First online volume
Jour. Indian Association of Sedimentologists, Vol. 35, No. 1 (2018), pp.99-106
ISSN 0970-3268

Microfacies analysis and depositional environment of Maastrichtian – Eocene limestone of the Ukhrul district, Manipur, Northeast India

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Abstract: Microfacies analysis of the carbonate rocks of Ukhrul were conducted to understand the sedimentological features, microfacies associations and depositional environment of the flyschoidal sediments deposited within Upper Disang Group. These rocks are composed mainly of microcrystalline calcite matrix, sparry calcite cement, skeleton grains and shell fragments. Three microfacies were identified as mudstone, wackestone and packstone. Based on the energy index classification, these limestones can be categorized into Sub-Type II_1 of Type II (Intermittently Agitated), deposition alternately in agitated water and in quiet water. Foraminifera of Upper Cretaceous to Eocene age have been identified in the present study. The recognized microfacies of the present study have been compared and correlated with the standard microfacies association (SMA), and in all probability they falls in Standard Facies Zone 8, Restricted Platforms. The detail microfacies analysis show that the studied limestones are fine-grained and micritic in nature mostly biomicrite, dominantly benthic and planktonic foraminifera deposited in a shallow marine shelf condition with restricted to moderately agitated water within an interior platform basin during the Maastrichtian – Eocene time.

Key words: Microfacies, shallow water Carbonate, depositional environment.

Introduction

The present investigation has been carried out on the samples collected from three sections viz. Paoyi, Ukhrul Town and Hundung sections of Ukhrul district, Manipur. Study of Maastrichtian – Eocene limestone deposits of Ukhrul and reconstruction of their depositional environment is essential and important because of Ukhrul limestones normally occur along or near the western margin of main Ophiolite belt and is considered as one of the deep seated oceanic pelagic sediment of the Nagaland–Manipur Ophiolite Belt (NMOB) by many workers (Singh, 1992; Singh, 2009). Singh (1992) identified microfacies in carbonate rocks of Ukhrul and designated as fossiliferous micrite, sparse biomicrite and packed biomicrite. According to Acharyya *et al.* (1989) the close association of carbonates with the pelagic sediments suggests deposition took place above carbonate compensation-depth. In Manipur limestone deposits are found occuring as scattered pockets within the Disang Group as well as within the oceanic pelagic sediments with Ophiolite suites. Some of the limestone blocks occur within Disang Group and its associated sediments has also been treated as Olistostromal/Exotic deposits. Because of the genetic systematic and occurrence of carbonates in the broader framework of geodynamic evolution of the Manipur – Nagaland Orogenic belt it seems to be difficult and unclear to understand and to study the limestone deposits in detail. As a matter of fact, very few attempts have been made earlier. Inspite of the published account of earlier workers (Mitra *et al*. 1986; Chungkham *et al.*, 1992; Chungkham and Caron, 1996; Singh, 2011; Singh *et al.* 2013) on this aspect, there are many gaps when one considers the relationship accruing between carbonates and flyschoidal sediment deposits and no record of microfacies study of these limestone. Foraminiferas were recorded earlier from the studied sequence by previous workers (Nandy and Sriram, 1970; Bhattacharyya and Bhattacharyya, 1987; Chunngkham *et al*., 1992; Prithiraj and Jafer, 1998; Singh *et al.,* 2013) however, re-examination is necessary to document the Cretaceous–Tertiary foraminifera from the sediments of Ukhrul in a better and justified manner as they did not mention the importance of benthic foraminifera which are very sensitive to the depositional environment.

In view of this, a detail study of carbonate rocks that occur in scattered pockets in the upper part of the Disang Group of sediments. The objective of the present study is to determined the characteristic of microfacies types and discuss diagnostic features of palaeoenvironmental condition through examination of their sedimentological and palaeontological characteristic. Microfacies types and facies associations are fundamental to the development of models for carbonate sedimentations (Flugel, 2010).

