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IMPACT OF SEDIMENTALOGICAL PROCESSES ON MANGROVE ECOSYSTEM OF THE INDUS DELTA

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ABSTRACT: A detailed sedimentalogical study concerning the depletion of mangrove in the Indus Delta due to the marked decrease in the supply of silt was undertaken. Thirty one stations were established for sampling in a selected area of 12000 hectares between Korangi creek and Waddo Khuddi creek. Seventy one samples of soil were collected from 6cm and 1m depth, out of which fifty one samples were selected for sedimentalogical studies. It was inferred from this study that the marine depositional processes are distinctly dominating over the fluvial processes, which is major cause in decreasing the growth of mangrove. It was also inferred that among the sampled stations the sites having clayey silt (with silt 60%-70% and clay 25%-30%) are most favourable for mangrove plantation.

KEY WORDS: Sedimentalogical Processes, Mangrove Ecosystem, Indus Delta.

INTRODUCTION

The Indus Delta mangrove, the largest in the world arid zone, is under stress and is degrading. A strategy for conservation and reforestation is needed. Mangrove ecosystem plays a significant role in fisheries, coastal stabilization and in the maintenance of critical habitats for many common, threatened and endangered species. The mangrove ecosystem within the Indus Delta, extending from Karachi to Indian border, contributes significantly to the coastal economy. Given the economic significance of this ecosystem the changes in the process, controlling the forcing factors that appear to stress and degrade the ecosystem, have received concerned attention over the past decade. These stressful and degrading changes are both natural and man induced. The most perceptibly identifiable changes are (i) substantial reduction in fresh water and sediments input from the Indus river (ii) steady sea level rise (iii) substantial increase in the pore water salinities in the mangrove habitat and vastly decreased species diversity of mangrove plants (iv) overgrazing and indiscrete falling of trees for fodder and fuel and (v) progressive dominance of marine over fluvial sedimentation.

This paper describes methodology and the results of the sedimentalogical study and the discussion of the impact of sedimentation pattern on mangrove dynamics. In mangrove ecosystem research, several studies have demonstrated that the evolution of vegetation patterns is closely related to the dynamics of shoreline and sedimentation. However, the study is quite complex and for this reason it is hardly surprising that this type of research is not widespread (Broto, 1984). As such, the present study is of wider interest and increased importance.

Thirty one stations were established in a selected area of 12000 hectares between Korangi creek and Waddo Khuddi creek. Soil samples were collected from 6cm and from one meter depth for sedimentalogical studies. At present, marine depositional processes are distinctly dominating over the fluvial processes, which played a significant

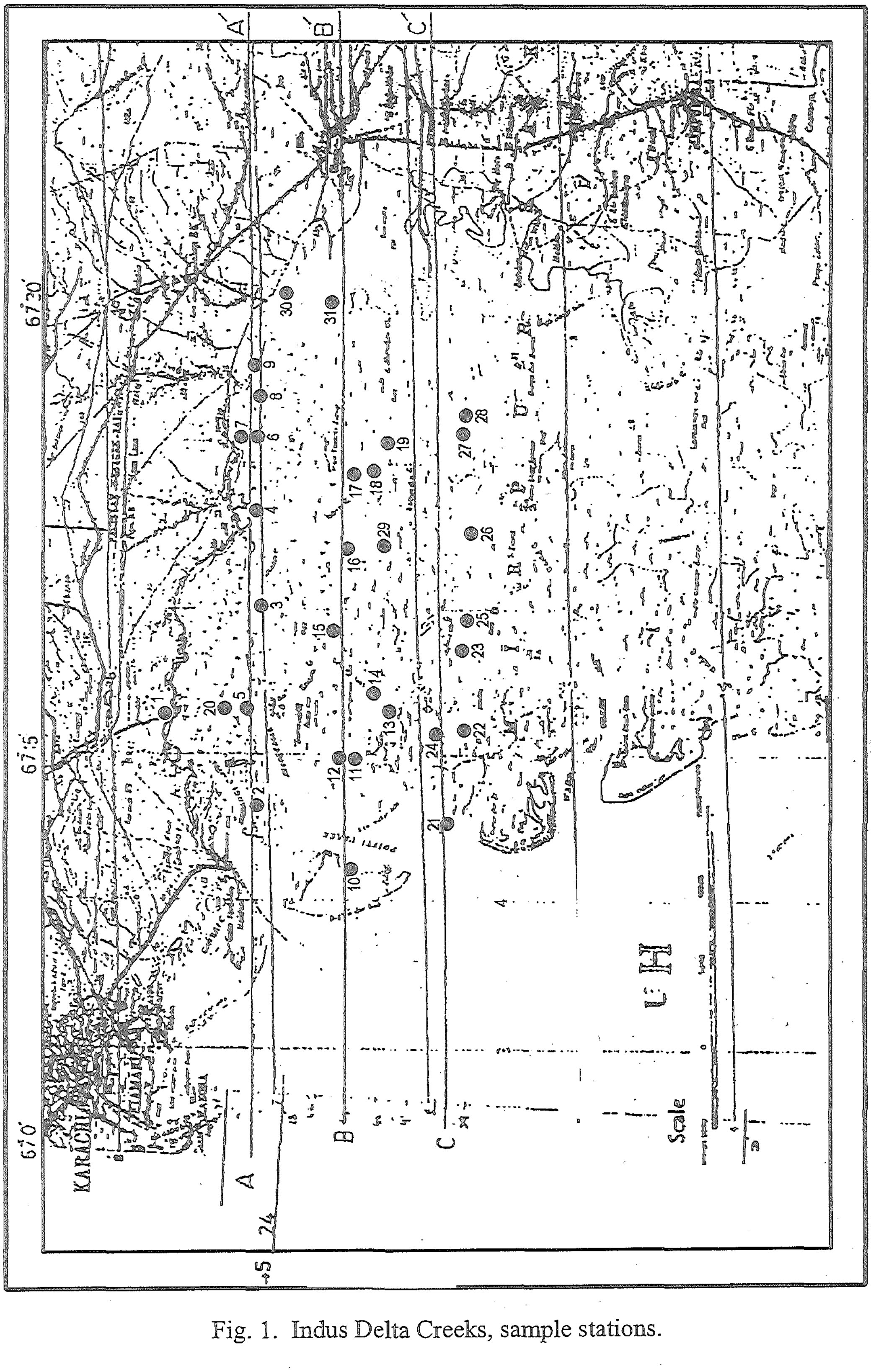


Fig. 1. Indus Delta Creeks, sample stations.

