"Nature, if she has any preference, probably takes more interest in the ratios between quantities; she is rarely concerned with size for the sake of size."

FRÁNCIS J. PETTIJOHN (1975)

5 GRANOLOMETRIC ANALYSIS

CHAPTER 5
GRANULOMETRIC ANALYSIS

GENERAL

Ever since the pioneering work of Krumbein (1937, 1938), grain size analysis of terrigenous sediments have served as an effective tool in deciphering the depositional environment of sediments and in determining the depositional process responsible for their formation. In the last four decades, studies by, Inman (1949, 1952). Passega (1957). Folk and Ward (1957), Stewart (1958), Moss (1962), Spencer (1963), Friedman (1961, 1967), Moiola and Weiser (1968), Gleister and Nelson (1974) and Sahu (1964, 1983) have underlined the importance of relationship between the grain size of clastic sediments and the environment in which they form and the processes that form them.

These studies have been applied in the present work with an aim to provide a separate line of evidence in interpreting the depositional environment of the clastic assemblage of the Lower Gondwana Group of rocks in the study area.

METHODOLOGY

The sediments analysed, include samples of sandstones, from the finest to the coarsest, from the four formations of the Lower Gondwana Group of the study area. To minimize the weathering effect, mainly core samples were selected In case of Talchir Formation and Upper Kamthi Member fresh surface samples were chosen. In all, 160 samples were subjected to grain size analyses.

The samples were disaggregated by using standard methods (Carver, 1971) and sieved at half phi interval, ASTM mesh. Data obtained from sieving were plotted as cumulative frequency curves on arithmetic probability papers, various graphic parameters (mean, standard deviation, skewness and kurtosis) were calculated by using Folk and Ward's (1957) formula.

The various aspects on grain size analysis vis-a-vis environment and/or processes are dealt separately for individual formation of the study area.

GRAIN SIZE DISTRIBUTION CURVES

Grain size distribution curves can be reoresented as :

- individual frequency distribution curve which gives a measure of excess, if any, of coarse or fine particles within a sediment sample and
- cumulative frequency curve which when plotted on a probability scale (vertical axis), points to different modes of sediment transport and deposition, thus providing a measure of their importance in the genesis of a sand unit.

C-M PATTERNS

C-M pattern, (Passega, 1957, 1964) is used as a tool to decipher transport history. It is a standard plot of two variables, - C, the one percentile and M, the 50th percentile - deduced from the grain size distribution curves. However, instead of selecting the values of variables in microns on a log-log paper, the present author has adopted the phi scale for the two variables without changing the shape of the C-M curve.

BIVARIANT DISCRIMINANT PLOTS

Standard bivariant discriminatory plots devised by Stewart (1958), Friedman (1967), and Moiola and Weiser (1968), by combination of two of the grain size parameters (mean size, median size, standard deviation, skewness, kurtosis) to understand the ancient environment of deposition, have been used for the Lower Gondwana sands of the study area.

Friedman's (1967) discriminatory plot using mean size and standard deviation is based on moment measures and may be little less a accurate when used with graphic parameters - but still, it has been used by many workers (Moshrif, 1980; Goldbery, 1980; Mahender and Banerjee, 1989).

Gleister and Nelson's (1974) bivariant plot of standard deviation (σ_I) vs. mean grain size (M_z) gives the textural maturity of sand as per the environment of deposition.

LOG-LOG PLOT

Sahu (1964) has shown that a log-log plot of mean phi-deviation of all samples on the ordinate against the ratio of standard deviation of kurtosis to standard deviation of mean size times the standard deviation of variance (σ_I^2) of all samples along the abscissa gives the best separation between such processes and environment of deposition as turbidites, fluvial (deltaic), shallow marine, beach and aeolian. The plot can be represented as :

$$\sqrt{\overline{\sigma_I}^2} \text{ against } \left\{ \frac{S_{K_G}}{S_{M_Z}} \cdot S(\sigma_I^2) \right\}$$

This plot which is useful only when two or more samples are available from the same unknown environment of deposition has been used for determining the environment of deposition for Lower Gondwana sands.

MULTIGROUP DISCRIMINATORY PLOT

Multigroup discriminatory plot (Sahu, 1983) among five depositional environments involves two variables viz vectors $\overline{V_1}$ and $\overline{V_2}$ which can be calculated by the following formulae.

$\overline{V_1}$ = 0.48048 X_1 + 0.62310 X_2 + 0.40602 X_3 + 0.44413 X_4

$\overline{V_2}$ = 0.24523 X_1 - 0.45905 X_2 + 0.15715 X_3 + 0.83931 X_4

Where X_1, X_2, X_3, X_4 are the four size statistics.

RESULTS

TALCHIR FORMATION

The Talchir Formation consists predominantly of diamictite and shale with interbedding sequence of sandstones. Seven surface samples of sandstone and two borewell samples from various levels within the Talchir Formation at different localities were subjected to grain size analyses, the results of which are tabulated, (Table 5.1).

Grain size parameters

The **mean diameter** of Talchir sands ranges from 1.65 phi to 2.93 phi with an average value of 2.31 phi which correspond to the fine sand category. **Standard deviation** values which gives a measure of the sorting, range from 0.46 phi to 1.22 phi with an average of 0.93 phi which falls in Folk's category of moderately sorted sand. The **skewness** of Talchir sands show more or less uniformity in value with a majority of them being fine skewed. Barring one sample, the **Kurtosis** values are all greater than 1 and are leptokurtic to very leptokurtic.

Grain size distribution curves

The individual grain size frequency distribution curves of Talchir sandstones show "open-ended" distribution, where, the pan-fraction, consisting of a sizeable proportion (maximum of 9 %) of fine silt and clay, constitute a fairly large amount of sediment distribution. This high proportion of silt and clay has rendered positive tail fraction to the frequency curves of the Talchir sands (Fig. 5.1 a). The presence of intergranular fines is also responsible for the poor sorting and bimodality of the Talchir sandstones. The primary mode is between 2 to 3 while the secondary mode lies in the range > 4.5 .

The cumulative frequency size distribution curves of Talchir sands can be broadly divided into three types of probability plots : **Type 1**, shows one inflection point between saltation and suspension loads; **Type 2**, exhibits two inflection points between traction and saltation and saltation and suspension loads and **Type 3**, with three inflection points has two saltation sub-populations. Out of 10 samples analysed, five show Type 3 size distribution, three show Type 2 and two exhibit Type 1 size distribution. The cumulative curves representing each type is shown (Fig. 5.1 b). In all the curves, saltation fraction is predominant, constituting about 70 to 90 % by weight of the sample. Suspension fraction varies between 10 to 20 % whereas in type 2 & 3 traction load constitutes about 1 to 10 % by weight of the sample. Particle size inflection at coarser end between traction and saltation (C.T. point) ranges

TABLE 5.1 : TEXTURAL PARAMETERS OF TALCHIR SANDS

Sample No.	Depth (m)	M_z	σ_1	Sk_1	K_G	$\Phi_1 = C$	$\Phi_{50} = M$	σ_1^2	$\overline{V}_1$	$\overline{V}_2$
		Folk and Ward (1957)				Passega (1957)		Sahu (1964)	Sahu (1983)	
C1/50	325.00	1.89 (M.G.)	0.98 (M.S.)	0.32 (V.F.S.)	1.66 (V.L.K.)	0.20	1.79	0.96	2.38	1.45
C1/51	340.00	2.61 (F.G.)	0.97 (M.S.)	0.19 (F.S.)	1.95 (V.L.K.)	0.55	2.50	0.94	2.80	1.86
BTL 1	Surface	2.93 (F.G.)	0.70 (M.S.)	0.46 (V.F.S)	1.25 (L.K.)	2.05	2.80	0.49	2.53	1.02
BTL 2	"	2.83 (F.G.)	1.10 (P.S.)	0.46 (V.F.S.)	0.89 (M.K.)	0.10	2.50	1.21	2.62	1.01
BTL 3	"	2.08 (F.G.)	0.82 (P.S.)	0.42 (V.F.S.)	1.72 (V.L.K.)	0.00	1.90	0.67	2.44	1.64
BTL 4	"	1.65 (M.G.)	0.46 (W.S.)	-0.10 (N.S.)	1.60 (V.L.K.)	0.37	1.70	0.21	1.73	1.52
KTL 1	"	2.45 (F.G.)	1.16 (P.S.)	0.27 (F.S.)	1.56 (V.L.K.)	0.40	2.35	1.34	2.70	1.42
KTL 2	"	2.02 (F.G.)	1.22 (P.S.)	0.15 (F.S.)	1.56 (V.L.K.)	-0.45	1.85	1.49	2.48	1.27
KTL 3	"	2.30 (F.G.)	0.62 (M.W.S.)	0.35 (V.F.S.)	1.17 (V.L.K.)	1.15	2.20	0.38	2.15	1.32

Note : C.G. - Coarse grained; M.G. - Medium grained; F.G. - Fine grained; V.F.G. - Very fined grained
W.S. - Well sorted; M.W.S. - Moderately well sorted; M.S. - Moderately sorted; P.S. - Poorly sorted
V.C.S. - Very coarse skewed; C.S. - Coarse skewed; N.S. - Near symmetrical; F.S. - Fine skewed; S.F.S./V.F.S. - Very fine skewed
P.K. - Platykurtic; M.K. - Mesokurtic; L.K. - Leptokurtic, V.L.K. - Very Leptokurtic

Same abbreviations are used in all subsequent tables.

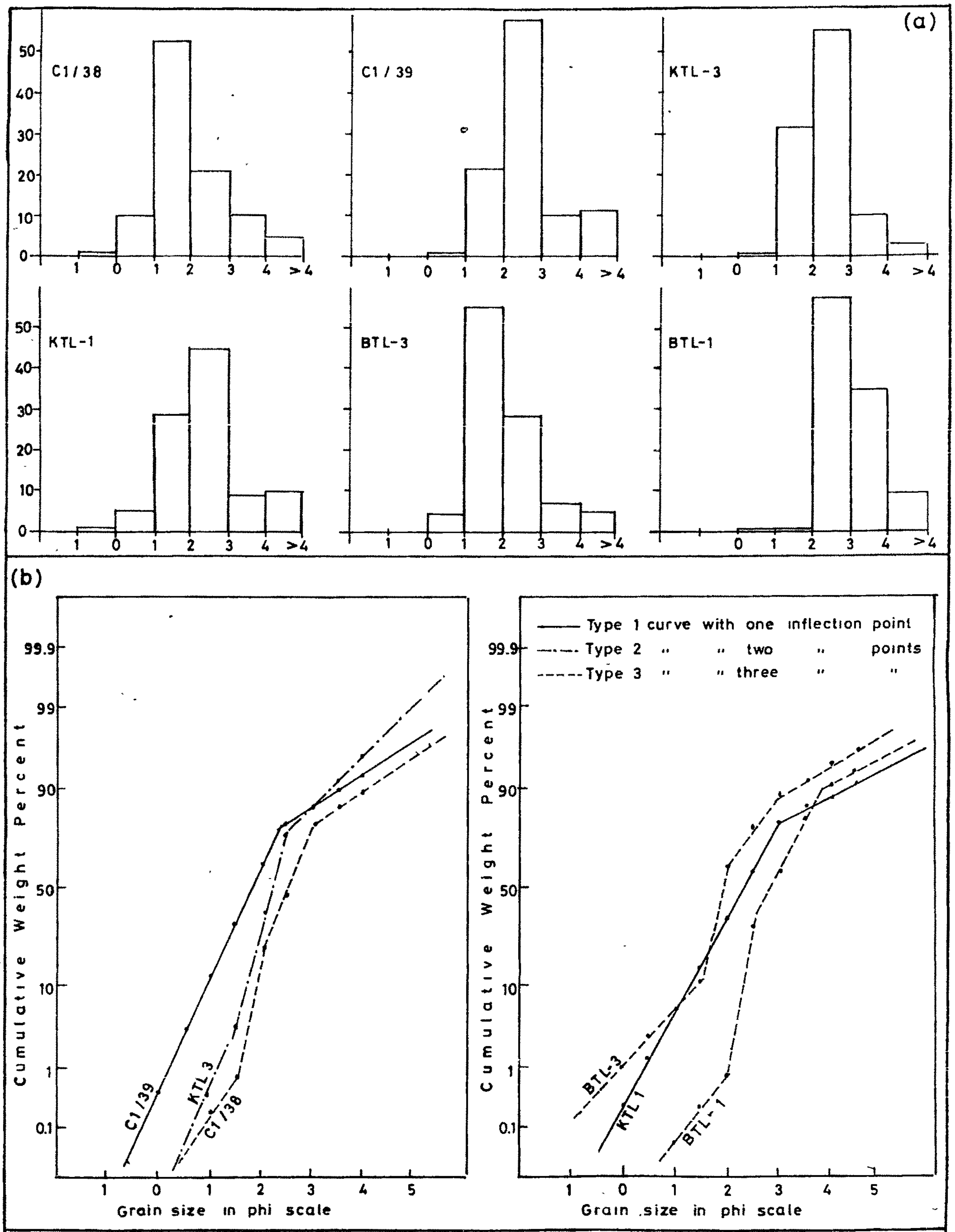

Fig.5.1 : Representative Histograms (a) and Cumulative frequency curves (b) of grain size distribution of Talchir sands.

between 1 phi to 2 phi and those between saltation and suspension (F.T. point) fall between 3 phi to 4 phi.

C-M Pattern

The C-M pattern of the Talchir sandstones shows that the points representing the samples are falling within the standard C-M pattern for tractive currents as devised by Passega (1957, 1964) (Fig. 5.2a). 65 % of the samples were transported and/or deposited by rolling and graded suspension while the rest had undergone graded suspension only. Another interesting feature observed in the Talchir sands is that 80 % of the samples analysed are having C-M pattern identical to that of undaturbidites (Fig.5.2 b) which has been described by Passega (1964) as the deposits of certain turbidity currents which still reflect the grain size distribution of tractive current sediments from which they originated.

Bivariant discriminant plots

Except one sample (BTL-4), all the other samples representing Talchir sandstones are falling in the river field of the Bivariant discriminatory plots devised by Friedman (1967) and Moiola and Weiser (1968) (Fig. 5.3), to discriminate between beach and river sands using mean size-standard deviation and skewness-standard deviation combinations.

Stewart's discriminatory plot (1958) between river and wave process shows that 45 % of Talchir sands were transported and/or deposited by river process (Fig. 5.4). The rest of the samples give inconclusive results.

Gleister and Nelson's (1974) bivariant plot of mean size and standard deviation gives the gradational change of depositional system within a fluvial regime. The Talchir sands are falling in the region intermediate between braided bar and delta front (Fig. 5.5).

Multigroup discriminatory plots

The multigroup discriminatory plots of Sahu (1983) show that except one, all Talchir sands are falling in the fluvial (river) field (Fig. 5.6).

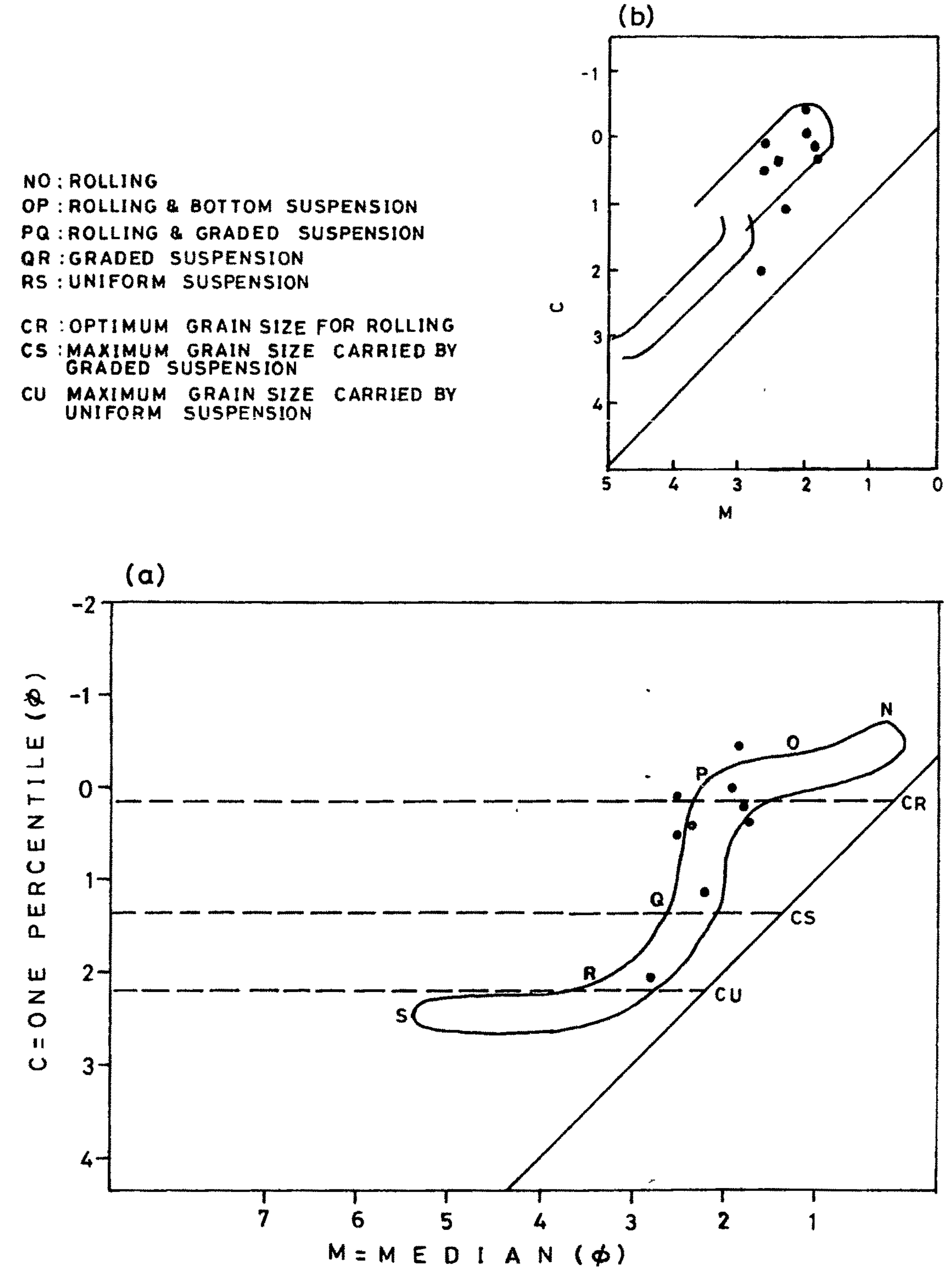

Fig.5.2: a) C-M Pattern of tractive current deposits showing sedimentary dynamics of Talchir sands

b) Figure showing Undaturbidite mechanism of transport for Talchir sands.

