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Study Of Textural Characteristics And Heavy Mineral Assemblage Of Shallow Subsurface Sediments Of A Part Of The Brahmaputra Valley In Assam, India

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Abstract: The study area is located on the south bank of the mighty river Brahmaputra in the districts of Tinsukia and Dibrugarh of Assam within the interfluves between the rivers Noa Dihing and Burhi Dihing. Thick deposits of Recent alluvial sediments comprising Older Alluvium, High level Terraces and New Alluvium along with active flood plain deposits are well exposed in natural cut bank sections of the Burhi-Dihing and Noa-Dihing rivers and their tributaries.The alluvium had been drilled for coring up to about 50 m at four sites, viz. Dhola, Dum Duma, ChotaTingrai and Naharkatiya, which are almost equally placed in a north-south direction from the river Brahmaputra towards south close to the foot of the Naga Hills. Grain size distribution of the sediments reveals that the samples are invariably sand with minor amount of clay and silts. Most of the sediments show bimodal size distribution. Cummulative curves indicate combination of different modes of transport and deposition and represent mostly two line segments and a few three line segments. Mean size of the sediments varies from very fine sand to medium sand. Majority of the sediments are moderately sorted and fine skewed. The frequency of leptokurtic and extremely leptokurtic sediments are maximum. Bivariate plots of standard deviation, skewness and kurtosis vs mean size show wide scatter of the valuessuggesting fluctuating energy conditions.. The bivariate plots and the CM plot suggest the fluvial nature of the sediments deposited chiefly in channel sub environment under medium to high energy condition. Ultra stable and unstable heavy mineral assemblage in the sediments points to their derivation mainly from source areas consisting mainly of high grade metamorphic and acid igneous rocks.

Keyword: grain size parameters, C-M pattern, heavy minerals, depositional condition, Recent sediments, Brahmaputra valley, Assam, India.

INTRODUCTION

The study area represents the extreme north-eastern part of the plains of the Brahmaputra valley. It is demarcated by the Brahmaputra river in the north-west and Burhi-Dihing in the south and Noa-Dihing in the east. The present study area is covered by the Survey of India topographic sheets - 83I/11, 83I/12, 83I/14, 83/15, 83/16, 83M/2, 83M/3, 83M/5, 83M/6, 83M/7, 83M/8, 83M/9, 83M/10, 83M/12, 83M/13, 83M/14, 83M/15, 92A/2 , 92A/3 and lies between longitudes 96º11´30´´E and 94º41´23´´E and latitudes 27º48´44´´N and 27º12´49´´N (Fig. 1).

Sedimentological research on modern sediments have gained importance in recent times , but investigations on Recent alluvial sediments in North Eastern India are still very meagre. Scrutiny of the literature reveals that no detailed sedimentological studies of the alluvial sediments of the south bank of Brahmaputra River have been carried out so far except a few isolated studies. Sarma (1980) had carried out sedimentological and geomorphological studies on the alluvial sediments of Burhi-Dihing river.

In this paper an attempt has been made to understand the grain size distribution and heavy mineral assemblage of the shallow subsurface sediments from the samples of undisturbed sediment cores of the four bore holes.

GEOLOGY OF THE AREA:

Upper Assam valley is an alluvial plain of the river Brahmaputra and forms a part of the shelf area of the Assam-Arakan basin. The sub surface geology of oilfield area indicates that the Precambrian basement is overlain by thick Tertiary sediments. The Quaternary sediments. unconformably rest over the Tertiary sediments . Kar et al.(1997) have classified the Quaternary sediments of the valley into Older Alluvium and Newer Alluvium. The Older Alluvium forming High Level Terraces and the Newer Alluvium superimposed over the Older Alluvium close to the foothills as fans and within narrow flood plain of the present rivers defined by their paleo banks as Low Level terraces. Mazumder et al.(2001) have recognised four major episodic Terraces in Quaternary Alluvial sediments of Upper Assam Valley. Disposition of these Terraces is believed to be structurally controlled and related to the major tectonic phases.

A generalized lithostratigraphic succession of the Quaternary deposits of Brahmaputra valley by Kar et al. (1997) is given in Table 1.

Table 1: A generalized lithostratigraphic succession of Quaternary deposits of Brahmaputra valley.

Age		Lithostratigraphy
Holocene	Newer Alluvium	Channel Alluvium (T_0)
		Terrace Alluvium (T_1)
		Terrace Alluvium (T_2)
		Alluvial Fan (F_a)
? Middle	Disconformity	Older Terrace Alluvium (T_3)
to	Older Alluvium	Older Terrace Alluvium (T_4)
Upper Pleistocene	Unconformity	Older Terrace Alluvium (T_5)
Upper Pliocene To Lower Pleistocene	Kimin (Upper Siwalik) and Dihing Formation	

METHOD OF STUDY:

For granulometric study sixteen samples are taken from all the four wells, four from each well.The samples are then sieved into half phi (1/2 φ)grade for 15 to 20 minutes using 22cm diameter A.S.T.M. sieves and automatic electrically operated Ro-tap sieve shaker. The size fraction are then weighted to an accuracy of 0.01gm. Cumulative curves are prepared and different percentile values are calculated from the cumulative curve.

The statistical grain size parameters are calculated with the help of the formula given by Folk and Ward(1957) which reflects the size distribution, depositional conditions, sorting characteristics and energy condition of the transporting medium. To know the depositional conditions of the sediments the C-M pattern plots are made following Passega and Bayramjee (1969).

For heavy mineral study, thirty samples are taken from the all four wells viz., Naharkatia, Dhola, ChotaTingrai and Dum Duma . The different size fractions of the sediments obtained from granulometric analysis are subjected to heavy mineral separation using bromoform with specific gravity greater than 2.89. The method use for heavy mineral separation is the "funnel separation method" proposed by Milner (1962). Micro slides are prepared from the heavy mineral residues for the detailed petrographic study and statistical analysis. ZTR maturity index of individual samples are calculated following Hubert (1962) to know the maturity of the study sediments with the help of Zircon , Tourmaline and Rutile.

