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BATHYMETRY, TEXTURE AND COMPOSITION OF BOTTOM SEDIMENTS OF SHANAAB BAY, RED SEA, SUDAN

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ABSTRACT

39 stations were selected for bathymetric, textural and compositional study in 1984. Depth ranges to 40.0 m with an average of 10.7 m Shanaab Bay is narrow central basin surrounded by shallow banks. THE basin deepens towards the mouth of the bay. Only two environments were identified: the central basin and the shallow banks surrounding it . Sediments from the basin have small means and are negatively skewed while those from the banks have large means and are positively skewed Factors controlling distribution of texture are: (1) abundance, type and size of organisms living in bay, (2) wind, (3) seasonal freshwater discharge, (4) transport from adjacent shores and shelf, (5) depth, and (6) hydrography.

Sediments are composed of mollusks, corals, echinoderms, foraminifera, pelecopods, bryozoans, pellets, rock fragments, quartz, feldspars and unidentified particles. FActors controlling composition are: (1) organisms living in the bay and their skeletal fragments, (2) erosion of bay shores, (3) input of terrigenous material, and (4) transport from adjacent shores and shelf by selective winowing.

INTRODUCTION

From 1915 to 1969 the Sudan government utilized Dongonab Bay (Fig. 1) for the cultivation of the oyster **Pinctada margaritifera** on commercial basis. in 1969 a mass mortality occurred among the cultivated oysters in the bay and commercial cultivation stopped subject to finding mortality cause (s). Other mortalities also occurred among oysters cultivated in Dongonab Bay for research purposes in 1973, 1975, 1979, and 1981. In 1974 the Red Sea Fisheries Research Section decided to search for other cultivation sites outside Dongonab Bay. In 1974 some oyster spat (seed) were transferred from Dongonab Bay to Shanaab Bay (Fig. 1) and other bays. In 1977 a joint research project was signed between the Sudan Government and the International Development Research Center (IDRC) of Canada for the revival of commercial oyster cultivation. Among the project objectives are the testing of new sites for oyster culture and the application of other culture techniques. Shanaab Bay was among the selected sites.

Since 1981 oyster spat (seed) have been transferred annually from Dongonab Bay to Shanaab Bay for experimental purposes. Because no mortality occurred in Shanaab Bay, oyster demonstration farms have been established in the bay to train local people. In addition to the traditional bottom culture technique, off-bottom and near surface culture techni ques have been tested. The type of culture technique depends on bottom nature. The bottom culture is used for areas with sandy bottom while off-bottom and near-surface cultures are used for areas with muddy bottoms.

It is important to mention that no oceanographic research was done prior to the transfer of oyster spat (seed) to Shanaab Bay. This encouraged the author to study the bathymetry, texture and composition of bottom sediments of Shanaab Bay with the objectives of (1) mapping the distribution of depth and texture to facilitate selection of appropriate culture techniques, and (2) finding out the origin of the bottom sediments and the factors that contributed to the grain size distribution.

Shanaab Bay lies about 210 km north of Port-Sudan on the Sudanese Red Sea coast (approximately 25 km north of Dongonab Bay) between lat. 21^{o} 20′ and 21^{o} 23′ N and long . 37^{o} 00 and 37^{o} 05′ E (Fig.1). The bay is a canal-like bay running into the coastal plain in an E-W direction with cross branches running N-S. The bay extends from east to west for a maximum length of 6 km. The width of the bay ranges from 0.25 km to 2.8 km with an average of 0.85 km. The total area of the bay is about 6.3 km^{2}. Modern reefs are actively building in Shanaab Bay almost paralleling the 5 m contour (Fig. 2). High coral cliffs (up to 3 m) surround both sides of the eastern and southern segments of the bay and the eastern side of the northern segment (Fig. 3). The western segment and the western side of the northern segment are surrounded by non-carbonate gravel cliffs and hills of quartz sandstones and lenses of conglomerate and rounded igneous pebbles (fig.3).

