CHAPTER IV

SEDIMENTOLOGICAL STUDIES

In this chapter various petrographic studies of the Quaternary sediments representing different microenvironments from the area under investigation have been carried out. The petrographical studies include mainly heavy mineral analysis, granulometric analysis and shape analysis. The emphasis has been laid on these petrographical characters as these help to understand the nature and mode of transportation, nature of the source rocks the provenance alongwith the variations in various textural characters of these sediments. Thus, these petrographical studies can help to construct history of the processes of sedimentation.

For the sake of convinence, the petrographical studies maintioned above have been divided into three different sections and accordingly have been described in detail in the following paragraphs.

PART A

HEAVY MINERAL ANALYSIS

Representative samples from low tide, high tide, raised marine terrace and beach dune samples were collected for heavy mineral analysis. For the purpose, -100 mesh size fraction of about 10 gm. was taken in a separating funnel containing about 100 c.c. of bromoform (sp.gr. 2.89) and heavy minerals were separated by adopting float and sink method. For better separation, initially small amount of sample was sprinkled on bromoform in the separating funnel. The bromoform was then stirred for few minutes and then allowed to settle the heavies at the bottom of the separating funnel. The heavies were then collected on filter paper, washed with alcohol and dried. The permanent mounts were prepared by using canada balsam. The heavy minerals were identified and their frequencies were calculated, according to the scale suggested by Evans, Hayman and Majeed (1934). The frequencies are represented by way of histograms in Fig. 4.1. The heavy minerals present are opaques, tourmaline, rutile, garnet, epidote, amphibole, sillimanite and pyroxene. These are presented in Table 4.1 and photographically in Plate I. The following paragraphs deal with the petrographical characters of these minerals, studied under microscope.

OPAQUES

Opaque minerals are identified in reflecting light, which exhibit metallic lustre. The opaque minerals are

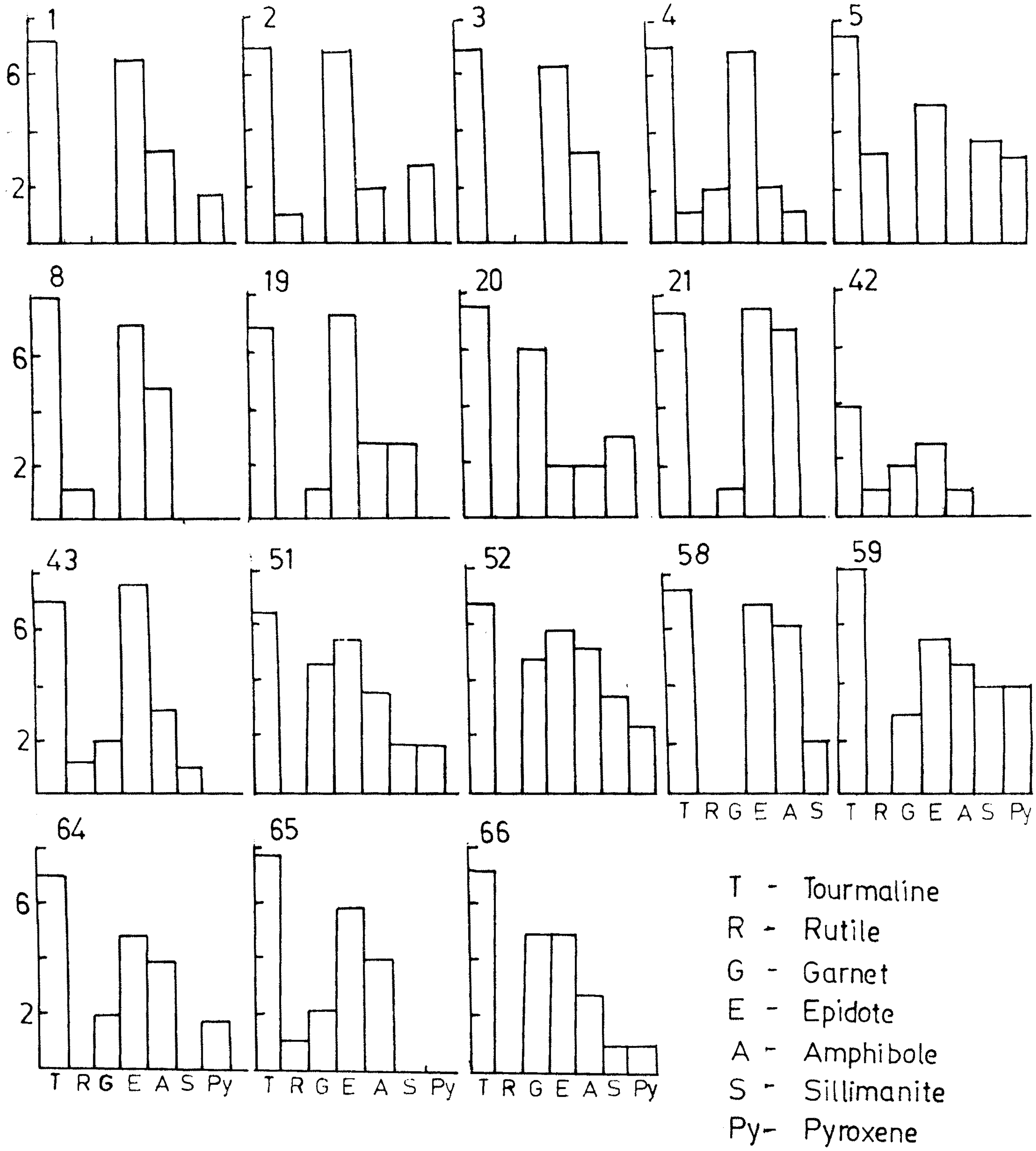

Fig 4·1 Frequency distribution of Heavy Minerals from Quaternary sediments of Malvan Area.

TABLE NO. 4.1 FREQUENCY NUMBER OF THE HEAVY MINERALS FROM THE MALVAN BEACH SAND(NORTH)

Sample No.	Tourmaline	Rutile	Garnet	Epidote	Amphibole	Sillimanite	Pyroxene
1.	7^{+}	-	-	7	4	2	2
2.	7^{+}	1	-	7^{+}	2	-	3
3.	7^{+}	1	-	7	4	-	-
4.	7	1	2	7^{+}	2	1	-
5.	8^{-}	3	-	5	5	5	4
8.	7	1	-	7^{+}	3	5	-
19.	7^{+}	-	1^{*}	7^{+}	3	3	-
20.	8^{-}	-	-	6^{+}	2	2	2
21.	7^{+}	-	1^{*}	7^{+}	7^{-}	-	-
42.	7^{+}	4	6^{-}	6^{+}	4	-	-
43.	7	1	2	7^{+}	3	1	-

TABLE NO. 4.1 FREQUENCY NUMBERS OF THE HEAVY MINERALS FROM THE MALVAN BEACH SAND (SOUTH)

Sample No.	Tourmaline	Rutile	Garnet	Epidote	Amphibole	Sillimanite	Pyroxene
51	7^+	-	5	6	5	1	2
52	7^+	1^*	5	6^-	5	4	3
58	7^+	-	-	7^-	6	2	2
59	8	-	3	6	5	4	4
64	8^-	-	2	6	5	1	2
65	8^-	1^*	3	7^-	4	-	-
66	8^-	-	6^-	6^-	4	1	2

1 : Less than 0.5 % or one or two grains(After Evans,Hayman and Majeed, 1934).

2 : 1 % to 2 % scaree

4 : 4 % to 6 % common

7^- : 28 % to 34 %

7 : 35 % to 44 % abundant

7^+ : 45 % to 59 %

8^- : 59 % to 74 % very abundant

1 : 0.5 % to 1 % rare

3 : 2 % to 3 % fairly common

5 : & % to 13 % very common

6^- : 14 % to 17 %

6 : 18 % to 22 % fairly abundant

6^+ : 23 % to 27 %

magnetite and ilmenite. Ilmenite is distinguished from magnetite by its blue tinge and metallic lustre.

TOURMALINE

Tourmaline is abundant to very abundant with frequency No. varying between 7^+ and 8^-. It is prismatic and subrounded in habit. Prismatic, idiomorphic to perfectly rounded grains are also observed. Perfectly rounded grains rather represent the second cycle of abrasion. The inclusions in tourmaline are also prominent, which indicate pegmatitic origin (Krynine, 1946). Two varieties are common which are green and brown in colour. The prismatic elongated habit of crystals have also been observed which show pale yellow to pale green pleochroism (Plate I, No. 1 - 7).

RUTILE

Rutile is rare with frequency No. 1. It is reddish in colour and is prismatic with thick borders having subrounded pyramidal terminations,

GARNET

Garnet is scarce to fairly abundant with frequency No. varying between 2 and 6^-. It is anhedral to subrounded in habit with high relief and it is slightly pink in colour (Plate I, No.9 - 12).

EPIDOTE

Epidote is abundant with frequency No. -7 to 7^+. It is colourless, anhedral, granular in habit with high order interference colours (Plate I, No. 8).

AMPHIBOLE

Amphibole is fairly common to very common with frequency No. varying between 3 and 5, while it is fairly abundant in raised marine terraces in the southern most zone of the beach. The common amphibole is hornblende with elongated prismatic habit and with inclined extinction angle. It is pleochroic from light green to slightly dark green in colour (Plate I, No. 13, 14).

SILLIMANITE

It is rare to fairly common in few samples with frequency No. varying between 1 and 5. It is in the form of prismatic slender crystals, which are colourless and show yellowish blue interference colours in cross nicol (Plate I, No. 15).

PYROXENE

Pyroxenes are present in few samples and are rare to fairly common with frequency No. varying between 2 and 6. Clinopyroxene is predominant that has prismatic habit with inclined extinction of about 35° and shows high order interference colours between cross nicol. It is identified as augite (Plate I, No. 16).

PART B

TEXTURAL STUDIES

Textures are important attributes of a sedimentary particle, as they originate after a particle has undergone transportation, physical, mechanical and chemical wear. Thus, it documents the imprints of the processes through which it has undergone. Moreover, it also represents nature of source or provenance from which it has derived. Thus, nature of transport, climate and provenance are responsible in deciphering various textural attributes of a sedimentary particle and are, therefore, of significance in sedimentological studies.

Size, shape and fabric are considered as the textural attributes of a sedimentary particle (Blatt, et al. 1980). Of these, size has been studied in detail by many earth scientists to understand the nature of transport and environments of deposition, Shape, in turn, has four different aspects, namely; sphericity, roundness, form and surface texture; of which sphericity and roundness have caught relatively more attention than other aspects for sedimentologists; whereas, fabric refers to packing and orientation of sedimentary particles in space.

GRAIN SIZE ANALYSIS

Considering the significance of the textural altributes, size, sphericity and roundness aspects of the Quaternary sediments from the area under investigation, have been dealt with in detail.

It was Udden (1898), who proposed for the first time the size scale that was based on geometric proportion. Krumbein (1939) worked out the statistical parameters of sediments and suggested their graphical presentation. Commonly, graphical presentation includes histogram, frequency curve and cumulative curve and have found their applications in understanding various characteristics of a sedimentary deposit, including nature of processes responsible for its deposition; Inman (1949), recognised that there are three different modes of transport of sediments, viz., i. traction, ii. saltation, and iii. suspension. While studying the grain size curves, Moss (1962, 1963) identified that a single sample contains all the three sub-populations, representing three different modes of transport.

For the purpose of grain size analysis, samples were collected by following a systematic sampling procedure (Fig. 2.2). Accordingly, sediment samples were collected representing each microenvironment along the tract between Achra Creek and Karli Creek. The microenvironments were low tide, high tide, raised marine terrace and beach dune.

The samples collected from the various sedimentary units mentioned above were disaggregated. The representative fraction from the sample was obtained by coning and quartering method, and the initial weight was noted by weighing it with the help of a single pan balance. The fraction so obtained was then treated with dilute (1:10) hydrochloric acid, so as to remove the molluscan shell fragments and carbonates. The samples were then washed with distilled water to make it free from acid. The samples were dried and weighed on single pan balance.

Each sample was then sieved by placing it on BSS sieves arranged on a half phi-interval. The BSS sieves were placed on ro-tap sieve shaker, which was run for about 20 - 25 minutes. The sieves were removed and the fraction retained on each sieve was collected and weighed accurately. The sieved fractions upto 4 phi (240 mesh) size were collected. The weight of each size fraction has been tabulated and converted to percentages and presented in Table Nos. 4.2, 4.3 and 4.4. Cumulative weight percent for each size has also been computed and presented in Table Nos. 4.5, 4.6 and 4.7. The histograms for each sample has been drawn by plotting percent weight against phi size and is presented in Fig. 4.2a, 4.2b, 4.2c and 4.3. The cumulative weight percent frequency has been plotted on arithmetic scale and also on arithmetic probability scale. The plots on arithmetic scale were used to compute various graphic measures, according to the formulae suggested by Folk and Ward (1957). Whereas the plots on arithmetic probability scale were used to know the three different sub-populations, representing three modes of transport, as suggested by Visher (1969). The log-probability plots are presented in Fig. 4.4a, 4.4b, 4.4c, 4.5a and 4.5b.

Graphic statistical measures suggested by Folk and Ward (1957) are as follows;

TABLE NO. 4.2 WEIGHT FREQUENCY IN GRAMS FOR THE QUATERNARY SEDIMENTS FROM NORTH OF MALVAN BEACH

	Low Tide						High Tide					
Sample No.	1	5	8	11	15	19	2	6	9	12	31	41
Phi. Size.												
0.0	0.07	0.01	-	-	0.10	-	-	-	-	-	-	-
0.5	0.24	0.07	0.09	0.01	0.10	0.01	0.04	0.00	-	-	-	0.02
1.0	1.43	0.70	0.13	0.08	0.19	0.04	0.43	0.01	0.18	-	0.00	0.11
1.5	21.72	9.05	1.52	0.67	0.38	0.93	1.46	1.69	0.61	0.18	0.32	9.41
2.0	34.73	23.21	5.70	8.25	1.51	26.06	9.46	5.92	4.50	2.00	8.82	45.77
2.5	21.00	27.06	17.90	22.87	7.09	36.52	23.09	25.09	17.48	13.74	28.68	29.26
3.0	17.76	36.51	60.65	57.01	25.10	32.00	56.69	54.60	55.46	73.79	38.17	13.92
3.5	2.13	2.49	10.35	8.11	33.16	1.51	5.10	9.14	8.19	7.75	5.82	1.24
4.0	0.91	0.89	3.70	3.01	32.35	0.91	3.72	3.54	13.58	3.47	18.18	0.38

TABLE NO. 4.3 WEIGHT FREQUENCY IN GRAMS FOR THE QUATERNARY SEDIMENTS FROM NORTH OF MALVAN BEACH

	Raised Marine Terrace						Beach Dune					
Sample No.	3	7	20	30	32	42	4	10	13	14	21	43
Phi. Size.												
0.0	-	0.00	-	-	-	-	-	-	-	-	-	-
0.5	-	0.00	-	-	0.00	-	0.01	-	-	-	0.00	-
1.0	0.00	0.01	-	0.03	0.03	0.05	0.04	-	0.02	0.01	0.01	0.05
1.5	0.42	1.48	0.28	3.13	1.48	1.60	6.68	0.55	0.12	0.15	0.91	2.98
2.0	7.61	12.34	12.46	31.83	14.04	13.55	6.81	6.13	2.62	2.66	12.26	29.67
2.5	25.91	32.64	42.25	43.62	37.69	28.13	21.58	21.00	16.10	19.98	31.58	40.40
3.0	55.07	48.83	37.47	20.39	40.17	49.19	51.50	57.58	72.09	62.97	49.54	23.17
3.5	6.10	2.95	2.67	0.53	3.17	6.39	5.76	7.12	6.72	6.47	3.36	2.60
4.0	4.88	1.85	4.88	0.56	3.41	1.09	3.63	7.60	2.31	7.76	2.32	1.12

TABLE NO. 4.4 WEIGHT FREQUENCY IN GRAMS FOR THE QUATERNARY SEDIMENTS FROM SOUTH OF MALVAN BEACH

	Low Tide			High Tide				Raised Marine Terrace			Beach Dune		
Sample No.	51	56	64	45	52	57	65	58	63	66	53	59	67
Phi. Size.													
0.0	-	-	0.01	-	-	-	-	-	-	-	-	-	-
0.5	0.04	0.01	0.13	-	-	-	0.03	-	-	-	-	-	-
1.0	0.07	0.07	0.32	0.03	-	0.01	0.10	0.05	-	0.01	0.01	0.02	0.00
1.5	1.09	1.96	1.87	1.25	0.03	0.04	1.50	0.50	0.11	0.56	0.02	0.24	0.37
2.0	7.02	14.08	7.10	7.52	0.24	0.17	10.63	7.99	0.51	5.70	1.58	4.81	4.68
2.5	21.05	32.77	17.55	15.57	11.98	8.01	26.97	34.35	12.67	26.79	27.54	24.70	25.40
3.0	51.68	41.71	53.09	51.51	67.26	67.99	46.87	49.71	70.70	52.98	62.92	55.97	57.13
3.5	10.31	6.17	11.59	14.35	11.14	12.09	7.36	3.85	11.84	7.41	5.38	7.15	6.31
4.0	8.77	3.22	8.34	9.76	9.36	11.69	6.52	3.54	3.16	7.15	2.54	7.10	6.10

TABLE NO. 4.5 CUMULATIVE WEIGHT PERCENT FREQUENCY FOR THE QUATERNARY SEDIMENTS FROM NORTH OF MALVAN BEACH

	Low Tide						High Tide					
Sample No.	1	5	8	11	15	19	2	6	9	12	31	41
Phi.Size.												
0.0	0.07	0.01	-	-	0.10	-	-	-	-	-	-	-
0.5	0.31	0.08	0.09	0.01	0.20	0.01	0.04	0.00	-	-	-	0.02
1.0	1.74	0.77	0.23	0.08	0.39	0.05	0.47	0.01	0.18	-	0.00	0.13
1.5	23.47	9.83	1.75	0.76	0.77	2.99	1.93	1.70	0.79	0.18	0.32	9.55
2.0	58.20	33.04	7.45	9.01	2.29	29.05	11.40	7.61	5.29	2.18	9.14	55.32
2.5	79.20	60.11	25.36	31.89	9.38	65.58	34.49	32.71	22.77	15.92	37.82	84.57
3.0	96.96	96.62	86.01	88.90	34.48	97.55	91.18	87.31	78.23	89.71	75.99	98.49
3.5	99.09	99.11	96.36	97.01	67.64	99.09	96.28	96.46	86.42	97.46	81.81	99.73
4.0	100.00	100.00	100.05	100.01	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.10

TABLE NO. 4.6 CUMULATIVE WEIGHT PERCENT FREQUENCY FOR THE QUATERNARY SEDIMENTS FROM NORTH OF MALVAN BEACH

	Raised Marine Terrace						Beach Dune					
Sample No.	3	7	20	30	32	42	4	10	13	14	21	43
Phi. Size.												
0.0	-	0.00	-	-	-	-	-	-	-	-	-	-
0.5	-	0.01	-	-	0.00	-	0.04	-	-	-	0.00	-
1.0	0.00	0.02	-	0.03	0.03	0.05	0.04	-	0.02	0.01	0.02	0.05
1.5	0.42	1.50	0.28	3.16	1.51	1.65	6.73	0.55	0.15	0.16	0.93	3.04
2.0	8.03	13.84	12.75	34.99	15.55	15.20	13.54	6.69	2.77	2.81	13.19	32.70
2.5	33.94	46.48	54.99	78.61	53.24	43.33	35.04	27.69	18.87	22.80	44.77	73.10
3.0	89.01	95.31	92.46	98.99	93.41	92.52	86.54	85.27	90.97	85.77	94.32	96.27
3.5	95.11	98.26	95.13	99.53	96.58	98.91	96.31	92.39	97.68	92.44	97.68	98.87
4.0	100.00	100.10	100.01	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

TABLE NO. 4.7 CUMULATIVE WEIGHT PERCENT FREQUENCY FOR THE QUATERNARY SEDIMENTS FROM SOUTH OF MALVAN BEACH.

