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RESEARCH ARTICLE

GRANULOMETRIC ANALYSIS AND PALAEOENVIRONMENTAL RECONSTRUCTION OF THE PALAEOGENE DISANG –BARAIL TRANSITIONAL SEQUENCE IN PARTS OF KOHIMA SYNCLINORIUM, NAGA HILLS, NE INDIA.

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Abstract

The Palaeogene Disang – Barail Transitional Sequence (DBTS) cropping at the tip of the Kohima Synclinorium, Naga Hills has been analyzed for its grain – size characteristics and their interpretations in terms of environmental processes. Besides graphical and statistical parameters; attempts have also been made to analyze the size – data using multigroup discriminant function after Sahu (1983). The grain-size frequency distribution, descriptive statistical parameters, nature of Cummulative curves and the multigroup discriminant function analyses including V1 – V2 plot, all indicate that the DBTS correspond approximately to turbidity deposits.

Introduction:-

The Kohima Synclinorium, a part of which constitutes the present area of investigation, is one of the most prominent structural units in the inner fold belt of Naga Hills (Evans, 1964; Chakrabarti and Banerjee, 1988). Its western and eastern limits are defined by Halflong-Disang thrust and Changrung-Zungki-Lainye thrust respectively (Naik, 1998). The northern limb of Kohima synclinorium forming the Barail ranges of North Cachar extends south-westward below Halflong and then westward, fringing the eastern extension of Meghalaya plateau. The southern limb extends into west Manipur, East Cachar and East Mizoram, both the limbs being lithologically dissimilar. The Surma basin forms the core of Kohima synclinorium. While the Barail Group of rocks of the Barail range is dominantly sandstone, shale becomes predominant in the southern limbs. The underlying Disang rocks constitute the outer most ring of Kohima Synclinorium south of Haflong and display a sequence of splintery shale with minor sandstone (Rao, 1983). It needs to be pointed out here that problems concerning lithostratigraphic intricacy and regional correlation of Disang – Barail sequences are yet to be resolved. Since fossil records of the region are equivocal, a careful and detailed lithostratigraphic mapping may be the only way out to understand and solve the stratigraphic problems (Chakrabarti and Banerjee, 1988).

In order to understand lithologic intricacies of Kohima Synclinorium, an area bounded between Latitudes 25^0 32’ N – 25^0 36’ N, and Longitudes 94^0 05’E – $94^0$10’E of the topographic sheet no. 83 K/2 of Survey of India has been targeted. It covers nearly 100 sq. km. and includes areas lying near Phesema, Kigwema, Jakhama, Viswema and Khuzama villages. The study area (Fig.1) is unique in the sense that the lithology here neither matches with the argillaceous Disangs nor the arenaceous Barails; rather it exhibits a gradational blending of the two lithologies. Shales with subordinate sandstone units dominate the eastern half of the area; which in turn passes into a succession

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having higher increments of sandstone interbeds towards the western half of the area. At places multistoried sandstone units having similar lithological attributes as those of the Barails are found to be overlain by thick succession of shales resembling Disangs. Following Pandey and Srivastava (1998), the lithologic unit exposed in the study area has been designated as Disang - Barail Transitional Sequence (DBTS).

Lithofacies:-

Based on the five diagnostic parameters of sedimentary facies, viz. bed geometry, lithology (including grain-size), primary sedimentary structures, palaeocurrent patterns and biogenic remains; if any (Selley, 1970, & 1976); the entire assemblage of Disang – Barail Transitional lithology was studied along six vertical profile sections measured at different locations across the study area. A total number of six litho-facies – **A**: Sand – Conglomerate facies**, B:** Sand facies**, C:** Sand – Mud facies**, D:** Mud – Sand facies-i**, E:** Mud – Sand facies-ii **& F:** Debrite facies have been identified following Mutti and Ricci Lucchi (1972) & McCaffrey and Kneller (2001).

