Granulometric Analysis of the Late Quaternary Sediments in and around Kimin, Arunachal Pradesh, India

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Abstract: Eighteen samples were collected from the foothills region of Arunachal Himalaya near Kimin across the state boundaries of Arunachal Pradesh and Assam, India. The samples were subjected to granulometric analysis to determine their textural characteristics and depositional processes. Sieve analysis was used for determining the grain size distribution of sand. Statistical analysis of the samples show that the samples were granule (-1.5φ) to very fine sand (3.55φ) diameter in size and varies from well sorted (0.46φ) to very poorly sorted (2.99φ). The sediments were very coarse skewed (-0.64φ) to fine skewed (0.24φ) in nature and the kurtosis value of the samples ranges from platykurtic (0.86φ) to very leptokurtic (2.23φ). Granulometric analysis of the sediments suggests that the sediments were deposited by a higher energy and fluctuating river regime. Bivariate analysis indicates that the sediments are river sediments which are associated with fluvial processes. By studying the distribution of sample points in the C-M pattern, it reveals that the sediment deposition was mainly by graded suspension with some rolled sediments which indicates that the sediments were deposited by fluvial processes by tractive current.

Keywords: *Granulometric analysis, standard deviation, skewness, kurtosis, depositional environment*

1. Introduction

The alluvial terraces in the north bank of the Brahmaputra River forms part of the extensive Himalayan foreland basin that has been undergoing sedimentation in late Quaternary time. Thickness of alluvial plain is more than 1000 meters at places. This thick pile of sediment deposited by numerous transverse Himalayan rivers bears imprints of Late Quaternary tectonics and climate variability. River rejuvenation intermittently affected the region resulting in development of multiple terrace levels. A relative chronology of these terraces can be worked out based on the subjective criteria viz., degree of compaction, oxidation, topographic offsets and degree of dissection (GSI, 1977). Older terrace sequences are more compact, often partially indurated, oxidized and stand out as raised table land bordered by well defined scraps. These scrap sections provide glimpses of the alluvial sequences representing various stages of river rejuvenation. On that background, this study is undertaken for the sediments both from the older terraces and from the present channel systems to evaluate the depositional environment. A host of literature are available in the form of standard book and research papers on textural parameters and their implications in the context of both lithified and non-lithified sediments [e.g. 1, 2 , 3, 4,5]etc. The detail work by Reineck and Singh, [1] provide a good insight of various depositional environments giving relation of forms and processes. Folk and Ward [2], contributed a significant work towards understanding the fluvial processes from sediments. His work on Brazos river sediments brought out a comprehensive account on computations of various textural and parameters viz. Graphic mean size, Inclusive graphic standard deviation, Inclusive graphic skewness and Kurtosis based on well defined mathematical relations for which the values are read directly from 'cumulative curves' plotted on arithmetic probability papers. This work also highlighted the bivariate relationships of these textural parameters which have been extensively used as standard reference by those working on textural aspects of the sediments.

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Location of the study area: The area under study lies in the foothills region of Arunachal Himalaya near Kimin across the state boundaries of Arunachal Pradesh and Assam. This area is covered by the survey of India topographic map no 83E/15 in 1:50,000 scale and is part of the Lakhimpur districts of Assam. Geographic co-ordinates defining the study area are: 27°15'N-27°30'N and 93°40'E-93°45'E.TheRangaNadi and its tributaries form the major drainage in the study area that drains into Subansiri River 10 km upstream of the confluence of the Brahmaputra River and Subansiri River.

Geology of the study area: The study area is a part of the lower catchment of RangaNadi River in the foothills of Arunachal Himalaya. South of 'Kimin', the state border township. The area is covered by Quaternary Alluvium down to the river Brahmaputra. This alluvium is abutting against a Neogene clastic sequence across the major boundary structure- the Himalayan Frontal Thrust (HFT).The generalized lithostratigraphic framework in the area is given in the area is given in the Table 1.