	Low Tide			High Tide				Raised Marine Terrace			Beach Dune		
Sample No.	51	56	64	45	52	57	65	58	63	66	53	59	67
Phi. Size.													
0.0	-	-	0.00	-	-	-	-	-	-	-	-	-	-
0.05	0.04	0.01	0.13	-	-	-	-	-	-	-	-	-	-
1.0	0.11	0.08	0.45	0.03	-	0.01	0.05	0.05	-	0.01	0.01	0.02	0.00
1.5	1.20	2.04	2.32	1.28	0.03	0.05	0.55	0.55	0.11	0.57	0.03	0.26	0.38
2.0	8.22	16.12	9.43	8.80	0.26	0.22	8.54	8.54	1.62	6.27	1.62	5.07	5.06
2.5	29.27	48.90	26.98	24.37	12.24	8.22	42.90	42.90	14.30	33.06	29.15	29.78	30.46
3.0	80.95	90.61	80.07	75.88	76.50	76.21	92.61	92.61	84.99	85.44	92.07	85.75	87.59
3.5	91.27	96.78	91.66	90.23	90.64	88.30	96.45	96.45	96.84	92.84	97.45	92.89	93.90
4.0	100.03	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

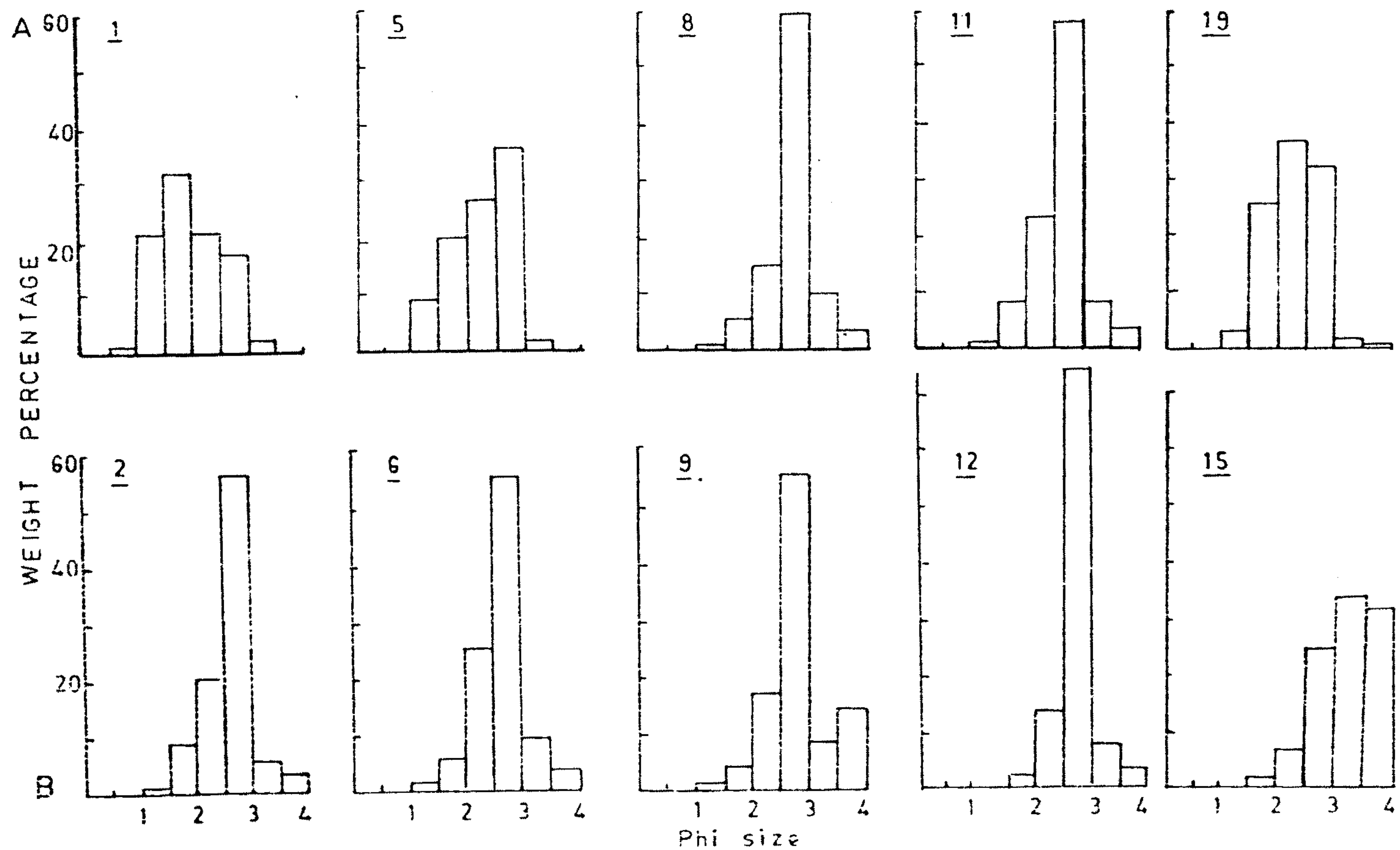

Fig.4·2(a) Histograms showing grainsize distribution from (A) Low tide, (B) High tide zone sediments from Malvan.

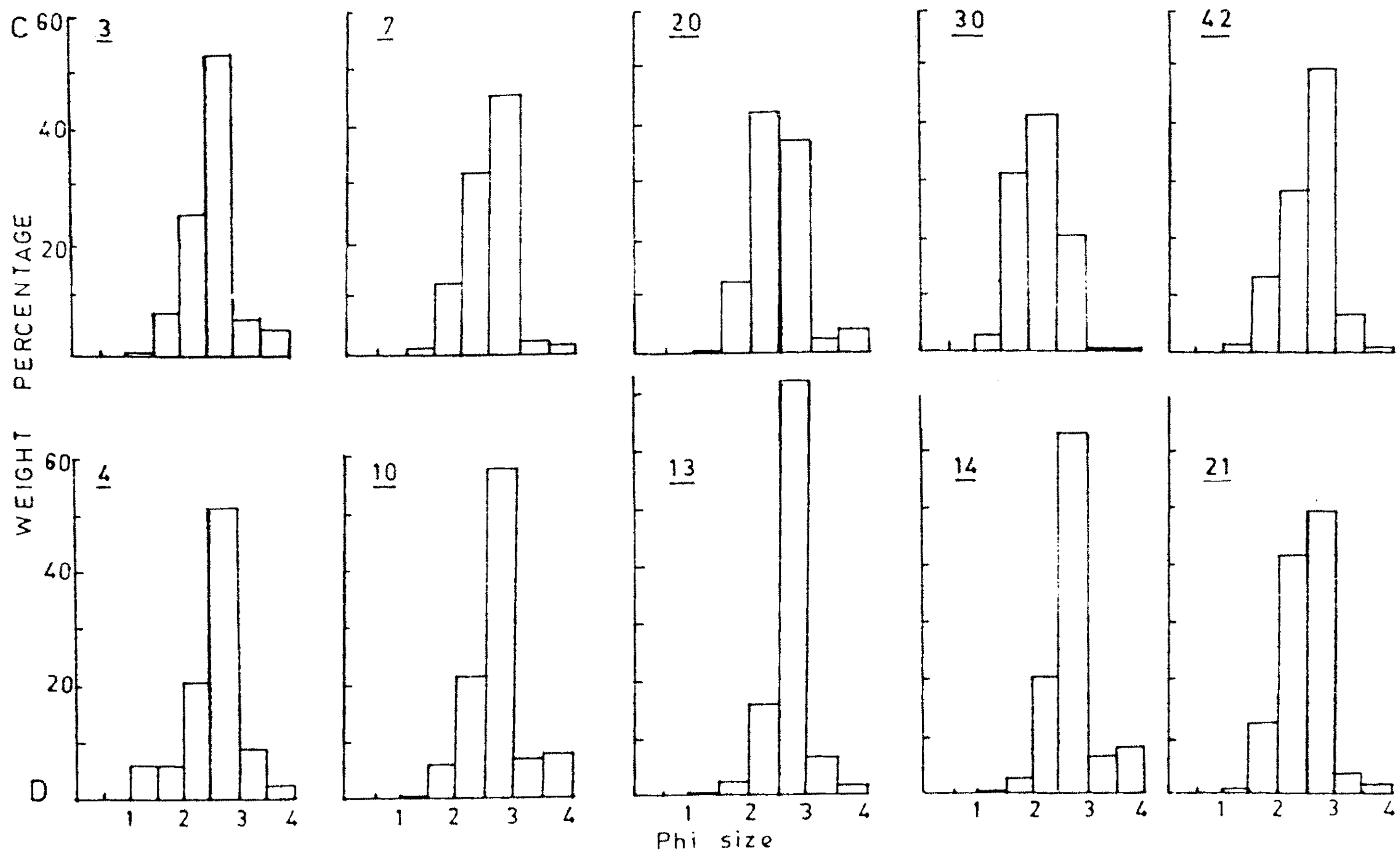

Fig.4·2(b) Histograms showing grainsize distribution from (C) Raised beach (D) Dune sediments from Malvan.

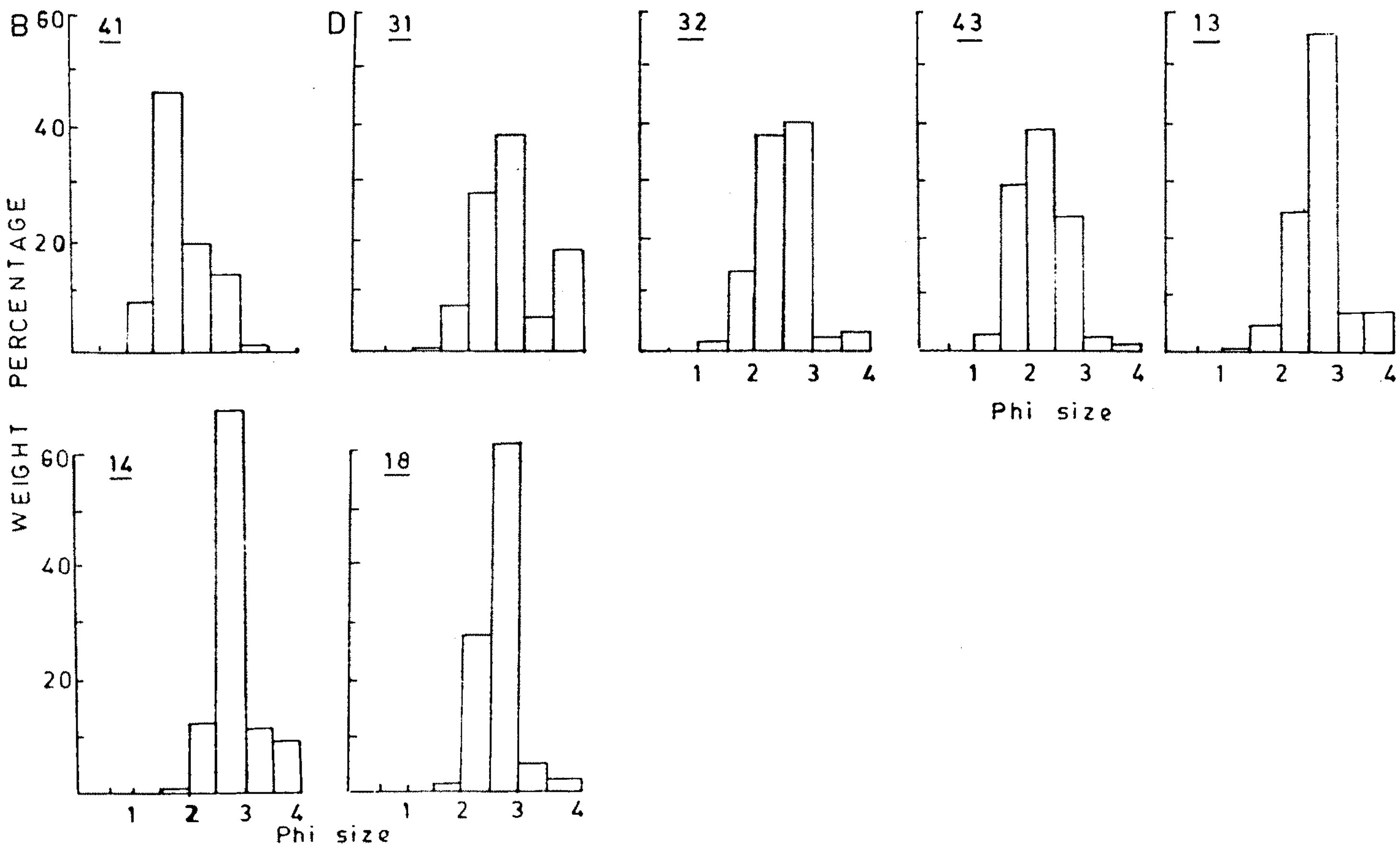

Fig.4·2(c) Histograms showing grainsize distribution from (B) High tide, (D) Dune sediments from Malvan.

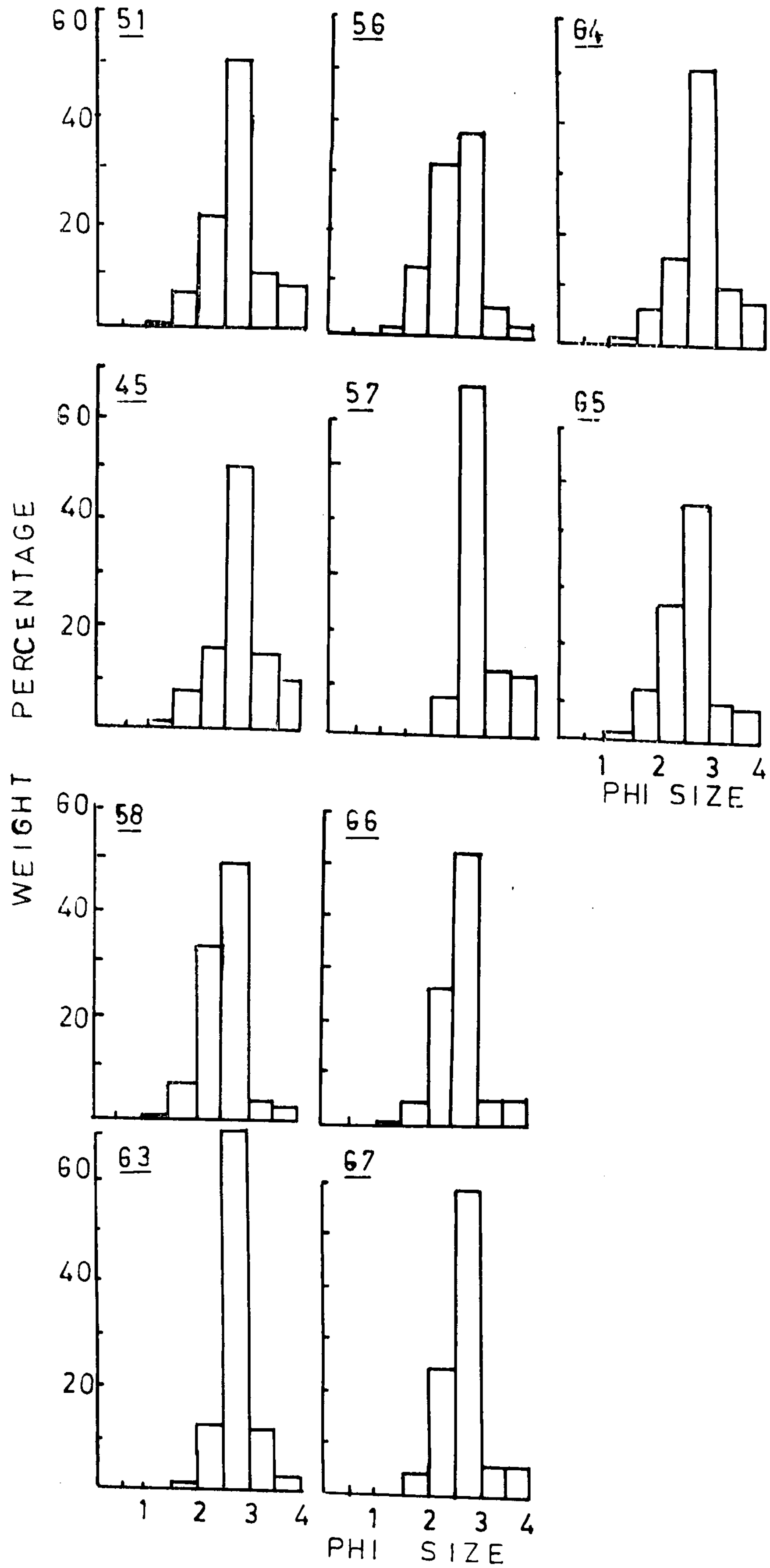

Fig. 4·3 Histogram showing grainsize distribution of sediment from Malvan area.

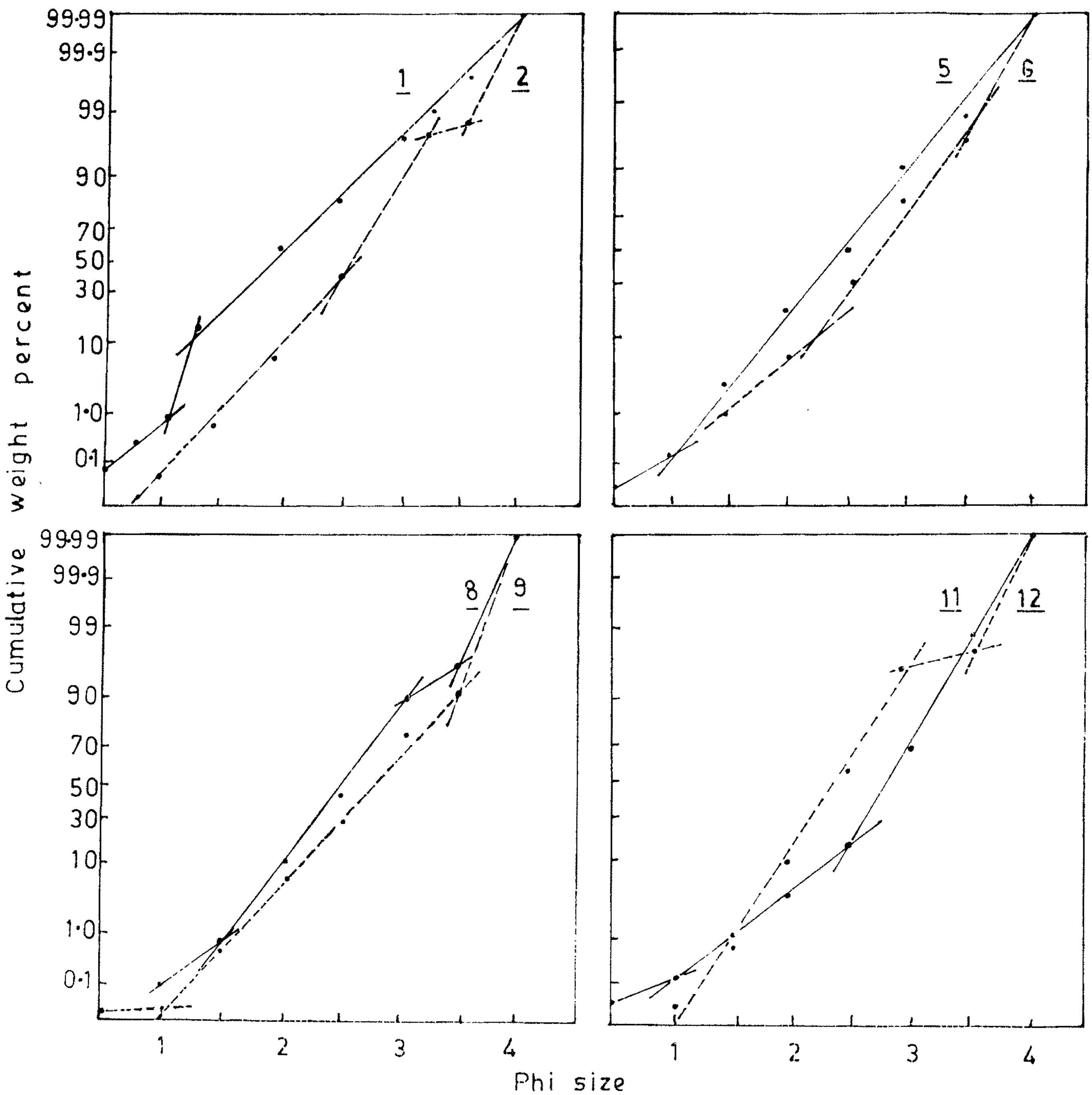

Fig.4.4(a) Log-normal probability curves for the Low tide and High tide zone sediments.