The coastal plain is a wide plain (about 30 km) the surface of which is covered by recent sand transported by wind and small seasonal streams (khors). The surface of the plain is underlain by Pliocene-Pleistocene gravel and sand lenses (Sestini, 1965). The gravel and sand rest on late Miocene evaporitic layer which in turn rests on a layer of limestone mixed with middle Miocene evaporates (Carella and Scarpa, 1962).The western end of the coastal plain is marked by the Red Sea hills formed of igneous, metamorphic and sedimentary rocks (Ruxton, 1956) which are classified as precambrian (Kabesh, 1962; Ruxton, 1956; Sestini, 1965).

The climate of Shanaab Bay area is hot and arid with temperature reaching 45 C^{o} during summer months (personal observations) and an average annual precipitation of about 0.05m (Morcos, 1970). during winter wind blows mainly from N-NNE attaining its maximum strength (50-80 km/hr) in January and February. During summer wind can blow from any direction but often from NW (Iocally called Huror) and from SSE. The NW (Huror) winds carry large amounts of sand dust that sometimes limit visibility to 100 m (Crossland, 1907). Shanaab Bay lacks any river that drains into it. Freshwater enters the bay from a seasonal stream (K. Shanaab) that drains into the western segment of the bay (Fig. 3) during rainy seasons (August and winter) carrying large amounts of terrigenous material. Tide in the middle part of the Red Sea is very low (>30 cm) (Crossland, 1907). Variation of level of about 50 cm occur almost daily (personal observations). The mean level is about 90 cm lower in summer than in winter due to the effect of the Monsoons in the Indian Ocean (Crossland, 1907).

METHODOLOGY

A small outboard engine boat was used for this study. Boat traverses were made across the bay in N-S directions. Sampling stations were located by boat-to-shore triangulation with a sextant . 39 stations were fixed inside the bay (Fig. 2). At each station the water depth was measured using a lead line.

Bottom samples from 38 stations were taken using a peterson grab sampler. At Station 1 the bottom was so hard that I was unable to take a sample. The samples were air dried, stored in cloth sample bags and taken to the department of soil survey laboratory, Medani, Sudan for analysis. About 50 gm of each sample were soaked in distilled water to remove soluble salts and destroy aggregates (Matthews, 1966). Each sample was then sieved through 2 mm and 0.2 mm sieves to separate pebbles (>2 mm) and coarse sand (2-0. 2 mm) from the sample. Fine sand (0.2-0.2 mm), silt (0.02-0.002) and clay (>0.002 mm) size fractions were separated by decantation method (Jackson, 1973). Pebbles, coarse sand, fine sand, silt and clay size fractions were weighed on a Metler balance with an accuracy of +0.005 gm. The percentage of each size fraction was calculated. The data obtained were processed in an IBM micro-computer for determining the moment measures (zeta) representing the grain-size parameters using the formulas of Friedman (1962). Pebbles and sand size fraction of the 38 samples were examined under a binocular microscope for particle identification.

RESULTS

Bthymetry

The distribution of depth is shown in Fig. 3. Depth ranges to 40.0 m with an average of 10.7 m. The bay is a narrow and deep central basin surrounded by shallow banks. The basin deepens towards the month of the bay where maximum depth (40.0 m) is attained. Unlike Dongonab Bay (Farah, 1982) there is no sill separating the bay from the Red Sea proper. The depth profiles probably indicate that Shanaab Bay was once a valley of an ancient river.

Texture of Sediments

The areal distributions of pebbles (>2 mm), total sand (2-0.02 · mm) and silt and clay (<0.02 mm) are shown in Fig. 4, 5 & 6 respectively pebbles range between 0.0% and 35.6% with an average of 10.9%. The distribution of pebbles in the eastern segment of the bay is different from the segments. Patches of high pebbles content (>20%) are scattered near the eastern segment shores. Pebbles content decreases gradually from banks and margins towards the center of the basin (except at the eastern end of the bay). In the western, northern and southern segments a gradual decrease of pebbles is observed from the outer parts of each segment towards the common center (Fig. 4). Sand ranges between 2.3% and 94% with an average of 56.0%. The central basin of the southern and eastern segments (except the eastern end of the bay) has low values of sand (>10%). Sand increases gradually towards banks. In the western segment sand increases from south to north while in the eastern segment sand increases from east to west (Fig. 5). Silt and clay range between 0.6% and 96.0% with an average of 33.1%. The distribution of silt and clay is just the reverse of the distribution of sand (Fig. 6).