(After Passega, 1957, 1962)

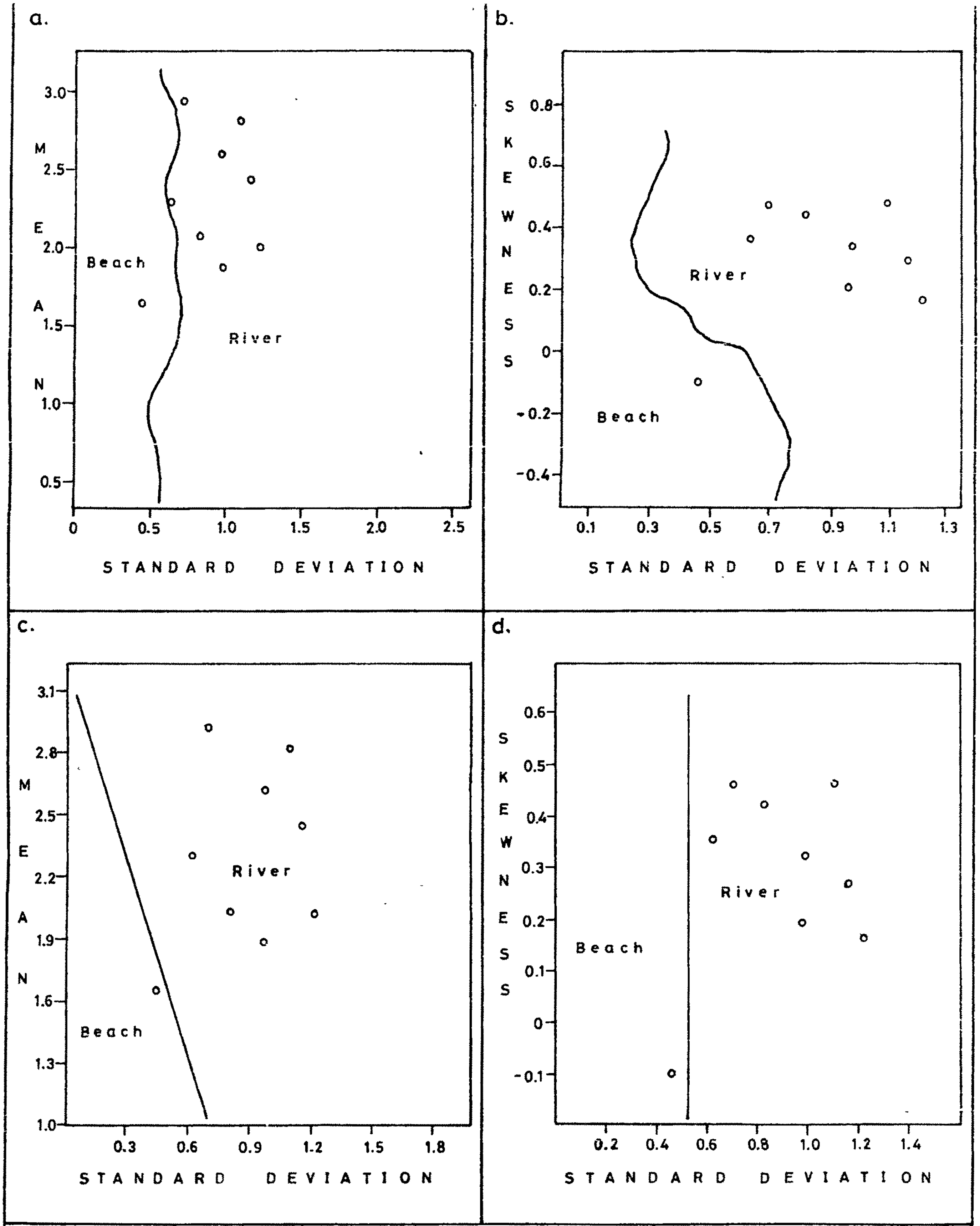

Fig. 5.3 : BIVARIANT PLOT: Mean against Standard Deviation and Skewness against Standard Deviation of Talchir sands.

(After Friedman, 1967, a & b; Moiola and Weiser, 1968, c & d)

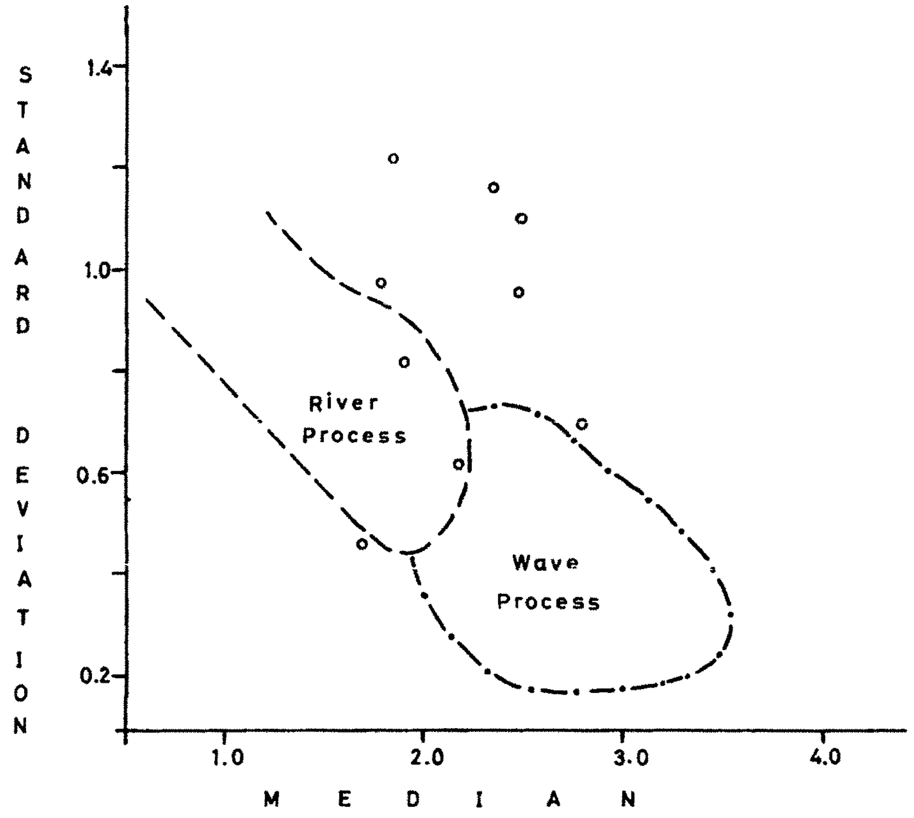

Fig.5.4 : Bivariant plot of Standard Deviation Vs. Median of Talchir sands. (After Stewart, 1958)

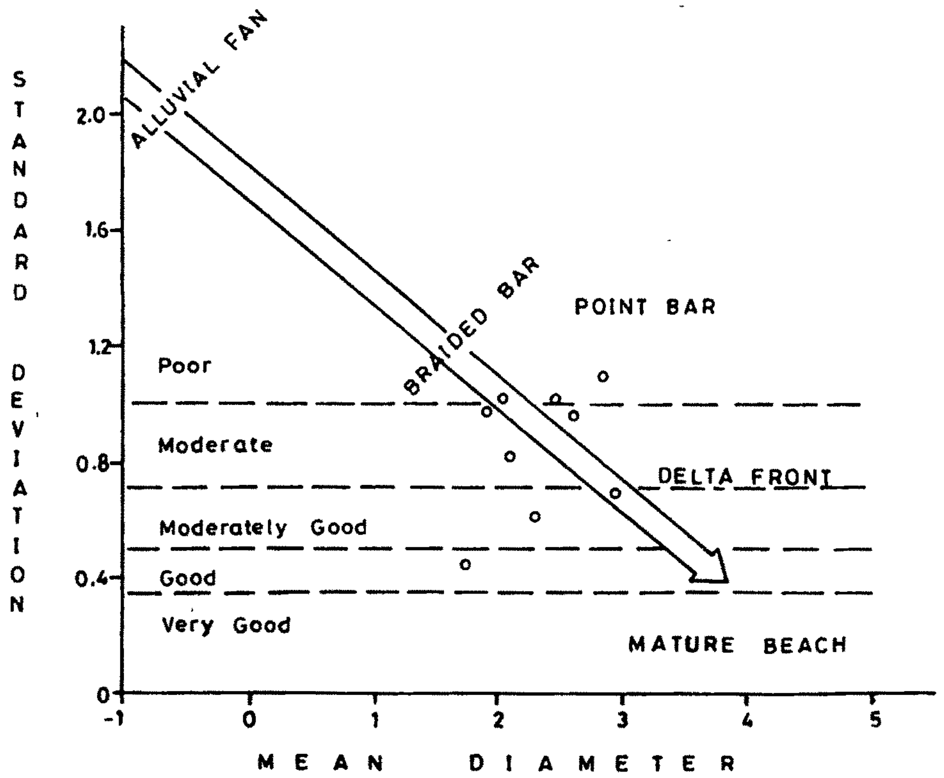

Fig.5.5 : Gradational change in Sorting and Grain size with environment of Talchir sands. (After Glaister and Nelson, 1974)

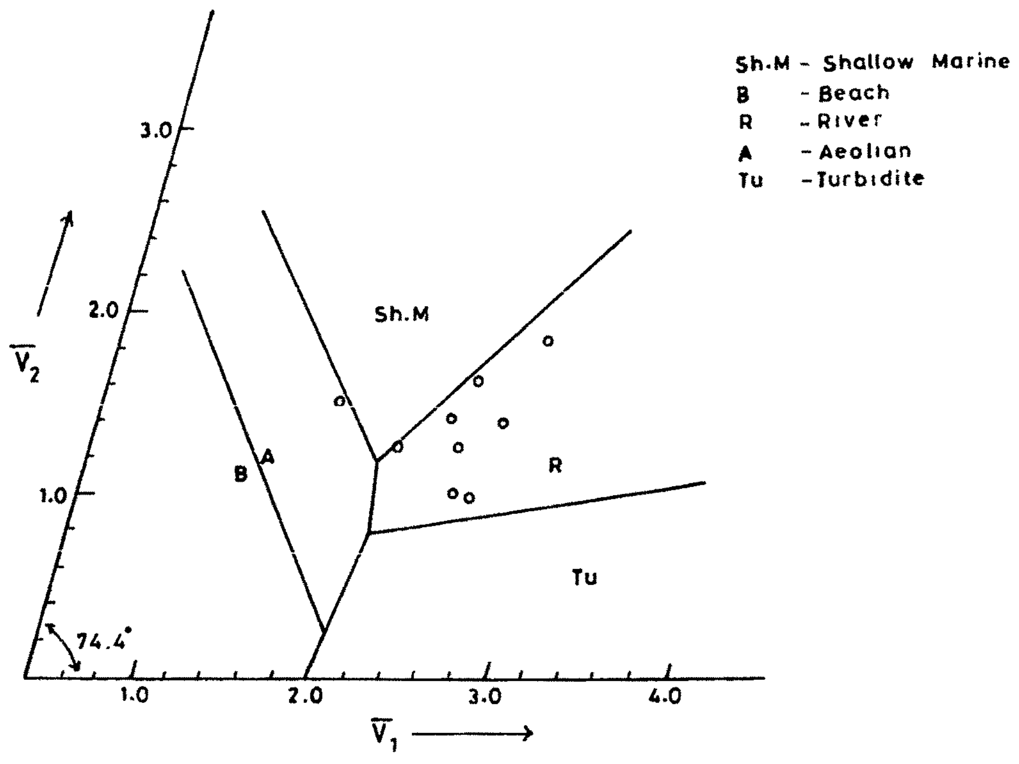

Fig.5.6 : Multigroup Discriminatory Plot of Talchir sands.
(After Sahu, 1983)

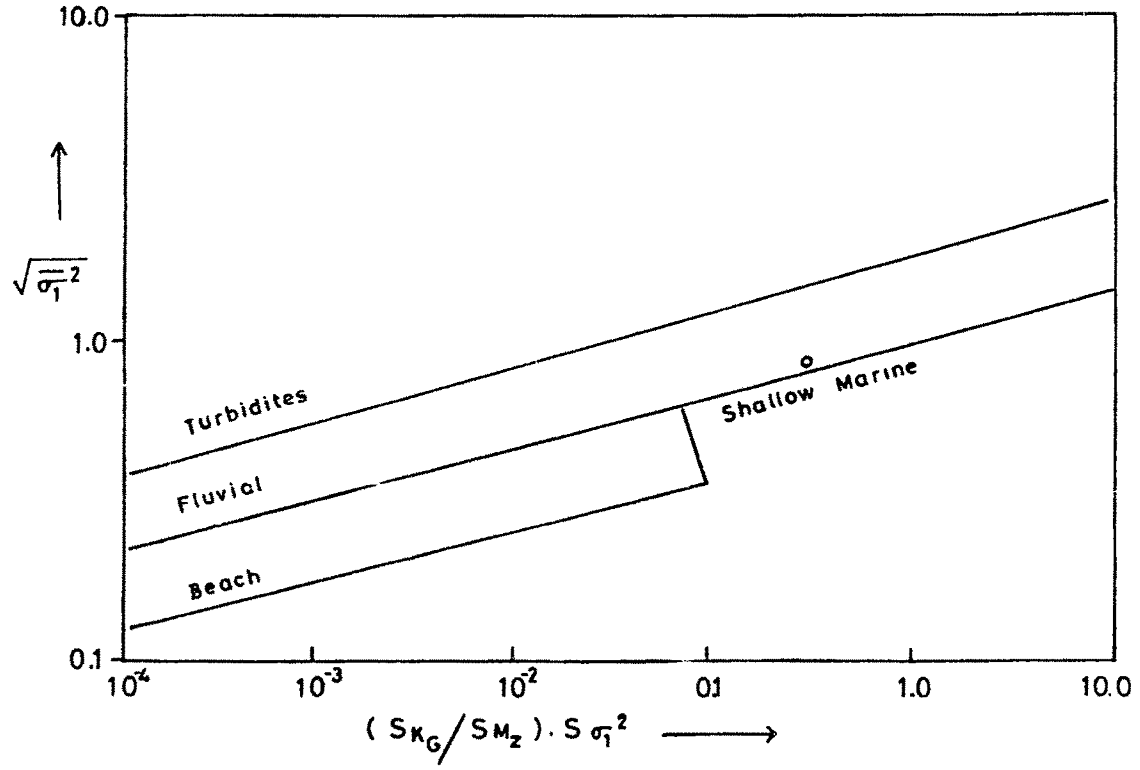

Fig. 5.7 : Log-log plot showing general sedimentary environment of deposition of Talchir sands. (After Sahu 1962)

Log-Log Plot

The log-log plot of Sahu (1964) shows that the Talchir sandstones under study, fall in the field of fluvial environment (Fig. 5.7).

BARAKAR FORMATION

Totaly of 40 sandstone samples of Barakar Formation were subjected to grain-size analysis, the results of which are furnished (Table 5.2).

Grain size parameters

The mean diameter of Barakar sands range from 2.5 phi to 0.77 phi with an average value of 1.78 phi (medium sand). Standard deviation value ranges from 0.74 phi to 1.74 phi with a mean value of 1.01 phi, which implies that the Barakar sands are poorly sorted. Skewness value ranges from + 0.03 to + 0.65 with an average value of + 0.32, which means that the Barakar sands are strongly fine skewed. Kurtosis value of Barakar sands ranges from + 0.8 to + 1.91 with an average of 1.34 which points to the leptokurtic nature of these sands.

Grain size distribution curves

The individual grain size frequency distribution curves of Barakar sands show fine skewed tail fraction due to the predominance of finer fractions trapped within the grains of principal mode (Fig. 5.8 a). Due to this abundance of intergranular fines, even a coarse grained sandstone shows fine to very fine skewness. 82% of Barakar sands show unimodality, while 18 % show polymodality. Within the unimodal sand samples, 78 % have the principal mode between 1 phi to 2 phi (medium sand), 9 % have between 0 phi to 2 phi (coarse sand) while 12.5 % shows unimodality between 2 phi to 3 phi (fine sand). The polymodality of Barakar sands is not discrete i.e. the principal modes are not widely separated but they lie adjacent to one another. Barring one sample (M1/67) all others are bimodal.

Close examination of cumulative grain size frequency curves of Barakar sands reveals 3 broad types (Fig. 5.8 b). (a) **Type 1 curve** having one