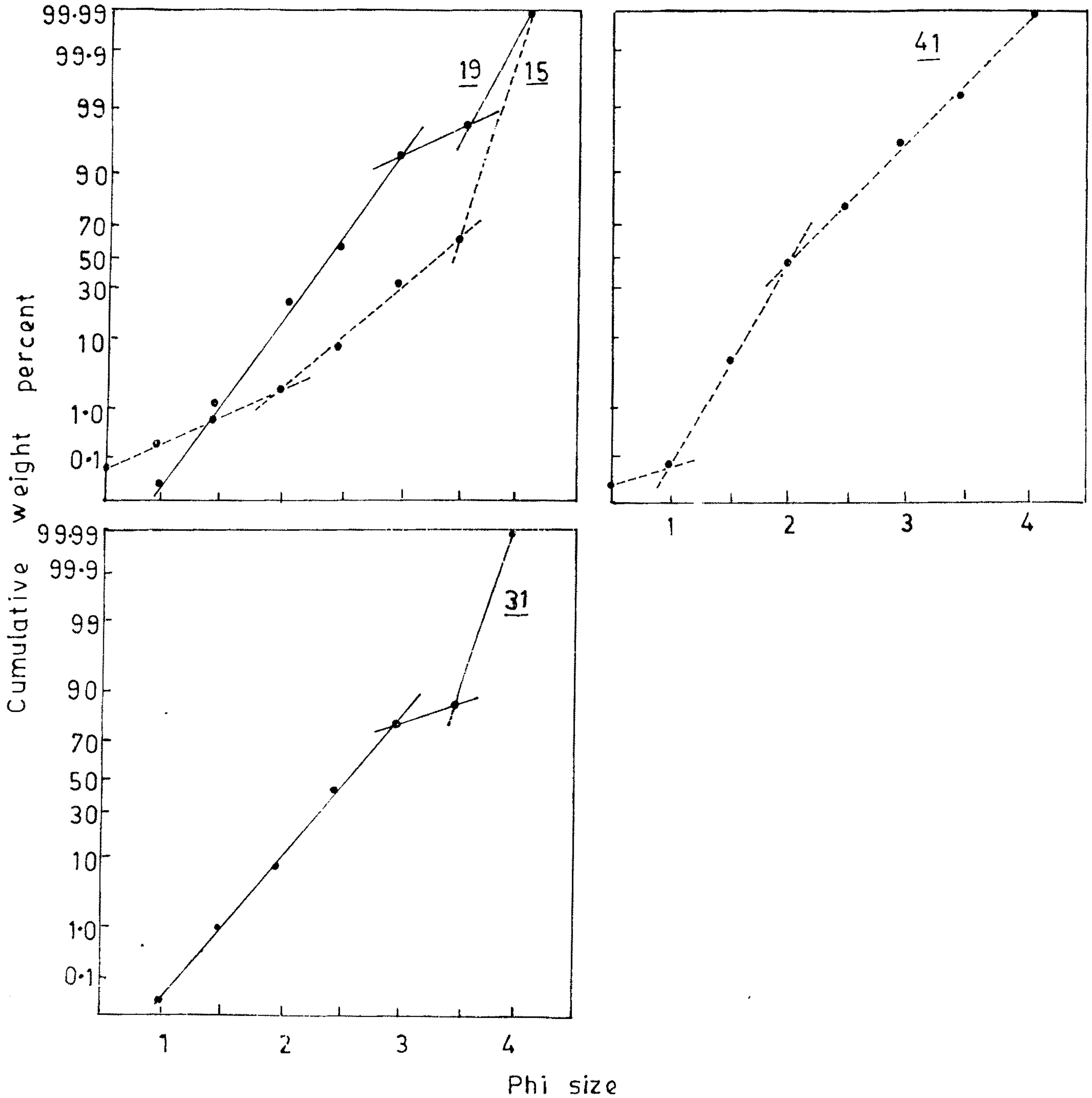

Fig. 4·4(a) Log-normal probability curves for the Low tide and High tide zone sediments

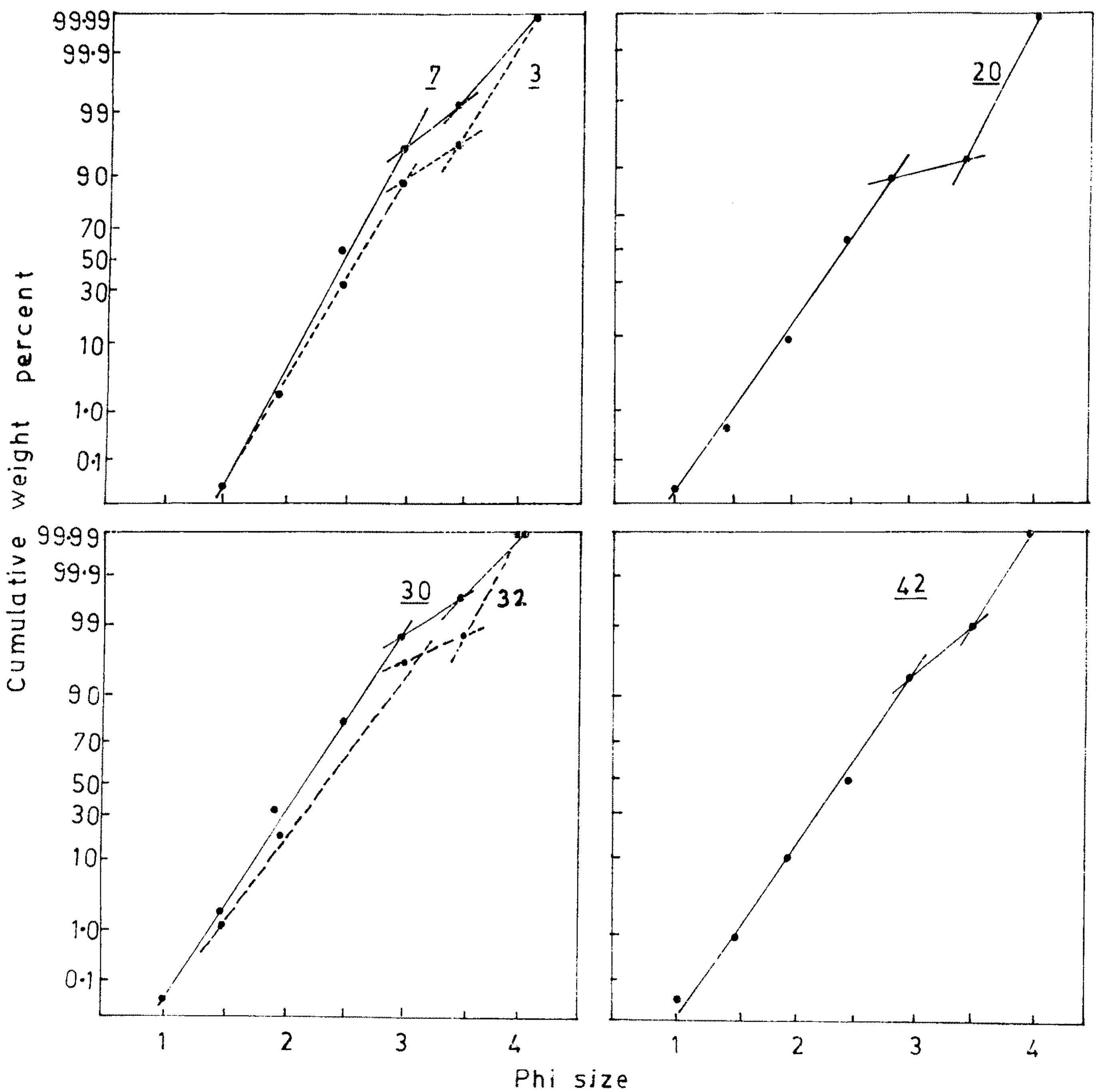

FIG 4.4(b) LOG – NORMAL PROBABILITY CURVES FOR THE RAISED BEACH ZONE SEDIMENTS.

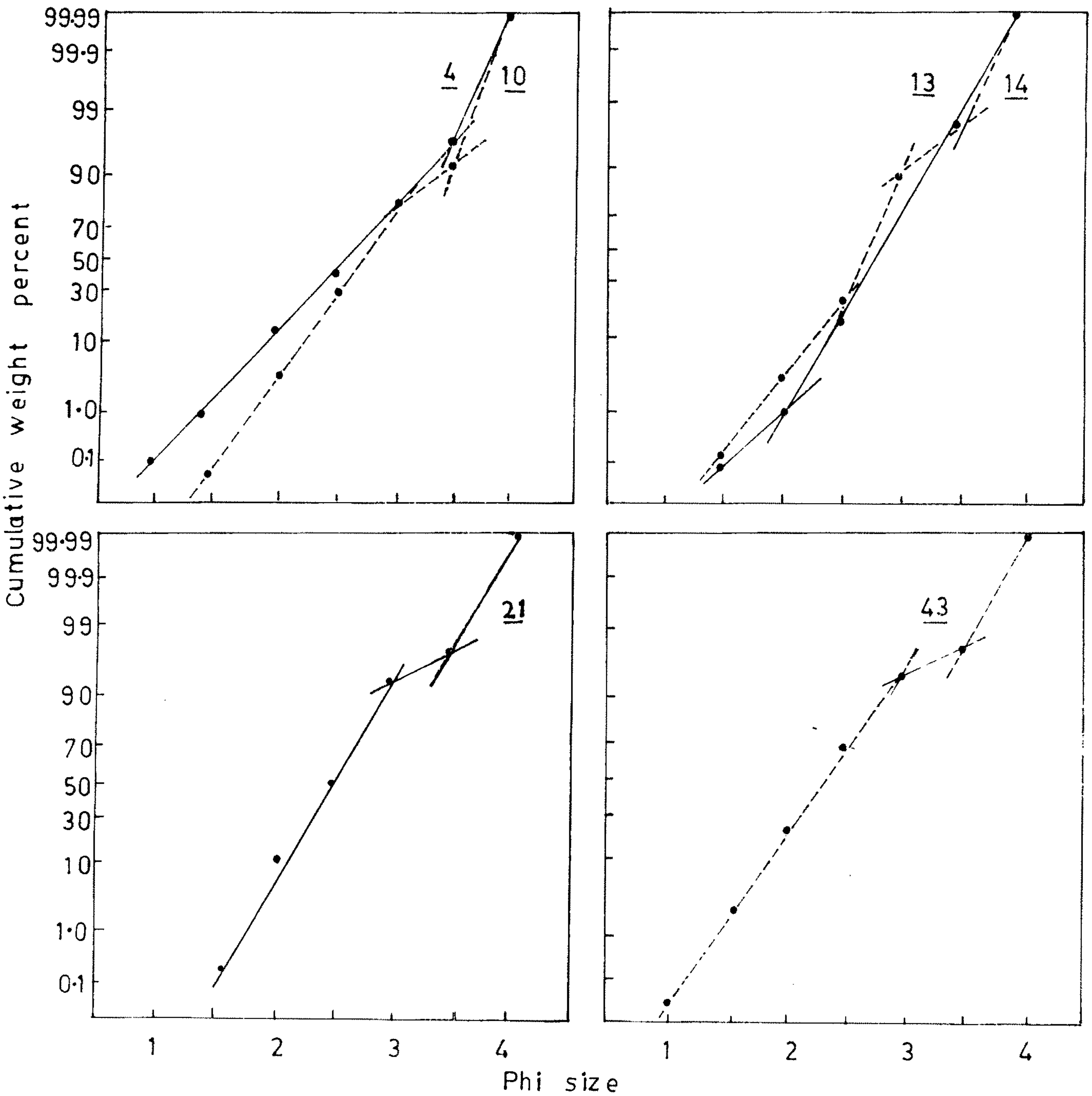

FIG.4.4(c) LOG – NORMAL PROBABILITY CURVES FOR THE DUNE SEDIMENTS.

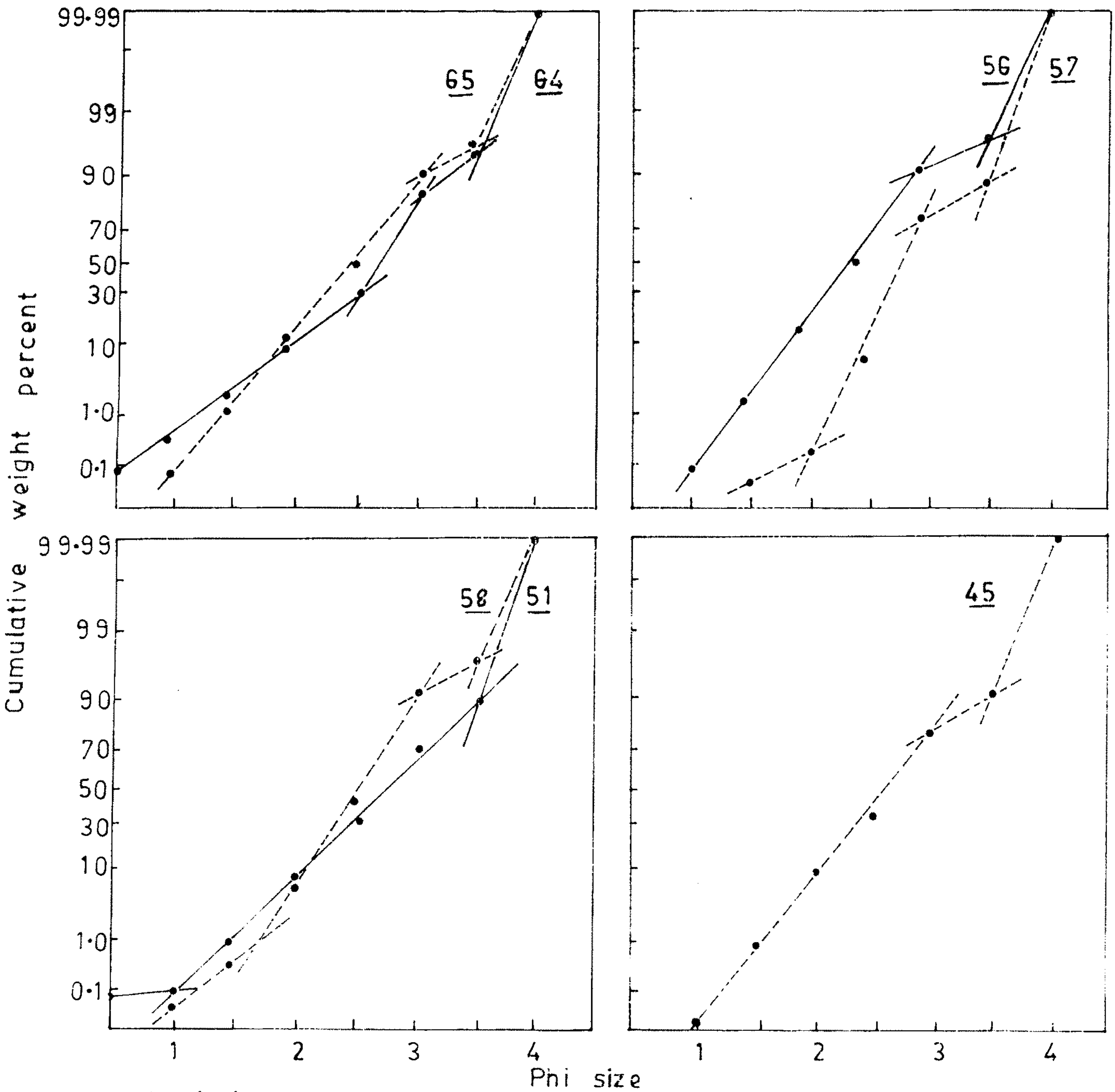

Fig. 4·5(a) Log – normal probability curves for the Low tide and High tide zone sediments.

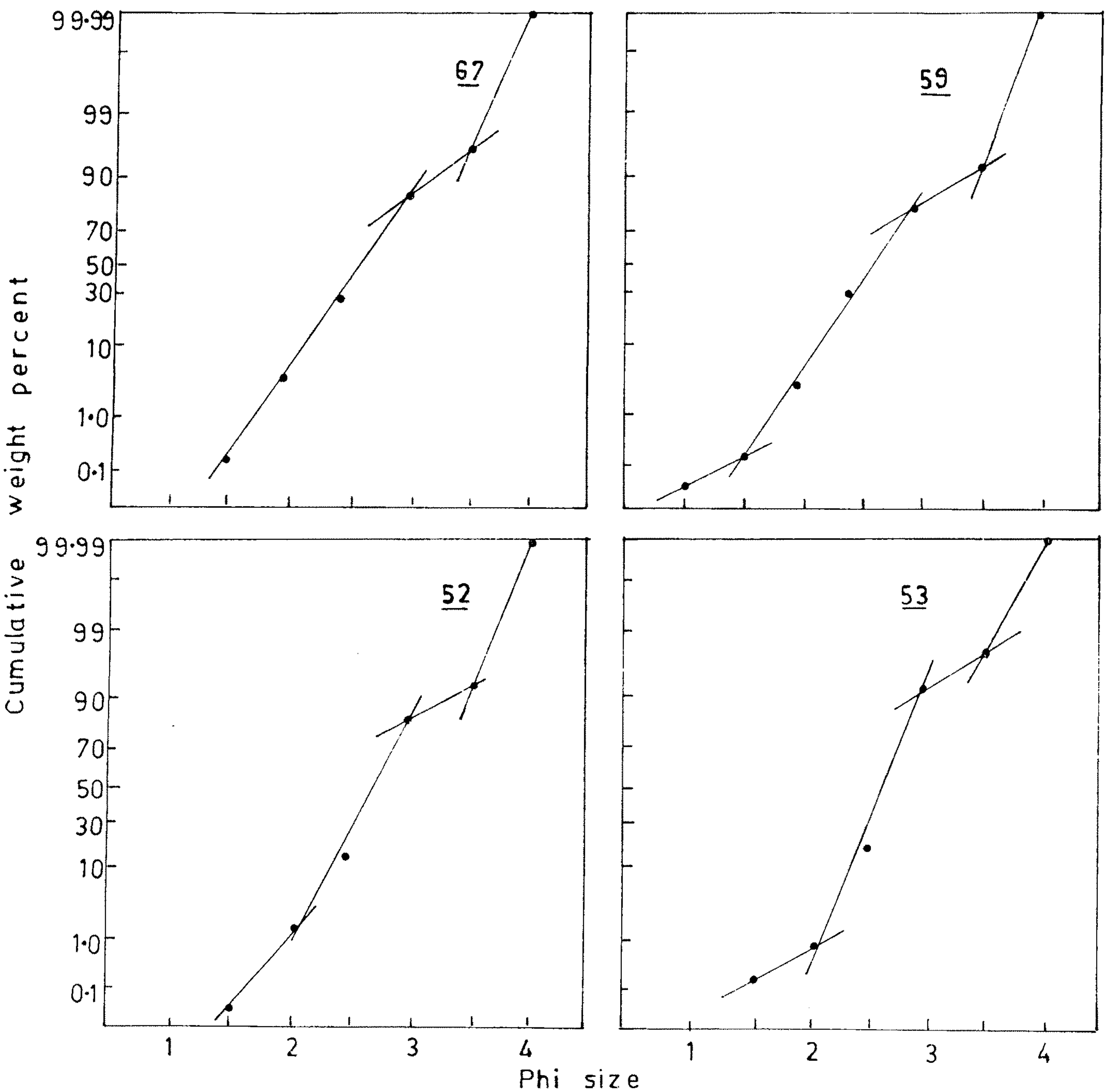

FIG.4·5(b) LOG NORMAL PROBABILITY CURVES FOR THE DUNE SEDIMENTS.

