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Clay Mineralogy, Palynology and Geochemistry of the Paleogene sediments in Inner Fold Belt of Nagaland, Northeast India

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Abstract

The present study frame on the paleoclimate, paleoenvironmental, depositional settings and lithological variations based on lithofacies study, clay mineralogy, palynofossils, organic concentrations and geochemical trace concentration in the tectonic units of Inner Fold Belt of Nagaland. Clay mineralogy in both study areas suggest dominance of Illite followed by Chlorite and less concentration of Montmorillonite and Kaolinite. High contents of Illite and Chlorite suggests that these sediments were derived by the continental erosion of pre-existing rocks, subjected to low intensity chemical weathering associated with a temperate climate. The palynological assemblage consists of pteridophytic spores, angiosperm pollen grains, fungal spores, Algal filaments, woody and organic matter. Analysis of the palynofloral assemblage yielded a total of 14 different dominant and accessory palyno taxa. Out of 14 species 9 species Cyathidites sp1, Lycopodiumsporites sp, Triletes sp1 Triletes sp2, Triletes sp3, Polypodiisporites sp, Laevigatosporites sp, Cyathidites sp2 and Polypodiaceosporites sp belongs to pteridophytes spores, and 4 species Tetracolpies sp, Tricolporites sp and Arecipites 1 & Arecipites 2 sp. belong to angiosperms pollens, and 1 Phragmothrites sp. belongs to fungal spores. Its recorded assemblages and occurrences indicate the prevalence of subtropical to tropical climate under very warm and humid condition, and show an affinity of Tertiary age of non-marine condition. While palynomorph on deep water marine facies do contain several palynofossils assemblages of shallow water/ continental origin as reported from deep sea Bengal fan sediments. Low values of organic matter in both the study locations shows that both may be sourced authigenic chiefly from planktons and plant debris from continental flora deposited in an oxidising environment. Trace element concentration in both the study areas shows up appreciable variation in Fe, Mn, Zn, Cr, Ni and Cu contents. Whereas in the case of Cd, Co, and Pd the variation is relatively moderate. Appreciable increase in the concentration of Cr, Ni, Zn, and Mn content is observed in Disang black shale and in siltstone. The ophiolite complex which is haphazardly juxtaposed along faults or they consist of lensoid slices interbedded with Disang group of rocks, where the lower Disang sediments are intermixed with pelagic cherts and limestone. Elevated Cr concentration values in both the study areas are indicative of mafic or ultramafic source rock, caused by the mineralised ophiolitic rocks and sedimentary rocks derived from them. The Cd trace concentration of both the study areas is relatively higher than the average Cd crustal abundance. Elevated Cd values are generally indicative of sulphide mineralisation.

Keywords: Upper Disang formation, Disang Barail Transition Sequence (D.B.T.S), Paleoclimate, Paleoenvironment.

Introduction

The Eocene (55.8-33.9 Ma) was the warmest period during the Cenozoic and is well known as the Middle Eocene Climatic Optimum (M.E.C.O). But it also marked by the decline into an icehouse climate and the rapid growth of Antarctic ice-sheet. The climatic change at the Cretaceous-Tertiary boundary event in northeast India was a catastrophic event when the mass extinction took place at Meghalaya, in Shillong Plateau was recorded, where fossilized remains of Dinosaur bones and fossilized Ammonites have been recorded from the Uppermost Mahadeo Formation of the Cretaceous age [1-2]. The Eocene-Oligocene extinction event has been recorded where planktonic Forams of Hantkeninidae got extinct during this time period and it is seen in Disang group of Nagaland where Hantkeninids and Cribrohantkeninds were discovered . The top of the Priabonian stage is at the extinction of Foraminifers genus *Hantkenina.* Late Eocene foraminiferal markers such as *Cribrohantkenina inflata, Hantkenina alabamensis* and other planktonic and Benthic foraminifers were reported from the Disang group of Nagaland[3-4].

Regional Geology of the Area: The Geodynamic evolution of the Himalayan and Indo-Myanmar (Burma) Ranges (IMR) is a consequence of the convergence of the Gondwanaland fragmentation where the Northward flight of the Indian Plate led to its convergence and subsequent subduction under the Eurasian Plate along the Tethyan zone in the north and Burma Plate in the east during the Alpine Himalayan Tectogenesis [5]. This caused the obduction and emplacement of the Naga Ophiolite along the IMR with the destruction of oceanic lithosphere. The Naga Hills Ophiolite (NHO) reported that these Ophiolites were represented by dismembered mafic and ultramafic rocks with closely associated oceanic pelagic sediments and occur as folded thrust slices occupying the highest tectonic level and are brought to lie over distal shelf sediment of Eocene to Oligocene age[6]. This would correspond to the fast rising Naga Ophiolite, which probably emerged above sea level during the Mid-Eocene, prevailing high temperatures and humid climate caused intense chemical weathering of the source rocks. Sediments from the nearby east were rapidly dumped on the seafloor causing rapid mixing, leading to textural and chemical immaturity, paleomagnetic studies endorse published paleontological evidence too indicate that most of the sediments of the Upper Disang Formation were deposited during the Late Eocene, where The sediments from the west were transported great distances by turbidity currents into an easterly deepening basin. Deposition took place in a westward-migrating accretionary-prism complex in an active-margin setting at the convergence of the Indian and Burma plates. This was a rapidly-closing basin where anoxic conditions prevailed. Towards the end of the Eocene this basin closed completely with the destruction of the Tethyan Ocean[7].

Study Areas: The present areas of investigation was carried out in the Upper Disang shale (Upper Cretaceous – Middle Eocene) located along the road side on the way to Nagaland University (Kohima campus) and amongst the Palaeogene sequences preserved in parts of Naga Hills, there occurs a distinctive lithology which liaise gradationally the underlying monotonous Disang shale with the overlying multi-storeyed Barail Sandstone. It is an approximately 80m thick succession of heterogeneous lithology comprising Sand-Silt-Mud alternation that has been designated as Disang-Barail Transitional Sequences (Upper Eocene)[8] (D.B.T.S) (Table-2). This forms part of the Inner Fold Belt of the geotectonic units in Nagaland. The Disang turbidite which comprises a thick sequence is divided into Lower and Upper formations. It Consist of monotonous sequence of dark grey to black splintery shales, occasionally intercalated with siltstone and fine to medium grained sandstone of light to brownish grey, whereas Barails are characterized by light grey to brown, fine to medium grained sandstone with minor to considerably thick interbands of shale[9]. The age of the Disangs is assigned to be Upper Cretaceous to Middle Eocene with that of the Barail to be Oligocene[9] (Table-1).

Table-1
Generalised Stratigraphic Succession of Nagaland, Eastern Himalaya (Compiled after Evans, 1932 and Ranga Rao, 1983)

Age	Group/Sub Group	Formation and Thickness in MTS.	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 (1300-2300m) .... Tipam s.st	Mottled clays, shales of varied colours with medium to fine grained sandstone.
			Massive sandstone, medium to coarse grained with current bedded structures.
Miocene	Surma	Bokabil (400m)	Alternation of shales with silt- stone and sandstone.
		Upper Bhubhan(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, fined grained, well sorted, occasional carbonaceous shales.
		Jenam (850m)	Shale with subordinate sandstone, sandstone 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, phyllite with lenticular limestone beds. .... Ophiolites.

Table-2
Lithostratigraphy of the Study Area (D.B.T.S, after Pandey and Srivastava, 1998, and Srivastava, 2002)

Sequence	Lithology	Age	Reference
Barail Group	Sandstone with minor shale	Oligocene	Krishnan (1982)
DBTS (Disang-Barail Transitional sequences)	Sand, silt and shale alternations	Upper Eocene	Pandey and Srivastava (1998)
Disang Group	Shales with minor sandstone	Upper Cretaceous to Middle Eocene	Krishnan (1982)

Field Studies: The inferences one can collect from the field studies is enormous and more dependable that laboratory generated data as detailed out in the present study. On the observations of Disang Group sediments on National Highway - 39, of D.B.T.S and nearby Disang group formations of Kohima Campus, Nagaland University several lines of information can be summed up based on the lithofacies distribution and their depositional conditions. The study on the Upper Disang towards Nagaland University is of Black shale and fine argillaceous sandstone and siltstone. The black shales indicate the presence of organic and carbonate matter. Lamination of sandstone, siltstone and shale are to be found. Sandstone beds bulged out as they are more resistant to weathering, where as shale are more or less concave as they are less resistant to erosion and showing differential erosion. Numerous joints are present but no bedding planes were observed**.** In D.B.T.S it displays a succession of heterogeneous lithology, the monotonous argillaceous sediments of Disang Group and in turn passes upward into the arenaceous sediments of Barail Group. On observations of Upper Disang Group an interbedded fine thin siltstone/sandstone facies and dominant dark shales Figure-1(a) which attest to their deep water deposition comparable to turbidite sequence. Further these facies also show up rolled down curling shale layers Figure-1(b) which may be possible only due to deposition of fine clastics on a sloping surface such as continental slope or other deep water ramps. Even the overlying Disang Barail Transitional Sequence (D.B.T.S) which can be considered as an extension of Upper Disang Group sediments is similar to organic rich shales at the bottom and intercalated with thin fine grain sandstone/siltstone laminations/beds towards top Figure-1 (c,d,e). However the upper horizons of D.B.T.S become more sandy and thick bedded and finally transit into Barail sandstone facies. Within the D.B.T.S several ichno fossils of deep water nature such as trails and tacks of organisms, shelter structures, and sole structures akin to deep water turbidite facies are well preserved and documented Figures-1 (f,g,h). The polished pebble in the shale sequence, sporadic occurrence of leaf impression, ball structure under the sandstone unit, and even the asymmetrical ripples Figure-1 (i,j,k,l) are quite common in the deep water marine facies. Asymmetrical ripples can never be considered as infallible indicators of shallow bathymetry as such features can be shaped by deep water currents on fine sediments such as turbidity and currents.