TABLE 5.2 : TEXTURAL PARAMETERS OF BARAKAR SANDS

Sample No.	Depth (m)	M_z	σ_1	Sk_1	K_G	$\Phi_1 = C$	$\Phi_{50} = M$	σ_1^2	$\overline{V}_1$	$\overline{V}_2$
		Folk and Ward (1957)				Passega (1957)		Sahu (1964)	Sahu (1983)	
B1/74	415.72	1.90 (M.G.)	1.03 (M.S.)	0.52 (V.F.S.)	1.68 (V.L.K.)	0.50	1.55	1.06	2.46	1.48
B1/75	421.82	1.06 (M.G.)	1.13 (P.S.)	0.031 (N.S.)	1.18 (L.K.)	-1.40	1.00	1.28	1.75	1.48
B1/78	444.24	1.25 (M.G.)	0.79 (M.S.)	0.26 (F.S.)	1.72 (V.L.K.)	-0.10	1.15	0.62	1.96	0.73
B1/83	465.00	1.26 (M.G.)	1.01 (P.S.)	0.14 (F.S.)	1.31 (L.K.)	-1.20	1.40	1.02	1.87	1.42
B1/86	497.80	1.38 (M.G.)	1.17 (P.S.)	0.45 (V.F.S.)	1.07 (M.K.)	-0.45	1.00	1.37	2.05	0.96
B1/89	514.00	0.95 (M.G.)	0.76 (M.S.)	0.27 (F.S.)	1.27 (L.K.)	-0.25	0.90	0.58	1.60	0.77
B2/40	222.50	1.65 (M.G.)	1.08 (M.S.)	0.10 (N.S.)	1.26 (L.K.)	-0.65	1.40	1.17	2.06	0.98
B2/41	229.50	1.35 (M.G.)	0.96 (M.S.)	0.10 (N.S.)	1.27 (L.K.)	-0.75	0.90	0.92	1.85	0.97
B2/47	250.00	2.26 (F.G.)	0.93 (M.S.)	0.45 (S.F.S.)	1.21 (L.K.)	0.80	2.05	0.86	2.38	1.21
B2/49	262.00	1.96 (M.G.)	0.82 (M.S.)	0.33 (S.F.S.)	0.99 (M.K.)	0.30	1.75	0.67	2.02	0.98
B2/50	268.00	1.23 (M.G.)	1.08 (P.S.)	0.15 (F.S.)	1.05 (M.K.)	-0.85	1.20	1.16	1.79	0.71
B2/51	278.10	2.50 (F.G.)	0.79 (M.S.)	0.096 (N.S.)	0.80 (P.K.)	1.20	2.45	1.62	2.09	0.93
B2/54	283.00	2.41 (F.G.)	0.67 (M.W.S.)	0.36 (S.F.S.)	1.33 (L.K.)	1.65	2.35	1.45	2.31	1.45
B2/56	284.00	2.45 (F.G.)	0.80 (M.S.)	0.26 (F.S.)	1.30 (L.K.)	2.00	2.90	1.64	2.31	1.28
B2/59	287.50	2.15 (F.G.)	1.02 (P.S.)	0.23 (F.S.)	1.18 (L.K.)	-0.50	1.95	1.04	2.28	1.08
B2/60	290.50	2.31 (F.G.)	0.83 (M.S.)	0.57 (S.F.S.)	0.98 (M.K.)	1.05	2.00	0.69	2.29	1.09
B2/61	293.50	2.55 (F.G.)	0.84 (M.S.)	0.65 (S.F.S.)	0.88 (P.K.)	1.60	2.20	0.70	2.40	1.08
B2/67	306.50	2.61 (F.G.)	0.84 (M.S.)	0.43 (S.F.S.)	0.87 (P.K.)	1.60	2.35	0.70	2.34	1.05
B2/68	312.50	0.85 (C.G.)	1.07 (P.S.)	0.28 (F.S.)	1.60 (V.L.K.)	-0.95	0.80	1.14	1.90	1.10
B2/79	317.50	1.18 (M.G.)	1.12 (P.S.)	0.43 (S.F.S.)	1.68 (V.L.K.)	-0.50	0.95	1.25	2.18	1.25
B2/74	331.00	3.21 (V.F.G.)	0.75 (M.S.)	0.43 (S.F.S.)	1.10 (L.K.)	1.70	3.00	0.56	2.67	1.43
B2/80	345.00	2.45 (F.G.)	0.74 (M.S.)	0.32 (S.F.S.)	1.73 (V.L.K.)	1.00	2.30	0.55	2.53	1.08
B2/81	346.50	2.10 (F.G.)	0.90 (M.S.)	0.33 (S.F.S.)	1.23 (L.K.)	0.25	1.85	0.81	2.25	1.14
B2/87	365.00	1.65 (M.G.)	1.11 (P.S.)	0.12 (F.S.)	1.56 (V.L.K.)	-0.80	1.60	1.23	2.22	1.22
B2/89	380.50	1.25 (M.G.)	1.21 (P.S.)	0.49 (F.S.)	0.97 (M.K.)	-0.75	0.80	1.46	1.98	0.64
M1/61	484.00	0.85 (C.G.)	1.67 (P.S.)	0.39 (S.F.S.)	1.29 (L.K.)	-2.55	-0.20	2.79	2.18	0.58
M1/62	486.00	0.77 (C.G.)	1.74 (P.S.)	0.44 (N.S.)	1.76 (V.L.K.)	-2.30	-0.15	3.02	2.25	1.19
M1/63	498.00	1.85 (M.G.)	1.04 (P.S.)	0.33 (S.F.S.)	1.83 (V.L.K.)	0.20	1.75	1.08	2.48	1.56
M1/64	505.00	2.15 (F.G.)	1.01 (P.S.)	0.50 (S.F.S.)	1.31 (L.K.)	-0.60	1.75	1.02	2.44	1.24
M1/66	525.00	2.25 (F.G.)	0.95 (M.S.)	0.45 (S.F.S.)	1.80 (V.L.K.)	0.30	2.00	0.90	2.65	1.69
M1/67	561.00	1.67 (M.G.)	1.41 (P.S.)	0.12 (F.S.)	1.32 (L.K.)	-1.60	1.20	1.99	2.31	0.89
M1/69	575.00	1.52 (M.G.)	0.79 (M.S.)	0.26 (F.S.)	1.91 (V.L.K.)	0.30	1.50	0.62	2.18	1.65
C1/43	233.00	2.05 (F.G.)	1.17 (P.S.)	0.48 (V.F.S.)	1.21 (L.K.)	-0.05	1.70	1.37	2.45	1.06
C1/44	238.00	0.77 (C.G.)	1.31 (P.S.)	0.16 (F.S.)	1.28 (L.K.)	-1.85	0.70	1.72	1.82	0.69
C1/45	240.00	1.32 (M.G.)	1.06 (P.S.)	0.52 (V.F.S.)	1.30 (L.K.)	0.00	1.00	1.12	2.08	1.01
C1/46	247.00	2.62 (F.G.)	1.01 (P.S.)	0.18 (F.S.)	1.82 (V.L.K.)	-0.10	2.45	1.02	2.77	1.73
C1/47	275.00	2.05 (F.G.)	1.10 (P.S.)	0.27 (F.S.)	1.25 (L.K.)	0.40	2.10	1.21	2.33	1.09
C1/48	295.00	1.63 (M.G.)	1.10 (P.S.)	0.58 (V.F.S.)	1.71 (V.L.K.)	0.15	1.30	1.21	2.45	1.42
C1/49	316.00	1.87 (M.G.)	1.02 (P.S.)	0.45 (V.F.S.)	1.60 (V.L.K.)	0.20	1.65	1.04	2.42	1.40

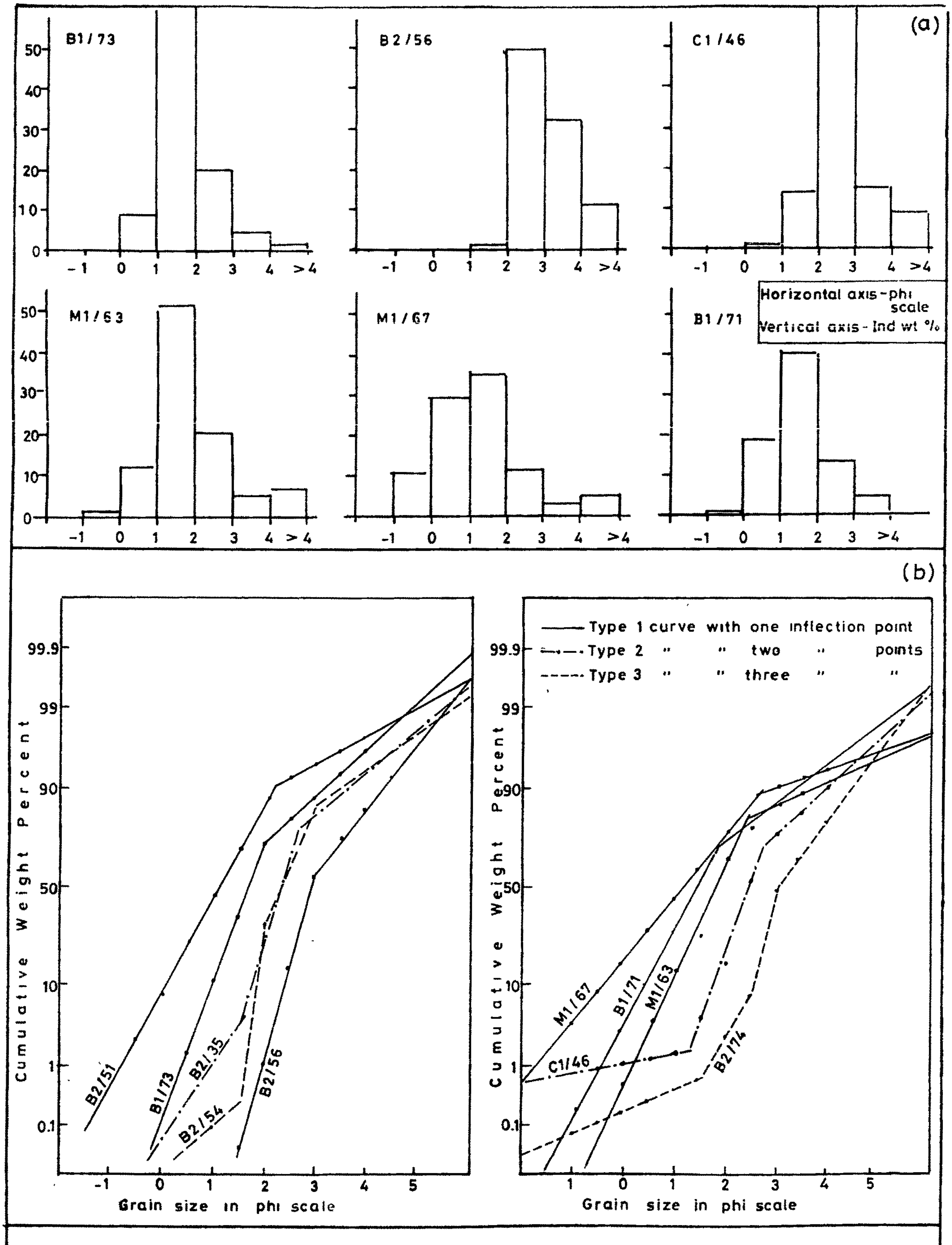

Fig.5.8 : Representative Histograms (a) and Cumulative frequency curves (b) of grain size distribution of Barakar sands.

inflection point between saltation and suspension population, which constitutes about 76 % of all samples. (b) **Type 2 curve** having 3 populations of traction, saltation and suspension, constitutes about 18 % of Barakar sand samples. (c) **Type 3 curve** having two saltation sub-populations, covers 6 % of the samples. Saltation population varies from 65 to 90 % by weight of the sample. However, in some samples (e.g. B2/56, B2/66, B2/61, B2/79), the saltation population is as low as 45 to 50 %. These samples are marked by very high suspension population (of the order of 45 to 50 %). Otherwise, in general the suspension population constitutes about 7-10 % by weight of the samples. Traction load constitutes less than 1 % wt. of the samples in all type 2 & 3 curves. Particle size inflection between traction and saltation population (C. T. Point) ranges between 1 phi to 1.5 phi. The inflection point between saltation and suspension population shows wide variation from as low as 1.5 phi to 3 phi.

C-M Pattern

83 % of the Barakar sands are falling within the C-M pattern for tractive current (Passega 1957, 1964). Of these, 44 % account separately for rolling bottom suspension and rolling graded suspension. 12 % of the samples have been transported by graded suspension only (Fig. 5.9).

Bivariant discriminant plots

All the Barakar sand samples are falling in the river field in beach-river bivariant discriminatory plots of Friedman (1967) and Moiola and Weiser (1968) (Fig. 5.10).

Stewart's (1958) discriminatory plot between river and wave process shows that 60 % of Barakar sands were transported by river process while 7 % of the samples were subjected to wave process during their transportation (Fig. 5.11).

In Gleister and Nelson's (1971) maturity trend bivariant plot, 70 % of the samples are clustering around the field of braided bar, 5 % fall in the region between alluvial fan and braided bar, while 22 % fall in the region between braided bar and delta front (Fig. 5.12).

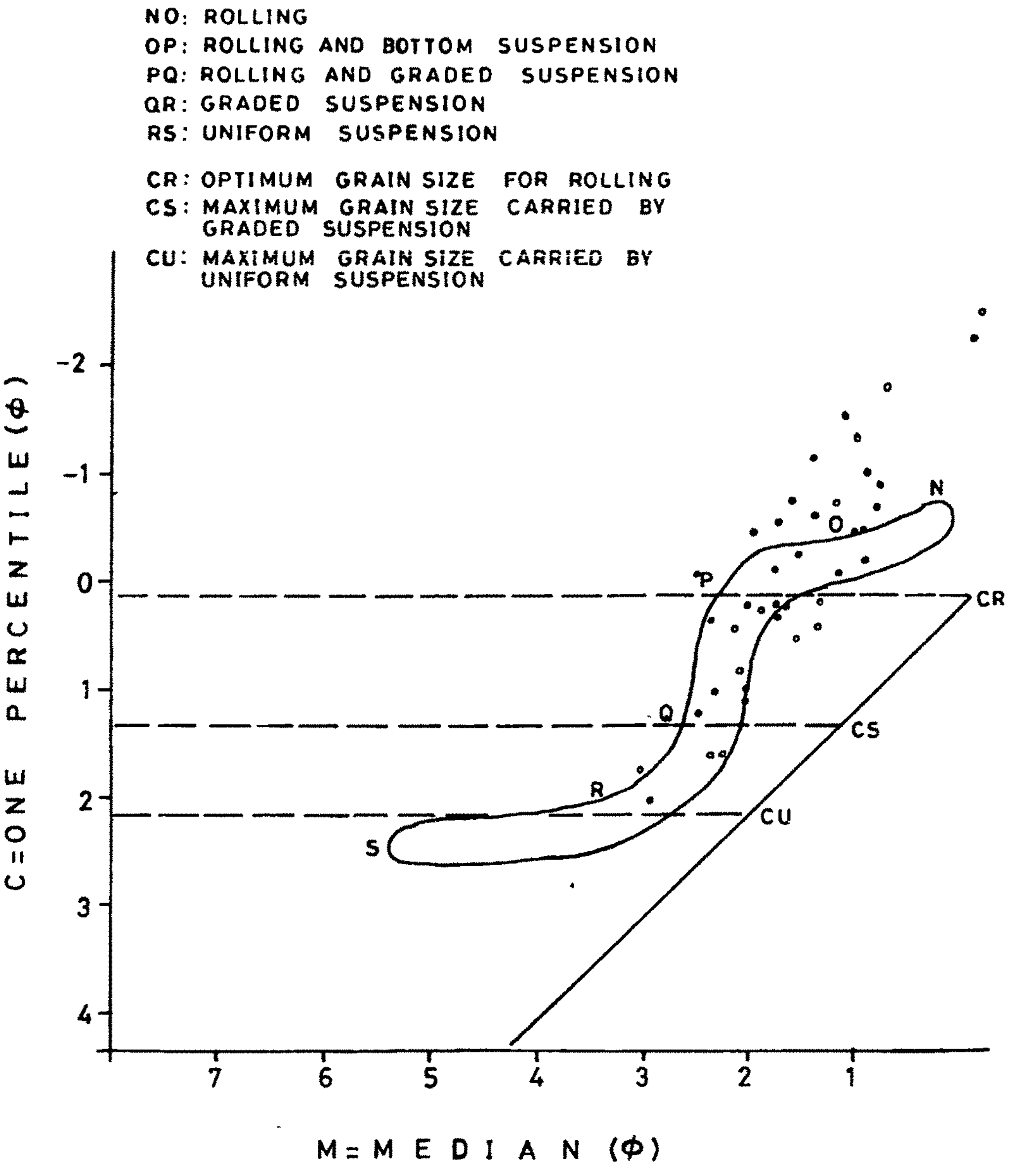

Fig.5.9: C-M Pattern showing sedimentary dynamics of Barakar sands. (After Passega, 1957, 1962)

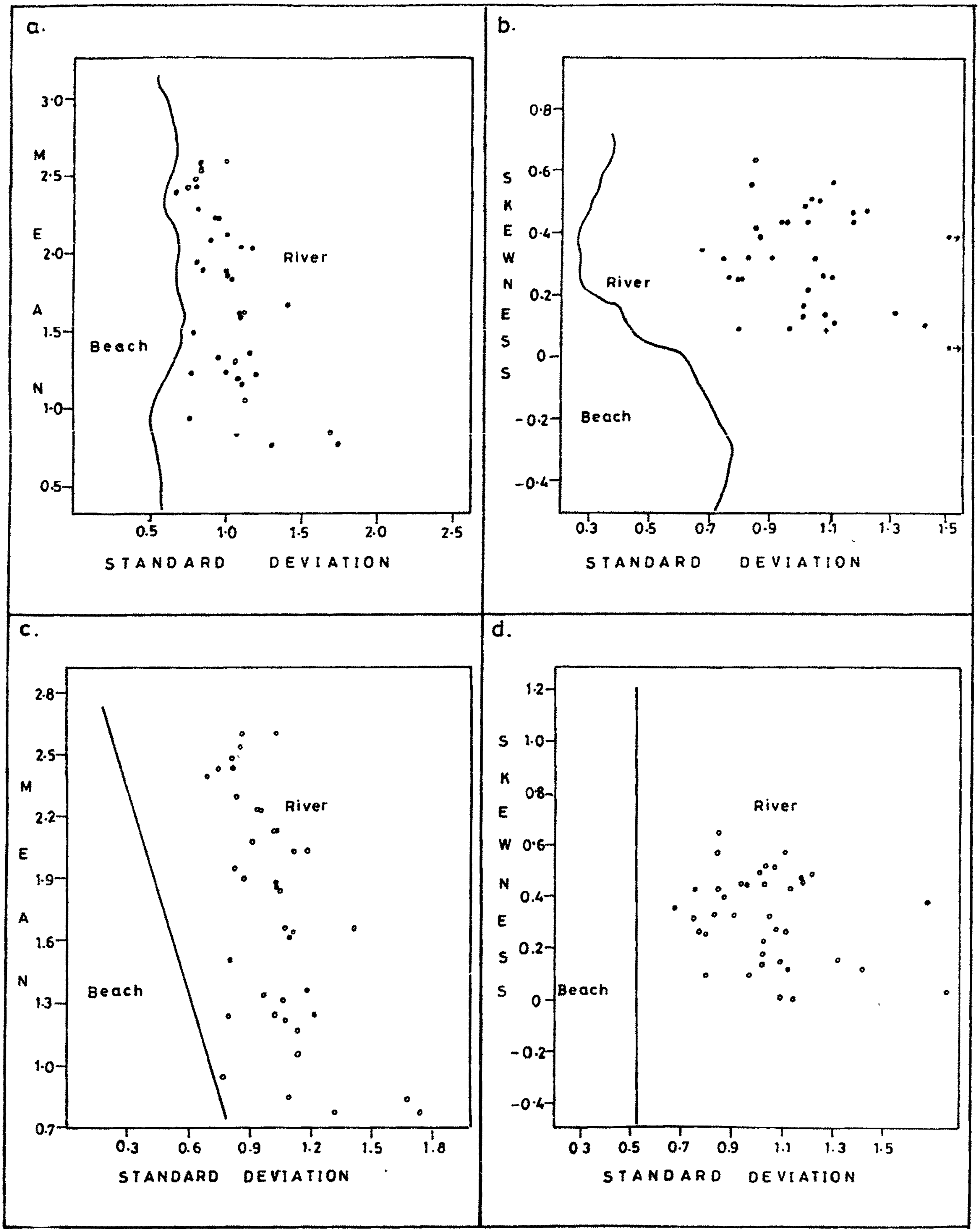

Fig.5.10: BIVARIANT PLOT : Mean against Standard Deviation and Skewness against Standard Deviation of Barakar sands.

