Research Article

Sedimentological studies of tertiary rocks from west coast of Maharashtra India

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Abstract

Introduction: Megascopic and microscopic characters, granulometric studies and size analysis of Ratnagiri area revealed that Tertiary sediments are constituted of loosely cemented gravely sandstone, gray shale, carbonaceous shale and lignite. These sediments are ill-sorted and include rock fragments of laterite and basalt. Skewness and kurtosis plots inferred the estuarine environment prevailed at the time of deposition of these sediments.
Keywords: gravely sandstone, shale, mean, mode, median, depositional environment.

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INTRODUCTION

The recent sediments of various environments deposited along the coast of Maharashtra have been studied by several workers (Sawant, 1980; Sawant and Sukthankar, 1985; Sukthankar, 1986 Kulkarni, 1993). The tertiary lignite beds 60 m. above the present sea level has been reported by Suryawanshi (1995). Occurrence of lateritic gravel beds and bouldery-pebbly-gravels below the sea level has been reported by Rajguru and Marathe (1985). The studies also indicated the occurrence of primary and secondary laterite around Ratnagiri, revealing the erosional surfaces, buried channels and fossil littoral deposits within a distance of about 2-3 km. from the present sea coast. These sediments differ in their compositions and textural characteristics decipher source and depositional environment.

Geology of Study area

The study area is a coastal tract which lies between Jaigarh creek in the North (Latitude 17^0 10' N and Longitude 73^0 25' E) to Pavas creek in the south (Latitude 16^0 50' N and long. 73° 10' E). This area is covered in Toposheet number 47 G/3, G/7, G/8 and H/5 (Fig.1), which is composed of Deccan basalts, which are invariably capped by laterite and in subordinate amount of bauxite. The Tertiary sediments are sandwiched between two laterite and at places they are directly deposited on basalt. Very little attempts have been made study the Tertiary sediments which are exposed in the well sections around Gholap-Pawas plateau. The present investigation is aimed to know their environment of deposition with the help of sedimentological characters.

METHODOLOGY

The sediments were systematically sampled by collecting of sub-surface samples in the wells from different locations (Fig 1 and 2) by grid pattern method. In order to study the origin and nature of the sediments, mineralogical and granulometric studies were carried out using various techniques. Paulin's altimeter was used to determine the levels and thicknesses of the units.

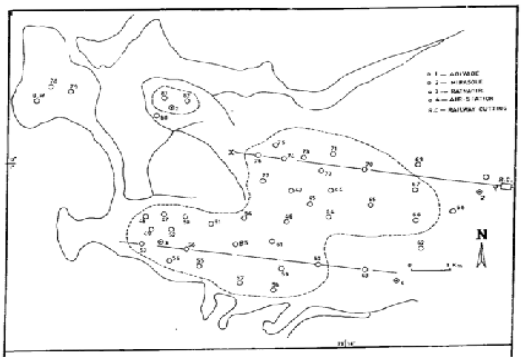

Figure 1a

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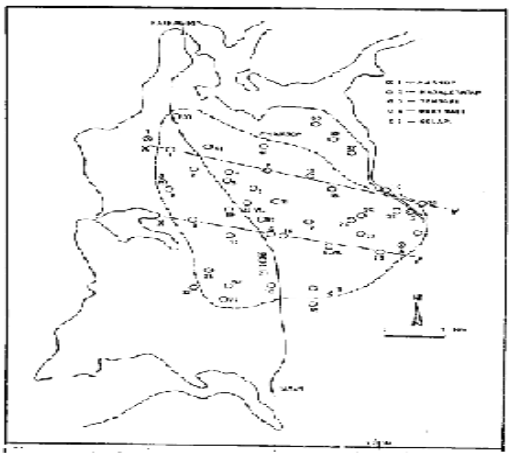

