera are most abundant and are distributed almost throughout the marine part of the succession.

Baruah *et al.* (1987) were the first to work a detailed foraminiferal biostratigraphy on the Disang Group of rocks in Nagaland. Baruah *et al.* (1987) worked on Disang and Barail Groups of rocks of a part of Nagaland. Based on the foraminiferal assemblages recorded, they recognized two assemblage zones namely *Cribrohantkenina inflata-Hantkenina alabamensis* Zone and *Nummulites pengaronensis-Pellatispira madraszi-Discocyclina dispansa* Zone which have been dated as middle to late Late Eocene age (Zone P16 and early part of Zone P17 of Blow, 1969).

Bhatia and Dave (1996) recorded a rich foraminiferal assemblage of Paleogene sequence encountered in five exploratory wells viz. Chumukedima, Tynyphe, Naojan, Kasomarigoan and Barpathar across the Dhansiri Valley. They recognized three biozones viz. *Nummulites acutus-Fasciolites elliptica* assemblage Zone, *Nummulites dicorbinus-Assilina* sp. assemblage Zone, *Nummulites pengaronensis* Zone and a poorly fossiliferous zone ranging in age from Middle Eocene to Oligocene. According to them, the thickness of Paleogene sequence is considerably reduced in the northeastern part of Dhansiri Valley at Barpathar in Assam, where it unconformably overlies the Gondwanas. However, it attains maximum thickness at Chumukedima, suggesting a basinal slope towards southwest.

4.3 DISTRIBUTION OF FORAMINIFERA AND PLANKTIC FORAMINIFERAL ZONATIONS OF THE STUDY AREA

In the course of this study a total of 14 species of planktic foraminifera belonging to 7 genera and 2 subfamilies, 5 families, 4 superfamilies and 1 suborder have been recorded and are used for zonation and correlation. Among these, species of *Globigerinatheka semiinvoluta*, *Chiloguembelina cubensis*, *C. martini*, *C.* cf. *tenuis*, *Hantkenina liebusi*, *P. naguewichiensis*, *Turborotalia cerroazulensis cocoaensis* and *T. c. pomeroli* have been reported for the first time from Nagaland.

Foraminifera are globally used for biostratigraphic subdivision and correlation of sedimentary strata. However, no precise planktic foraminiferal zonation has been made in Nagaland so far. Micropaleontological investigations by Venkatachalapathy, Raju & Kapesa suggest that some parts of the Tertiary sequence in Nagaland are rich in foraminifera, which may be utilized as suitable zone fossils.

According to Abdelghany (2002), two Upper Eocene planktic foraminiferal zonations (bipartite and tripartite zonations) are currently used by different workers as mentioned below:

Bipartite Zonation: Some authors consider the Upper Eocene to include a lower *Globigerinatheka semiinvoluta* s.l Zone and *Turborotalia cerroazulensis* Zone (P16/17); e.g. Bolli (1966), Stainforth *et al.* (1975), Saunders *et al.* (1984), Toumarkine and Luterbacher (1985). The boundary between these two zones is marked by the last occurrence of *Globigerinatheka semiinvoluta.* This criterion is used in the absence or disappearance of *Cribrohantkenina inflata* due to ecological factors.

Tripartite Zonation: The tripartite subdivision of the Upper Eocene (P15, P16, P17) has been used by some authors; (Blow 1969, 1979; Samanta 1970; Berggren and Miller 1988; Berggren *et al.*, 1995; Coccioni 1988; Parsi *et al.*, 1988; Anan 1995). The *Cribrohantkenina inflata* Zone (P16) was first defined by Blow (1969) as an interval representing the total range of the marker species. In this case, this zone is located between the *Globigerinatheka semiinvoluta* Zone (P15) and the *Turborotalia cerroazulensis* Zone (P17). Anan (1995) noted that the literature dealing with local and worldwide Late Eocene planktic foraminifera and the stratigraphic occurrences of *G. semiinvoluta, C. inflata* and *T. cerroazulensis cunialensis* indicate that the youngest occurrence of *G. semiinvoluta* occurs after the earliest appearance of *C. inflata* in the lower part of P16 (Blow 1969, Keller 1985, Toumarkine and Luterbacher 1985, Berggren and Miller 1988). The overlap between ranges of *C. inflata* and *T. cerroazulensis* *cunialensis* exists either in the upper part of P16 only (Coccioni *et al.* 1988: Parsi *et al.*, 1988) or extends throughout the *T. cerroazulensis* s.l. Zone (top part of P16 and total range of P17) (Toumarkine and Luterbacher 1985, Keller 1985 and Berggren *et al.*, 1995). No stratigraphic overlap between *G. semiinvoluta* and *T. Cerroazulensis cunialensis* was recorded by these authors.

In the study area, 3 biozones in Late Eocene are recognized (Fig. 4.1). They are based on the first appearances and last occurrences of marker species and their ranges. The zones are proposed in accordance with the code of stratigraphic nomenclature of India. The zonation used in the present study is a combination of zones of Blow (1969), Bolli (1985), Berggren *et al.* (1995) and Hardenbol *et al.* (1998). This zonal scheme is primarily intended for the purpose of correlation within Disang Group of Nagaland. At the same time, this planktic foraminiferal zonal scheme for the Upper Disang Group (Late Eocene) is correlated with those of Raju (1971) for Cauvery Basin, South India and Samanta (1973) for Assam, Northeast India. The correlation is based on the ranges of species of *Globigerinatheka semiinvoluta*, *Cribrohantkenina inflata* and *Turborotalia cerroazulensis* within the regions concerned.

4.3.1 *Globigerinatheka semiinvoluta* Zone (Zone P15)

Category: Interval Zone

Author: Bolli (1957) modified by Berggren *et al.*, 1995.

Definition: Biostratigraphic interval between the first occurrence of *Globigerinatheka semiinvoluta* and first occurrence of *Cribrohantkenina inflata.*

Estimated age: 38.4-35.5 Ma in Hardenbol *et al.* (1998).

Remarks: The *Globigerinatheka semiinvoluta* Zone has its upper boundary defined by the last occurrence *Globigerinatheka semiinvoluta* (Keijzer). In the Disang Group *Globigerinatheka semiinvoluta* is extremely rare. The zone is represented at Chobama 1 section, consisting of nodular/concretionary shales, which have a high frequency of foraminifers. In this section, the biozone is represented by a 10 cm thin bed that conformably underlies the *Cribrohantkenina inflata* Zone (P16). This biozone lies in the lowermost part of the road cutting as shown in Fig. 4.2 of Chobama section 1. This Zone is not encountered at the other studied sections of Chobama 2, Chobama 3, Leshemi, Pfutsero 1 and 2. The planktic foraminifers recorded from this zone include- *Chiloguembelina cubensis* (Palmer), *C. martini* (Pijpers), *C.* cf. *tenuis* (Todd), *Globigerina* sp. (d'Orbigny), *Hantkenina alabamensis* (Cushman), *H. liebusi* (Shokhina), *Pseudohastigerina micra* (Cole), *P. barbadoensis* (Blow), *Turborotalia pomeroli*

Figure 4.1 **Tentative stratigraphic ranges of planktic foraminifera distribution in the Disang Group, Nagaland.**

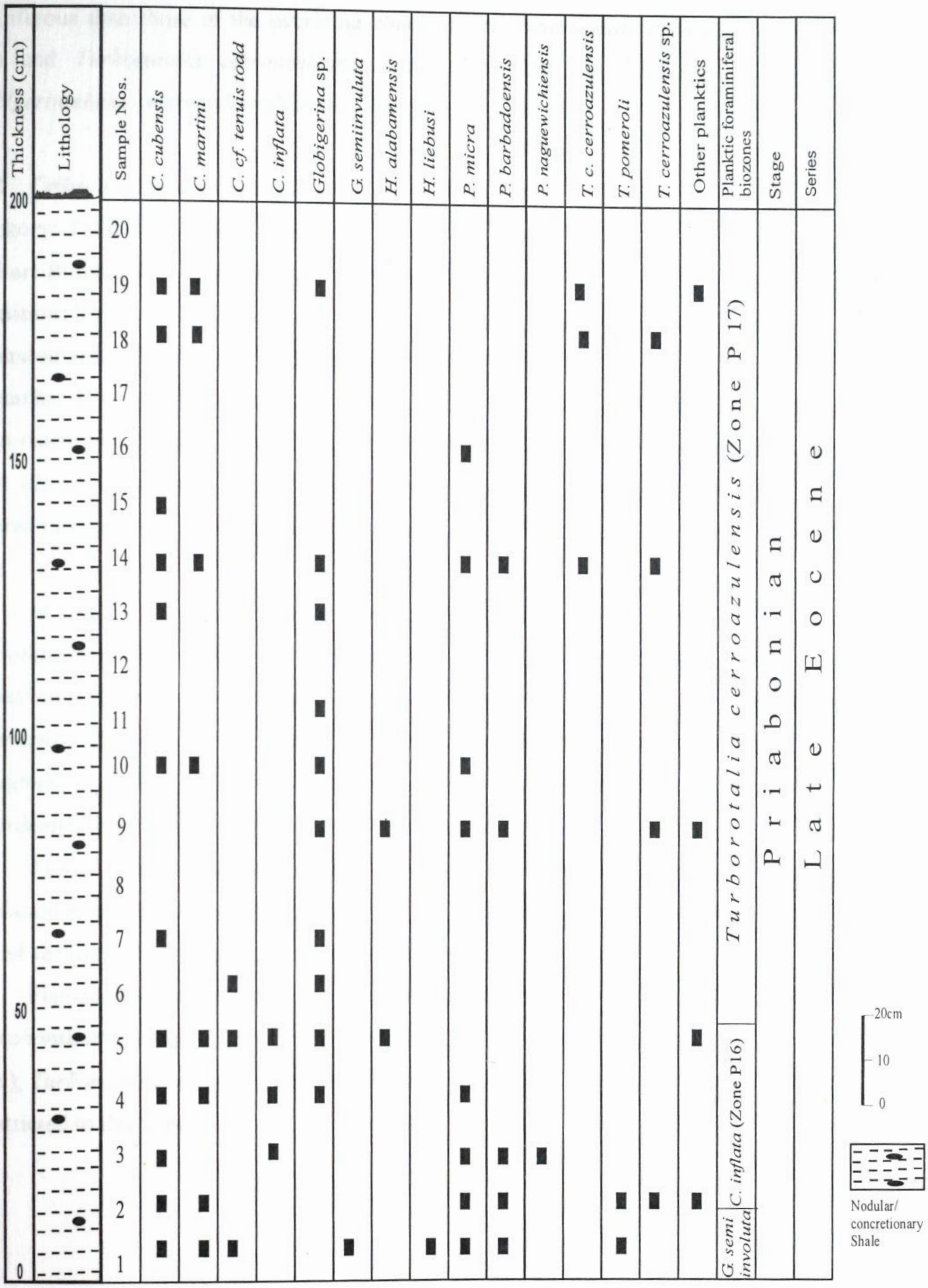


Figure. 4.2 **Distribution of planktic foraminifera and biozones in Chobama 1 section.**

(Toumarkine and Bolli). The foraminiferal assemblage of this zone is more richly fossiliferous than those of the overlying zones of *Cribrohantkenina inflata* Zone (Zone P16) and *Turborotalia cerroazulensis* Zone (Zone P17) at Chobama 1 section. *Globigerinatheka semiinvoluta* (Keijzer) is restricted to this zone.

4.3.2 *Cribrohantkenina inflata* Zone (Zone P16)

Category: Total Range Zone

Author: Blow (1969), modified by Berggren *et al.*1995.

Definition: This zone is characterized by the total range of *Cribrohantkenina inflata.*

Estimated age: 35.5-43.0 Ma in Hardenbol *et al.* (1998).

Remarks: The base and top of the zone is marked by the first and the last appearances of *Cribrohantkenina inflata* (Howe). At Chobama 1 section, this zone has a thickness of about 120 cm comprising of grey-coloured nodular/concretionary shales. The frequency of foraminifers in this zone is lower than the underlying *Globigerinatheka semiinvoluta* Zone.

At Chobama 1 section the planktonic foraminiferal assemblage recorded from the *Cribrohantkenina inflata* Zone (Zone P16) includes- *Chiloguembelina cubensis* (Palmer), *C. martini* (Pijpers), *C.* cf. *tenuis* (Todd), *Globigerina* sp. (d'Orbigny), *Hantkenina alabamensis* (Cushman), *H. liebusi* (Shokhina), *Pseudohastigerina micra* (Cole), *P. barbadoensis* (Blow), and *Turborotalia pomeroli* (Toumarkine and Bolli). *Cribrohantkenina inflata* (Howe) is restricted to this zone.

At Chobama 3 section, Zone P16 is represented by two samples of grey colour, nodular/concretionary shale (as shown in Fig. 4.3). This zone is not encountered at other studied sections of Chobama 2, Leshemi, Pfutsero 1 and 2.

Planktonic foraminiferal assemblage recorded at Chobama 3 section consists of *Cribrohantkenina inflata* (Howe), *Globigerina* sp. (d'Orbigny), *Pseudohastigerina micra* (Cole), *Turborotalia pomeroli* (Toumarkine and Bolli). *Cribrohantkenina inflata* (Howe) is restricted to this zone.

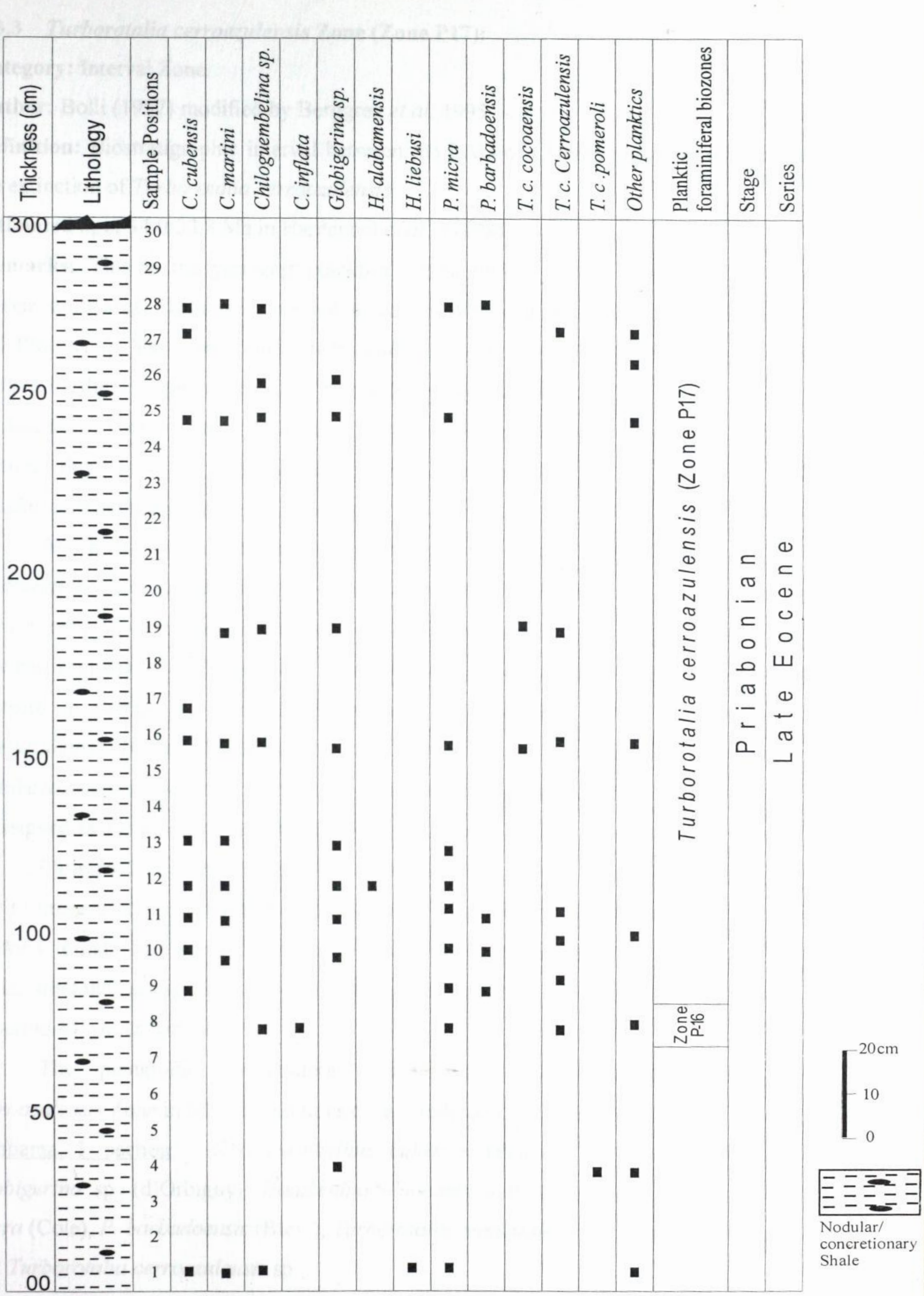


Figure 4.3 Distribution of planktic foraminifera and biozones in Chobama 3 section

4.3.3 *Turborotalia cerroazulensis* Zone (Zone P17):

Category: Interval Zone.

Author: Bolli (1957) modified by Berggren *et al.* 1995.

Definition: Biostratigraphic interval between the LAD of *Cribrohantkenina inflata* and the extinction of *Turborotalia cerroazulensis*

Estimated age: 34.0-33.8 Ma in Hardenbol *et al.*, (1998).

Remarks: This is the youngest planktonic foraminiferal zone recognized from the present study area. This zone is present at sections of Chobama 1, Chobama 3, Pfutsero 1 and Pfutsero 2. The *Turborotalia cerroazulensis* Zone (Zone P17) has its lower limit marked by the disappearance of *Cribrohantkenina inflata* (Howe) and its top marked by the last occurrence of *Turborotalia cerroazulensis cerroazulensis* (Cole). At Chobama 1 section this zone is represented by the samples 14 to 20 consisting of nodular/concretionary shales of grey colour.

At Chobama 3 section the base of the zone is marked by the disappearance of *Cribrohantkenina inflata* (Howe). The top is marked by the last occurrence of *Turborotalia cerroazulensis cerroazulensis* (Cole). In this section, the zone is represented between samples 9 to 30 consisting of nodular/concretionary shales of grey colour. At Pfutsero 1 section the only zonal marker found is *Turborotalia cerroazulensis cerroazulensis* (Cole). Pfutsero 1 section is 23m thick consisting of alternating nodular/concretionary shales, silty shale, siltstone and argillaceous silty sandstone and it is assigned as *Turborotalia cerroazulensis* Zone (Zone P17).

Pfutsero 2 section is assigned as *Turborotalia cerroazulensis* Zone (Zone P17) due to presence of *Turborotalia cerroazulensis cerroazulensis.* There are no other zonal markers found. This section consists of alternating nodular/concretionary shales, silty shale, siltstone, argillaceous silty sandstone and sandstone. Sandstone bed marks the uppermost layer at this section.

The planktonic foraminiferal assemblages recorded from *Turborotalia cerroazulensis* Zone in different sections of the study area are as follows:

Chobama 1 section: *Chiloguembelina cubensis* (Palmer), *C. martini* (Pijpers), *Globigerina* sp. (d'Orbigny), *Hantkenina alabamensis* (Cushman), *Pseudohastigerina micra* (Cole), *P. barbadoensis* (Blow), *Turborotalia cerroazulensis cerroazulensis* (Cole), and *Turborotalia cerroazulensis* sp.

Chobama 3 section: *Chiloguembelina cubensis* (Palmer), *C. martini* (Pijpers), *Chiloguembelina* sp., *Globigerina* sp. (d'Orbigny), *Hantkenina alabamensis* (Cushman), *Pseudohastigerina micra* (Cole), *P. barbadoensis* (Blow), *Turborotalia cerroazulensis cerroazulensis* (Cole), *Turborotalia cerroazulensis cocoaensis* (Cushman).

Pfutsero 1 section: *Chiloguembelina cubensis* (Palmer), *C. martini* (Pijpers), *Chiloguembelina* sp., Globigerina sp. (d'Orbigny), *Turborotalia cerroazulensis cerroazulensis* (Cole).

Pfutsero 2 section: *Chiloguembelina cubensis* (Palmer), *C. martini* (Pijpers), *Chiloguembelina* sp., *Globigerina* sp. (d'Orbigny), *Pseudohastigerina micra* (Cole), *P. barbadoensis* (Blow), *Turborotalia cerroazulensis cerroazulensis* (Cole), *Turborotalia cerroazulensis cocoaensis* (Cushman), *Turborotalia cerroazulensis pomeroli* (Toumarkine and Bolli) and *Turborotalia cerroazulensis* sp.

4.4 CORRELATION

The potentiality of planktic foraminifera in biostratigraphic investigation, particularly in long distance correlation of marine sediments is well known. The detailed and systematic studies carried out in the Caribbean region during the post-war period contributed greatly to establish the usefulness of planktic foraminifera in biostratigraphic investigation. It was here in Trinidad that Bolli (1957) proposed for the first time a detailed zonation of the Tertiary rocks based on planktic foraminifera. Most of Bolli's zones were subsequently recognized in other localities in the tropical-subtropical region in Samanta (1973).

Subsequent studies on more complete sections with rich planktic foraminifera have led to several modifications of Bolli's zonal scheme. For the late Middle to Upper Eocene period, most significant contributions have been made by Blow and Banner (1962) in Samanta (1973). Thus Bolli's zonal scheme with modifications and additions introduced by Blow and Banner (1962) is usually regarded as the standard for the late Middle to Upper Eocene warm water marine sediments. A comparison of the planktonic foraminiferal zones of the Disang Group of rocks of Nagaland is made with those proposed by Bolli (1957), Blow (1969), Berggren and Couvering (1974), Blow 1979, Berggren et al. (1995), Raju (1968, 1971) of Cauvery Basin, South India, Samanta (1969, 1970 and 1973) of Assam Northeast India and Sulaiman Range, Pakistan and Baruah et al. (1987) from Disang and Barail Groups of a part of Nagaland.