Geological Setting

The study area, Ukhrul district of Manipur, India is a part of Indo-Myanmar Range (IMR) within the Assam-Arakan Basin and represents a complex geological terrain in the subduction zone evolved by ocean–continent collision which gradually transformed into continent–continent collision forming a fold–thrust belt (Ranga Rao, 1983). The basin originated through dextral shear coupling between Indian and Burmese plates resulting to a schuppen belt (Ibotombi, 1998). The sedimentary process involved initial deep sea flysch sedimentation in the basin, namely the Disang Group, which gradually become shallow through sediment filling and tectonic squeezing. There was a shift of sedimentation pattern from finer shaly sediments of Disang Group that gradually transformed into a coarse sandy facies known as Barail Group. This gradual change in marine sedimentation is without any evidence of break in sedimentation. There is probability of getting an intervening neritic environment with favourable carbonate facies deposition (Devi and Duarah, 2015; Devi *et al*., 2016). The sedimentation of the Disang Group commenced during the Late Cretaceous (Maastrichtian) and continued till the end of the Eocene and the sandstone deposition of Oligocene sediments belonging to Barail Group took place conformably on the Disang Group (Kachhara, *et al* 2009). The carbonate rocks of Ukhrul area occupy the upper part of the Disang Group and appear to be of Maastrichtian to Eocene age as evidenced by the occurrences of several microfossils in the carbonate sediments (Devi, 2016). **3.**

Methods

The present study is based on approximately 60 thin sections from samples collected in three section viz. Paoyi, Ukhrul Town and Hundung of Ukhrul district (P_1-P_{16}: U_1-U_9: H_1-H_{33}) shown in Fig. 2. Staining of thin section have been done followed the procedure of Dickson (1965). Insoluble residues (IR) were determined by acid digestion using Hydrochloric acid (HCl) solution to dissolve the carbonate minerals (Carver, 1970). Microfacies studies include the analyses of matrix and grains, textural features, microfossil content, petrographic and energy index classification. The classification of facies types is based on Dunham's (1962) and Folk's (1962) limestone classification scheme. Energy index has been analysed according to Plumley *et al.* (1962) and Catalov (1972). For the identification of facies and

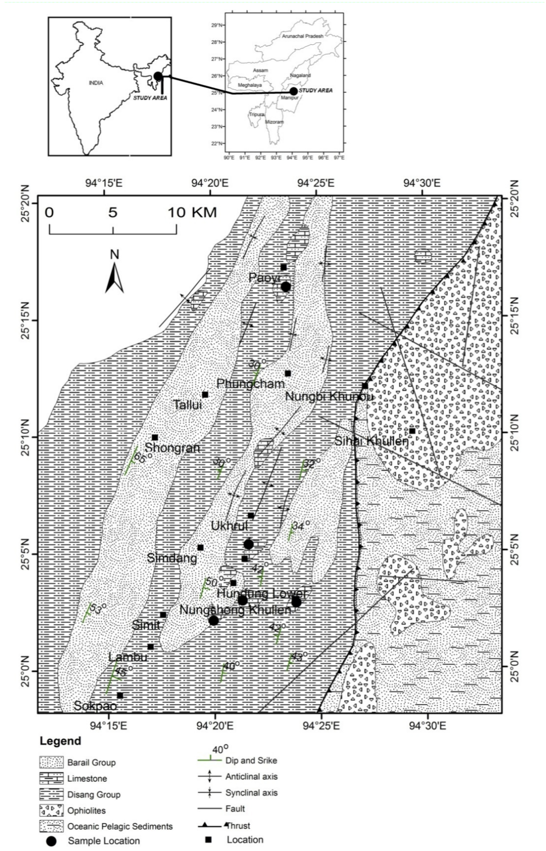

Figure 1: Geological map of the study area (Singh, 2011 and modified on the basis of field study).

interpretation of depositional environments, thin sections were analysed from each sections. The recognition of the "standard microfacies (SMF) types" and the "facies zones" have been defined based on Wilson (1975) and Flugel (2010).