1. Mean size (MZ) $= \dfrac{\phi16 + \phi50 + \phi84}{3}$

2. Median (MD) $= \phi\ 50$

3. Standard Deviation (SD) $= \dfrac{\phi84 - \phi16}{4} + \dfrac{\phi95 - \phi5}{6.6}$

4. Skewness (SK) $= \dfrac{\phi84 + \phi16 - (\phi50)}{(\phi84 - \phi16)} + \dfrac{\phi95 + \phi5 - (\phi50)}{(\phi95 - \phi5)}$

Simplified form of ø skewness of Folk and Ward;

$$\frac{\phi84 - \phi50}{\phi84 - \phi16} - \frac{\phi50 - \phi5}{\phi95 - \phi5}$$

(after Warren, 1974)

5. Kurtosis $= \dfrac{\phi95 - \phi5}{2.44\ (\phi75 - \phi25)}$

SHAPE ANALYSIS

Shape of a sedimentary particle has four aspects, viz. sphericity, roundness, form and fabric (Blatt et al. 1980). Of these, sphericity and roundness have found relatively more attention in sedimentological studies, whereas fabric has been considered mainly of a sedimentary deposit. In the present study, therefore, sphericity and roundness of the Quaternary sediments have been dealt with and have been described in the following paragraphs;

SPHERICITY

Sphericity is a measure of how nearly equal the axial dimensions of a particle are. True sphericity is the surface area of a grain divided by the surface area of a sphere of the same volume.

According to Wadell, (1932), sphericity is expressed as,

$$\sqrt[3]{\frac{Vp}{Vcs}}$$

Where Vp = volume of particle and

Vcs = volume of smallest sphere that would enclose the particle.

Vcs is approximated (Krumbein, 1941) by

$$\sqrt[3]{\frac{LIS}{L^3}} = \sqrt[3]{\frac{IS}{L^2}}$$

Where I = Intermediate axis

S = Short axis, and

L = Long axis

Determination of sphericity values of loose sand grains can prove useful in determination of paleohydrodynamic conditions (Moss, 1972), particularly when combined with studies of size distributions and sedimentary structures.

ROUNDNESS

Roundness indicates the extent of abrasion, grains have undergone. Extent of abrasion reflects overall transportation history but does not necessarily reflect the distance, grains have travelled from their source.

Roundness is generally expressed quantitatively, by the Wadell's (1932) formula as;

$$Pd = \Sigma \; r/R/N$$

Where Pd = degree of roundness,

r = radius of curvature of grain corners,

R = radius of largest incribed circle and

N = number of corners.

Roundness of grains within a sediment will commonly vary even if all grains have been subjected to the same history of abrasion, mechanical or chemical, because mineral and rock fragments differ in their physical and chemical properties, such as; hardness, brittleness, type of internal anisotropism, solubility, etc. Therefore, in comparing samples amongst themselves, it is necessary to contrast roundness of the same type of component. For the purpose, quartz is generally selected, as quartz is abundant, much resistant to abrasion and has relatively isotropic physical and chemical properties. Even if the grain assemblage as a whole has the same history, individual grains within the assemblage would be subjected to differential degrees of abrasion, mechanical and/or chemical. It is generally necessary to record the range in roundness values and also the average, to note any variations with respect to size and/or composition.

For the purpose of shape analysis, a few grains at random were picked up from each sieved fraction and mounted separately on a glass slide. To study the palaeohydrodynamic conditions at the time of deposition, loose grains of sediment samples were selected from low tide, high tide, raised marine terrace and beach dune environments. The mounts of each sieved fraction were prepared by fixing with the help of transperent adhesive tape to the glass slide. The slide so prepared were then observed on Wild M3Z microscope. The outline of ten grains at random were traced from each slide. The sphericity and roundness values were then computed by using Wadell's formulae (1932).

Sphericity was computed by the ratio of the diameter of the largest inscribed circle to the diameter of the smallest circumscribed circle for each grain. Similarly, roundness of each grain was also computed by measuring radius of largest inscribed circle and radii of curvatures of every corner of each grain. Number of corners of each grain were measured and roundness values computed.

The mean sphericity value for each sieved fraction was calculated and presented in Table No. 4.18 and 4.19. The percent frequency distribution of the sphericity values for each sample was also calculated and presented in Table No. 4.20 and 4.21.

Similarly, the mean roundness value for each sieved fraction was calculated and presented in Table No. 4.22 and 4.23. The percent frequency distribution of the roundness value for each sample was also calculated and presented in Table No. 4.24 and 4.25.

The frequency distribution of mean sphericity and mean roundness have been represented by way of histograms in Fig. 4.10 and 4.11. The plots of mean sphericity and mean roundness against size for each microenvironment have also been made and are presented in Fig. 4.12 a,b , 4.13 a,b and 4.14 a,b .

TABLE NO.4.18 MEAN SPHERICITY VALUES IN RELATION TO SIZE (IN PHI) FOR THE QUATERNARY SEDIMENTS FROM MALVAN BEACH

Phi.Size Sample No.	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	Mean Sphericity
Low Tide									
1.	-	0.55	0.51	0.45	0.31	0.55	0.55	0.51	0.49
8.	-	0.61	0.61	0.58	0.50	0.53	0.57	0.57	0.56
High Tide									
9.	-	0.62	0.62	0.51	0.60	0.61	0.55	0.55	0.58
Raised Marine Terrace									
3.	-	-	0.60	0.60	0.63	0.70	0.53	0.54	0.60
20.	-	-	0.35	0.49	0.66	0.80	0.62	0.62	0.59
30.	-	0.64	0.62	0.64	0.60	0.51	0.54	0.57	0.58
32.	-	0.52	0.64	0.50	0.60	0.51	0.63	0.61	0.57
42.	-	0.67	0.65	0.65	0.61	0.61	0.60	0.52	0.61
Beach Dune									
10	-	-	0.57	0.57	0.60	0.65	0.53	0.52	0.57

Table No. 4.19 **Mean sphericity values in relation to size (in phi) for the Quaternary sediments from Malvan Beach.**

Phi. Size / Sample No.	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	Mean Sphericity
Low Tide									
51	-	-	0.60	0.59	0.59	-0.60	0.61	0.54	0.58
64	0.58	0.60	0.51	0.64	0.51	0.55	0.57	0.53	0.56
High Tide									
52	0.57	0.65	0.58	0.64	-0.57	-0.67	0.63	0.61	0.61
57	-	0.38	-0.37	0.43	-0.37	-0.65	0.63	-0.61	0.49
65	-	0.60	-0.51	-0.64	0.51	-0.55	-0.57	-0.53	0.55
Beach Dune									
53	-	0.67	0.70	-0.66	0.56	0.63	0.61	-0.55	0.62
67	-	0.67	0.67	0.66	0.66	0.48	0.65	0.55	0.52

TABLE NO.4.20: PERCENT FREQUENCY DISTRIBUTION OF THE SPHERICITY VALUES FOR THE QUATERNARY SEDIMENTS FROM THE MALVAN BEACH

	Low Tide		High Tide	Raised Marine Terrace			Beach Dune		
Sample No.	1	8	9	3	20	30	10	32	42
Class Interval									
0.2 - 0.3	03	-	-	01	-	-	-	02	-
0.3 - 0.4	09	06	-	06	02	-	08	-	01
0.4 - 0.5	17	17	24	15	06	19	15	14	16
0.5 - 0.6	36	30	32	32	29	46	28	29	22
0.6 - 0.7	20	25	30	27	30	16	30	28	35
0.7 - 0.8	12	20	09	10	23	14	10	20	19
0.8 - 0.9	-	-	01	05	08	03	08	06	05
0.9 - 1.0	-	-	01	01	-	-	-	-	-

TABLE NO. 4.21 PERCENT FREQUENCY DISTRIBUTION OF THE SPHERICITY VALUES FOR THE QUATERNARY SEDIMENTS FROM THE MALVAN BEACH.

	Low Tide		High Tide			Beach Dune	
Sample No.	51	64	52	57	65	53	67
Class Interval							
0.2 - 0.3	-	-	-	-	-	-	-
0.3 - 0.4	01	06	03	03	06	03	01
0.4 - 0.5	15	24	14	07	14	06	08
0.5 - 0.6	33	33	23	29	32	30	16
0.6 - 0.7	36	26	29	41	21	32	43
0.7 - 0.8	13	14	25	15	21	23	30
0.8 - 0.9	-	-	06	03	03	05	-
0.9 - 1.0	-	-	-	-	01	-	-

TABLE NO.4.22 MEAN ROUNDNESS VALUES IN RELATION TO SIZE (IN PHI) FOR THE UNCONSOLIDATED QUATERNARY SEDIMENTS FROM MALVAN BEACH

Phi. Size. / Sample No.	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	Mean Roundness
Low Tide									
1.	-	0.49	0.50	0.46	0.38	0.38	0.52	0.47	0.45
8.	-	0.22	0.31	0.36	0.38	0.52	0.38	0.40	0.36
High Tide									
9.	-	0.19	0.30	0.32	0.42	0.37	0.38	0.48	0.35
Raised Marine Terrace									
3.	-	-	0.39	0.46	0.45	0.51	0.46	0.55	0.47
20.	-	-	0.33	0.36	0.47	0.38	0.35	0.39	0.38
30.	-	0.40	0.52	0.45	0.41	0.45	0.47	0.45	0.45
32.	-	0.41	0.43	0.44	0.45	0.44	0.46	0.47	0.44
42.	-	0.41	0.43	0.44	0.45	0.44	0.46	0.47	0.44
Beach Dune									
10.	-	-	0.31	0.40	0.40	0.36	0.45	0.41	0.38

Table No.4.23 Mean Roundness values in relation to size (in phi.) for the Quaternary sediments from Malvan Beach.

Phi. Size. Sample No.	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	Mean Roundness
<u>Low Tide</u>									
51	-	-	0.26	0.36	0.37	0.30	0.32	0.44	0.34
64	0.23	0.26	0.34	0.33	0.44	0.40	0.37	0.36	0.34
<u>High Tide</u>									
52	0.69	0.47	0.42	0.39	0.49	0.63	0.33	0.51	0.49
57	-	0.41	0.32	0.31	0.35	0.47	0.44	0.46	0.39
65	-	0.32	0.46	0.40	0.41	0.52	0.37	0.36	0.40
<u>Beach Dune</u>									
53	-	0.42	0.39	0.39	0.42	0.42	0.37	0.57	0.42
67	-	0.30	0.43	0.46	0.42	0.37	0.47	0.50	0.42

TABLE NO.4.24 . PERCENT FREQUENCY DISTRIBUTION OF THE ROUNDNESS VALUES FOR THE QUATERNARY SEDIMENTS FROM THE MALVAN BEACH

	Low Tide		High Tide	Raised Marine Terrace			Beach Dune		
Sample No.	1	8	9	3	20	30	10	32	42
Class Interval									
0.1 - 0.2	-	05	08	-	-	-	-	02	-
0.2 - 0.3	02	28	23	08	12	08	20	11	08
0.3 - 0.4	32	34	32	23	49	35	35	38	32
0.4 - 0.5	37	21	20	28	26	28	27	31	29
0.5 - 0.6	17	11	15	20	10	09	17	17	20
0.6 - 0.7	03	02	02	15	02	12	-	02	05
0.7 - 0.8	09	-	-	03	-	06	02	-	05
0.8 - 0.9	-	-	-	02	-	-	-	-	02
0.9 - 1.0	-	-	-	-	-	02	-	-	-

TABLE NO. 4.25 PERCENT FREQUENCY DISTRIBUTION OF THE ROUNDNESS VALUES FOR THE QUATERNARY SEDIMENTS FROM THE MALVAN BEACH.

	Low Tide		High Tide			Beach Dune	
Sample No.	51	64	52	57	65	53	67
Class Interval							
0.1 - 0.2	07	04	-	-	05	-	-
0.2 - 0.3	27	20	09	15	09	05	09
0.3 - 0.4	40	50	40	41	42	46	34
0.4 - 0.5	13	16	29	20	17	23	31
0.5 - 0.6	13	06	12	18	12	22	17
0.6 - 0.7	-	03	06	07	14	03	05
0.7 - 0.8	-	02	03	-	02	02	-
0.8 - 0.9	-	-	-	-	-	-	03
0.9 - 1.0	-	-	02	-	-	-	02

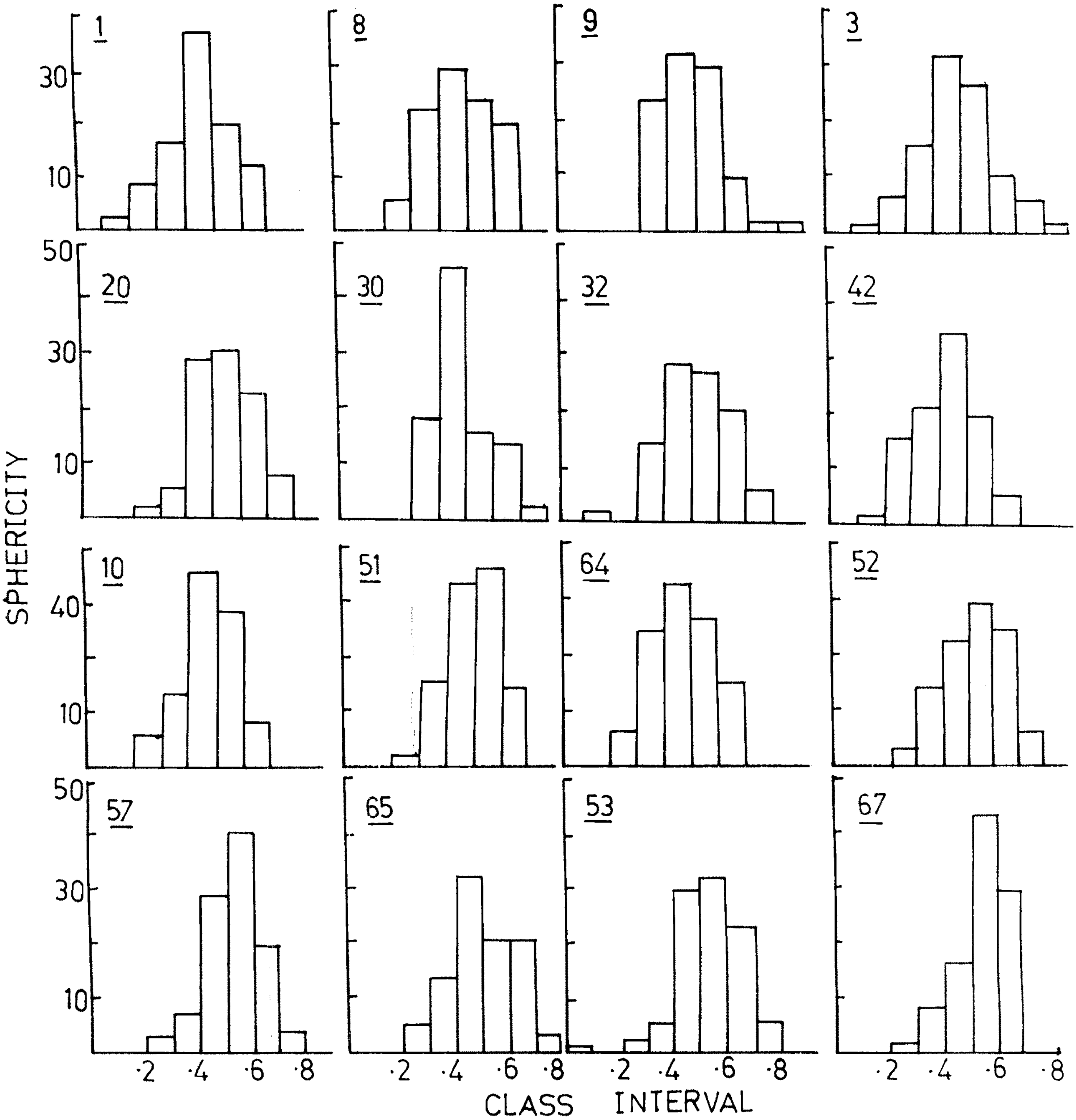

Fig. 4·10 Histograms showing the frequency distribution of Sphericity.

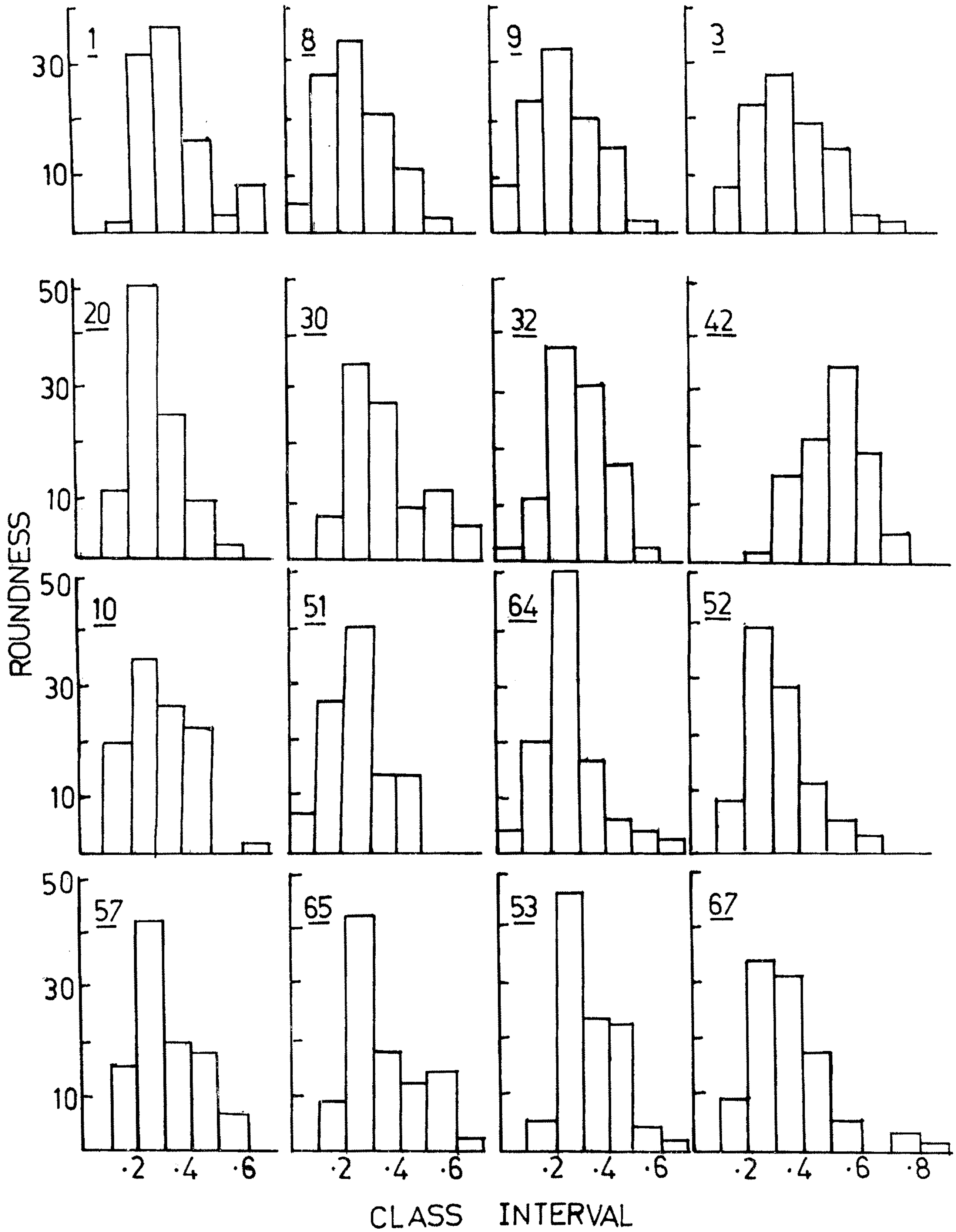

Fig 4·11 Histograms showing the frequency distribution of Roundness.