4.4.1 Correlation of the planktic foraminiferal zones in the present studied sections

Correlations of planktic foraminiferal zones between the studied sections show that Chobama 1 section (Fig.4.2) has three biozones namely *Globigerinatheka semiinvoluta* Zone (P14), *Cribrohantkenina inflata* Zone (P15) and *Turborotalia cerroazulensis* Zone (P16).

Chobama 2 section has no zonal marker. Therefore no zone has been assigned to it.

Chobama 3 section (Fig.4.3) has been assigned to two zones, namely *Cribrohantkenina inflata* Zone and *Turborotalia cerroazulensis* Zone.

Pfutsero 1 and 2 sections (Figs.4.4, 4.5a,b) are assigned *Turborotalia cerroazulensis* Zone due to the presence of the zonal marker *Turborotalia cerroazulensis.*

Leshemi section (Fig.4.6) is assigned as Priabonian age due the presence of *Hantkenina alabamensis* but without Middle Eocene zonal markers and no zone is assigned as no zonal marker foraminifera are encountered.

4.4.2 Correlation of planktic foraminiferal zones with other regions

Three planktic foraminiferal zones of the studied sections are correlated with other parts of India and of the world as shown in Table II.

4.4.2.1 *Globigerinatheka semiinvoluta* Zone: *Globigerinatheka semiinvoluta* Zone in Blow (1969) was defined by the total stratigraphic range of the zonal marker *Globigerapsis mexicana* (=*G. semiinvoluta*). The correlation of the different zones of Disang Group is done with those of Blow (1969) and Blow (1979) in tropical areas with the similar occurrence of *Globigerapsis mexicana* (=*G. semiinvoluta*). Raju (1971) recorded a rich assemblage of planktic foraminifera from *G. semiivoluta* Zone, including a zonal marker *G.* cf. *tropicalis* along with *Globigerinatheka barri*, *G.* cf. *lindiensis, Pseudohastigerina micra, Hantkenina alabamensis, H. suprasuturalis, H. trinitatatensis, H.* cf. *thalmanni, Hantkenina* sp., *Globigerina corpulenta, G. psedocorpulenta, G. gortanii praeturritilina, Chiloguembelina martini* and *Chiloguembelina cubensis.* The correlation of Disang Group with Cauvery Basin is based on similar assemblages containing (although rare) *G. semiinvoluta* (=*G. mexicana*). In the Rakhi Nala section of Pakistan, only one planktic zone, namely, the *Globigerina officinalis* Zone was proposed

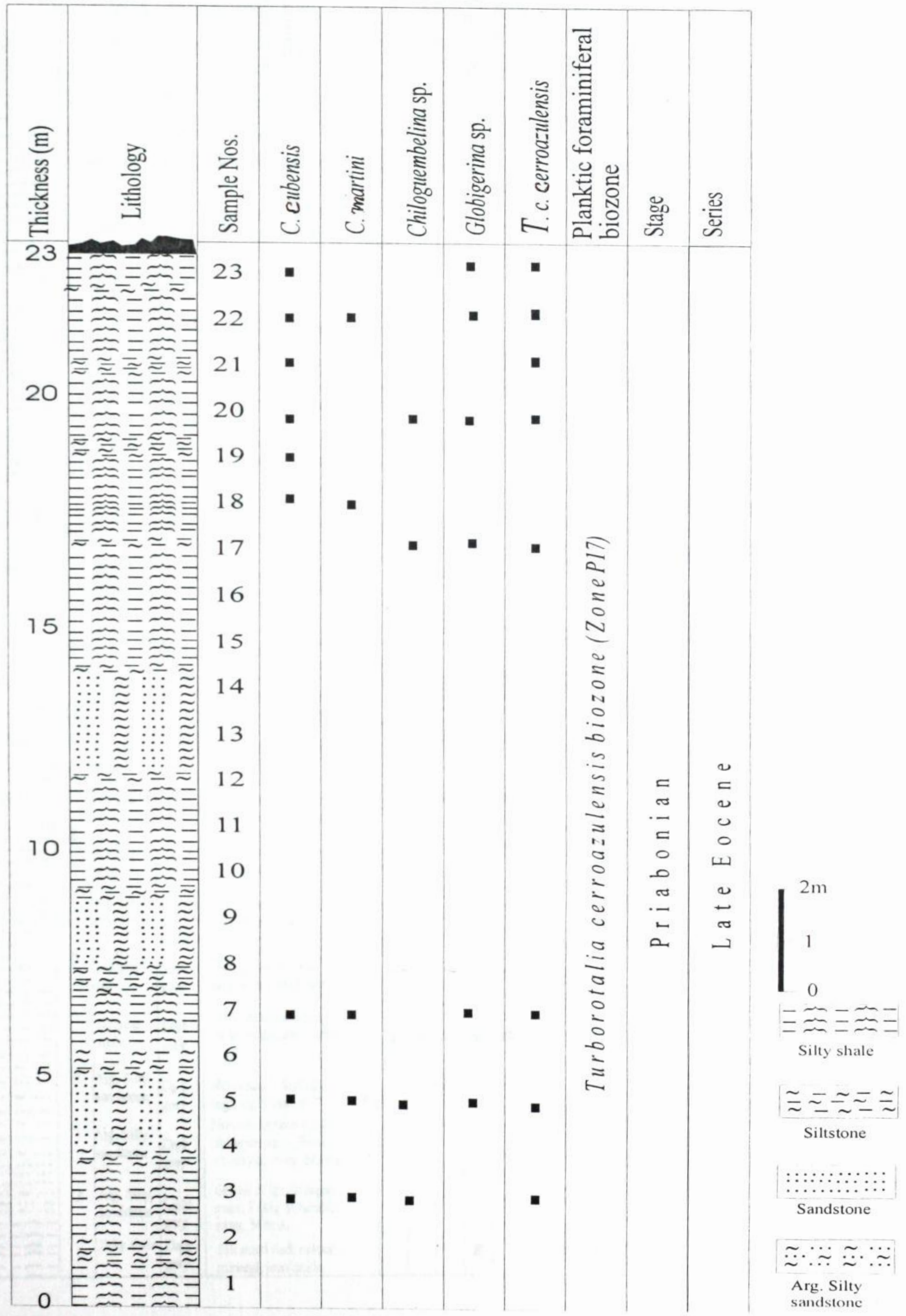


Figure 4.4 **Distribution of planktic foraminifera and biozones in Pfutsero 1 section**

Thickness (M)	Lithology	Sample Nos.	Gross lithology	Colour	Characteristic Sed. Features	*C. cubensis*	*C. martini*	*Chiloguembelina sp*	*Globigerina sp.*	*T. c. cerroazulensis*	*T. c. cocoaensis*	*T. c. pomeroli*	*T. ceroazulensis sp.*	*P. barbadoensis*	*P. micra*	*Pseudohastegerina sp.*	Planktic foraminiferal biozone	Stage	Series
20		20	Silty shale	Light grey	Thin lamination of silt layer.			■	■						■		*Turborotalia cerroazulensis* biozone (Zone P-17)	Priabonian	Late Eocene
		19	Laminated Siltstone	Dirty white	B.C.R. 0.2mm-1mm thick but with 0.2mm lamination.														
		18	Nodular shale	Light grey	Fissile,carbonaceous.					■	■	■	■						
		17	Siltstone	L. grey/ dirty white	Well jointed, cross laminated, indurated together.														
15		16	Nodular shale	Light grey	Fissile non-calc., Carb. fine to medium grains.	■	■	■	■	■	■	■	■	■	■	■			
		15	Nodular shale	Light grey	Fissile non-calc., Carb. fine to medium grained.			■	■		■		■			■			
		14	Siltstone	Light grey	Layered, silt to v. fine q.f. Fe Mg minerals set in calcite cement, calcite concretions.														
		13	Nodular shale	Dark grey	Fissile, Carbonaceous, Micaceous, Non-calc.		■	■	■	■									
		12	Sandstone	Light grey	Massive, fine to medium, sub rounded to subangular, well sorted grains of q. F, FeMg mineral indicating debris flow														
10		10	Nodular shale	Light grey	Fissile, silt grain embedded in shale with lenticular layers of silt st. Rich in carbonate & mica.	■		■	■	■	■	■	■	■	■	■			
		9	Nodular shale	Light grey	Fissile, silt grain embedded in shale.	■		■	■	■	■		■	■	■	■			
		8	Nodular shale	Light grey	Fissile, silt grain embedded in shale.	■	■	■	■	■	■	■							
			Nodular shale	Light grey	Fissile, silt grain embedded in shale.	■		■	■	■	■		■	■	■	■			
		7	Arg. silty sandstone	L.grey/ dirty white	Fissile, silt grain embedded in shale.										■				
5		6	Nodular shale	Dark grey	Fissile, Micaceous, silty with carb. Matrix	■			■	■		■	■	■	■	■			
		5	Nodular shale	Dark grey	Fissile, Micaceous, silty with carb. Matrix	■	■	■	■	■	■		■		■	■			
		4	Arg. Silty sandstone	Dark grey	Non-calc.,V.fine silt, high arg. Content.														
		3	Arg. Silty sandstone	Dark grey	Non-calc,grains of qtz, feldspar, mica, FeMg minerals, inorg. Matrix.														
		2	Arg. Silty sandstone	Light grey	Grains of qtz,feldspar, mica, FeMg minerals, inorg. Matrix.														
0		1	Silty shale	Dark grey	Silt sized dark colour mineral, iron oxide.				■			■	■	■		■			

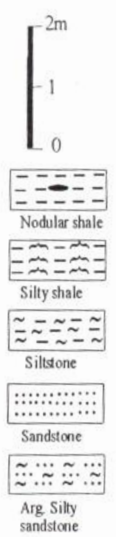


Figure 4.5a **Distribution of Planktic foraminifera and biozones from Pfutsero 2 section**

Thickness	Lithology	Sample Nos.	Gross lithology	Colour	Characteristic Sed. Features	*C. cubensis*	*C. martini*	*Chiloguembelina sp.*	*Globigerina sp.*	*T. c. cerroazulensis*	*T. c. cocoaensis*	*T. c. pomeroli*	*T. cerroazulensis sp.*	*P. barbadoensis*	*P. micra*	*Pseudohastegerina sp.*	Planktic foraminiferal biozone	Stage	Series
40		40	Nodular shale	Light grey	Non-calc, massive with silt grains.												*Turborotalia cerroazulensis* biozone (Zone P17)	Priabonian	Late Eocene
		39	Nodular shale	Light grey	Non-calc, massive with silt grains.														
		38	Nodular shale	Light grey	Micaceous, carb., With silt grains.														
		37	Silty shale	Light grey	Carb., Micaceous, silt sized, lithic fragments.														
35		36	Nodular shale	Light grey	Carb., Micaceous.														
		35	Nodular shale	Light grey	Shale laminated with V. Fine sandstone.														
		34	Laminated sandstone	Dirty white /light grey	Parallel laminated 0.5Cm-0.5mm thick calcite cement.														
		33	Nodular shale	Light grey	Carb. Occassional silt, massive, fissile.														
		32	Nodular shale	Light grey	Carb. Occassional silt, massive, fissile.														
30		31	Nodular shale	Light grey	Carb. Occassional silt, massive, fissile.														
		30	Nodular shale	Light grey	Carb. Occassional silt, massive, fissile.														
		29	Nodular shale	Light grey	Carb. Occassional silt, massive, fissile.	■			■	■									
		28	Nodular shale	Light grey	Carb. Occassional silt, massive, fissile.	■	■	■		■	■					■			
		27	Nodular shale	Light grey	Carb. Occassional silt, massive, fissile.	■		■	■		■			■		■			
			Nodular shale	Light grey	Carb. Occassional silt, massive, fissile.	■		■							■	■			
25		26	Nodular shale	Medium grey	Carb. Occassional silt, massive, fissile.	■			■	■	■			■	■	■			
		25	Nodular shale	Light grey	Carb. Occassional silt, massive, fissile.	■		■					■		■	■			
		24	Silty shale	Dark grey	Massive, carb, Mica ceous with silt.														
		22	Nodular shale	Dark grey	Massive, micaceous, non-calc., Fissile & rarely silty.														
20		21	Silty shale	Light grey	Thin lamination of silt layer.	■	■	■		■									

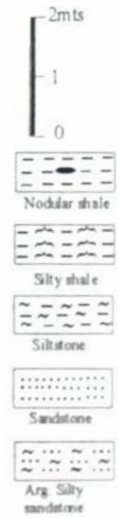


Figure 4.5b **Distribution of planktic foraminifera and biozones in Pfutsero 2 section**

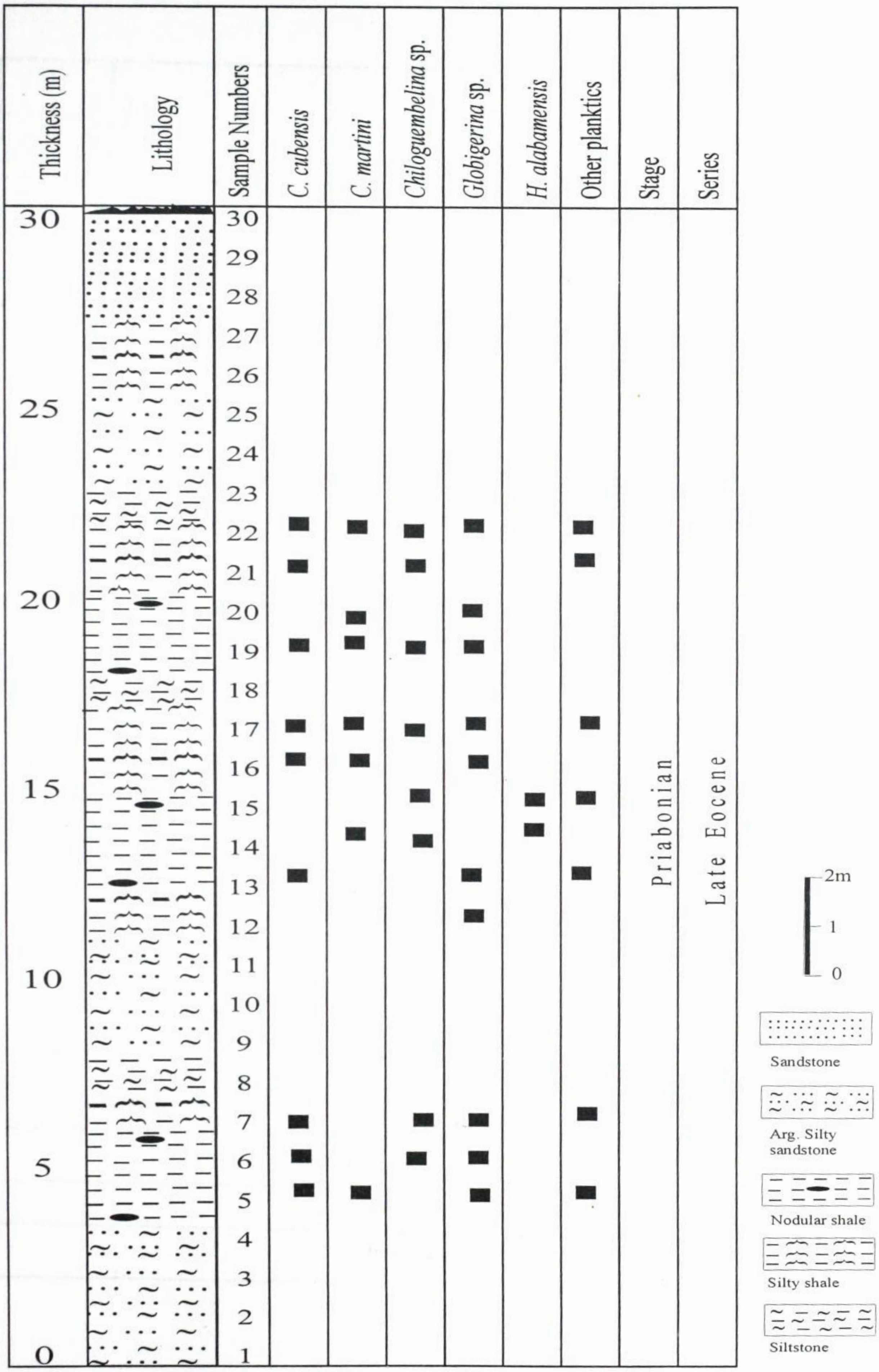


Figure 4.6 **Distribution of Planktic foraminifera and biozones in Leshemi section.**

Formations	Series	Age	Bio-zones	Southeast Nagaland N.E. India Present work	Western Nagaland, N.E. India Baruah et al., 1987	Assam, N.E. India Samanta 1973	Cauvery Basin, S. India Raju, 1971	Rakhi Nala, Pakistan Samanta, 1973.	Tropical/subtropical areas: Blow, 1969 Berggren & Couvering (1974)	Tropical/subtropical areas: Blow, 1979
Disang Formation (upper)	Late Eocene	Priabonian	*Turborotalia cerroazulensis* zone P17	*Turborotalia cerroazulensis*	*N. pengaroenensis* -*P. madaraszi* -*D. dispansa*	*Globigerina gortanii*	*Globorotalia cerroazulensis* (spans P17–P16)	*Globigerina officinalis* (spans P17–P15)	*Globigerina gortanii*/ *Globorotali centralis*	*Globigerina gortanii gortanii*/ *Goborotalia* *T. centralis*
			Cribrohantkenina inflata Zone P16	*Cribrohantkenina inflata*	*C. inflata* -*H. alabamensis*	*Cribrohantkenina inflata*			*Cribrohantkenina inflata*	*Cribrohantkenina inflata*
			Globigernatheka semiinvoluta Zone P15	*G. semiinvoluta*		*Globigerapsis semiinvoluta*	*Globigerapsis mexicana* = (*G. semiinvoluta*)		*Globigerapsis mexicana* = (*G. semiinvoluta*)	*P. semiinvolutus*

Table II **Correlation of foraminiferal zones** for the Eocene succession overlying the *Truncorotaloides rohri* Zone by Samanta in 1973. *Globigerapsis semiinvoluta* Zone of Assam consists of seventeen species and two subspecies belonging to the genera *Globigerina, Globigerinatheka, Globorotalia, Hantkenina, Pseudohastigerina* and *Chiloguembelina.* This Zone is correlatable with *G. semiinvoluta* Zone of Disang Group with the similar assemblages of *Hantkenina, Pseudohastigerina* and *Chiloguembelina.*

4.4.2.2 *Cribrohantkenina inflata* Zone: *Cribrohantkenina inflata* Zone of Disang Group of Nagaland is the same as Blow (1969), Berggren and Couvering (1974) and Blow (1997). In Nagaland, the zonal marker is restricted within the zone. In India, this zonal assemblage has also been reported from Cauvery Basin within *Globorotalia cerroazulensis* Zone of Raju (1968, 1971), and in Assam where Samanta (1973) recorded twenty three species and subspecies belonging to the genera *Globigerina, Globorotalia, Hantkenina, Cribrohantkenina, Globigerinina, Pseudohastigerina* and *Chiloguembelina* from this zone. The genus *Cribrohantkenina* is restricted to this zone. The *Cribrohantkenina inflata* Zone in the present study area is correlatable with the same zone proposed by Baruah et al., 1987 from western part of Nagaland. *Cribrohantkenina inflata* Zone is tentatively correlated with the upper part of the *Globigerina officinalis* Zone of Rakhi Nala, Pakistan (Samanta 1973).

4.4.2.3 *Turborotalia cerroazulensis* Zone: *Turborotalia cerroazulensis* Zone of Disang Group of Nagaland is correlatable with *Globigerina gortanii/Globorotalia centralis* Zone of Blow (1969), Berggren and Couvering (1974) and Blow (1979) of tropical areas. In Cauvery Basin, South India, Raju (1968, 1971) recognized *Globorotalia cerroazulensis* Zone consisting of *Cribrohantkenina inflata, Hantkenina alabamensis, Globorotalia cerroazulensis, G. centralis* and other species. In Nagaland, the upper part of *Globorotalia cerroazulensis* Zone of Cauvery Basin is correlatable with *Turborotalia cerroazulensis* Zone.

In Assam, Samanta (1972, 1973) recognized *Globigerina gortanii* Zone as the youngest planktic foraminiferal zone consisting of fifteen species and three subspecies belonging to genera *Globigerina, Globorotalia, Pseudohastigerina* and *Chiloguembelina* and the zone is followed by sediments devoid of planktic foraminifera. *Globigerina gortanii* Zone of Assam is correlatable with *Turborotalia cerroazulensis* Zone of Nagaland with the occurrence of similar planktic foraminiferal assemblage. It is also observed in Nagaland that the *T. cerroazulensis* Zone is followed by sediments devoid of planktic foraminifera. *Turborotalia cerroazulensis* Zone of the present study is correlatable with the *N. pengaronensis-P. madaraszi-D. dispansa* Zone of Baruah *et al.* (1987), from western Nagaland.