role by providing a suitable habitat, a thousand years ago. The study suggests that where sediments are clayey silt (with silt 60-70% and clay 25-30%) are most favourable for mangrove plantation.

MATERIALS AND METHODS

The Indus Delta mangroves are spread over an area of 260,000 hectares. A small area of about 120 Sq.Km. (12000 hectares) was selected between Korangi creek and Waddo Khuddi creek for sedimentalogical studies.

Soil samples were collected along three east-west transects, each 10Km long and 6Km apart. Surface sample were obtained from depth of 6cm and the core samples from one meter depth on mudflats or creek embankments. The sample sites were located on 1:50,000 map (prepared by SUPARCO) by siting the location in relation to the coastal installations of Port Qasim with the help of a clino-compass and prominent physiographic features.

A total of 31 stations on the transects AA' BB' and CC' have been marked (Fig. 1). At each station 2 samples were collected one from the surface of island or creek embankment at 6cm depth, the other by auger from 1 meter depth. At a few stations more samples were collected where some variation was observed.

Transect	No. of Station	Sample from 6cm depth	Sample from 1m depth	Total number of samples
A – A'	12	12	12	24
B – B'	11	14	12	26
C – C'	08	11	10	21
Total	31	37	34	71

Grain size analysis by sieving:

Sieving is commonly used to determine the grain size distribution of sand samples which are naturally dried, worked down to about 100 gms using a sample splitter. The dry sample is placed in the uppermost sieve in a set of stacked sieves arranged in the order of coarser at the top with successively finer ones below. The mesh size used in the present exercise were: ASTM mesh numbers 10, 18, 35, 60, 120, 230 corresponding to the different sand grades. The nest of sieves was placed on a shaker for about 10-15 minutes and the sand retained on each sieve and the pan was removed and weighed accurately.

Pipette analysis of silt and clay:

For pipette analysis all materials coarser than 230 mesh were removed from the sample either by dry sieving or by wet sieving. A suitable amount of the sample to work was 10-15 gms. The sample was washed on a 230 mesh with dispersant solution to separate silt and clay from sand. The dispersant used in these analyses was sodium hexametaphosphate (calgon). The washings were transferred to one liter graduated cylinder and were allowed to stand overnight. On the next day the cylinder were stirred vigorously, starting from the bottom and working upward until the material was distributed uniformly throughout the cylinder.

A specific volume of suspension was then withdrawn from a prescribed depth, generally from 20, 10, and 5cm., on a time schedule determined by calculation based on Stoke's law (Stokes, 1851). At these timings all particles of a given size which have settled below that depth, only the finer particles remain in the suspension which are withdrawn. The dry weight of the pipetted fraction is used to calculate the grain size distribution of the original sample.

Placement of Silt-clay boundary:

The geologically accepted boundary between silt and clay lies at 8 (1/256mm) as per Udden-Wentworth scale and adopted by Krumbein and Folk in (Krumbein and Sloss, 1963). The ASTM places this boundary at 0.005mm. The same has been adopted by the civil engineers of American Association of State Highways (AASHO). The U.S. bureau of soils, under the department of Agriculture shifts the silt and clay boundary to 0.002mm (9 phi). Thus much of clay sized material falls in silt if this recommendation is followed. We have strictly followed the boundary suggested in Udden-Wentworth scale and modified by Krumbein and Folk which is 0.004mm (8phi).

RESULTS

A systematic sampling of soils from the Indus Delta creeks and mudflats has been carried out . Thirty one stations were established on three transects by carefully locating the sites on a map of Indus Delta Port Qasim area. The soil samples have been analysed in the laboratory to determine sedimentalogical characters. The results of the sieve and pipette analysis have been summarized (Table 1 & 2).

The interpretation of histogram generally follows three different paths; one relates the characteristics related to hydro-dynamics (to the depositional process itself), the second attributes the difference to the provenance while the third looks for an explanation in the process of transportation. In general unimodal histogram implies deposition from a current of wind or water that flows along a constant direction while a bimodal histogram signifies deposition from two different mechanism, namely traction and suspension, such as river. A polymodal distribution results by the reworking of the sediments that has been deposited earlier. Since the bimodal distribution is characteristic of river currents which transport coarse and fine grains at the same time, the distribution curve of a fine silt or mud tends to be unimodal. It is attributed to fluvial processes and not to tidal processes which operate with varying energies in opposite directions. Histograms of 53 samples have been prepared, 26 samples from 6cm (Fig. 3a) and 27 samples from 1m depth (Fig. 3b).

Classification of soil samples:

Various schemes of naming sediment mixtures are available and no general agreement is present among geologists, oceanographers, pedologists and engineers. Some of the popular schemes of classification of sedimentary aggregates reviewed by (Pettijohn, 1975) includes the scheme of (Robinson, 1966), (Folk, 1968) and (Shepard, 1954). The last mentioned is used by oceanographers in general and is easy to name the soil type, so it has been preferred to others. It envisages a classification of aggregates on a ternary diagram with sand-silt-clay as end members, based on the relative proportions of the components. Soil samples in this report are characterized here by using the Shepard ternary diagrams (Fig. 2a & 2b), Table 1 & 2 represent percentage of sand silt and clay in the mangrove soil samples collected from 6cm and 1m depth respectively.