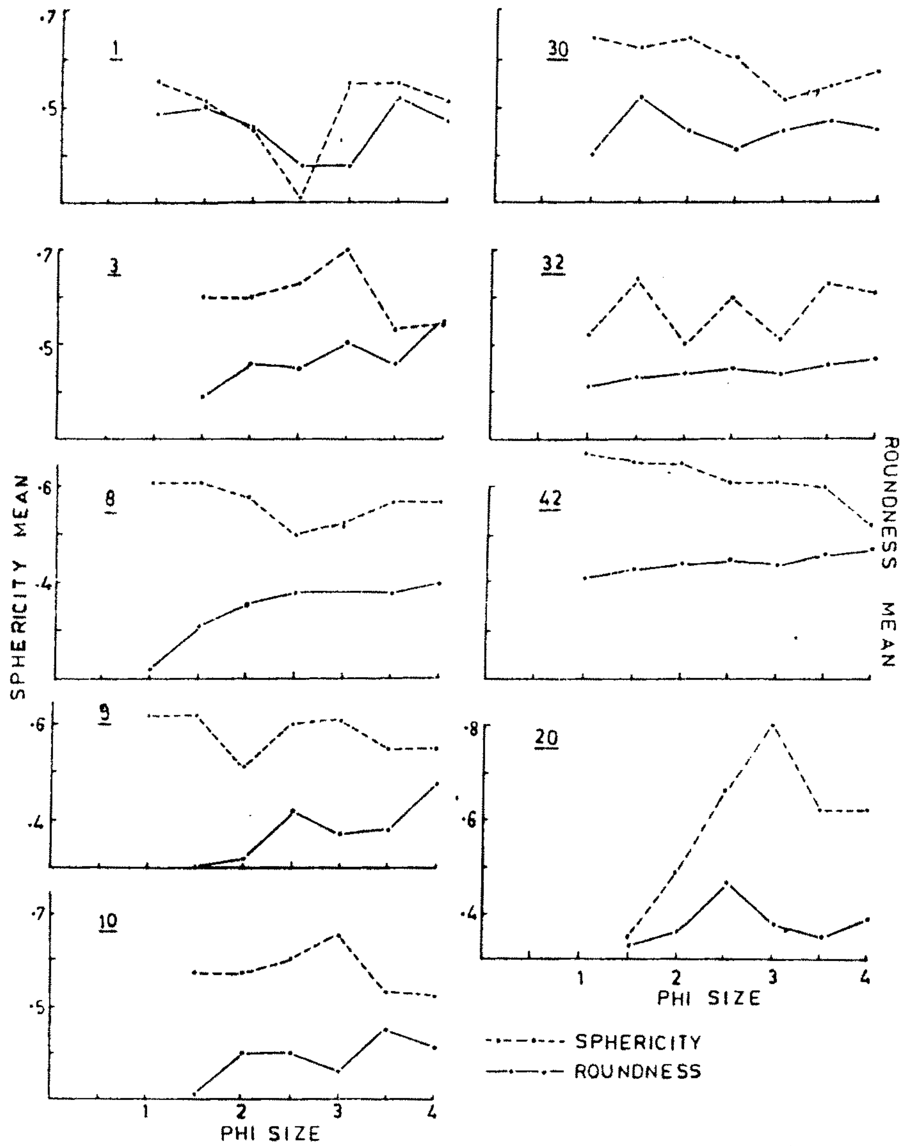

FIG.4-12(a) MEAN SPHERICITY AND ROUNDNESS IN RELATION TO SIZE (IN Phi) FOR THE LOOSE SEDIMENTS FROM MALVAN BEACH

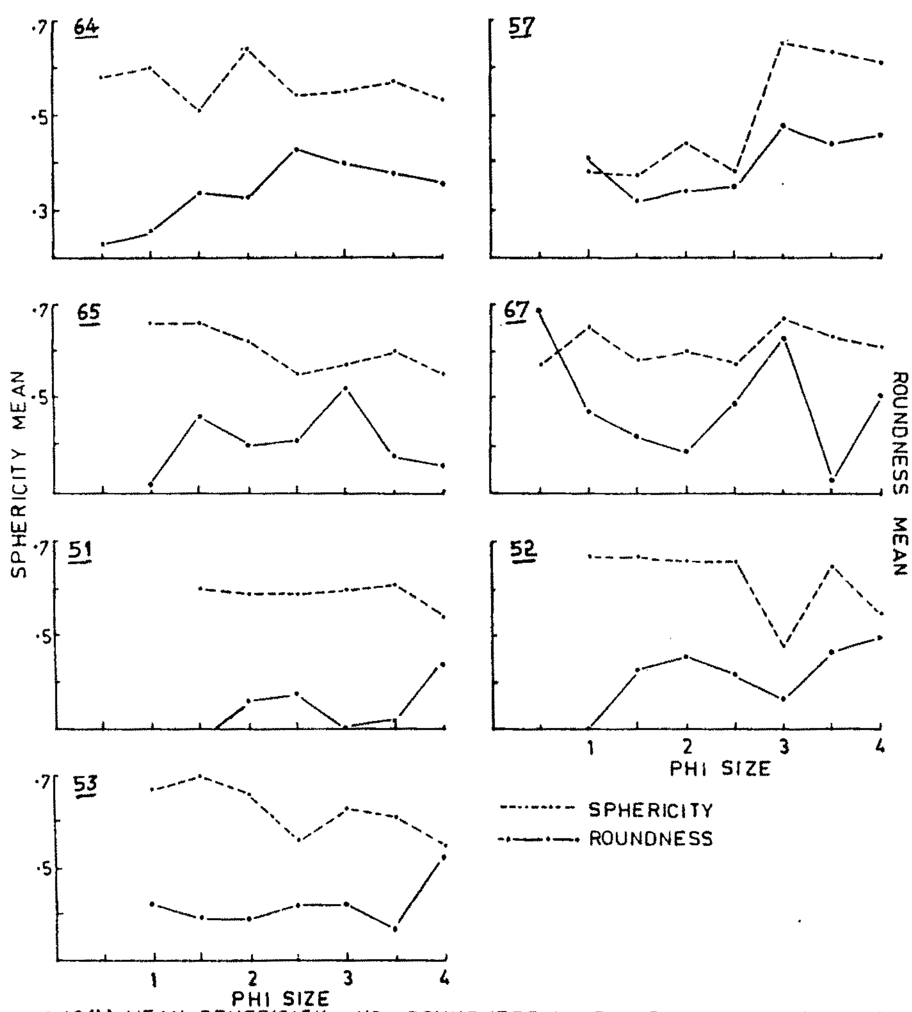

FIG.4·12(b) MEAN SPHERICITY AND ROUNDNESS IN RELATION TO SIZE (IN Phi) FOR THE LOOSE SEDIMENTS FROM MALVAN BEACH.

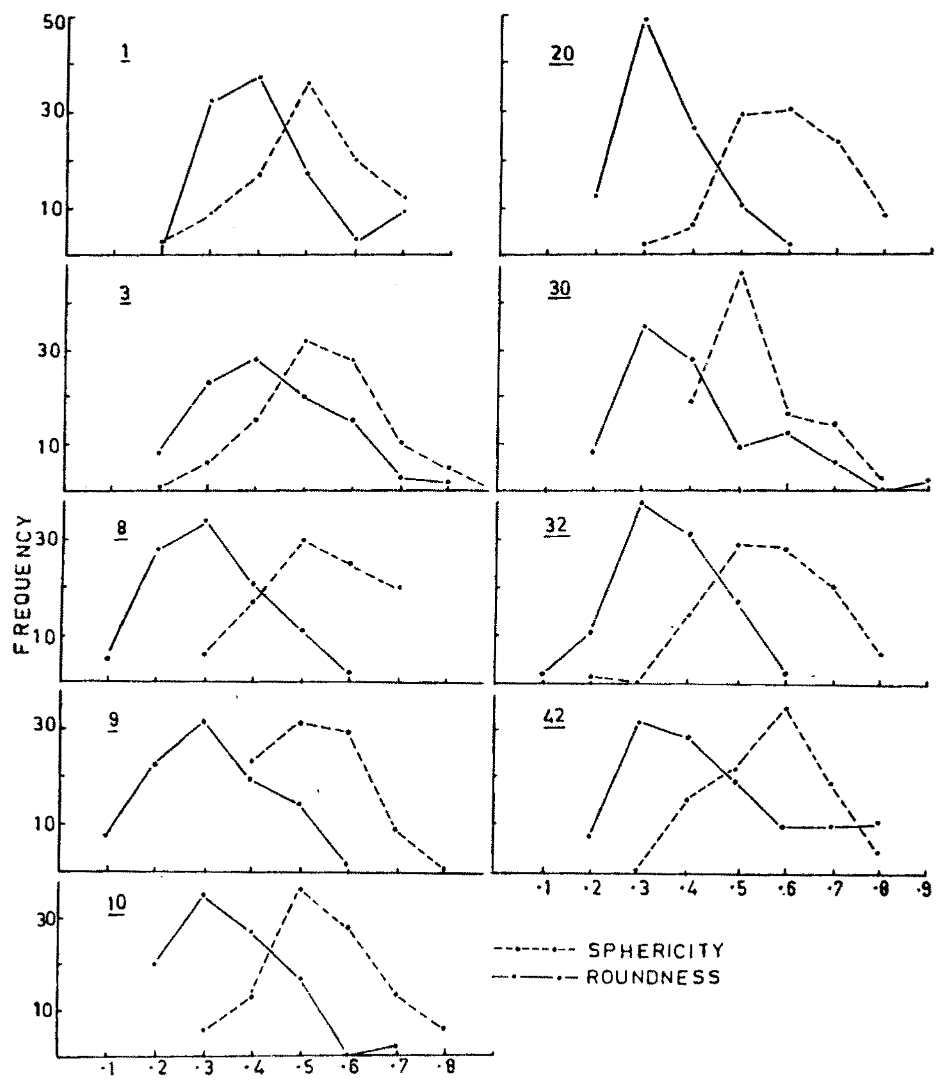

FIG.4·13(a) PERCENT FREQUENCY DISTRIBUTION OF THE SPHERICITY AND ROUNDNESS VALUES FOR THE SEDIMENTS FROM THE MALVAN BEACH

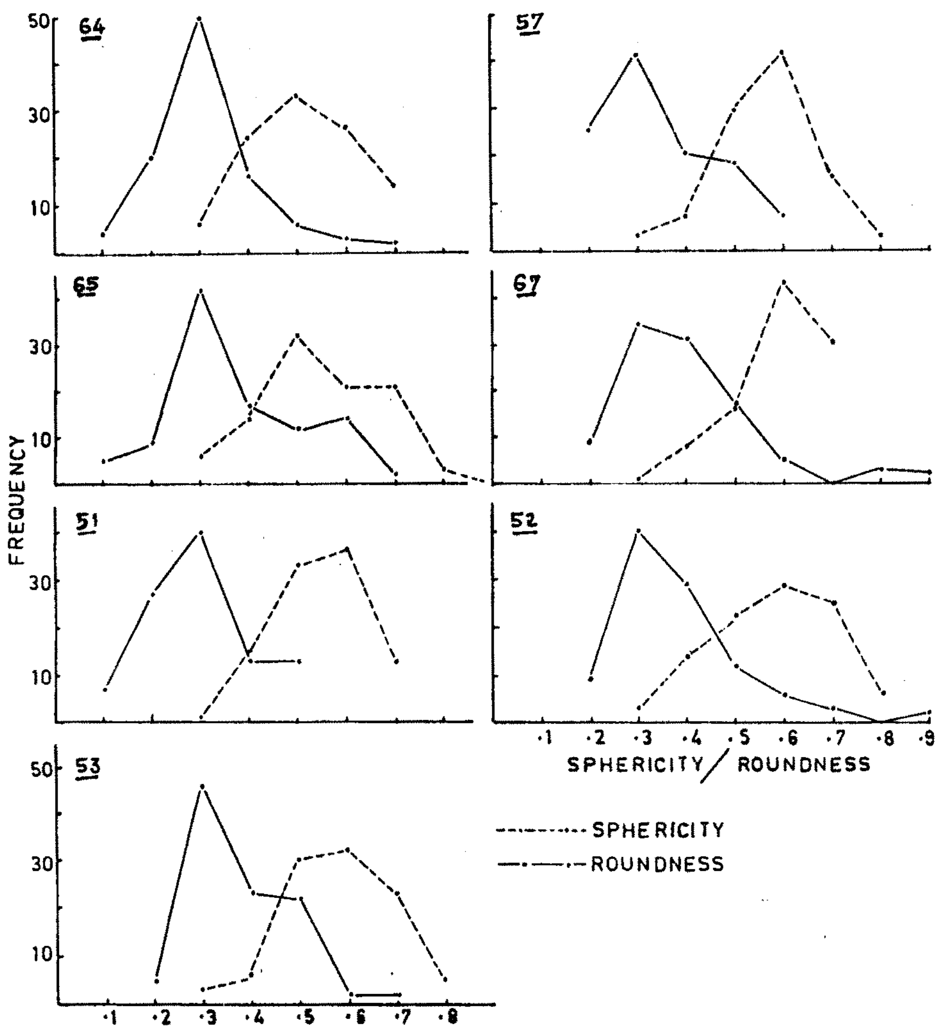

FIG.4·13(b) PERCENT FREQUENCY DISTRIBUTION OF THE SPHERICITY AND ROUNDNESS VALUES FOR THE SEDIMENTS FROM THE MALVAN BEACH.

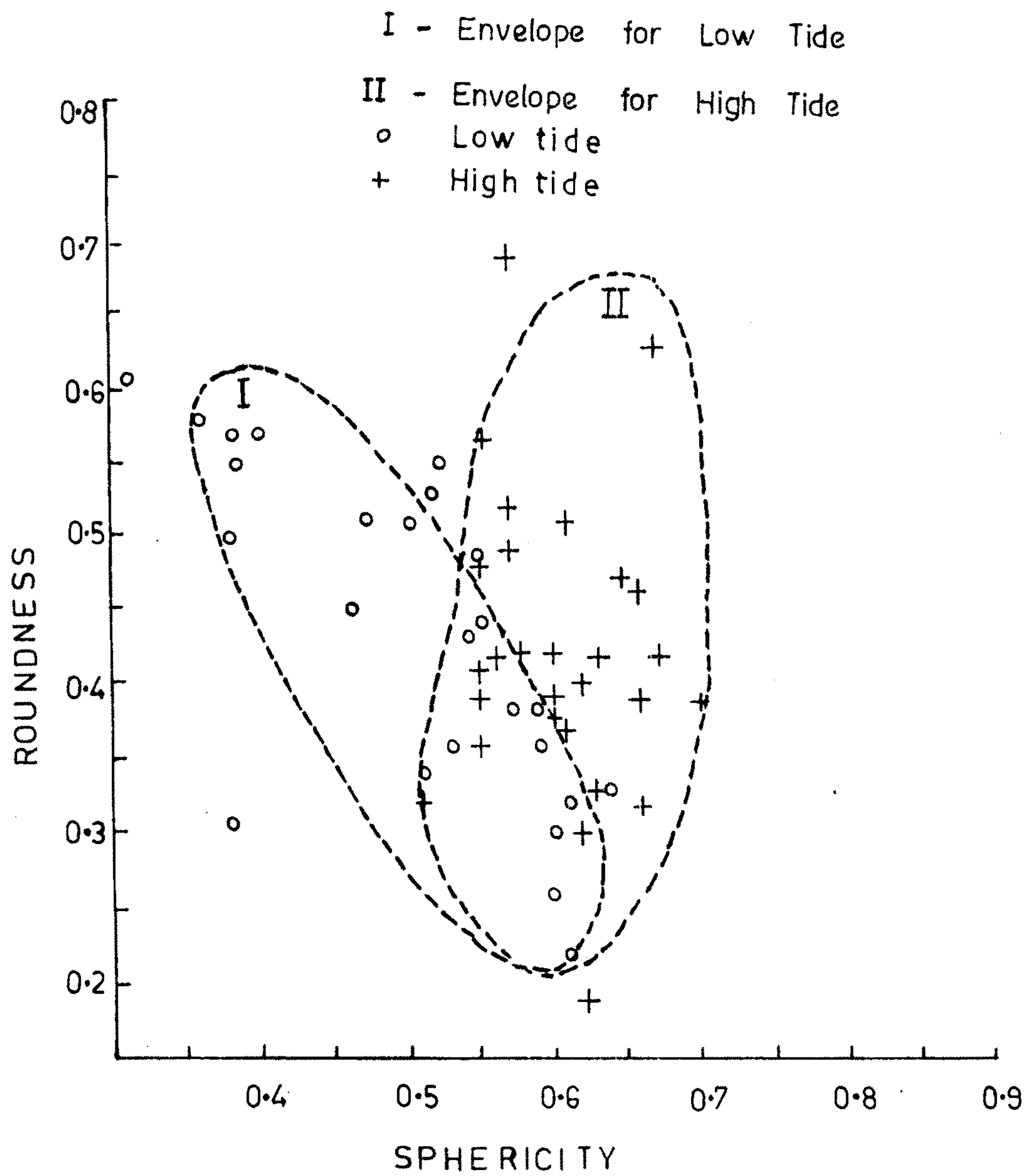

Fig. 4·14 (a) Plot of Sphericity vs. Roundness for Low tide and High tide zone sediments from Malvan Area.

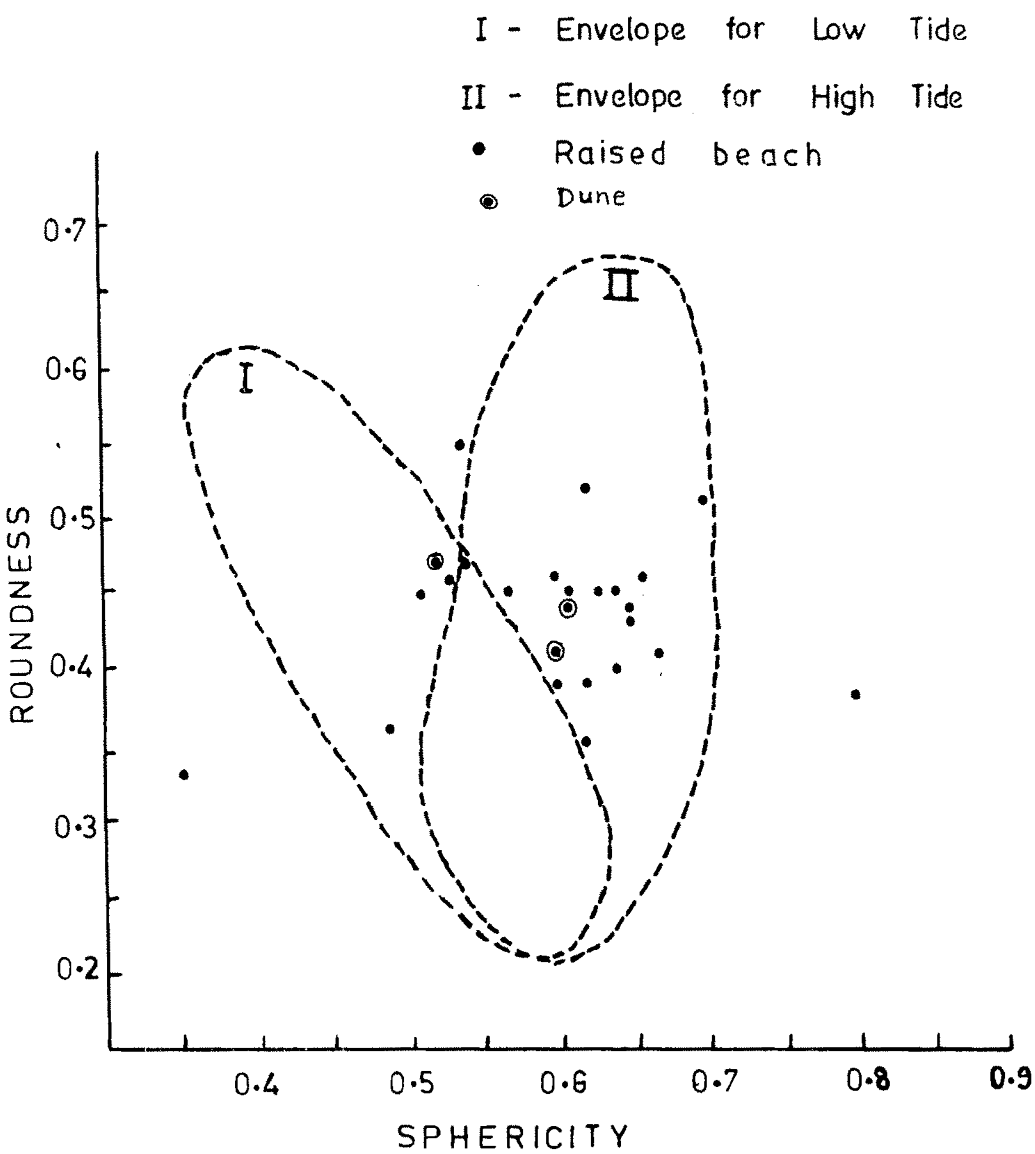

Fig.4·14 (b) Plot of **Sphericity** vs. Roundness for Raised beach sediments from Malvan Area. Envelopes from the Fig. No. 4·14(a).