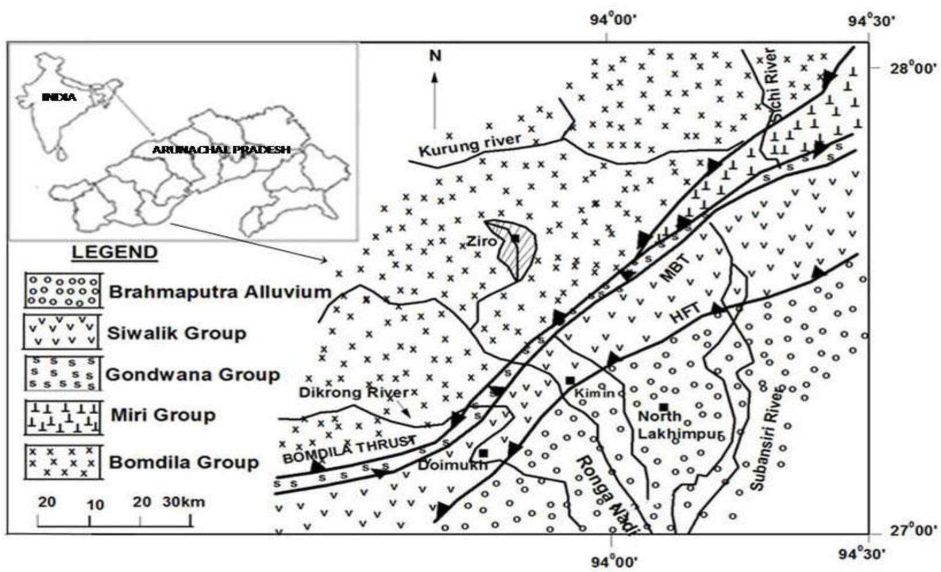

Figure1: Geological map of parts of Kiminarea(after Agarwal et al. 2009)

Table 1: Generalized Lithostratigraphy of the Himalaya Foothills region (Kimin area) (after GSI)

Group	Formation	Lithology
Newer Alluvium Deposit	Channel Alluvium(T_o) Newer Terrace deposit/Alluvium(T_1)	Unoxidised sediments of active channel boulders, cobbles, pebbles with unoxidised sand
---Disconformity--		
Older Alluvium Deposit	Older Terrace deposit(T_2) Older Terrace deposit(T_3)	Boulders, cobbles, pebbles with oxidized sand and sandy clay
-------------------------------------- Unconformity---		
Basement floor of hard rock's(Siwalik)		

Further north, the Neogene sequence is juxtaposed with a thin sequence of Gondwana affinity across the Main Boundary Thrust (MBT). Thus, from south to north, the geological framework is characterized by lithostartigraphic units bound by boundary thrust. The age of the rock increases towards north. The Gondwana sequence is found exposed along a narrow zone following the Arunachal Himalaya Trend. Northward towards Bomdila and beyond, metamorphic rocks composed of mainly phyllite, quartzite, schist and gneisses are encountered. These metamorphic shows a general increase in grade towards north and are variously grouped under different lithostratigraphic names viz., Bomdila group, Sela group[6], [7], [8]. Rocks in the upland terrainshow a regional trend of E-W to ENE-WSW in conformity with the eastern Himalayan trend. The Neogeneclastics in Arunachal Himalayas been correlated with the 'Siwaliks' of Western Himalaya[9] and are divided into the Dafla Formation, Subansiri Formation and Kimin Formationin the stratigraphic order. The Dafla Formation consists of a thick sequence of massive sandstone while the Subansiri Formation consists of a predominantly sandstone shale association with minor coal beds. The Kimin Formation also presents a sandstone shale association, but shows predominant vertical facies variation, with conglomerate beds towards the top part.