Results and Discussion

Microfacies analysis based on thin-section studies subdivide the different facies into units of similar compositional aspect that reflect specific depositional environment. Basic prerequisites for defining microfacies types (MFT) are based on discrimination of grain categories, limestone classifications based on textural criteria, the recognition of depositional fabrics and the ability to attribute thin section fossils to major systematic groups and taxonomic units (Flugel, 2010). Facies zones (FZ) are limestone belts differentiated according to the changes of their sedimentological and biological criteria across shelf-slope basin transects. These Facies Zones (FZ) described idealized facies belts along an abstract transect from open-marine deep basins to the coast. Carbonates formed within these Facies Zones often exhibit specific Standard Microfacies Types (SMF) assemblages that are used as additional criteria in recognizing the major facies belts The Standard Facies Zones (FZ) describe idealized facies belts.

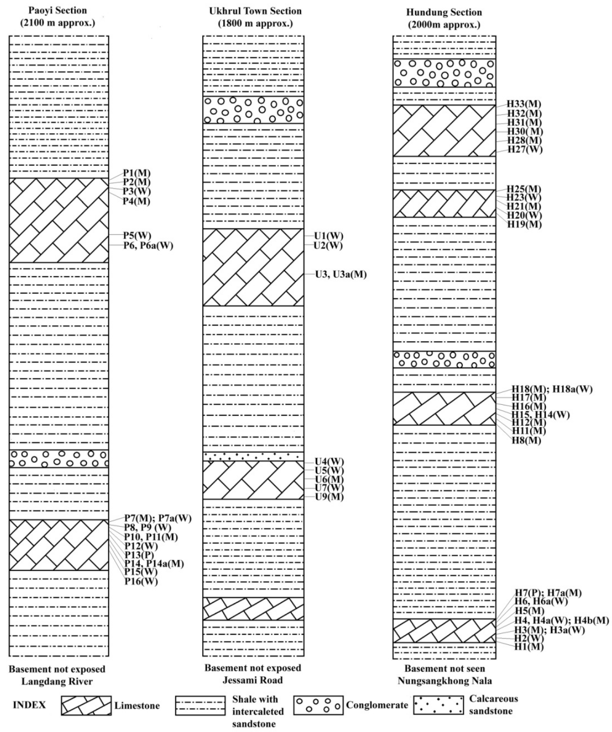

Figure: 2. Lithological column of the sample site of the study area.
W: Wackestone, P: Packstone and M: Mudstone

Classification of microfacies

The petrographic thin section analysis revealed three different types of microfacies viz., mudstone, wackestone and packstone (Fig. 3(A-L). These are described as follows:

(A) Mudstone Microfacies

This microfacies is common within the Ukhrul limestones and found in all the studied sections (Fig. 2). This microfacies

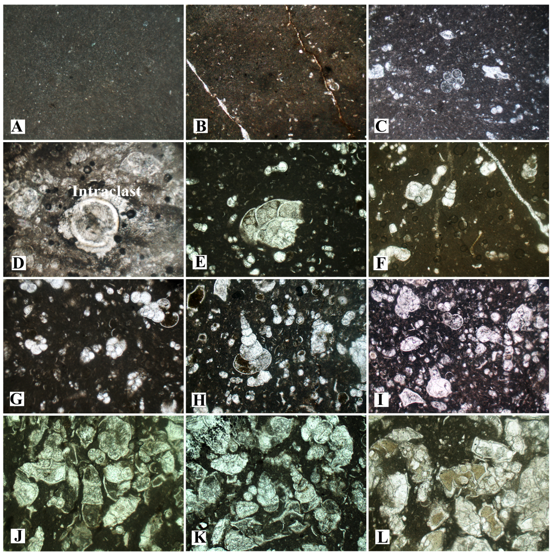

Figure: 3.Photomicrograph of the limestone of the study area: A-C. Mudstone with little allochem, D. Wackestone with Intraclast, E-I. Wackestone with fosil allochem. J-L. Packstone with fossil allochem