PART C

DISCUSSION

The preceding paragraphs have dealt with the studies carried out on heavy mineral analysis and the textural aspects of the Quaternary sediments. In this part, an attempt is made to arrive at the inferences drawn therefrom. The following paragraphs deal with there aspects.

HEAVY MINERAL ANALYSIS

Frequency distribution of the heavy minerals present in the Quaternary sediments indicates that they are represented mainly by tourmaline, rutile, garnet, epidote, amphibole, sillimanite and pyroxene. The heavy mineral assemblage indicates that it is mixed assemblage that is derived from either igneous-plutonic and metamorphic rocks. The geological formations present in the area, however, clearly suggest that they are not the likely source to this heavy mineral suite, as major part of the area has been occupied by the Deccan volcanics, while a very small part, i.e., the southern part of the area investigated, has been occupied by the sedimentary rocks of the Kaladgi Supergroup. The source for such an heavy mineral assemblage should therefore, be sought from the provenance not from within the area but probably from the areas adjacent to the study area. However, such areas should be characterised by either igneous-plutonic or metamorphic rocks. Longshore transport for the dispersal of this heavy mineral suite is also a possibility.

The dispersal pattern of the heavy minerals in the Quaternary sediments along the coast indicate that

i. there is nearly even distribution of tourmaline,

ii. concentration of garnet nearly at the estuarine mouth of the Gad river,

iii. the presence of pyroxene and amphibole, though less, only in the northern and southern part of the coast and their near absence in the central part and

iv. zircon seems to be absent.

For such dispersal pattern, it can be inferred that the tourmaline dispersal is mainly due to longshore current and its source lies probably towards the southern part of the area investigated where Archean granites and pegmatites are exposed. Such a source for tourmaline has been suggested by Krynine (1946). Its source to the north is least likely because the area is occupied by the Deccan volcanics and its associated differentiates.

Concentration of garnet at the estuarine mouth and its occurrence on the beach sediments on either side of the estuary suggests that it has been transported mainly by the fluvial channel of the Gad river. The source should be the Archaean metamorphic rocks. It can be found that the Gad river has originated further inland in the upper reaches of the Western Ghats and has carved its channel in the area around Kankavali, which is characterised by the Archaean metamorphic rocks. This can be considered as a support to the garnet concentration at the estuarine mouth. Similarly, the presence of epidote, sillimanite and amphibole also seem to have the same source. The presence of rutile can also be explained from the same source as that for tourmaline, whereas for pyroxene - augite the basalt flows of the Deccan volvanics seems to be the most probable source.

It can be inferred, therefore, that the heavy mineral suite is derived from the provenance of the mixed characters, represented by the Archaean granites and pegmatites and associated metamorphics and also the basaltic lava flow of the Deccan volcanics.

The heavy mineral studies from the coastal Quaternary sediments along the West Coast of India and also from the offshore areas of the West Coast have been attempted by some workers. To quote a few amongst them are Siddiquie et al. (1979), Kidwai, et al. (1981), Nayak and Chavadi (1987) and

Jayappa and Subramanya (1991). These studies have brought out the distribution pattern of the heavy mineral assemblage, their concentration and also their probable source areas. Comparing their studies with the present investigations, it can be stated that the observations made from the present studies are in conformity with the inferences arrived at by the earlier workers.

GRAIN SIZE ANALYSIS

Regional variations in grain size help to reconstruct environment. For the purpose, size frequency distribution is studied within a sample. Grain size frequency distribution of modern sediments has been described by Shephard and Moore (1954). Folk and Ward (1957) used textural parameters for identification of sedimentary environments. With the help of textural characters of the modern sediments; dune, beach and river environments have been distinguished by Friedman (1961, 1967), Sahu (1964, 1982, 1983). Friedman (1967) compared dynamic processes and statistical measures of the grain size frequency distribution for beach and river environments. Passega (1957, 1964) and Passega and Byramjee (1969) suggested C/M diagrams for environmental analysis. According to them, C/M diagram provides reference points for the environmental discrimination F/M, L/M, A/M characterise essentially the finer fraction of sedimentary deposits (Passega and Byramjee op.cit.). These parameters are related to the processes of transport and deposition.

Visher (1969), while working on grain size distribution with the help of arithmetic probability plots of both modern and ancient sands differentiated three modes of transport and has also distinguished depositional environments on the basis of transport population distribution, whereas Komar (1976) described the configuration and classification theory of wave motion, morphology of the beaches alongwith the sediment movement.

From the above, it is imperative that grain size statistical measures, when considered either individually or even jointly, have some definite applications in understanding mode of transport, environment of deposition and sediment characteristics. Taking into consideration such an application of the statistical measures, the same have been examined in this context and the inferences arrived therefrom have been discussed in the following paragraphs.

The grain size distribution has been presented by way of histograms. From the histograms, it is clear that both the low tide zone sediments and high tide zone sediments are unimodal in distribution. However, the sediments from raised marine terraces and dune shows unimodal as well as bimodal distribution (Sample No. 20, 30 raised beach sediments)(Sample No. 21, 32, 43 dune sediments) with 2.5 Ø to 3 Ø as mode.

Various grain size parameters and the inferences therefrom have been explained in the following paragraphs(Table 4.8 and 4.9).

MEAN SIZE

Mean size is the average grain size of the sediment. The mean size of low tide zone sediments is between 1.9 Ø to 2.6 Ø, whereas the mean size has slightly increased to 2.7 Ø in the northern part and also to 2.8 Ø in the southern part of the area. The mean size in raised marine terrace is between 2.1 Ø to 2.5 Ø in the north. It slightly increases to 2.7 Ø in the south. In the dune sediments mean size varies between 2.2 Ø to 2.6 Ø. This indicates that these sediments in general are fine sands.

MEDIAN

Median is the 50th percentile of the distribution. In the present study, the median is used to find out variations, if any, in the hydraulic energy in every micro environment. There is little variation in the median values (2.3 Ø to 2.2 Ø)

TABLE NO. 4.8 GRAPHIC MEASURES FROM THE GRAINSIZE ANALYSIS OF THE QUATERNARY SEDIMENTS FROM NORTH OF MALVAN BEACH

Sample NO.	Mean	Median	Mode	Standard Deviation	Skewness	Kurtosis
Low Tide						
1.	1.96	1.87	2.0	0.59	0.19	0.86
5.	2.22	2.30	3.0	0.53	- 0.29	0.85
8.	2.62	2.67	3.0	0.40	- 0.04	1.61
11.	2.59	2.62	3.0	0.41	- 0.05	1.70
15.	2.21	3.27	3.5	0.53	- 0.06	0.87
19.	2.30	2.32	2.5	0.48	- 0.02	0.86
High Tide						
2.	2.51	2.57	3.0	0.39	0.07	2.01
6.	2.61	2.62	3.0	0.41	- 0.01	1.40
9.	2.77	2.75	3.0	0.49	0.98	1.78
12.	2.70	2.67	3.0	0.28	0.22	2.56
31.	2.67	2.60	3.0	0.56	0.18	1.16
41.	2.01	1.95	2.0	0.45	0.20	1.04
Raised Marine Terrace						
3.	2.54	2.55	3.0	0.39	0.07	2.01
7.	2.47	2.55	3.0	0.36	- 0.32	1.18
20.	2.44	2.45	2.5	0.41	0.03	1.13
30.	2.17	2.12	2.5	0.41	0.18	0.99
32.	2.45	2.47	2.9	0.40	- 0.02	0.98
42.	2.46	2.55	2.5	0.44	0.03	0.88
Beach Dune						
4.	2.57	2.50	3.0	0.52	- 0.17	2.12
10.	2.66	2.65	3.0	0.45	0.13	2.04
13.	2.66	2.62	3.0	0.29	0.22	1.92
14.	2.65	2.62	3.0	0.40	0.17	1.60
21.	2.47	2.55	3.0	0.39	- 0.24	1.35
43.	2.22	2.22	2.5	0.44	0.03	0.88

TABLE NO. 4.9 GRAPHIC MEASURES FROM THE GRAINSIZE ANALYSIS OF THE QUATERNARY SEDIMENTS FROM SOUTH OF MALVAN BEACH.

Sample No.	Mean	Median	Mode	Standard Deviation	Skewness	Kurtosis
Low Tide						
51	2.69	2.60	3	0.51	0.60	1.22
56	2.47	2.52	3	0.48	- 0.07	1.17
64	2.67	2.70	3	0.46	- 0.80	1.42
High Tide						
45	2.76	2.72	3	0.53	0.11	1.68
52	2.82	2.72	3	0.38	0.45	2.08
57	2.90	2.77	3	0.40	0.50	1.82
65	2.54	2.55	3	0.51	0.05	1.66
Raised Marine Terrace						
58	2.51	2.52	3	0.36	- 0.00	1.91
63	2.77	2.80	3	0.30	- 0.05	1.78
66	2.62	2.65	3	0.43	0.03	1.85
Beach Dune						
53	2.62	2.65	3	0.27	- 0.05	1.84
59	2.60	2.52	3	0.43	0.36	2.39
67	2.61	2.65	3	0.36	- 0.06	1.44

for low tide environment except sample No. 15 (3.2 Ø). Median value also does not show much variation in high tide zone sediments (2.5 Ø). However, in the raised marine terraces the median value varies between 2.1 Ø and 2.5 Ø. Dune sediments show very little variation in median value (2.5 Ø).

Thus, it is clear that there is little variation in median values of each environment, indicating that there is little variation in the hydraulic energy in low tide and high tide zone environments at the time of deposition of these sediments. The variation in the median value for raised marine terrace indicates that these depositional features have formed under differring hydraulic energy conditions.

STANDARD DEVIATION

The value of standard deviation measures the degree of sorting of sediments. Higher the value of standard deviation poor is the nature of sorting of sediments, whereas lesser the value of standard deviation better is the sorting of sediments (Folk, 1974). To understand the sorting of the sediments from low tide, high tide, raised marine terraces and dunes, standard deviation values have been computed. These values indicate that low tide zone sediments are well sorted to moderately well sorted (0.41 to 0.59); high tide zone sediments are well sorted to very well sorted (0.28 to 0.56), sediments of the raised marine terrace are well sorted (0.36 to 0.44), while dune sediments are well sorted to very well sorted (0.29 to 0.52).

SKEWNESS

Skewness measures the asymmetry of the distribution. Positive skewness values show predominance of coarser tails and negative skewness value show predominance of finer tails. Predominance of symmetrical distribution indicates the presence of both finer and coarser tails in nearly equal proportion. It has been observed that low tide zone sediments are nearly symmetrical to coarse skewed (0.02 to -0.8), those from high tide zone are finely skewed to nearly skewed. Sediments from the raised marine terrace are finely skewed to nearly symmetrical (0.18 to 0.03). Beach dune sediments are finely skewed to strongly fine skewed (0.13 to 0.17), except sample No. 4 and 21 which are coarse skewed (-0.17 to -0.24).

KURTOSIS

Kurtosis indicates the peakedness of the distribution. Kurtosis value of the low tide zone (0.85) indicates platykurtic distribution except sample Nos. 8 and 11, which are very leptokurtic. Kurtosis values of the high tide zone sediments indicate leptokurtic to very leptokurtic (1.04 to 2.01) nature. Sediments of the raised marine terrace are leptokurtic to very leptokurtic (0.88 to 2.01) except sample No. 32, which is mesokurtic (0.98), while sediments from dune are very leptokurtic (1.92 to 2.12) in their character.

The inferences derived from individual parameter for different samples have been presented in Table No. 4.10 and 4.11, 4.12, 4.13, 4.14, 4.15, 4.16 and 4.17.

From these statistical measure, when considered separately, it can be stated that these Quaternary sediments, in general, are of fine sand grade, well sorted to moderately well sorted, nearly symmetrical to coarse skewed to fine skewed and are mesokurtic to very leptokurtic.

These statistical measures have also been analysed with the help of bivariate plots to examine the characteristics of the Quaternary sediments from each microenvironment, namely; low tide, high tide, raised beach and beach dunes. For the purpose, bivariate plots of C/M pattern, mean size vs. standard deviation, standard deviation vs. skewness and simple sorting measures vs. simple skewness measure have been used. The observations made therefrom have been discussed in the following paragraphs.

TABLE NO. 4.10 INTERPRETATION OF THE GRAIN SIZE MEASURES FROM NORTH OF MALVAN BEACH

Sample No.	Mean Size	Standard Deviation	Skewness	Kurtosis
Low Tide				
1.	MS	MWS	SFS	P
5.	FS	MWS	CS	P
8.	FS	WS	NS	VL
11.	FS	WS	NS	VL
15.	FS	MWS	CS	P
19.	FS	WS	NS	P
High Tide				
2.	FS	WS	CS	VL
6.	FS	WS	NS	L
9.	FS	WS	SFS	VL
12.	FS	VWS	FS	VL
31.	FS	MWS	FS	L
41.	FS	WS	FS	M
Raised Marine Terrace				
3.	FS	WS	NS	VL
7.	FS	WS	SCS	L
20.	FS	WS	NS	L
30.	FS	WS	FS	L
32.	FS	WS	NS	M
42.	FS	WS	CS	L
Beach Dune				
4.	FS	MWS	CS	VL
10.	FS	WS	SFS	VL
13.	FS	VWS	FS	VL
14.	FS	WS	FS	VL
21.	FS	WS	CS	L
43.	FS	WS	NS	P

TABLE NO. 4.11 INTERPRETATION OF THE GRAIN SIZE MEASURES FROM SOUTH OF MALVAN BEACH.

Sample No.	Mean size	Standard Deviation	Skewness	Kurtosis
Low Tide				
51	FS	MWS	SFS	L
56	FS	WS	NS	L
64	FS	WS	NS	L
High Tide				
45	FS	MWS	FS	VL
52	FS	WS	SFS	VL
57	FS	WS	SFS	VL
65	FS	MWS	NS	VL
Raised Marine Terrace				
58	FS	WS	S	VL
63	FS	VWS	NS	VL
66	FS	WS	NS	VL
Beach Dune				
53	FS	VWS	S	VL
59	FS	WS	SFS	VL
67	FS	WS	S	L

TABLE NO. 4.12 GRAIN SIZE CHARACTERISTICS OBTAINED FROM THE LOG - NORMAL PROBABLITY PLOTS OF THE LOW TIDE ZONE SEDIMENTS FROM THE MALVAN AREA.

Sample No.	C.T.	F.T.	Traction population %	Saltation population %	Suspension population %
<u>North</u>					
1	1.0	-	0.95	98.9	-
5	1.0	-	0.90	98.0	-
8	1.0	-	0.12	99.7	-
11	1.5	3.5	0.67	96.0	2.9
19	-	3.5	-	99	0.9
<u>South</u>					
51	1.0	3.5	0.1	90.9	8.9
56	-	3.5	-	95.9	3.9
64	2.5	3.5	24	68	8.9

TABLE NO. 4.13 GRAIN SIZE CHARACTERISTICS OBTAINED FROM THE LOG - NORMAL PROBABLITY PLOTS OF THE HIGH TIDE ZONE SEDIMENTS FROM THE MALVAN AREA.

Sample No.	C.T.	F.T.	Traction population %	Saltation population %	Suspension population %
North					
2	2.5	3.5	32	64	3.9
6	2.25	3.5	9.6	89	0.9
9	1.0	3.5	0.04	87.9	12.0
12	-	3.0	-	88.9	11.0
15	2.0	3.5	1.6	65	33
41	1.0	-	0.1	99.8	-
South					
45	-	3.5	-	90	9.9
52	2.0	3.5	0.3	89.7	9.9
57	2.0	3.5	0.15	87.8	11.0
65	-	3.5	-	94	5.9

TABLE NO. 4.14 GRAIN SIZE CHARACTERISTICS OBTAINED FROM THE LOG - NORMAL PROBABLITY PLOTS OF THE RAISED MARINE TERRACE SEDIMENTS FROM THE MALVAN AREA.

Sample No.	C.T.	F.T.	Traction population %	Saltation population %	Suspension population %
North					
3	-	3.5	-	95	4.9
7	-	3.5	-	98	1.9
20	-	3.5	-	95	4.9
30	-	3.5	-	99.5	0.49
42	-	3.5	-	98	1.9
South					
58	1.5	3.5	1.6	94.4	3.9
66	-	3.5	-	92.9	7.9

TABLE NO. 4.15 GRAIN SIZE CHARACTERISTICS OBTAINED FROM THE LOG - NORMAL PROBABLITY PLOTS OF THE BEACH DUNE SEDIMENTS FROM THE MALVAN AREA.

Sample No.	C.T.	F.T.	Traction population %	Saltation population %	Suspension population %
<u>North</u>					
4	-	3.5	-	95.9	4.9
10	2.5	3.5	27.5	66	7.9
13	1.75	-	0.2	99.7	-
14	2.5	3.5	14.8	74.2	8.9
21	-	3.5	-	97	2.9
31	-	3.5	-	81	18.9
32	-	3.5	-	95	3.9
43	-	3.5	-	98	2.9
<u>South</u>					
53	2.0	3.5	1.2	90.0	8.9
59	1.5	3.5	0.18	91.8	8.9
67	-	3.5	-	94	8.9

TABLE NO. 4.16 SIMPLE SORTING MEASURE (SOS) AND SIMPLE SKEWNESS MEASURE (SKS) VALUES FOR THE QUATERNARY SEDIMENTS FROM NORTH OF MALVAN BEACH

Sample No.	SOS	SKS
Low Tide		
1.	0.90	- 1.95
5.	0.84	- 2.92
8.	0.79	- 3.77
11.	0.80	- 3.65
15.	0.82	- 4.90
19.	0.76	- 3.12
High Tide		
2.	0.82	- 3.50
6.	0.81	- 3.62
9.	0.92	- 3.65
12.	0.62	- 4.10
31.	0.96	3.27
41.	0.76	- 2.37
Raised Marine Terrace		
3.	0.80	- 4.30
7.	0.65	- 3.80
20.	0.72	- 3.45
30.	0.70	- 2.85
32.	0.69	3.57
42.	0.74	- 3.62
Beach Dune		
4.	1.03	- 3.12
10.	0.87	- 3.55
13.	0.59	- 4.07
14.	0.64	3.97
21.	0.70	- 3.70
43.	0.72	- 3.00

TABLE NO. 4.17 SIMPLE SORTING MEASURE (SOS) AND SIMPLE SKEWNESS MEASURE (SKS) VALUES FOR THE QUATERNARY SEDIMENTS FROM SOUTH OF MALVAN BEACH.