2. Materials and methods

Both channel and spot sampling method was adopted during the collection of the samples from the field. A total number of 18 samples were taken from different lithofacies units of the vertical sections. Sampling with bottom up procedure is followed during the field study. For the size analysis the collected samples were dried and subjected to coning and quartering. Samples were subjected to ASTM sieves using Ro-tap sieve shaker. Pipetting was done for all the samples. Grain size analysis is a significant tool for relating textural characteristics of sediments to their depositional processes [3], [10].Using the technique proposed by Folk and Ward[2] cumulative curves were plotted and statistical parameters such as mean, median, standard deviation, skewness and kurtosis were calculated. Bivariate Scatter plot were carried out to find clues to mode of deposition and identifying environment by size analysis.

3. Results and discussion

3.1. Grain size parameters

To reconstruct the depositional environment of the sediments, the textural parameters viz. mean (Mz), Standard deviation (σ_1), Skewness (Ski) and Kurtosis (K_G) and lithofacies association are widely used. Statistical grain size parameters can be computed either graphically or analytically. In the graphic method, percentiles are computed from the cumulative curves. The analytical method involves the computation of moment measures. In the present study, grain size parameters are calculated using the graphic method after Folk and Ward [2].

3.1.1 Graphic Mean Size (M_Z)

It indicates the central tendency of distribution of the average size of the sediments which indicate the average kinetic energy of the depositing agent [11]. In case of present study, the mean size of the samples ranges from granule (-1.56φ) to very fine sand (3.55 φ) averaging 1.934φ. This may indicate that high energy condition associated with the depositing agent.

3.1.2 Inclusive Graphic Standard Deviation (σ_1)

It measures the sorting or uniformity of the particle size distribution. It reflects the function of the kinetic energy of the depositing medium about the average kinetic energy. The standard deviation values ranges from 0.46φ (well sorted) to 2.99φ (very poorly sorted) averaging 1.08φ.

3.1.3 Inclusive Graphic Skewness (Sk_I)

It measures the asymmetry of the distribution around the mean. Symmetrical curves have Sk_I=0. Thus with excess coarser materials (i.e. Mz value towards the coarser side), the coarser tail towards the left will have negative skewness values. The reverse case indicates positive skewness. It determines whether the sediments are characterized by predominantly coarse or fine sediments. The skewness of the samples ranges from -0.64φ (very coarse skewed) to 0.24φ (fine skewed).Unidirectional flow may be responsible for the generally positive skewness obtained in the study. But the dominance of finer sediments resulting to negative skewness can be attributed to lower energy condition of the flow regime. Dominance of positive skewness also suggests that the velocity of the depositing agent operated at a higher value than the average value for a greater length of time than normal and / or the velocity fluctuations towards the higher values occurred more often than normal[11].

3.1.4 Graphic Kurtosis (K_G)

It measures the ratio between the sorting in the 'tails' of the distribution and the sorting in the central portion of the distribution. It is a sensitive and valuable test of the normality of a distribution, [2]. If the central portion is better sorted than the tails, the frequency curve is said to be excessively peaked or leptokurtic. If the tails are better sorted the central portion, the curve is said to be flat peaked or platykurtic. Normal curve have K_G=1.00. In the present study the kurtosis value for samples ranges from 0.86 φ (platykurtic) to 2.23 φ (very leptokurtic). A more or less equal mixture of two populations gives a platykurtic distribution, whereas a dominance of one or other population gives a leptokurtic distribution [12]. Leptokurtic to very leptokurtic is shown by samples with one mode dominant and the other very subordinate and also by samples with unimodal distribution showing distinct tailings in one side. Folk and Ward[2] opined that unimodal sediments have kurtosis values near unity (hence mesokurtic). Whereas the appearance of a small subsidiary mode resulted in the curve becoming strongly leptokurtic with kurtosis values greater than unity. In case of the present study, the mesokurtic distribution is shown by samples having unimodal character.