RESULTS AND DISCUSSION:

Grain size distribution of sediments:

Cummulative curves:

Visher (1965, 1969) has shown that it is possible to differentiate amongst environments of deposition on the basis of the shape of cumulative curves and on the position of the truncation points among the traction, saltation and suspension populations. The parameters of frequency distribution are calculated from certain points on the cumulative curves as shown in Table2. In the present study, samples from four wells of Dhola, Dum Duma, Naharkatiya, Chota Tingrai and Dhola were analysed and the curves thus obtained (Fig.2) are studied in the light of Visher, (1969).

The maximum value of coarse truncation percent is 1.5, shown by the sample NHK-14.The minimum value of the coarse truncation is 0.1, shown by the sample NHK-12. The maximum value of suspension population percent is 70. It is shown by the sample DHL-18. The minimum value of suspension population percent is 25. It is shown by the sample DHL-4. The maximum value of saltation population is 74 percent. It is shown by the sample NHK-14. The minimum value of saltation population percent is 15. It is shown by the sample DHL-22. The maximum value of rolling population percent is 47. It is shown by the sample DMA-16. The minimum value of rolling population percent is 8 shown by the sample DHL-22.

Calculation of size parameters

The size parameters are calculated from certain points on the cumulative curves as shown in Table 3. The statistical size thus calculated are described as follows:

i) Graphic mean: (Mz)

In the present study the mean grain size of Naharkatiya well samples ranges from 1.04 Φ to1.96 Φ (medium sand of Wentworth scale), and the mean value is 1.66 Φ (medium sand) The mean grain size of Dhola samples ranges from 1.09 Φ(medium sand) to 2.31 Φ (fine sand), and the average value is 1.69 (medium sand). The mean grain size of Dum Duma ranges from 1.07 Φ to 1.90 Φ (medium sand), and the average value is 1.52 (medium sand). The mean grain size of well of Chota Tingrai ranges from 1.27 Φ to 1.90 Φ (medium sand), and the average value is 1.63 (medium sand).

ii) Inclusive graphic standard deviation (σ1)

The standard deviation (σ1) for the samples from the Naharkatiya well ranges from 0.62 Φ (moderately well sorted) to 1.05 Φ (poorly sorted). The σ1 for the samples from the Dhola well ranges from 0.54 Φ (moderately well sorted) to 1.26 Φ (poorly sorted). The σ1 for the samples from the Dum Duma well ranges from 1.01 Φ to 1.42 Φ (poorly sorted). The standard deviation for the samples of Chota Tingrai well ranges from 0.52 Φ (moderately well sorted) to 1.00 Φ (poorly sorted).

iii) Inclusive Graphic Skewness Sk1

The skewness of the samples from the wells of Naharkatiya well varies from 0.19 (fine skewed) to 0.49 (very fine skewed) with an average of 0.35 (fine skewed). The skewness of the samples from the wells of Dhola well varies from -0.22 (coarse skewed) to 0.47 (very fine skewed) with an average of 0.18 (fine skewed). The skewness of the samples from the wells of Dum Duma well varies from 0.28 (fine skewed) to 0.37 (very fine skewed) with an average of 0.31 (very fine skewed). The skewness of the samples from the wells of Chota Tingrai varies from 0.14 (fine skewed) to 0.56 (very fine skewed) with an average of 0.32 (very fine skewed). As observed from all the wells the frequency of very fine skewed sediments is maximum (50%) and very coarse skewed sediment is minimum (6.25%), which is the characteristic feature of fluvial deposit.

As observed from all the wells, almost all the samples (except one sample from Dhola-12) are positively skewed. There are some depositional significance of positive skewness and negative skewness. Duane (1964) and Brambati (1969) considered negative skewness as a product of erosion of fine particles from the sediment of winnowing action, whereas positive skewness resulted from sediments of materials in sheltered environment. Martins (1965) explained positive skewness as a result of unidirectional sediment transport.

iv) Graphic kurtosis (KG)

The kurtosis of the samples from the wells of Naharkatiya varies from 1.32 (leptokurtic) to 2.54 (very leptokurtic) with an average of 2.18 (very leptokurtic). The kurtosis of the samples from the wells of Dhola varies from 0.98 (mesokurtic) to 1.86 (very leptokurtic) with an average of 1.33 (leptokurtic). The kurtosis of the samples from the wells of Dum Duma varies from 1.02 (mesokurtic) to 1.76 (very leptokurtic) with an average of 1.30 (leptokurtic). The kurtosis of the samples from the wells of Chota Tingrai varies from 1.72 (very leptokurtic) to 1.88 (very leptokurtic) with an average of 1.77 (very leptokurtic). The frequency of very leptokurtic sediments are the maximum (43.75%) and platykurtic sediment is minimum (6.25%) as observed from all the wells.

INTERRELATIONSHIP OF SIZE PARAMETERS

i) Mean size (Mz) Vs Standard deviation (σ1)

It has been recognised by various authors that the sorting coefficient (standard deviation) is strongly dependent upon the median grain size (Kurmbein and Aberdeen, 1937; Imam 1949; Griffits 1951; Emery and Stevenson, 1950).

The relationship between mean size and standard deviation for the sample under study is plotted in Fig. 3 for the samples from the wells. From the plot, it is apparent that the values of standard deviation decreases with increase in mean size.

It has been recognised by Miola and Weiser (1968), that differentiation of river sand from beach sand is possible using scatter plot of mean size (mz) vs. standard deviation (σ1).The scatter of the sample points is in river field with wide size ranges.

ii) Mean size (Mz) Vs Skewness (SkI)

The relationship of mean size vs. skewness has been shown by a plot in Fig.4 for the different samples. Pettijhon (1969) referred that the fine grained sediments show somewhat better relationship between mean size and skewness. Hough (1942) noted that, the finer sediments, the more skewed the sediments are. Inman supporting Hough's view showed that the finest sediments should normally be highly skewed towards the finer fraction. In the following case the skewness of the grain samples are all positive (except for one sample from Dhola), thus indicating them as finer.