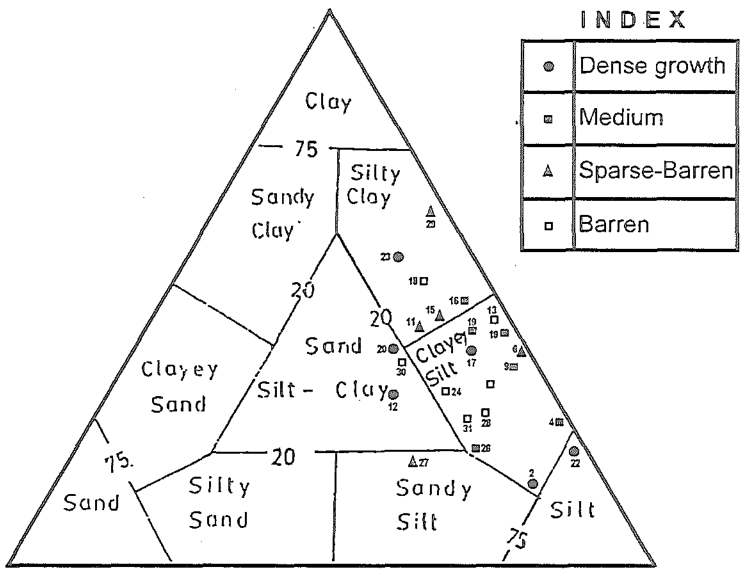


Fig. 2a. Mangrove growth density and Soil type (6.cm depth)

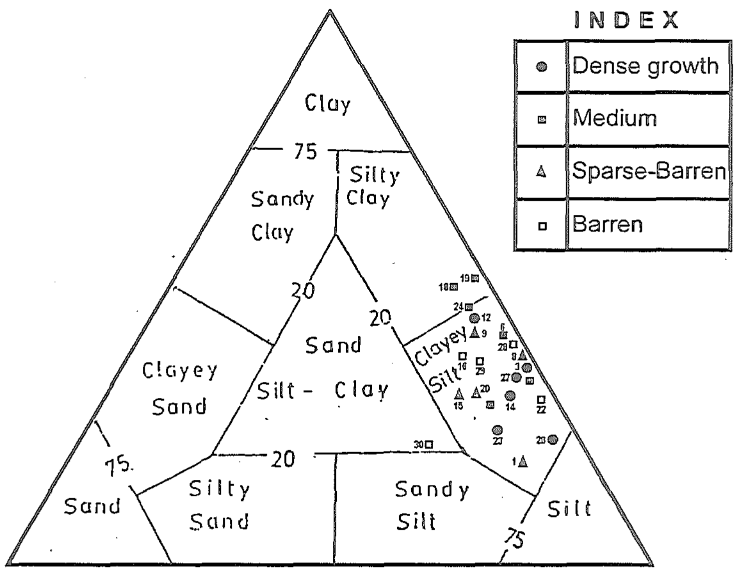


Fig. 2b. Mangrove growth density and Soil type (1.m depth)

Table 1. Classification of Mangrove soil from 6 cm depth

Station No.	Sand %	Silt %	Clay %	Soil classification after Shepard (1954)
1.	---------- Sample not taken ----------			
2.	100	0	0	Sand
3.	0.55	65.16	34.29	Clayey silt
4.	2.23	73.33	24.44	Clayey silt
5.	10.67	57.42	31.91	Clayey silt
6.	0.28	60.55	39.17	Clayey silt
7.	100	0	0	Sand
8.	3.85	62.99	33.16	Clayey silt
9.	6.05	59.15	34.8	Clayey silt
10.	100	0	0	Sand
11.	15.01	41.8	43.19	Silty clay
12.	26.54	40.88	32.58	Sand silt clay
13.	5.83	48.49	45.68	Clayey silt
14.	9.78	52.12	42.34	Clayey silt
15.	11.76	42.06	46.18	Silty clay
16.	6.47	47.43	46.1	Silty clay
17.	2.55	55.05	42.4	Clayey silt
18.	9.90	38.12	51.98	Silty clay
19.	7.47	50.53	42.0	Clayey silt
20.	21.05	38.95	40.0	Sand silt clay
21.	100	0	0	Sand
22.	0.43	76.84	22.73	Silt
23.	12.30	32.03	55.67	Silty clay
24.	18.58	51.99	33.41	Clayey silt
25.	14.6	69.59	15.81	Clayey silt
26.	19.10	59.13	21.77	Clayey silt
27.	28.04	50.5	21.1	Sandy silt
28.	13.75	59.15	27.1	Clayey silt
29.	1.97	32.3	65.73	Silty clay
30.	20.2	42.4	37.3	Sand silt clay
31.	15.3	57.1	27.6	Clayey silt