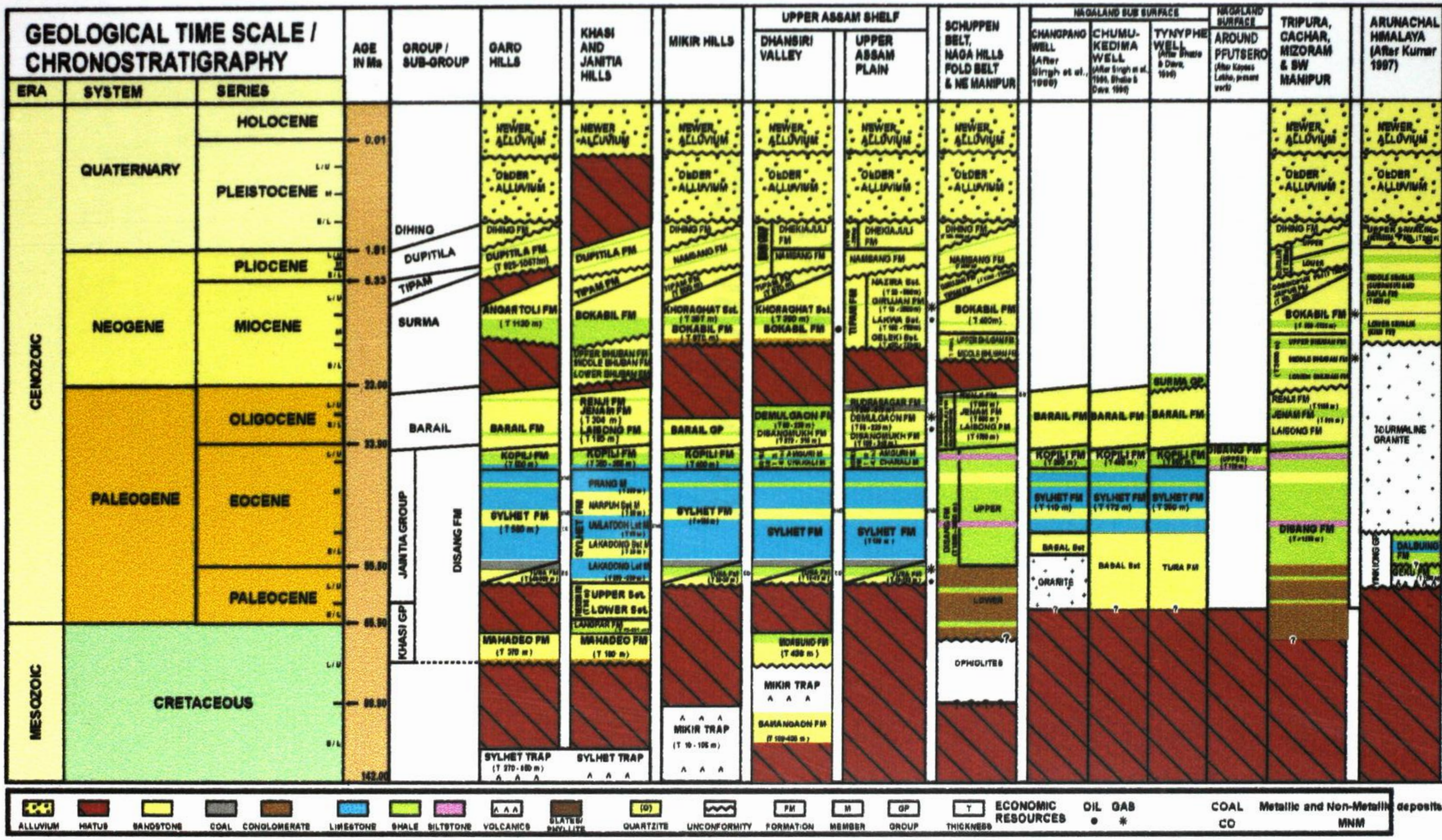
4.5 STRATIGRAPHIC CORRELATION OF NORTHEAST BASINS OF INDIA

A stratigraphic table (Table III) covering the time span of the Cretaceous and Cenozoic of Northeast basins of India including the states of Arunachal Pradesh, Assam, Meghalaya, Nagaland, Manipur, Tripura and Mizoram are compiled by Kapesa *et al.*, 2004 and presented to provide an overview and frame work of the succession. It shows the succession of lithounits against geological time scale, the thickness (T) of each unit and gross lithology with a colour scheme. Duration and magnitude of major hiatus are shown.

The stratigraphic table presented here are the result of a compilation based on various publications mainly those of Evans (1932), Mathur and Evans (1964), Das Gupta (1977), Ranga Rao (1983), Jokhan Ram and Venkataraman (1984), Ganju *et al.*, (1986), Gopendra Kumar (1997), Pandey and Dave (1998), Das Gupta and Biswas (2000), who did both original work and compilation based on the works of several geologists. The age for the Upper Disang Group of Nagaland is confirmed Late Eocene based on the present work with the findings of Late Eocene markers viz. *Globigerinatheka semiinvoluta, Cribrohantkenina inflata, Hantkenina alabamensis* and *Turborotalia cerroazulensis*.

TABLE III STRATIGRAPHIC UNITS, LITHOLOGY, THICKNESS AND MAJOR HIATUSES OF THE MESOZOIC AND CENOZOIC OF NORTHEAST, INDIA

COMPILED BY KAPESA LOKHO, D.S.N. RAJU, P. RAMESH, GOPENDRA KUMAR AND R. VENKATACHALAPATHY



CHAPTER 5

PALEOECOLOGY

CHAPTER 5
PALEOECOLOGY

5.1 INTRODUCTION

Paleoecology has grown during the past several decades to become a major component of paleontology. The activities in paleoecology have expanded from an initial strong focus on the reconstruction of the ancient physical environment to a wide range of topics of both biological and geological emphasis. Foraminifera were used in inferring paleoenvironments (Dodd and Stanton, 1981).

Foraminiferal abundance, diversity and dominance patterns enable discrimination of a range of environments (Murray, 1973 & 1991; Jones, 1984 as reported in Jones, 1996). Cross-plots of various foraminiferal 'morphogroups' also enable discrimination of environments (Stehli, 1996; Murray, 1973 & 1991; Jones, 1984; Jones and Charnock, 1985 in Jones, 1996). The ratio of planktic to benthic foraminifera provides a crude measure of the distance from the shoreline and, hence indirectly the depth (Zwaan *et al.*, 1990).

Boersma (1984) stated that 'through most of its stratigraphic and geographic range, each species occupies a depth-related physiographic region of the ocean bottom; the shelf, the bathyal zone, or the abyss. The shelf extends to depths near 200m; the bathyal zone extends to 2,000m and the abyss below'. However, these depth zones vary from one school of geologists to another.

5.2 FORAMINIFERA AS PALEOENVIRONMENTAL INDICATORS

Of all the marine microfossils, foraminifera are the most valuable in the interpretation of the paleoenvironmental trends because:

1. **Distribution:** It is distributed world wide in great numbers.

2. **Temperature:** Foraminifera are very tolerant of temperature variations. The group occurs all the way from tropical lagoons and tide pools where temperatures may be over 40° C to high-latitude areas where sea water is freezing at nearly – 2° C. The distribution of planktic species, in particular, seems to be temperature-controlled, and have been more thoroughly studied than that of benthic species. The distribution of benthic species also is clearly temperature-dependent (Dodd and Stanton, 1981).

Several other features of foraminiferal morphology vary with temperature. The planktic species in particular show several such features (Kennett, 1977). For example, *Globorotalia truncatulinoides* varies in shape from conical in tropical waters to more discoidal in cooler climates.

3. **Salinity:** Foraminifera occur over a wide range of salinity, from almost fresh to hypersaline values of $90_{0/00}$ or more (Sellier de Civrieux, 1968, as reported in Dodd and Stanton, 1981).

4. **Depth:** Benthic foraminifera occur at all depths from sea level to the bottom of the deepest trenches sampled. Depth is not a pure environmental variable. Many parameters change with depth (e.g., temperature, light, pressure, Oxygen, $CaCO_3$ saturation). Some species appear always to occur at a certain depth regardless of temperature or other variables (Walton, 1964; Murray, 1973 and Wright, 1976 as reported in Dodd and Stanton, 1981).

5. **Substrate:** Silty and muddy substrates are often rich in organic debris and the small pore spaces contain bacterial blooms. Such substrates are therefore attractive to foraminifera and support large populations. Many of these species are thin-shelled, delicate and elongate forms. Those foraminifera which prefer hard substrates (i.e. rock, shell, sea grasses and algae) are normally attached, either temporarily or permanently by a flat or concave lower surface. They often develop a relatively thin test and exhibit greater morphological variability than seen in sediment dwelling and planktic forms (Brasier, 1980).

Published data on the stratigraphy of the Disang Group of Nagaland suggest a geosynclinal and/or deep marine set-up but direct evidences like foraminifera and other paleontological and sedimentological data have been documented so far. The present study on Uvigerinids and smaller benthic foraminifera from the south-central part of Nagaland (around Pfutsero), planktic foraminifera and published data from outcrops from the western and northern part suggests:

i) Inner shelf facies at Tehai Reu section and Lotsu Village Section in the western part based on reported occurrence of *Pellastispira, Nummulites* and *Discocyclina.*

ii) Middle to outer shelf set-up by an association of larger benthic and planktic foraminifera and some Uvigerinids (*Uvigerina* cf. *jacksonensis*) from a locality of Heina Reu section.

iii) Lower part of upper bathyal set-up supported by dominant *Uvigerina* facies consisting *Uvigerina cocoaensis, U. continuosa, U.* cf. *eocaena, U. glabrans, U.*

jacksonensis, U. longa, U. moravia, U. cf. *steyeri and U. vicksburgensis* from the localities of Pfutsero 1 and 2, Chobama and Leshemi sections of Phek District.

This chapter is to summarize the paleoecologic and paleobathymetric history of Eocene sediments belonging to the Disang Group of rocks of Nagaland State. The present interpretation of the paleoecology setting in and around the studied area is based on new data on Uvigerinids, published data on smaller benthic and planktic foraminifera from the south-central part of Nagaland, and published data from outcrops/deep wells from the western and northern part of Nagaland. For the inference of paleobathymetry in the present work, a special emphasis has been used on Uvigerinids and therefore notes on each species have been described in detail.

5.3 SIGNIFICANCE OF UVIGERINIDS

5.3.1 Introduction

The genus *Uvigerina* was introduced by d'Orbigny in 1826. The significance of wall structure of *Uvigerina* in paleobathymetric reconstruction from shelf through bathyal to abyssal was emphasized by Bandy (1960). In India Raju *et al.* (1970) made use of Bandy's views in reconstruction of paleoenvironments of Eocene-Oligocene succession of Cambay Basin on a regional scale. Loeblich and Tappan (1988) in their work 'Foraminiferal Genera and their Classification' recognized 5 genera of Uvigerinids. Boersma (1984) and Zwann et al. (1986) published most detailed accounts on the Uvigerinids and did not recognize different genera within Uvigerinids. Realizing their importance, Raju et al. (1996) studied Recent Uvigerinids along a few profiles from Bay of Bengal from depths between 20m and 3000m and recognized 10 bathymetric zones within 20-1200m solely based on Uvigerinids, but they took account of other smaller benthic foraminifera as well. Raju and Dave (1996) demonstrated the usefulness of Uvigerinids in reconstructing refined paleobathymetric curves for selected deep wells of Oligocene of Cauvery and Miocene to Recent of Krishna-Godavari basin. Dave and Chatterjee (2001) utilised the *Uvigerina* criteria of Raju et al. (1996) in reconstruction of paleobathymetric trends for the western offshore succession of India.

5.3.2 Notes on species of *Uvigerina* from Nagaland

The Uvigerinids show wide morphological variation in respect of size, shape, ornamentation (costate, spinose/hispidity). Due to such wide variation, the species concept varied from one author to another and a large number species of Uvigerinids were described and illustrated during the last seven decades.

In the present study, the identification of species is based on the publication of Boersma (1984) because:

i) she compared her collection with topotype material, and

ii) data on inferred paleoenvironment/ paleobathymetry was well documented.

Nine species of *Uvigerina* are identified from our material from Upper Disang Group. They are mentioned below with notes on their reported/inferred paleobathymetry during Late Paleogene and their established ranges in region of U.S.A., Mediterranean etc.

1) *Uvigerina cocoaensis* Cushman, 1925: upper bathyal, reported from Gulf of Mexico, western coast of the United States, circum-Caribbean, circum-Mediterranean, Turkey, Europe, Alabama and Czechoslovakia.

Stratigraphic range: Middle Eocene to Oligocene.

2) *Uvigerina continuosa* Lamb, 1964: upper bathyal reported from circum-Caribbean, western South America, American Gulf Coast, Alabama and Mississippi.

Stratigraphic range: Middle Eocene to Middle Oligocene.

3) *Uvigerina* cf. *eocaena* Guembel, 1870: lowermost upper to upper middle bathyal, reported from circum-Caribbean, Middle East and Indo-Pacific, New Zealand, Mediterranean, Appenines, central Tasman Sea at DSDP Site 592, Czechoslovakia.

Stratigraphic range: Late Eocene to Oligocene.

4) *Uvigerina glabrans* Cushman, 1933: upper bathyal, reported from South Carolina, Alabama, California.

Stratigraphic range: Late Eocene to Early Oligocene.

5) *Uvigerina jacksonensis* Cushman, 1925: upper bathyal, reported from circum-Mediterranean, American Gulf Coast, Aral Sea, Mississippi and Mexico.

Stratigraphic range: Early Eocene to Late Oligocene.

6) *Uvigerina longa* Cushman and Bermudez, 1937: lower part of upper bathyal and uppermost middle bathyal, reported from Caribbean, Atlantic and Mediterranean.

Stratigraphic range: Late Eocene to Oligocene.

7) *Uvigerina moravia* Anne Boersma, 1984: Upper bathyal, reported from Para-tethys, southern Europe, western South America, Italy, Czechoslovakia, Hungary and Romania.

Stratigraphic range: Late Eocene to Early Miocene.

8) *Uvigerina* cf. *steyeri* Papp, 1975: Upper bathyal, reported from circum-Mediterranean Para-tethys, Venezuela and Turkey.

Stratigraphic range: Early Eocene to Late Oligocene.

9) *Uvigerina vicksburgensis* Cushman and Ellisor, 1931: upper bathyal to shelf, reported from American Gulf Coast, Venezuela, Mexico and northeast Africa.

Stratigraphic range: Middle Eocene to Early Oligocene.

5.4 SOME ASSOCIATED FORAMINIFERA AND INFERRED PALEOBATHYMETRY FROM EACH SECTIONS OF THE PRESENT STUDY

Chobama 1 section (N 25°33′43″-E 94°19′27″)

The lithology of this section (Fig. 5.1) comprises of concretionary shales with a thickness of 2m. In this section, two layers at the height of 1.65m and 2m are without foraminifera. The lower layers contain more foraminifera consisting both planktics and benthics and a gradual decrease in foraminiferal number is observed towards the top part of the section. The layer at the height of 30.5cm has the maximum total number of foraminifera with 413 specimens belonging to 9 genera. This indicates a maximum flooding surface. Paleobathymetric markers found at this section are *Uvigerina longa* and *U. Jacksonensis,* which give an inference of paleobathymetry of lower part of upper bathyal and uppermost middle bathyal.

In this section smaller benthic foraminifera of *Turborotalia cerroazulensis cerroazulensis, Turborotalia cerroazulensis pomeroli, Hantkenina alabamensis, H. liebusi, Cribrohantkenina inflata, Globigerinatheka semiinvoluta, Globigerina* sp., *Pseudohastigerina micra, P. barbadoensis, Chiloguembelina martini, C. cubensis, C. cf. tenuis* and benthic foraminifera of *Uvigerina longa, U. jacksonensis, Lagena acuticosta, L. sulcata, Baggina cojimarensis, B. dominicana, B. subinaequalis, Turrilina* sp., *Osangularia plummerae, Bolivina* sp., *Miliola* sp., *Nonionella* sp., *Cancris mauryae, Cyclammina* sp. *Cibicidoides* sp., *Pseudonodosaria* sp. and *Pyrgo* sp. are encountered.

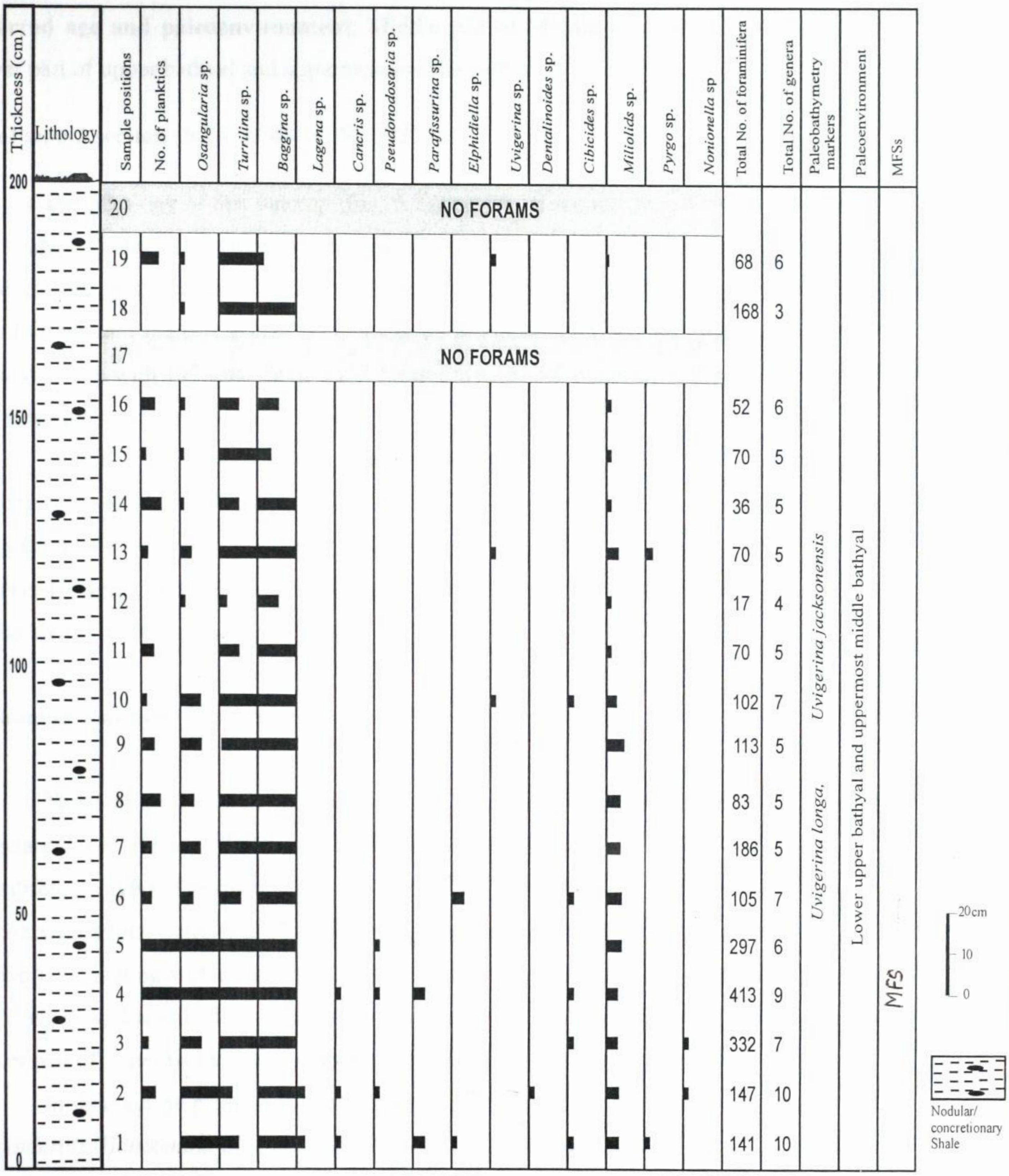


Figure 5.1 **Succession of lithology, sample position, paleoenvironment and MFSs in Chobama 1 section.**

Inferred age and paleoenvironment: Middle part of Middle Eocene to Late Eocene and lower part of upper bathyal and uppermost middle bathyal.

Chobama 2 section (N 25°33′43″-E 94°19′27″):

The lithology of this outcrop (Fig. 5.2) consists of monotonous concretionary shales. It is about 1.9m thick with a vegetation cover on the top. Four layers are without foraminifera in the middle part of the section. The lower part of the section is poorly fossiliferous and there is a gradual increase of foraminifera towards the top of the section around 1.75m with 155 total numbers of foraminifera and 6 numbers of genera. This level is considered a maximum flooding surface.

In this section, no planktic foraminifera are encountered. Some smaller benthics foraminifera of *Osangularia* sp., *Turrilina* sp., *Baggina cojimarensis, B. dominicana and Cancris* sp., *Cibicidoides* sp. are encountered.

Inferred age and paleoenvironment: In this section no age markers and paleoenvironmental markers are found.

Chobama 3 section (N 25°33′42″-N 94°19′27″):

This section (Fig. 5.3) is 3m thick with a lithology of concretionary shales covered by vegetation on the top. There are five layers without foraminifera alternating with the fossiliferous layers. The distribution of foraminifera is dense between the levels of 70.5cm to 1.25m with a total number of 374 foraminifera and a total number of 10 genera suggesting a maximum flooding surface at 10.5cm height. Paleobathymetry markers found at this section are *Uvigerina longa* and *U. jacksonensis*, which gives an inference of paleobathymetry of lower part of upper bathyal and uppermost middle bathyal.

In this section planktic foraminifera of *Turborotalia cerroazulensis cerroazulensis, T. c. pomeroli, Hantkenina alabamensis, H. leibusi, Cribrohantkenina inflata, Globigerina* sp., *Pseudohastigerina micra, P. barbadoensis, P. naguewichiensis, Chiloguembelina martini, C. cubensis, C. cf. tenuis* and smaller benthic foraminifera of *Uvigerina longa, U. jacksonensis, U. vicksburgensis, Lagena striata, Lagena* sp., *Baggina cojimarensis, B. dominicana, B. subinaequalis, Turrilina* sp., *Osangularia* sp., *Bolivina* sp., *Miliola* sp., *Cibicidoides* sp., and some pteropods are encountered.