consists of lime mud matrix with little or no allochems as shown in Fig. 3(A-C). In the outcrop mud supported limestone is characterized by different shades of light grey to buff colour. Petrographically, it shows a high percentage of mud i.e., microcrystalline calcite matrix reach to 99.12% (P_{11}) in Paoyi section, 97.45% (U_9) in Ukhrul Town and 99.30% (H_{12}) in Hundung section (Table 1).

According to Dunham (1962), mudstone facies are deposited in low energy environment either in protected seas or below fair weather base (calm water). This facies is similar to the Standard Microfacies, SMF-23, Non-laminated unfossiliferous mudstone (Flugel, 2010), which corresponds to the Facies Zone 8 of restricted platform (Wilson 1975; Flugel 2010). Moreover, this facies type also indicates low maturity of the limestone, as the rocks of low maturity are characterized by a high proportion of micrite and low proportion of allochems. High percentage of micrite reflects deposition in a setting where current or wave energy was insufficient to winnow away the fine matrix (Folk, 1962).

(B) Wackestone Microfacies

This is one of the most common microfacies occurring in all the three sections (fig. 2). The grains consist more than 10% of the lithology. It consists of sparry calcite and skeletal remains of foraminifera represented by both panktonic and benthic forms. The planktonic foraminifera include *Globotruncana* sp., *Globotruncanita* sp., *Globorotalia* sp., *Hedbergella* sp., *Heterohelix* globulosa, *Pseudotextularia* sp., *Globigerina* sp., *Globigerinelloides* sp., *Rugoglobigerina* sp. etc. [Fig 4(A-N)] whereas benthic foraminifera include *Textularia* sp., *Valvulina* sp. and other unidentified benthic foraminifera as shown in Fig. 4 (O, P, Q, S & T). Presence of planktonic foraminifera like *Globotruncana* sp., *Pseudotextularia* sp. denotes a Maastrichtian age. The *Globigerina* sp., *Globorotali*a sp. represent Paleocene as Globigerinidae become the most planktonic family in Palaecene time, while planktonic genera Globigerinoides appear in the Eocene (Loeblich and Tappan, 1964). All these fossil records indicate that the age of limestones found in Ukhrul ranges from Upper Cretaceous i.e Maastrichtian to Eocene. The Upper Cretaceous is supported by Prithiraj and Jafar (1998) also. The foraminiferal taxas identified in this facies are very common and similar with those identified by earlier workers from different localities of Manipur. It is generally found that the fossil bearing carbonate rocks occupy the space in the upper part of the Disang Group. The preservation potential of these fossils are mostly poor and in deformed state. Presence of broken skeletal indicates perhaps gentle disturbances in the depositional environment. Intraclasts are found in negligible amount in the present study (only in few rock samples). Its value ranges from 0.02% to 0.9 % as shown in Table 1. Though the amount is negligible, the presence of intraclast (fig. 3D) can be