Figure 1b

Megascopic and Microscopic Observations

The Tertiary sediments are represented by sandstone, carbonaceous shale and gray shale along with lignite. Unconsolidated sandstone is exposed in the area around Ratnagiri. The sandstone shows many variations in the grain size, between -2.00 ϕ (Granules) to 1.00 ϕ (mud). The rock fragments of the coarse sandstone are of laterite, basaltic sand fragments with clay. These sediments are ill-sorted with gravels or pebbles of laterite and basalt, associated with argillaceous cement. In micro-sections, the texture of the gravelly sandstone shows polycrystalline grains of quartz along with lateritic grains. Rounded grains of lithic fragments of shale are observed in some samples. The fragments of shale enclosed in another shale fragment were also observed which indicates reworking of sediments. Three types of shale have been distinguished on the basis of colour viz. white, gray and black, they exhibit fine lamination 0.25 mm. to 0.50 mm. White shale contains more clay fraction and is composed of hydrated aluminous silicate. The gray shale is an admixture of carbonaceous matter and plant fibers. The black shale contains predominance of carbonaceous matter. In thin sections, the shales are fine-grained showing clastic texture. They comprise predominant argillaceous matter and clay minerals with a few fine grains of detritus quartz, anatase along with carbonaceous material and opaque's. Alternate thin layers of dark and light colours in shale are due to the presence of organic matter. Transparent, blue-coloured, well rounded detritus grains of anatase occur in almost all samples of shale. The well-rounded nature of anatase indicates extensive transportation before deposition. Crystals of secondary calcite are present in the cracks and bedding planes above lignite beds which is absent bellow lignite. Alternate coatings of calcite and ferruginous material were observed on a few rhombohedral grains.

Granulometric Analysis

Tertiary sediments are classified by measuring weights of gravel, sand and mud for ten selected samples. The weight percentage of it (Table 1) is plotted in triangular diagram (after Folk 1980) (Fig. 3) shows percentage of gravel ranges between 3.10 to 5.50, that of sand between 87.50 to 92.40 and mud 2.10 to 10.80 percentage which indicate sediments samples are of gravelly sand type.

Table 1: Weight percentage of gravel, sand and mud in the tertiary sediments

Sample No.	and Gravel	% Sand	% Mud
48	4.10	87.80	8.10
49	3.80	87.60	8.60
50	4.50	87.70	10.80
51	3.10	91.10	5.80
52	4.75	88.40	6.85
53	4.25	87.50	8.25
55	4.60	91.20	4.20
57	5.50	92.40	2.10
59	3.75	92.35	3.90
61	3.10	92.35	2.45

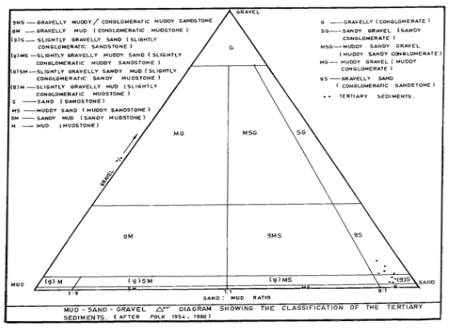

Figure 2

For granulometric analysis 50 gms. sample obtained by coning and quartering. The fraction was first treated with 10% dil. HCl, to remove the carbonates present in the sample and washed with distilled water till all the traces of acid were removed. The sample was then dried in an oven at 85^0 C temperatures and initial weight was taken. These samples were subjected to sieve analysis for which sieves arranged in half phi intervals. The sieves were subjected to sieving for about 30 minutes on a rotap shaker. The fraction retained on the individual sieves was weighed and their percentages were determined. From these percentages, cumulative weight percentage has been calculated and cumulative curves have been drawn. The data is shown in the Table No. 2.1, 2.2 and 2.3 and is also represented in the form of histograms (Fig. 3). From the cumulative curves an arithmetic probability scale, different percentile measures have been determined and are presented in Table No. 3. From these percentile measures, various statistical parameters as have been calculated suggested by Folk and Ward (1957).