The first four moments of the size distribution: mean, standard deviation, skewness and kurtosis are shown in Table 1. The mean size vary between 0.259 (=0.140) and 2.720 (=8.073) with an average of 1.386 (=3.605). Small means (2.118-2.723) occur in the central basin of the southern and eastern segments (except at the eastern end of the bay) while high means (0.759-1.763) are found on banks and at the deep parts at the eastern end of the bay. Modern correlation exists between the mean and the depth (r= 0.391). The standard deviation (sorting) varies between 0.772 (= 1.628) and 1.198 (= 3.980) with an average of 0.772 (= 0.561). Using Folk's (1968) nomenclature for sorting, all the samples range from sorted to very poorly sorted. Sorting is independent of depth (r= -0.0097) and mean (r= 0.1849).

The skewness values range between -1.884 and 1.602 with an average of 0.047. All samples from the central basin of the southern and eastern segments (except at the eastern and of the bay) are negatively skewed, while most of the banks sediments are positively skewed. Poor correlation exists between skewness and depth (r= -0.2451) while good correlation exists between slowness and mean (r= -0.8032). The kurtosis values vary between 2.303 and 8.011 with an average of 4.883. Only 4 samples are platykurtic while the rest are leptokurtic. Poor correlation exists between kurtosis and depth (r= 0.2615) and between kurtosis and mean (r= 0.04960).

Composition

Examination of sediments under the binocular microscope showed that the sediments are composed of mollusks, corals, echinoderms, foraminifera, pelecopods, bryozoans, pellest, rock fragments, quartz, feldspars and unidentified particles. Rock fragments, quartz and feldspars decrease gradually from west to east.

DISCUSSION

Only two environments are identified these are (1) the central basin and (2) the banks surrounding it. Bank sediments have large means and are positively skewed while sediments from the basin have small means and are negatively skewed. This indicates that the banks are regions of erosion and the basin is a region of deposition. Waves and currents transport fine particles from the banks and deposit them into the deep basin. Once being deposited, waves and currents become unable to resuspend them from such depths.

Sediments in Shanaab Bay are a mixture of unimodal, bimodal and polymodal distribution (Fig. 7). The mode in the unimodal distribution ranges from coarse sand to silt (Fig. 7a, b, c). The modes in the bimodal distribution range from pebbles and coarse sand to silt and clay (Fig. 7d, e, f, g), while the modes in the polymodal distribution are always of pebble, coarse sand and fine sand (Fig. 7h, i). This is due to the abundance of heterogenous skeletal debris in some areas, abundance of terrigenous material in some areas and a mixture of both in other areas. The absence of a sill at the mouth of the bay enhances exchange between the bay and the Red Sea. This is well documented in the large mean size of the deep samples (sample 2/6/8) from the eastern end of the bay (Fig. 8). Selective winowing by waves and currents transport large size particles from adjacent shores and shelves a distance of about 1.5 km inside the bay.

The poor sorting of sediments of Shanaab Bay suggests that Shanaab Bay is a low energy system. Indeed, the bay is a low energy system due to the protection offered by the high cliffs and coral reefs in addition to the absence of strong tidal currents and fresh water streams. The low energy regime manifests itself in keeping the canal-like structure of the bay for a long time while the corresponding structures on the equatorial coasts of East Africa are widened and their vertical sides are broken into shelving shores by erosion of powerful tidal currents, waves and freshwater streams (Crossland, 1907). As a result of the offered protection the wind-generated waves and currents are unable to better sort sediments from very shallow areas.

The skeletal parts are composed of organisms presently living in the bay and fragments of organisms eroded from shores by waves and currents. Skeletal fragments are also brought from the Red Sea proper into the bay by selective winowing by waves and currents. The skeletal parts of Shanaab Bay sediments are similar to those of the Persian Gulf (Emery, 1956; Kendall and Skipwith, 1969; Shafetz et al., 1988), the Bahamas (IIIing, 1954), the Gulf of Agaba (Friedman, 1968), the Arabian Sea (Mallik, 1976), Sharam Obhur, Red Sea (EI Sabrouti, 1983) and Florida Keys (Ginsburg, 1956).