Sample No.	SOS	SKS
<u>Low Tide</u>		
51	0.94	- 3.32
56	0.86	- 3.32
64	0.82	- 3.75
<u>High Tide</u>		
45	0.97	- 3.50
52	0.76	- 3.92
57	0.72	- 4.10
65	0.96	- 3.17
<u>Raised Marine Terrace</u>		
58	0.70	- 3.65
63	0.60	- 4.40
66	0.85	- 3.60
<u>Beach Dune</u>		
53	0.56	- 4.17
59	0.87	- 3.30
67	0.66	- 3.97

C/M pattern has been suggested by Passega (1957, 1964) and Passega and Byramjee (1969). In this pattern, C is the first percentile and M is the median of the distribution, both considered in microns and plotted on a double-log scale. On the basis of such a plot, Passega and Byramjee, (op.cit) have distinguished the mode of transport of the sediments,as bed load, graded suspension, uniform suspension, Pelagic suspension and turbidity current deposits. By understanding the mode of transport, they have attempted to infer the environments of deposition of the sediments and sedimentary rocks. The Quaternary sediments from each microenvironment have been examined with the help of C/M plot (Fig. 4.6 a and b). It has been observed that low tide sediments from an envelope and indicate graded suspension deposit, while high tide sediments, forming an envelope indicate transition from graded to uniform suspension deposit (Fig. 4.6 a). It has also been noted that the envelopes of low tide and high tide environments overlap each other. The sediments from the raised beach and beach dune have also been plotted (Fig. 4.6 b). It is clear that raised beach sediments indicate graded suspension deposit, while beach dune sediments indicate uniform suspension deposit, each forming again an envelope of its own. However, when compared these envelopes with those of low tide

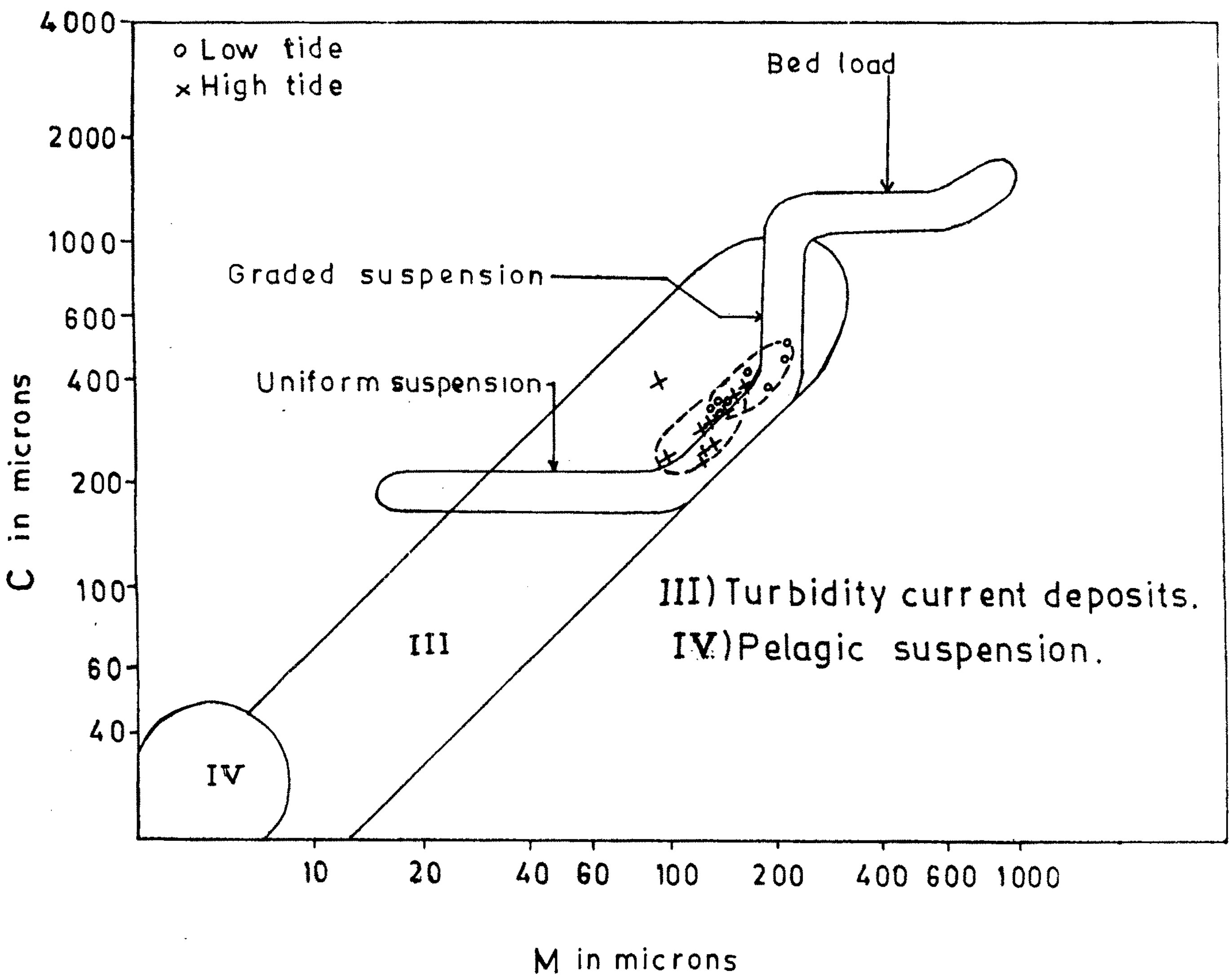

Fig.4·6(a) C-M Pattern of the Low tide and High tide zone sediments from Malvan area.

(after Passega and Byramjee, 1969.)

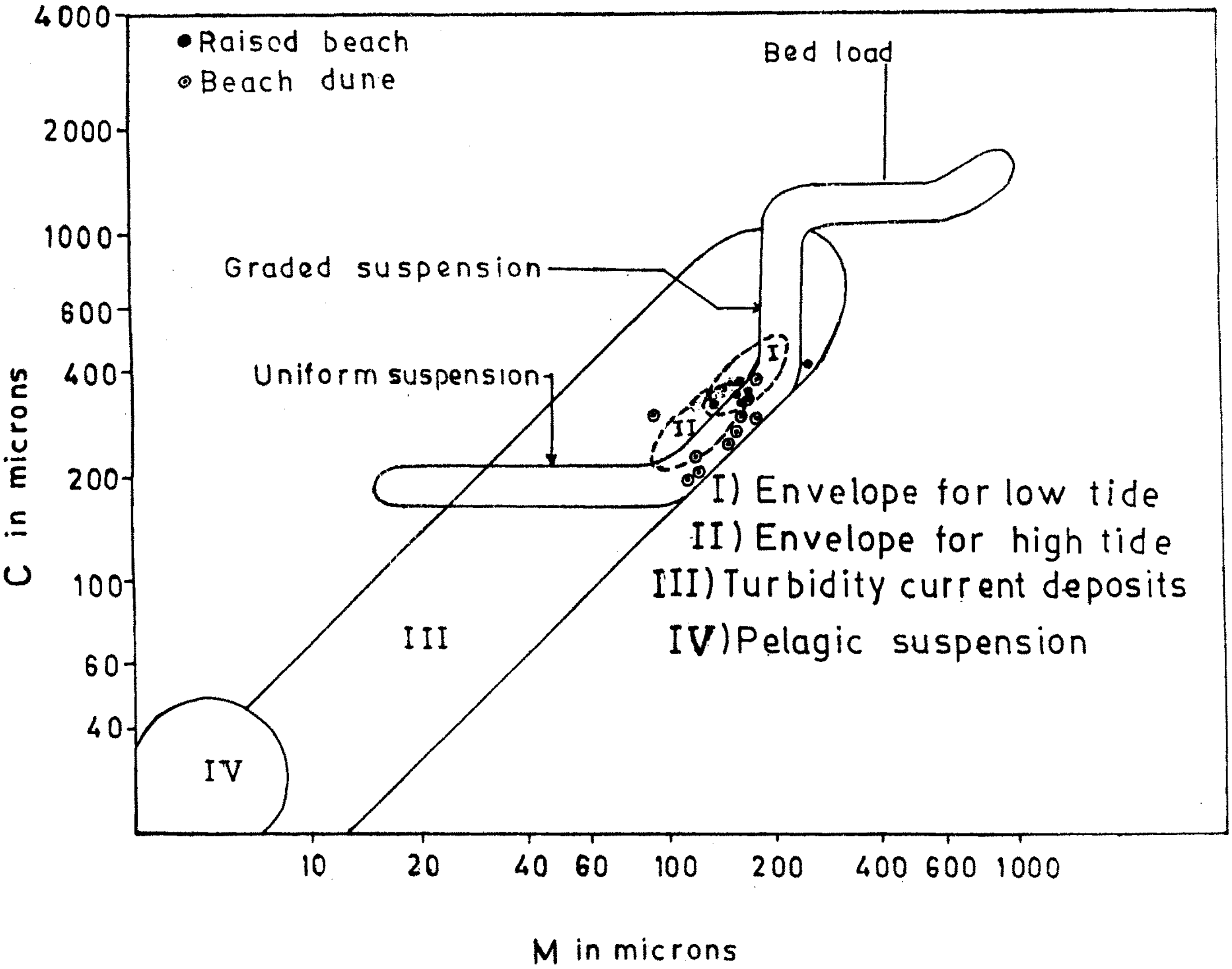

Fig.4·6(b) C-M Pattern of the Raised beach and beach dune sediments from Malvan area.

(after Passega and Byramjee,1969.)

and high tide environments in Fig. 4.6 a, it is clear that the envelope of the raised beach sediments very well compares with that of the low tide; while the one of the beach dune compares with that of the high tide.

Friedman (1961, 1967) has presented a bivariate plot of mean size against standard deviation to distinguish river, beach and dune environments. The Quaternary sediments from each environment have been examined accordingly. It has been observed that after plotting mean size vs. standard deviation, most of the sediment samples from the low tide environment indicate a beach environment, while few fall in dune environment (Fig. 4.7 a). An envelope of the low tide environment lies for its most part in a beach environment, further transitional into dune environment; whereas majority of the samples from high tide fall in dune environment (Fig. 4.7 a), forming again a small envelope, However, such an envelope of the high tide, though overlapping with that of the low tide, lies for its most part in the dune environment. The sediments from the raised beach and beach dune have also been plotted (Fig. 4.7 b). It has been observed, however, that all these samples plot in the dune environment, forming a common envelope that lies for its most part in the dune environment. When such an envelope is compared with those from Fig. 4.7 a, it is

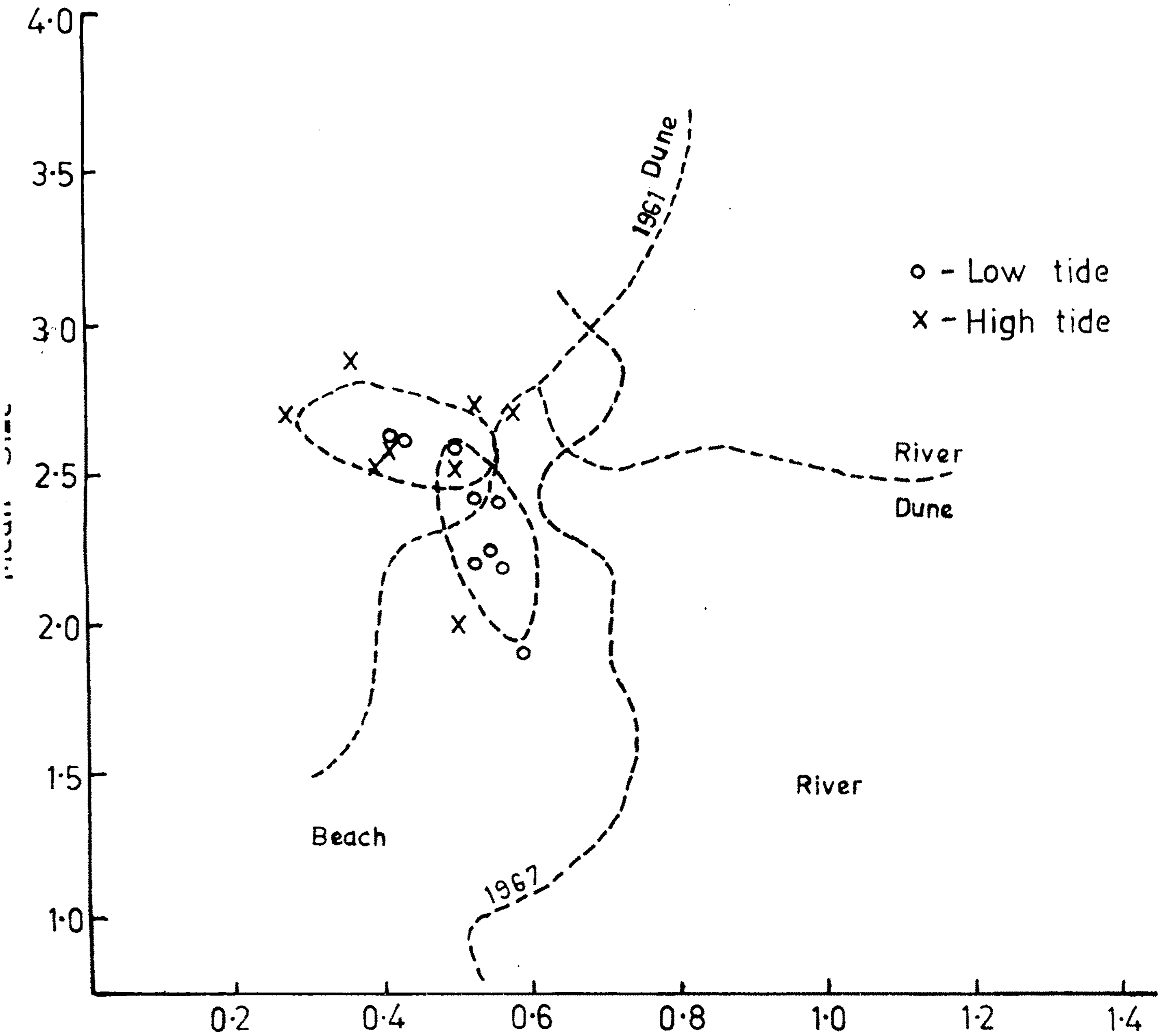

Fig.4·7(a) Mean size vs. inclusive graphic standard deviation for Low tide and High tide zone sediments from Malvan Area.

(after Friedman,1961, 1967.)

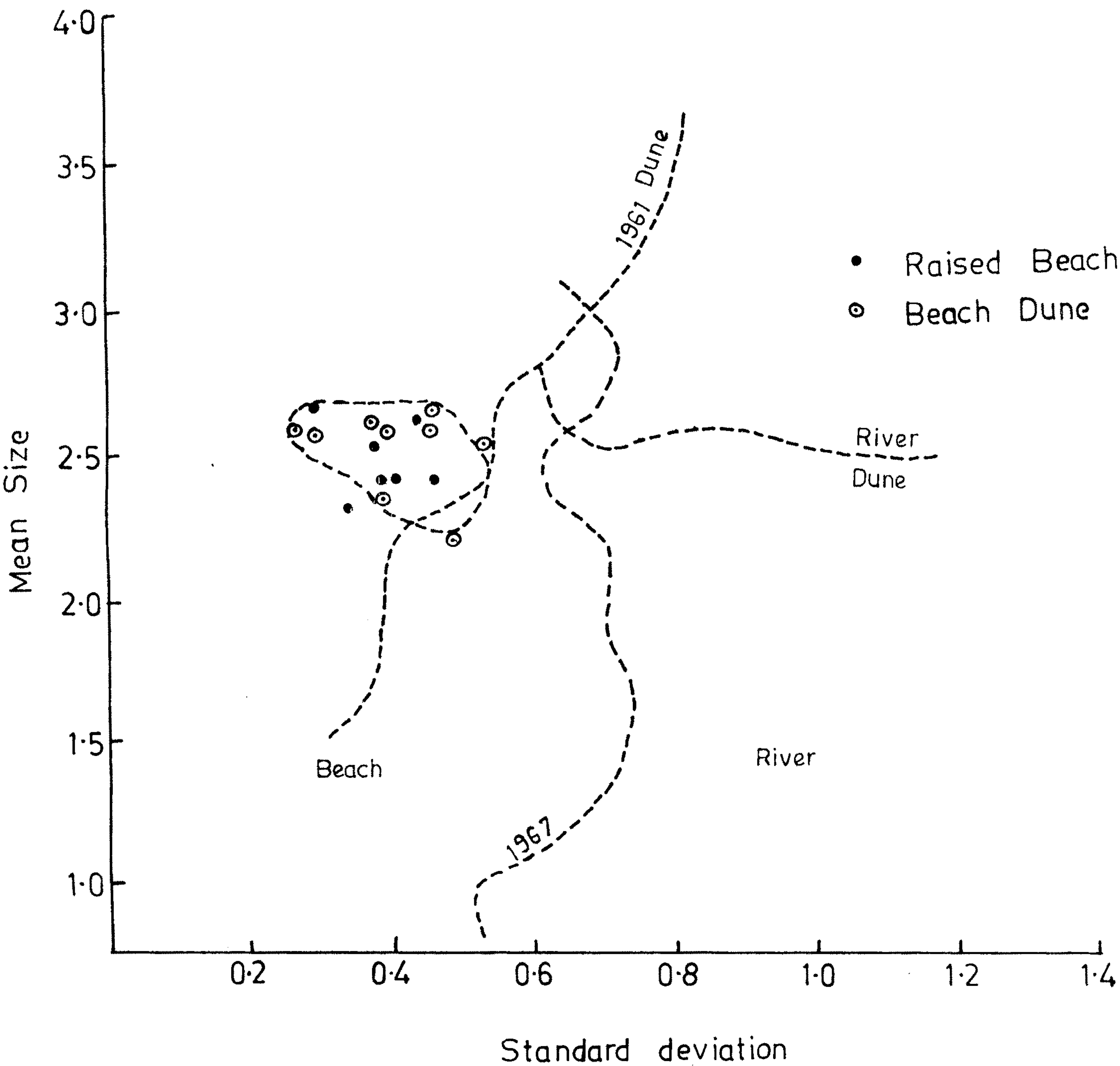

Fig. 4·7(b) Mean size vs. inclusive graphic standard deviation for Raised beach and Beach dune sediments from Malvan Area.

evident that this envelope of the raised beach and beach dune matches well with that of the low tide environment.

Plot of standard deviation against skewness have also been suggested by Friedman (1967) to distinguish between river and beach environments. After plotting standard deviation vs. skewness of the Quaternary sediments (Fig. 4.8 a and b), it is observed that the low tide sediments and the high tide sediments form separate envelopes, with a small overlap. These envelopes also indicate that the low tide sediments are relatively better sorted than those from high tide environment (Fig. 4.8 a). A similar plot for the raised beach and beach dune sediments has been made (Fig. 4.8 b). In this figure, the sediments from both environments from independent envelopes with a small overlap of the beach dune environment with that for raised beach sediments. If these envelopes from Fig.4.8 b are compared with those from Fig. 4.8 a, it is seen that the envelope for raised beach compares statisfactorly with that of low tide environment.