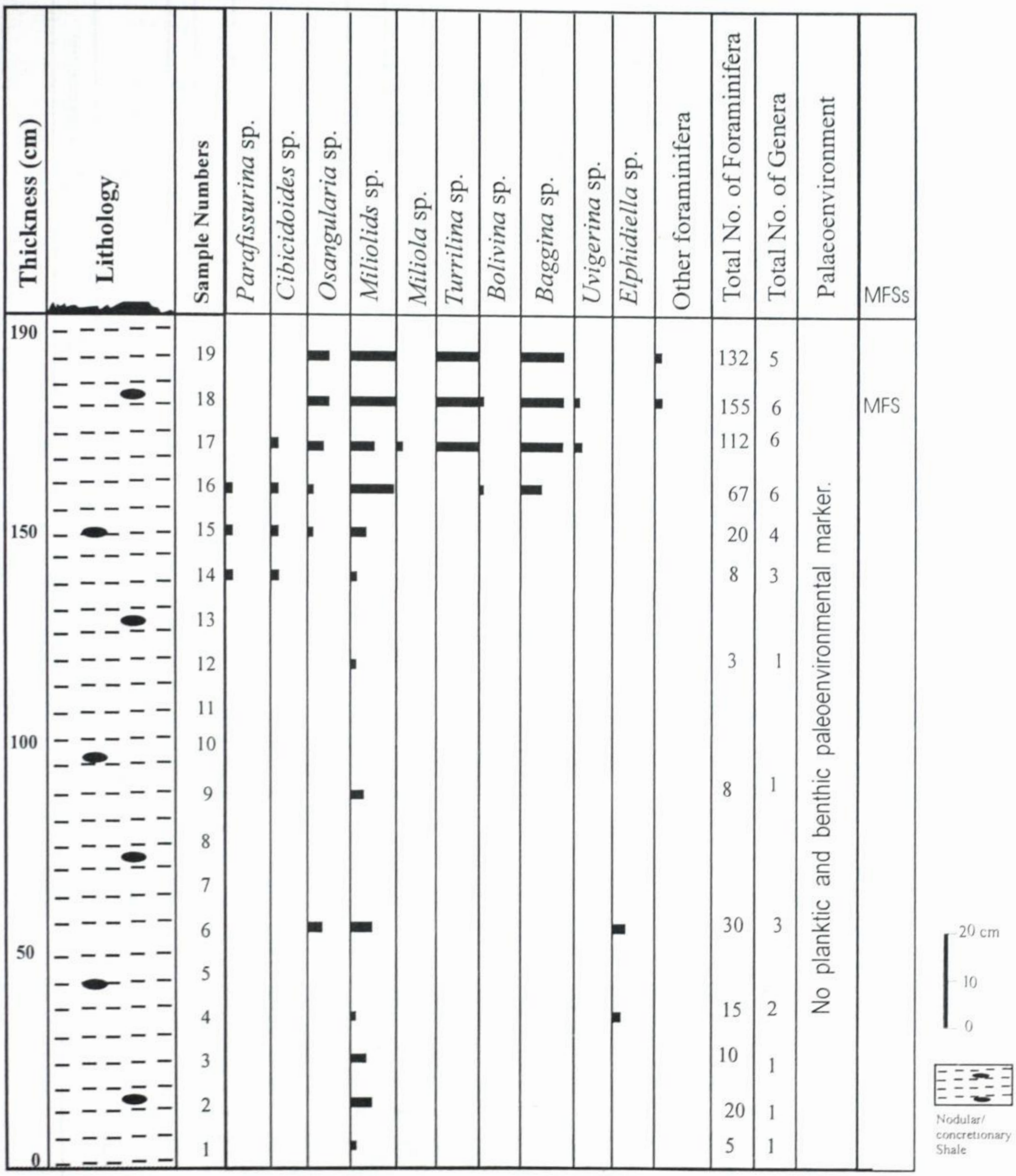


Figure 5.2 **Succession of lithology, sample position, paleoenvironment and MFSs in Chobama 2 section.**

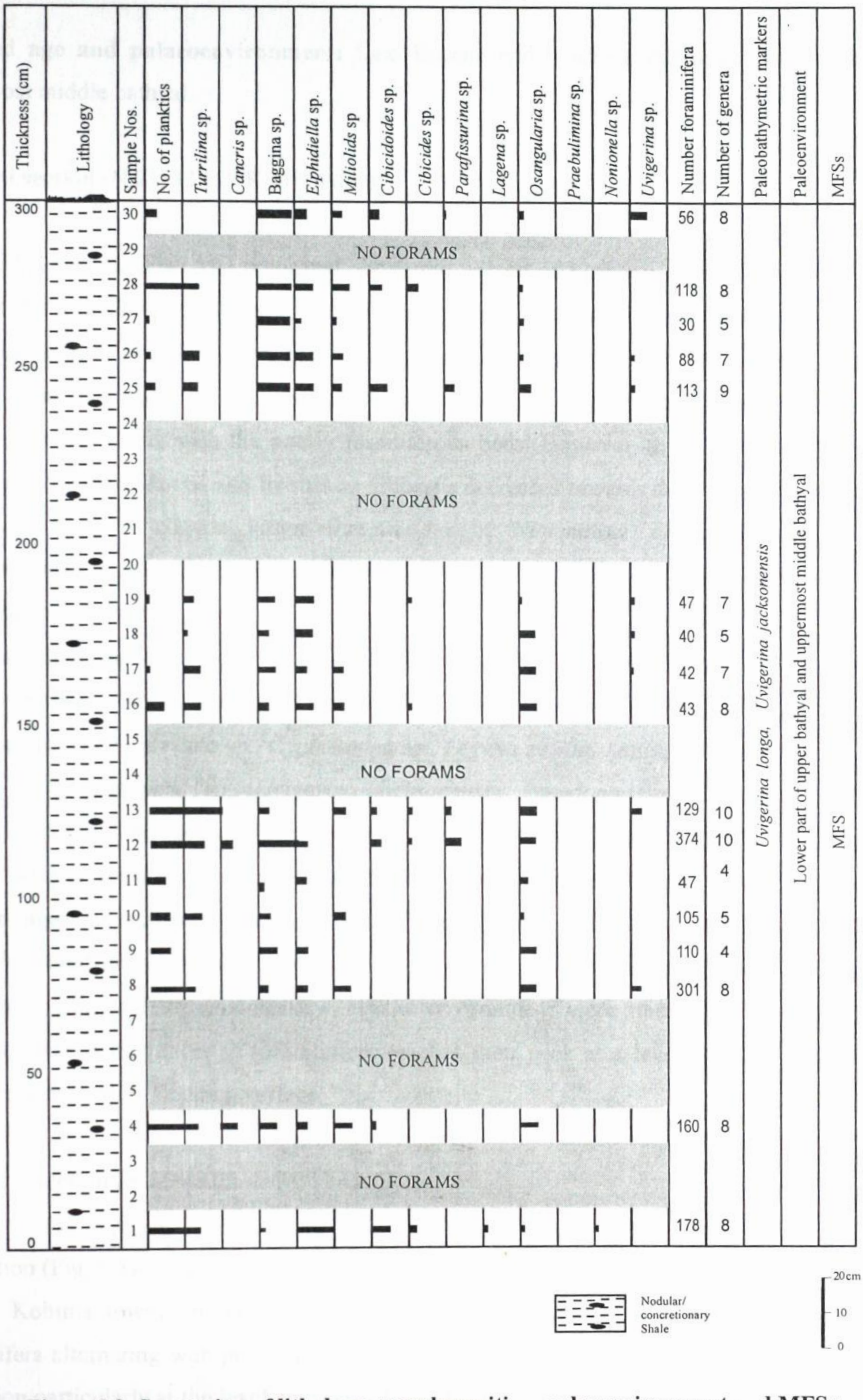


Figure 5.3 **Succession of lithology, sample position, paleoenvironment and MFSs in Chobama 3 section.**

Inferred age and palaeoenvironment: Late Eocene and within lower upper bathyal to uppermost middle bathyal.

Leshemi section (N 25°32′10″-E 94°14′05″):

This section (Fig. 5.4) is located above the village of Leshemi on the Khezhakeno road). It has a thickness of about 30m consisting of silty shale, argillaceous silty sandstone and laminated siltstone. The upper part of the section has thick-bedded sandstone beds with thinner layers of shale in between these beds. There are five beds/layers without foraminifera alternating with the poorly fossiliferous beds. However, the lower part of the section is more fossiliferous and frequency of fossils decreases towards the top. The samples from 4 through 7 contain larger foraminifera of *Nummulites chavannesi* and *N. pengaroenensis*. Paleobathymetry markers for this section are larger foraminifera and *Uvigerina jacksonensis*.

In this section, larger benthic foraminifera of *Nummulites chavannesi, N. pengaronensis* and *Nummulites* sp. are encountered besides the smaller benthic foraminifera of *Cibicidoides* sp., *Turrilina* sp., *Cyclammina* sp., *Legena striata, Lagena* sp., *Miliolids* sp., *Miliola* sp., *Osangularia* sp., *Uvigerina jacksonensis, Pseudonodosaria* sp. and some microgastropods. This section also yielded planktic foraminifera of *Globigerina* sp., *Turborotalia cerroazulensis cerroazulensis*, *Chiloguembelina martini* and *C. cubensis*.

Inferred age and paleoenvironment: Late Eocene. The larger benthic foraminifera of *Nummulites chavannesi, N. pengaronensis* and some microgastropods along with *Uvigerina jacksonensis* suggests lagoonal-shallow marine environment were transported to bathyal condition. The total number of foraminifera reaches their peak at a level of 6.5 m, which represents a maximum flooding surface.

Pfutsero 1 section (N 25°43′02″-E 94°17′43″):

The section (Fig. 5.5) is about 23m thick and located approximately 1 km from Pfutsero town towards Kohima town). In the lower part of the section, there are 5 intervals without foraminifera alternating with poorly fossiliferous layers/beds. However, in the upper part of the section particularly at the level between 19m and 23m, the number of planktics as well as Uvigerinids increases rapidly.

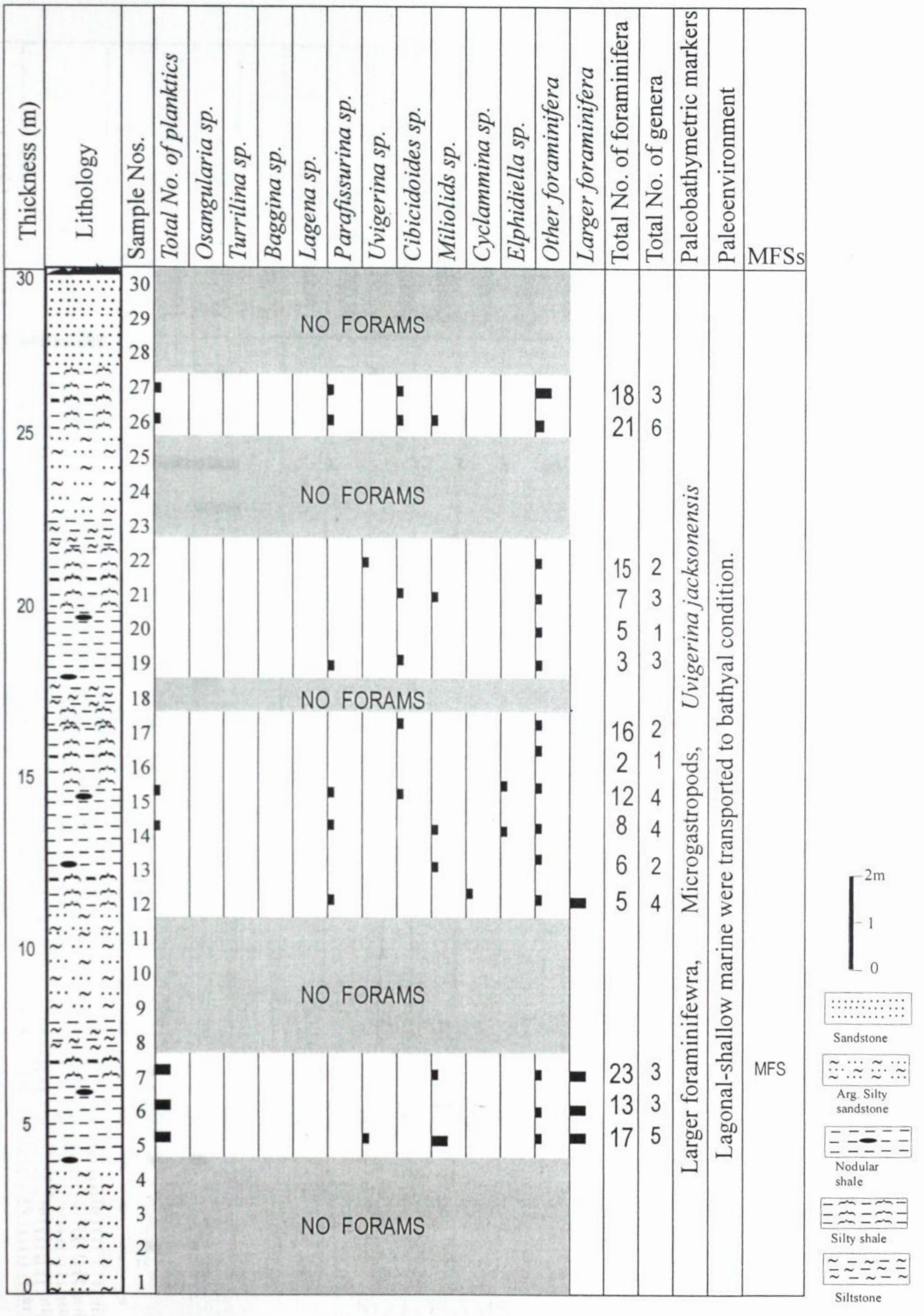


Figure 5.4 **Succession of lithology, sample position, paleoenvironment and MFSs in Leshemi section.**

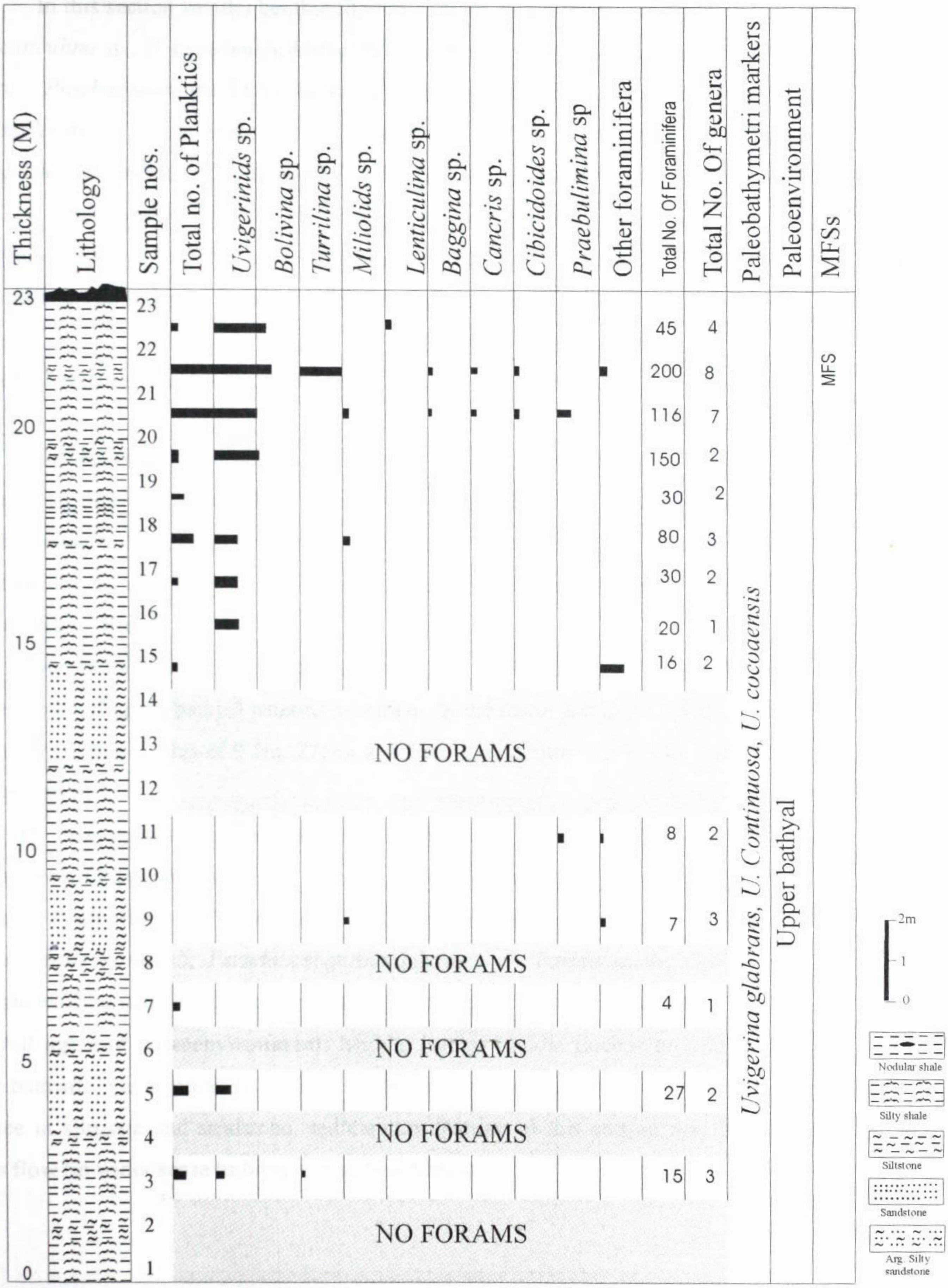


Figure 5.5 **Succession of lithology, sample position, paleoenvironment and MSFs at Pfutsero 1 section.**

In this section smaller benthic foraminifera of *Bolivina* sp., *Elphidiella* sp., *Lagena* sp., *Lenticulina* sp., *U. cocoaensis, Uvigerina continuosa, U.* cf. *eocaena, U. glabrans, U.* cf. *steyeri, Praebulimina* sp., *Turrilina* sp., *Osangularia* sp., and planktic foraminifera of *T. cerroazulensis cerroazulensis, Globigerina* sp., *Chiloguembelina martini, Chiloguembelina martini, Chiloguembelina* sp., and some pteropods are encountered.

The total number of foraminifera reaches their peak at the level of 21.5m, which represents maximum flooding surface for this section.

Inferred age and paleoenvironment: Late Eocene and upper bathyal.

Pfutsero 2 section (N 25°34′02″-E 94°18′23″):

This section (Fig. 5.6) is located about 1 km from Pfutsero town towards Phek. The thickness of this outcrop is about 40m and is covered by vegetation on the top. Nine beds/layers are unfossiliferous. The lithology of the unfossiliferous layers comprises of silty sandstone, laminated siltstone and sandstone. The beds of nodular/concretion shale and silty shale are fossiliferous.

The most abundant foraminifera found in this section are the Uvigerinids, which are inferred to be of upper bathyal paleoenvironment. In the lower and middle part of the section particularly at the heights of 9.5m, 27.5m and 32.2m, maximum number of Uvigerinids and planktics occur.

In this section, smaller benthic foraminifera of *Osangularia* sp., *Uvigerina jacksonensis, U. continuosa, U.* cf. *eocaena, U. cocoaensis, U.* cf. *steyeri, U. moravia* and planktic foraminifera of *Turborotalia cerroazulensis cerroazulensis, Turborotalia cerroazulensis pomeroli, Pseudohastigerina micra, P. barbadoensis, Globigerina* sp., *Chiloguembelina martini, C. cubensis,* sp. and some pteropods are encountered.

Inferred age and paleoenvironment: Middle part of Middle Eocene to Late Eocene and upper bathyal. Due to presence of foraminifera in nodular/concretion shale and silty shales, absence in siltstone and sandstone, sedimentary features at this section may be termed as debris flow (in wider sense turbidites of some authors).