Friedman (1961) suggested the 0-0 skewness line as the environmental boundary between river and beach deposits. It is observed from the plot of mean size vs. skewness that sample points are scattered above 0-0 line; mostly positively skewed with limited size range.

iii) Skewness (Sk1) Vs Standard deviation (σ1)

The relationship between skewness Vs standard deviation of the samples under study is shown in Fig.5. Friedman (1967) showed that plot of skewness vs. standard deviation gives a good separation between beach and river sediments with only 10.50% of the samples deviating from the environmentally environment designated field. In the present study it has been found that all the samples fall within the field of river above 0-0 line showing positive skewness but wide scatter of sorting values.

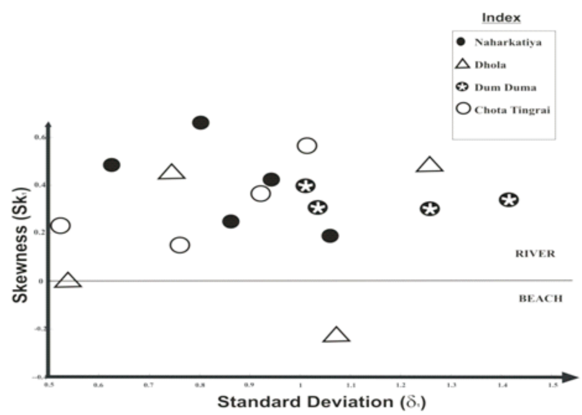


Fig. 5 Plot of Skewness vs standard deviation

iv) Skewness (Sk1) vs. Kurtosis (KG)

Scatter plot of inclusive graphic skewness vs. graphic kurtosis for the sediments is shown in Fig.6. Friedman (1961) has suggested 0-0 skewness line as an environmental boundary between river and beach sediments. From the plot it has been observed that almost all the samples fall in river environment with wide range of kurtosis values. Only one sample of Dhola well shows negative skewness..

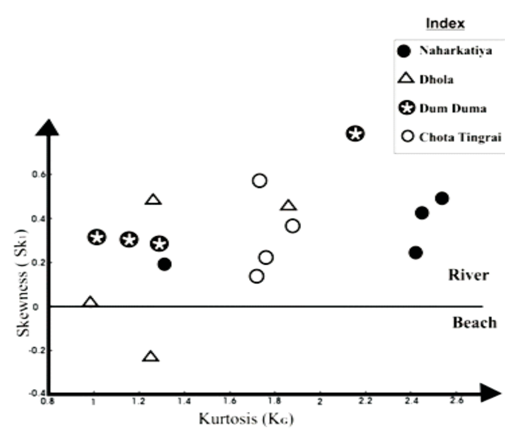


Fig.6. Plot of Skewness vs kurtosis.

v) C-M Diagram (After Passega 1957)

Passega (1957, 1964) suggested the use of C-M characteristic diagram for environmental analysis. In the present work C and M parameter are computed by intersecting the cumulative curves at 1% and 50% lines and reading the diameter in phi equivalent to these percentile values. These diameters are converted to millimeter values, using conversion chart (Phi to mm conversion table, after Page, 1955) and then the micron values (1 mm= 1000 micron). The computed micron values of C-M parameters of different samples are given in Table 6. Then a C-M diagram of the preset work is constructed from these data and shown in the Fig.7.

The alluvial sediments of the study area cluster in the field of fluvial domain of the CM plot. The angle between the different segments of the fluvial domain in which the sediment samples projections are grouped and the C=M line have comparable values to the basic CM pattern. These features provide information regarding the predominance of one of the means of transport and deposition. Most of the samples are projected in O/P segment of the sectors II and III, which indicate mainly rolled sediments with minor suspension sediments. The rest of the samples fall in the P/Q and O/N segments of the sectors IV and V, which represent bottom load graded suspension with minor rolled sediments having C<1mm. This indicates the mixing of very fine sand to medium sand as graded suspension with a little contribution of coarse grained sand by rolling in the admixture.

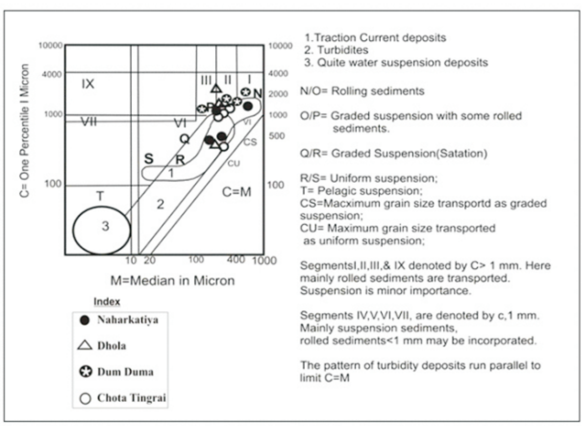


Fig. 7 C –M plot (After Passega 1957,1964 and Byramjee,1969)