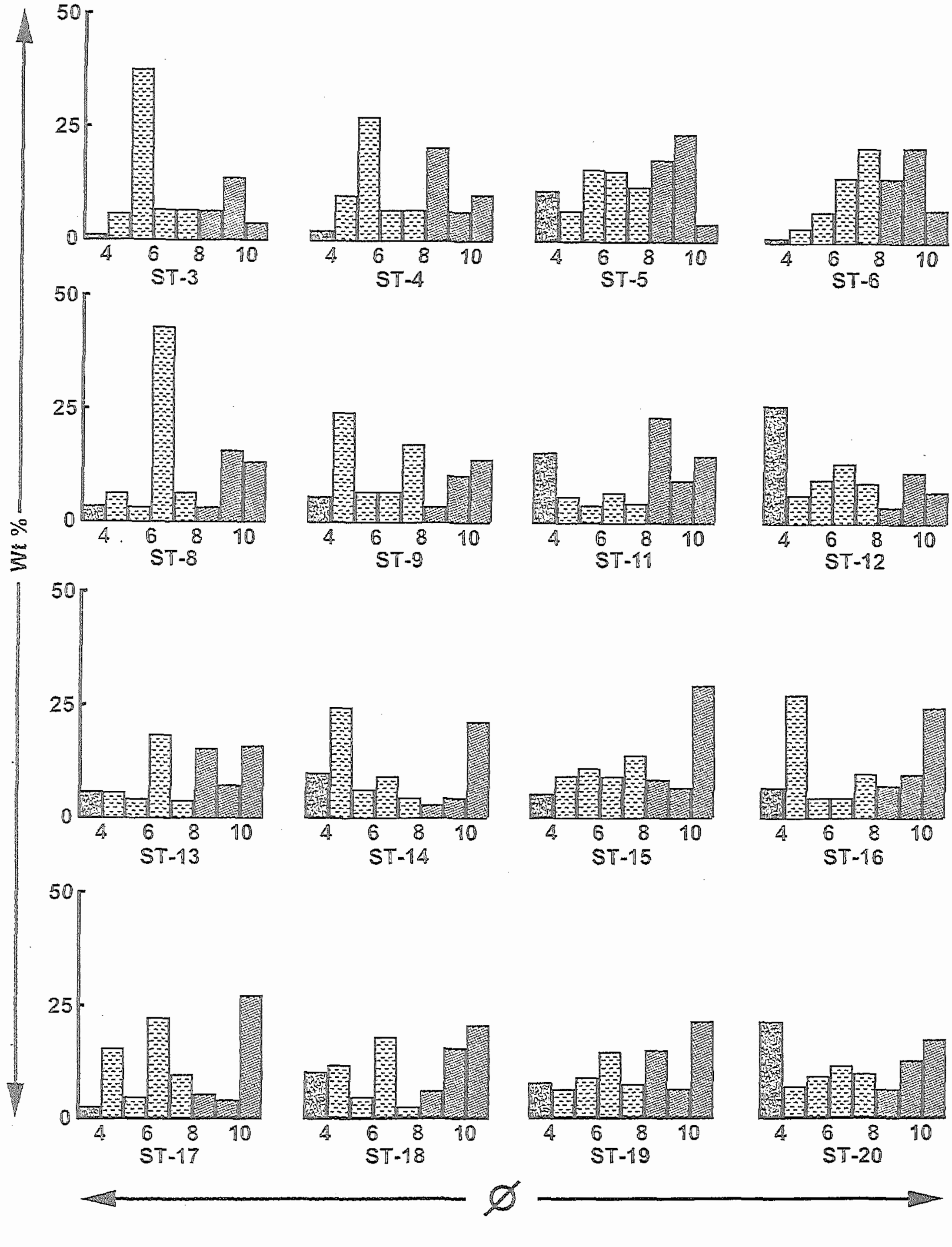
Table 2. Classification of Mangrove soil from 1 m depth

Station No.	Sand %	Silt %	Clay %	Soil classification after Shepard (1954)
1.	11.92	68.07	20.01	Clayey silt
2.	100	0	0	Sand
3.	3.31	62.15	34.54	Clayey silt
4.	1.29	64.67	34.04	Clayey silt
5.	5.72	52.38	41.96	Clayey silt
6.	8.78	43.92	47.3	Clayey silt
7.	100	0	0	
8.	5.26	52.63	42.11	Clayey silt
9.	1.75	45.61	52.64	Clayey silt
10.	100	0	0	Sand
11.	1.75	49.12	49.13	Clayey silt
12.	7.12	47.48	45.4	Clayey silt
13.	11.5	49.55	38.95	Clayey silt
14.	7.9	60.82	31.28	Clayey silt
15.	15.4	53.26	31.34	Clayey silt
16.	2.98	56.11	40.91	Clayey silt
17.	2.55	55.05	42.4	Clayey silt
18.	2.20	46.18	51.62	Silty clay
19.	5.79	43.75	50.46	Silty clay
20.	2.26	60.9	36.84	Clayey silt
21.	100	0	0	Sand
22.	3.5	66.04	30.46	Clayey silt
23.	12.6	61.7	25.7	Clayey silt
24.	5.7	47.19	47.21	Silty clay/Clayey silt
25.	3.0	70.06	26.94	Silt
26.	3.7	62.21	32.09	Clayey silt
27.	12.3	56.77	30.93	Clayey silt
28.	9.5	53.26	37.24	Clayey silt
29.	1.6	60.14	38.26	Clayey silt
30.	25.1	53.50	21.4	Sand silt clay
31.	1.04	57.29	41.67	Clayey silt

Cumulative curves for all the samples analyzed have been drawn. However, only those representative curves have been presented here fig. (4a, b & c) which show different types of skewness or asymmetry of curve namely negatively skewed (4a) positively skewed (4b) and symmetrical cumulative curve (4c).

Cumulative curves on probability graph have been drawn for all the samples analyzed. However, we present only 2 graphs that show two different depositional energy regime. (Fig. 5a) represents a nearly stable and (Fig. 5b) a highly unstable for a fluctuating energy regime.