Wind and seasonal streams play important role in transporting terrigenous material to the bay. During heavy rains, Khor Shanaab discharges considerable amounts of terrigenous material to the western segment of the bay. This results in the high percentage of rock fragments, quartz and feldspars in the western segment. The NW (Huror) wind carry large amounts of sand, silt and clay size particles into the bay during summer months.

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Table 1: Grain-size Parameters of Shahaab Bay Samples

Moment Measures (zeta)

Sample No.	Mean	Standard Deviation	Skewness	Kurtosis
02	0.772	0.769	1.277	5.224
03	1.373	0.597	-0.657	6.341
04	0.827	0.740	0.326	3.631
05	0.680	0.751	0.628	4.023
06	0.549	0.600	0.601	4.945
07	2.640	0.566	-0.316	4.423
08	0.557	0.663	1.521	8.611
09	0.392	0.763	0.770	4.923
10	2.720	0.558	-0.324	4.498
11	0.302	0.734	0.826	4.603
12	2.640	0.470	-0.201	6.309
13	0.259	0.652	0.420	2.856
14	0.843	0.802	0.617	4.435
15	2.560	0.552	-0.323	4.686
16	0.460	0.595	0.723	5.390
17	2.211	1.198	-1.227	3.598
18	2.460	0.631	-1.162	5.982
19	1.092	0.744	0.337	3.978
20	0.512	0.727	0.733	3.912
21	0.904	0.799	0.534	3.293

22	2.206	0.881	-0.811	4.387
23	1.276	0.689	-0.261	4.116
24	2.215	0.951	-1.493	5.317
25	2.118	1.128	-1.540	4.457
26	2.411	0.944	-1.884	6.852
27	0.643	0.610	1.602	8.008
28	1.924	1.121	-0.927	2.303
29	0.662	0.753	0.765	4.402
30	0.530	0.757	1.195	5.422
31	0.560	0.751	0.920	4.766
32	1.674	1.015	-0.766	2.570
33	1.642	1.066	-0.424	2.615
34	0.705	0.847	1.302	5.470
35	1.763	0.687	0.144	5.028
36	2.222	1.190	-1.366	3.709
37	2.378	0.800	-1.809	7.702
38	1.647	0.569	1.279	8.341
39	1.230	0.578	0.464	3.884

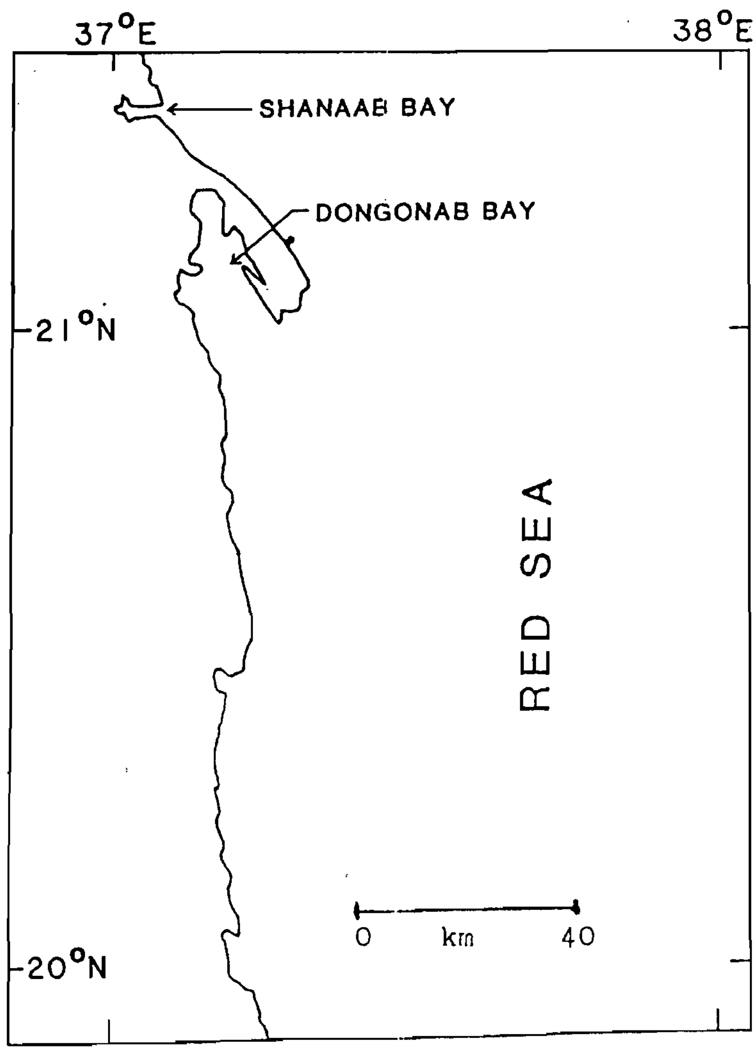

Fig. 1 : Location of Shanaab Bay.