Methodology:-

Since all the rock samples are hard and compact, thin-section method of grain-size analysis has been employed following the method suggested by Krumbein (1935). Further improvements to this method has been proposed by several workers including Friedman (1962), Stauffer (1966), Connor and Ferm (1966), Smith (1966) and Textoris (1971). Grain-size measurements of thirty-four fresh and representative rock samples were carried out in thin-section using the Leitz Laborlux 12 polarizing microscope. About 500 grains were measured in each thin section. During the course of size measurement, care has been taken to measure the apparent maximum dimension of the grains. The measured grain-size values were grouped into half-phi intervals in order to represent the size-distribution graphically. Graphic measures of size-distributions were obtained by reading the values of different percentiles ***(**P_5 **,** P_{16} **,** P_{25} **,** P_{50} **,** P_{75} **,** P_{84} **,** P_{95}**)*** from cumulative curves and placing them into the formulae suggested by Folk (1974) and later modified by Friedman and Sanders (1978). The grain-size frequency distribution data and their interpretation in terms of processes for different lithofacies are shown in Table 1 and 2 respectively.

Cumulative Curve Analysis:-

It has long been recognized that the shape of a cumulative curve is a function of relative proportions of two or more log normally distributed grain-size sub-populations (Tanner, 1964; Visher, 1969, 1970; Lambiase, 1982). Many workers suggested that each sub-population signifies a specific sediment transport mechanism operative during deposition, e.g. bed-load or 'surface creep' (coarsest sub-population), saltation (intermediate sub-population) and the suspension (finest sub-population) (Visher, 1970; Moss, 1972; Sagoe and Visher, 1977; Middleton, 1976). However, Shea (1974) attributed the shape of a cumulative curve to grain-size distribution of the source material.

There is varied opinion about the exact nature of boundary between different sub-populations. According to Visher (1969) and Sagoe and Visher (1977), grain populations are truncated at their boundaries as a result of differing transport mechanisms. However, Tanner (1964), Middleton (1976), Walton et al., (1980), Lambiase (1982) are of the opinion that grain populations are overlapping or mixed. What so ever may be the case; results obtained from cumulative curve analysis must be interpreted with caution due to the following possibilities of error as suggested by James and Oaks (1977).

1. Preferential losses from finer grain-sizes during diagenesis.
2. Statistical errors due to population size (200 grains or more should be counted).
3. Sampling error of the different laminae in the rock.

The representative cumulative curves for different lithofacies, as shown in Fig. 2 may be grouped into two types. Type I curves, characterized by initial steep; straight lines with little convexity in the middle and again a steep straight end part, are common in lithofacies A, B and F. The lithofacies C, D and E are characterized by type II curves which are moderately steep, straight initial curves with prominent convexity in the middle and steep, straight end part. All the cumulative curves consist of two populations only, i.e. saltation and suspension (Table.4). The saltation population shows good to moderate sorting and constitutes 88 % to 99.9 % of the total population in type I and II respectively. In type I curves this population is truncated on the finer side between the limits of 1.0 and 7.5, whereas the same varies between 2.0 to 6.5 in case of type II. The suspension population is fairly to moderately sorted in type I curves, whereas the same is generally moderately sorted in type II. Almost all curves show a major slope break separating transportation by suspension from saltation. This break (FT) lays around 5.20 defining approximately the silt- clay boundary. The break at fine truncation may be co-related in terms of current velocities, flow separation, flow regimes, velocity gradients, grain shape and densities and fluid density (Sagoe and Visher, 1977). The saltation population (A) is actually transported by intermittent suspension or turbulence caused by velocity fluctuations in water (Lambiase, 1982). The observed shift at A-B (saltation to suspension population) boundaries from A, B and F facies to C, D and E facies, and the gentle nature of curve segments reflects that the transport mechanism was gradually changing from primarily intermittent suspension to suspension in response to greater flow strength. A comparison with the pattern of cumulative curves for various types of environments, as suggested by Visher (1969), indicates that the rocks of the present area correspond approximately to turbidity current deposited sandstones.