Table 2.1: weight frquency (in grams) of the tertirary sediments

Sample No. Phi. Size	48	49	50	51	52	53	55	57	59	61
– 2.0	0.2639	0.3164	0.2759	0.3126	0.6293	0.2184	0.2345	0.8531	0.4750	0.4321
– 1.5	0.8743	0.9312	0.8069	0.8543	0.9987	1.2461	1.7126	1.1758	0.9326	0.8449
– 1.0	2.2136	2.1678	2.0919	4.0321	3.1864	2.9407	3.1545	3.8740	3.8694	2.8794
– 0.5	3.2431	3.0112	2.6989	4.8113	4.6749	4.2571	4.8576	4.2136	4.1537	4.5321
0.0	3.8493	3.9864	3.4778	5.7291	5.3480	5.4723	6.2136	4.9780	5.9450	6.1294
0.5	4.6524	4.3562	5.9287	6.4321	6.2403	7.1391	7.9424	6.2130	6.2436	6.9426
1.0	6.2134	6.0214	3.3710	5.9264	4.9873	5.2755	6.4305	7.4321	8.8035	4.8573
1.5	5.3184	5.1314	1.4807	3.8426	3.0123	3.1521	5.2316	3.8325	4.3210	3.1352
2.0	4.1329	3.1321	1.1275	1.2438	1.7134	1.0324	3.0425	2.0573	2.0516	1.9864
2.5	1.5243	1.0134	0.9118	1.2365	1.3632	1.0250	1.0052	1.1394	1.1372	0.7426
3.0	1.2745	0.9921	0.7529	0.9684	0.8465	0.9432	0.7264	0.5073	0.8645	0.4325
3.5	0.9272	0.9386	0.6933	0.7067	0.6867	0.8535	0.5461	0.2157	0.3150	0.2305
4.0	**0.6269**	**0.8748**	**0.4601**	**0.6420**	**0.3478**	**0.7745**	**0.4463**	**0.1918**	**0.2570**	**0.1850**

Table 2.2: Weight frquency (in percent) of the tertirary sediments

Sample No. Phi. Size	48	49	50	51	52	53	55	57	59	61
– 2.0	0.7515	0.9625	1.1470	0.8556	1.8490	0.6343	0.5643	2.3255	1.2714	1.2953
– 1.5	2.4899	2.8327	3.3545	2.3382	2.9343	3.6192	4.1224	3.2052	2.4963	2.6226
– 1.0	6.3040	6.5944	8.6967	11.0359	9.3622	8.5411	7.5914	10.5606	10.3571	8.6313
– 0.5	9.2359	9.1601	11.2203	13.1685	13.7356	12.3645	11.7139	11.4864	11.1180	13.5854
0.0	10.9622	12.1266	14.4584	15.6806	15.7133	15.8940	14.9631	13.5701	15.9127	18.3735
0.5	13.2493	13.2516	24.6477	17.6047	18.3351	20.7352	19.1135	16.9368	16.7120	20.8112
1.0	17.6948	18.3171	14.0144	16.22505	14.6535	15.3224	15.4751	20.2056	18.2107	14.5602
1.5	15.1460	16.6098	6.1558	10.5172	8.8506	9.1551	12.5899	10.4475	11.5658	9.3981
2.0	11.7699	9.5278	4.6874	3.4043	5.0343	2.9986	7.3219	5.6083	5.4914	5.9544
2.5	4.3409	3.0827	3.7907	3.3815	4.0053	2.9770	2.4191	3.1060	3.0439	2.2260
3.0	3.6296	3.0179	3.1307	2.6505	2.4871	2.7394	1.7480	1.3829	2.3139	1.2965
3.5	2.6405	2.8552	2.8823	1.9342	2.0176	2.5789	1.3142	0.5880	0.8435	0.6909
4.0	**1.7855**	**2.6616**	**1.8147**	**1.2083**	**1.0221**	**2.4403**	**1.0732**	**0.5771**	**0.6633**	**0.5549**