Materials and Methods

Extensive field work was carried out and a total of Forty-two (42) samples were collected, Ten (10) samples from Upper Disang (Meriema) and Thirty-two (32) samples from D.B.T.S. (Zubza). The samples collected from D.B.T.S were taken for every 0.5 meter intervals upto 15 meter i.e. from 0 to 15m height. For clay mineralogical studies finely powdered samples of the sediments were fractionated for total clay (< 2 µm) and fine clay (< 0.2 µm) after dispersion. A total of eight (8) samples were selected for the clay mineralogical studies, three (3) from Upper Disang sediments and five (5) samples from the (D.B.T.S) covering all the bottom, centre and top sections. The qualitative mineralogy of the clay samples was determined with the standard interpretation procedures of XRD data[10]. A semi quantitative estimation of clay minerals was done from peak area using the formula.

$$\% \text{ Clay minerals} = 100 \times [\, I_{\text{Clay minerals}} / \sum I_{\text{all clay minerals in that sample}}]$$

Where I= Peak area of clay minerals used

Palynomorphs were recovered by using standard procedures, 32 samples were examined for every 0.5 meter intervals upto 15 meter i.e. from 0 to 15m height at D.B.T.S of Zubza village Samples were first crushed by hand with a mortar and pestle, and the powder dissolved with standard wet chemical processes using HCl, HF and HNO_3. The organic residue was not sieved to retain palynomorphs smaller than 10µ, and then acetolyzed using acetolysis method[11], mixed with glycerine and stored in small glass bottles. For LM examination, a drop of well-mixed organic residue and glycerine was evenly distributed on a glass slide. Each sample was screened carefully, using up two to four slides to yield both common and, most importantly, the accessorial taxa.

Organic matter has a high affinity for fine-grain sediment because it adsorbs into mineral surfaces. The adsorption process helps to preserve the organic matter[12]. The organic matter concentration was determined for all the 42 samples in both the study areas, 10 from the Upper Disang formation and 32 samples from the D.B.T.S. For total digestion the geochemical analytical procedures were followed [13]. This method was preferred because the sediments consist essentially of detritus silicate minerals, resistant sulphides and small quantity of refractory material. Treatment with mixture of HF, $H2SO_4$ and Perchloric acid reagent results in complete dissolution. The solution was finally analyzed for total elements of (Fe, Mn, Cu, Zn, Cr, Pb, Co, Ni, and Cd. A total of 42 samples were selected 10 Samples from Upper Disang formation and 32 samples from the (D.B.T.S).

Figure-1
Field photographs from the two study areas. (a) Disang black shale shows intercalation of thin bedded siltstone (Meriema) (b) Rolled-down black shale (Meriema) (c) Full section of D.B.T.S (d) Black shale of D.B.T.S (e) Boundary of D.B.T.S and overlying Barail Sandston (f) Sole features found at the bottom fine sandstone D.B.T.S (g) Trace fossils (trails) on bedding plane of D.B.T.S (h) A shelter feature of an unknown organism in D.B.T.S (i) A large polished pebbles embedded in shale of D.B.T.S (j) Leaf impression as preserved in the fine grain sandstone of the D.B.T.S (k) Ball structure found at the top of D.B.T.S (l) Asymmetrical ripples in D.B.T.S .

Results and Discussion

Clay Mineralogy Assemblages and its Distribution: The Clay minerals study is considered as one of the most important tools for provenance analysis and it also provides information regarding the burial history of the sedimentary formation[14]. The clay mineralogical composition of sediments can reflect the effects of several paleoenvironmental conditions (climate, sea level fluctuations, tectonic activity as well as continental and basin morphology). Clay mineral assemblages of the Disang sediments from both the study areas shows the dominance of illite followed by chlorite and with less concentration of Montmorillonite and Kaolinite (Tables- 3, 4 and Figures-2-15). Illite shows its dominance of (Max. 66.6% and Min. 25% in D.B.T.S and in Upper disang shows Max. 50% and Min. 37.5%), Chlorite (Max. 50% and Min. 14.3% in D.B.T.S and in Upper disang shows Max. 50% and Min. 20%), Montmorillonite (Max. 40% and Min. 14% in D.B.T.S and in Upper disang shows Max.1 4% and Min.12%), Kaolinite (Max. 16.6% and Min. 14.2% in D.B.T.S and in Upper Disang shows Max. 40% and Min. 12%). Clay minerals at the surface of the Earth originated mainly from weathering of parent rocks, including physical weathering leading to rock fragmentation and chemical weathering with subtraction of ions. Hydrolysis is by far the most efficient chemical weathering, which attacks rocks by low ionized water at medium pH conditions ($5<pH<9.6$). Clay minerals are common components in most marine sediments, especially those deposited on continental margins, where there is a significant terrigenous input[16]. The analysis of clay mineralogy is considered to be a powerful tool for the interpretation of weathering conditions and palaeoclimate in the source area[15].

High content of Illite and Chlorite in the Disang Group of sediments and (D.B.T.S) suggests that these sediments were derived by the continental erosion of pre-existing rocks, subjected to low intensity chemical weathering associated with initially a temperate climate. Illite is by far the most dominant species of clay minerals in argillaceous sedimentary rocks[18]. Illite is favoured by the alkaline environment, and low K-aluminous mica like mineral which can form during burial metamorphism or as early product under immediate conditions[16]. The occurrence of abundance of illite concentration may be due to the increase in the supply of detrital illite from the source areas, as well as diagenetic alternation of Kaolinite into illite after their burial. The X-Ray diffraction response to illite often indicates the diagenetic and low-grade metamorphic history of sedimentary rocks[17]. The main requirement for the diagenetic alterations of kaolinite to illite is the availability of adequate potassium[20]. In general, formation of illite and chlorite is typical during the initial stages of chemical weathering by the transformation of micas and ferromagnesian minerals, respectively[21].

Table-3
Minerals identified from XRD Analysis in Disang Group samples

S.No	Area	Sample No	Untreated Clay Mineralogy	Glycolated Clay Mineralogy
1	Disang Group Samples	B1	Chlorite, Illite	Chlorite, Illite, Kaolinite
2		B7	Montmorillonite, Illite, Kaolinite, Chlorite	Chlorite, Illite, Kaolinite
3		B9	Illite, Chlorite	Chlorite, Illite,Kaolinite

Table-4
Minerals identified from XRD Analysis in Disang-Barail Transitional Sequences (D.B.T.S)

S.No	Area	Depth in meter	Sample No	Untreated Clay Mineralogy	Glycolated Clay Mineralogy
1	Disang Barail Transitional Sequence	0	C1	Montmorillonite, Chlorite, Illite	Montmorillonite, Chlorite, Illite
2		4	C9	Illite, Chlorite	-
3		8	C17	Montmorillonite, Chlorite, Illite	Chlorite, Illite, Kaolinite
4		12	C25	Montmorillonite, Illite, Chlorite, Kaolinite	-
5		14.9	C31	Illite,Chlorite,	Montmorillonite, Chlorite, Illite