(After Friedman, 1967, a & b ; Moiola and Weiser, 1968, c & d)

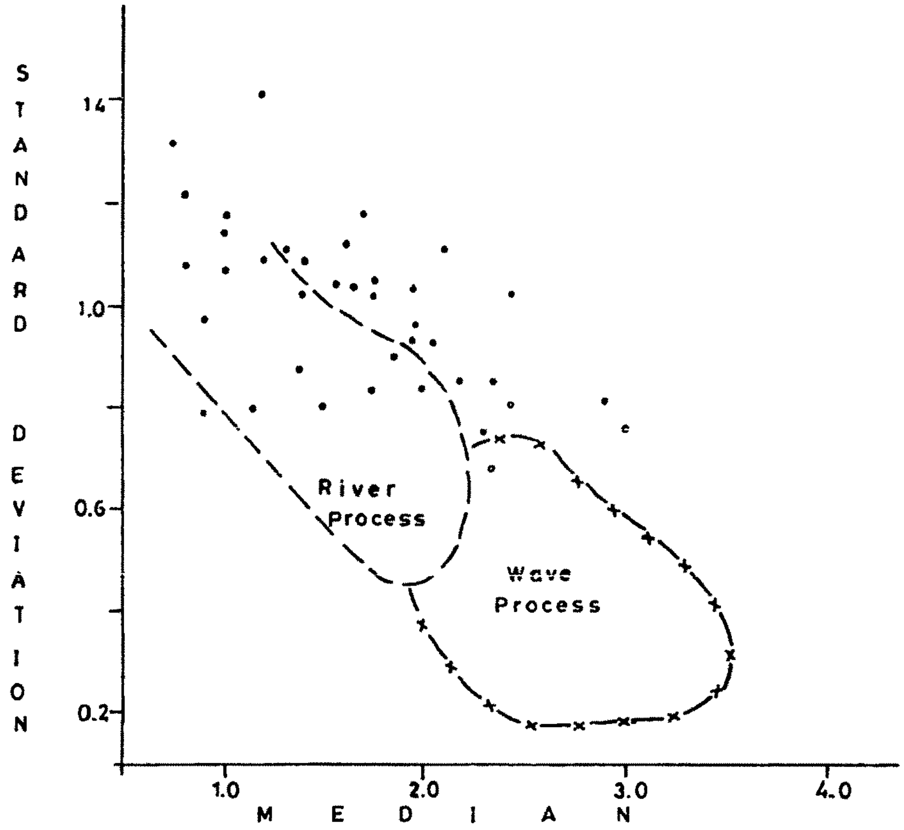

Fig.5.11: Bivariant plot of Standard Deviation Vs. Median of Barakar sands. (After Stewart, 1958)

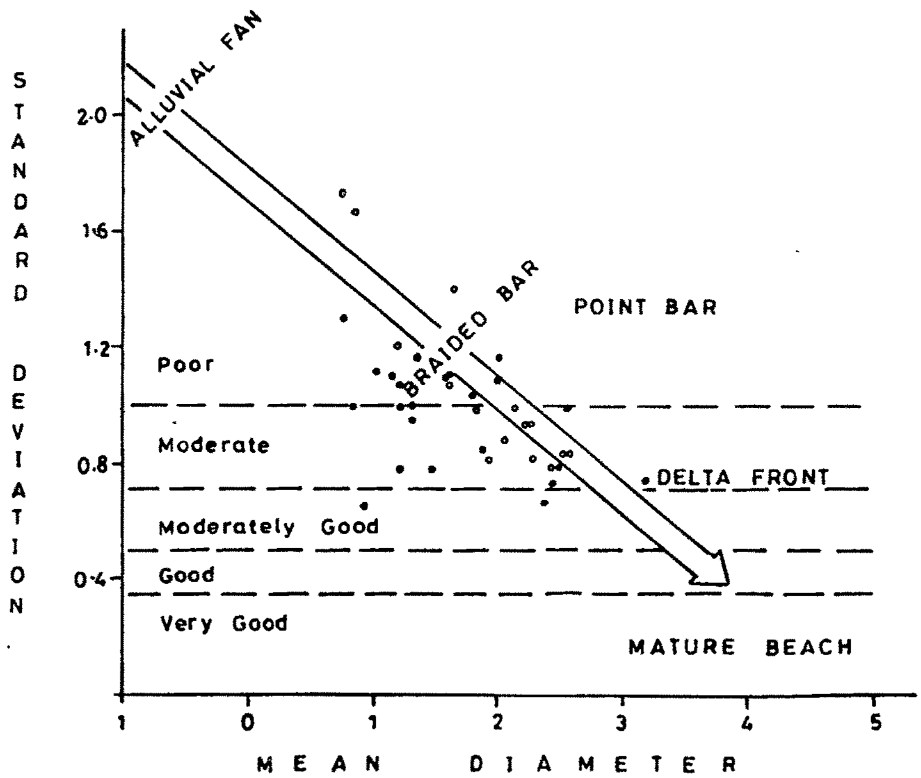

Fig.5.12: Gradational change in Sorting and grain size with environment of Barakar sands. (After Glaister and Nelson, 1974)

Multigroup discriminatory plot

In Sahu's (1982) multigroup discriminatory plot 62.5 % of the sand samples fall in the river field, while 27.5 % fall in the eolian field. 3 samples shows shallow marine origin while one sample falls in the turbidity current region (Fig. 5.13).

Log-Log plot

Sahu's (1964) plot, shows that sands of Barakar Formation were deposited in an fluvial environment (Fig. 5.14).

BARREN MEASURES FORMATION

In all, samples from 4 borewells - 2 from Bellampalli and one each from Mandamarri and Chinnur, were subjected to grain size analysis, the results of which are given (Table 5.3).

Grain size parameters

Mean diameter of Barren Measures sands ranges from 0.33 phi to 2.81 phi with an average value of 1.64 phi (medium sand). Standard deviation, which gives a measure of sorting, ranges from 0.39 phi to 1.56 phi with an average value of 0.97 phi, which implies that Barren Measures sands are moderately sorted. Skewness values vary between 0.69 to -0.28 with a mean value of + 0.23 which denotes that Barren Measures sands are fine skewed. Kurtosis value of Barakar sands ranges from 0.95 to 2.45 implying that on an average they are leptokurtic.

Grain size frequency curves

54 % of Barren Measures sands show bimodality, while the rests show unimodal distribution (Fig. 5.15 a). The bimodal nature of the sands are not apparent on the individual frequency curves because in 99 % of the bimodal cases, the two main modes represent the two adjacent grain size classes (medium sand-coarse sand or medium sand-fine sand). Distribution of particles in Barren Measures sand is open-ended at the finer end. Fine silt and clay in

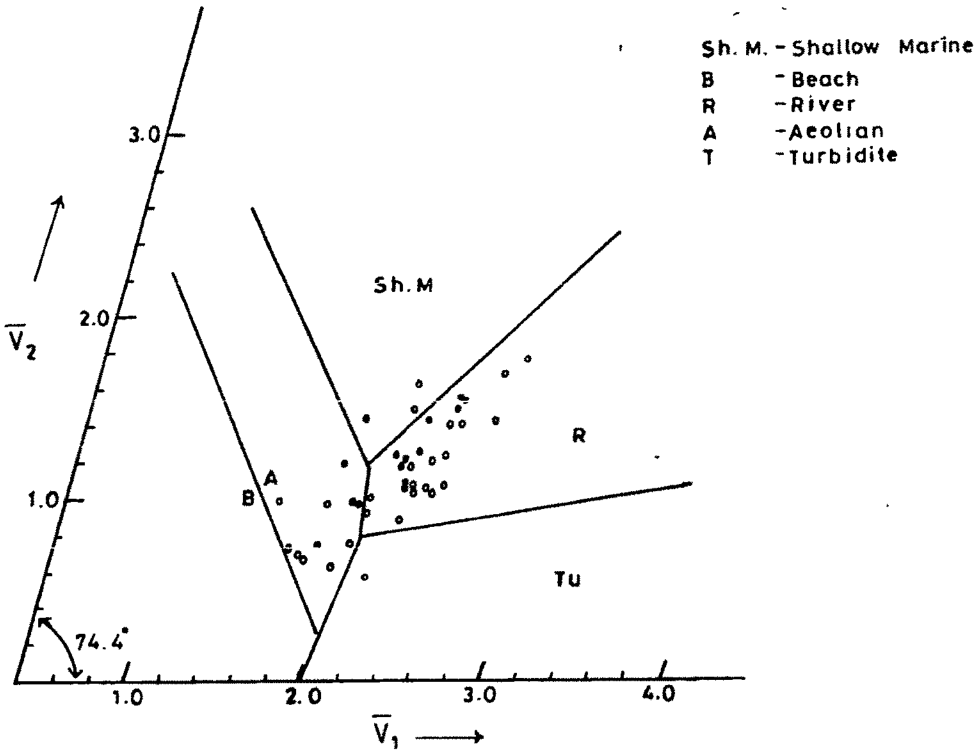

Fig.5.13 : Multigroup Discriminatory Plot of Barakar sands.
(After Sahu, 1983)

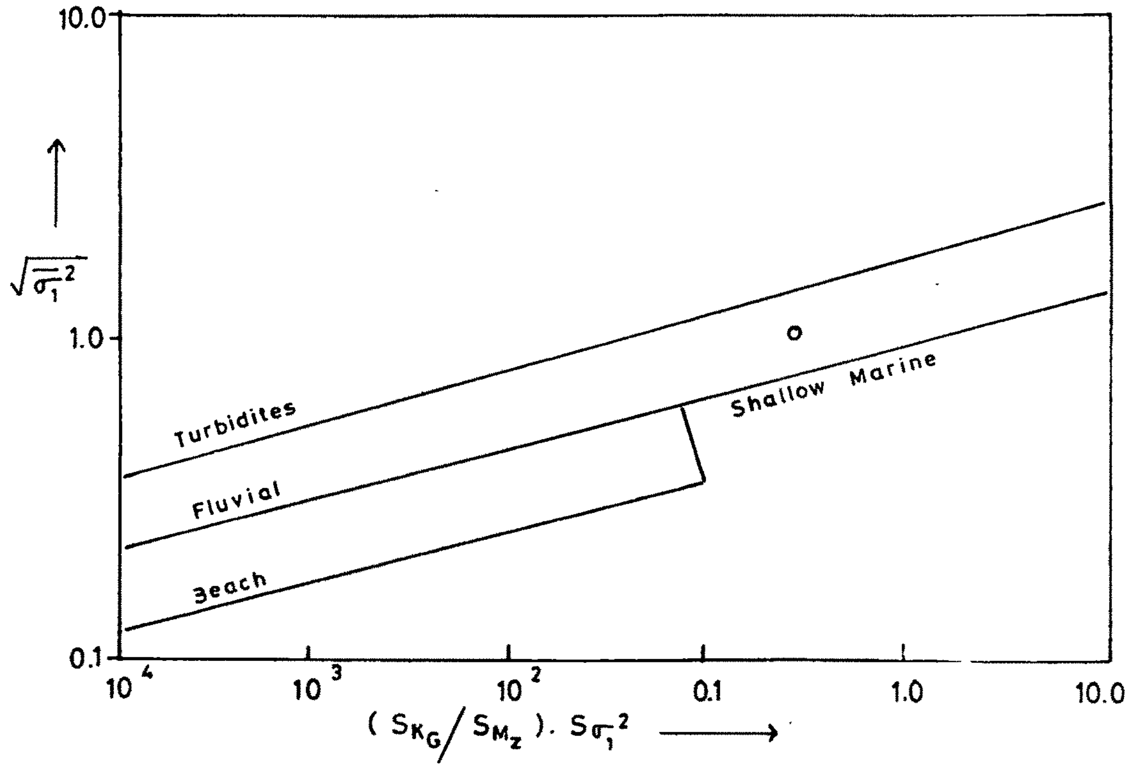

Fig.5.14: Log-log plot showing general sedimentary environment of deposition of Barakar sands. (After Sahu, '62)

TABLE 5.3 : TEXTURAL PARAMETERS OF BARREN MEASURES SANDS

Sample No.	Depth (m)	M_z	σ_1	Sk_1	K_G	$\Phi_1 = C$	$\Phi_{50} = M$	σ_1^2	$\overline{V}_1$	$\overline{V}_2$
		Folk and Ward (1957)				Passega (1957)		Sahu (1964)	Sahu (1983)	
B1/31	97.20	1.65 (M.G.)	0.81 (M.S.)	0.10 (N.S.)	1.31 (L.K.)	0.00	1.65	0.66	1.92	1.15
B1/32	106.00	2.35 (F.G.)	1.03 (P.S.)	0.31 (V.F.S.)	0.98 (M.K.)	0.80	2.20	1.06	2.33	0.97
B1/33	117.84	2.60 (F.G.)	0.73 (M.S.)	0.17 (F.S.)	1.33 (L.K.)	1.10	2.55	0.53	2.36	1.44
B1/40	161.72	1.10 (M.G.)	0.95 (M.S.)	0.05 (N.S.)	1.09 (M.K.)	-1.00	1.10	0.90	1.62	0.76
B1/43	173.65	1.66 (M.G.)	0.62 (M.W.S.)	0.27 (F.S.)	1.84 (V.L.K.)	0.65	2.00	0.38	2.11	1.70
B1/44	180.00	1.30 (M.G.)	0.01 (P.S.)	0.32 (V.F.S.)	1.22 (L.K.)	-0.15	1.15	1.02	1.92	0 93
B1/45	230.00	2.28 (F.G.)	0.91 (M.S.)	0.36 (V.F.S.)	1.32 (L.K.)	-0.95	0.85	0.83	2.39	1.03
B1/53	270.00	2.46 (F.G.)	1.07 (P.S.)	0.26 (F.S.)	1.05 (M.K.)	0.30	2.40	1.14	2.42	1.03
B1/54	276.00	0.58 (C.G.)	0.89 (M.S.)	0.23 (F.S.)	0.95 (M.K.)	-1.05	0.50	0.79	1.34	0.49
B1/56	288.50	0.96 (C.G.)	1.32 (P.S.)	-0.28 (C.S.)	1.86 (V.L.K.)	-3.50	1.05	1.74	1.99	1.14
B1/58	299.49	0.93 (C.G.)	1.07 (P.S.)	0.25 (F.S.)	1.23 (L.K.)	-0.95	0.85	1.14	1.76	0.81
B1/59	325.50	0.92 (C.G.)	1.30 (P.S.)	-0.13 (C.S.)	1.20 (L.K.)	-0.40	1.10	1.69	1.73	0.61
B1/66	367.63	1.68 (M.G.)	1.08 (P.S.)	-0.01 (N.S.)	0.98 (M.K.)	-0.85	1.70	1.16	1.91	0.74
B1/67	374.00	1.38 (M.G.)	0.87 (M.S.)	0.15 (F.S.)	1.35 (L.K.)	-0.40	1.35	0.76	1.86	1.10
B1/70	397.77	1.73 (M.G.)	0.99 (M.S.)	0.30 (F.S.)	1.14 (L.K.)	-0.10	1.66	0.98	2.07	0.97
B1/71	406.25	1.51 (M.G.)	1.10 (P.S.)	0.29 (F.S.)	1.29 (L.K.)	-0.40	1.40	1.21	2.10	0.99
B2/1	10.00	1.82 (M.G.)	0.77 (M.S.)	0.25 (F.S.)	1.48 (L.K.)	-0.15	1.75	0.59	2.11	1.37
B2/2	42.50	1.73 (M.G.)	0.86 (M.S.)	0.05 (N.S.)	1.16 (L.K.)	-0.15	1.40	0.74	1.90	1.01
B2/7	70.00	2.06 (F.G.)	0.74 (M.S.)	0.38 (V.F.S.)	1.27 (L.K.)	0.85	1.85	0.55	2.17	1.29
B2/11	97.50	1.40 (F.G.)	1.22 (P.S.)	0.07 (N.S.)	1.20 (L.K.)	-0.30	1.40	1.49	1.99	0.80
B2/13	109.00	1.99 (F.G.)	1.19 (P.S.)	-0.25 (C.S.)	1.21 (L.K)	-0.90	2.20	1.42	1.13	0.92
B2/15	121.50	1.23 (F.G.)	0.84 (M.S.)	-0.42 (V.C.S.)	1.17 (L.K.)	-0.35	1.25	0.70	1.46	0.83
B2/16	127.50	0.92 (C.G.)	0.75 (M.S.)	0.12 (F.S.)	1.22 (L.K.)	-0.70	0.90	0.56	1.50	0.92
B2/17	139.50	1.01 (M.G.)	0.70 (M.S.)	0.22 (F.S.)	1.73 (V.L.K.)	-0.50	0.90	0.49	1.77	1.41
B2/18	142.00	2.36 (F.G.)	0.78 (M.S.)	-0.10 (N.S.)	1.11 (L.K.)	-0.80	2.25	0.61	1.62	1.13
B2/23	156.50	1.96 (M.G.)	0.96 (M.S.)	0.09 (N.S.)	1.24 (L.K)	0.00	1.95	0.92	2.13	1.09
B2/25	160.50	2.33 (F.G.)	0.94 (M.S.)	0.17 (F.S.)	1.21 (L.K.)	0.65	2.15	0.88	2.31	1 18
B2/26	163.50	1.73 (M.G.)	0.79 (M.S.)	0.28 (F.S.)	1.50 (V.L.K.)	0.25	1.65	0.62	2.10	1.36
B2/27	164.50	0.96 (C.G.)	1.00 (M.S.)	-0.05 (F.S.)	1.18 (L.K.)	-1.40	1.05	1.00	1.59	0.76
B2/28	165.50	2.01 (F.G.)	0.90 (M.S.)	0.69 (S.F.S.)	1.17 (L.K.)	0.00	1.90	0.81	2.32	1 16
B2/29	174.50	1.85 (M G.)	0.75 (M.S.)	0.35 (S.F.S.)	1.38 (L.K.)	0.35	1.70	0.56	2.12	1.32
B2/30	178.50	1.68 (M.G.)	0.93 (M.S.)	0.30 (S.F.S.)	1.44 (L.K.)	0.10	1.55	0.87	2.15	1.24
B2/31	184.50	2.15 (F G.)	0.84 (M.S.)	0.34 (S.F.S.)	1.17 (L.K.)	-0.20	2.00	0.71	2.21	1 18
B2/32	178.50	1.85 (M.G.)	0.93 (M.S.)	0.19 (F.S.)	6.55 (E.L.K)	0.05	1.70	0.87	4.21	5 09
B2/34	212.00	2.28 (F G.)	0.86 (M.S)	0.06 (N.S.)	0.92 (M.K.)	0.75	2.00	0.74	2.06	0 94

Contd.