Table 2.3: Cumulative percent frequency of the tertrary sediments

Sample No. Phi. Size	48	49	50	51	52	53	55	57	59	61
– 2.0	0.7515	0.9625	1.1470	0.8556	1.8490	0.6343	0.5643	2.3255	1.2714	1.2953
– 1.5	3.2404	3.7952	4.5015	3.1938	4.7833	4.2535	4.6867	5.5307	3.7677	3.9179
– 1.0	9.5454	10.3896	13.1982	14.2297	14.1455	12.7946	12.2781	16.0913	14.1248	12.5492
– 0.5	18.7813	19.5497	24.4185	27.3982	27.8811	25.1591	23.9920	27.5777	25.2428	26.1346
0.0	29.7435	31.6763	38.8769	43.0788	43.5944	41.0531	38.9451	41.1478	41.1555	44.5081
0.5	42.9928	44.9279	63.5246	60.6835	61.9295	61.7883	58.0586	58.0846	57.8675	65.3193
1.0	60.6876	63.2450	77.5390	76.9040	76.5830	77.1107	73.5337	78.2902	76.0782	79.8795
1.5	75.8336	78.8548	83.6948	87.4212	85.4336	86.2658	86.1236	88.7377	87.6440	89.2776
2.0	87.6035	88.3826	88.3822	90.8255	90.4679	89.2644	93.4455	94.3460	93.1354	95.2320
2.5	91.9444	91.4653	92.1729	94.2070	94.4732	92.2414	95.8646	97.4520	96.1793	97.4580
3.0	95.5740	94.4852	95.3030	96.8575	96.9603	94.9808	97.6126	98.8349	98.4932	98.7545
3.5	98.2145	97.3384	98.1853	98.7917	98.7979	97.5597	98.9268	99.4229	99.3367	99.4451
4.0	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

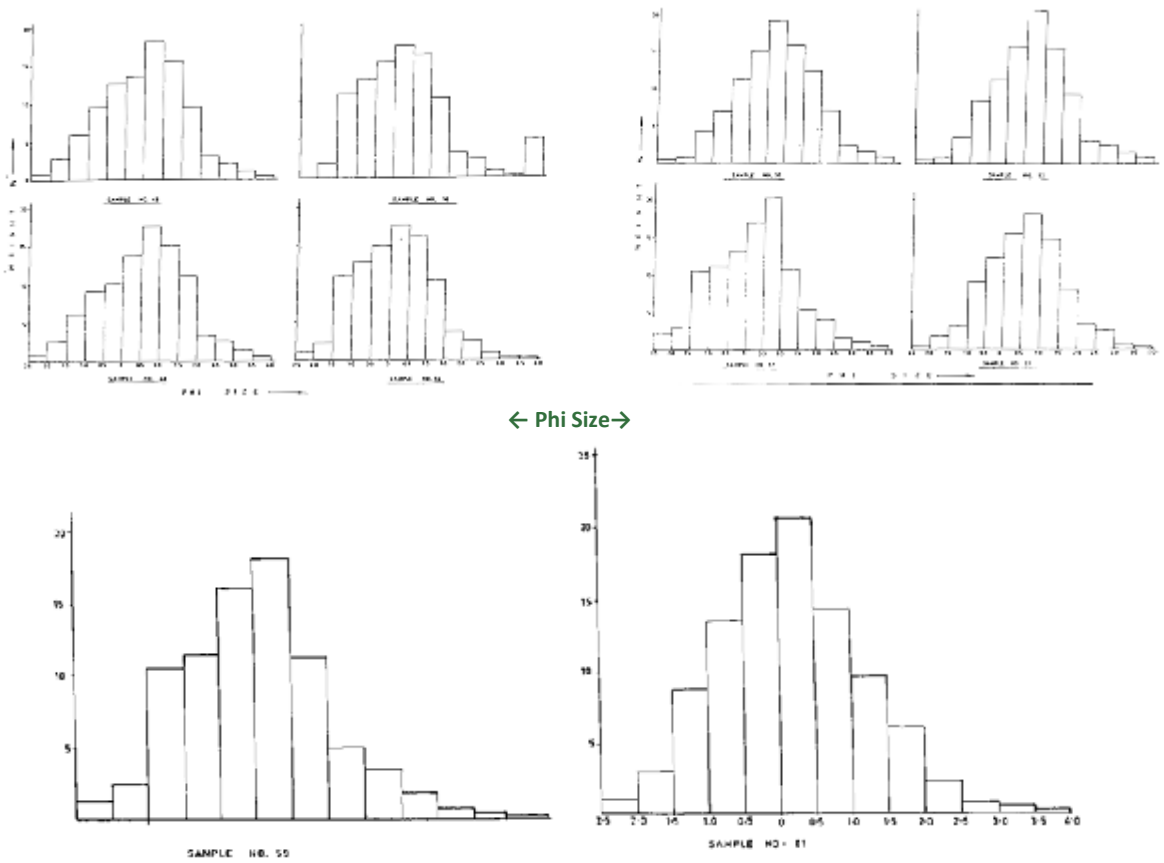

Figure 3: Weight percentage Vs Phi size

Table 3: The percentile measuresfrom the cumulative curves of mechanical analysis of the tertiary sediments