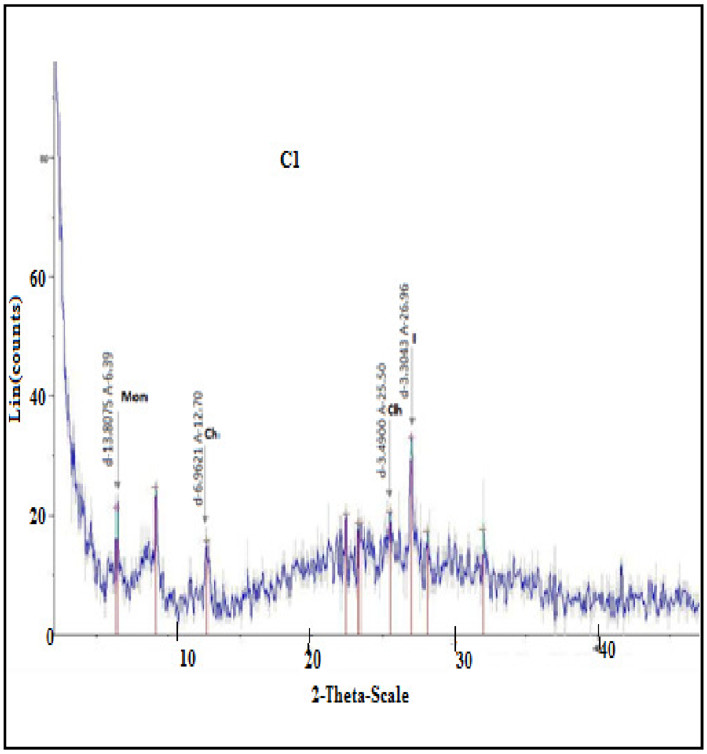

Figure-2
XRD patterns of clay minerals D.B.T.S- C1, Level-0m from bottom

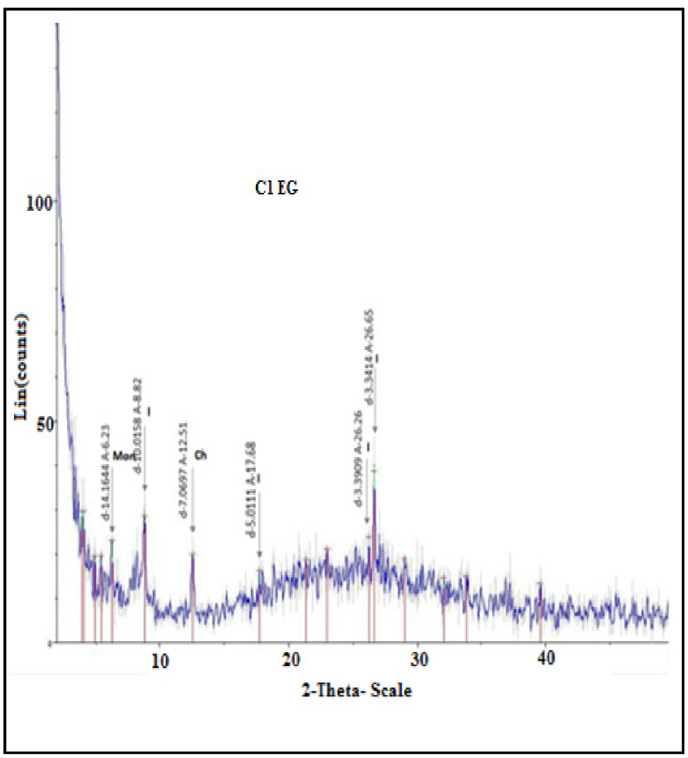

Figure-3
XRD patterns of Clay minerals, D.B.T.S- glycolated C1, Level-0m i.e., Mon-Montmorillonite, I-Illite, Ch- Chlorite

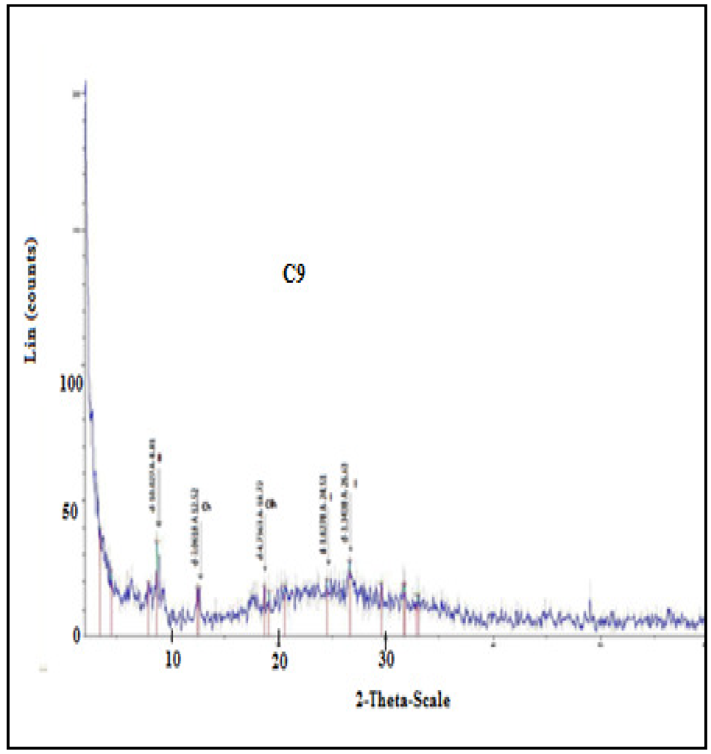

Figure-4
XRD patterns of clay minerals, D.B.T.S-C9, Level-4m from bottom

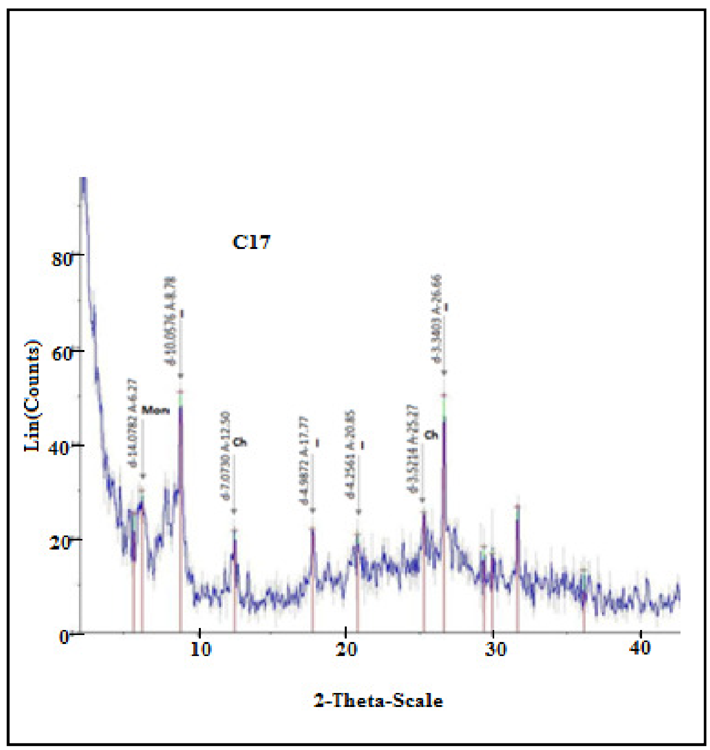

Figure-5
XRD patterns of clay minerals, D.B.T.S- C17, Level-8m

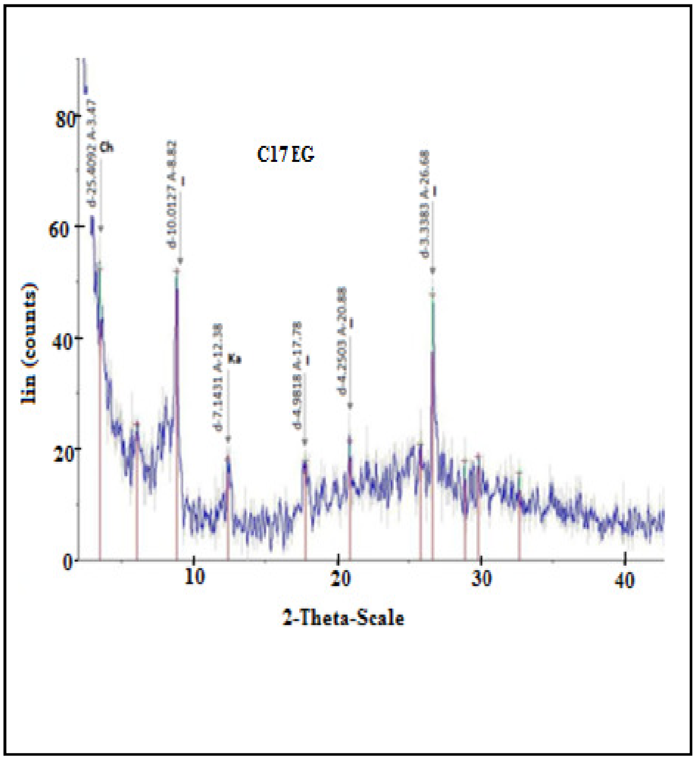

Figure-6
XRD patterns of clay minerals, D.B.T.S –glycolated C17, Level-8m i.e., Ch-Chlorite, I-Illite, Ka-Kaolinite