Sl. No.	*Sample No.	Micrite %	Sparite %	Fossil %	Oolite %	Pellet %	Intra-clast %	Insoluble Residue (IR) %	Dunham (1962)	Folk (1962)
1	P_1	92.07	5.83	2.07	-	-	0.03	27	mudstone	Fossiliferous micrite
2	P_2	96.42	2.39	1.19	-	-	-	24	mudstone	Fossiliferous micrite
3	P_3	89.51	9.44	1.03	-	-	0.02	26	wackestone	Fossiliferous micrite
4	P_4	91.20	7.99	0.81	-	-	-	24	mudstone	Micrite
5	P_5	84.08	12.22	3.70	-	-	-	25	wackestone	Fossiliferous micrite
6	P_6	79.37	16.78	3.85	-	-	-	19	wackestone	Fossiliferous micrite
7	P_{6a}	89.20	6.20	4.60	-	-	-	21	wackestone	Fossiliferous micrite
8	P_7	91.06	6.85	2.09	-	-	-	24	mudstone	Fossiliferous micrite
9	P_{7a}	69.70	21.5	8.80	-	-	-	20	wackestone	Biomicrite
10	P_8	82.12	13.67	4.21	-	-	-	16	wackestone	Fossiliferous micrite
11	P_9	73.81	15.59	10.2	-	-	0.9	36	wackestone	Biomicrite
12	P_{10}	94.40	5.00	0.60	-	-	-	25	mudstone	Micrite
13	P_{11}	99.12	0.88	-	-	-	-	21	mudstone	Micrite
14	P_{12}	87.12	11.5	1.38	-	-	-	18	wackestone	Fossiliferous micrite
15	P_{13}	42.58	44.57	12.85	-	-	-	17	packstone	Sparse Biomicrite
16	P_{14}	92.99	4.66	2.35	-	-	-	18	mudstone	Fossiliferous micrite
17	P_{14a}	98.10	1.80	0.10	-	-	-	16	mudstone	Micrite
18	P_{15}	83.16	4.40	12.44	-	-	-	21	wackestone	Biomicrite
19	P_{16}	86.21	2.98	10.81	-	-	-	24	wackestone	Biomicrite
20	U_1	89.10	1.10	9.80	-	-	-	21	wackestone	Fossiliferous micrite
21	U_2	84.00	4.40	11.6	-	-	-	17	wackestone	Biomicrite
22	U_3	92.00	2.10	5.90	-		-	20	mudstone	Fossiliferous micrite
23	U_{3a}	96.81	2.29	0.90	-	-	-	18	mudstone	Micrite
24	U_4	84.00	5.60	10.4	-	-	-	19	wackestone	Biomicrite
25	U_5	77.80	9.40	12.8	-	-	-	20	wackestone	Biomicrite
26	U_6	92.90	1.70	5.40	-	-	-	16	mudstone	Fossiliferous micrite
27	U_7	89.20	8.20	2.60	-	-	-	18	wackestone	Fossiliferous micrite
28	U_9	97.45	1.80	0.75	-		-	21	mudstone	Micrite
29	H_1	93.21	4.30	2.49	-	-	-	26	mudstone	Fossiliferous micrite
30	H_2	72.90	19.5	7.60	-	-	-	20	wackestone	Fossiliferous micrite
31	H_3	87.67	8.90	3.43	-	-	-	14	mudstone	Fossiliferous micrite
32	H_{3a}	92.38	5.11	2.51	-	-	-	17	mudstone	Fossiliferous micrite
33	H_4	69.45	22.83	7.72	-	-	-	32	wackestone	Fossiliferous micrite
34	H_{4a}	86.31	9.09	4.60	-	-	-	27	wackestone	Fossiliferous micrite
35	H_{4b}	91.04	7.61	1.35	-	-	-	24	mudstone	Fossiliferous micrite
36	H_5	94.01	4.80	1.19	-	-	-	26	mudstone	Fossiliferous micrite
37	H_6	81.64	13.66	4.70	-	-	-	22	wackestone	Fossiliferous micrite
38	H_{6a}	76.05	13.8	10.15	-	-	-	17	wackestone	Biomicrite
39	H_7	45.80	38.6	15.6	-		-	20	packstone	Biomicrite
40	H_{7a}	52.80	31.6	15.6	-	-	-	19	mudstone	Biomicrite
41	H_8	92.35	4.00	3.65	-	--	-	16	mudstone	Fossiliferous micrite
42	H_{10}	95.8	3.69	0.51	-	-	-	11	mudstone	Micrite
43	H_{12}	99.30	0.70	-	-	-	-	28	mudstone	Micrite
44	H_{13}	85.03	4.18	10.79	-	-	-	10	wackestone	Biomicrite
45	H_{15}	89.04	9.61	1.35	-	-	-	18	wackestone	Fossiliferous micrite
46	H_{16}	99.01	0.80	0.19	-	-	-	15	mudstone	Micrite
47	H_{17}	93.84	3.83	2.33	-	-	-	14	mudstone	Fossiliferous micrite
48	H_{18}	95.00	1.60	3.40	-	-	-	21	mudstone	Fossiliferous micrite
49	H_{18a}	87.05	8.35	4.60	-	-	-	20	wackestone	Fossiliferous micrite
50	H_{19}	92.30	4.30	3.38	-	-	0.02	16	mudstone	Fossiliferous micrite
51	H_{20}	80.36	6.57	13.07	-	-	-	24	wackestone	Biomicrite
52	H_{21}	98.21	1.49	0.30	-	-	-	20	mudstone	Micrite
53	H_{23}	89.01	9.79	1.20	-	-	-	17	wackestone	Fossiliferous micrite
54	H_{25}	93.20	4.96	1.84	-	-	-	21	mudstone	Fossiliferous micrite
55	H_{27}	87.60	8.62	3.78	-	-	-	19	wackestone	Fossiliferous micrite
56	H_{28}	98.53	1.43	0.04	-	-	-	22	mudstone	Micrite
57	H_{30}	97.61	1.79	0.60	-	-	-	18	mudstone	Micrite
58	H_{31}	98.01	1.69	0.30	-	-	-	21	mudstone	Micrite
59	H_{32}	92.17	7.80	0.03	-	-	-	25	mudstone	Micrite
60	H_{33}	98.65	0.95	0.40	-	-	-	23	mudstone	Micrite