C-M Pattern:-

Passega (1957, 1964) suggested the use of C-M pattern for environmental analysis. C is the one percentile diameter in microns, an approximation of maximum grain-size and M, the fifty percentile diameter in microns, is the median. The position of points in a C-M diagram depends upon the mode of deposition of sediments. Deposits of various environments give characteristic patterns. Passega (1957) states the significance of C and M in the interpretation of the depositional agencies. M, the median grain-size is the size such that 50% of the sample is coarser than this size, which is the approximation of the maximum grain-size present in the population. He states that the loads of coarse and fine sediments in hydrodynamic equilibrium are largely dependent of each other. The coarser fraction is almost invariably more representative of the depositional agent than the finer fraction. Advantage is taken of this observation in representing texture in the C-M diagram. The only parameter of the overall texture used in the C-M diagram is the median which expresses the average coarseness of the sediments. C, the one percentile, is the parameter which measures the competency of the depositing agent to transport. The one percentile value is selected for a parameter as an approximation of the maximum grain-size because some coarser grains may have been introduced by extraneous agents. On the C-M diagram, the limit of the area in which points can fall is restricted by line C=M. It is designated as the limit of the diagram. Points situated on this line represent samples in which the median approximately equals the coarsest grain-size. C, the one percentile, and the median, in case of the sediments under question, range from 71.8 to 353.6 and > 0.3 to 220.7 respectively (Fig.3). On plotting C against M following Passega (1957, 1964), Passega and Byramjee (1969) and Reineck and Singh (1980) the sediments are found to be an admixture of sand, silt and clay which are transported mostly in saltation and also to some extent in suspension and then deposited by turbidity currents. Long and rectilinear turbidity pattern is indicative of fine to coarse grain particles which are carried in saltation and suspension with very little or no rolling (Passega, 1957). On losing velocity, turbidity current first deposits sand and then coarse and medium silt (Passega, 1977).

Multigroup Discrimination Function Analysis:-

Although, the linear discriminant function (Sahu, 1964; Sevon, 1966) is an effective method for discrimination among two groups, somehow it could not yield optimal result for the sediments of the study area. It may be due to the approach to the alternative hypothesis which is restricted to two groups only; whereas the sample may not belong to any of the two environments. The effectiveness of discriminant functions in environmental interpretation has also been questioned by Tucker and Vacher 1980). To overcome this problem, a multigroup discrimination method after Sahu (1983) was employed, as it considers for,

1. The alternative hypothesis which may belong to anyone of the several groups
2. The ratio of among - group to within group quadratic forms to be maximized
3. Only significant number of co-ordinates are to be retained for the discriminating space and,
4. A simple Euclidean distance for purposes of classification in the discrimination space.

Sahu's empirically retained discriminating Eigen's vectors V_1 and V_2 were used to distinguish the depositional environments for the sediments under question. The discriminant functions V_1 and V_2 are expressed as

$$V_I = 0.48048\, M_Z + 0.62301\, \sigma_I^2 + 0.40602\, Sk_I + 0.44413\, K_G$$

$$V_2 = 0.24523\, M_Z + (-0.45905)\, \sigma_I^2 + 0.15715\, Sk_I + 0.83931\, K_G$$

Where, M_Z, σ_I^2, Sk_I and K_G represent the mean size, the size variance, graphic skewness and graphic kurtosis, respectively.

The average values for V_1 and V_2 thus obtained (V_1 = 2.40, V_2 = 1.40) were plotted in the diagram of V_1 and V_2 with $V_1 \wedge V_2$ = 74.4˚, after Sahu (1983). The position of the point in the diagram (Fig.4) falls well within the range of turbidite deposits.