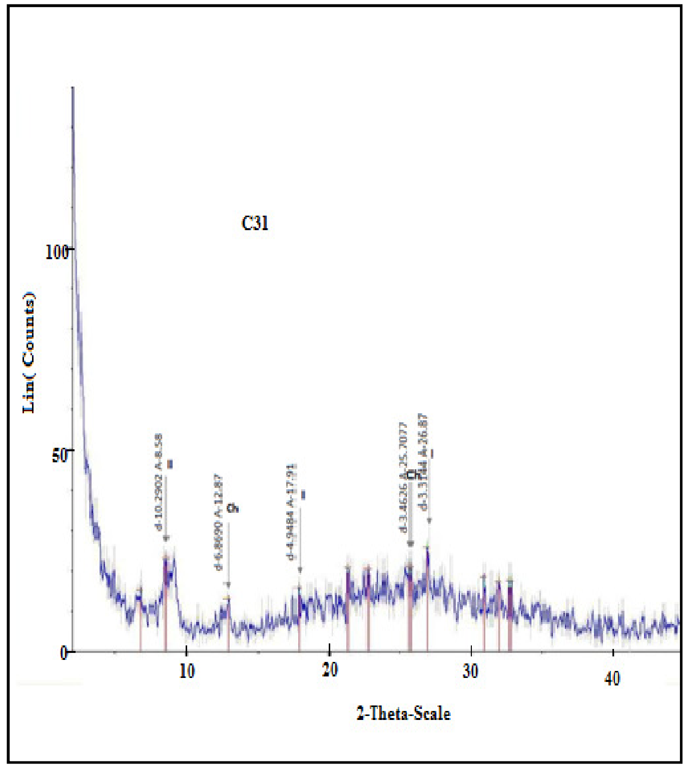

Figure-8
XRD patterns of Clay minerals, D.B.T.S- C31, Level-14.9m

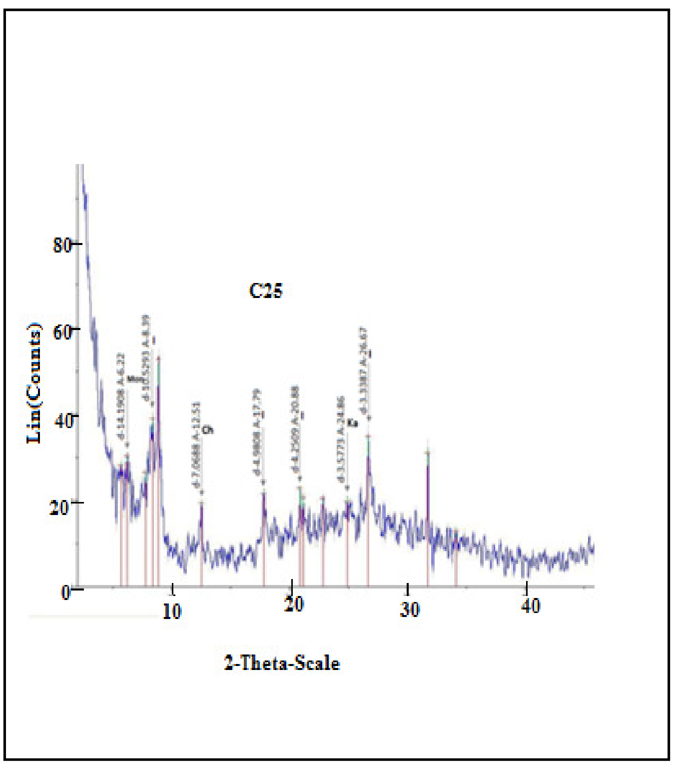

Figure-7
XRD patterns of clay minerals D.B.T.S- C25, Level-12m

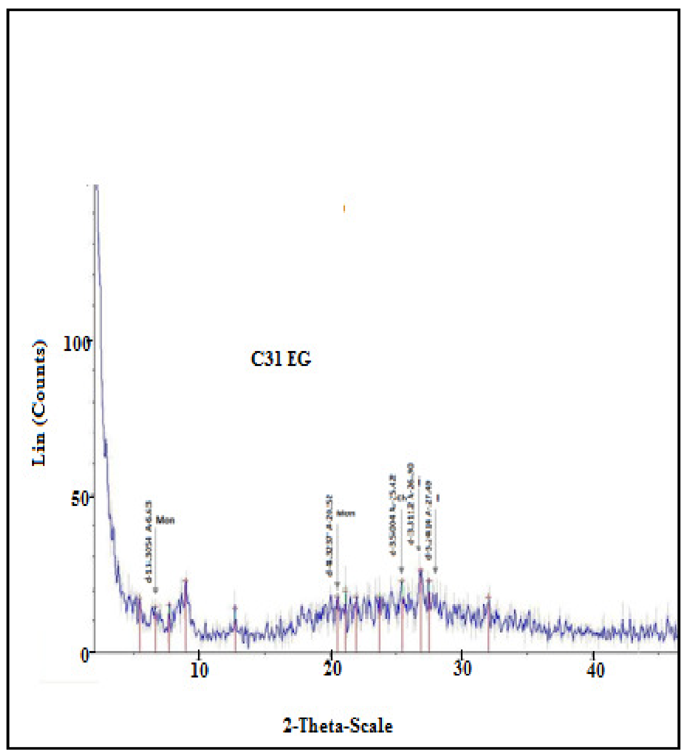

Figure-9
XRD patterns of Clay minerals, D.B.T.S- glycolated C31, Level-14.9m i.e., Mon- Montrollonite, Ch-Chlorite, I-illite

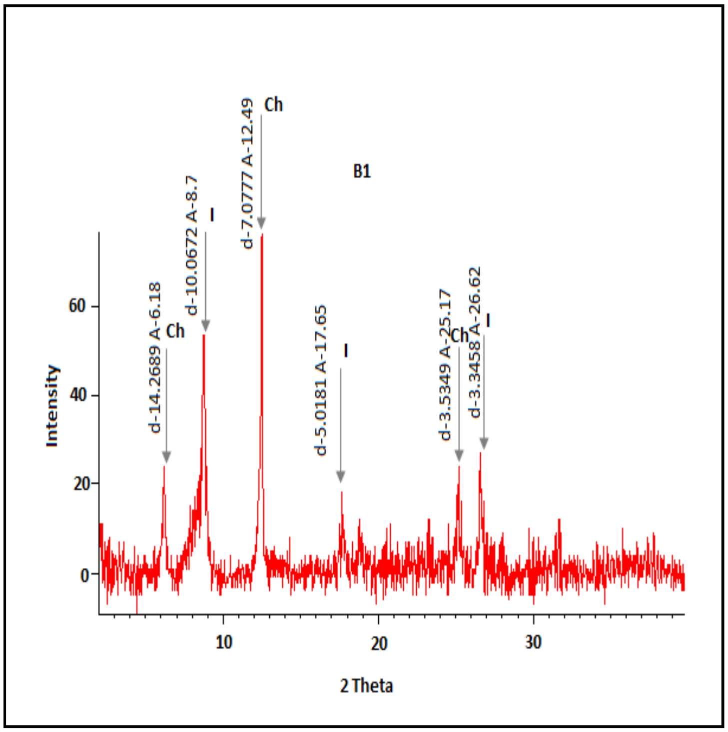

Figure-10
XRD patterns of Clay minerals, Disang Group - B1

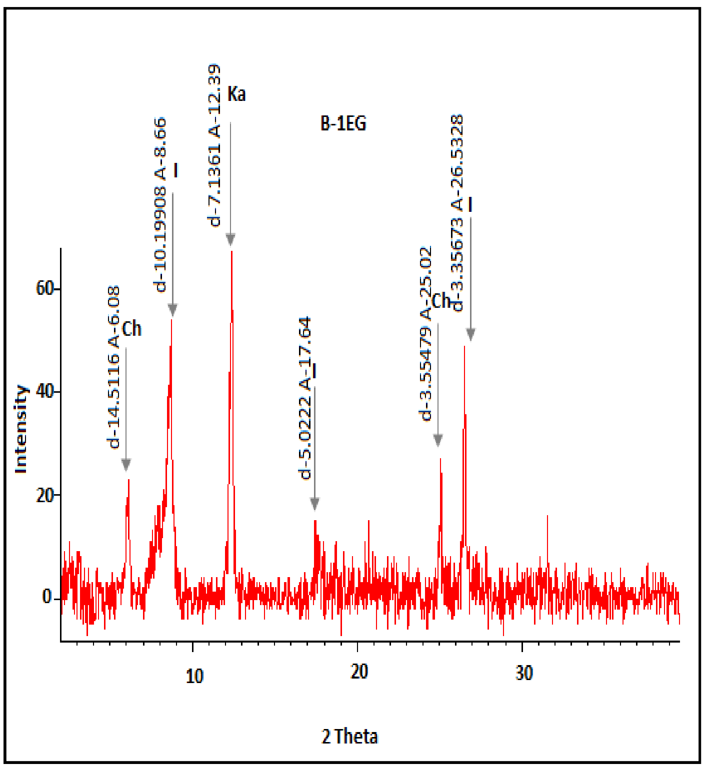

Figure-11
XRD patterns of Clay minerals, DisangGroup glycolated B1
i.e., Ch-Chlorite, I- Illite, Ka- Kaolinite