Table 1: Major constituent components of Ukhrul limestone (in percentage) *Samples with prefix “P” are from Paoyi; “U” from Ukhrul Town and “H” from Hundung sections while “IR” is Insoluble Residue.

evidence of intrabasinal transport and shallow water regime, as the bottom would have shallow enough to be periodically affected by turbulence that causes intraclast formation because even intense storms have little effect below certain depths.

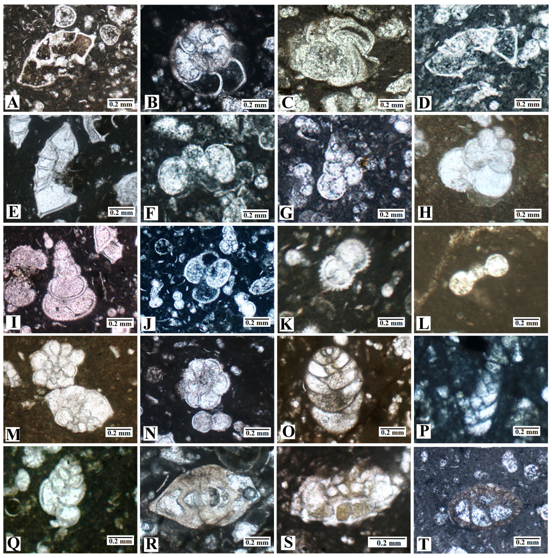

Fig 4: Photomicrograph of the foraminiferal fossils identified from the studied limestone: A-C. *Globotruncana* sp.; D-F. *Hedbergella* sp.; G-H *Heterohelix* sp.; I. *Pseudotextularia* sp.; J-K.*Globigerina* sp.; L. *Globigerinelloides* sp.; M. *Rugoglobigerina* sp.; N. *Globorotalia* sp.; O. *Valvulina* sp.; P-Q. *Textularia* sp.; R. *Robuloides* sp.; S-T. unidentified benthic foraminifera