Sample No.	Depth (m)	M_z	σ_1	Sk_1	K_G	$\Phi_1 = C$	$\Phi_{50} = M$	σ_1^2	$\overline{V}_1$	$\overline{V}_2$
		Folk and Ward (1957)				Passega (1957)		Sahu (1964)	Sahu (1983)	
M1/1	38.00	1.78 (M.G.)	1.08 (P.S.)	0.30 (S.F.S.)	1.34 (L.K.)	-0.15	1.60	1.16	2.24	1.11
M1/2	54.00	1.55 (M.G.)	1.00 (P.S.)	0.56 (S.F.S.)	1.66 (V.L.K.)	0.25	1.25	1.00	2.33	1.40
M1/5	92.00	2.70 (F.G.)	1.10 (P.S.)	0.45 (S.F.S.)	1.20 (L.K.)	1.10	2.70	1.21	2.69	1.23
M1/7	107.00	1.10 (M.G.)	1.53 (P.S.)	0.03 (N.S.)	1.51 (V.L.K.)	-3.45	1.00	2.34	2.16	0.84
M1/9	121.00	2.12 (F.G.)	0.78 (M.S.)	0.41 (S.F.S.)	1.64 (V.L.K.)	0.10	1.90	0.61	2.40	1.60
M1/10	122.00	1.05 (M.G.)	0.87 (M.S.)	0.12 (F.S.)	1.35 (L.K.)	-0.75	0.50	0.76	1.69	1.01
M1/11	126.00	1.52 (M.G.)	1.25 (P.S.)	0.50 (S.F.S.)	1.29 (L.K.)	-0.50	1.50	1.56	2.28	0.96
M1/14	161.70	0.80 (C.G.)	1.01 (P.S.)	0.04 (N.S.)	1.26 (L.K.)	-1.80	0.60	1.02	1.59	0.80
M1/16	175.00	2.50 (F.G.)	1.23 (P.S.)	0.55 (S.F.S.)	1.68 (V.L.K.)	0.45	2.30	1.51	2.93	1.54
M1/18	183.50	1.65 (M.G.)	0.57 (M.W.S.)	0.36 (S.F.S.)	1.88 (V.L.K.)	0.50	1.40	0.37	2.13	1.77
M1/22	210.00	2.07 (F.G.)	1.24 (P.S.)	0.15 (F.S.)	1.44 (L.K.)	-1.30	1.90	1.54	2.47	1.17
M1/24	218.00	2.02 (F.G.)	1.31 (P.S.)	0.16 (F.S.)	2.45 (V.L.K.)	-3.10	1.80	1.72	2.94	1.97
M1/28	230.00	2.54 (F.G.)	1.08 (P.S.)	0.34 (V.F.S.)	0.95 (M.K.)	-0.25	2.30	1.17	2.45	0.98
M1/30	243.50	1.57 (M.G.)	0.85 (M.S.)	0.09 (N.S.)	1.19 (L.K.)	-0.30	1.55	0.72	1.85	1.00
M1/32	256.30	1.00 (M.G.)	0.81 (M.S.)	0.12 (F.S.)	1.31 (L.K.)	-0.65	1.00	0.66	1.61	0.99
M1/34	273.50	0.78 (C.G.)	1.10 (P.S.)	0.21 (F.S.)	2.02 (V.L.K.)	-1.50	0.70	1.21	2.05	1.41
M1/35	278.00	1.00 (M.G.)	1.09 (P.S.)	0.13 (F.S.)	1.39 (L.K.)	-0.90	1.00	1.19	1.82	0.93
M1/36	284.00	1.37 (M.G.)	0.80 (M.S.)	0.19 (F.S.)	1.66 (V.L.K.)	0.50	1.35	0.65	1.97	1.39
M1/37	293.00	0.65 (C.G.)	1.02 (P.S.)	0.17 (F.S.)	1.53 (V.L.K.)	-1.30	1.65	1.04	1.69	1.00
M1/39	303.00	2.21 (F.G.)	0.79 (M.S.)	0.68 (V.F.S.)	1.27 (L.K.)	1.15	1.95	0.62	2.39	1.35
M1/42	321.50	1.18 (M.G.)	0.90 (M.S.)	0.42 (V.F.S.)	2.03 (V.L.K.)	-0.40	2.10	0.81	2.19	1.64
M1/43	330.20	0.93 (C.G.)	0.80 (M.S.)	0.24 (F.S.)	1.69 (V.L.K.)	-0.70	0.85	0.64	1.79	1.31
M1/45	359.50	0.76 (C.G.)	1.10 (M.S.)	0.09 (N.S.)	1.23 (L.K.)	-1.60	0.75	1.21	1.63	0.73
M1/46	370.00	2.76 (F.G.)	1.23 (M.S.)	0.45 (F.S.)	1.40 (L.K.)	0.80	2.60	1.51	2.89	1.35
M1/47	375.00	1.75 (M.G.)	1.01 (M.S.)	0.15 (F.S.)	1.95 (V.L.K.)	-0.55	1.70	1.02	2.40	1.62
M1/48	380.50	2.80 (F.G.)	1.12 (M.S.)	0.50 (S.F.S.)	1.89 (V.L.K.)	1.55	2.55	1.25	3.08	1.83
M1/50	393.00	2.00 (F.G.)	1.08 (M.S.)	0.33 (S.F.S.)	1.93 (V.L.K.)	-0.15	1.80	1.16	2.62	1.67
M1/52	419.00	2.33 (F.G.)	1.56 (M.S.)	0.54 (S.F.S.)	1.25 (L.K.)	0.10	1.80	2.43	2.86	0.99

Contd.

Sample No.	Depth (m)	M_z	σ_1	Sk_1	K_G	$\Phi_1 = C$	$\Phi_{50} = M$	σ_1^2	$\overline{V}_1$	$\overline{V}_2$
		Folk and Ward (1957)				Passega (1957)		Sahu (1964)	Sahu (1983)	
C1/8	57.8	0.82 (C.G.)	0.79 (M.S.)	0.21 (F.S.)	1.54 (V.L.K.)	-0.65	0.80	0.63	1.65	1.16
C1/9	60.00	1.15 (M.G.)	0.84 (M.S.)	0.30 (S.F.S.)	1.91 (V.L.K.)	-0.35	1.10	0.70	2.05	1.55
C1/10	68.00	0.33 (C.G.)	1.87 (P.S.)	-0.13 (C.S.)	1.84 (V.L.K.)	-6.45	0.65	3.50	2.08	0.77
C1/11	72.50	1.32 (M.G.)	0.97 (M.S.)	0.25 (F.S.)	1.16 (L.K.)	-0.20	1.25	0.95	1.86	0.88
C1/12	83.00	2.01 (F.G.)	0.89 (M.S.)	0.29 (F.S.)	1.27 (L.K.)	0.35	1.95	0.79	2.20	1.19
C1/13	88.00	1.80 (M.G.)	0.39 (W.S.)	0.16 (F.S.)	1.52 (V.L.K.)	-0.20	1.80	0.15	1.85	1.56
C1/14	94.50	0.87 (C.G.)	1.14 (P.S.)	0.31 (S.F.S.)	1.32 (L.K.)	-0.20	0.50	1.30	1.83	1.85
C1/18	103.50	1.88 (M.G.)	0.70 (M.S.)	0.38 (S.F.S.)	2.09 (V.L.K.)	0.20	1.75	0.49	2.42	1.95
C1/24	122.00	1.38 (M.G.)	0.85 (M.S.)	0.22 (F.S.)	1.59 (V.L.K.)	-1.35	1.35	0.72	1.99	1.32
C1/27	138.00	1.89 (M.G.)	1.01 (P.S.)	0.41 (S.F.S.)	1.63 (V.L.K.)	0.25	1.70	1.02	2.42	1.43
C1/30	152.00	1.35 (M.G.)	1.13 (P.S.)	0.25 (F.S.)	1.24 (L.K.)	-0.80	1.20	1.28	2.00	0.89
C1/32	159.00	1.82 (M.G.)	1.10 (P.S.)	0.27 (F.S.)	1.21 (L.K.)	-0.30	1.65	1.21	2.21	0.99
C1/36	185.00	1.90 (M.G.)	1.25 (P.S.)	0.25 (F.S.)	1.07 (M.K.)	0.20	1.80	1.56	2.27	0.83
C1/37	194.00	2.81 (F.G.)	1.16 (P.S.)	0.41 (S.F.S.)	1.02 (M.K.)	1.00	2.55	1.34	2.70	1.07
C1/38	206.00	2.35 (F.G.)	0.94 (M.S.)	0.64 (S.F.S.)	1.02 (M.K.)	1.15	1.95	0.88	2.42	1.10
C1/39	225.00	1.15 (M.G.)	1.51 (P.S.)	0.19 (F.S.)	1.42 (L.K.)	-2.20	0.95	2.23	2.20	0.81
C1/40	227.00	1.67 (M.G.)	1.36 (P.S.)	0.33 (S.F.S)	1.20 (L.K.)	-0.70	1.40	1.85	2.31	0.84

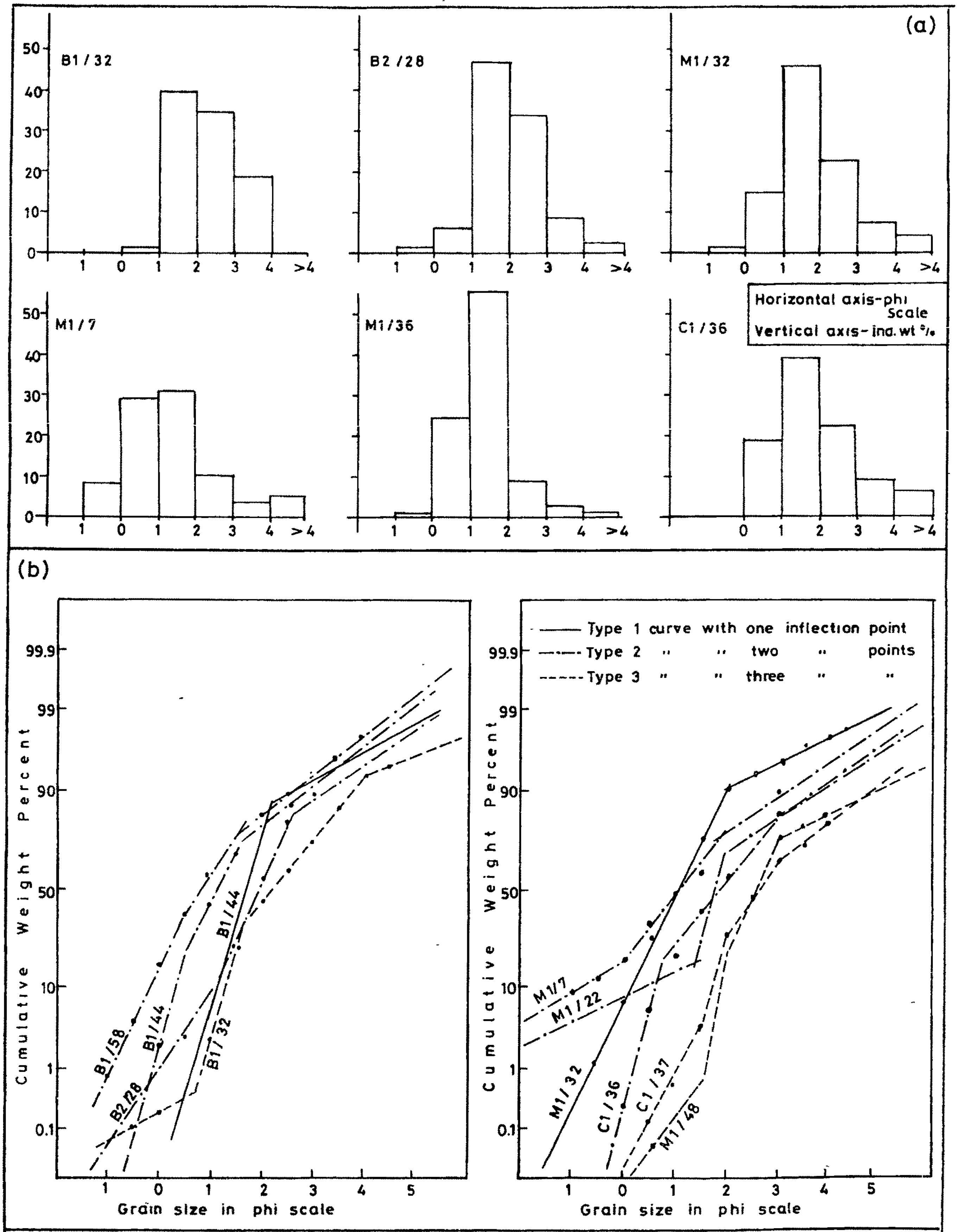

Fig.5.15: Representative Histograms (a) and Cumulative frequency curves (b) of grain size distribution of Barren Measures sands.

the pan fraction contributes substantially (as high as 15 %) to the weight of the sample. Due to this, more than 85 % of the samples are fine to very fine skewed.

60 % of the cumulative frequency distribution curves match with those of Visher's (1969) fluvial curve, having, one inflection between saltation and suspension (Type 1) (Fig. 5.15 b). 21 % of the cumulative curves are Type 2 curves, showing 3 populations of traction, suspension and saltation, while 19 % are Type 3 curves showing, 3 inflection points with two sub-populations within the saltation load. The saltation load constitutes 65 to 95 % by weight of the samples. In 3 samples (M1/22, M1/24, M1/28) the cumulative weight of the saltation population is as low as 45 % to 50 %. Traction load varies from 0.2 to 10 %. In some samples (e.g. M1/7, C1/10, B2/20, M1/22, M1/24, C1/25 and C1/28), the traction load is equal to 20 % by weight of the samples. Suspension population constitutes about 3 to 15 % of the total weight of the sample. The fine-truncation point for Type 1 curve ranges between 1.5 phi and 3.5 phi. For the Type 2 curve it varies between 2.25 phi to 3.5 phi. The coarse truncation point between traction and saltation population for Type 2 and Type 3 curves ranges from 0 phi to 1 phi.

C-M Pattern

80 % of the Barren Measures sand samples are falling within C-M pattern of tractive current. Of these, 67 % were transported by rolling and rolling - bottom suspension. 30 % were subjected to rolling and graded suspension. 3 % underwent graded suspension only (Fig. 5.16).

Bivariant discriminant plot

In all the four bivariant plots of Friedman (1967) and Moiola and Weiser (1968) (Fig. 5.17), there is one sample (C1/13) common to all the plots that are falling in the field of beach sand. Friedman's plot of mean size vs. standard deviation contains two more points (of samples B1/43 and M1/17) falling in the field of beach. These two samples are however, falling in the river domain in other 3 plots.

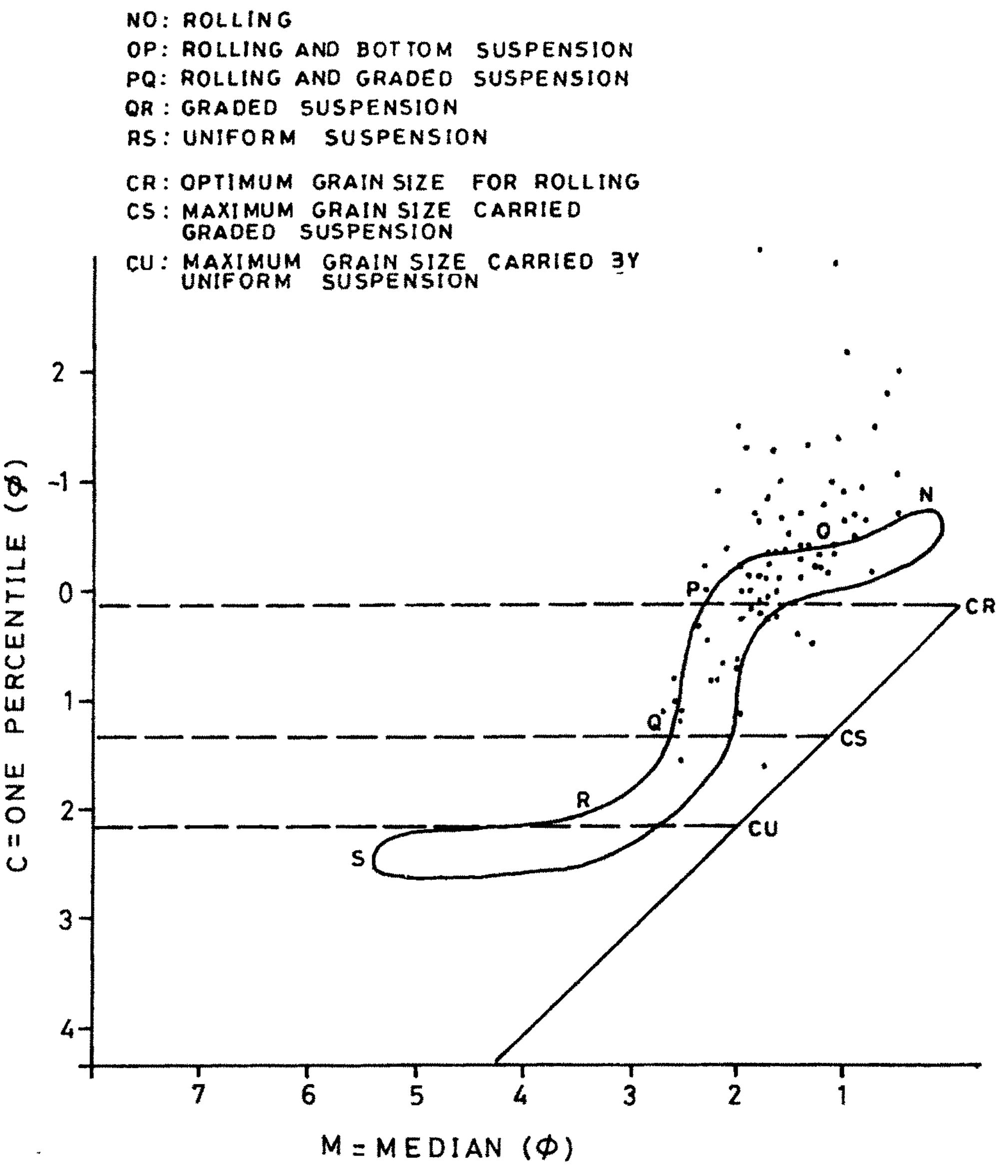

Fig.5.16 : C-M Pattern showing sedimentary dynamics of Barren Measures sands

(After Passega, 1957, 1962)

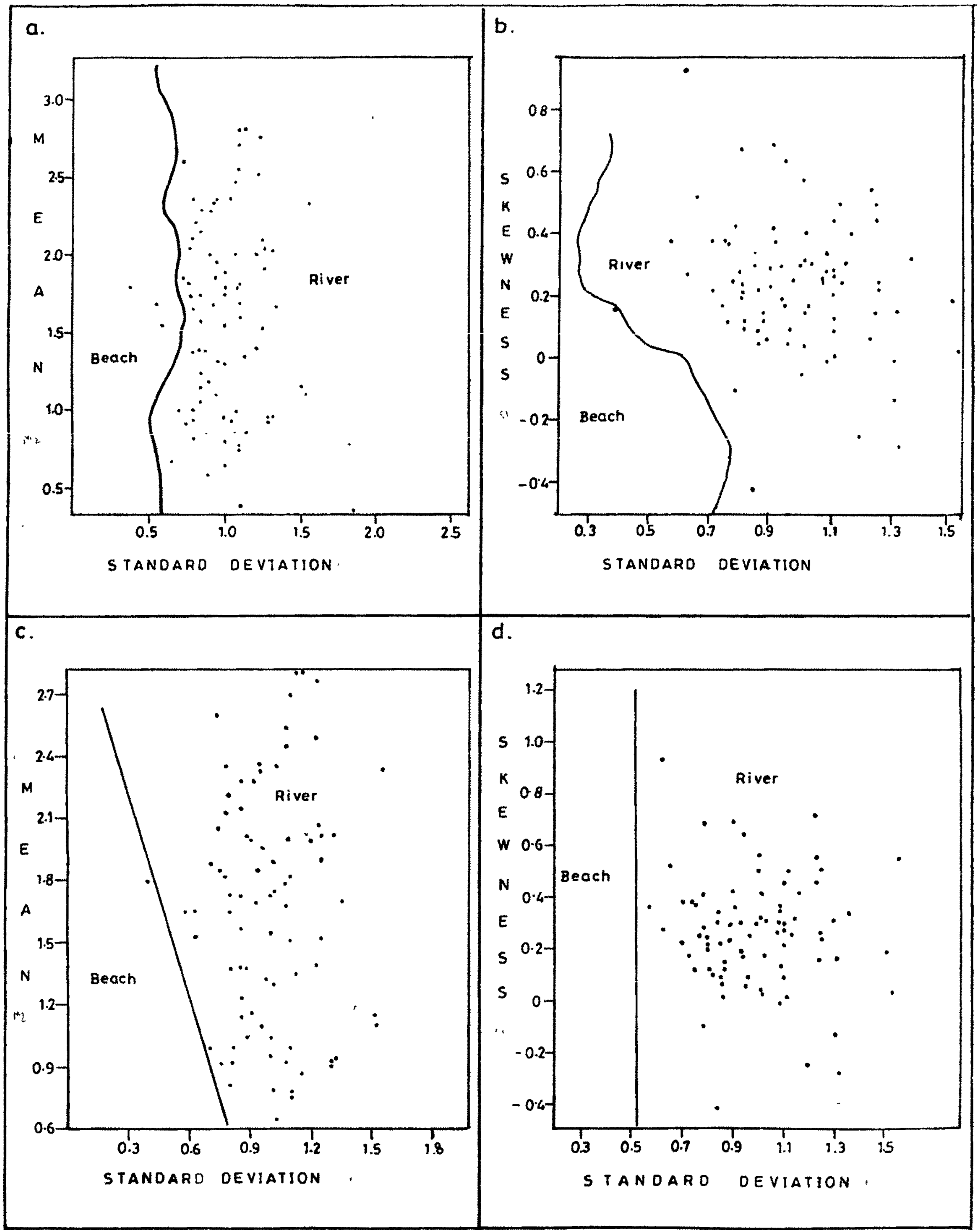

Fig.5.17: **BIVARIANT PLOT** : Mean against Standard Deviation and Skewness against Standard Deviation of Barren Measures sands

(After Friedman, 1967, a&b ; Moiola and Weiser, 1968, c&d)

In Stewart's (1958) bivariant plot of standard deviation vs. median (Fig. 5.18), 71 % of the Barren Measures sand samples are falling in and around the field of river process. Not a single point is falling within the zone of beach process. The other samples show inconclusive results.