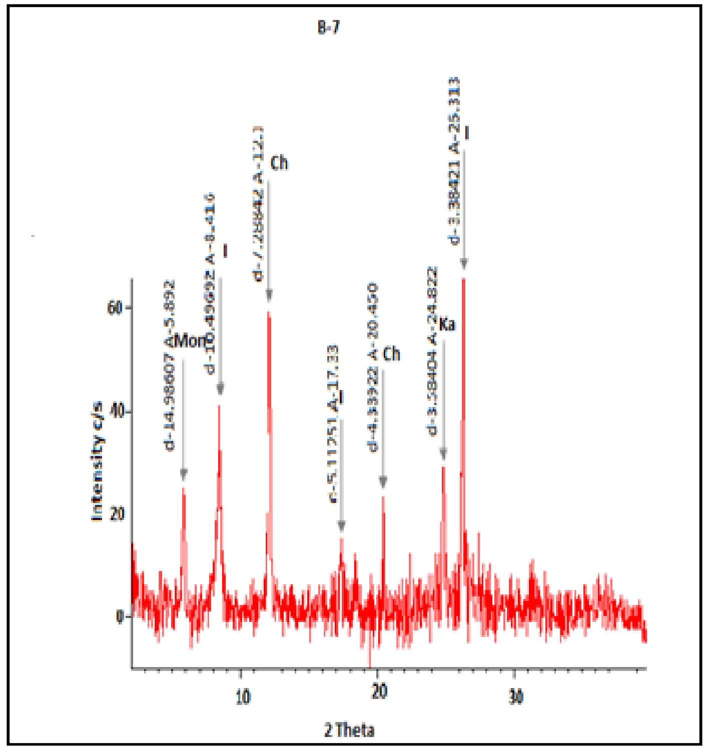

Figure-12
XRD patterns of Clay minerals, Disang Group B7

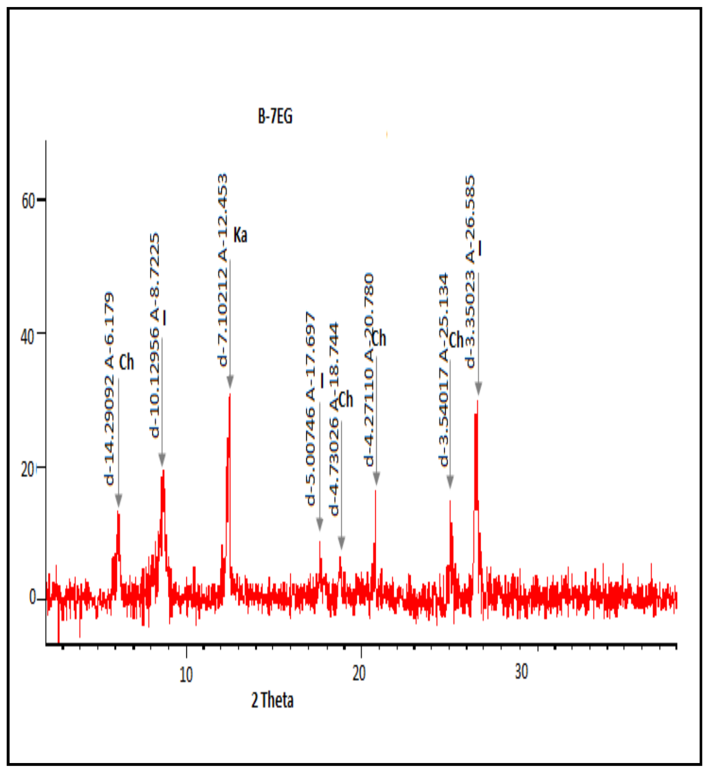

Figure-13
XRD patterns of clay minerals, Disang group - glycolated B7
i.e., Ch-Chlorite, I- Illite Ka-Kaolinite

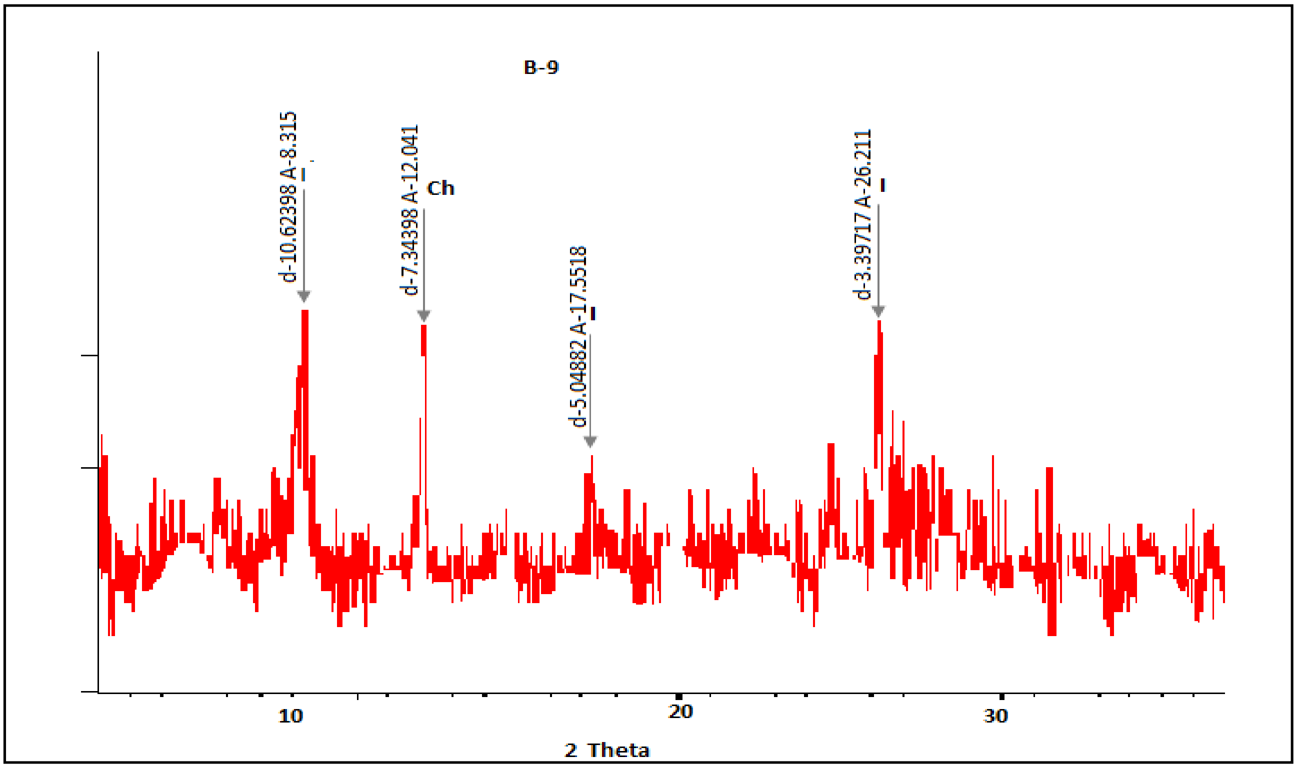

Figure-14
X-Ray Diffraction patterns of Clay minerals, Disang Group

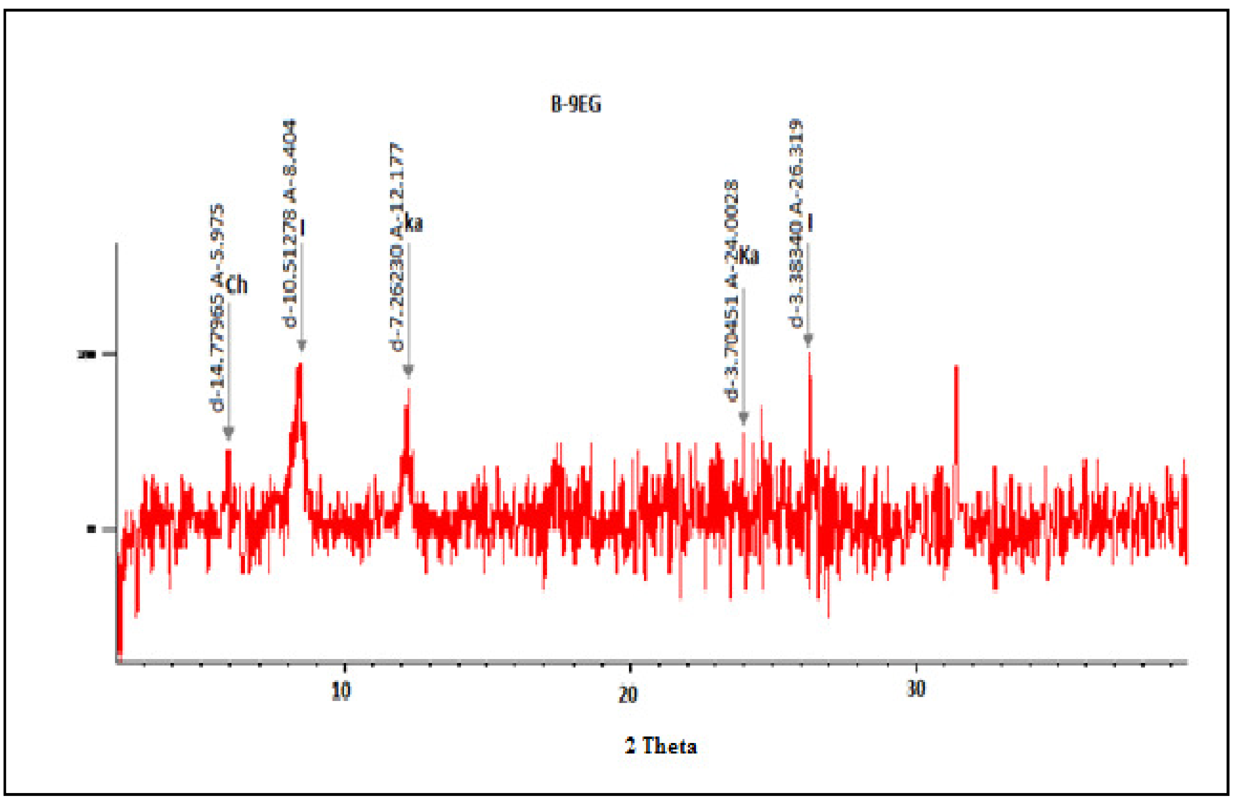

Figure-15
X-Ray Diffraction patterns of Clay minerals, Disang Group -glycolated B9 i.e., Ch-Chlorite, I-Illite, Ka-Kaolinite,