3.2 Bivariate analysis (inter relationship of size parameters)

Scatter diagrams were plotted to understand the geological meaning and the interrelationships of the four grain size parameters. Such bivariate scatter plot give clues to the mode of deposition and helps in identifying environment by size analyses, [2].The bivariate plot between mean size and standard Deviation reveals that as the mean size becomes smaller, the sorting tends to be better in the terrace samples (Figure 2). However the sample from Harmoti(H1) and Kherkatiriver bank section near Kimin quarry (Q2) shows poorer sorting and mean size also tends to be coarser. The poorersorting in sample H1 and Q2 may be attributed to the addition of cobble gravels to sediments with dominant very coarse sand and granule grains. The geological significance of the observed trend may be attributed to the variations of depositional conditions as well as to the sediment supply. The relatively better sorting in the samples may be due to the selective deposition of the particles under stable energy conditions. The plots of mean sizeagainst skewness shows that positive skewness values are shown by the samples which show mostly near symmetrical nature (figure 3).Among the samples, the highest skewness value of 0.24 is obtained at a mean size of 2.33φ.In the plot of skewness versus standard deviation (Figure 4) the samples were plotted for differentiate between the river and beach sands. Most of the samples in the present study fall within river field with an exception of one sample falling near the boundary line of Friedmans beach and river fields on the beach field side. Againfrom the plot of mean diameter versus standard deviation(figure 5**)**, it was found that most of the samples fall within the two fields, river field and mixed river-dune field with an exception of only one sample falling within the dune field . Againthe samples were plotted for bivariate plot of mean diameter versus standard deviation to differentiate between the river and sand beach sands (figure 6). Most of the samples in the present study fall within river field with an exception of one sample falling on the beach field.

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Table2. Results of statistical analysis of grain size data:

SAMPLE NO.	MEAN SIZE (in Φ)	STANDARD DEVIATION (in Φ)	GRAPHIC SKEWNESS (in Φ)	KURTOSIS (in Φ)
R4	Fine sand (2.6)	Moderately well sorted (0.57)	Fine skewed (0.24)	Mesokurtic (1.09)
R3	Very fine sand (3.55)	Moderately well sorted (0.65)	Fine skewed (0.17)	Mesokurtic (1.04)
R2	Medium sand (1.97)	Well sorted (0.46)	Near symmetrical (-0.05)	Mesokurtic (1.01)
R1	Medium sand (1.93)	Moderately well sorted (0.52)	Near symmetrical (-0.03)	Mesokurtic (1.10)
J3	Very fine sand (3.07)	Moderately sorted (0.91)	Near symmetrical (0.03)	Mesokurtic (0.98)
J2	Fine sand (2.03)	Moderately well sorted (0.64)	Near symmetrical (0.09)	Leptokurtic (1.26)
J1	Medium sand (1.9)	Moderately well sorted (0.66)	Near symmetrical (0.08)	Leptokurtic (1.16)
D2	Fine sand (2.75)	Moderately sorted (0.96)	Fine skewed (0.12)	Platykurtic (0.86)
D1	Medium sand (1.62)	Poorly sorted (1.55)	Coarse skewed (-0.19)	Very leptokurtic (2.23)
Q3	Fine sand (2.92)	Moderately sorted (0.83)	Fine skewed (0.17)	Mesokurtic (1.06)
Q2	Granule (-1.56)	Very poorly sorted (2.06)	Near symmetrical (0.08)	Leptokurtic (1.15)
Q1	Very fine sand (3.35)	Moderately sorted (0.96)	Very coarse skewed (-0.57)	Platykurtic (0.89)
W1	Fine sand (2.33)	Poorly sorted (1.2)	Fine skewed (0.24)	Mesokurtic (0.97)
K2	Medium sand (1.98)	Moderately well sorted (0.65)	Fine skewed (0.13)	Leptokurtic (1.18)
K1	Medium sand (1.7)	Moderately well sorted (0.63)	Fine skewed (0.15)	Mesokurtic (0.96)
A2	Medium sand (1.35)	Poorly sorted (1.95)	Coarse skewed (-0.15)	Leptokurtic (1.38)
A1	Fine sand (2.08)	Poorly sorted (1.18)	Near symmetrical (0.014)	Leptokurtic (1.13)
H1	Very coarse sand (-0.75)	Very poorly sorted (2.99)	Very coarse skewed (-0.64)	Very leptokurtic (1.60)