Sample No.	5 %	16 %	25 %	50%	75%	84%	95%
48	– 0.76	– 0.23	– 0.25	0.70	1.93	2.25	3.50
49	– 1.30	– 0.62	– 0.22	0.75	1.55	1.80	3.25
50	– 0.70	– 0.85	– 0.45	0.25	1.10	1.45	3.70
51	– 1.25	– 0.80	– 0.37	0.24	1.00	1.40	2.85
52	– 1.40	– 0.85	– 0.50	0.25	0.95	1.50	3.40
53	– 1.30	– 0.90	– 0.50	0.30	0.80	1.45	3.35
55	– 1.50	– 0.80	– 0.45	0.25	1.10	1.35	2.50
57	– 1.65	– 0.90	– 0.40	0.35	1.00	1.25	2.12
59	– 1.35	– 0.88	– 0.50	0.30	1.00	1.12	2.35
61	**– 1.50**	**– 0.80**	**– 0.65**	**0.20**	**0.85**	**1.25**	**2.00**

Graphical parameters

The different statistical parameters viz., mean size, standard deviation, skewness and kurtosis have been calculated and presented in Table No. 4. These parameters are influenced by the average velocity of their depositing agent, wave conditions, geomorphology of the depositional site, nature of the provenance and environment of deposition. However, these statistical parameters have been proved to be suggestive of the environments under which a particular sediment or sedimentary rock has been deposited. The cumulative weight frequency has been plotted on arithmetic probability paper for all the samples, and presented in Figs. 4. From these plots coarse and fine truncation points and also traction, saltation and suspension populations have been found-out by following a procedure suggested by Visher (1969) and are presented in Table No. 5.

Table 4: Graphic measures from the grain size analysis of the tertiary sediments

Sample No.	Median	Mean	Deviation	Skewness	Kutosis	Simple Sorting	Simple Skewness
48	0.70	0.906	1.2654	0.3122	0.8082	2.13	1.37
49	0.75	0.643	1.2943	– 0.0167	1.2853	2.275	0.975
50	0.25	0.280	1.1712	0.1637	1.2265	1.70	1.00
51	0.24	0.283	1.0901	0.2422	0.8989	2.05	0.80
52	0.25	0.316	1.3147	0.1881	1.3566	2.40	1.00
53	0.30	0.283	0.7045	0.3639	1.4659	2.325	1.025
55	0.25	0.266	1.1435	0.0741	1.0576	2.00	0.50
57	0.35	0.233	1.1087	0.0509	1.1036	1.885	0.235
59	0.30	0.213	1.0454	0.1316	0.9836	1.80	0.45
61	**0.20**	**0.200**	**1.0303**	**0.0434**	**0.95623**	**1.75**	**0.25**

Mean Size

The mean size is considered as the average size of the sediment and is indicative of the average velocity of the depositing agent. The mean size for the Tertiary sediments varies between 0.20 ϕ and 0.90ϕ, thus indicating variation in mean size. This suggests that there is more variation in the velocity of the depositing agent. From mean size, it can be said that the provenance and geomorphology had more influence at the time of deposition. In general, the mean size for all these samples shows much variation, which can be resulted either due to the changes in the velocity of the depositing agent or due to the digenetic changes.

Median

Median is the central tendency of the distribution. It is considered as a reflection of hydrodynamic conditions responsible for the deposition of particular sediment or it is used to find out variations in the hydraulic energy conditions. The median value varies between 0.20 ϕ and 0.70ϕ. There is much variation in the values of central tendency and are characteristic of agitated hydraulic energy regime. Further the values of central tendency indicate finer grain size of sediments and therefore, relatively lower is the hydraulic energy responsible for its deposition. These samples show much variation indicating agitated energy conditions prevailed during their deposition.