According to Dunham (1962) wackestone is a mud supported framework carbonate rock implies with low hydraulic energy of deposition. The occurrence of microfossil especially foraminifera locally in great abundance but limited in diversity in the fine grain low energy depositional limestone of the present study can also be correlated to Standard Facies belt 8 i.e. restricted circulation and tidal flates of Wilson's (1975) facies model. The sediments of this belt are characterized mostly lime mud and muddy sand with terrigenous influx common. The biota should be shallow water biota of reduced diversity, but commonly with high number of individuals. Restricted shallow subtidal environments in the inner ramp are indicated by low diversity skeletal fauna in general, abundant of imperforate foraminifera (miliolids and *Archaias*) and lack of subariel exposure features (Hallock, 1984; Buxton and Peddely, 1989; Barattolo *et al*., 2007). Based on the foraminiferal assemblages with abundant miliolids this microfacies can be correlated to the Standard Microfacies (SMF) Type 18 (Wilson, 1975; Flugel, 2010), which fall in FZ 8, because miliolid foraminifera are very common in lagoonal environments of Mesozoic and Cenozoic restricted inner platforms and inner ramps (Flugel, 2010).

(C) Packstone microfacies

This facies is not common in all the studied sections. Exceptionally, only very few samples viz., sample No. P_{13} and H_7 (Table 1) showing such facies [Fig. 3(J,K&L)]. Due to lack of sufficient samples it would not be possible to correlate with standard microfacies. This microfacies is found in Paoyi and Hundung sections (Fig. 2). In this facies the grain percent is more than lime mud, where some of the sparite grains may be due to neomorphism.

Energy Index Classification

The classification proposed by Plumley *et al.* (1962) and Catalov (1972) was adopted for the energy index analysis. From the energy index classification it can be interpreted that limestone genesis is based primarily upon the energy level of depositional environment, which is a function of wave and current action reflecting a fundamental concern with environmental interpretation. These genetic classifications constitute a grading spectrum between quiet water and strongly agitated water. Plumley *et al.* (1962) distinguished five major limestone categories as Type I (quiet water), Type II (intermittently agitated water), Type III (slightly agitated water), Type IV (moderately agitated water) and Type-V (strongly agitated water). Our study reveals that microcrystalline calcite matrix ranges from 99.30- 42.58% while detrital particles i.e insolule residue % ranges from 36% to 10% (Table-1) and the presence of complex fossil assemblages of both benthic and plantonic type in the studied rocks represent the influence of both quiet and slightly agitated water condition, which fall in subtype II_1 of Type II i.e., mixed types occuring in the transition zone between deep water and very shallow water (Plumley *et al.*1962). According to Catalov (1972) classification the studied rocks fall in Type I, deposited in quiet water as the micrite percent ranges from 42.58% to 99.30% in Ukhrul district limestone.

Conclusion

Dominance of mud supported microfacies indicates the studied rocks were deposited in quiet water and low energy setting environment. Though high amount of micrite reflects a relatively low-turbulent environment however taphonic features of fossils suggest gentle disturbance due to intrabasinal transport. It is also supported by energy index classification. Microcrystalline calcite matrix comprises more than 50% of the rock and presence of complex fossil assemblages representing alternate deposition in agitated and quiet shallow water. Based on the sedimentological and paleontological criteria the identified microfacies types (MFT) were similar with SMF Type 18 and 23, which fall in Standard Facies Zone (FZ) 8, restricted platforms (Flugel, 2010). Associations of MFT occurring within the same lithofacies and deposited in the same general environment suggest local sedimentary sub-environments or local processes (Flugel, 2010). The paleoecological set up of the microfacies and foraminifers observed in the limestone of Ukhrul district of Manipur indicates that the sedimentation take place under marine shelf condition with restricted to moderately water circulation within an interior platform during the Maastrichtian–Eocene Epoch.

Acknowledgements

The authors acknowledge their sincere gratitude to CSIR, New Delhi for the funding this research endeavor (09/059(0053)/2013 EMR-1). Authors also express their sincere gratitude to the unknown reviewers whose suggestions help us greatly to improve the article.

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