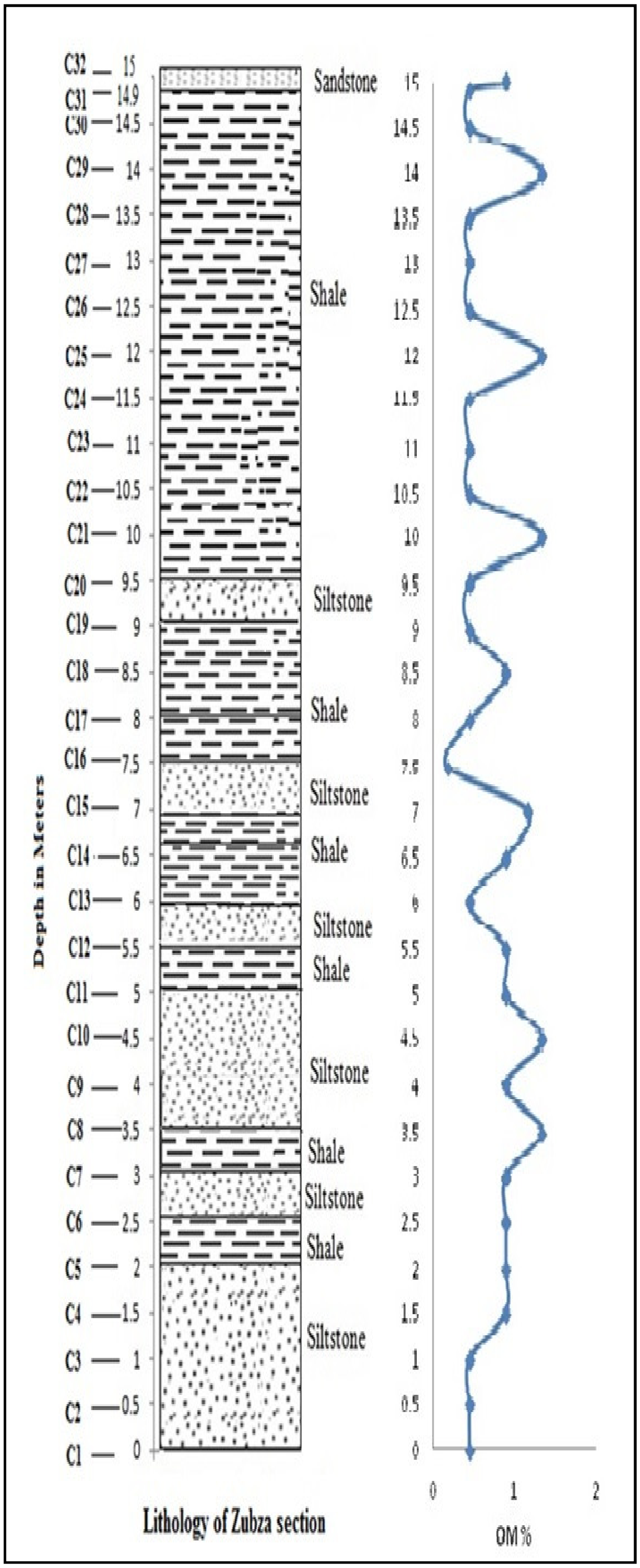

Table-5
Organic matter concentration in (%) of Meriema samples (upper Disang)

SL. No.	Sample No.	OM %
1	B_1	0.45
2	B_2	0.9
3	B_3	0.45
4	B_4	1.34
5	B_5	0.45
6	B_6	0.45
7	B_7	3.13
8	B_8	0.45
9	B_9	0.45
10	B_{10}	0.45
	Maximum	**3.13**
	Minimum	**0.45**
	Average	**0.852**

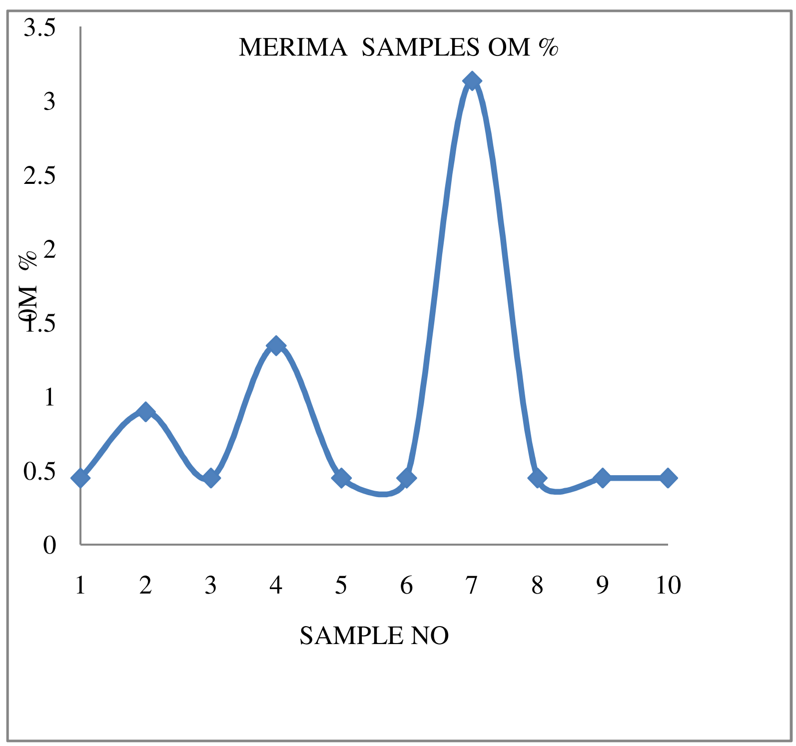

Figure-16
Organic matter percentage (%) of Zubza Section (D.B.T.S) and Meriema samples (upper Disang)

Palynology: A first attempt on Palynological study was made, So far no work has been carried out from the D.B.T.S of Upper Eocene and their identification and comparison were carried out on the basis of published literature on the Tertiary Palynology of the Assam and Bengal Basin[22-24] of the neighbouring country. Thirty two (32) samples were examined for Palynological studies from the D.B.T.S of Zubza village. To assess on its paleoenvironmental conditions. Though the study area is exposed, there are few palynotaxa well preserved and those were documented.

The check list of the palynotaxa is shown in Tata sheet**.** An analysis of the present palynofloral assemblage recorded in th*e* Data sheet reveals that of a total 14 species recorded 9 species *Cyathidites* sp1, *Lycopodiumsporites* sp, *Triletes* sp1 *Triletes* sp2, *Triletes* sp3, *Polypodiisporites* sp, *Laevigatosporites* sp*, Cyathidites* sp2 and *Polypodiaceosporites* sp belongs to pteridophytes Spores, and 4 species *Tetracolpies sp. Tricolporites sp and Arecipites 1 and 2 sp.* belong to angiosperms pollens, and 1 *Phragmothrites sp.* belongs to fungal spores, and the check list of the same is given in (Table-9) (Figure-17-18)**.** Pteridophytic spores Laevigatosporites, Lycopodiumsporites, Polypodiisporites, and Cyathidites, are indicative of humid conditions where fresh water swampy and lake conditions near the deposition site[25].

The recovered palynomorphs have been compared with the modern families. On the basis of morphological variations and previous reports spores and pollen assigned to different families and groups. The occurrences of the above mentioned palynotaxa indicate the prevalence of a subtropical to tropical climate which was very warm and humid condition. The above recorded palynotaxa range in Tertiary age and got deposited under non-marine condition. While palynomorph on deep water marine facies do contain several palynofossils assemblages of shallow water/ continental origin as reported from deep sea Bengal fan sediments[34].

Geochemistry: Organic Concentration: The contents of organic matter in sediments are a comprehensive reflection of sedimentary environmental factors such as primary organic abundance, depth of sedimentary water, sedimentation rate and physical and chemical conditions**.** The sediment samples from the Upper Disang shows a low content concentration ranging from 0.45% to 3.13% with an average of 0.45% as shown. Its maximum and minimum organic concentration are shown in (Table-5) where its maximum recorded is at 3.13% of friable black shale and minimum concentration at an average values of 0.45% in Disang siltstones. D.B.T.S samples analysed shows very low content of organic concentrations.

The samples show the organic concentration ranging of low content of organic concentration from 0.18% to 1.34 % as shown in (Table-6). Its maximum values are recorded at 1.34% of Disang shale and minimum at 0.18% of siltstone. The average value recorded at is 0.76%. Its maximum and minimum organic concentration is shown in (Figure-16). The low values of organic matter in both the study locations indicate that both may be of authigenic nature, chiefly contributed by algae and phytoplanktons or continental plant debris. Its maximum values concentrations are to be recorded in Black shale; this is due to the very fine grained nature of shale deposited in oxygen constrained environment.

Trace Element Concentration: The geochemistry of clastic sedimentary rocks reflects the tectonic setting of the basin and provides insight into chemical environment of deposition. From the nature of detrital components present in the sedimentary rocks, their provenance can be identified[26]. Further post depositional changes due to plate tectonic movement can be inferred from their chemical composition[19]. The geochemistry of shales, especially trace elements, is believed to represent the average composition of the upper continental crust than other sedimentary rocks**,** since they preserve the original signature of the provenance and diagenetic history**.** The clay in the sediments, therefore, preserves the signature of the source material of these trace elements[27].