Table 3 Results of Graphic size parameters of four borehole samples

WELL	SAMPLE NO.	1ST PERCENTILE VALUE IN Φ	MEDIAN =50 PERCENTILE VALUE IN Φ	MEAN SIZE (M_Z) VALUE IN Φ	(STANDARD DEVIATION) (Σ_1)		GRAPHIC SKEWNESS (SK_1)		GRAPHIC KURTOSIS (K_G)	
					VALUE	INDICATION	VALUE	INDICATION	VALUE	INDICATION
DUMDUMA	DMA12	-0.68	1.12	1.28	1.01	Poorly sorted	0.37	Very fine-skewed	1.76	Platykurtic
	DMA16	0.20	1.74	1.90	1.04	Poorly sorted	0.29	Fine skewed	1.16	Leptokurtic
	DMA18	0.94	0.82	1.07	1.42	Poorly sorted	0.31	Very fine skewed	1.02	Mesokurtic
	DMA20	-0.74	1.55	1.83	1.27	Poorly sorted	0.28	Fine-skewed	1.29	Leptokurtic
CHOTA TINGRAI	CHTNG 6	-0.35	1.02	1.27	1.01	Poorly sorted	0.56	Very fine skewed	1.73	Very letokurtic
	CHTNG 8	-0.30	1.64	1.60	0.72	Moderately sorted	0.14	Fine-skewed	1.72	Very leptokurtic
	CHTNG 20	0.02	1.62	1.75	0.92	Moderately sorted	0.36	Veryfine-skewed	1.88	Very leptokurtic.
	CHTNG 22	0.63	1.83	1.90	0.52	Moderately well sorted	0.22	Fine-skewed	1.75	Very leptokurtic
DHOLA	DHL4	-0.30	1.36	1.34	0.54	Moderately well sorted	0.0068	Near symmetrical	0.98	Mesokurtic
	DHL12	-.23	1.32	1.09	1.07	Poorly sorted	-0.22	Coarse skewed	1.24	Leptokurtic
	DHL18	0.35	-1.85	2.02	0.74	Moderately sorted	0.45	Very fine-skewed	1.86	Very leptokurtic
	DHL22	-1.4	1.81	2.31	1.26	Poorly sorted	0.47	Very fine-skewed	1.27	Leptokurtic
NAHARKATIYA	NHK10	-0.39	1.76	1.04	0.94	Moderately sorted	0.49	Very fine-skewed	2.45	Leptokurtic
	NHK12	-0.40	0.85	1.93	1.05	Poorly sorted	0.19	fineskewed	1.32	Leptokurtic
	NHK14	0.72	1.88	1.96	0.62	Moderately well sorted	0.48	Very fine-skewed	2.54	Very leptokurtic
	NHK-16	0.49	1.7	1.71	0.86	Moderately sorted	0.24	Fine skewed	2.42	Very leptokurtic

Heavy mineral study

Heavy minerals are volumetrically minor constituents in terrigenouss ediments which are characterized as having a specific gravity greater than 2.89. According to Pettijohn (1984), the minerals of the pre-existing rocks surviving destruction, mechanical or chemical action or intrastratal solution are the heavy minerals. Heavy minerals are studied as a guide to source rock lithologies and dispersal patterns. The results obtained from this heavy mineral study have been presented in the Table 4 & 5. The ZTR maturity index of sediments were calculated following Hubert (1962) to know the maturity of terrigenous sediments with the help of recalculated percentage of zircon, tourmaline, and rutile which have been presented in the Table 6.

The sediments of the four well contain both opaque and non-opaque minerals (Table 7). The non-opaque minerals include zircon, tourmaline, rutile, sillimanite, kyanite, staurolite, epidote, garnet, chlorite, chloritoid, hornblende, hypersthene and apatite. The percentages of the ultra-stable minerals, i.e. zircon, tourmaline and rutile for NHK 3.43-11.54, 2.86-9.61 and 0.60-9.24, for DHL 8.17-12.70, 1.79-4.33 and 0.90-2.48 for CH.TNG 5.25-11.76, 1.44-4.02, 0.69-1.75 and for DMA 5.02-8.53, 1.79-3.88, 0.72-2.79 respectively and their distribution is shown in as bar diagrams (Fig. 10 & 11). The character of the heavy minerals is evident from photomicrographs (Fig. 12).

ZTR Maturity index of the sediments:

The ZTR maturity index of sediments were calculated following Hubert (1962) to know the maturity of terrigenous sediments with the help of recalculated percentage of zircon, tourmaline, and rutile which have been presented in the Table 6. The triangular diagram(Fig.8 & 9) shows the distribution of heavy minerals in three main blocks viz. A, B and C. Each block of the triangle had been divided into two tiers. Each tier had different proportion of Zircon (Z), Tourmaline (T), and Rutile.

The ZTR maturity index for the sediments of Naharkatiya, ChotaTingrai, Dum Duma, Dhola wells varies from 7.53-25.55. It is evident from Table 9 that the ZTR maturity index of Naharkatiya sediments is greater than that of other three wells, which indicates that the sediments of Naharkatiya are more matured. The ZTR diagrams of Dhola, ChotaTingrai and Dum Duma (Fig. 8&9) show that the points are concentrated in the A1 tier of block A indicating Z>T>R. But samples of Naharkatiya well are clustered in the A1, A2 and C2 tier that points to their derivation from a separate source or mixing of sediments.

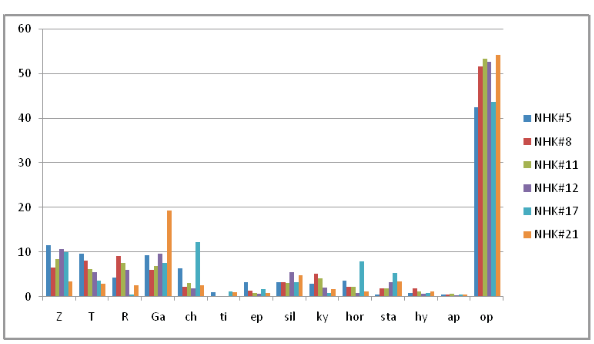
Moreover, the percentage of chlorite is 12.53-16.81 for the sediments of Dhola, Dum Duma and ChotaTingrai indicating an igneous source. On the contrary percentage of chlorite in Naharkatiya sediments is low (4.73), which indicates low rank metamorphic source. So it can be inferred that the source of Naharkatiya sediments is different to that of other three wells.