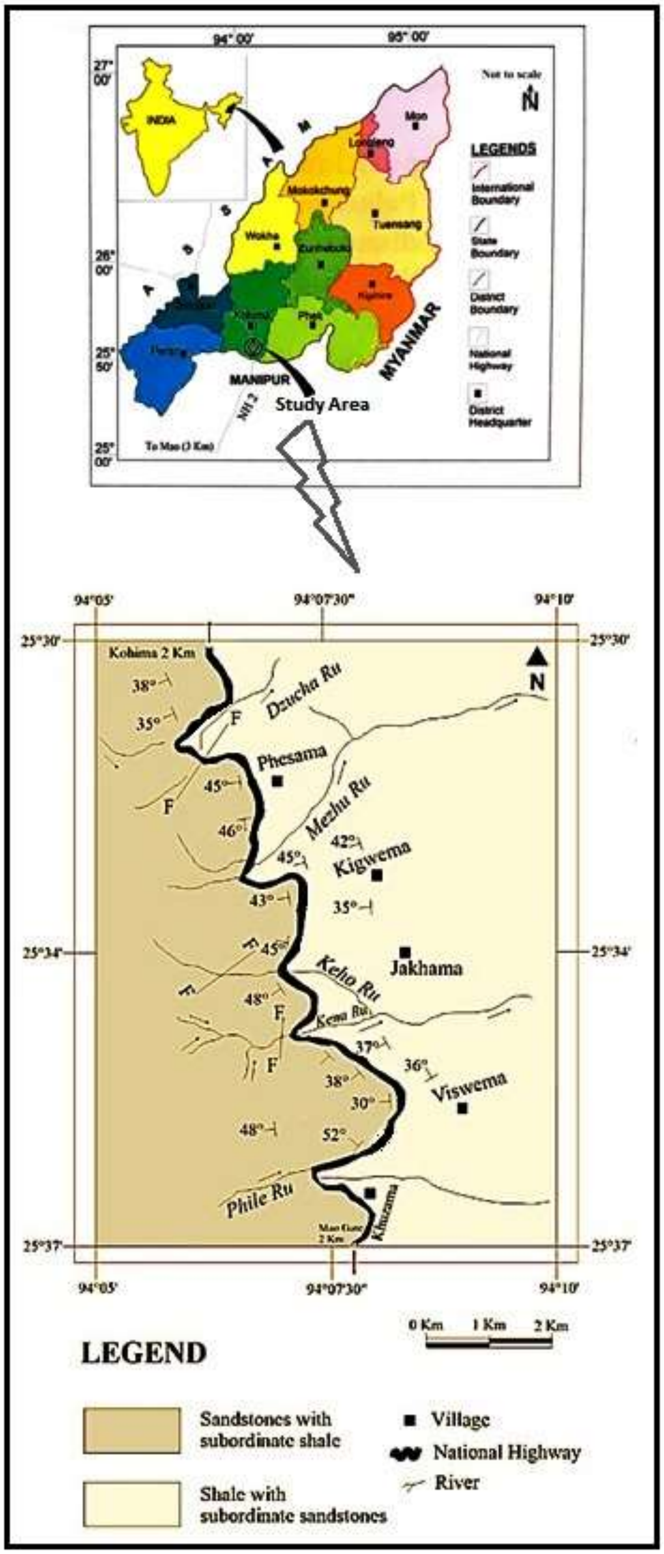

Fig. 1:-Location and Geological map of the study area

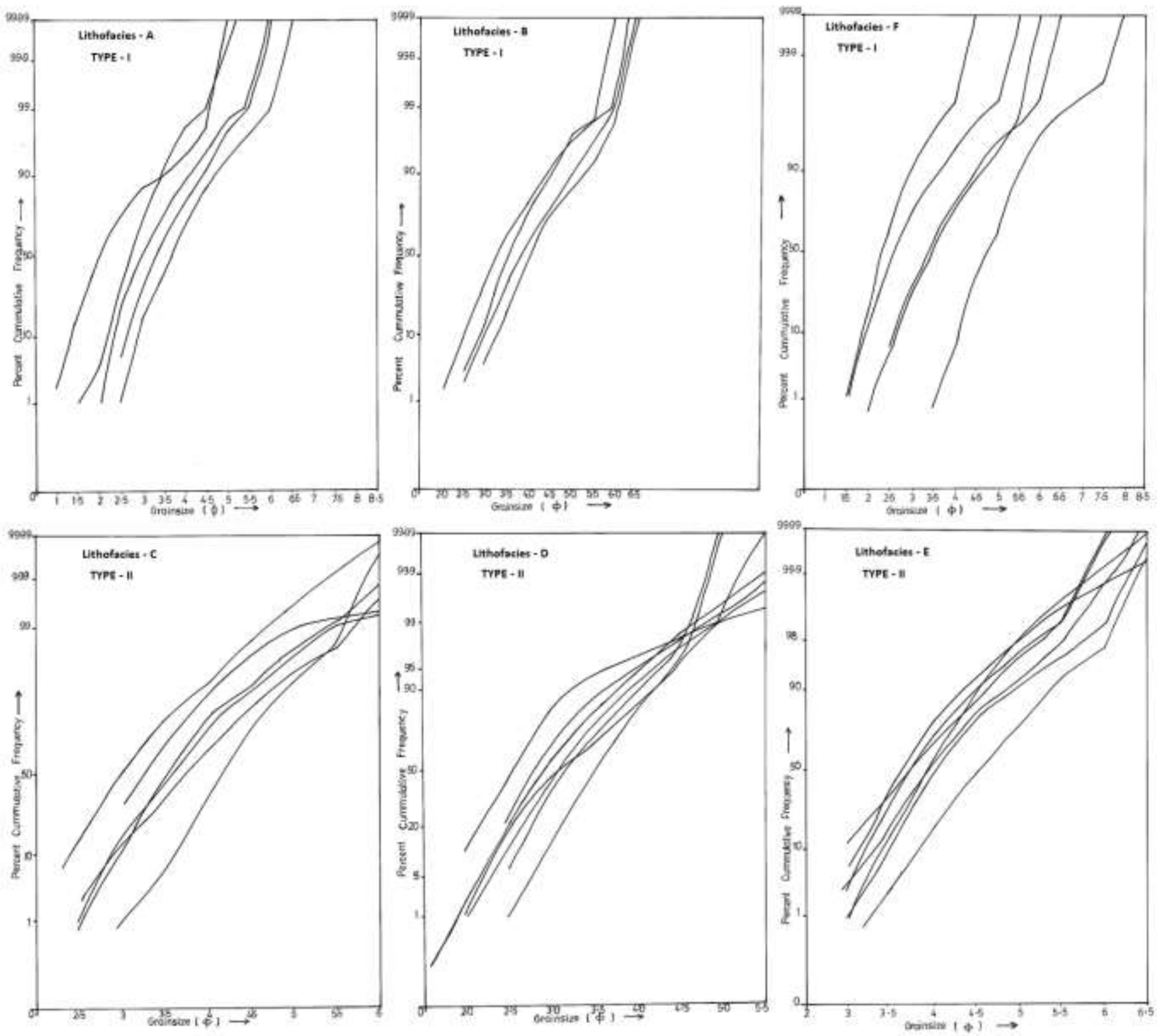

Fig. 2:- Cumulative Curve Types for