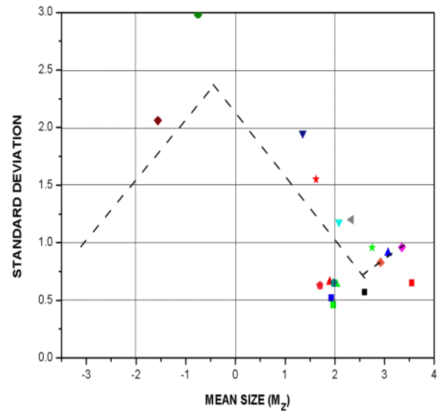


Figure 2: Bivariate scatter plot of Mean size versusStandard deviation [2]

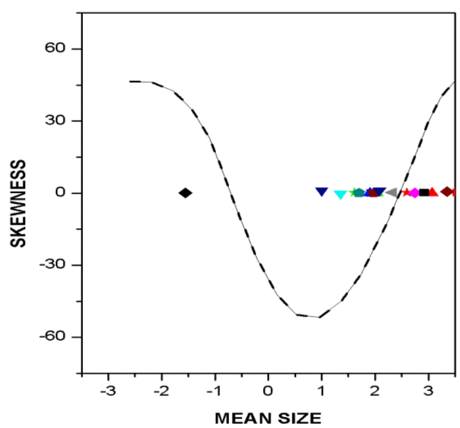


Figure 3: Bivariate scatter plot of Mean size versus Skewness, [2]

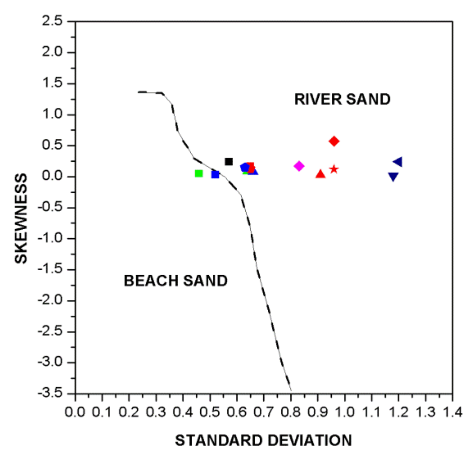


Figure 4: Plot of Skewness versus Standard deviation, [13]

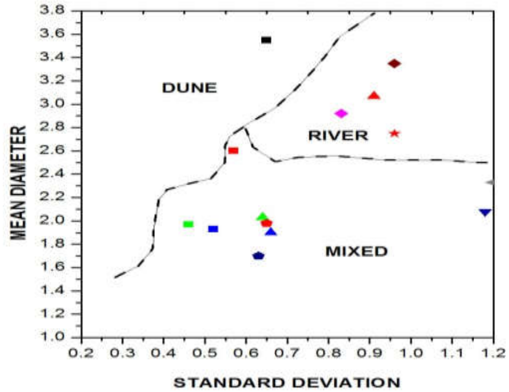


Figure 5: Plot of Mean diameter versus Standard deviation, [13]

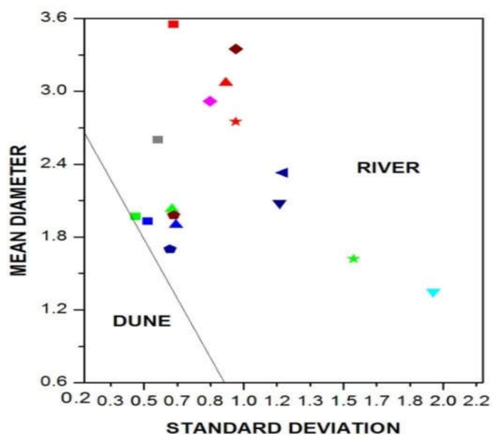
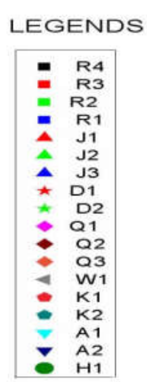


Figure 6: Plot of mean diameter versus standard deviation, [4]



3.2.1 C-M pattern

The C-M pattern is a means of analyzing transportation mechanisms, determining the process and characteristic agents that are responsible for the formation of clastic deposits [14].In the present study, the C-M pattern plots are made following Passega and Byramjee,[5] and the two parameters are plotted on double log scale (figure 7). The different environments forthe different segments are given in the index table with the C-M pattern.By studying the distribution of sample points in the C-M pattern it reveals that the sample points mostly concentrate in and around 'PQ' segment of NO-OP-PQ-QR-RS diagram.