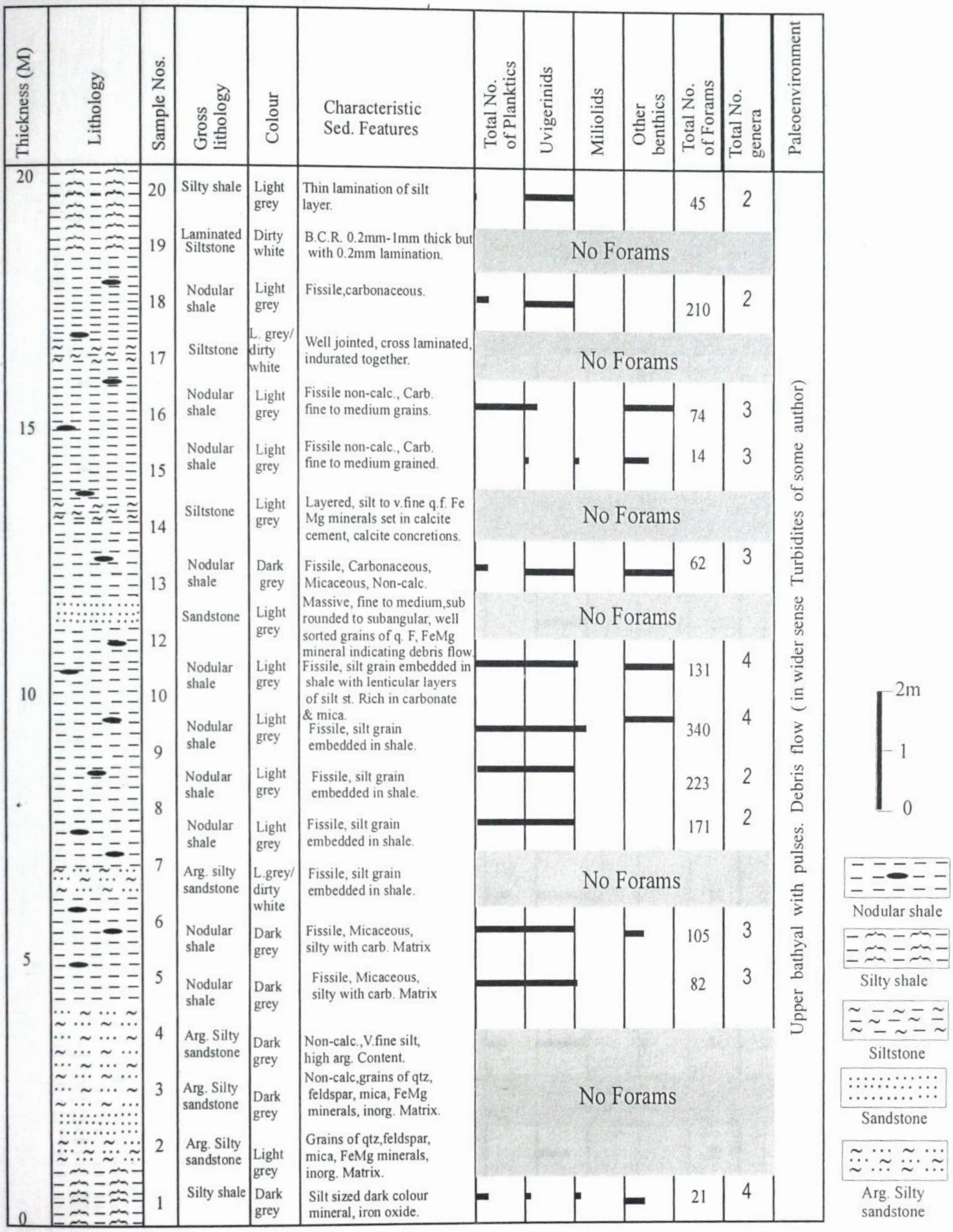


Figure 5.6a **Succession of lithology, sample position, gross lithology, colour, sedimentary features and paleoenvironment from Pfutsero 2.**

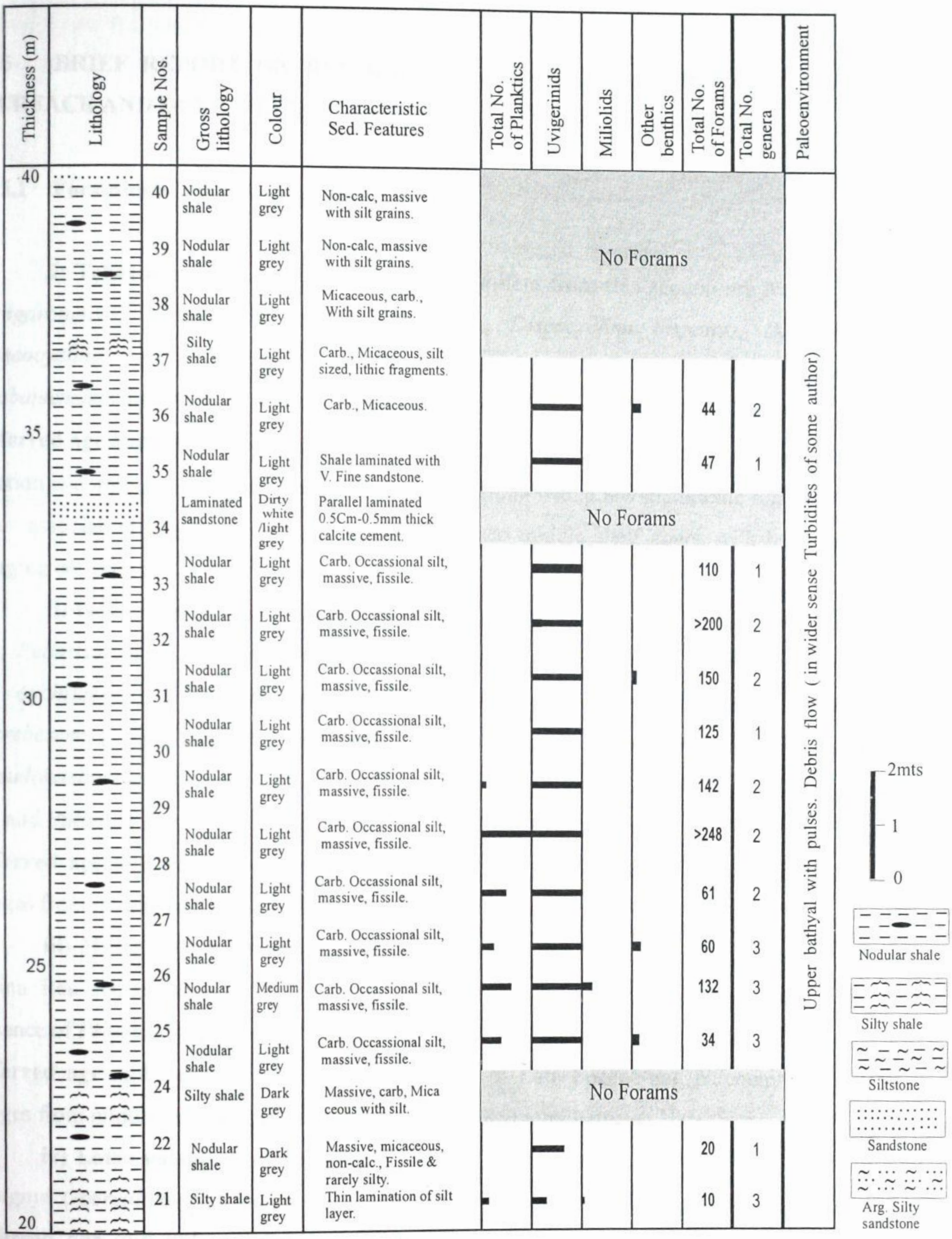


Figure 5.6b Succession of lithology, sample position, gross lithology, colour, sedimentary features and paleoenvironment, Pfutsero 2 section.

5.5 BRIEF REPORT ON RECORDED FORAMINIFERA FROM NAGALAND SURFACE AND DEEP WELLS (1-4 after Baruah *et al.*, 1987)

5.5.1 Foraminifera from outcrops:

i) Tehai Reu section: The recorded foraminifera from this section are *Nummulites pengaronensis, N. discorbinus, Nummulites* sp., *Discocyclina dispansa, D. eamesi, Discocyclina* sp., *Pellastispira madaraszi, P. inflata, Pellatispira* sp., *Hantkenina alabamensis, Globorotalia centralis, G. cerroazulensis* and *Globigerina amplipertura.*

Inferred age and paleoenvironment: Late Eocene age. The foraminiferal assemblage at this section is dominated by larger benthic foraminifera along with a few planktonic foraminifera. This association suggests a deposition under inner to middle shelf zones with bathymetry ranging between 50-80m.

ii) Heina Reu section: The recorded foraminifera from this section are: *Nummulites* sp., *Pellatisppira* sp., *Pseudoamplipertura, Globigerina yeguaensis, Globigerina tripartite, G. ouchitaensis, Globigerina sp., Globorotalia cerroazulensis, G. centralis, G. increbescens, G. insolita, Hantkenina alabamensis, Cribrohantkenina inflata, Pseudohastigerina barbadoensis, Uvigerina* sp., *Marginulina* sp., *Cibicides* sp., *Dentalina* sp. and *Bulimina* sp.

Inferred age and paleoenvironment: Middle part of Late Eocene and paleoenvironment ranges from middle to outer shelf zones indicating bathymetry between 100-150m.

iii) Manglu River section: The recorded foraminifera from this section is similar to Heina Reu section except for the common occurrence *of Cribrohantkenina inflata* and absence of *Pseudohastigerina barbadoensis.*

Inferred age and paleoenvironment: Middle part of Late Eocene and paleoenvironment ranges from middle to outer shelf zones indicating bathymetry between 100-150m.

iv) Lotsu village: The assemblages includes *Pellatispira madaraszi, Nummulites* cf. *orbignyi, Operculina* sp., *Cibicides* sp., *Quinqueloculina* sp., *Lagena* sp. and *Glandulina* sp.

Inferred age and paleoenvironment: Upper Eocene based on *Pellatispira*. The Barail Group at this section suggests the brackish water environment of deposition.

v) Changtongka, Northern Nagaland: Nagappa (1959) recorded larger foraminifera including reticulate *Nummulites*. Some arenaceous small foraminifera, such as

Ammobaculites, Ammodiscus, Bathysiphon, Cyclammina, Gaudryina and *Haplophragmoides* have been found in the Disangs underlying the Barails near Damchara. Some of these fossils have also been reported from Changtongka. Sinha (1974) and Sinha and Chatterjee (1982) reported reticulate *Nummulites* in Disang Group at Changtongka.

A calcareous shale sample collected by Metre and Jgannathan (Basu et al., 1964 in Ranga Rao, 1983), near Changtongka and studied by Eames yielded *Discocyclina dispansa, D. omphalus* and *N.margoclari*. Eames assigned a Kopili age for the sample.

Inferred age and paleoenvironment: Nagappa (1959) suggests the top of the Disangs probably not younger than the Upper Eocene as there was no other fossil evidence available. Interpretation on palaeoenvironment has not been mentioned due to absence of paleoenvironmental markers.

vi) Pfutsero and Meluri in Phek District: Sinha *et al.* 1982 reported *Dictyoconoides* sp. and *Nummulites* sp. from the Disang Group exposed around Pfutsero and Meluri.

Inferred age and paleoenvironment: Based on *Nummulites,* Sinha *et al.* (1982) suggested the Lower age limit of the fossiliferous members of the upper part of the Disang Group as Paleocene. The record of Middle Eocene index form *Dictyoconoides* suggests that the age of the upper Disang Formation may extend at least upto Middle Eocene. The association of bivalves, gastropods and *Nummulites* suggests shallow marine conditions of deposition. We have not got *Dictyoconoides* in the sections studied around Pfutsero. The location of their exact outcrop is not known.

5.5.2 Foraminifera recorded from deep wells:

i) Champang well, NW Nagaland, (after Singh *et al.*, 1986): The recorded foraminifera from this well are: *Anomalina* sp., *Cibicides* sp., *Elphidium* sp., *Quinqueloculina* sp., *Rotalia* sp., *Nummulites acutus, N. beaumonti, N. discorbinus, N. pengaronensis, N.* cf .*wemmellensis*, *Nummulites* sp.*A*, *Nummulites* sp.*B*, *Assilina praespira, A.* cf. *pustulsa, Assilina* sp., *Operculina* sp. and *Operculinoides* sp.

Inferred age and paleoenvironment: Middle Eocene to Late Eocene, non-marine to inner shelf.

ii) Chumukedima well, SW Nagaland (after Singh *et al.*, 1986): The recorded foraminifera from this well are: Arenaceous foraminifera, *Trochammina* sp., *Haplophragmoides* sp., *Osangularia* sp., *Pararotalia* sp., *Lagena* sp., *Quinqueloculina* sp., *Heterolepa* sp., *Uvigerina* sp., *Rotalia* sp., *Cibicides* sp., *Operculina* sp., *Nummulites* sp., *N. pengaronensis*, *N. discorbinus*, *N. acutus*, *N. beaumonti*, *Assilina* sp., *Discocyclina* sp., *Fasciolites* (F.) *elliptica*.

Inferred age and paleoenvironment: Middle Eocene to Late Eocene and inner shelf environment.

iii) Tynyphe well, SW Nagaland (after Bhatia and Dave, 1996): The recorded foraminifera from this well are: *Nummulites acutus*, *N. beaumonti*, *N. discorbinus*, *N. pengaronensis*, *Nummulites* sp., *Assilina spira*, *A. praespira*, *Assilina* sp., *Discocyclina* sp., *Fasciolites* (F) *elliptica*, *Operculina* sp., *Quenculoculina* sp., *Cibicides* sp., *Rotalia* sp., also the arenaceous foraminifera includes *Ammodiscus* sp., *Cyclammina* sp., *Trochammina* sp.

Inferred age and paleoenvironment: Middle Eocene to Late Eocene and inner shelf to brackish.

5.6 SIGNIFICANCE OF PRESENT STUDY

1. (a) Confirms a deeper marine (lower part of upper bathyal) environmental set-up for the Upper Disang Group of central part of Nagaland (Fig. 5.7) at Leshemi section, Chobama 1, 2, 3 sections, Pfutsero 1 and Pfutsero 2 sections. Presence of abundant Miliolids and some *Nummulites pengaronensis* and *Nummulites chavanenssi* in association with *Osangularia* sp., *Cyclammina* sp. and *Uvigerina jacksonensis* at Leshemi section suggests that the larger foraminifera along with microgastropods from lagoonal-shallow marine was transported to bathyal condition. Studies by Raju *et al.* (1996) on morphological variation of Uvigerinids along Bay of Bengal support a paleobathymetry deeper than 350m.

(b) ONGC well/outcrop data: Shallow marine conditions during Late Eocene in western part of Nagaland at Changpang, Chumukedima and Tynyphe wells, Heningkunglwa and Lotsu indicate paleo-shelf edge/margin is along a belt in western Nagaland.

2. Haq *et al.* (1988) suggested a global drop of sea level around 80m during Late Eocene. The deeper part of upper bathyal set up during Disang was due to rapid subsidence.

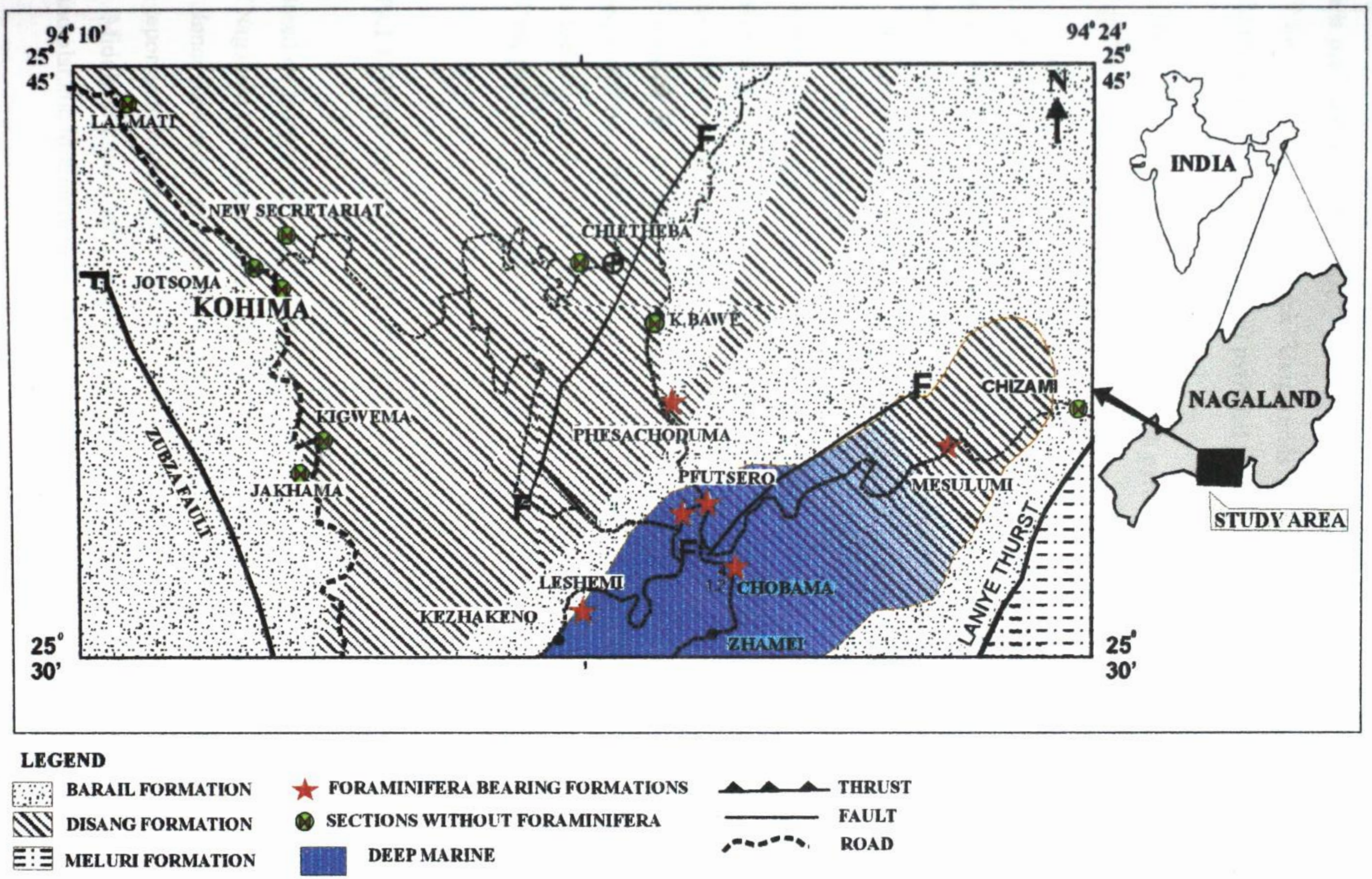


Figure 5.7 **GEOLOGICAL MAP OF THE STUDY AREA SHOWING LOCATION OF THE STUDIED SECTIONS WITH FORAMINIFERA AND WITHOUT FORAMINIFERA (map modified after Ganju *et al.*, 1986; Foraminiferal data and Paleoenviromental setting after present work)**

3. The foraminiferal criteria employed to infer anoxic conditions are based on an approach of a paleontologist by the name of Robertson Reuach (see Chandra *et al.*, 1993). The criteria pertinent to our study are:

i) localized occurrence of thick "Uvigerinids";

ii) presence of pteropods and iii) pyritised tests.

4. Very high percentage of Uvigerinids with pyritised tests indicate anoxic conditions, suggesting of possible source rocks (Fig. 5.8a, b).

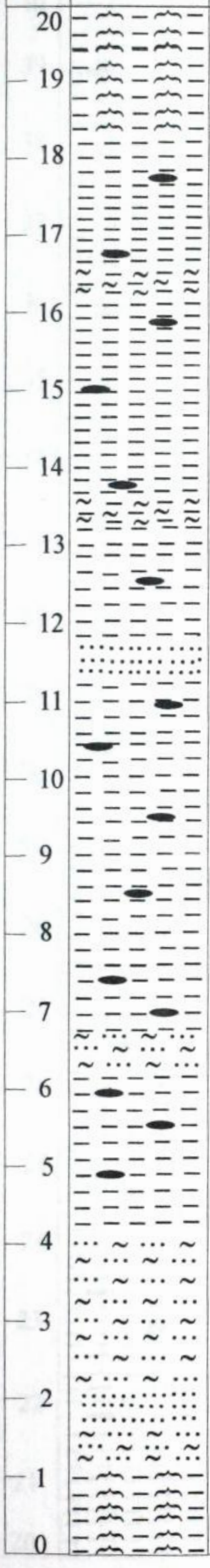
5. According to Narayanan (2004), the general consensus today is that the Burma Platelet a part of the Sundaland Plate was generally opposite the Indian Plate from Late Cretaceous. The rest of the Sundaland Plate is considered to have moved away dextrally along the Sagging Transform. The movement of the Shillong Platelet, again dextrally, along the Dawki Transform ends with a soft collision with the Sundaland Plate closing off what could be termed the Upper Disang Sea from the Tethys to the North. The Eocene granites of the Pynmana area on the edge of the Shan Massif, along the Sagging fault indicate the age of dextral movement there. The Disang Sea could be considered to have been the progenitor of what later became the Bay of Bengal but would have been essentially a narrow gulf, a couple of hundred kilometers long, which replaced the earlier existing subduction zone trench. Although local/regional variations are known, some of the species of Uvigerinids from Nagaland support open sea connection but had a restricted circulation at times to deep marine.

5.7 PALEOENVIRONMENTAL INFERENCES

Based on the previous works and present work, we may infer the paleoenvironmental set-up of Nagaland (which is shown in the figures 5.9a, b) as:

1. Inner shelf facies at Tehai Reu section and Lotsu Village section in the western part based on reported occurrence of *Pellatispira, Nummulites* and *Discocyclina*.

2. Middle to outer shelf set-up for the Heina Reu section by an association of larger benthic and planktic foraminifera and some Uvigerinids (*Uvigerina* cf. *jacksonensis*).