the Palaeogene DBTS, Naga Hills

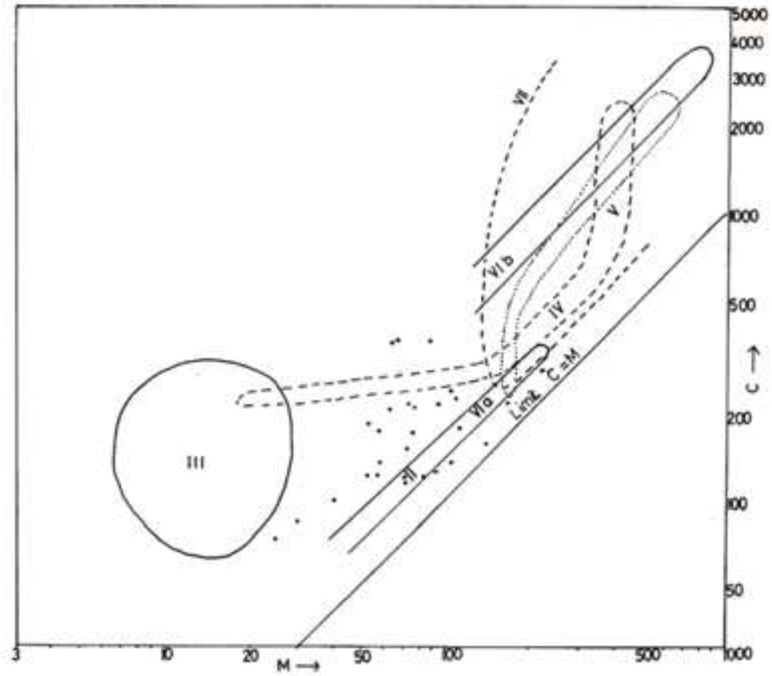

Fig. 3: C - M Pattern of the DBTS, Naga Hills
(after Passega, 1957; Passega and Byramjee, 1969)