Table4: Heavy mineral distributoin of the sediments of Naharkatiya and Dhola wells

Well No.	Sample no.	Z	T	R	Garnet	chlorite	titanite	epidote	sillimanite	kyanite	hornblende	staurolite	hypersthene	apatite	opaque
NAHARKATIYA	NHK#5	11.54	9.61	4.40	9.34	6.32	1.09	3.30	3.30	3.02	3.57	0.55	0.82	0.55	42.58
	NHK#8	6.52	8.15	9.24	5.98	2.17	0.00	1.36	3.26	5.16	2.17	1.90	1.90	0.55	51.63
	NHK#11	8.50	6.29	7.55	6.92	3.14	0.00	0.94	3.14	4.09	2.20	1.88	1.26	0.63	53.46
	NHK#12	10.67	5.49	6.10	9.76	1.83	0.00	0.61	5.49	2.13	0.91	3.35	0.61	0.30	52.74
	NHK#17	9.97	3.63	0.60	7.55	12.34	1.26	1.81	3.32	0.90	7.88	5.44	0.91	0.60	43.81
	NHK#21	3.43	2.86	2.57	19.45	2.57	1.12	0.86	4.86	1.71	1.14	3.43	1.14	0.57	54.29
DHOLA	DHL#6	12.50	1.79	0.90	10.71	9.82	2.08	2.68	5.65	1.78	8.63	6.25	0.90	0.60	35.71
	DHL#9	10.87	2.80	2.48	8.70	15.53	2.48	0.62	2.80	2.17	6.83	2.80	0.00	0.31	41.61
	DHL#13	12.70	4.33	0.93	7.12	7.43	1.55	1.55	2.47	2.16	9.29	4.64	0.62	0.31	44.90
	DHL#15	8.83	3.78	0.95	2.52	26.18	1.58	0.00	2.52	0.63	7.89	3.15	0.32	0.32	41.32
	DHL#19	8.17	2.29	0.98	2.94	13.07	2.94	1.30	2.28	0.65	3.27	3.60	0.65	0.33	57.52
	DHL#21	9.63	2.06	1.03	3.78	10.31	2.40	1.37	2.40	1.03	4.47	7.22	0.69	0.34	53.26
	DHL#23	10.53	2.81	1.75	3.51	11.93	2.11	1.05	3.51	0.70	4.91	4.21	0.00	0.35	52.63
	DHL#24	10.46	2.71	1.55	3.10	9.69	1.94	0.78	2.71	1.16	4.65	3.88	0.78	0.39	56.20
	DHL#25	10.70	1.85	1.11	3.32	8.85	2.21	1.11	2.21	0.74	4.06	4.80	0.00	0.00	59.04

Table 5: Heavy mineral distribution of the sediments of Chotatingrai and Dum Duma wells

Well no.	Sample no.	Z	T	R	Garnet	chlorite	titanite	epidote	sillimanite	kyanite	hornblende	staurolite	hypersthene	apatite	opaque
CHOTA TINGRAI	CH.TNG#5	11.76	4.02	1.24	0.93	12.38	1.85	0.93	2.17	1.24	4.64	3.72	0.31	0.62	54.18
	CH.TNG#7	9.23	1.47	0.74	4.06	16.24	1.47	1.11	0.74	0.74	3.32	6.64	0.00	0.74	53.50
	CH.TNG#9	6.94	1.74	0.69	5.55	19.09	1.30	0.00	2.43	0.69	9.38	1.39	0.35	0.00	50.35
	CH.TNG#13	6.48	2.16	1.23	25.31	8.95	0.62	0.62	1.54	0.62	2.78	5.56	0.62	0.31	43.20
	CH.TNG#17	6.86	1.44	0.72	4.69	20.58	1.44	1.08	0.72	1.08	4.69	3.25	0.72	0.36	52.36
	CH.TNG#19	5.25	2.80	1.75	4.89	20.63	1.75	1.05	1.39	0.69	3.15	2.10	1.04	0.35	53.15
	CH.TNG#21	7.22	1.81	1.44	4.33	18.05	2.17	1.08	1.08	0.72	3.61	2.53	0.00	0.00	55.96
	CH.TNG#23	5.26	2.11	1.05	4.91	18.60	2.46	0.70	1.05	0.70	4.21	2.11	0.35	0.35	56.14
DUMDUMA	DMA#7	8.14	2.93	2.61	13.36	9.45	2.61	0.65	1.30	0.65	2.93	3.26	0.65	0.65	50.81
	DMA#9	7.00	2.00	1.33	3.33	23.00	2.67	2.00	1.00	0.67	3.33	2.33	1.00	0.33	50.00
	DMA#11	5.02	1.79	0.72	2.15	25.09	2.51	0.36	1.43	0.72	0.72	1.08	1.08	0.36	56.97
	DMA#15	5.57	2.79	2.79	23.83	7.12	0.93	0.62	5.57	2.48	1.24	1.86	0.62	0.31	44.27
	DMA#17	6.97	2.44	1.05	2.44	20.21	2.44	4.53	1.39	1.05	0.69	1.05	0.69	0.69	54.36
	DMA#19	8.53	3.88	2.33	1.94	15.50	2.33	5.43	1.94	0.76	0.78	1.94	0.39	0.00	54.25
	DMA#21	6.67	2.59	2.22	2.22	14.07	1.85	6.30	1.48	0.74	0.74	2.22	0.37	0.74	57.78



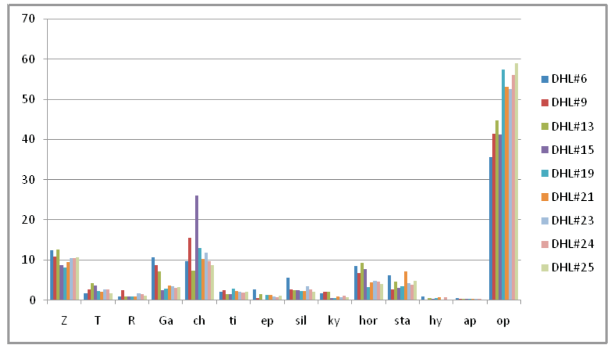


Fig. 10: Percentages of the different heavy minerals present in the sediments of the Naharkatiya and Dhola wells.