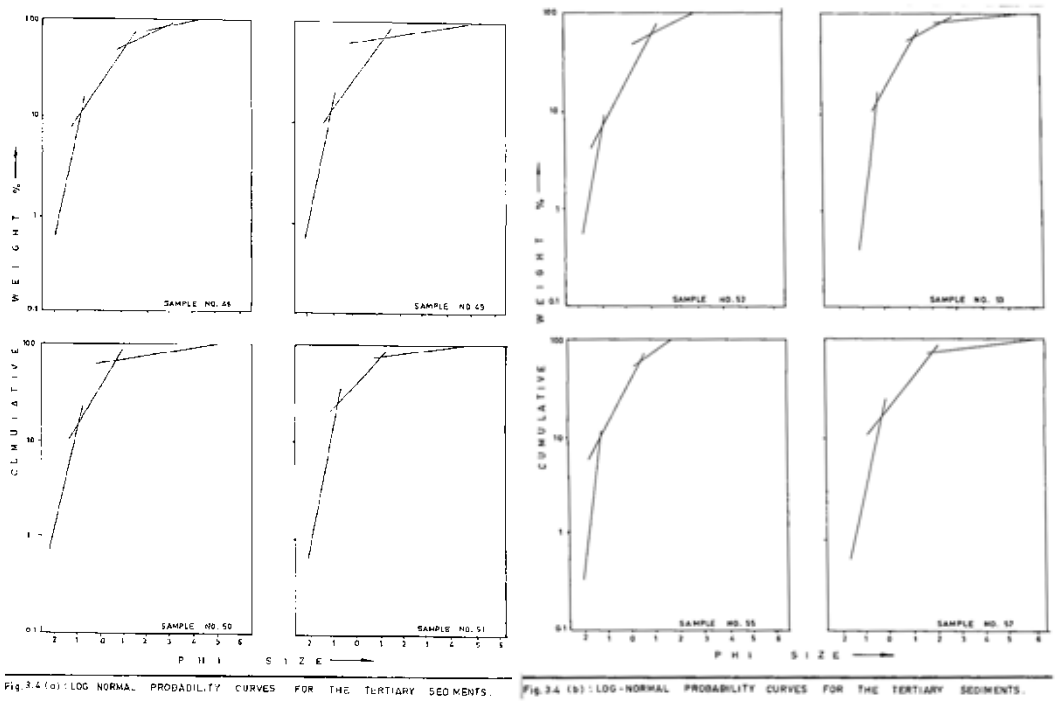

Fig. 3.4 (a) : LOG NORMAL PROBABILITY CURVES FOR THE TERTIARY SEDIMENTS.

Fig. 3.4 (b) : LOG-NORMAL PROBABILITY CURVES FOR THE TERTIARY SEDIMENTS.

Figure 4

Table 5: Grain size characteristics obtained from the log. normal probability plots of the tertiary sediments

Sample No.	Coarsetrunca	Fine trunca	Traction Popula	Saltation Population	Suspension Population
48	– 0.70	1.35	13.50	52.50	34.00
49	– 0.65	1.30	14.80	65.70	19.50
50	– 0.90	0.75	14.25	51.60	34.15
51	– 0.85	1.25	28.40	5760	14.00
52	– 1.50	2.00	6.51	49.46	44.03
53	– 1.25	0.75	12.50	60.80	26.70
55	– 1.20	1.10	9.10	71.80	19.10
57	– 1.15	1.00	16.25	63.75	20.00
59	– 0.90	1.10	19.25	65.50	15.25
61	**0.85**	**0.65**	**19.80**	**47.80**	**32.40**

Standard Deviation

The standard deviation measures sorting of sediments and fluctuations in the velocity conditions of the agent of deposition about its average velocity. Sorting has an inverse relation with the standard deviation values. Higher the values of standard deviation, poorer is the nature of sorting of sediments (Folk, 1974). The standard deviation values vary between 0.71 and 1.29 thereby suggesting that the majority of these sediments indicate the poor sorting in character. Standard deviation values of the sediments indicate that these are poorly sorted. However, sample collected from well No. 51 indicate, well sorting nature of the sediments.

Skewness

Skewness indicates the symmetry of the frequency distribution. It also suggests velocity fluctuations of the depositing medium. Most of the sediments, except one shows + ve skewness indicating that they are finely skewed. This implies that the velocity fluctuations towards the lower values occurred more often than normal.