Moreover, the points are falling near the Cs line sector of PQ. Segment PQ of the C-M pattern is formed by suspension sediments represented by point Q and rolled grains in small portion that does not affect the value of the median, [14]. Segment PQ also contains particles larger than the maximum value of 'Cs' in the suspension. The segment PQ reflects an increase in the amount of rolled materials, [5]. The concentration of the points in these segments indicates graded suspension with some rolled sediments. Since the grains are transported by suspension and rolling, it indicates a tractive current deposit. In the C-M pattern, the concentration of the points above the Cs line indicates the deposition of the sediments of the present sample on the river bed by tractive current. Moreover, the distribution of the sample points are mostly in the field of 'V' and 'lV', with majority falling in the field 'lV' suggests gradded suspension deposits of the sediments with high turbulence of the depositing agent.

Table 3: C-M values:

Sample No.	Φ_1=C	Φ_{50}=M	C		M	
			mm	micron	mm	micron
R4	1.35	2.5	0.3924	392.4	0.1768	176.8
R3	2.15	3.45	0.2253	225.3	0.0915	91.5
R2	0.4	2	0.7579	757.9	0.25	250
R1	0.4	1.95	0.7579	757.9	0.2588	258.8
J3	1.1	3.05	0.4665	466.5	0.1207	120.7
J2	0.5	2.05	0.7071	707.1	0.2415	241.5
J1	0.15	1.9	0.9012	901.2	0.2679	267.9
D2	1.4	2.7	0.3789	378.9	0.1539	153.9
D1	-6.55	1.65	93.7015	93701.5	0.3186	318.6
Q3	0.98	2.85	0.5070	507	0.1387	138.7
Q2	-6.1	-1.7	68.5935	68593.5	3.2490	3249
Q1	1.2	3.35	0.4353	435.3	0.0981	98.1
W1	0.41	2.15	0.7526	752.6	0.2253	225.3
K2	0.4	1.95	0.7579	757.9	0.2588	258.8
K1	0.35	1.65	0.7846	784.6	0.3186	318.6
A2	-5.65	1.45	50.2134	50213.4	0.3660	366.0
A1	-1.25	2.05	2.3784	2378.4	0.2415	241.5

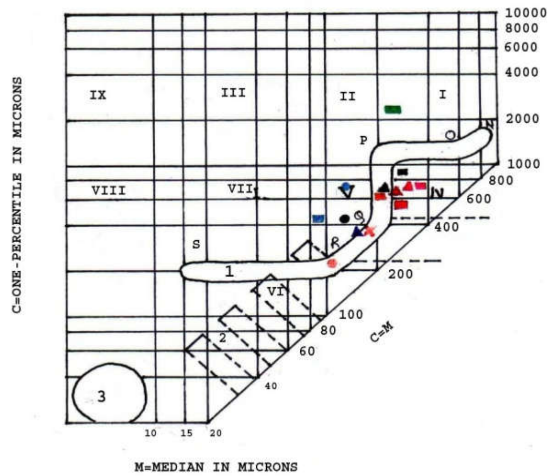


Figure 7: C-M Pattern (1.Traction current deposit, 2.Turbidites, 3. Quiet water suspension deposits; NO = Rolling sediments; OP = Rolling sediments with some suspension sediments; PQ = Graded suspension with some rolled sediments; QR = Graded suspension (Saltation) deposits; RS =Uniform suspension; T = Pelagic suspension; Cs = Maximum grain size transported as graded suspension; Cu = Maximum grain size transported as uniform suspension; Segments I, II, III and IX are denoted by C > 1mm. Here mainly rolled sediments are incorporated. Suspension is of minor importance. Segments IV, V, VI and VII are denoted by C < 1 mm. mainly suspension sediments, rolled sediments < 1 mm may be incorporated. The pattern of turbidity current deposits runs parallel to limit C = M).