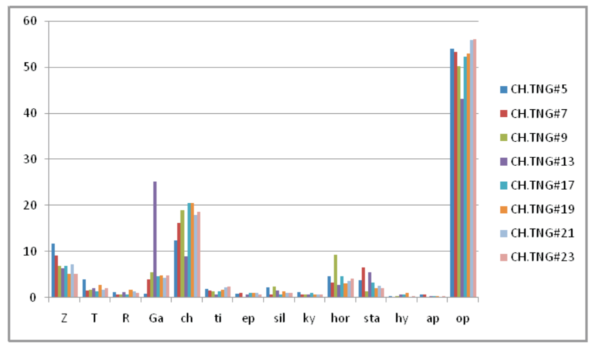


Fig. 11: Percentages of the different heavy minerals present in the sediments of theChota Tingrai and Dum Duma wells

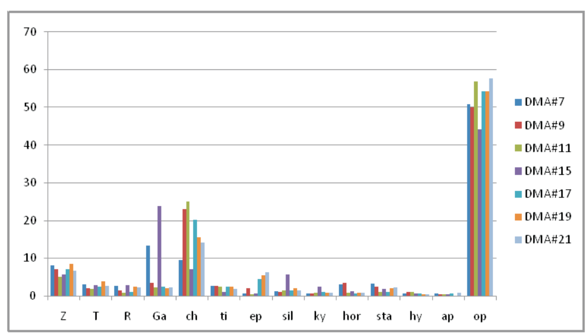


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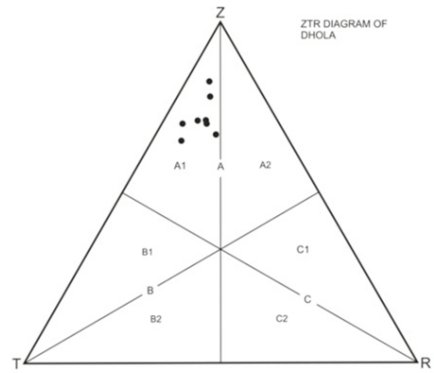
Table 7: Average heavy mineral distribution of the four wells

Heavy Mineral	Dhola	Dum Duma	ChotaTingrai	Naharkatiya
Zircon	10.49	6.84	7.38	8.44
Tourmaline	2.71	2.63	2.20	6.01
Rutile	1.30	1.86	1.11	5.08
Garnet	5.08	7.04	6.83	9.83
Chlorite	12.53	16.35	16.81	4.73
Titanite	2.14	2.20	1.63	0.58
Epidote	1.16	2.84	0.82	1.48
Sillimanite	2.95	2.02	1.39	3.90
kyanite	1.22	1.01	0.81	2.83
Hornblende	6.00	1.50	4.47	2.98
Staurolite	4.51	1.96	3.41	2.76
hypersthene	0.50	0.69	0.42	1.11
Apatite	0.33	0.44	0.34	0.53
opaque	49.13	52.63	52.36	49.75



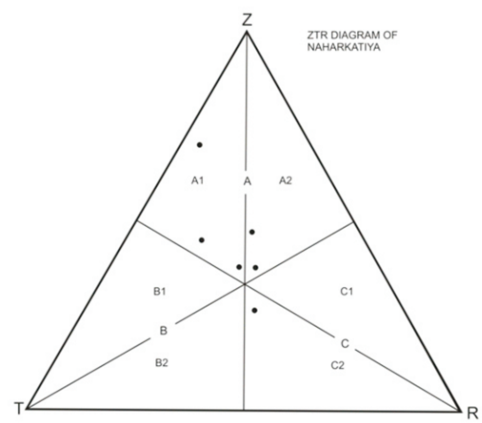
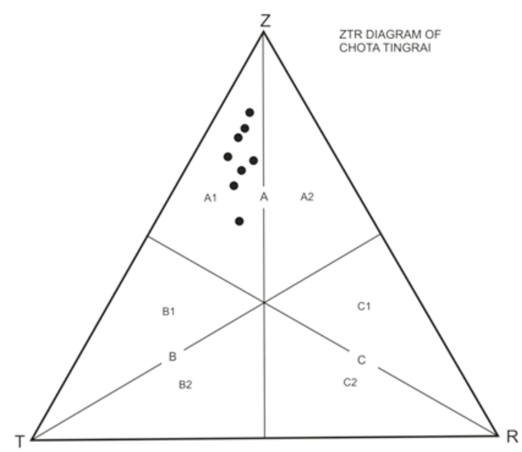


Table 6: ZTR maturity index and recalculated percentage of the sediments of Naharkatiya, Dhola, ChotaTingrai and Dum Duma wells