From the sedimentalogical characteristics of the soil samples from 6cm and from 1m depths, obtained from 30 sites between Korangi Gharo creek in the north and Waddi



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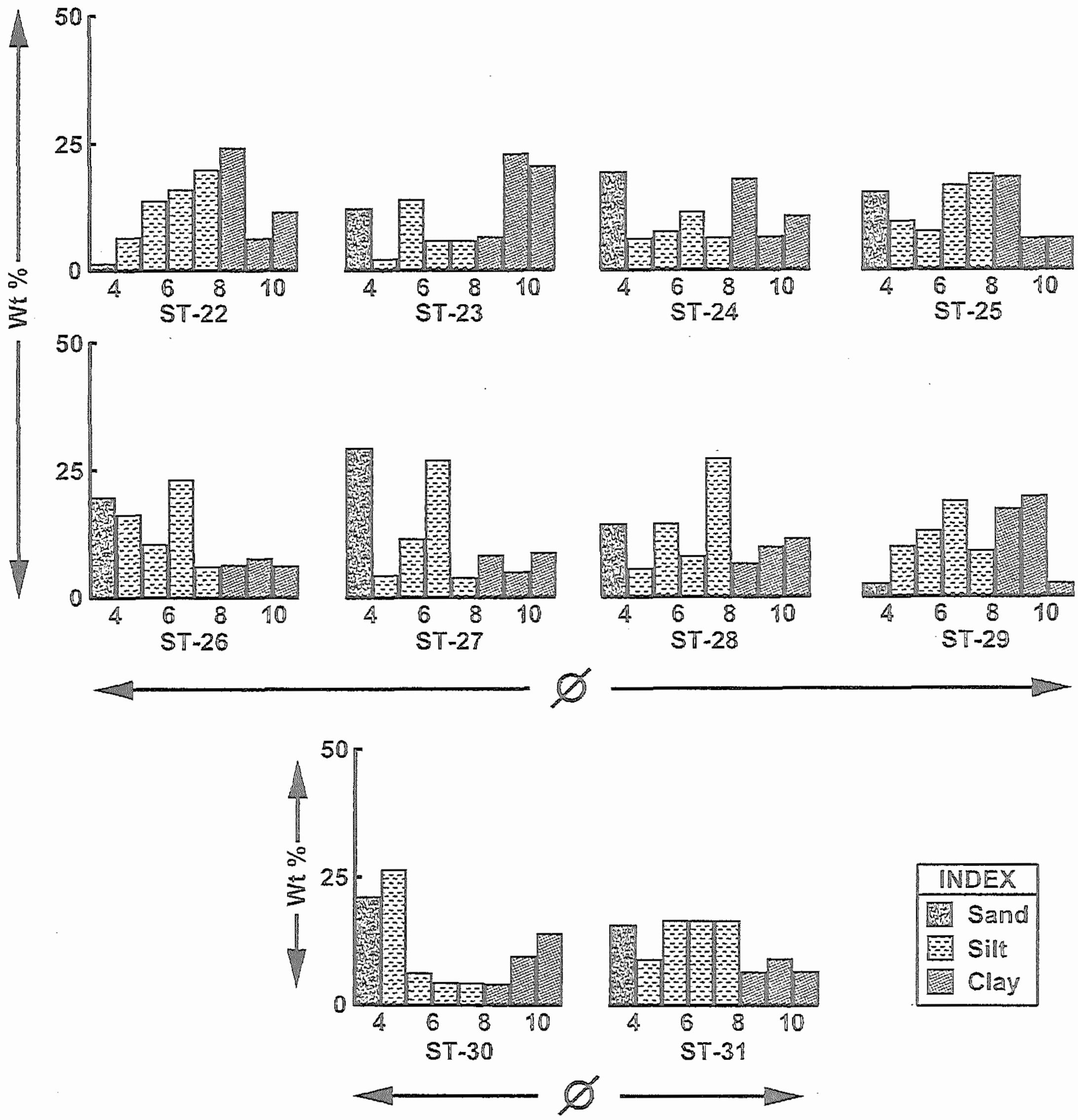


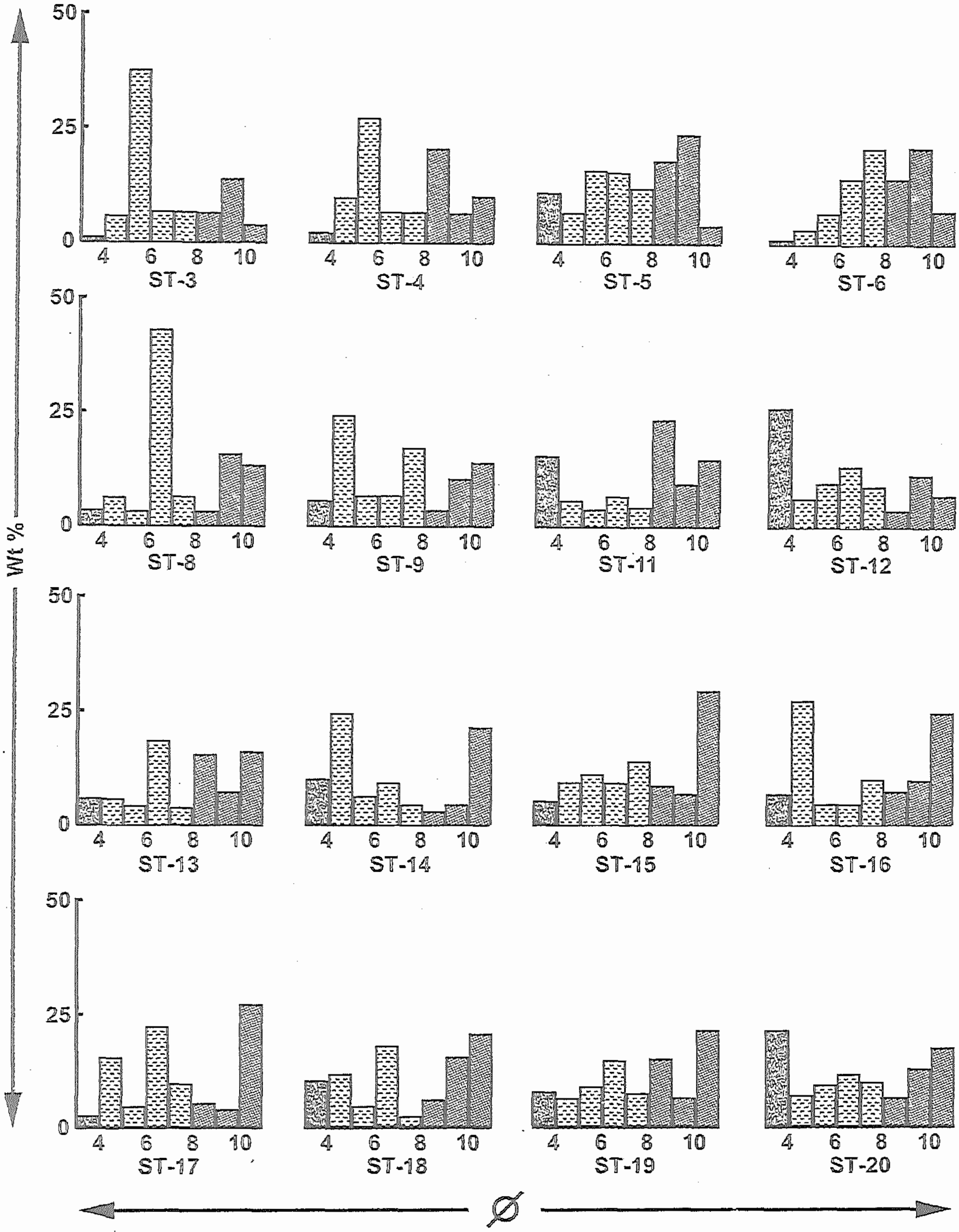
Fig. 3a. Histograms showing grain size composition of the Indus Delta Mangrove soil from 6 cm depth.