Gleister and Nelson's (1971) maturity trend plot (Fig. 5.19), shows that most of the points are falling in the region of braided bar with quite a few points showing tendency towards point bar.

Multigroup discriminatory plot

The percentage of samples falling in different field of environment in Sahu's (1982) multivariant discriminatory plot (Fig. 5.20) is as follows :

River - 50 %, Eolian - 30 %, Shallow marine - 10 %, Beach - 10 %.

No sample is falling in the field of turbidity current.

Log-Log plot

Sahu's (1964) log-log plot shows that the sands of Barren Measures Formation were deposited in a fluvial environment (Fig. 5.21).

KAMTHI FORMATION

Over all, 30 sandstone samples - 17 from Lower Kamthi Member and 13 from Middle Kamthi Member, were subjected to granulometric analysis, the results of which are tabulated in (Table 5.4). The sands of Upper Kamthi Member being a part of Upper Gondwana Group, were not included in grain size analysis.

Grain size parameters

The mean diameter (Mz) of Lower Kamthi sands ranges between 0.38 phi and 2.62 phi with an average value of 1.44 phi (medium sand). Standard deviation (σ_I) ranges from 0.46 phi to 1.23 phi with an average of 0.91 phi (moderately sorted sand). Skewness value (Sk_I) of Lower Kamthi sands varies between - 0.003 to + 0.93 with an average of + 0.26 (fine skewed). Kurtosis (K_G) value ranges from 0.94 to 1.68 with an average value of 1.33 (leptokurtic).

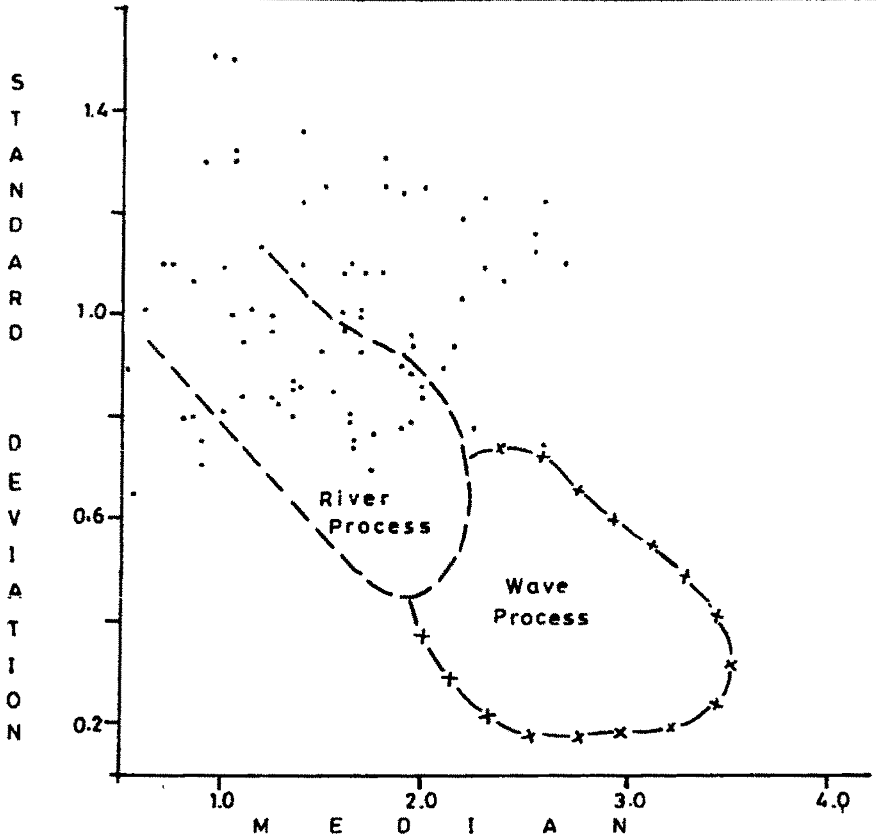

Fig.5.18: Bivariant plot of Standard Deviation Vs. Median of Barren Measures sands (After Stewart, 1958)

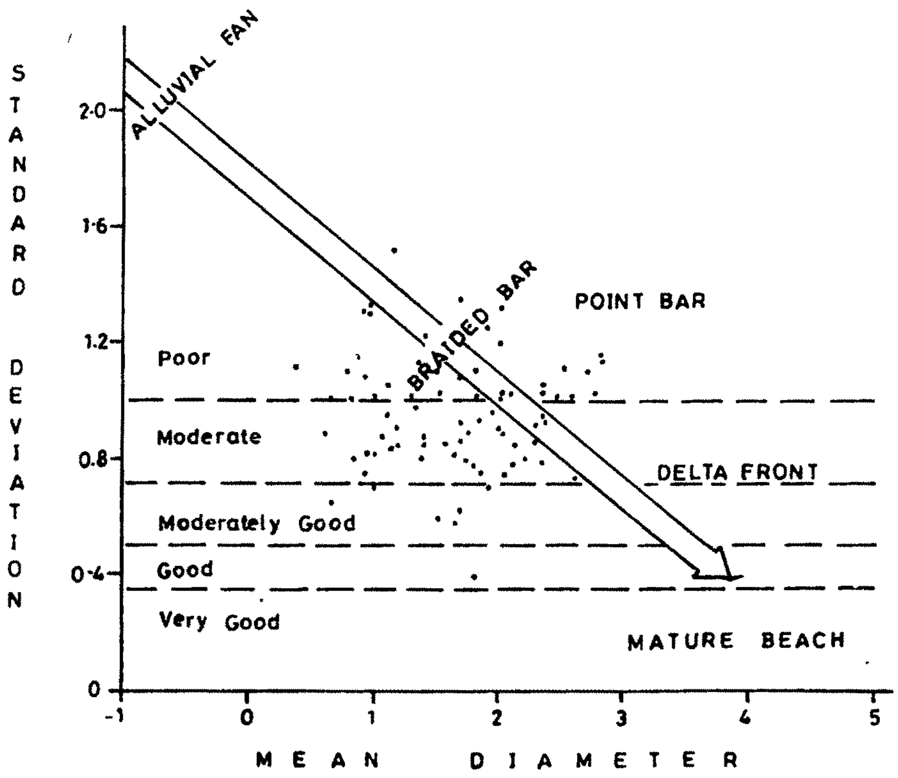

Fig.5.19: Gradational change in Sorting and Grain size with environment of Barren Measures sands (After Glaister and Nelson, 1974)

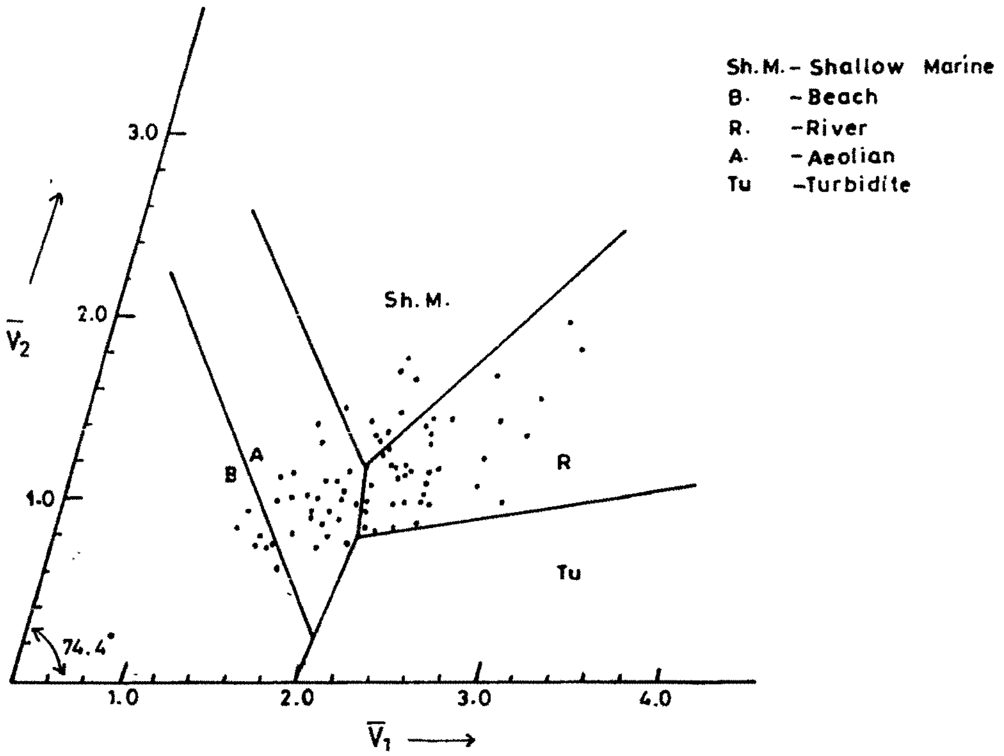

Fig.5.20: Multigroup Discriminatory Plot of Barren Measures sands.
(After Sahu, 1983)

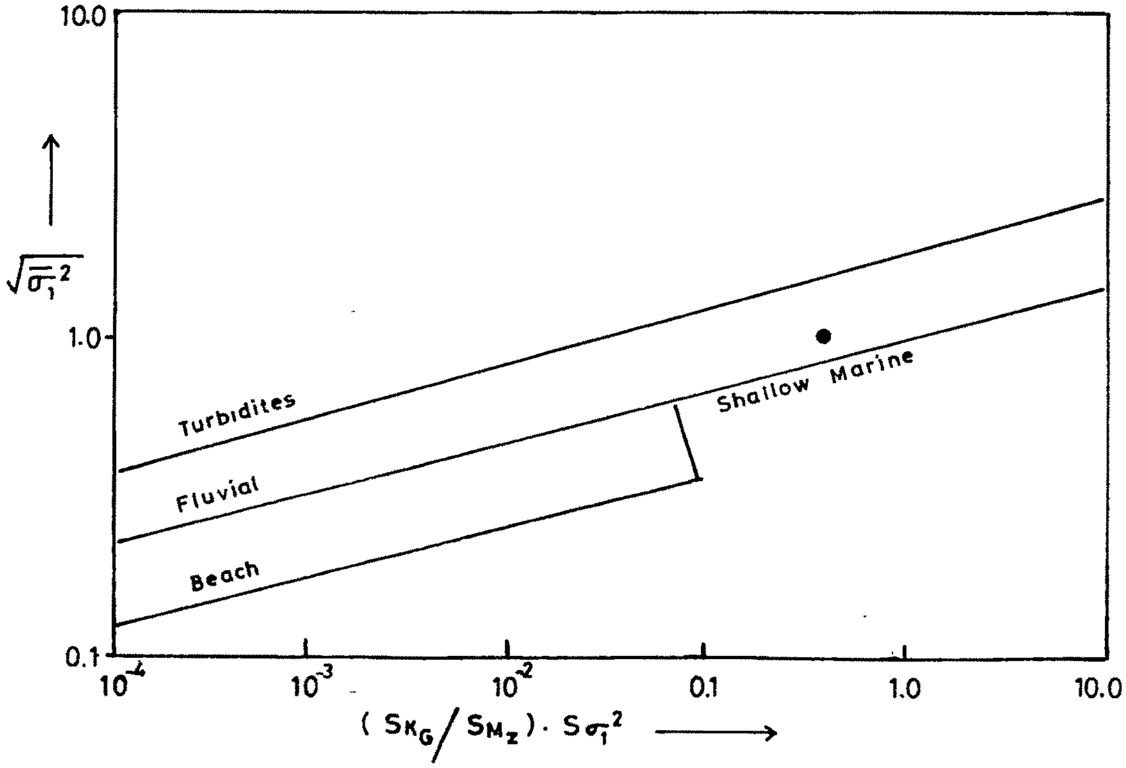

Fig.5.21: Log-log plot showing general sedimentary environment of deposition of Barren Measures sands. (After Sahu '62)

TABLE 5.4 : TEXTURAL PARAMETERS OF KAMTHI SANDS

Sample No.	Depth (m)	M_z	σ_1	Sk_1	K_G	$\Phi_1 = C$	$\Phi_{50} = M$	σ_1^2	$\overline{V}_1$	$\overline{V}_2$
		Folk and Ward (1957)				Passega (1957)		Sahu (1964)	Sahu (1983)	
B1/1	2.25	1.41 (M.G.)	1.23 (P.S.)	0.30 (V.F.S.)	1.20 (L.K.)	-0.70	1.20	1.51	2.09	0.83
B1/2	36.12	1.60 (M.G.)	0.96 (M.S.)	0.26 (V.F.S.)	1.53 (V.L.K.)	-0.10	1.50	0.92	2.15	1.27
B1/10	60.70	2.20 (F.G.)	1.02 (P.S.)	0.50 (V.F.S.)	0.94 (M.K.)	0.75	1.85	1.04	2.31	0.94
B1/12	65.61	1.85 (M.G.)	0.96 (M.S.)	0.33 (V.F.S.)	1.68 (V.L.K.)	-0.50	1.70	0.92	2.37	1.47
B1/18	72.70	0.78 (C.G.)	1.00 (M.S.)	0.12 (F.S.)	1.39 (L.K.)	-1.20	0.80	1.00	1.66	0.92
B1/25	80.10	2.61 (F.G.)	0.91 (M.S.)	0.29 (F.S.)	0.94 (M.K.)	1.35	2.45	0.82	2 36	1.06
B1/27	90.65	0.95 (C.G.)	0.62 (M.W.S.)	0.13 (F.S.)	1.25 (L.K.)	-0.25	1.00	0.38	1.45	1.01
B1/29	95.08	0.96 (C.G.)	0.94 (M.S.)	0.31 (V.F.S.)	1.59 (V.L.K.)	-0.60	0.90	0.88	1.87	1.19
C1/1	16.50	2.01 (F.G.)	0.72 (M.S.)	0.41 (V.F.S.)	1.30 (L.K.)	1.00	1.70	0.52	2.16	1.31
C1/3	34.00	1.53 (M.G.)	0.62 (M.W.S.)	0.93 (V.F.S.)	1.50 (L.K.)	0.40	1.45	0.38	2 16	1.49
C1/5	39.50	0.38 (C.G.)	1.11 (P.S.)	0.014 (N.S.)	1.07 (M.K.)	-2.15	0.40	1.23	1.34	0.48
C1/6	47.50	0.75 (C.G.)	0.69 (M.W.S.)	0.52 (V.F.S.)	1.37 (L.K.)	-0.12	0.60	0.42	1.60	1.09
C1/7	52.00	0.96 (C.G.)	1.30 (P.S.)	-0.003 (N.S.O	2.07 (V.L.K.)	-4.00	0.90	1.69	2.19	1.37
BLK 1	Surface	1.95 (M.G.)	1.10 (P.S.)	0.23 (F.S.)	1.13 (L.K.)	-0.20	1.80	1.21	2.22	0.96
BLK 2	"	2.62 (F.G.)	0.46 (W.S.)	0.28 (F.S.)	1.31 (L.K.)	1.75	2.55	0.21	2.24	1.57
BLK 3	"	2.50 (F.G.)	0.71 (M.S.)	-0.30 (C.S.)	1.20 (L.K.)	0.50	2.50	0.37	2.05	1.25
BLK 4	"	0.52 (C.G.)	1.07 (P.S.)	0.20 (F.S.)	1.19 (L.K.)	-1.95	0.35	1.14	1.52	0.67
BMK 1	"	1.26 (M.G.)	0.89 (M.S.)	0.09 (N.S.)	1.33 (L.K.)	-0.50	1.30	0.79	1.78	1.03
BMK 2	"	2.32 (F.G.)	0.87 (M.S.)	0.52 (V.F.S.)	1.17 (L.K.)	0.40	2.00	0.76	2.39	1.23
BMK 4	"	0.49 (C.G.)	0.73 (M.S.)	0.12 (F.S.)	1.14 (L.K.)	-0.95	0.50	0.53	1.24	0.76
BMK 5	"	2.09 (F.G.)	0.96 (M.S.)	0.38 (V.F.S.)	0.85 (P.K.)	0.50	2.05	0.92	2.13	0.84
BMK 6	"	1.96 (M.G.)	0.85 (M.S.)	0.47 (V.F.S.)	1.49 (L.K.)	0.75	1.75	0.72	2.32	1.41
BMK 8	"	2.05 (F.G.)	0.83 (M.S.)	0.53 (V.F.S.)	1.30 (L.K.)	0.40	2.00	0.69	2.29	1.29
BMK 9	"	1.32 (M.G.)	1.10 (P.S.)	0.32 (V.F.S.)	1.20 (L.K.)	-0.10	1.30	1.21	1.98	0.87
BMK 11	"	1.83 (M.G.)	1.00 (P.S.)	0.42 (V.F.S.)	1.50 (L.K.)	0.20	1.40	1.00	2.34	1.31
BMK 12	"	2.15 (F.G.)	1.05 (P.S.)	0.15 (F.S.)	1.45 (L.K.)	-0.14	2.10	1.10	2.39	1.28
MMK 2	"	2.10 (F.G.)	1.30 (P.S.)	0.23 (F.S.)	1.97 (V.L.K.)	-1.00	2.20	1.69	2.78	1.60
MMK 3	"	1.81 (M.G.)	0.99 (M.S.)	0.32 (V.F.S.)	1.21 (L.K.)	-0.20	2.00	0.98	2.15	1.05
MMK 4	"	2.52 (F.G.)	1.07 (P.S.)	0.37 (V.F.S.)	1.02 (M.K.)	-0.30	2.10	1.14	2.48	1.04
MMK 6	"	2.75 (F.G.)	1.08 (P.S.)	0.41 (V.F.S.)	1.10 (M.K.)	1.10	2.40	1.17	2.64	1 16

For Middle Kamthi sands the range of the grain size parameters and their average values are as follows :

M_z - 0.49 phi - 2.75 phi average 1.92 phi (medium sand)

σ_1 - 0.73 phi - 1.30 phi; average 0.97 phi (moderately sorted)

Sk_I - +0.09 - +0.53 ; average + 0.33 (strongly fine skewed)

K_G - 0.85 - 1.97 ; average 1.28 (leptokurtic)

Grain size frequency curves

The grain size frequency curves of majority of the samples of both Lower and Middle Kamthi are fine skewed (Fig. 5.22 a). 60 % of Lower Kamthi sands are unimodal and 40 % are bimodal. For Middle Kamthi, these figures are 61 % and 39 % respectively. Among the unimodal sands the medium size class (1 phi - 2 phi) is the primary mode in most of the cases.

Sixty five percent of cumulative curves for Lower Kamthi sands match with those of Visher's fluvial sands (Type - 1). 18 % of the cumulative curves belong to Type 2 with two inflection points. One curve shows the pattern of Type 3 having two saltation sub-populations. Two cumulative curves of Lower Kamthi sands show those patterns (Fig. 5.22 b), which, Visher (1969, p.1102) has stated, are having no analogues in modern sands. These curves show poorly developed saltation population or strong mixing between surface creep and suspension transport population. The present author names such curves as Type 4 in of this dissertation (Fig. 5.22 b).