4. Conclusion

From the overall study, an understanding could be arrived regarding the terraces that were being exposed in the foothills of Himalaya. The terrace sediments were deposited by a river in a shallow fore deep basin and the deposition took place rapidly and quickly from nearby source. Tectonic instability and disturbance prevail in the source area as well as in the site of deposition. Thus, it may be said that the sediments of the present area were derived from the complex rock basement of the rising Himalaya situated nearer to the north of the area. The sediments were carried down by the numerous rivers flowing down from the Himalayas and depositing the sediments in the present area during late quaternary time. Granulometric analysis of the sediments suggests that the terrace sediments weredeposited by a higher energy and fluctuating river regime. The fluctuating energy condition of deposition of terrace sediments also has been reflected in the sorting characteristics of the sediments which tend to poorer than the present day river system. Textural analysis suggests that the terrace sediments were deposited in the fluvial depositional environment. This further implies that the late quaternary river regime have undergone intermittent rejuvenation leading to uplift followed by incision resulting in multiple terrace levels. In Brahmaputra valley, in general, vertical tectonics is considered to be the trigger of river rejuvenation in post Siwalik deformation. Thus, the multiple terrace level in the study area represents a phase of subtle vertical movement. Moreover the Kimin sequence, older terrace sequence and the modern channel sequences can be distinguished based on the textural parameters which are suggestive of fluvial depositional environment.

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References

[1] Reineck, H.E., Singh, I.B., 1980. Tidal flats. In: Depositional Sedimentary Environments. Springer Berlin Heidelberg, pp. 430e456.

[2] Folk, Robert l. and Ward, William C., 1957: Brazos River Bar: A study in the significance of grain size parameters, Jour. Sed. Petrol., V. 27, p. 3-26.

[3] Visher G.S. Grain size distribution and depositional processes. Journal of Sedimentary Petrology. 1969; 39:1074- 2016.

[4] Moiola, R.J. & Weiser, D., 1968: Textural parameters and evaluation. Jour. Sed. Pet, V-38, p45-53.

[5] Passega, R. and Byramjee, R. 1969: Grain size image of clastic deposits, Sedimentology, v.13, p. 233-252

[6] Bakliwal, P. C. and Das, A. K., 1971. Geology of parts of Kameng district, NEFA,Unpub. Rep. G.S.I (1970-71).

[7] Kumar, G., 1997. Geology of Arunachal Pradesh. Geological Society of India, Bangalore

[8] Doundial, D.P., Kumar, G., Singh, S., Reddy, K.V. S., 1989, Unpub Report Geol. Surv. Ind.

[9] Ranga Rao, A., 1983. Geology and hydrocarbon potential of a part of Assam-Arakan basin and its adjacent region, Pet. Asia J. 6: 127-158

[10] Mason CC, Folk RL. Differentiation of beach, dune and Aeolian flat environments by size analysis. Journalof Sedimentary Petrology. 1958; 28:211-226. 3

[11]Sahu, B.K., 1964. Depositional mechanisms from the size analysis of clastic sediments. Journal of Sedimentary Research, 34(1), pp.73– 83.

[12]Cronan, D.S. (1972->Regional geochemistry of the ferromanganese nodules in the world oceans. In Ferromanganese Deposits on the Ocean Floor, (ed) b. R. Hoinl Washington, DC: National Science Foundation, 19-30.

[13] Friedman, Gerald M., 1961: Distinction between dune, beach and river sands from their textural characteristics, Jour. Sed. Petrol., V. 31, p.514-529

[14]Passega, R., 1957. Texture as characteristic of clastic deposition. American Association of Petroleum Geologists Bulletin 41, 1952–1984.