Appreciable variation is observed in the Fe, Mn, Zn, Cr, Ni and Cu contents, whereas in the case of Cd, Co, and Pd the variation is relatively moderate (Table-7, 8). High concentration of Fe element is observed in both the study areas of Upper Disang and Disang Barail Transitional Sequences having its concentration values from 11542 to 35788 ppm and 2864 to 29732ppm respectively. High oxidising and alkaline conditions promote Fe precipitation, whereas acid and reducing conditions favour the solution of Fe compounds; therefore, acid soil tends to have higher levels of soluble inorganic Fe compounds. Where Areas with Fe deficiency in soil occur under arid climatic conditions, and are related to calcareous, alkaline, or other specific soil types (*e.g.,* manganiferous soil), and in temperate climates with humic acid soil[28].

Appreciable variation of increase in the concentrations of Cr, Ni, Zn, and Mn is noticed in Disang black shale, and siltstone shows large concentration of Cr in Upper Disang formation ranging from 82 to 259.6ppm, where as in the D.B.T.S Cr value ranges from 79 to 350 ppm. Elevated Cr values are indicative of mafic or ultramafic rocks, even in strongly-weathered environments, such as laterite. The upper Disang which lies haphazardly along faults or they consist of lensoid slices interbedded with Disang group of rocks. The lower Disang sediments are intermixed with pelagic cherts and limestone[29]. Cr shows a strong anomaly caused by mineralised ophiolitic rocks, and sedimentary rocks derived from them. The Cr concentration is slightly increased than the average sandstone value[30] (35 mg kg-1).

The Cd trace concentration of both the study areas show ranging from 1.9 to 10.8ppm in upper Disang, and 2.6 to 49ppm in D.B.T.S. The average Cd crustal abundance is rather low, between 0.1 and 0.2 mg kg-1 [31]. Elevated Cd values are generally indicative of sulphide mineralisation.

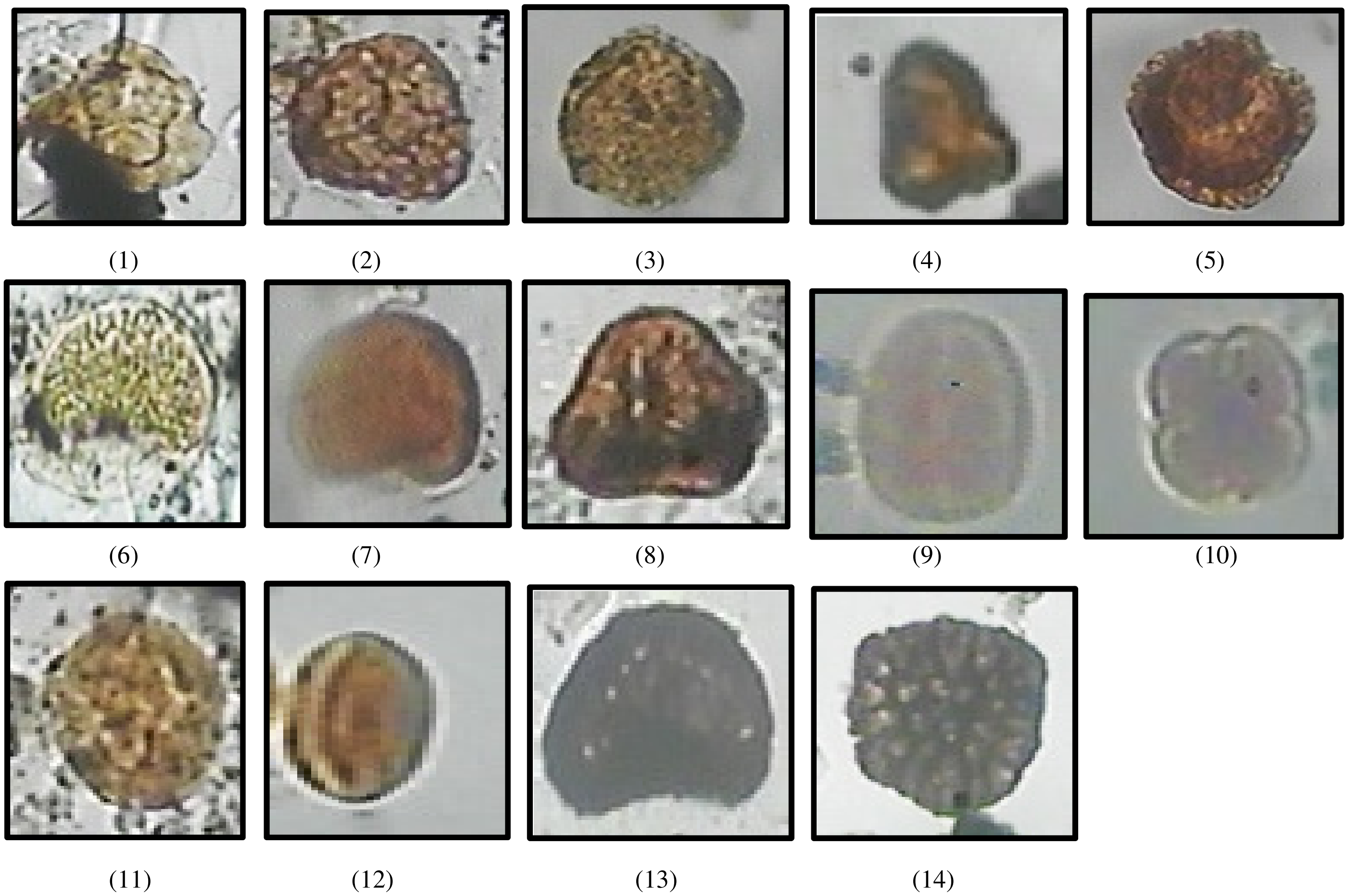

Figure-17
Identified Palynomorph from the D.B.T.S Zubza village
All photographs taken in transmission light and the magnification of photographs is x400: 1.Cyathidites sp1, 2..Lycopodiumsporites sp, 3.Triletes sp1, 4.Triletes sp2, 5.Triletes sp3, 6.Polypodiisporites sp, 7.Laevigatosporites sp, 8.Cyathidites sp2, 9.Arecipites sp1, 10.Tetracolpies sp, . 11.Tricolporites sp, 12.Arecipites sp2, 13.Polypodiaceoisporites sp, 14.Phragmothrites sp

(1) **(2)** **(3)** **(4)**

Figure-18
Identified Palynomorph from the D.B.T.S Zubza village
All photographs taken in transmission light and the magnification of photographs is x 400: 1. Algal filaments1, 2.Algal filaments2, 3. Organic matter, 4.Woody organic matter

Table-6
Organic matter concentration in (%) of Zubza section (D.B.T.S)

S. No.	Sample No.	Depth. In m	OM%
32	C32	15	0.90
31	C31	14.9	0.45
30	C30	14.5	0.45
29	C29	14	1.34
28	C28	13.5	0.45
27	C27	13	0.45
26	C26	12.5	0.45
25	C24	12	1.34
24	C24	11.5	0.45
23	C23	11	0.45
22	C22	10.5	0.45
21	C21	10	1.34
20	C20	9.5	0.45
19	C19	9	0.45
18	C18	8.5	0.90
17	C17	8	0.45
16	C16	7.5	0.18
15	C15	7	1.16
14	C14	6.5	0.90
13	C13	6	0.45
12	C12	5.5	0.90
11	C11	5	0.90
10	C10	4.5	1.34
9	C9	4	0.90
8	C8	3.5	1.34
7	C7	3	0.90
6	C6	2.5	0.90
5	C5	2	0.90
4	C4	1.5	0.90
3	C3	1	0.9
2	C2	0.5	0.45
1	C1	0	0.45
		Maximum	**1.34**
		Minimum	**0.18**
		Average	**0.76**

Table-7
Trace element concentration of Meriema(upper Disang) section in ppm

Sample.No	Fe ppm	Mn ppm	Cu ppm	Zn ppm	Cr ppm	Pb ppm	Co ppm	Ni Ppm	Cd ppm
B1	22826	131	67.2	276.92	152.3	43.1	26.9	163.8	9.7
B2	18460	171	65.3	201.19	259.6	43.7	25.4	79	4.5
B3	35788	1032	65.4	286.15	82.4	39.5	21.1	167.1	8.7
B4	17764	532	65.1	278.73	231.8	38.6	26.3	126.9	9.8
B5	19269	629	59.5	205.56	160.7	39	27	149	10.8
B6	26573	362	58.8	206.28	211.8	37.1	25.8	112.1	5.7
B7	19989	98	64.9	182.13	133.4	42	27.4	102.6	5.6
B8	19307	533	64.2	234.12	99.1	36.6	24	111	4
B9	14201	212	61.7	203.46	190.4	35	25.4	66.7	4.2
B10	11542	140	59.2	129.44	176.5	35.3	25.1	36.4	1.9
Max.	**35788**	**1032**	**67.2**	**286.15**	**259.6**	**43.7**	**27.4**	**167.1**	**10.8**
Min.	**11542**	**98**	**58.8**	**129.44**	**82.4**	**35**	**21.1**	**36.4**	**1.9**
Avg.	**21087.42**	**414.17**	**63.11**	**218.30**	**170**	**39.05**	**25.24**	**109.84**	**6.47**