For Middle Kamthi sands, 45 % of samples have cumulative curve pattern as that of Type 1 while 27 % each are corresponding to Type 2 and 3 (Fig. 5.22 b). The traction population in all these curves does not exceed by 15 % of the weight of the sample. The saltation population varies from values as low as 40 % (BMK-2) to as high as 95 % (C1/3). The suspension load constitutes 10 to 20 % of the sample weight. In one sample (BMK-2) its value reaches as high as 45 % of the total sample weight.

C-M Pattern

C-M Pattern of tractive current (Passega, 1957) shows that 37 % of

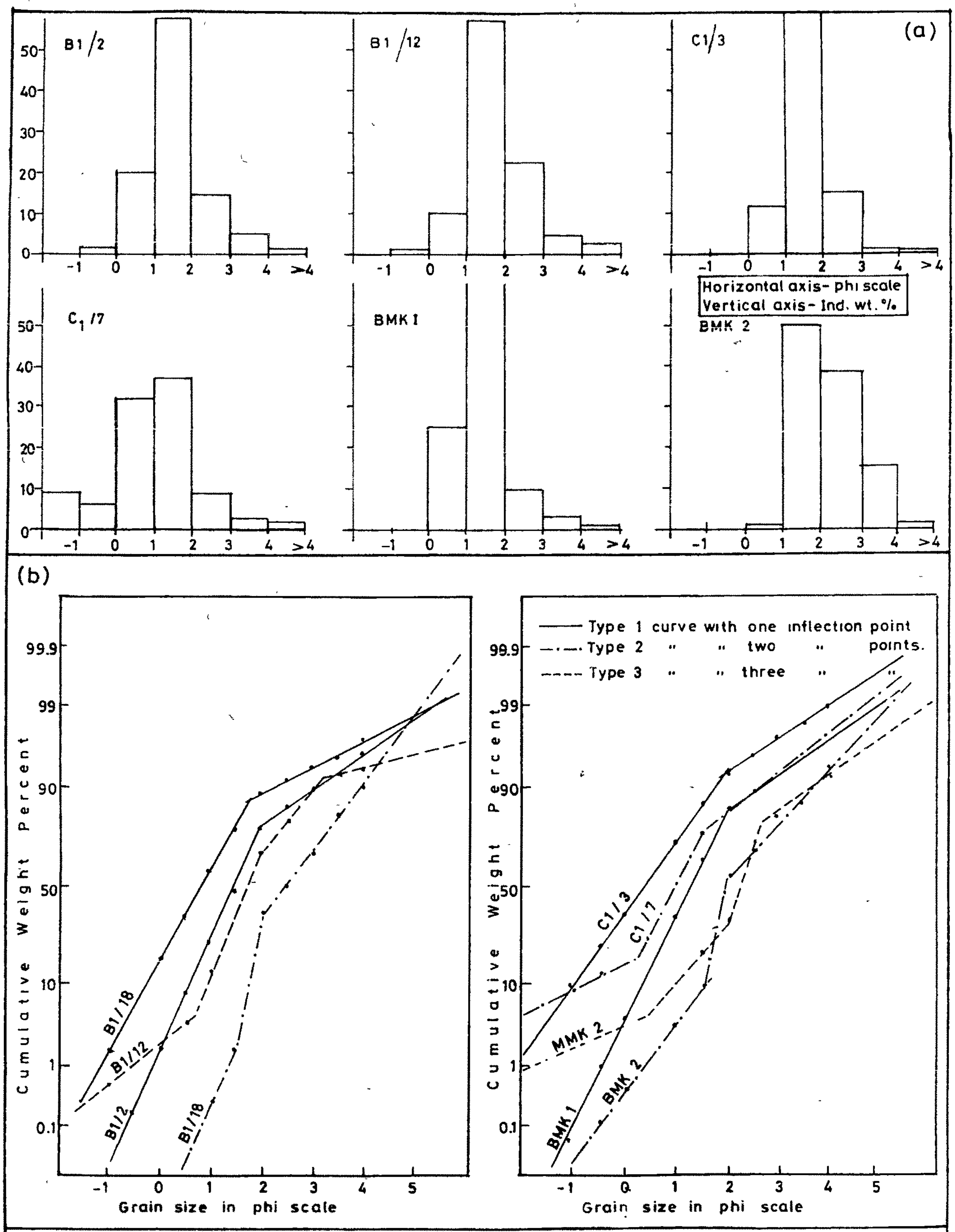

Fig.5.22:Representative Histograms (a) and Cumulative frequency curves (b) of grain size distribution of Kamthi sands.

Kamthi sands were transported by rolling and bottom suspension. Twenty five percent and 13 % account for samples which underwent rolling - graded suspension and graded suspension respectively. 25 % of samples fall outside the tractive current C-M Pattern (Fig. 5.23).

For Middle Kamthi sands, 38 % each are accounting for samples transported by rolling - bottom suspension and rolling - graded suspension (Fig. 5.23). 23 % of samples gives inconclusive results with respect to the pattern of tractive current.

Bivariant discriminatory plots

With the exception of 6 samples (5 from Lower and 1 from Middle Kamthi), all other samples are falling in the field of river sands in the four Bivariant plots of Friedman (1967) and Moiola and Weiser (1968) (Fig. 5.24). The above six samples which fall in beach field are as follows : C1/3 and BLK 4 (Fig. 5.24 a), BLK 3 (Fig. 5.24 b), B1/27, C1/6 and BMK 4 (Fig. 5.24 c) and BLK 2 (Fig. 5.24 d). The point worth mentioning here is that not a single sample falls at a time in the beach field in all the four graphical plots.

Stewart's (1958) (Fig. 5.25) plot shows that 65 % of the sand samples of Lower Kamthi Member falls in or cluster around the demarcated area of river process. Two samples (BLK 2 and BLK 3) are falling distinctly in the field of beach process. The rests show inconclusive results. For Middle Kamthi member, 62 % of the sand samples are falling in and around the area of river process (Fig. 5.25). The rests give no result.

The maturity trend plot of Gleister and Nelson (1971) (Fig. 5.26) shows a wide scatter of points, although 65 % of them cluster around the zone of braided bar. The dispersal pattern of the points of Lower Kamthi is more than that of Middle Kamthi.

Multigroup discriminatory plot

In Sahus (1982) multigroup discriminatory plot, the percent wise plot of samples of Lower Kamthi in different environmental fields are as follows :

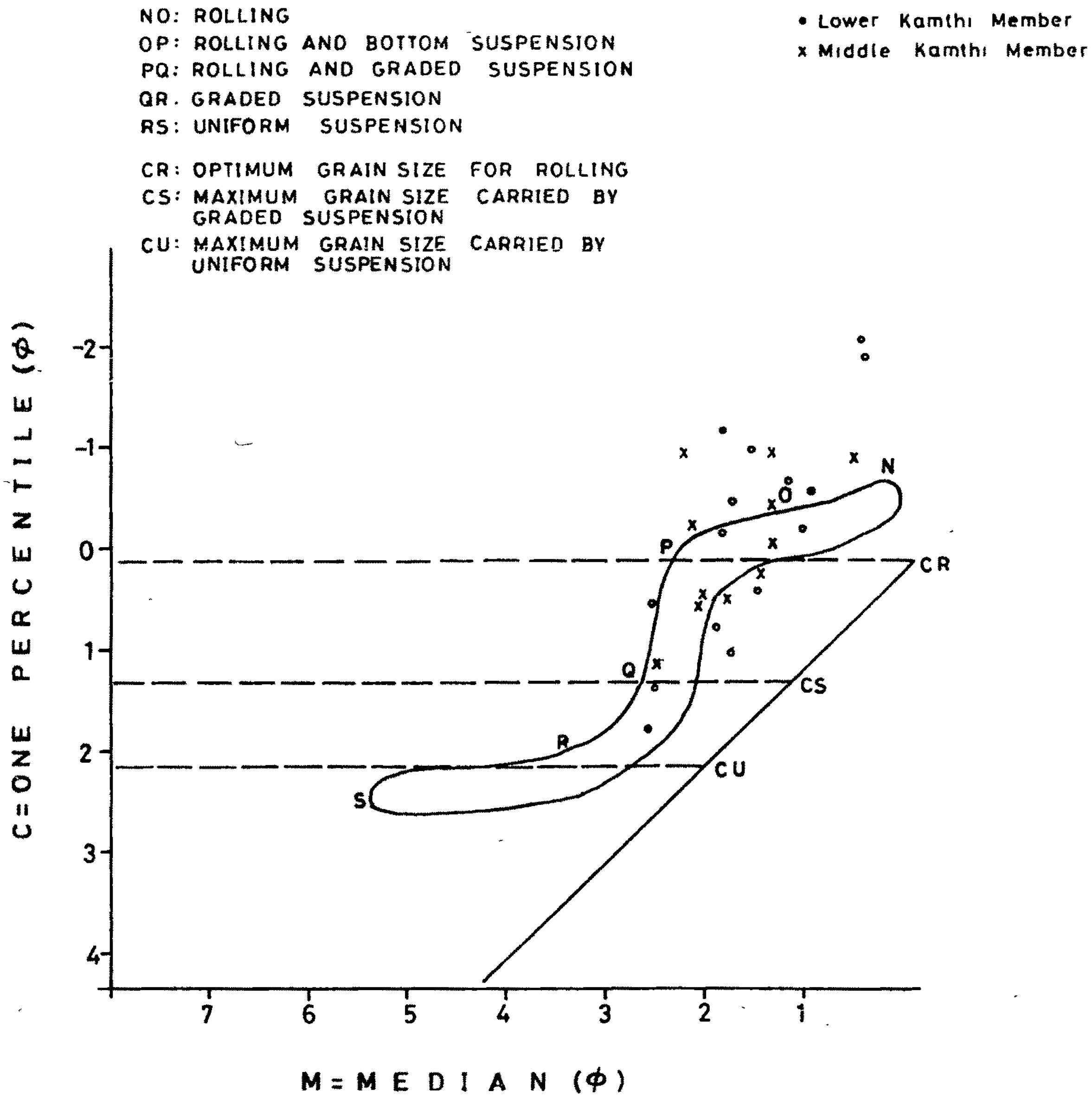

Fig.5.23 C-M Pattern showing sedimentary dynamics of Kamthi sands. (After Passega, 1957, 1962)

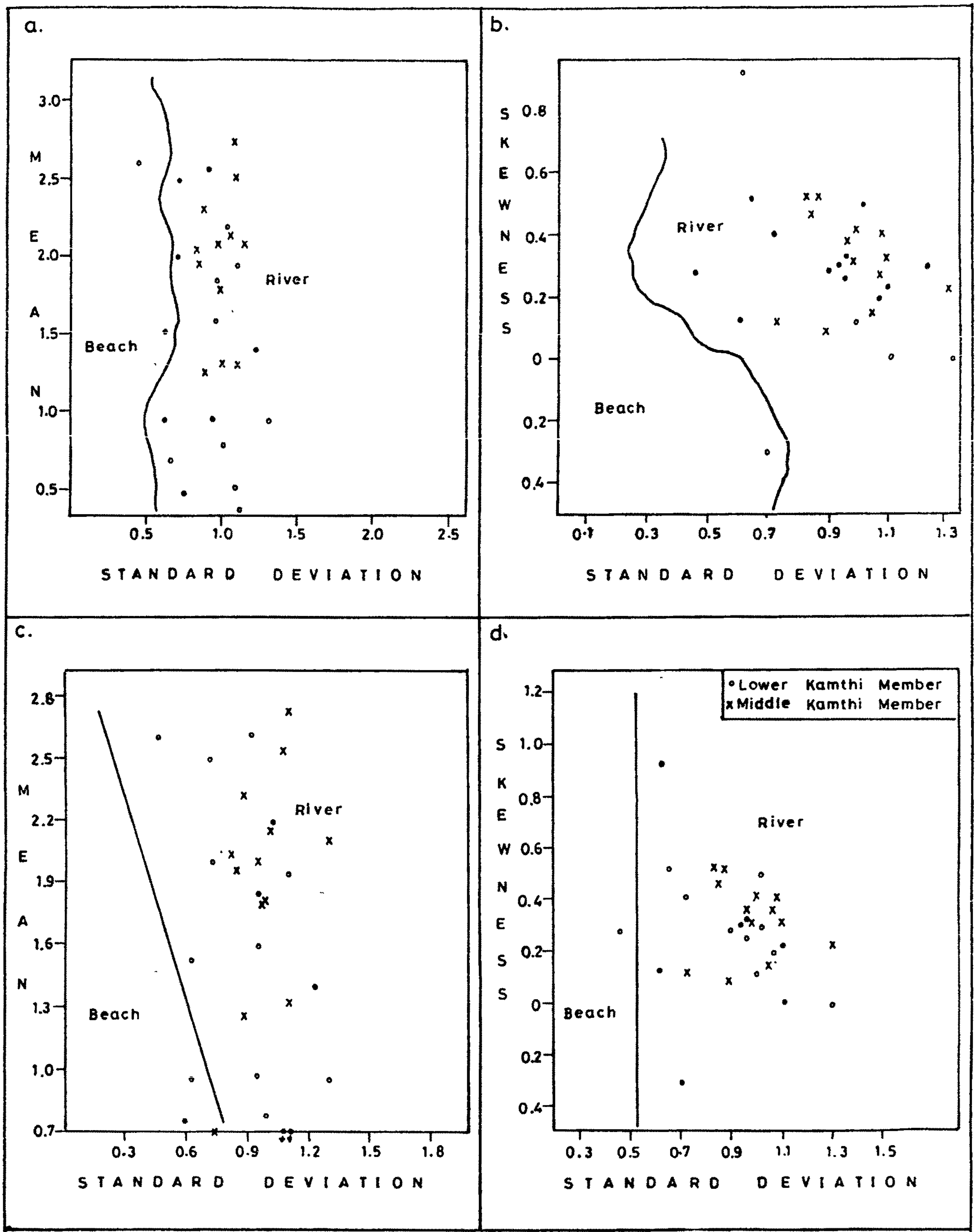

Fig.5.24 : BIVARIANT PLOT: Mean against Standard Deviation and Skewness against Standard Deviation of Kamthi sands.

(After Friedman, 1967, a & b; Moiola and Weiser, 1968, c & d)

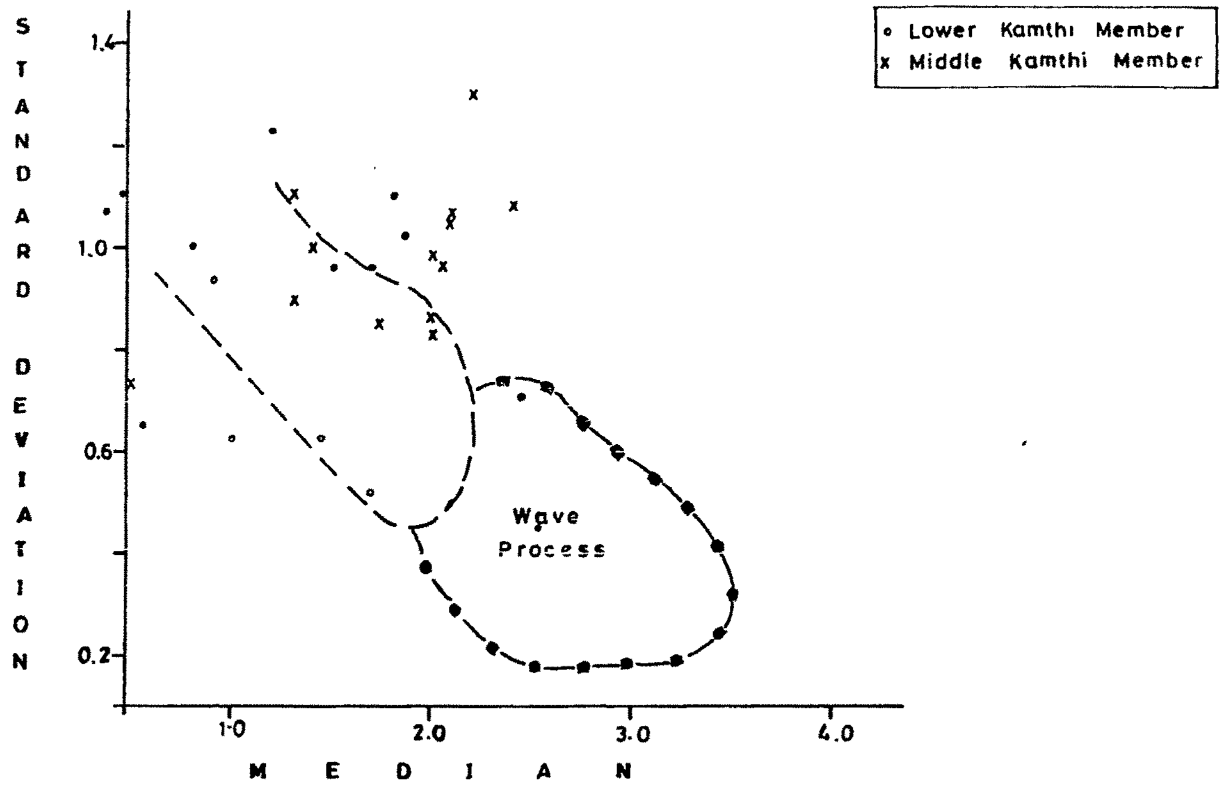

Fig.5.25:Bivariant plot of Standard Deviation Vs. Median of Kamthi sands. (After Stewart, 1958)

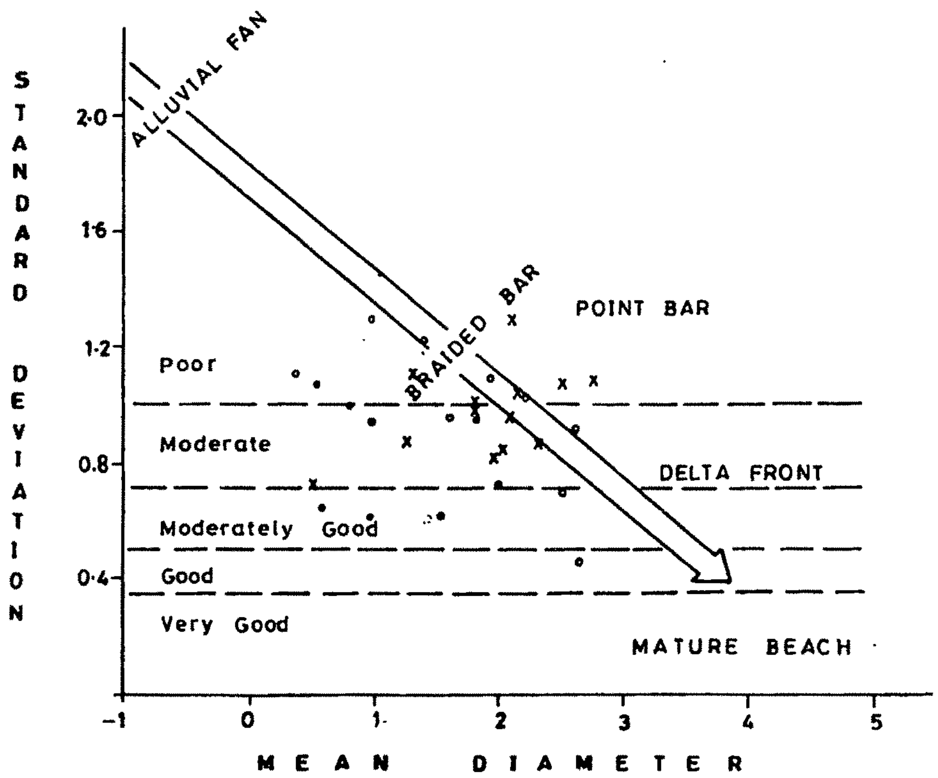

Fig.5.26 : Gradational change in Sorting and Grain size with environment of Kamthi sands. (After Glaister and Nelson, 1974)

River - 41 %, Eolian - 29 %, Beach - 18 %, Shallow marine - 12 %.
For Middle Kamthi this break up is :
River - 78 %, Eolian - 12 %, Beach - 8 % (Fig. 5.27).