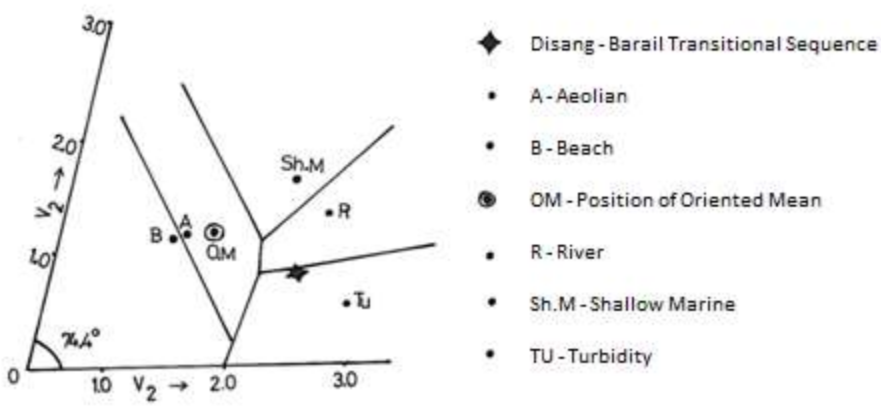

Fig. 4: Discrimination of Depositional Environment for Palaeogene DBTS, Naga Hills using V1 - V2 Plot after Sahu (1983)

Table:1 Grain-size frequency (in percent) distribution of six Lithofacies of the Palaeogene Disang-Barail Transitional Sequence

Class interval	Sample numbers of Lithofacies 'A'					
(Phi units)	**L10**	**L29**	**L31**	**L33**	**L34**	**Average**
0.50-1.00	-	-	-	-	1.64	1.64
1.00-1.50	-	-	-	1.00	14.84	3.16
1.50-2.00	1.27	-	-	3.50	35.25	8.00
2.00-2.50	16.81	1.28	0.54	24.66	21.85	13.02
2.50-3.00	32.35	19.42	5.12	43.66	12.16	21.34
3.00-3.50	24.68	24.00	24.90	21.00	4.53	19.82
3.50-4.00	12.79	29.71	33.51	4.50	4.53	17.00
4.00-4.50	6.94	18.28	17.76	1.13	3.09	9.42
4.50-5.00	3.65	7.14	9.89	0.50	2.06	4.64
5.00-5.50	0.36	3.28	5.86	-	-	4.90
5.50-6.00	1.09	1.85	1.64	-	-	0.91
6.00-6.50	-	1.00	0.74	-	-	0.34

Class interval	Sample numbers of Lithofacies 'B'				
(Phi units)	**L24**	**L26**	**L27**	**L28**	**Average**
2.00-2.50	-	-	-	1.12	1.12
2.50-3.00	1.63	2.89	-	7.10	2.90
3.00-3.50	8.18	8.69	3.55	23.92	11.08
3.50-4.00	19.63	33.62	11.40	31.40	24.01
4.00-4.50	27.81	28.84	31.77	15.14	25.89
4.50-5.00	20.36	14.49	27.10	12.14	18.52
5.00-5.50	12.36	7.82	15.32	6.16	10.41
5.50-6.00	5.81	1.44	4.85	1.49	3.39
6.00-6.50	3.09	1.44	4.29	1.30	2.53
6.50-7.00	1.09	0.72	1.65	-	0.86

Table-1 contd.

Class interval	Sample numbers of Lithofacies 'C'						
(Phi units)	L9	L12	L13	L17	L19	L36	Average
2.00-2.50	0.84	-	2.00	-	-	1.15	0.66
2.50-3.00	11.01	-	11.00	0.58	2.08	14.61	6.54
3.00-3.50	36.77	14.28	21.20	5.08	29.16	28.46	22.49
3.50-4.00	33.88	35.04	31.40	30.52	41.86	32.69	34.23
4.00-4.50	10.84	30.85	20.80	40.50	19.39	13.46	22.64
4.50-5.00	4.91	12.38	8.20	17.61	6.08	6.53	9.28
5.00-5.50	1.35	5.52	3.00	3.71	2.08	1.92	2.93
5.50-6.00	0.84	1.90	2.40	2.95	0.32	1.15	1.59