Sample Nos.	Gross lithology	Colour	Characteristic Sed. Features	Characteristic fauna	Biofacies With % of dominant foraminifera
●	Silty shale	Light grey	Thin lamination of silt layer.	*U.continousa, U.jacksonensis, Turrilina* sp.	Benthic dominant 59%
●	Laminated Siltstone	Dirty white	B.C.R. 0.2mm-1mm thick but with 0.2mm lamination.	No microfauna	No microfauna
●	Nodular shale	Light grey	Fissile,carbonaceous.	*U.steyeri, U.continousa, U.cocoaensis, U.eoceana U.jacksonensis, T.c.cerro,*	Uvigerinids dominant 95.2%
●	Siltstone	L. grey/ dirty white	Well jointed, cross laminated, indurated together.	No microfauna	No microfauna
●	Nodular shale	Light grey	Fissile non-calc., Carb. fine to medium grains.	*U.continousa, T.c.pomeroli, C.cubensis, T.c.cero, T.c.cocoaensis*	Planktics dominant 89.2%
●	Nodular shale	Light grey	Fissile non-calc., Carb. fine to medium grained.	*U.continousa, T.c.pomeroli, Quenqueloculina sp.*	T. cerro dominant 71.4%
●	Siltstone	Light grey	Layered, silt to v.fine q.f. Fe Mg minerals set in calcite cement, calcite concretions.	No microfauna	No microfauna
●	Nodular shale	Dark grey	Fissile, Carbonaceous, Micaceous, Non-calc.	*U.cocoaensis, U.cf. steyeri, T.c.cerro,C.cubensis, T.c.pomeroli, U.continousa,*	Uvigerinids dominant 54.7%
●	Sandstone	Light grey	Massive, fine to medium,sub rounded to subangular, well sorted grains of q. F, FeMg mineral indicating debris flow.	No microfauna	No microfauna
●	Nodular shale	Light grey	Fissile, silt grain embedded in shale with lenticular layers of silt st. Rich in carbonate & mica.	*U.eoceana , P.micra, U.continousa, T.c.pomeroli, U.jacksonensis, C.cubensis, Globogerina sp.*	Planktics dominant 56.2%
●	Nodular shale	Light grey	Fissile, silt grain embedded in shale.	*U.eoceana, C.cubensis. Osangularia sp., P.micra, P.barbadoensis, T.c.pomeroli,*	Planktics dominant 56.4%
●	Nodular shale	Light grey	Fissile, silt grain embedded in shale.	*U.continousa, U.jacksonensis, U.eocaena, T.c.pomeroli,*	Uvigerinids dominant 52.9%
●	Nodular shale	Light grey	Fissile, silt grain embedded in shale.	*T.c.pomeroli, P.micra, U.cocoaensis, U.jacksonensis, U.eoceana C.cubensis.*	Uvigerinids dominant 66.7%
●	Arg. silty sandstone	L.grey/ dirty white	Fissile, silt grain embedded in shale.	No microfauna	No microfauna
●	Nodular shale	Dark grey	Fissile, Micaceous, silty with carb. Matrix	*T.c.pomeroli U.eoceana, T.c.cerro, U.continousa, C.cubensis.*	Planktics dominant 48.1%
●	Nodular shale	Dark grey	Fissile, Micaceous, silty with carb. Matrix	*U.continousa, U.cf.steyeri, U.jacksonensis, T.c.pomeroli,*	Uvigerinids dominant 63.4%
●	Arg. Silty sandstone	Dark grey	Non-calc.,V.fine silt, high arg. Content.	No microfauna	No microfauna
●	Arg. Silty sandstone	Dark grey	Non-calc,grains of qtz, feldspar, mica, FeMg minerals, inorg. Matrix.	No microfauna	No microfauna
●	Arg. Silty sandstone	Light grey	Grains of qtz,feldspar, mica, FeMg minerals, inorg. Matrix.		No microfauna
●	Silty shale	Dark grey	Silt sized dark colour mineral, iron oxide.	*Quenqueloculina sp., Osangularia sp. Turrilina sp.*	Benthic dominant 61.9%

Interpretation

Presence of *T.cerroazulensis pomeroli* in good number and *T.cerroazulensis cerroazulensis* suggests Late Eocene.

Presence of Uvigerinids (*U. Jacksonensis, U. eocaena, U.cocoaensis, U.continuos, U.glabrans, U.jacksonensis, U.cf.steyeri*) often in high percentage suggets upper bathyal environment. (Borsma, 1948). In an analogy to present day morphotypes of Uvigerinids in Bay of Bengal (Raju et al. 1996, Raju and Dave, 1996), these Uvigerinids suggets a lower part of upper bathyal environment.

No microfauna internels (▬) in thin sandstone / siltstone layers within lower part of upper bathyal zone suggest that they are turbidites (in wider sense)

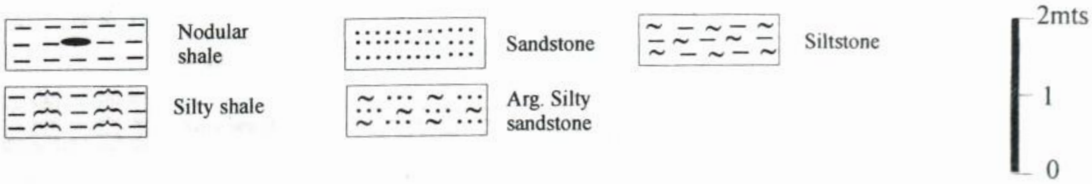
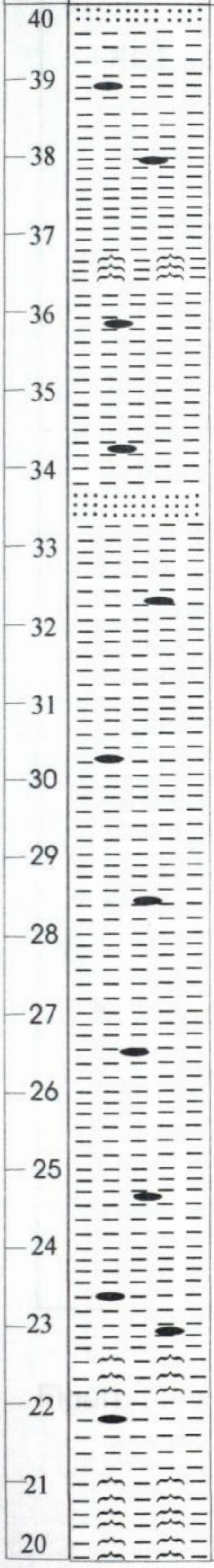


Figure 5.8a **Biofacies with % of dominant foraminefera at Pfutsero 2.**



Sample Nos.	Gross lithology	Colour	Characteristic Sed. Features	Characteristic faunas	Biofacies with % of dominant foraminifera
●	Nodular shale	Light grey	Non-calc, massive with silt grains.	No microfauna	
●	Nodular shale	Light grey	Non-calc, massive with silt grains.	No microfauna	
●	Nodular shale	Light grey	Micaceous, carb., With silt grains.	No microfauna	
●	Silty shale	Light grey	Carb., Micaceous, silt sized, lithic fragments.	No microfauna	
●	Nodular shale	Light grey	Carb., Micaceous.	*U.eocaena, U.jacksonensis, U.continousa. U.glabrans.*	Uvigerinids dominant 100%
●	Nodular shale	Light grey	Shale laminated with V. Fine sandstone.	*U.eocaena, U.continousa, U.jacksonensis,*	Uvigerinids dominant 100%
●	Laminated sandstone	Dirty white /light grey	Parallel laminated 0.5Cm-0.5mm thick calcite cement.	No microfauna	No microfauna
●	Nodular shale	Light grey	Carb. Occassional silt, massive, fissile.	*U.eocaena, U.continousa, U.jacksonensis, U.cocoaensis,*	Uvigerinids dominant 100%
●	Nodular shale	Light grey	Carb. Occassional silt, massive, fissile.	*U.cocoaensis, U.continousa, U.jacksonensis,*	Uvigerinids dominant 100%
●	Nodular shale	Light grey	Carb. Occassional silt, massive, fissile.	*U. Eocaena U.continousa, U.cocoaensis, U.jacksonensis,*	Uvigerinids dominant 100%
●	Nodular shale	Light grey	Carb. Occassional silt, massive, fissile.	*U.cocoaensis, U.continousa, U.jacksonensis.*	Uvigerinids dominant 100%
●	Nodular shale	Light grey	Carb. Occassional silt, massive, fissile.	*U.cocoaensis, U.continousa, U.jacksonensis, T.c.pomeroli,*	Uvigerinids dominant 98.6%
●	Nodular shale	Light grey	Carb. Occassional silt, massive, fissile.	*U.cf.steyeri, U.continousa, U.jacksonensis, U.eocaena*	Uvigerinids dominant 90%
●	Nodular shale	Light grey	Carb. Occassional silt, massive, fissile.	*U.jacksonensis, U.continousa, U.eocaena, T.c.pomeroli,*	Uvigerinids dominant 81.9%
●	Nodular shale	Light grey	Carb. Occassional silt, massive, fissile.	*U.continuosa, U.jacksonensis, U.eocaena T.c.pomeroli, Globigerina sp. C.cubensis,*	Uvigerinids dominant 91.6%
●	Nodular shale	Medium grey	Carb. Occassional silt, massive, fissile.	*U.continousa, T. C. Pomeroli, U.jacksonensis, T.c.cerroazulensis.*	Uvigerinids dominant 90.9%
●	Nodular shale	Light grey	Carb. Occassional silt, massive, fissile.	*U.continousa, U. Cf.eocaena U.jacksonensis, Globogerina sp. T.c.cero,*	Uvigerinids dominant 76.5%
●	Silty shale	Dark grey	Massive, carb, Mica ceous with silt.	No microfauna	No microfauna
●	Nodular shale	Dark grey	Massive, micaceous, non-calc., Fissile & rarely silty.	*U. Continousa, T. C. Pomeroli, U. Jacksonensis, U. Jacksonensis.*	Uvigerinids dominant 85.0%
●	Silty shale	Light grey	Thin lamination of silt layer.	*U. Cocoaensis, T. C. Pomeroli, Quenqueloculina sp. U. Eoceana Osangularia*	Uvigerinids dominant 85.0%

Interpretation

Presence of *T.cerroazulensis pomeroli* in good number and *T.cerroazulensis cerroazulensis* suggests Late Eocene.

Presence of Uvigerinids (*U.jacksonensis, U.eocaena, U.cocoaensis, U.continuos, U.glabrans, U.jacksonensis, U.cf.steyeri*) often in high percentage suggets upper bathyal environment. (Borsma, 1948). In an analogy to present day morphotypes of Uvigerinids in Bay of Bengal (Raju et al. 1996, Raju and Dave, 1996), these Uvigerinids suggets a lower part of upper bathyal environment.
No microfauna internels (■) in thin sandstone / siltstone layers within lower part of upper bathyal zone suggest that they are turbidites (in wider sense)

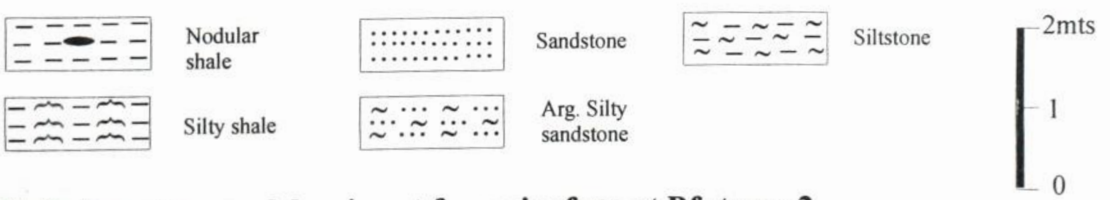


Figure 5.8b **Biofacies with % of dominant foraminefera at Pfutsero 2.**

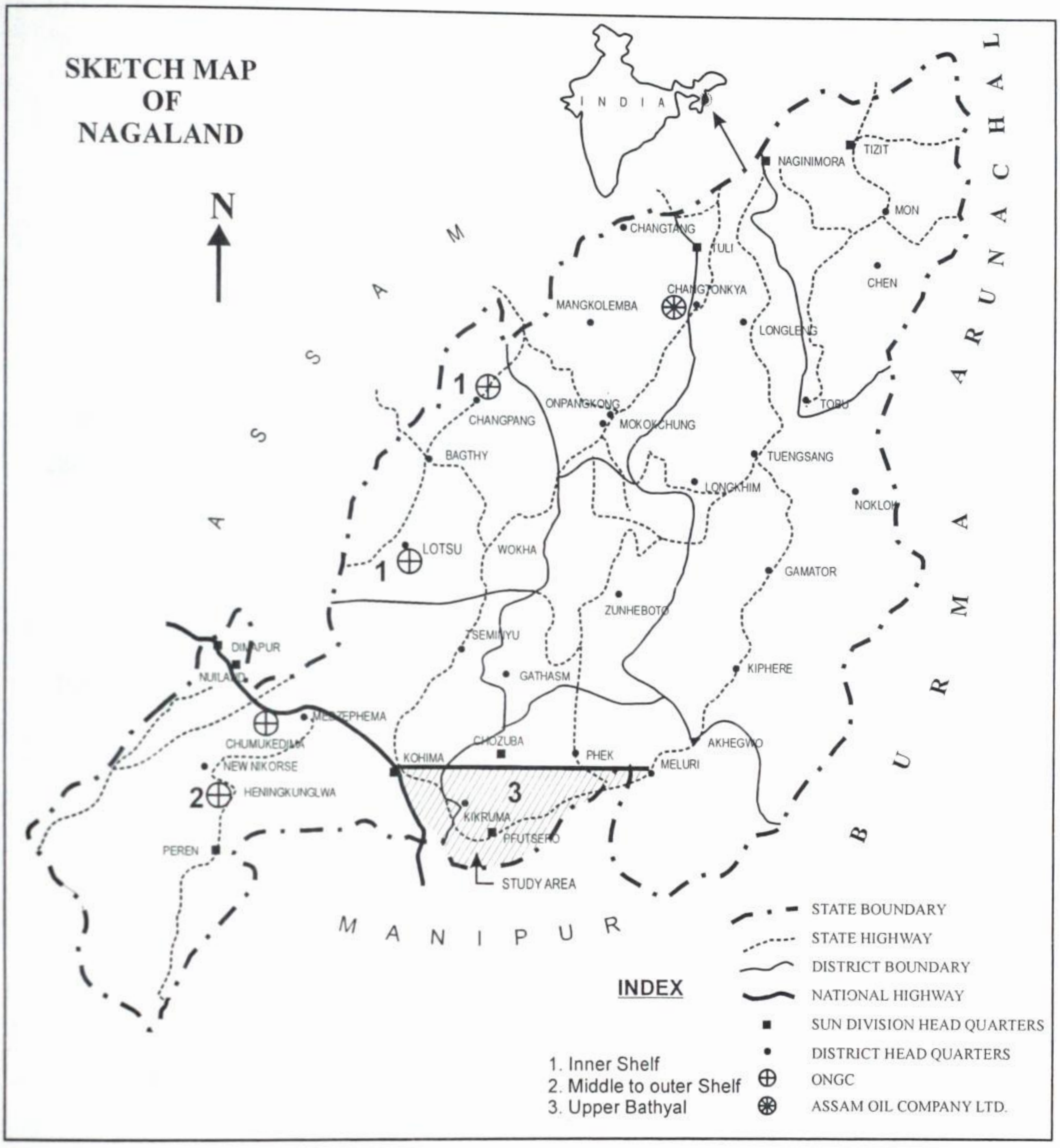


Figure 5.9a **Sketch map of Nagaland showing the location of outcrops and deep wells studied by Assam Oil Company, Ltd.; ONGC, GSI and present work.**

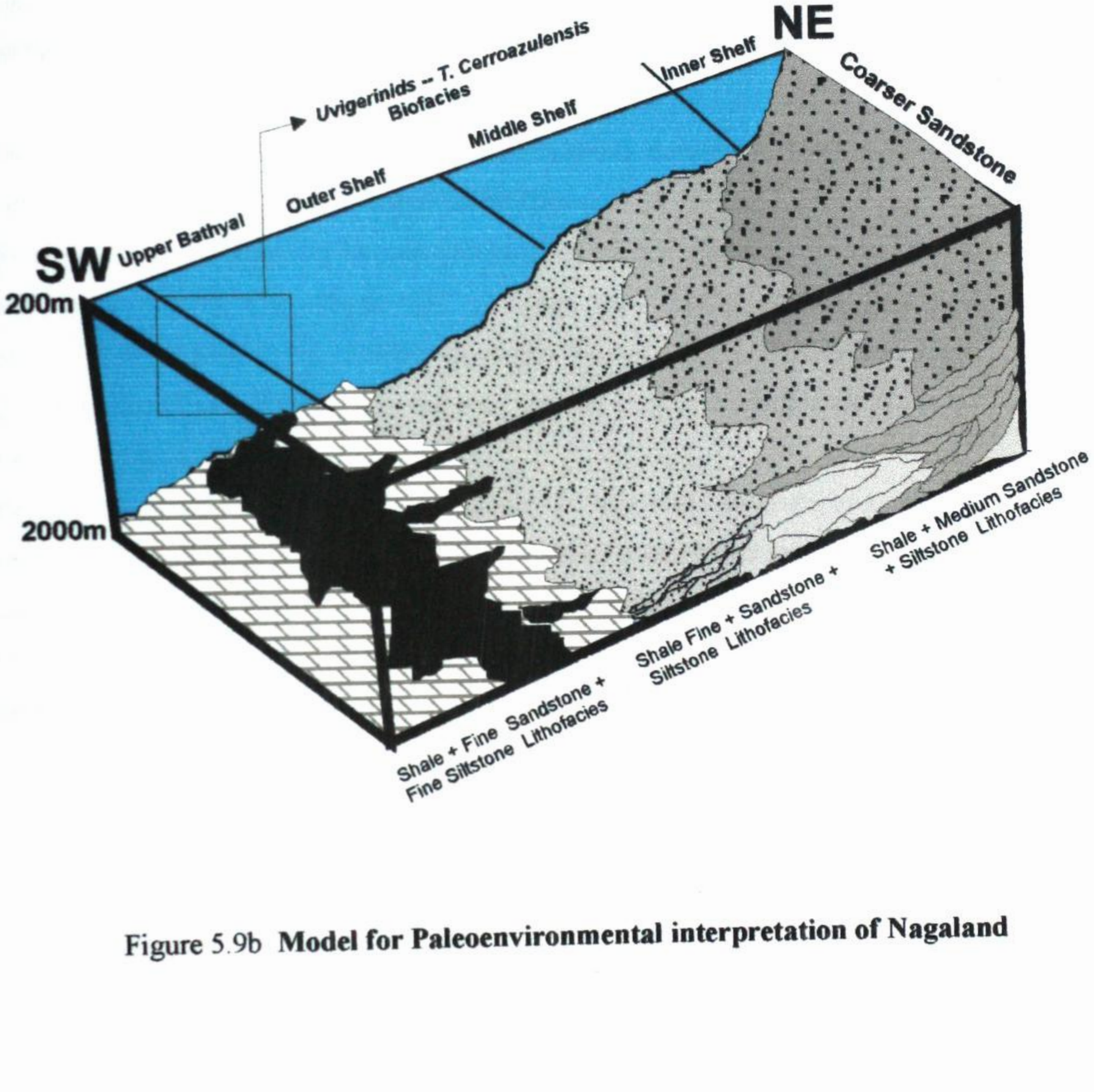


Figure 5.9b **Model for Paleoenvironmental interpretation of Nagaland**

3. Lower part of upper bathyal set-up fom the localities of Pfutsero 1, 2, Chobama and Leshemi in Phek District supported by dominant *Uvigerina* facies consisting *Uvigerina cocoaensis, U. continuosa, U. cf. eocaena, U. glabrans, U. jacksonensis, U. longa, U. moravia, U. cf. steyeri* and *U. vicksburgensis*.

5.8 CORRELATION OF PALEOENVIRONMENTAL SETUP OF NORTHEAST BASINS, INDIA

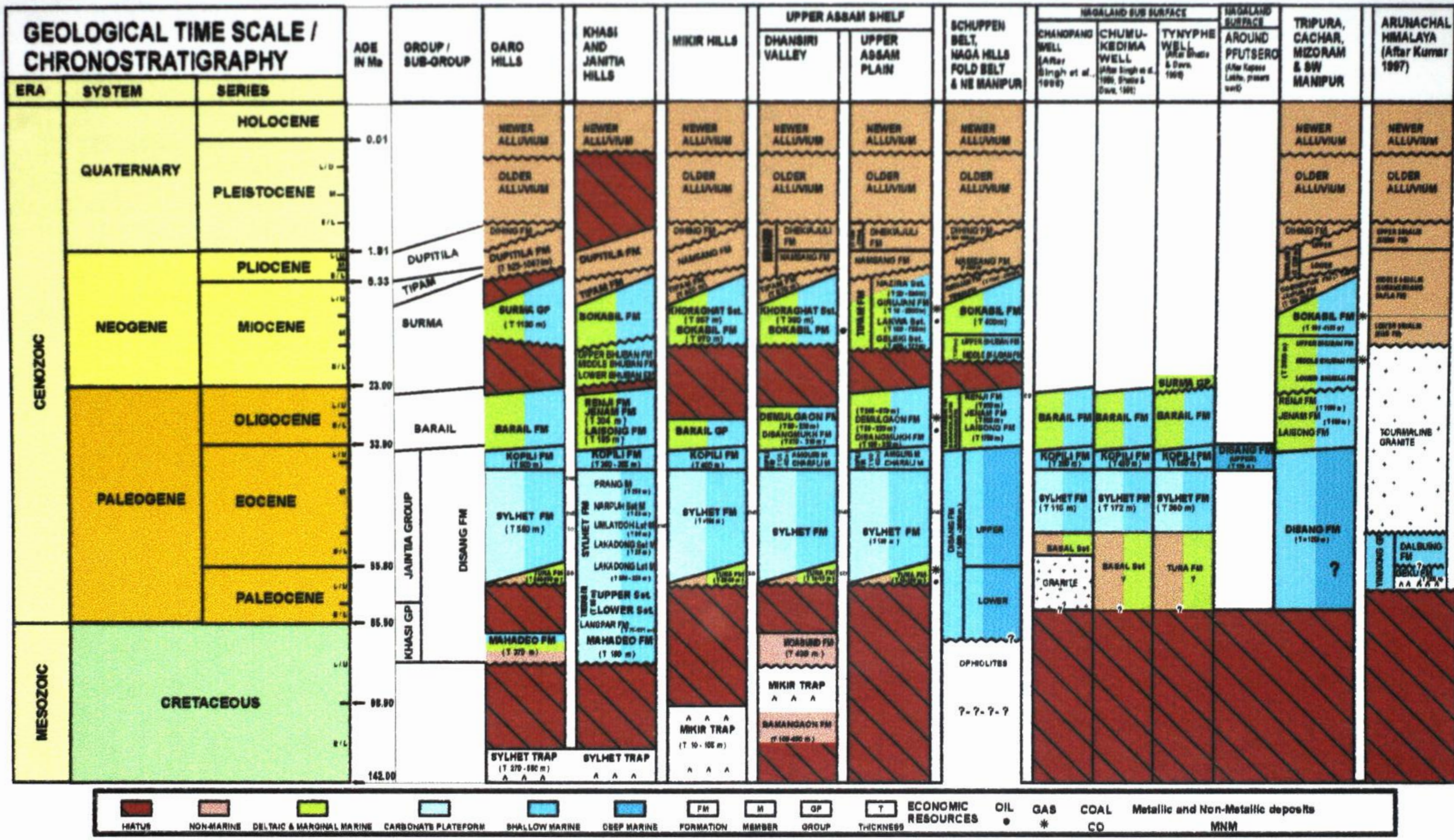
A stratigraphic units, thickness and paleoenvironments during the Cretaceous and Cenozoic of Northeast India (Table-IV), compiled by Kapesa *et al.*, 2004 is shown.