Log-Log plot

Sahu's (1964) log-log plot shows that the overall depositional environment of Lower and Middle Kamthi is a fluvial one (Fig. 5.28).

DISCUSSION

TALCHIR FORMATION

Environmental interpretation of Talchir sands based on various textural analysis discussed in the preceding paragraphs reveals that the Talchir sands were transported and/or deposited in a dominantly fluvial regime. The plot of the samples exclusively in the river field in the bivariant discriminatory plot of Friedman (1967) and Moiola and Weiser (1968) and multivariant discriminatory plot and log-log plot of Sahu (1964, 1983) confirms this view. The bivariant graph of Stewart (1958) however, shows that not all samples are transported by river process. Neither are the shape of all the cumulative frequency distribution curve of the Talchir sands fully identical to those of fluvial sands, standardised by Visher (1969). In fact, most of the curves show a sizeable proportion of traction population which is absent in a typical fluvial curve. These curves show a well sorted saltation population and very highly unsorted suspension population, which are the features of cumulative curve of a tractive current deposits of a deltaic (fluvial) environment (Visher, Op. cited).

The close association of three types of curves (Fig.5.1), viz. (a) fluvial type (b) fluvial with surface creep population and (c) truncated saltation population with a large suspension population reflects a deltaic distributary system (Visher, Op.cited). Visher (Op.cited) has described such sands to be deposited in low current velocity condition than the normal channel or fluvial sands. This condition is also evidenced in the C-M pattern (Fig. 5.2a) which shows the bottom suspension mechanism to be the dominating one in transportation of the Talchir sands.

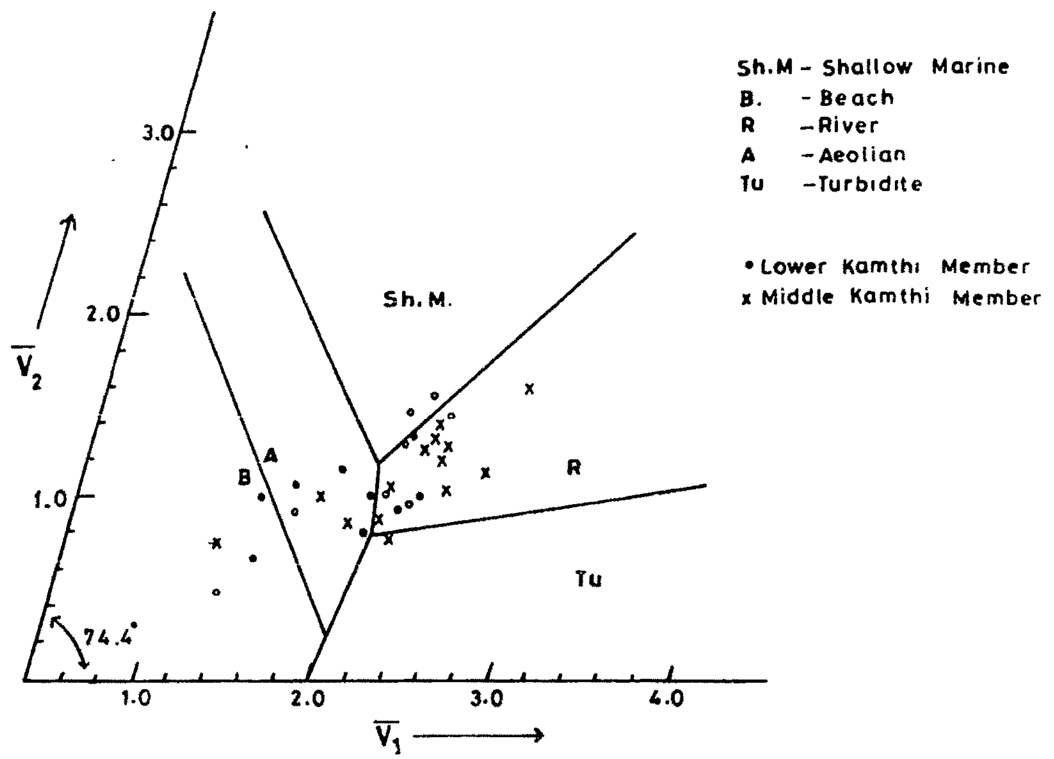

Fig.5.27: Multigroup Discriminatory Plot of Kamthi sands.
(After Sahu, 1983)

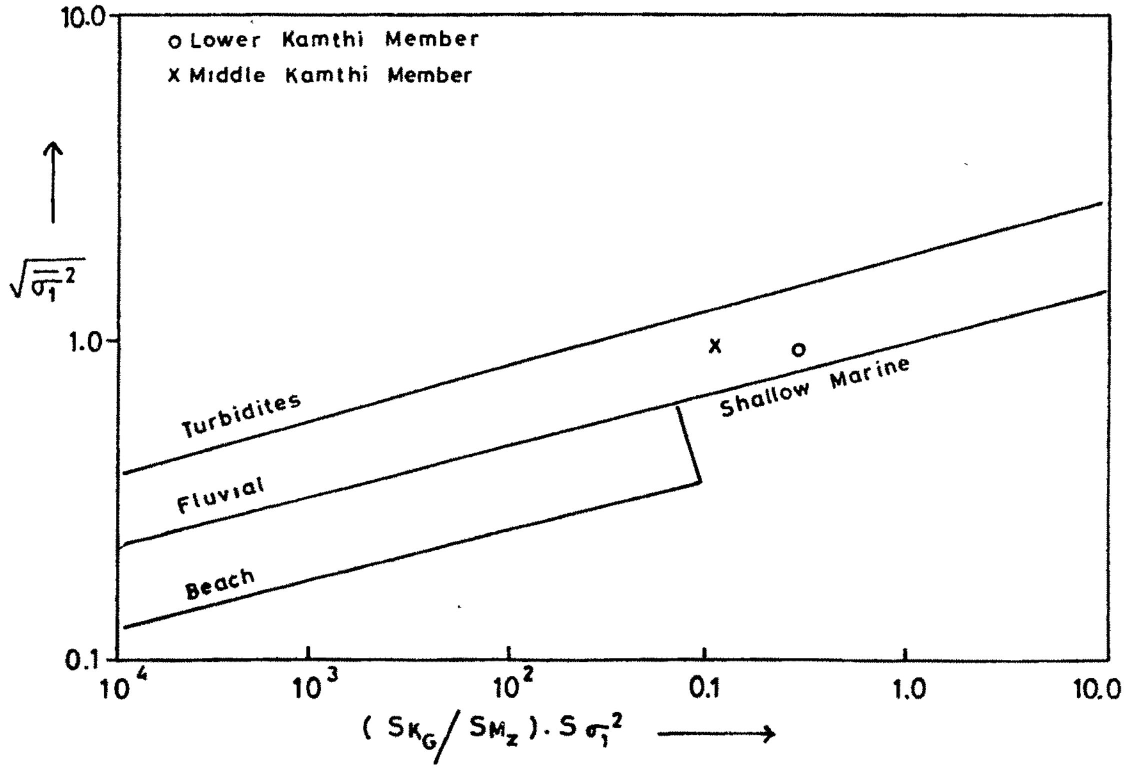

Fig.5.28: Log-log plot showing general sedimentary environment of deposition of Kamthi sands. (After Sahu, 1962)

Interestingly, the C-M plot of Talchir sands matches with that of undaturbidites which Passega (1968) has termed as deposits displaying the C-M pattern intermediate between tractive and turbidity current patterns (Fig. 5.2). According to him, these are the deposits of certain turbidity currents which reflect the grain size distribution of tractive current sediments from which they originated. Passega (1957) has also reported that undaturbidities are more likely than normal turbidites to contain pebbles. This feature is very clearly observed in the Talchir diamictite facies associated with Talchir sandstone.

Thus the Talchir sands can be assumed to be deposited not in uniform suspension but in graded suspension (density stratification of Passega, 1964), where the bottom friction and greater unidirectional current velocity seem to have played an important role. It is possible to consider that the bottom density underflow might have originated when streams having laden with sand and silt, transported their load and discharged it along steep slopes of the basin. From Gleister and Nelson's (1971) bivariant plot of maturity trend (Fig. 5.5), it can certainly be concluded that the depositional environment of Talchir sands lie somewhere between alluvial braided bar and delta front.

Thus from all the textural analyses and foregoing discussion, the author comes to the conclusion that the Talchir sandstones were not transported and/or deposited by a typical fluvial process, *Sensu-Stricto*, but by the bottom density current of a fluvial system characterised by density stratification. Genetically, he would like to term the Talchir sandstones as undaturbidites.

BARAKAR FORMATION

More than 95 % of the Barakar sands are fine skewed. This, as discussed earlier, is due to the fine grained suspended material, trapped in the sand that is being deposited. Owing to their presence in the coarse intergranular spaces, the Barakar sands are showing poor sorting. These two criteria, i.e. constant presence of fines within the coarser grains and poor sorting, are most important in differentiating fluvial sands from that of beach and dune sands (Friedman, 1961, 1967).

Type 1 cumulative curve of Barakar sands which constitutes about 76 % of all cumulative curve, indicate deposition by a system of turbulent continuous current (Visher, 1969). However for Barakar sands, in 73 % cases of Type I curve, the inflection point between saltation and suspension load lies between 1 phi to 2 phi and not between 2.5 phi to 3.0 phi as shown by Visher (Op. cited) in his study of fluvial sands. This may be due to the reason that during the process of deposition, the combined hydraulic factors (discharge, density, depth and velocity) attending the depositing current system plus the bed roughness were more or less alike (Moss, 1963). This had resulted in overall better sorting of saltation load in Barakar sandstones than the fluvial curves established by Visher. Few samples (B2/54, B2/74, B1/43) show two sub-population within the saltation population. Visher (1969) attributed two sub-populations of saltation load to swash and back wash deposits in a beach foreshore. Theoretically, two saltation sub-populations shall well develop in deposits of other subaqueous environments, which has been recorded by Moss (1963) in sandy river gravels. In fluvial regime, it is not unlikely that owing to higher buoyancy during highly turbulent flow or when it is loaded with greater sediment and has a higher density, as during floods, part of the saltation load may be uplifted temporarily into suspension to infiltrate subsequently into pore spaces of saltation load (1^{st} sub-population) during the decelerating phase (Moss, 1963).

The multigroup discriminatory plot (Fig. 5.13), shows that a sizeable proportion of Barakar sands (27 %) are falling in the aeolian field. This can be explained by the fact that the aeolian sediments form an integral part of a fluvial system, developing as dunes within the bars of an inter distributory network of channels. In coarse of time these dunes may become stabilised or a part of it may be partially reworked by the prevailing winds and introduced into the main channel. This might be the case during the Barakar time when the bars of the braided river as revealed by Gleister and Nelson's maturity trend diagram) probably acted as depositories of aeolian sediments. The plot of 3 samples in the shallow marine field can be attributed to lacustrine condition within the locally developed pools. Thus, from the results of textural analyses of Barakar sands, it becomes very clear that the environment of deposition was essentially fluvial.

BARREN MEASURES FORMATION

The most notable textural feature observed in the rocks of Barren

Measures Formation is the abundance of fines. Fine clastic suspension load appears to be more prominent in the rocks of Barren Measures Formation, occurring both as matrix of sandstone and separate beds of shale and clay. Following Visher (1969) the presence of high proportion of intergranular silt and clay within the sandstone may be attributed to (i) digenetic addition of clays, (ii) post-depositional mixing, (iii) sediment settling downward through pores and (iv) possible transport by moving interstitial fluids.

Majority (60 %) of the Type-1 curve (one inflection) of the Barren Measures Formation shows wider range of inflection point using between 2 phi to 3.5 phi. Unlike the Barakar sands, where the inflection is between 1 phi and 2 phi. Due to the inflection at the finer end, the sorting of saltation load of Barren Measures Formation is overall poor. This indicates that the hydraulic conditions of depositing current tended to vary in competency (Moss 1963). Type 2 and Type 3 curves of Barren Measures Formation do not represent typical fluvial curves of Visher (1969). But except 3 samples (B2/29, C1/13 and B2/20) all other samples representing Type 2 and Type 3 curves show fluvial mode of transportation and deposition as per the other tools applied in the present study. The reason for the occurrence of sizeable traction load and two saltation loads in fluvial sands has already been discussed earlier in reference to Barakar Formation.

The multigroup discriminatory plot, shows that 30 % of the samples show aeolian environment. This can quite likely be the case in the region where dune sands develop adjacent to fluvial channel sands in an arid region with a mix of two environments (Moshrif, 1980). Arid climate indeed was prevailing during the Barren Measures time (Krishnan, 1968; Shukal and Rai, 1977). It is also probable that sands derived from the upper exposed surfaces of the fluvial point bars or channel bars of the Barren Measures (as revealed by Gleister and Nelson's maturity diagram), may have been partially reworked by the prevailing winds in the area and were introduced into the main fluvial channel sands. Sahu's (1983) plot (Fig. 5.20) shows 8 samples to be falling in the zone of beach sand. All these samples (B1/40, B1/53, B1/59, B2/15, B2/16, B2/27, M1/14 and M1/45) are however, falling in the field of river sands in the bivariant plots of Friedman (1967) and Moiola and Weiser (1969) (Fig. 5.17). Stewart's (1958) bivariant plot (Fig. 5.18) reveals that most of these sample are falling in and some are clustering around the marked area of river process.

Moreover, except two samples (B2/16 and B2/27) the shape of cumulative frequency curves of the other six samples are similar to the fluvial curves established by Visher (1969). The anomaly observed, may be explained by the fact that these samples are either coarse grained or coarse skewed or both. It can be argued that the finer traction within this sand must have been winnowed away by the prevailing wind, the action of the aeolian current being justified by proximity of the position of the samples to the aeolian field in the discriminatory plot (Fig. 5.20). The plot of 8 samples in the shallow marine region, but close to river zone in figure 5.20 indicates, locally developed lacustrine conditions within the fluvial milieu. Out of 80 samples analysed for Barren Measures there is a conspicuous absence of samples in the demarcated boundary of turbidity current. This implies that there was on absence of mass flow or gravity slumping which are otherwise generally triggered off by a rise in gradient, thereby creating fluid disturbance (Davies 1983). In other words, the palaeotopography during the Barren Measures time was very gentle. This is clearly substantiated by Gleister and Nelson's (1971) maturity trend plot (Fig. 5.19) which shows the absence of any sample in the regions representing alluvial fan or delta front domain.

As already discussed, fine clastic suspension load, appearing as matrix of sandstone and separate beds of shale and clay, is one of the most prominent textural characteristics of the rocks of Barren Measures Formation. The dominance of finer clastics may be attributed to the deposition in point bars, levees or flood plains of a meandering river channel. On the other hand, presence of intermittent pebbly sands and crowding of points around the region of braided bar (Fig. 5.19) implies that deposition also took place within the channel bars. It is thus envisaged that an anabranching river system, denoting an interconnected network of low gradient, moderately sinuous channels seprated by channel bars of mixed load sediment, is the environment of deposition of the sediments of Barren Measure Formation.

KAMTHI FORMATION

From the foregoing paragraphs, it is found that in all the tools of textural analysis, the sands of Lower Kamthi Member are showing more discrepancies or variance than those of the Middle Kamthi Member. This is because the textural variation in the sands of lower member is more than those of the middle member. Since the textural variations are, to a certain extent, controlled by the hydrodynamic conditions of the depositing medium, it can likewise be concluded that the hydraulic factors attending the depositing current was more varying both in space and time, during the deposition of Lower Kamthi's than that of the Middle Kamthi's.

Plot of minor percentage of the samples in the beach and shallow marine field, in the multigroup discriminatory plot has already been explained in detail in earlier sections in reference to Barakar and Barren Measures Formation.

Higher mean grain size (in phi values), greater degree of skewness and abundance of thick shale and clay layer in the middle member than the lower member probably point to a higher degree of sinuosity of the channel during the deposition of the middle Kamthi's than during the deposition of lower Kamthis.

Cumulative curves, various bivariant plots, C-M diagram, discriminatory plot and log-log plot indicate that within a fluvial environment, mechanisms similar to other environments were operative sometime or other during the deposition of Lower Kamthi Member. As discussed, similar mechanisms within a fluvial environment, were in operation during the deposition of Barren Measures Formation. Thus it is envisaged that the anabranching stream pattern that was prevailing during the deposition of Barren Measures, persisted and continued during the deposition of Lower Kamthi's. Greater variation in stream hydraulics and coarser grain size in the Lower Kamthi's than in the Barren Measures however, indicate that there might have been sudden variation in discharge bed-material size due to the interplay of climate and increase in the slope of the intrabasinal tectonism. The channel pattern during the Middle Kamthi's, as discussed, had a much higher sinuosity, and was probably a meandering type.

INFERENCES

Environmental interpretation of grain size analyses of Lower Gondwana sands of the study area point to a fluvial environment of deposition. The various tools of environmental interpretation based on grain size analyses have been found to be highly effective in determining the depositional environment of each formation. Out of 160 samples analysed, only six to seven samples are showing deviation from river field. Out of these seven samples, only one is truly conforming to the character of a non-fluvial sand with respect to the other textural tools of environmental interpretations applied in the present study. Stewart's (1958) plot shows that 60 to 70 % of the samples of all formations (except Talchir) are falling in and around the area of river process. The rest of the samples give inconclusive results. Sahu's (1983) multigroup discriminatory plot also shows that majority (60-70 %) of the samples are falling in the field of fluvial environment.

Out of the rest, major percentage cluster in the aeolian field while a very minor amount fall in beach or shallow marine zones. The association of aeolian sediments with fluvial ones, have been explained by Friedman (1961). Moreover, both being unidirectional flow, there is likely to be textural overlap between the sediments derived from aeolian and fluvial transport. The plot of a minor percentage of samples in beach or shallow marine environmental field is to be anticipated, because short-lived local variations in stream hydraulics can influence sediments textural attributes, which, when analysed, tend to show a deviation from the main environment of deposition. Even, a sizeable number of cumulative grain size frequency distribution curves show deviation from a typical fluvial curve of Visher (1969). Thus within a broad fluvial framework, minor variation in current pattern and hydrodynamic condition is quite likely to occur within the river regime. This was more so the case in Pranhita-Godavari basin during the Lower Gondwana time, when an interrupted fluvial sedimentation (Sengupta, 1970) continued throughout the Permian to give rise to more than 2500 meters thick pile of continental sediments. The unquestionable fluvial character of the Lower Gondwana sediments is confirmed by Log-log plot.