Khuddi creek in the south, the important inferences are:

i) Soil forming the mud flats is clayey silt composed of silt, clay and sand fractions.

ii) Very fine silt is the dominant component (55%) both in the near surface and in one meter deep soils.

iii) Near surface soils (within 6 cms) are characterized by comparatively higher silt-clay ratio. Average silt-clay in the near surface soils is 1.7 with a standard deviation 0.5. Samples from one meter depth have a silt-clay ratio of 1.4 with standard deviation 0.7. Higher silt-clay ratio and lower standard deviation are indicative of dominance of marine processes in modern sedimentation. The comparatively lower silt-clay ratio and higher standard deviation suggest substantial fluvial input in the sediments at deep level (Fig. 3).



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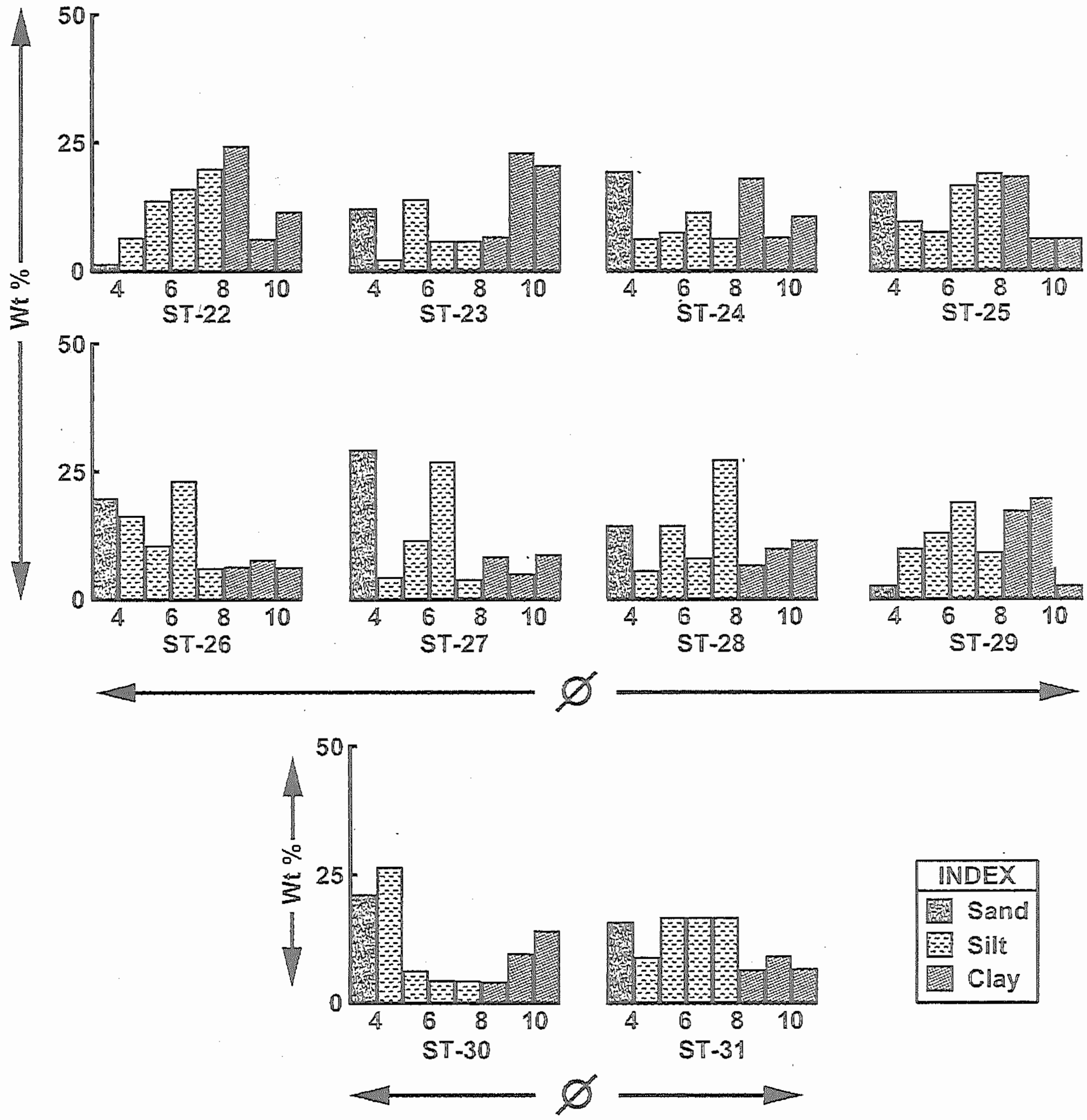