Well no.	Sample no.	Actual percentage of zircon(Z), Tourmaline(T), rutile(R)				Recalculated percentage of zircon(Z),tourmaline(T) and rutile(R)			
		Z	T	R	ZTR maturity index	Z	T	R	Total
NAHARKATIYA	NHK#5	11.54	9.61	4.40	25.55	45.17	37.61	17.22	100.00
	NHK#8	6.52	8.15	9.24	23.91	27.27	34.09	38.64	100.00
	NHK#11	8.50	6.29	7.55	22.34	38.05	28.15	33.80	100.00
	NHK#12	10.67	5.49	6.10	22.26	47.93	24.66	27.40	99.99
	NHK#17	9.97	3.63	0.60	14.20	70.21	25.56	4.23	100.00
	NHK#21	3.43	2.86	2.57	8.86	38.71	32.28	29.01	100.00
DHOLA	DHL#6	12.50	1.79	0.90	15.19	82.30	11.78	5.92	100.00
	DHL#9	10.87	2.80	2.48	16.15	67.31	17.34	15.35	100.00
	DHL#13	12.70	4.33	0.93	17.96	70.71	24.11	5.18	100.00
	DHL#15	8.83	3.78	0.95	13.56	65.12	27.87	7.01	100.00
	DHL#19	8.17	2.29	0,98	11.44	71.42	20.01	8.57	100.00
	DHL#21	9.63	2.06	1.03	12.72	75.71	16.20	8.09	100.00
	DHL#23	10.53	2.81	1.75	15.09	69.78	18.62	11.60	100.00
	DHL#24	10.46	2.71	1.55	14.72	71.06	18.41	10.53	100.00
	DHL#25	10.70	1.85	1.11	13.66	78.33	13.54	8.12	99.99
CHOTA TINGRAI	CH.TNG#5	11.76	4.02	1.24	17.02	69.10	23.62	7.28	100.00
	CH.TNG#7	9.23	1.47	0.74	11.44	80.68	12.85	6.47	100.00
	CH.TNG#9	6.94	1.74	0.69	9.37	74.07	18.57	7.36	100.00
	CH.TNG#13	6.48	2.16	1.23	9.87	65.65	21.88	12.46	99.99
	CH.TNG#17	6.86	1.44	0.72	9.02	76.05	15.96	7.98	99.99
	CH.TNG#19	5.25	2.80	1.75	9.80	53.57	28.57	17.86	100.00
	CH.TNG#21	7.22	1.81	1.44	10.47	68.96	17.29	13.75	100.00
	CH.TNG#23	5.26	2.11	1.05	8.42	62.47	25.06	12.47	100.00
DUMDUMA	DMA#7	8.14	2.93	2.61	13.68	59.50	21.42	19.08	100.00
	DMA#9	7.00	2.00	1.33	10.33	67.76	19.36	12.87	99.99
	DMA#11	5.02	1.79	0.72	7.53	66.67	23.77	9.56	100.00
	DMA#15	5.57	2.79	2.79	11.15	49.96	25.02	25.02	100.00
	DMA#17	8.53	3.88	2.33	14.74	57.87	26.32	15.81	100.00
	DMA#19	6.67	2.59	2.22	11.48	58.10	22.56	19.34	100.00
	DMA#21	6.97	2.44	1.05	10.46	66.63	23.33	10.04	100.00



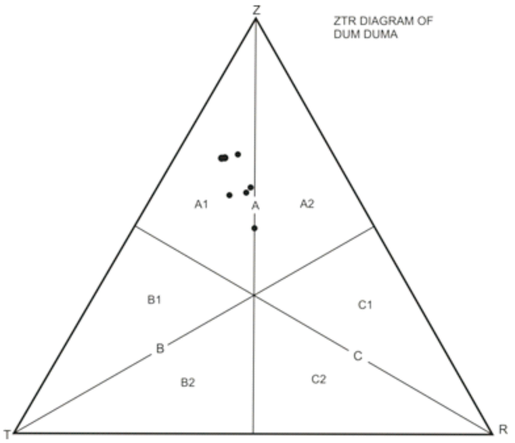


Fig. 9: ZTR Diagram of ChotaTingrai and Dum Duma

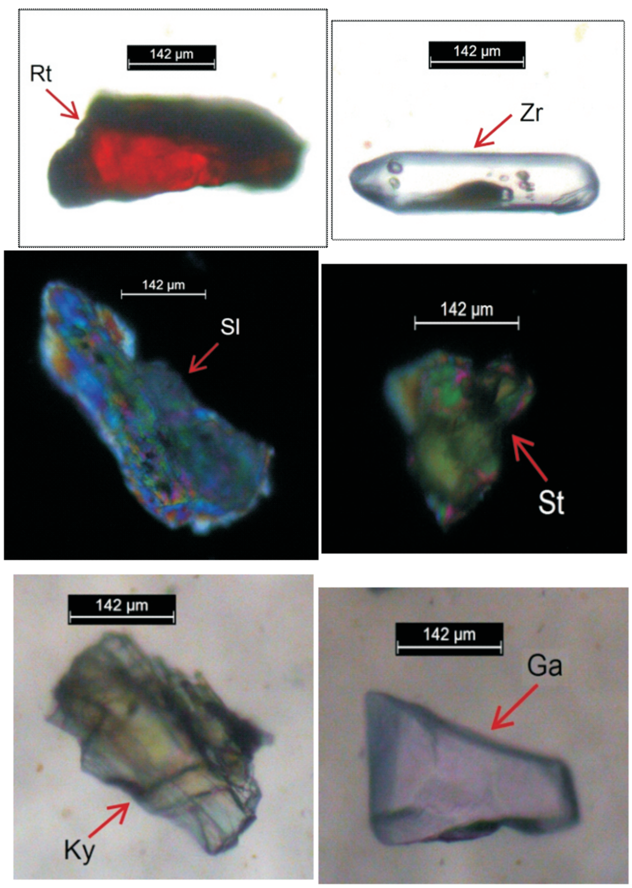


Fig. 12: Representative photomicrographs of heavy minerals: (a) rutile (b)zircon (c)sillimanite (d) staurolite (e) kyanite (f) garnet.

Table 2 : Sub populations in grain size distributionof sediments(in percent)

well	Sample no.	Traction population	Saltation population		Suspension population	Traction	Saltation	Suspension	Phi (φ) value	
			A	B					Coarse truncation	Fine truncation
NAHARKA TIYA	NHK#10	25	56	24	67	17.6	68.2	14.2	0.5	4.3
	NHK#12	63	56	16	52	10.5	71.7	17.8	0.1	4
	NKH#14	44	74	23	57	12.7	74.4	12.9	1.5	4.6
	NHK#16	44	62	23	63	15	73.4	11.6	0.5	4.5
DHOLA	DHL#4	45	--	68	25	16.4	35.4	48.2	0.5	2.4
	DHL#12	28	--	51	28	17	36	47	0.6	2.3
	DHL#18	47	72	31	70	34.1	56.9	9	1.4	4.4
	DHL#22	8	58	15	68	16.4	69.6	14	0.5	4.2
CHOTA TINGRAI	CHTNG#6	45	68	28	56	18.9	66	15.1	0.6	4.2
	CHTNG#8	30	60	19	56	17.9	67	15.1	0.5	4.2
	CHTNG#20	30	60	20	60	17.9	65.3	16.8	0.5	4.1
	CHTNG#22	15	59	23	63	17.9	69.2	12.9	0.5	4.4
DUM DUMA	DMA#12	39	62	16	53	20	50.6	29.4	0.5	3.4
	DMA#16	47	--	62	34	24.1	36.3	39.6	0.5	2
	DMA#18	41	62	26	50	20	54.6	25.4	0.5	3.9
	DMA#20	39	58	21	53	20	54.6	25.4	0.5	3.9