The compilation is based on various publications mainly those by Evans (1932), Mathur and Evans (1964), Das Gupta (1977), Ranga Rao (1983), Jokhan Ram and Venkataraman (1984), Ganju *et al.*, (1986), Gopendra Kumar (1997), Pandey and Dave (1998), Das Gupta and Biswas (2000), who did both original work and compilation based on the works of several geologists.

The table shows the successional stratigraphy in terms of lithounits and inferred paleoenvironments based on fossils mainly foraminifera. The paleoenvironments inferred are non-marine, deltaic marginal marine, carbonate platform, shallow marine and deep marine. The criteria used for recognition of deep marine are based on the present work findings of deeper marine Uvigerinids viz. *Uvigerina cocoaensis, U. continuosa, U.* cf. *eocaena, U. glabrans, U. jacksonensis, U. longa, U. moravia, U.* cf. *steyeri and U. vicksburgensis* Pfutsero.

TABLE IV STRATIGRAPHIC UNITS, THICKNESS AND PALEOENVIRONMENTS DURING THE CRETACEOUS AND CENOZOIC OF NORTHEAST, INDIA

COMPILED BY KAPESA LOKHO, D.S.N. RAJU, P. RAMESH, GOPENDRA KUMAR AND R. VENKATACHALAPATHY



CHAPTER 6

BOUNDARY EVENTS

CHAPTER 6

BOUNDARY EVENTS

6.1 INTRODUCTION

The geologic time scale organizes all of Earth's history into blocks of time during which important events occurred. Although many geologic events coincide with the divisions of the geologic time scale, most units of the scale are determined primarily by biological and not geological developments. The basic divisions of the geologic time scale were established during the nineteenth and early twentieth centuries by geologists and paleontologists who identified changing fossil assemblages-grouping of fossil organisms that, when found together within sedimentary strata, indicate the relative age of the strata-then applied the relative age of superposition, faunal succession and cross-cutting relationships to establish their sequence (Chernicoff *et al.*, 1997).

The idea of global biological events has been under discussion since the very beginning of the science of earth history. Bio-events, often in connection with a significant change in lithology, were used by Cuvier (1769-1832) and by most of the scientists concerned in the first three quarters of the 19th century in order to subdivide the Phanerozoic eon. According to the significance of the overturn, they distinguished between larger and smaller units, nowadays called Systems, Series and Stages (Walliser, 1996).

Event: In principle, a change or happening is an event. However in connection with global biological or geological events we should use this term for short-term exceptional changes and happenings. Bio-events occur at local, regional and global scales, reflecting short-term, extraordinary, environmental changes (Kauffman and Hart in Walliser, 1997). Five major planktic and benthic foraminiferal extinction events occurred during the past 100 m.y. at the Cenomanian/Turonian (C/T) boundary, at the Cretaceous/Tertiary (K/T) boundary, in the latest Paleocene, in the late Eocene, and in the early Middle Miocene (Kaiho, 1994).

The majority of global bio-events are combined with litho-events are combined with litho-events, i.e. strong facies changes. These often can be easily recognized in the sections. Insofar, they are of great help for mapping geologists (Walliser, 1997).

6.2 EOCENE-OLIGOCENE BOUNDARY

From a Paleontological point of view, the Eocene-Oligocene boundary is perhaps the most complex boundary event of the Cenozoic. Planktic foraminifers are considered as a very useful tool in precise delineation of the Eocene-Oligocene boundary (Mukhopadhyay, 2003, Premoli Silva, 1986; Premoli Silva et al., 1988, Prothero & Berggren 1992). In temperate and tropical regions, where complete boundary sequences supposedly are developed, the upper boundary of the *Turborotalia cerroazulensis* Zone (=P17 Zone) represents the end of the Eocene, and the lower boundary of the overlying *Cassigerinella chipolensis-Pseudohastigerina micra* Zone or *Chiloguembelina cubensis-Pseudohastigerina* spp. Zone (=P18 Zone), the beginning of the Oligocene (Bolli, 1957; Toumarkine and Luterbacher, 1985; Bolli and Saunders, 1985; Berggren and Miller, 1988; Berggren et al., 1995).

According to Mukhhopadhyay (2003), the Eocene-Oligocene boundary is coeval with the boundary between P17 and P18 Zones; however, there is clear difference of opinion on this. Differences also exist on the uniform use of the zonal indices. A number of workers considered the extinction of Hantkenids as coeval with the Eocene–Oligocene boundary. This criterion has been accepted by the IUGS for the stratotype section at Massignano, central Italy (Odin and Montanari, 1988), where the extinction level of the Hantkenids has been radiometrically dated as 33.7+/- 0.5 Ma (Odin and Montanari, 1989).

6.3 EOCENE-OLIGOCENE BOUNDARY EVENT IN INDIA

A continuous Late Eocene-Early Oligocene fossiliferous marine sequence is not known from any of the Tertiary basins of India. However, Mukhopadhyay (1997 & 2003), has reported the Eocene-Oligocene boundary in an apparently continuous sequence of calcareous sediments exposed near Dinod village in Cambay Basin, Gujarat. Here, he has recorded a foraminiferal assemblage comprising *Nummulites longilocula* n. sp., *Globigerina dinodensis* n. sp., *Turborotalia* sp. *A*, *Chiloguembelina* aff. *C. cubensis*, *Nonionella* cf. *N. wemmelensis* and *Noninella* aff. *N. pauciloba* has been recovered from a stratigraphic interval between the last occurrence of *Turborotalia cerroazulensis* s.1. and the first occurrence of *Cassigerinella chipolensis*.

Mukhopadhyay (1997) recognized Eocene-Oligocene at Gujarat based on the occurrence of a planktic foraminiferal assemblage represented by *Cassigerinella chiploensis* and *Pseudohastigerina micra* of Early Oligocene age and *Globorotalia cerroazulensis* of Late Eocene.

6.4 EOCENE-OLIGOCENE BOUNDARY IN NE INDIA

Since previous workers published evidences of the presence of Middle Eocene, Late Eocene and Oligocene sediments from various parts of Nagaland (Mathur and Evans, 1932, Ranga Rao, 1983). We thought it is worthwhile to demark the zonal and stage boundaries of local and regional importance. From the geology of Nagaland, we infer that the Paleogene rocks (Disang and Barail Group) of Nagaland occur continuously without any break or unconformity.

Baruah *et al.* (1987) has reported the occurrence of foraminifera from Laisong Formation (Barail Group). They have identified some fossiliferous beds near Lotsu village. The larger benthic foraminifera constitute the assemblages whereas planktic foraminifera are absent. The assemblage include *Pellatispira madaraszi*, *Nummulites cf. N. orbignyi(Galeotti)*, *Operculina* sp, *Cibicides* sp, *Qninqualeculina* sp, *Lagena* sp *and Glandulina* sp. In the absence of planktic foraminifera, it was equated with the fossiliferous part of Laisong formation to the upper-most part of Disang Group. They have suggested a thorough investigation on the Laisong Formation and opined that, 'if future studies confirm the stratigraphic position of Lotsu section as Laisong Formation, it would then represent a time transgressive sequence.

Madan Mohan (1978, as in GSI Spl. Publn. No 23, p.4) after a study of planktic foraminifers of Baghmara borehole cores of Garo Hills of Meghalaya has identified not only Late Eocene forms but also Oligocene taxa *Nummulites fichteli*. He dated Kopili Formation as Late Eocene to Early Oligocene. Micropaleontological studies carried out by Sinha (1974), have yielded reticulate *Nummulites* in Disang Group exposed at Changtongka (in GSI, Vol.112, 1982). Reticulate *Nummulites* range from late Middle Eocene to Early Oligocene, but exact age cannot be given without specific identification.

6.5 OBSERVATIONS AND DISCUSSION

Almost the whole of the Nagaland state is covered by Tertiary sediments, except the alluvial plains and Ophiolite and metamorphic complex occurring along Burma border. Though the occurrence of foraminifers was reported by various workers in different parts of Nagaland, no significant work on the foraminiferal biostratigraphy (except Baurah *et al.*, 1987) has been carried out. The state of Nagaland has a mountainous topography. The reported occurrences of foraminifers from places are vague. Even Baruah *et al.* (1987), have suggested a detailed study in parts of Nagaland.

In the present study an attempt has been made to locate the fossiliferous horizon in parts of Kohima and Phek districts. In the course of our work on DST Major Research Project by a team comprising Venkatachalapathy (P.I), D.S.N. Raju (Co P.I) and Kapesa Lokho has found highly fossiliferous sections in and around Pfutsero town in Phek District of Nagaland.

In the present study area we have recorded 54 species belonging to 29 genera, 13 subfamilies, 23 families, 17 superfamilies and 5 suborders. Of the total species 14 are planktic forms and 40 are benthic forms. The present work recorded a good number of foraminifera especially the planktic foraminifers and Uvigerinids.

Among these, species of *Globigerinatheka semiinvoluta, Chiloguembelina cubensis, C .martini, C. cf. tenuis, Hantkenina liebusi, Pseudohastigerina naguewichiensis, Turborotalia cerroazulensis cocoaensis* and *T. c. pomeroli* are reported for the first time in Nagaland. The *Globigerinatheka semiinvoluta* Interval zone (P15) has been proposed for the first time Nagaland.

In the study area, 3 biozones in Late Eocene are recognized. They are based on the ranges of the marker planktic foraminiferal species. The planktic foraminiferal zones proposed in the study area are *Globigerinatheka semiinvoluta* Interval Zone, *Cribrohantkenina inflata* Total Range Zone and *Turborotalia cerroazulensis* Interval Zone to represent P15, P16 and P17 Zones respectively.

In the study area, the Disang Group of rocks is well exposed and is overlain by Barail Group of rocks. The foraminiferal assemblages from Disang Group of rocks in this area (South Central Nagaland) confirms a deeper marine environment .The occurrence of index planktic foraminifers helped us in establishing 3 biozones and for their correlation with other regions. Correlation of the biozones in the study area with other regions shows that the Upper Eocene in Nagaland is also represented by *Turborotalia cerroazulensis* zone.

The Eocene-Oligocene boundary delineation by faunal criterion depends on the development and availability of a continuous marine succession, where the biological events established in relation to the boundary can be studied. However, only few seemingly continuous, marine sequences have been established so far, because the Upper Eocene and Lower Oligocene sequences are discontinuous in most of the Indian Basins. While in some of the cases Late Eocene is either totally absent or it lacks its upper part.

The Upper Eocene and Lower Oligocene sequence is discontinuous in most of the basins. In Assam and adjoining regions the Upper Eocene to Lower Oligocene succession are seemingly continuous, but the depositional facies are not suitable to hold the diagnostic fauna. The Oligocene sediments studied so far in N.E India shows that they are poorly fossiliferous.

In the absence of fauna on the level above the *Turborotalia cerroazulensis* Zone in the study area and elsewhere in Nagaland we are unable to establish Eocene-Oligocene boundary. In the study area, so far we have got only Late Eocene foraminifera. There were no markers in these sections to recognize Oligocene. Although three planktic foraminiferal zones are recognized in some of the sections, planktic foraminifers are not uniformly present making it difficult to discuss all the problems involved in marking zonal boundaries and related events.

CHAPTER 7

SUMMARY AND CONCLUSION

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SUMMARY AND CONCLUSIONS

Amongst all the states of the Northeast, maximum geological studies have been carried out in Assam owing to the discovery of Oil in 1889 in Digboi in Upper Assam. Not much attention has been paid to geological studies of Nagaland up to the present possibly because of the difficult terrain and poor transport and communication facilities. The earliest geological studies of Nagaland were carried out by the geologists of Assam Oil Company, Geological Survey of India, Oil and Natural Gas Corporation and Department of Geology and Mining of Nagaland state.

The geology of Nagaland is complex due to the interacting of three plates, viz., the Indian plate, the Burmese plate and the Tibetan plate. Kent *et al.* (2002) stated 'the Assam-Arakan thrust belt extends along the India-Myanmar border, from the Chinese border in the north to the Bay of Bengal in the south'. Ganju *et al.* (1986) identified seven major longitudinal thrusts/faults namely Naga, Disang, Tapu, Changrang-Zungki-Laniye, Laruri, Moya and Namya from west to east.

Mallet (1876) was the first to work on Disang rocks on account of the Coalfields of the Naga Hills and first named it as 'Disang Series'. He proposed the name Disang Group for dark grey shales and minor sandstones exposed along Disang (Dilli) river section (23°5'N: 95°23'E). Later Oldham (1883) correlated the Disang with Axials of Arakan Yoma. Since the inception of biostratigraphy work nearly a century ago, only a few selected sections and a few deep wells have been studied in Nagaland. The biostratigraphical data published by different authors, particularly with reference to paleoenvironment, show differing views.

Baruah *et al.* (1987) recognized two biozones from south western part of Nagaland namely *Nummulites pengaronensis – Pellatispira madraszi – Disclocyclina dispansa* Zone and *Cribrohantkenina inflata – Hantkenina alabamensis* Zone and dated them as middle to late Late Eocene age (Zone P16 and early part of zone P17 of Blow, 1969).

The foraminiferal assemblage recorded by Baruah *et al.* (1987) from the Disang and Barail Group represents deposition in shallow marine environment with oscillations in bathymetry. Heina Reu and Manglu sections are stated to be rich in planktic foraminiferal assemblage with *Uvigerina* sp. and *Bulimina* sp., corresponding to middle to outer shelf zones and indicating bathymetry between 100 to 150m. Scanty occurrence of arenaceous foraminiferal assemblage on top part of Disang Group and in Barail Group suggests the brackish water environment of deposition.

In the present work, six sections viz., Chobama 1, 2, 3, Leshemi, Pfutsero 1 and 2 have been studied and based on foraminiferal assemblages three biozones namely, *Turborotalia cerroazulensis cerroazulensis* zone (P-17), *Cribrohantkenina inflata* zone (P-16) and *Globigerinatheka semiinvoluta* zone (P-15) have been established with the help of which the age of the Disang Group has been confirmed as Late Eocene. Among the studied sections, Chobama 1 section has three biozones viz., *Globigerinatheka semiinvoluta* Interval Zone, *Cribrohantkenina inflata* Total Range Zone and *Turborotalia cerroazulensis cerroazulensis* Interval Zone. This section consists of maximum amount of foraminiferal assemblage. Chobama 3 section has two biozones viz. *Cribrohantkenina inflata* Total Range Zone and *Turborotalia cerroazulensis cerroazulensis* Interval Zone. No biozone is assigned to Chobama 2 section as no foraminiferal zonal marker is found. Leshemi section, Pfutsero 1 and 2 sections are assigned as *Turborotalia cerroazulensis cerroazulensis* biozones. Pfutsero 2 section yielded a rich assemblage Uvigerinids. Some of the samples contain 100% Uvigerinids. Uvigerinids were found in all the sections studied although in lesser numbers in Chobama 1, 2 & 3 and Leshemi.

Ranga Rao (1983) remarked that Disangs have been considered for long time as the geosynclinal facies of the Sylhet and Kopili cropping out at the Shillong-Mikir Hills front but no precise evidence for the facies is mentioned. Brunnschweiler (1966 in Acharyya, 1997) states 'in Naga Hills, the sediments, located above the Disang thrust to the west and tectonically below the ophiolitic rocks to the east, are essentially made up of thick pile of flooded Paleogene sediments'. The belt is commonly referred to as the flysch belt. He has shown no direct evidence for considering the Disangs as flysch belt. Acharyya (1997) noted turbiditic structures like load cast, flute cast, convolutes and slump structures.

From the present work, with the findings of Uvigerinids, a deeper marine (lower part of upper bathyal) environmental set-up is confirmed for the Upper Disangs of central part of Nagaland at Leshemi section, Chobama 1, 2, 3 Sections, Pfutsero 1 and Pfutsero 2 sections. Presence of abundant Miliolids and some *Nummulites pengaronensis* and *Nummulites chavannesi* in association with *Osangularia* sp., *Cyclammina* sp. and *Uvigerina jacksonensis* at Leshemi section suggests that the larger foraminifera along with microgastropods from lagoonal-shallow marine were transported to bathyal condition. Studies by Raju *et al.* (1996) on morphological variation of Uvigerinids along Bay of Bengal support a paleobathymetry deeper than 350m.

ONGC well/outcrop data show that shallow marine conditions during Late Eocene in western part of Nagaland at Champang, Chumukedima and Tynyphe wells, Heningkunglwa and Lotsu indicate paleo-shelf edge/margin is along a belt in western Nagaland.

Haq *et al.* (1988) suggested a global drop of sea-level around 80m during Late Eocene. The deeper part of upper bathyal set-up during Disang was due to rapid subsidence. The foraminiferal criteria employed to infer anoxic conditions are based on an approach by Robertson Reuach, a paleontologist (see Chandra *et al.*, 1994). The criteria pertinent to our study are: i) localized occurrence of thick "Uvigerinids"; ii) presence of pteropods, and, iii) pyritised tests. Very high percentage of Uvigerinids and colour from some sections indicate anoxic conditions suggestive of possible source rocks.

According to Narayanan (2004), the general consensus today is that the Burma Platelet a part of the Sundaland Plate was generally opposite the Indian Plate from late Cretaceous. The rest of the Sundaland Plate is considered to have moved away dextrally along the Sagging Transform. The movement of the Shillong Platelet, again dextrally, along the Dawki Transform ends with a soft collision with the Sundaland Plate closing off what could be termed the Upper Disang Sea from the Tethys to the North. The Eocene granites of the Pynmana area on the edge of the Shan Massif, along the Sagging fault indicate the age of dextral movement there. The Disang Sea could be considered to have been the progenitor of what later became the Bay of Bengal but would have been essentially a narrow gulf, a couple of hundred kilometers long, which replaced the earlier existing subduction zone trench.

Although local/regional variations are known, some of the species of Uvigerinids from Nagaland support open sea connection which had a restricted circulation at times to deep marine.

Based on the previous works and present work, we may infer the paleoenvironmental set-up of Nagaland as:

Inner shelf facies at Tehai Reu Section and Lotsu Village Section in the western part based on reported occurrence of *Pellatispira*, *Nummulites* and *Discocyclina*, middle to outer shelf set-up by an association of larger benthic and planktic foraminifera and some Uvigerinids (*Uvigerina* cf. *jacksonensis*) from a locality of Heina Reu Section. A lower part of upper bathyal set-up supported by dominant *Uvigerina* facies consisting *Uvigerina cocoaensis*, *U. continuosa*, *U. eocaena*, *U. glabrans*, *U. jacksonensis*, *U. longa*, *U. moravia*, *U. steyeri* and *U. vicksburgensis* from the localities of Pfutsero 1, 2, Chobama and Leshemi.

If the fossiliferous foraminifera from the layer reported from the western part are not transported by turbidity current, we may infer a shelf-shelf margin-slope set-up within western to central part of Nagaland. The morphological features of some cosmopolitan "species" of Uvigerinids and their dominance in central Nagaland suggests an anoxic set-up which at least in part connected at times to Tethyan Sea.

FUTURE RESEARCH

1. Geological time concept based on biostratigraphy and finer subdivisions of strata played a major role for more than a century in deciphering the geological evolution at the scale of inter-basinal and global. It is valid even now.

2. In a tectonically complex area like northeast region of India, it is important to study all exposed and key subsurface sections between every two thrust faults both West to

East and North to South and infer age and paleoenvironments including paleobathymetry during the deposition of known strata.

3. The importance of studies on the morphological variation in Uvigerinids in the reconstruction of paleobathymetry is well realized in ONGC during the last one decade. Detailed study, particularly on morphological variation and wall structure on Uvigerinids from Bay of Bengal and Andaman Sea is essential to improve our interpretations on paleobathymetry.