Fig. 3b. Histograms showing grain size composition of the Indus Delta Mangrove soil from 1 m depth.

iv) Comparison of histogram of the samples from near surface and one meter depths shows that grain size distribution in term of modal class points at some difference in the mode of deposition. Out of twenty six samples from near surface six are bimodal and twenty are polymodal. On the other hand histograms of samples from one meter depth from twenty seven stations reveal that three are unimodal, twelve are bimodal and the remaining twelve are polymodal. This percentage wise the polymodal distribution decreases with depth. The polymodal distribution arises from reworking of sediments and thus we may infer that the near surface sediments of the mud flats are the result of reworking of fluvial sediments by marine processes. The presence of unimodal distribution in one meter depth samples implies that there was less reworking and the sediments were deposited mainly through fluvial processes at that time.

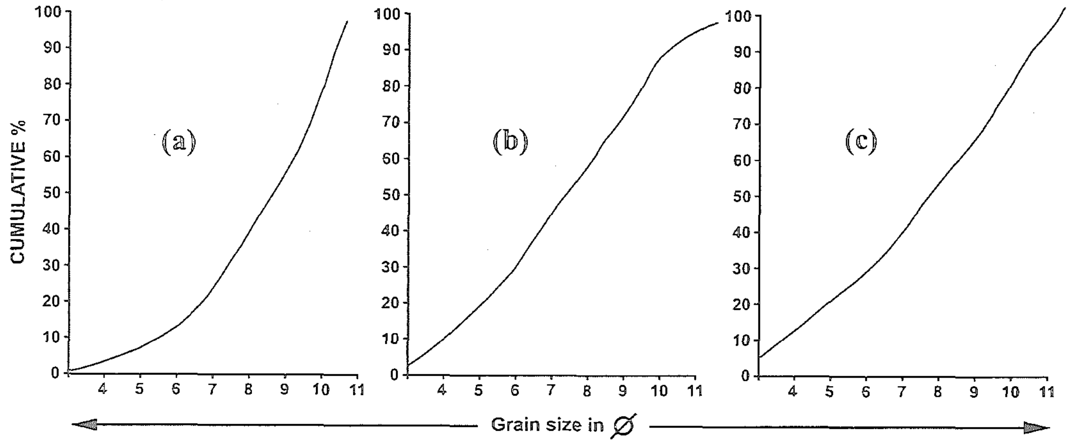

Fig. 4 (a). Negatively skewed, (b) Positively skewed, (c) Symmetrical.

v) The depositional energy regime that prevailed at the time of deposition of sediments found now at one meter depth was highly fluctuating. This inference is based on the observation that in a probability plot of grain size against cumulative percentage larger number of sub populations line segments (S_1 S_2 S_3........S_n) exist in a highly fluctuating regime (Fig. 5).

vi) Clayey-silt, with 60-65% silt, appears to be conducive substrate for mangrove vegetation.

The sediments at one meter depth in the mangrove area were laid down in a highly fluctuating depositional regime perhaps 1000-1500 years before present. Sedimentation rate in the sub aqueous delta has so far not been determined. However a rate of deposition 0.5-1mm/yr may be a reasonable guess. At that time Gharo and Gizri creeks were the active distributary channels of the Indus River and brought down fluvial sediments in large quantities particularly during strong moonsoon seasons. These fluvial sediments included populations of suspended, saltatory and tractive particles in varying proportions. It is the suspended particles in the sediments which carried the nutrients.

The nutrient rich suspended fraction of the sediments, deposited 1000-1500 years before present, perhaps provided a conducive habitat for mangrove colonization. In contrast, the sediments being deposited now are almost entirely of marine nature and are poor in nutrient-carrying fluvial suspended particles and therefore they are comparatively less suitable for the growth of the mangrove species generally found in the Indus Delta.

CONCLUSIONS AND RECOMMENDATIONS

Sedimentalogical studies carried out for the first time on a regional scale with 31 study sites in an area of 120 sq. km. of the Indus Delta creek system have demonstrated the applicability and utility of such studies in understanding the vegetation dynamics in a Mangrove Ecosystem.

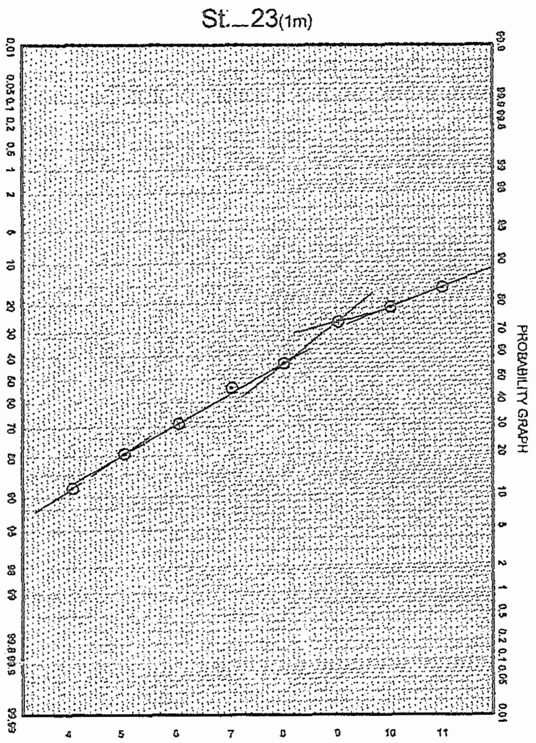

Fig. 5a. Slightly fluctuating Depositional energy regime.