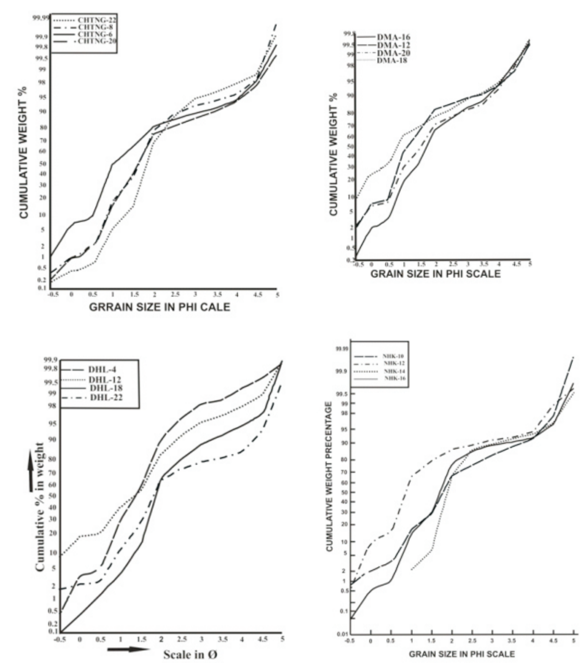


Fig. 2: Representative cummulative curves of the sample from the wells of ChotaTingraI, Dum Duma, Dhola and Naharkatiya

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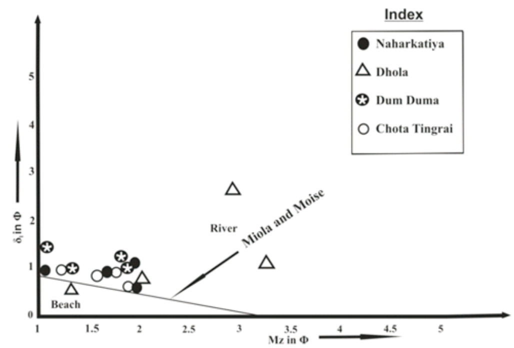

Fig. 3: Plot of mean size vs Standard Deviation

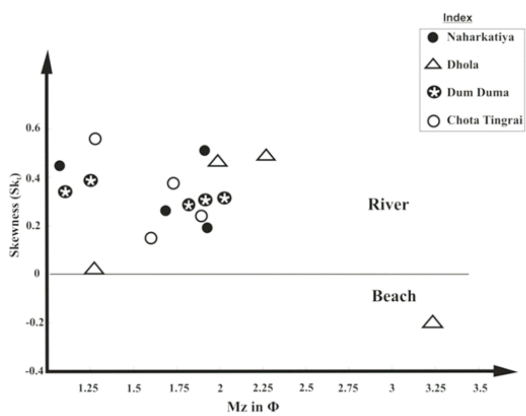

Fig. 4: Plot of mean size vsSkewness

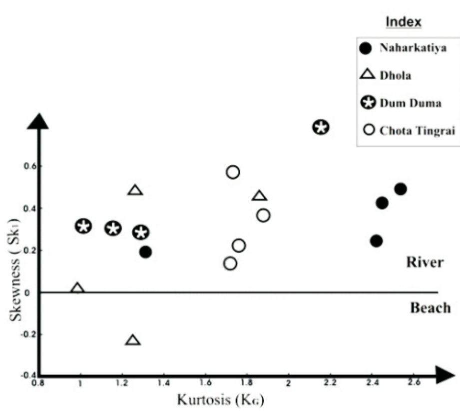

Fig. 5.Plot of Skewness vs Standard deviation

CONCLUSIONS:

The grain size distribution of the subsurface sediments reveals that the sorting of different size fractions varies in limited range; the shape, slope of the cumulative curves resembles to that of fluvial deposits having poorly sorted admixtures of variable amount of saltation and suspension subpopulations with low amount of rolling subpopulation.

From the calculation of size parameters it shows that the mean grain size of Naharkatiya, Chotatingrai and Dum Duma well samples are medium sand and that of the sediments of Dhola well is fine to medium grained, poorly to moderately well sorted. The samples are in general very fine skewed with minor (6.25%)) fractions of coarsely skewed sediments. The The frequency of very leptokurtic sediments are the maximum (43.75%) and platykurtic sediment is minimum (6.25%) as observed from all the wells. The bivariate plts reveal that the values of standard deviation decreases with increase in mean size; the skewness values are not widely scattered but mean and kurtosis vary widely. These features indicate fluctuations in flow energy conditions during transport in unidirectional flow regime.

It is observed that the alluvial sediments of the study area cluster in the field of fluvial domain of the CM plot. The angle between the different segments of the fluvial domain in which the sediment samples projections are grouped and the C=M line have comparable values to the basic CM pattern. Most of the samples are projected in O/P segment of the sectors II and III, which indicate mainly rolled sediments with minor suspension sediments. The rest of the samples fall in the P/Q and O/N segments of the sectors IV and V, which represent bottom load graded suspension with minor rolled sediments having C<1mm. This indicates the mixing of very fine sand to medium sand as graded suspension with a little contribution of coarse grained sand by rolling in the admixture.

The heavy mineral study reveals the sediments are mineralogically immature except the ssediments of Naharkatiya well. High percentage of garnet and epidote and the presence of staurolite, kyanite and sillimanite within the heavy mineral assemblage indicate that the source area having high grade metamorphic rocks such as schist and gneiss have contributed the supply of detritus.. Presence of rutile indicates their derivation from acid igneous and crystalline metamorphic rocks. Igneous source is also indicated by the presence of prismatic and angular zircon grains and high percentage of opaque minerals Subhedral and rounded zircon grains indicate their derivation from reworked sedimentary sources. The colourless grains of zircon indicate their derivation from metamorphic source.

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