Implication on its Paleoclimate and Depositional Environment: The Eocene (55.8-33.9 Ma) is not only known for the warmest period during the (Middle Eocene Climatic Optimum), but it also marked by the decline into an icehouse climate and the rapid growth of Antarctic ice-sheet. Isotopes of carbon and oxygen indicated a shift into global cooling climate[32]. At the end of the Middle Eocene Climatic Optimum, cooling and carbon dioxide drawdown continued through the Late Eocene and into the Eocene-Oligocene transition around 34 million years ago[33]. The event is known as the "Great break" in continuity or the Eocene-Oligocene extinction event, where the planktonic forams of the Hantkeninidae got extinction during this time period[3-4]. From the generated datas, where the dominance of Illite and Chlorite in clay mineralogy with less concentration of Montmorillonite and kaolinite it suggests that these sediments were derived by the continental erosion of pre-existing rocks. XRD response to illite often indicates the diagenetic and low-grade metamorphic history of sedimentary rocks[17]. Further the content of illite indicates the chemical weathering of acid and intermediate crystalline rocks in the distributive province under a temperate paleoclimate. Considerable amount of Illite may be derived from diagenetic alternation of kaolinite and smectite and these changes may be attributed to the increasing temperature and pressure with increasing depth and due to good supply of fluids which tends to cause the digenetic changes. For marine diagenesis, marine sediments that are poor in calcite but rich in organic matter and sulfides, are relatively rich in kaolinite and concluded that kaolinite is formed by an acid reaction in an anaerobic medium[35]. The low values of organic matter may be sourced as authigenic chiefly from planktons and plant debris from continental flora deposited in an oxidising environment. It's high oxidising and alkaline conditions promote Fe precipitation. Its Elevated Cr values are indicative of mafic or ultramafic source rocks which could be caused by mineralised ophiolitic rocks, and sedimentary rocks derived from them. Abundance of micaceous matter in clastic rocks might control the distribution of Cr as supported by the studies carried out elsewhere. The Cd trace concentration shows a varied distribution Compared to its crustal average, the enrichment of Cd in the samples could be related to its source from sulphide mineralisation area, perhaps of the ophiolitic complex of Manipur.

Conclusion

Even though the palynological studies of Disang samples point out a non-marine environment based on the occurrence of spores and pollens, even deep water marine facies do contain several palynofossil assemblage of shallow water/continental origin as reported from deep sea Bengal Fan sediments. Hence it is concluded that these fine grain sediments of siltstone and shale facies are of deep marine facies, very much comparable to the modern silty/clay facies of Bay of Bengal. These fine clastics could have been transported to the deep marine setting through a network of submarine channels and turbidity like transporting mechanisms. Field analysis, and outcrop facies distribution from both the study areas unequivocally point out the deep water nature of the Disang sediments. Perhaps during the deposition of Upper Disang, and D.B.T.S a shift in climate change from temperate to sub-tropic climate is arrived. The source area had a combination of metamorphic/igneous and sedimentary terrains which contributed these fine clastics rich sequence.

Table-8
Trace element concentration of Zubza section (D.B.T.S) in ppm

S.No	Height in m	SampleNo	Fe ppm	Mn ppm	Cu ppm	Zn ppm	Cr ppm	Pb ppm	Co ppm	Ni Ppm	Cd ppm
32	15	C32	20441	557	59	234.19	80.5	41	25	127.3	11.6
31	14.9	C31	14900	348	67.4	166.29	138	42.1	29.7	60	2.6
30	14.5	C30	16449	336	69.5	209.4	276.4	43.1	27.9	83.2	4.6
29	14	C29	18267	829	69.1	206.09	154.4	45.3	27.5	118.1	2.9
28	13.5	C28	21926	627	72.7	77.58	252.6	44.3	27.2	86.3	4.3
27	13	C27	20622	734	74.3	235.89	158	46.4	29.5	143.7	10.6
26	12.5	C26	25189	718	73.4	107.68	132.4	46.2	28.9	142.2	11.4
25	12	C25	21184	538	72.2	221.55	90.6	47.8	29	147.7	13.4
24	11.5	C 24	18952	540	73.9	127.58	274.7	44.9	28.6	69.1	3.4
23	11	C23	29732	327	71.2	68.53	97.6	45.1	31.5	206.7	15.6
22	10.5	C22	17538	319	78	54.81	162.2	44	32	87.4	5.8
21	10	C21	24158	396	75	66.8	79.6	46	28.5	122.3	8.4
20	9.5	C20	24247	427	65.8	69.69	156.9	42.9	21.1	74.8	3.8
19	9	C19	24644	502	75.6	57.99	147.3	49.2	28.6	110.2	7.1
18	8.5	C18	23940	506	76.5	67.15	204.3	46	29.3	116.8	6.7
17	8	C17	26749	492	77.7	97.97	232.9	44	29.9	144.6	9
16	7.5	C16	28318	401	63.2	90.24	147.6	37	23.4	161.4	10.3
15	7	C15	24940	586	71.5	109.93	179.3	49	31.8	107.7	4.3
14	6.5	C14	2864	343	62.2	147.95	151.4	41	23.8	135.4	6.7
13	6	C13	18949	415	63.1	153.23	270.8	39.5	24.4	131.9	9.4
12	5.5	C12	23387	489	72.2	178.93	125.7	47.8	31.2	171	12.5
11	5	C11	18178	349	65.1	23.01	117.6	38	22.8	87.6	49
10	4.5	C10	16551	373	67.2	33.73	161.8	49	23.3	99.6	6.8
9	4	C9	20603	378	65.2	75.94	262.2	41.6	25.2	125.8	8.8
8	3.5	C8	20430	441	70.1	63.92	172.8	48.7	32	136.5	6.4
7	3	C7	19442	336	62.8	76.32	191	41.6	22.7	128.5	9.4
6	2.5	C6	18585	424	71.4	82.85	168.3	49	32.6	136.3	8.8
5	2	C5	19442	404	59.7	142.26	159.3	41.2	20.8	115.7	8.3
4	1.5	C4	22472	395	55.1	138.65	350	35.5	25.5	150.5	7.6
3	1	C3	26294	326	62.9	214.02	259.7	38	21.5	180.5	13.3
2	0.5	C2	20264	307	63.3	213.24	181	39.2	26	180.3	12.9
1	0	C1	11316	341	59.3	202.32	173.4	38.1	25.1	176.4	11.7
		Max	**29732**	**829**	**78**	**235.89**	**350**	**49.2**	**32.6**	**206.7**	**49**
		Min	**2864**	**307**	**55.1**	**23.01**	**79.6**	**35.5**	**20.8**	**60**	**2.6**
		Avg	**20399.1**	**460**	**68.20**	**125.72**	**180.59**	**43.45**	**27.05**	**127.42**	**10.56**

Table-9
Tata sheet of the palynomorphs

Data Sheet		
Sample no.	**Depth in m**	**Species**
32	15	Cyathidites sp2, Triletes sp3, Cyathidites sp1
31	14.9	Triletes sp2, Cyathidites sp1, Arecipites sp1,
30	14.5	Phragmothrites sp, Arecipites sp1, Triletes sp2
29	14	Woody organic matter, Cyathidites sp1
28	13.5	Cyathidites sp2, Lycopodiumsporites sp
27	13	Triletes sp3, Algal filaments sp1, Algal filaments2
26	12.5	Triletes sp1, Laevigatosporites sp,
25	12	Organic matter , Woody organic matter
24	11.5	Triletes sp3, Cyathidites sp1, Polypodiisporites sp
23	11	Laevigatosporites sp, Polypodiisporites sp
22	10.5	Cyathidites sp2, Polypodiisporites sp
21	10	Fungal filaments, Arecipites sp1, Laevigatosporites sp
20	9.5	Triletes sp1, Organic matter Woody organic matter
19	9	Polypodiisporites sp, Cyathidites sp1
18	8.5	Laevigatosporites sp, Arecipites sp1, Tetracolpies sp
17	8	Arecipites sp1, Laevigatosporites sp
16	7.5	Triletes sp2, Phragmothrites sp
15	7	Cyathidites sp1, Cyathidites sp2 , Woody Organic matter
14	6.5	Arecipites sp1 ,Tetracolpies sp
13	6	Tricolporites sp, Phragmothrites sp
12	5.5	Arecipites sp2, Triletes sp1, Cyathidites sp1
11	5	organic matter, Arecipites sp1, Arecipites sp2
10	4.5	Polypodiaceoisporites sp, Phragmothrites sp
9	4	Arecipites sp1, Triletes sp2, Cyathidites sp2
8	3.5	Cyathidites sp1, Triletes sp2

Data Sheet		
Sample no.	**Depth in m**	**Species**
7	3	Triletes sp2, Algal filaments sp2
6	2.5	Cyathidites sp1 , Organic matter
5	2	Algal filaments sp1 , Algal filaments2
4	1.5	Triletes sp3, Triletes sp2, Algal filaments sp2
3	1	Algal filaments sp2, Triletes sp3, Laevigatosporites sp
2	0.5	Arecipites sp1, Arecipites sp2, Triletes sp1
1	0	Triletes sp3, Phragmothrites sp

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