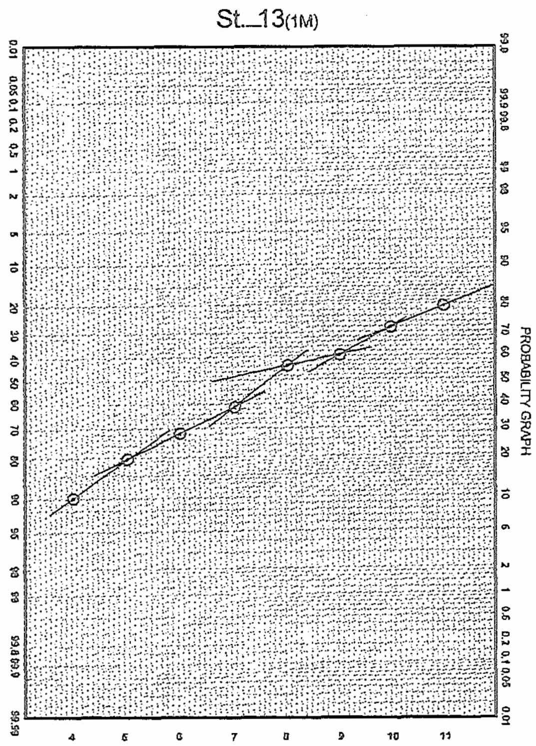

Fig. 5b. Highly fluctuating Depositional energy regime.

The depositional processes at present are almost entirely marine in contrast to the depositional conditions which prevailed 1000-1500 years ago when fluvial processes played a significant role and provided a suitable habitat for mangrove colonization. The study suggests that in a plantation programme sedimentalogical characteristics should be taken into consideration. Sites where the sediments are clayey-silt (which silt 60-70% and clay 25-30%) are most favourable for mangrove plantation.

For predicting direction and magnitude of changes in vegetation communities the changing patterns of water mass circulation and sedimentation should be monitored in the Indus Delta creek system. Measurements of tidal current velocities, rate of sedimentation, salinity gradients and analysis of sediments at carefully selected sites in the creeks and mud flats with mangrove growth should be carried out. Relationship of geomorphological features of the island margins and the vegetation dynamics should be studied in detail. Topographical survey of a few selected islands should be carried out in order to determine the control of topography on salinity and nutrient contents of the soil. Very little attention has been paid so far to the study and monitoring of the deltaic processes operating so close to the city. Hardly we know the rate of sedimentation on mud flats and creeks. No assessment of shoreline erosion is available and only recently some preliminary estimates of sea level rise has been undertaken.

The present work is a first attempt to analyze the sedimentation patterns of mudflats of the Indus Delta over a selected area. This study was a goal oriented research and on a very limited scale. The mangroves are spread over 280,000 ha and if the whole area is studied for geomorphic and sedimentalogical processes, their impact will be understood with far more clarity. The study will provide basic information on the geology of the Indus Delta which will be useful to exploration geophysicists, planners and conservationists.

REFERENCES

Blasco, F. 1984. Mangrove evolution and Palynology, In: The Mangrove ecosystem research methods, (Eds. Snedaker, S.C. and J.G. Snedaker), UNESCO, Paris. Pp. 36-37.

Broto, K.G. 1984. Water-logged saline soil, In: The Mangrove ecosystem: research methods, (Eds. S.C. Snedakar and J.G. Snedakar), UNESCO, Paris. Pp. 119-121.

Clark, J.R. 1977. Coastal ecosystem management: A technical manual for the conservation of coastal zone resources. John Willey New-York.

Farah, A. 1990. A Geological study of coastal environment of Pakistan. Coastal environment management plan for Pakistan, U.N. ESCAP, Bangkok.

Farah, A. and P.J. Meynell, 1991. Sea level rise-possible impacts on Indus Delta. Korangi Ecosystem Project, Issue paper No. 2: 1-14.

Folk, R.L. 1968. Petrology of sedimentary rocks, Hemphills Austin, Texas. 170 p.

Holmes, D.A. 1968. The recent history of the Indus. Geographical Journal, In: Marine Geology and oceanography of Arabian Sea and Coastal Pakistan (Eds. B.U. Haq and J.D. Milliman), Van Nostrand. 134: 367-381.

Krumbein, W.C. 1934. Size frequency distribution of sediments. *Journal of Sedimentary Petrology*. 4: 65-77.

Krumbein, W.C. and L.L. Sloss, 1963. Stratigraphy and Sedimentation. W.H. Freeman, San Francisco. 660 p.

Pettijohn, F.J. 1975. Sedimentary Rocks, Harper and Row, New York, 628 p.

Robinson, A.H.W. 1966. Residual Currents in relation to Shoreline evolution of the East Anglian Coast. *Marine Geology.* 4: 57-84.

Shepard, F.P. 1954. Submarine Geology. Happer and Row. N.Y. 348 p.

Snead, R.E. 1985. Pakistan Coast, In: The world's line, (Eds. E.C.F Bird and M.L. Schwertz), Van Nostrand New York. Pp. 735-739.

Stokes, G.G. 1851. On the effect of internal friction of fluids on the motion of pendulums. *Transactions of Cambridge Philosophical Society,* 9(2): 8-106.

Wells, J.T. and M.J. Coleman., 1984. Deltaic Morphology and sedimentology with special reference to the Indus River Delta, In: Marine Geology and Oceanography of Arabian Sea and Coastal Pakistan, (Eds. B.U. Haq and J.D. Milliman), Van Nostrand. Pp. 85-100.

Wentworth, C.K. 1922. A scale of grade and class terms for clastic sediments. *Journal of Geology,* 30: 377-392.

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