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PLATES

PLATE-1

(bar = 0.1mm)

Figures 1-2 — *Hantkenina alabamensis* Cushman, 1925; Stratigraphic range: Middle Eocene to Late Eocene (later part of Zone P12-P17)

Location: Chobama 3 section

1. Umbilical view, Sample Cho 3-3
2. Spiral view, Sample Cho 3-3

Figures 3-4 — *Hantkenina liebusi* Shokhina, 1937; Stratigraphic range: Middle Eocene

Location: Chobama 1 and 3 sections

3. Umbilical view, Sample Cho 3-1
4. Umbilical view, Sample Cho 1-1

Figures 5-6 — *Cribrohantkenina inflata* Howe, 1928;

Stratigraphic range: Late Eocene (Zone P16-P17)

Location: Chobama 3 section

5. Apertural view, Sample Cho 3-8
6. Spiral view, Sample Cho 3-8

Figure 7 — *Pseudohastigerina naguewichiensis* Myatliuk, 1950;

Stratigraphic range: Late Eocene (Zone P16 and continues)

Location: Chobama section

7. Umbilical view, Sample Cho 1-3

Figure 8 — *Pseudohastigerina micra* Cole, 1927;

Stratigraphic range: Early to Late Eocene (Zone P8-P17)

Location: Chobama 3 section

8. Umbilical view, Sample Cho 3-9

Figure 9 — *Pseudohastigerina barbadoensis* Blow 1969;

Stratigraphic range: Late Eocene (Zone P16-P17)

Location: Chobama 1 section

9. Umbilical view, Sample Cho 1-3

PLATE - 1

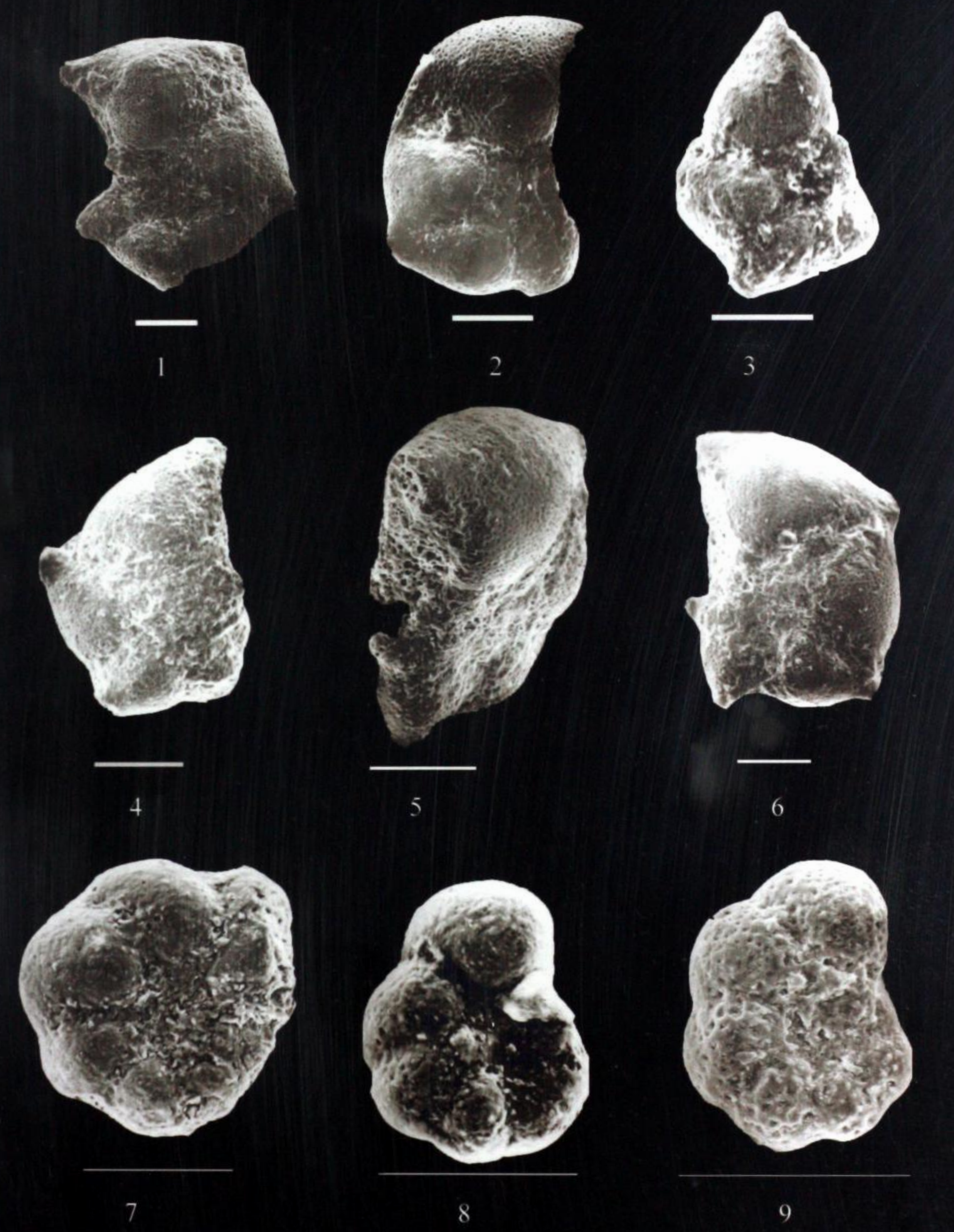

PLATE-2

(bar = 0.1mm)

Figures 1-2, 4 — *Turborotalia cerroazulensis pomeroli* Toumarkine and Bolli, 1970;

Stratigraphic range: Middle to Late Eocene (probable range from P11 to early part of P12 and definite range from middle of P12-P17)

Location: Pfutsero 2, Chobama 1 and 3 sections

1. Umbilical view, Sample P2-11
2. Umbilical view, Sample Cho 3-4
4. Spiral view, Sample Cho 1-2

Figures 3, 5 — *Turborotalia cerroazulensis cocoaensis* Cushman, 1928;

Stratigraphic range: Late Eocene (Zone P15-P17)

Location: Pfutsero 2 section

3. Umbilical view, Sample P2- 8
5. Spiral view, Sample P2- 8

Figure 6 — *Globigerina sp.*, 1826; Stratigraphic range: Upper Eocene to Holocene;

Location: Chobama 1 section

6. Umbilical view, Sample Cho 1-4

Figures 7-9 — *Turborotalia cerroazulensis cerroazulensis* Cole, 1928;

Stratigraphic range: Middle to Late Eocene (probable range from Zone P12 to later part of P13 and definite range from P14 to P17;

Location: Chobama 3 and Pfutsero 2 sections

7. Umbilical view, Sample Cho 3-27
8. Spiral view, Sample P2- 10
9. Peripheral view, Sample P2- 8

PLATE - 2

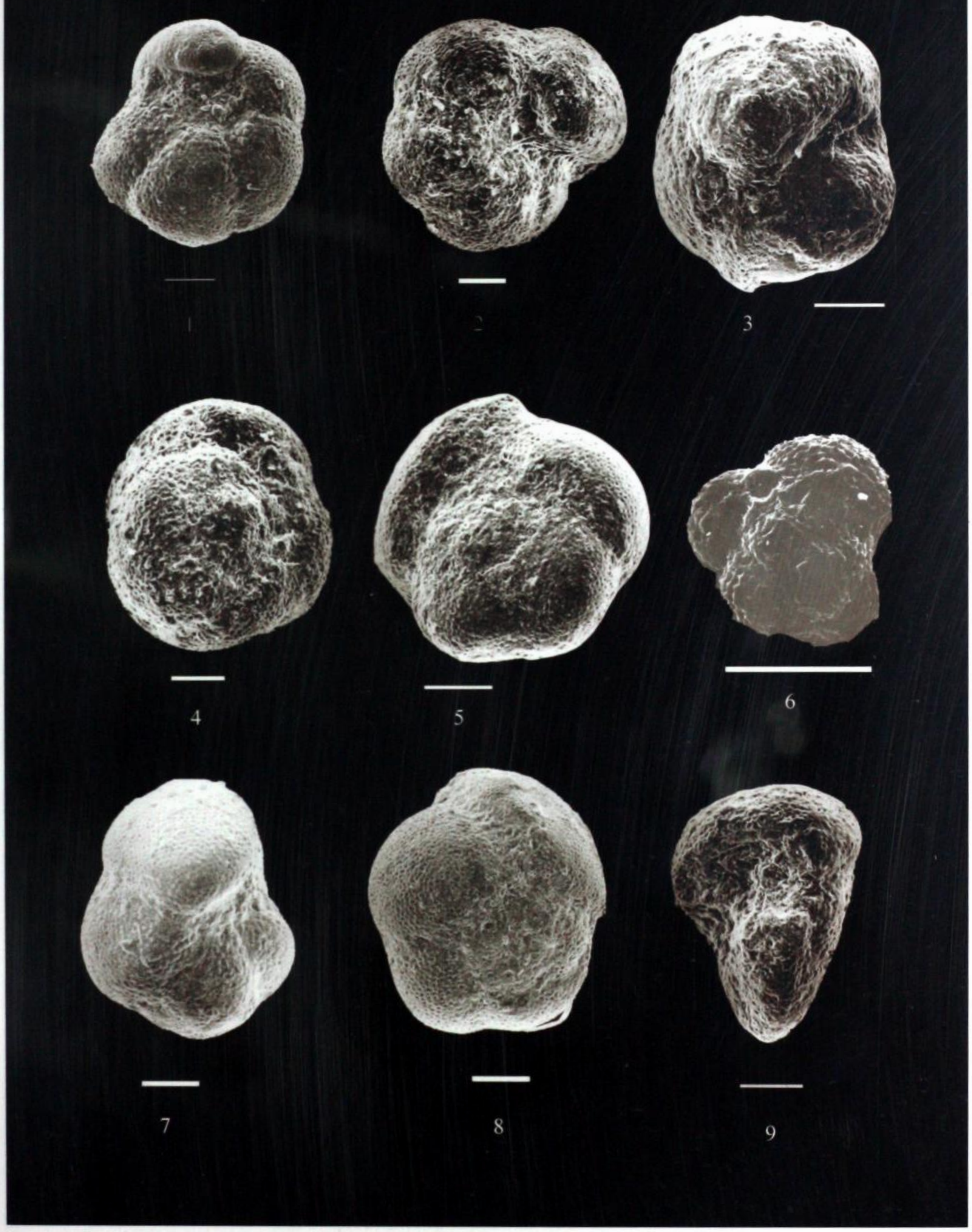

PLATE-3

(bar = 0.1mm)

Figure 1

Chiloguembelina martini Pijpers, 1933; Stratigraphic range: Late Eocene

Location: Chobama 1

1. Side view, Sample Cho 1-2

Figure 2

Chiloguembelina cubensis Palmer, 1934;

Stratigraphic range: Late Eocene to Oligocene (Zone P13-P22)

Location: Leshemi section

2. Side view, Sample L6

Figure 3

Chiloguembelina cf. *tenuis* Todd, 1957;

Stratigraphic range: Paleocene-Eocene, Tappan (1956)

Location: Chobama section

3. Side view, Sample Cho 1-5

Figure 4

Chiloguembelina sp., Stratigraphic range: Lower Paleocene to Oligocene

Location: Pfutsero 2 section

4. Side view, Sample P2- 8

Figure 5-6

Globigerinatheka semiinvoluta Keijzer, 1954; Stratigraphic range: Latest part of Middle Eocene to early part of Late Eocene (Zone P15)

Location: Chobama 1 section

5. Umbilical view, Sample Cho 1-1
6. Edge view, Sample Cho 1-1

Figure 7-9

Globigerina sp., Stratigraphic range: Upper Eocene-Holocene

Location: Leshemi and Chobama 1 sections

7. Umbilical view, Sample L5
8. Umbilical view, Sample Cho 1-1
9. Umbilical view, Sample Cho 1-1

PLATE - 3

PLATE-4

(bar = 0.1mm)

Figures 1-4 — *Nummulites chavannesis* De La Harpe, 1878;

Stratigraphic range: Top Lutetian-Upper Priabonian

Location: Leshemi section

1. Surface view, Sample L6
2. Surface views, Sample L7

3-4. Section view, Sample L7

Figures 5-8 — *Nummulites pengaronensis* Verbeek, 1871

Stratigraphic range: Middle Eocene

Location: Leshemi section

5-6. External view, Sample L6

5-7. Equatorial view, Sample L6

PLATE - 4

PLATE-5

(bar = 0.1mm)

Figures 1, 3	*Baggina cojimarensis* Palmer, 1941	
	Stratigraphic range: Uppermost Oligocene	
	Location: Chobama 1 section	
	1. Umbilical view, Sample Cho 1-3	
	3. Spiral view, Sample Cho 1-3	
Figure 2	*Baggina dominicana* Bermudez, 1949	
	Location: Chobama 1	
	2. Umbilical view, Sample Cho 1-3	
Figures 4-5	*Baggina dentate* Hagn, 1956	
	Stratigraphic range: Lower part of Upper Eocene	
	Location: Chobama 1 section	
	4. Umbilical view, Sample Cho1-2	
	5. Spiral view, Sample Cho1-2	
Figure 6	*Baggina subinaequalis* Kleinpell, 1939	
	Location: Chobama 1 section	
	6. Umbilical view, Sample Cho1-3	
Figure 7-9	*Cibicidoides* sp.	
	Location: Chobama 3 section	
	7-9. Side views, Sample Cho 3-1	

PLATE - 5

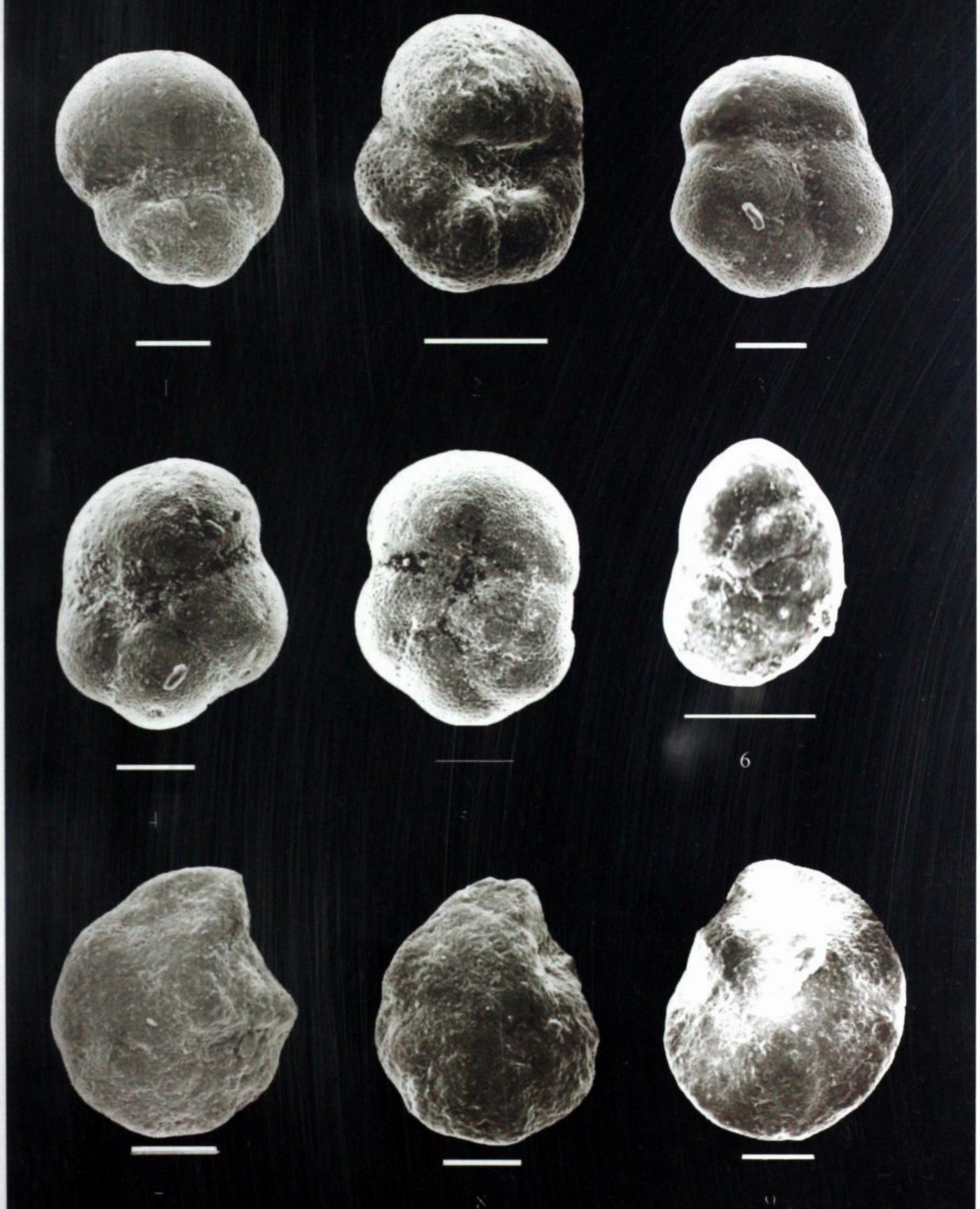

PLATE-6

(bar = 0.1mm)

Figure 1	*Cancris mauryae* Cushman and Renz, 1942 Location: Chobama 1 section 1. Side view, Sample Cho 1-2
Figure 2	*Nonionella* sp. Location: Chobama 1 section 2. Side view, Sample Cho 1-2
Figure 3	*Cibicidoides* sp. Location: Chobama 3 section 3. Side view, Sample Cho 3-1
Figure 4-5	*Cyclammina* sp. Location: Leshemi section 4. Side view, Sample L12 5. Apertural view, Sample L12
Figure 6	*Pseudonodosaria* sp. Location: Chobama 1 section 6. Side view, Sample Cho 1-2
Figure 7-9	*Cibicides* sp. Location: Chobama 1 section 7. Umbilical view, Sample Cho 1-1 8. Spiral view, Sample Cho 1-3 9. Peripheral view, Sample Cho 1-6

PLATE - 6

PLATE-7

(bar = 0.1mm)

Figure 1	*Lagena acutiscosta* Reuss Var. *proboscidialis,* Bandy, 1951 Location: Chobama 1 section 1. Side view, Sample Cho 1-1
Figure 2	*Lagena striata* (d' Orbigny) Location: Chobama 3 section 2. Side view, Sample Cho 3-1
Figure 3, 5	*Lagena* sp. Location: Leshemi section 3. Side view, Sample L5 5. Side view, Sample L6
Figure 4	*Lagena sulcata* Walker and Jacobs var. *spicata* Cushman and McCulloch, 1950, new name Location: Chobama 1 section 4. Side view, Sample Cho 1-2
Figure 6	*Lenticulina* sp. Location: Pfutsero 1 section 6. Side view, Sample P1-23
Figure 7-8	*Pyrgo* sp. Location: Chobama 1 section 7. Edge view, Sample Cho1-3 8. Side view, Sample Cho 1-1
Figure 9	*Praebulimina* sp. Location: Pfutsero 1 section 9. Side view, Sample P1- 21


PLATE - 7
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PLATE-8

(bar = 0.1mm)

Figure 1, 4-5	*Osangularia* sp. Location: Leshemi and Chobama sections 1. Spiral view, Sample L6 4. Dorsal view, Sample L7 5. Dorsal view, Sample Cho 3-4
Figure 2-3, 6	*Osangularia plummerae* Brotzen, 1940 Location: Chobama 1 section 2. Dorsal view, Sample Cho 1-5 3. Spiral view, Sample Cho 1-5 6. Peripheral view, Sample Cho 1-6
Figure 7	*Bolivina* sp. Location: Chobama 2 section 7. Side view, Sample Cho 2-16
Figure 8	*Rectobolivina* sp. Location: Pfutserol section 8. Side view, Sample P1-15
Figure 9	*Dentalinoides* sp. Location: Chobama 1 section 9. Side view, Sample Cho 1-2

PLATE - 8

PLATE-9

(bar = 0.1mm)

Figure 1-6	*Elphidiella* sp.	
	Location: Leshemi and Chobama sections	

Figure 1-6 — *Elphidiella* sp.

Location: Leshemi and Chobama sections

1. Umbilical view, Sample L14
2. Spiral view, Sample L15
3. Axial apertural view, Sample L14
4. Spiral view, Sample L15
5. Peripheral view, Sample Cho 2-4
6. Apertural view, Sample Cho 2-6

Figure 7-8 — *Miliola* sp.

Location: Chobama 2 section

7. Edge view, Sample Cho 2-18
8. Side view, Sample Cho 2-18

Figure 9-10. — *Triloculina* sp.

Location: Chobama 1 section

9. Side view, Sample Cho 1-4
10. Edge view, Sample Cho 1-6

PLATE - 9

PLATE-10

(bar = 0.1mm)

Figures 1-2	*Turrilina robertsi* Howe and Ellis, 1939 Location: Chobama 1 and Chobama 3 sections 1. Side view, Sample Cho 3-3 2. Side view, Sample Cho 1-18
Figure 3-6	*Turrilina* sp. Location: Chobama 1 section 3. Side view, Sample Cho 1-1 4. Side view, Sample Cho 1-2 5. Side view, Sample Cho1-3 6. Side view, Sample Cho1-5
Figure 7-9	*Parafissurina* sp. Location: Chobama 1 section 7. Side view, Sample Cho 1-1 8. Side view, Sample Cho 1-1 9. Side view, Sample Cho 1-1

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PLATE-11

(bar = 0.1mm)

Figure 1, 4 — *Uvigerina continuosa* Lamb, 1964

Ecology: Upper bathyal

Location: Pfutsero 2 and Chobama 3 sections

1. Side view, Sample P2-32
4. Side view, Sample Cho 3-8

Figures 2-3, 5-6 — *Uvigerina cf. eocaena* Guembel, 1975

Ecology: Lowermost-upper to upper-middle bathyal

Location: Pfutsero 2 section

2. Side view, Sample P2-4
3. Side view, Sample P2-13
5. Side view, Sample P2-32
6. Side view, Sample P2-32

Figure 7-8 — *Uvigerina longa* Cushman and Bermudez, 1937

Ecology: Lower part of upper bathyal and uppermost middle bathyal

Location: Chobama 3

7. Side view, Sample Cho 3-8
8. Side view, Sample Cho 3-8

Figure 9 — *Uvigerina* cf. *steyeri* Papp, 1975

Ecology: Upper bathyal

Location: Pfutsero 1

9. Side view, Sample P1- 22

PLATE - 11

PLATE-12

(bar = 0.1mm)

Figure 1	*Uvigerina cocoaensis* Cushman, 1925 Ecology: Upper bathyal Location: Pfutsero 1 section 1. Side view, Sample P1- 22
Figure 2	*Uvigerina moravia* Boersma, 1984 Ecology: Upper bathyal Location: Pfutsero 2 section 2. Side view, Sample P2-21
Figure 3	*Uvigerina vicksburgensis* Cushman and Ellisor, 1931 Location: Chobama 3 section 3. Side view, Sample Cho 3-8
Figure 4	*Uvigerina* cf. *steyeri* Papp, 1975 Ecology: Upper bathyal Location: Pfutsero 2 section 4. Side view, Sample P2- 21
Figure 5-6	*Uvigerina jacksonensis* Cushman, 1925 Ecology: Upper bathyal Location: Chobama 1 and 3 sections 5. Side view, Sample Cho 1-10 6. Side view, Sample Cho 3-8
Figure 7-8	*Uvigerina glabrans* Cushman, 1933 Ecology: Upper bathyal Location: Pfutsero 1 section 7, 8. Side views, Sample P1-22

PLATE - 12

FIELD PHOTOS

1. Leshemi fossiliferous section.

2. Leshemi fossiliferous section.

3. Pfutsero 2 fossiliferous section.

4.Chobama 3 fossiliferous section.