Kurtosis

Kurtosis is another statistical parameter, which has been considered as a measure of peakedness of a frequency curve. It is a ratio between sorting in the "tails" of the distribution and sorting in the central portion of the distribution, thus kurtosis measures the sorting ratio. It implies that kurtosis does not provide information diagnostic of depositional environment of the sediments (Friedman, 1968). It is observed from the values that, there is no much variation in the velocity conditions. Based on the scale suggested by Folk (1974), tertiary sediments have the kurtosis values ranging between 0.8082 to 1.4659 suggests that, out of ten samples analysed, four sample sediments are showing mesokurtic nature, while, four samples are leptokurtic in nature and two are showing platy kurtic in nature. The inference drawn from the individual parameters for various samples have been presented in Table No.6. The various grain size statistical parameters of these sediments have been used in combination with one another to discriminate the possible environment under which the sediments have been deposited. For this purpose environmental bi-variate plots have been used i) Standard deviation Vs Skewness. ii) Skewness Vs Kurtosis.

Table 6: Interpretation of grain size measures of the tertiary sediments

Sample No.	Mean Size	Standard Deviation	Skewness	Kurtosis
48	C.S.	P.S.	F.S.	P
49	C.S.	P.S.	N.S.	L
50	M.S.	P.S.	F.S.	L
51	F.S.	P.S.	V.F.S.	P
52	M.S.	P.S.	F.S.	L
53	M.S.	P.S.	V.F.S.	L
55	M.S.	P.S.	N.S.	M
57	M.S.	P.S.	N.S.	M
59	M.S.	P.S.	F.S.	M
61	**F.S.**	**P.S.**	**N.S.**	**M**

Mean C.S. = Coase sand M.S. = Medium sand F.S. = Fine sand F.S. = Fine skeued
V.F.S. = Very fine skewed N.S. = Near svmmetrical P.S. = Poorly sorted
M.S. = Moderatelv sorted P = Palatykurtic M= Mesokurtic L= Leptokurtic

Simple sorting measure Vs simple skewness measure

The values of simple sorting measures and simple skewness measure have been calculated according to the formulae suggested by Friedman (1968).The values of so obtained for the tertiary sediments have been tabulated and are presented in Table No.4.The grain size bivariate plots, stated earlier, have been made for the Tertiary sediments and are presented graphically in Fig. 5, for standard deviation Vs. skewness, Skewness Vs kurtosis and simple sorting measure Vs simple skewness measure. From these plots, it has been observed that, these samples fall in mixed type of environment, while few fall in the fluvial environment.

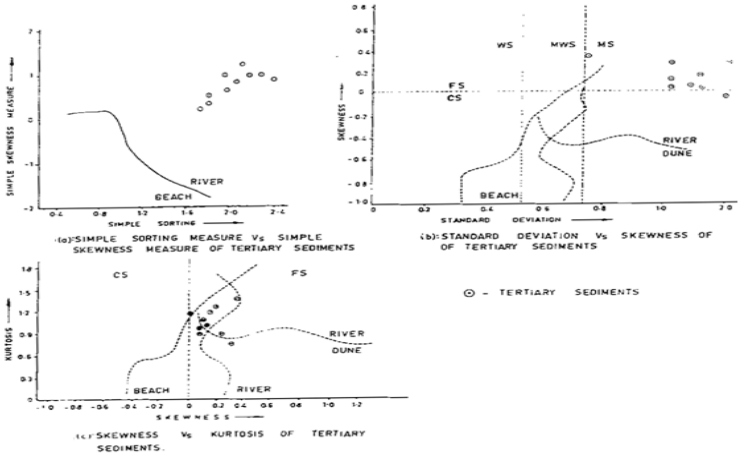

Figure 5

DISCUSSION AND CONCLUSION

Tertiary sediments are exposed at shallower depth on the eastern side of the area and upper surface of these sediments is exposed at about 67 to 70 m. above MSL. These loosely cemented gravely sandstone sediments are reworked secondary deposits. Wide range of mean size indicates fluctuation in velocity of depositing agent. There is variation in the central tendency of median indicate agitated hydraulic energy regime which is confirmed by slandered deviation. The statistical parameters infer that these sediments show mixed type of environment having hydraulic energy responsible for their deposition. From the foregoing discussion it is inferred that the estuarine environment prevailed at the time of deposition of these sediments.

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