Class interval	Sample numbers of Lithofacies 'D'							
(Phi units)	L2	L6	L7	L8	L18	L25	L32	Average
1.50-2.00	-	1.09	0.54	-	-	-	10.09	1.67
2.00-2.50	-	16.00	9.09	6.03	20.00	1.58	32.33	12.14
2.50-3.00	-	27.63	33.81	26.66	46.07	10.19	40.56	26.41
3.00-3.50	2.31	21.45	32.18	35.07	21.07	31.56	10.46	22.01
3.50-4.00	18.00	18.18	15.45	20.95	8.03	40.39	3.17	17.73
4.00-4.50	35.65	10.54	6.36	7.61	3.03	12.15	1.49	10.97
4.50-5.00	25.13	4.18	2.18	3.49	0.89	4.11	1.12	5.87
5.00-5.50	11.76	0.90	0.36	0.15	0.89	1.98	0.74	2.39
5.50-6.00	4.63	-	-	-	-	-	-	0.66
6.00-6.50	1.60	-	-	-	-	-	-	0.22

Table-1 contd.

Class interval	Sample numbers of Lithofacies 'E'							
(Phi units)	L1	L3	L11	L15	L16	L20	L21	Average
2.50-3.00	-	2.68	-	0.18	1.23	-	12.23	2.33
3.00-3.50	-	17.11	6.35	14.00	11.13	3.40	24.27	10.89
3.50-4.00	2.73	36.24	32.66	42.18	35.05	27.20	30.67	29.53
4.00-4.50	14.15	25.67	40.10	32.18	31.95	40.60	18.83	29.06
4.50-5.00	28.76	11.91	14.33	8.72	12.37	19.20	9.70	14.99
5.00-5.50	27.98	3.69	4.71	1.45	5.15	7.29	2.91	7.58
5.50-6.00	18.00	1.84	1.81	0.54	32.68	1.80	1.35	8.28
6.00-6.50	5.28	0.83	-	-	1.41	0.68	-	1.17
6.50-7.00	2.93	-	-	-	-	-	-	0.41

Class interval	Sample numbers of Lithofacies 'F'					
(Phi units)	L4	L14	L22	L23	L35	Average
1.00-1.50	-	-	1.20	-	0.55	0.35
1.50-2.00	-	0.50	16.66	-	11.00	5.63
2.00-2.50	-	5.50	47.80	5.50	31.00	17.96
2.50-3.00	-	22.00	24.60	19.41	31.19	19.44
3.00-3.50	0.55	30.00	6.80	26.97	13.21	15.50
3.50-4.00	6.42	19.33	1.80	22.38	7.70	11.52
4.00-4.50	26.67	12.00	0.20	13.76	3.30	11.18
4.50-5.00	27.23	6.50	-	6.42	1.46	8.32
5.00-5.50	27.93	1.66	-	3.66	0.55	6.76
5.50-6.00	7.82	1.50	-	1.83	-	2.23
6.00-6.50	1.95	1.00	-	-	-	0.59
6.50-7.00	0.55	-	-	-	-	0.11
7.00-7.50	0.41	-	-	-	-	0.08
7.50-8.00	0.41	-	-	-	-	0.08

Table 2: Probable Depositional Environments for different Lithofacies of the DBTS (after Visher, 1969)