Friedman (1967) has also suggested a plot of simple skewness measure vs. simple sorting measure for the discrimination of the river and beach environments. Plots of simple sorting measure vs. simple skewness measure have also been made for the sediments from each microenvironment

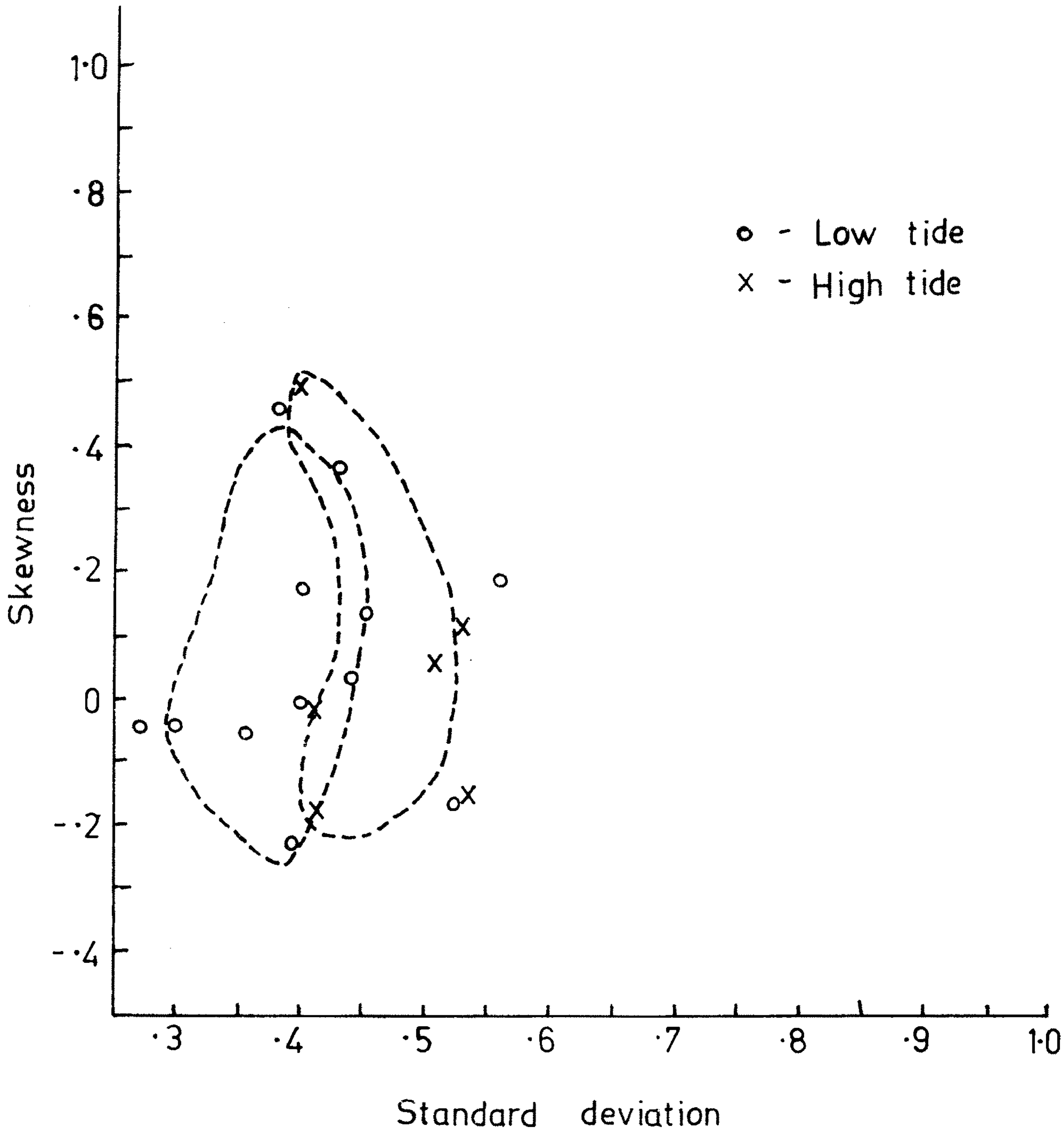

FIG.4·8(a) Plots of skewness vs. standard deviation for Low tide and High tide zone sediments from Malvan Area.

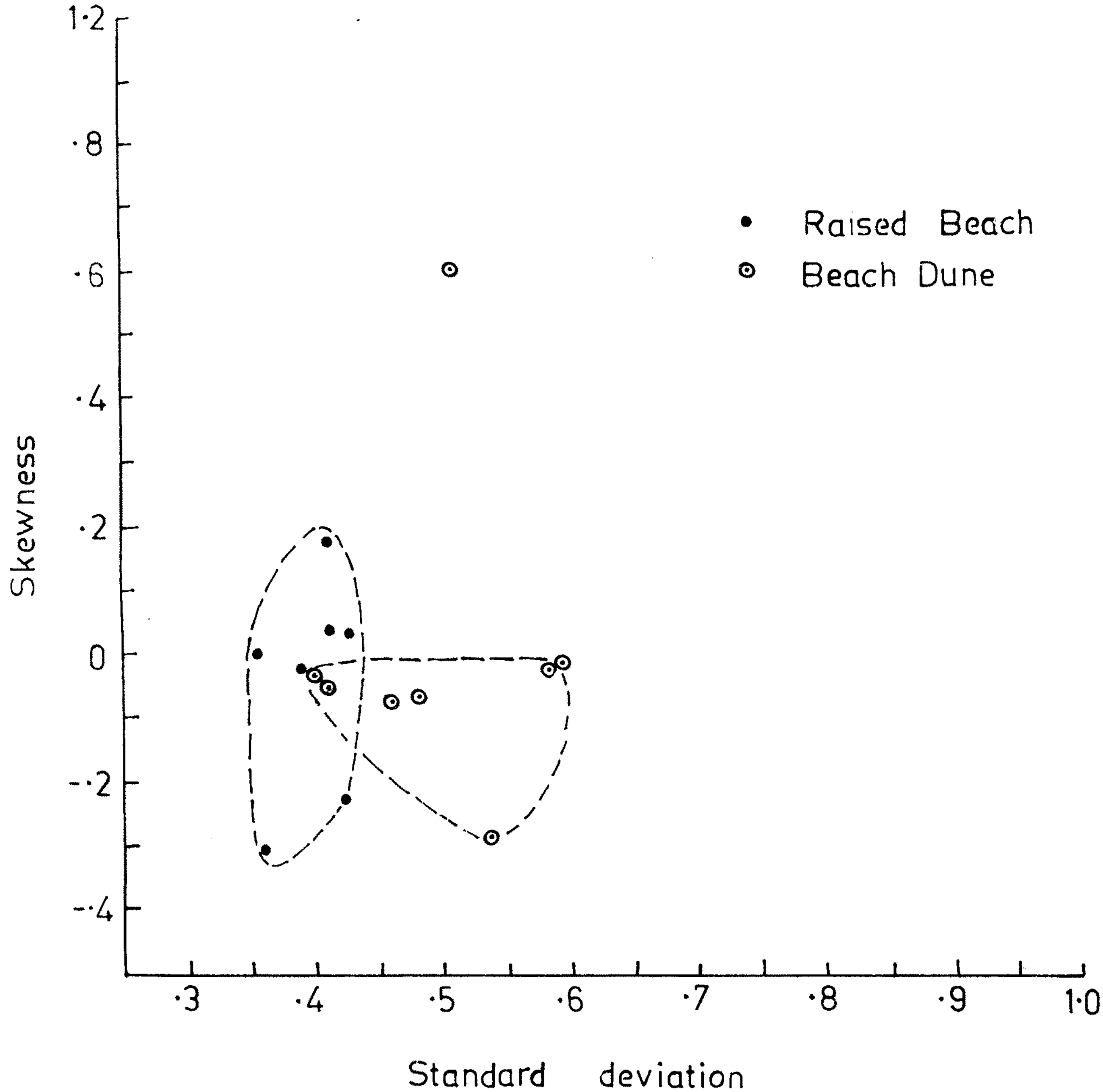

FIG.4·8(**b**) Plots of skewness vs. standard deviation for Raised beach and Beach dune sediments from Malvan Area.

(after Friedman, 1967.)

(Fig. 4.9 a and b) from the area of investigation. It has been observed that the sediments from the low tide and high tide environments together constitute a single envelope, However though, it appears to be quite spreaded (Fig. 4.9 a). The plot for the raised beach and the beach dune sediments again indicates the envelope encompassing the sediments from both environments. Such an envelope compares well with that from Fig. 4.9 a for low tide and high tide environment deposits.

From the preceding paragraphs, it can be stated that with the help of bivariate plots, distinction between each microenvironment seems to be possible, i.e. the distinction between low tide and high tide environments. Such an observation however is not conclusive.

SHAPE ANALYSIS

As stated earlier, sphericity and roundness aspects of the Quaternary sediments from each microenvironment have been studied in detail.

The frequency distribution of sphericity and roundness values has been studied and both also with respect to size.

The frequency distribution of sphericity represented by way of histograms (Fig. 4.10) indicates the unimodal

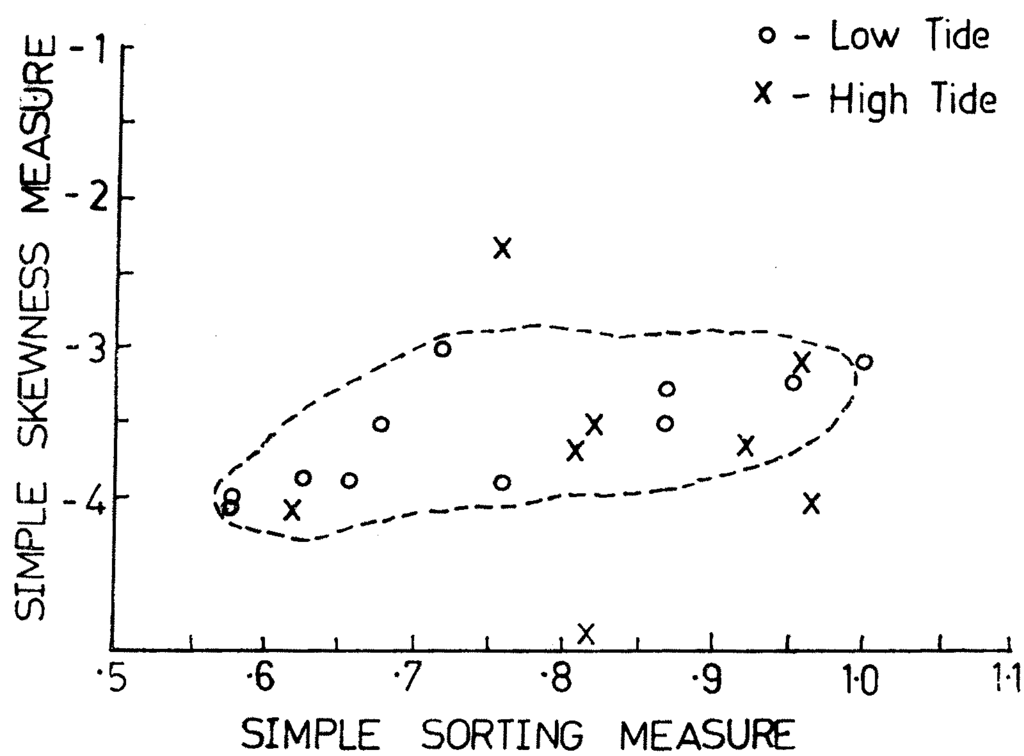

Fig. 4·9(a) Plots of simple skewness measure vs. simple sorting measure for Low tide and High tide zone sediments from Malvan Area

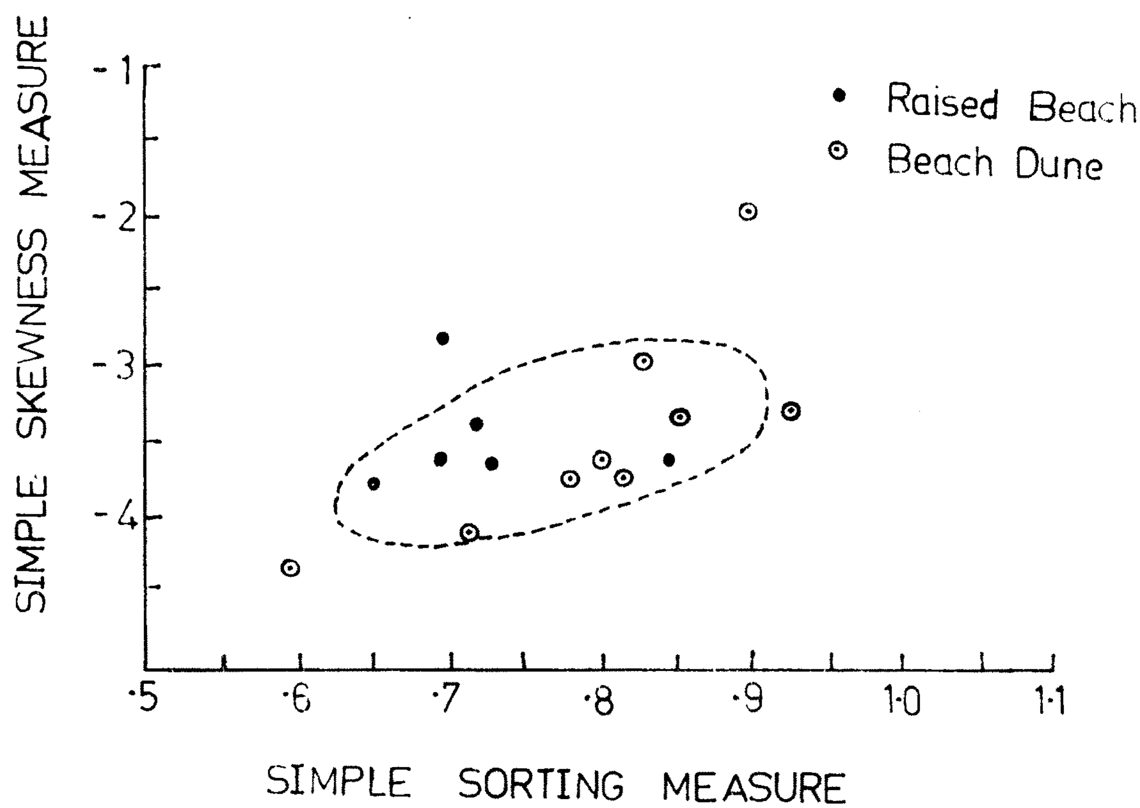

Fig.4·9(b) Plots of simple skewness measure vs. simple sorting measure for Raised beach and Beach dune sediments from Malvan Area.

distribution. The mode of the sphericity values lies between 0.4 and 0.5 in ten samples, while it lies between 0.5 and 0.6 in six samples. This suggests nearly uniform characteristics of all the sediments. It is also seen that the sphericity values in all the samples range between 0.2 and 0.8 and the proportion of more spherical grains, i.e. say more than 0.6 is relatively less.

The histograms showing the frequency distribution of the roundness values (Fig. 4.11) also show unimodal distribution for most of the samples, except two, which indicate bimodal distribution. It is observed that the roundness values more commonly range between 0.1 and 0.7. The mode of roundness values is found to lie between 0.2 and 0.3, practically for all the samples, except sample No. 3, where it lies between 0.3 and 0.4. While in case of the sample No. 42, it lies between 0.5 and 0.6. The unimodal distribution of roundness values is, therefore, much similar to that for the distribution of the sphericity values.

The relationship between mean sphericity and mean roundness with respect to size in phi has also been examined. From the Fig. 4.12 (a and b) no definite relationship between mean sphericity and roundness in relation to size can be inferred, as there seems to be much variation in the mean values of sphericity and roundness in relation to size.

Percent frequency distribution of the sphericity and roundness values has also been plotted that has been presented in Fig. 4.13 (a and b) by way of frequency curves. It is interesting to note that the nature and the trend of the frequency curves of sphericity runs parallel to that of the roundness. This rather suggests that as the frequency of the spherical grains has increased with the increase in sphericity value, there is also an increase in the frequency of the rounded grains with the increase in the roundness values. It is further observed that there is a decrease in the frequency distribution of the spherical grains with the decrease in sphericity values. Similar is true for roundness values. From this observation it can be stated that as the frequency of spherical grains has increased, there is also an increase in rounded grains and vice versa, in the samples from each microenvironment.

The relation between mean sphericity and mean roundness from each microenvironment has been examined with the help of a bivariate plot. It is observed from Fig. 4.14 (a) that the sediments from low tide environment from an envelope with little overlap on an envelope of sediments from the high tide environment. Such a relationship between sphericity and roundness has also been examined for the sediments from raised beach and dune environments (Fig. 4.14 b) and the envelopes for the low tide and high tide environments from Fig. 4.14 a have been transferred to Fig. 4.14 b. From this plot, it is seen that most of these sediments bear a similar relationship between sphericity and roundness as that from the sediments from high tide environment.

The regression of the mean roundness with mean sphericity (Fig. 4.15) has been examined for the sediments from each microenvironment. An average line or the regression line indicates that as the mean sphericity has increased, there is a corresponding increase in mean roundness of the grains and a vice versa. Such a relationship between mean sphericity and mean roundness has been supported by the plot of percent frequency distribution of sphericity and roundness values (Fig. 4.13 a and b).

From the above characteristics of the sediments, when examined in the light of sphericity and roundness values, it is seen that these sediments show unimodal distribution, which rather is an indication of their derivation more from a singular source of rock. This rather contradicts to the inference arrived at from the heavy mineral studies. However, the studies made by different workers, as stated by Blatt et al.

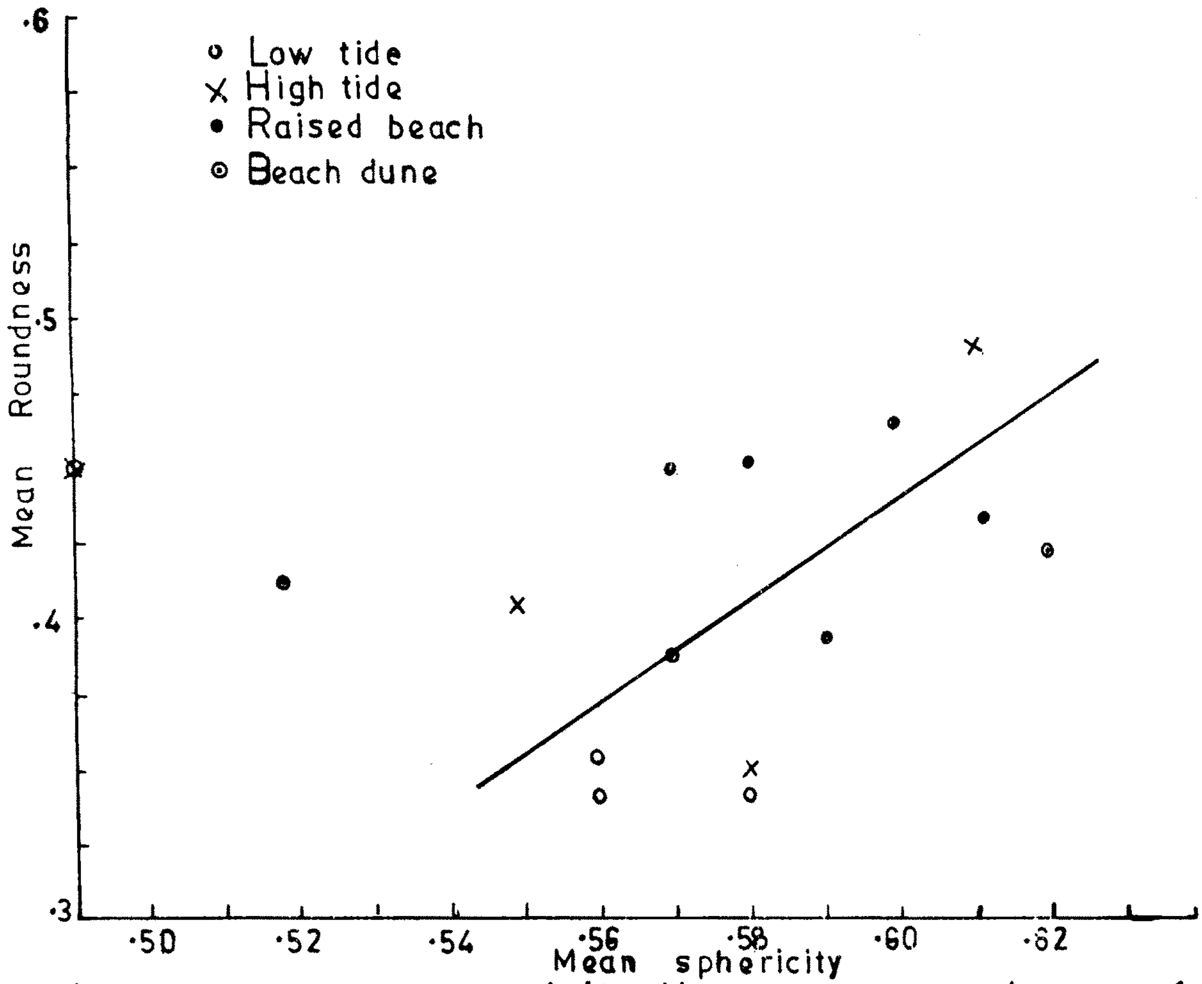

Fig. 4·15 Mean sphericity Vs. mean roundness of Malvan beach sediments.

(1980), an index of sphericity has been related to the inherence from the source of a particle and not to the extent of transportation. It therefore seems to be a chance that a mixed provenance, as inferred from the heavy mineral analysis is a sourse for unimodal distribution of the sphericity values. No distinct relationship of sphericity with size has been considered as the characteristics of immature or primitive sands (Pettijohn, 1984).

The roundness values indicate that the sediments have short abrasion history, indicating that they have undergone less transportation and have derived probably from a nearby source.

It has been inferred therefore, that the coastal sediments from each microenvironment from the area investigated are immature or primitive sands and though derived from a mixed provenance have a short abrasion history having a nearby source.