Lithofacies & S.No	Saltation Population (A)				Suspension Population (B)				Probable Depositional Environment
	Percent	Sorting	C.T (phi)	F.T (phi)	Percent	Sorting	Mixing (A+B)	F.T (phi)	
Lithofacies 'A'									
L10	99%	moderate	2.0	5.5	1%	good	average	6.0	Sub sea fan
L20	99%	moderate	2.5	6.0	1%	good	much	6.5	
L31	99%	moderate	2.5	5.5	1%	good	much	6.0	
L33	99%	moderate	1.5	4.5	1%	good	much	4.7	
L34	98%	moderate	1.0	4.5	2%	good	much	5.5	
Average	98.8%	moderate	1.9	5.2	1.2%	good	much	5.7	
Lithofacies 'B'									
L24	99%	good	2.5	5.9	1%	good	much	6.5	Sub sea fan
L26	98%	moderate	2.5	5.9	2%	good	average	6.5	
L27	98%	good	3.0	6.0	2%	good	average	6.5	
L28	99%	moderate	2.0	5.5	1%	good	average	6.5	
Average	98.5%	moderate	2.5	5.8	1.5%	good	average	6.5	
Lithofacies 'C'									
L9	99.2%	moderate	2.5	5.5	6%	good	average	6.0	Turbidity current
L12	97%	moderate	3.0	5.5	3%	moderate	much	6.5	
L13	98%	moderate	2.5	5.5	2%	good	much	6.0	
L17	98%	good	3.0	6.5	2%	good	much	6.0	
L19	98.5%	moderate	3.0	4.5	1.5%	good	much	5.5	
L36	99%	moderate	2.5	5.5	1%	good	much	6.0	
Average	98.2%	moderate	2.7	5.5	2.5%	good	much	6.0	
Lithofacies 'D'									
L2	98%	moderate	3.5	4.4	2%	moderate	much	7.0	Turbidity current
L6	97%	moderate	2.0	4.5	3%	good	much	5.0	
L7	99%	moderate	2.0	4.5	1%	good	much	5.0	
L8	97%	moderate	2.5	4.5	3%	good	much	6.0	
L18	80%	moderate	2.5	5.0	20%	moderate	much	5.5	
L25	99%	moderate	2.5	4.5	1%	good	much	5.0	
L32	91%	moderate	2.0	3.1	8%	fair	much	5.5	
Average	94.4%	moderate	2.4	4.3	5.4%	good	much	5.7	
Lithofacies 'E'									
L1	97%	moderate	4.0	5.4	3%	moderate	much	6.4	Sub sea fan
L3	99%	moderate	3.0	4.5	1%	moderate	much	6.5	
L11	91%	moderate	3.5	5.0	9%	moderate	much	7.0	
L15	99%	moderate	3.0	5.0	1%	good	much	6.0	
L16	96%	moderate	3.0	4.7	4%	moderate	much	6.5	
L20	88%	moderate	3.0	5.5	12%	moderate	much	6.5	
L21	99%	moderate	3.0	5.5	1%	moderate	much	6.0	
Average	95.2%	moderate	3.2	5.0	4.4%	moderate	much	6.1	
Lithofacies 'F'									
L4	96.4%	good	3.5	7.5	4%	good	much	8.0	Turbidity current
L14	98%	good	2.5	6.0	1%	good	much	6.5	
L22	99%	moderate	1.5	4.0	1%	good	much	4.5	
L23	99%	moderate	2.5	5.5	1%	good	much	6.0	
L35	99%	moderate	1.5	5.6	1%	good	much	5.5	
Average	98.2%	moderate	2.3	5.6	1.6%	good	much	6.1	

C.T = coarse truncation point F.T= fine truncation point

Discussion and Conclusion:-

The study of grain-size characteristics of the different lithofacies of the Palaeogene Disang – Barail Transitional Sequence in parts of Kohima synclinorium suited best in understanding the lithologic intricacies and reconstructing the broader aspects of the depositional environment. A comparison with the pattern of cumulative curves for various types of environments, as suggested by Visher (1969), indicates that the rocks of the present area correspond approximately to turbidity current deposited sandstones. A long and rectilinear C-M pattern which is indicative of transportation of fine to coarse grain particles under saltation and suspension modes with very little or no rolling (Passega, 1957) characterizes sediments of the study area. In addition, the position of point in $V_1 – V_2$ diagram after Sahu (1983) clearly depict a turbidite environment for the deposition of DBTS. The sedimentary basin receiving detritus for the deposition of the Palaeogene sequence appears to have passed through different stages of tectonic regime leading to the development of deep sea channelized fan systems. The deposition seems to have progressed largely under the influence of turbidity currents causing superimposition of submarine fans that ultimately resulted into the heterogeneous Palaeogene Disang – Barail Transitional Sequence of the Naga Hills.

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