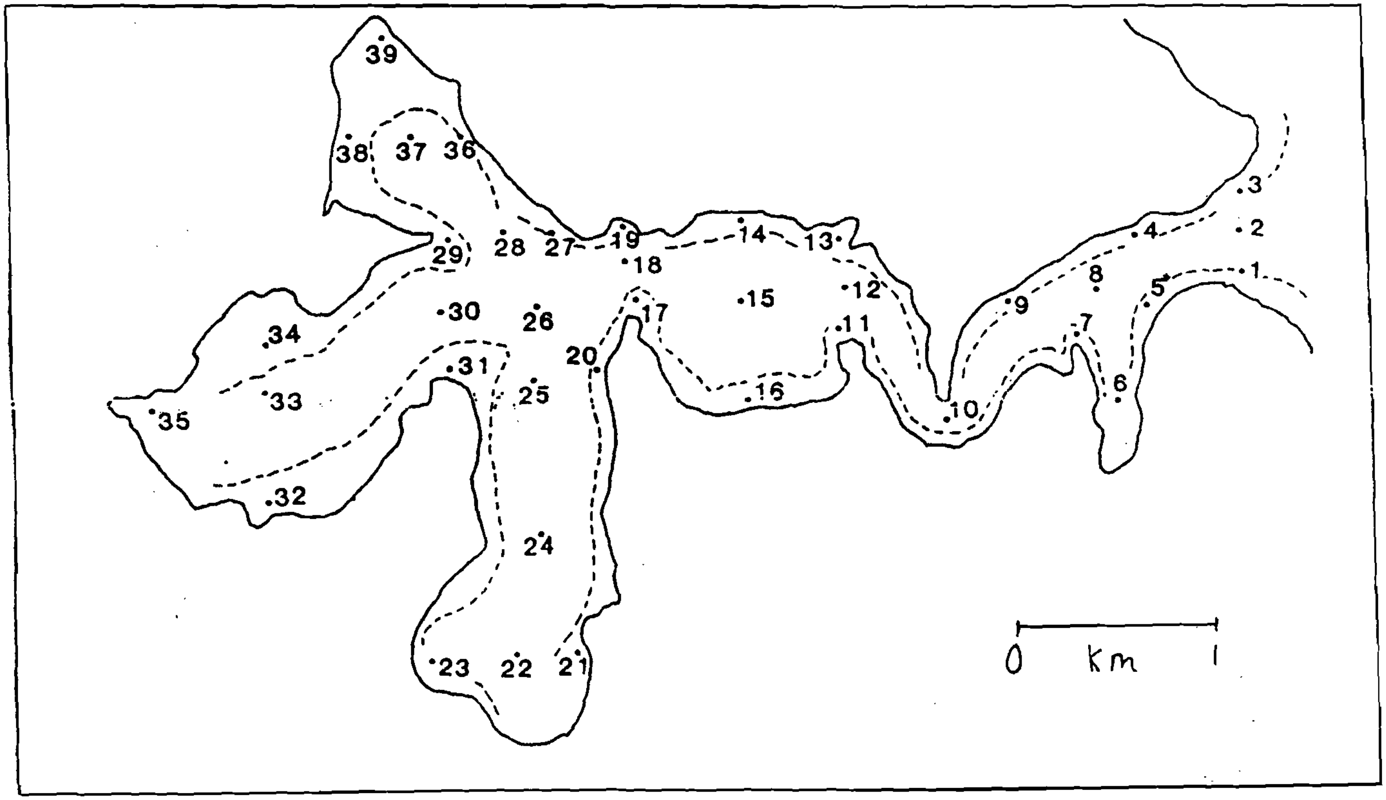

Fig. 2 : Sampling station locations. --- = coral reef.

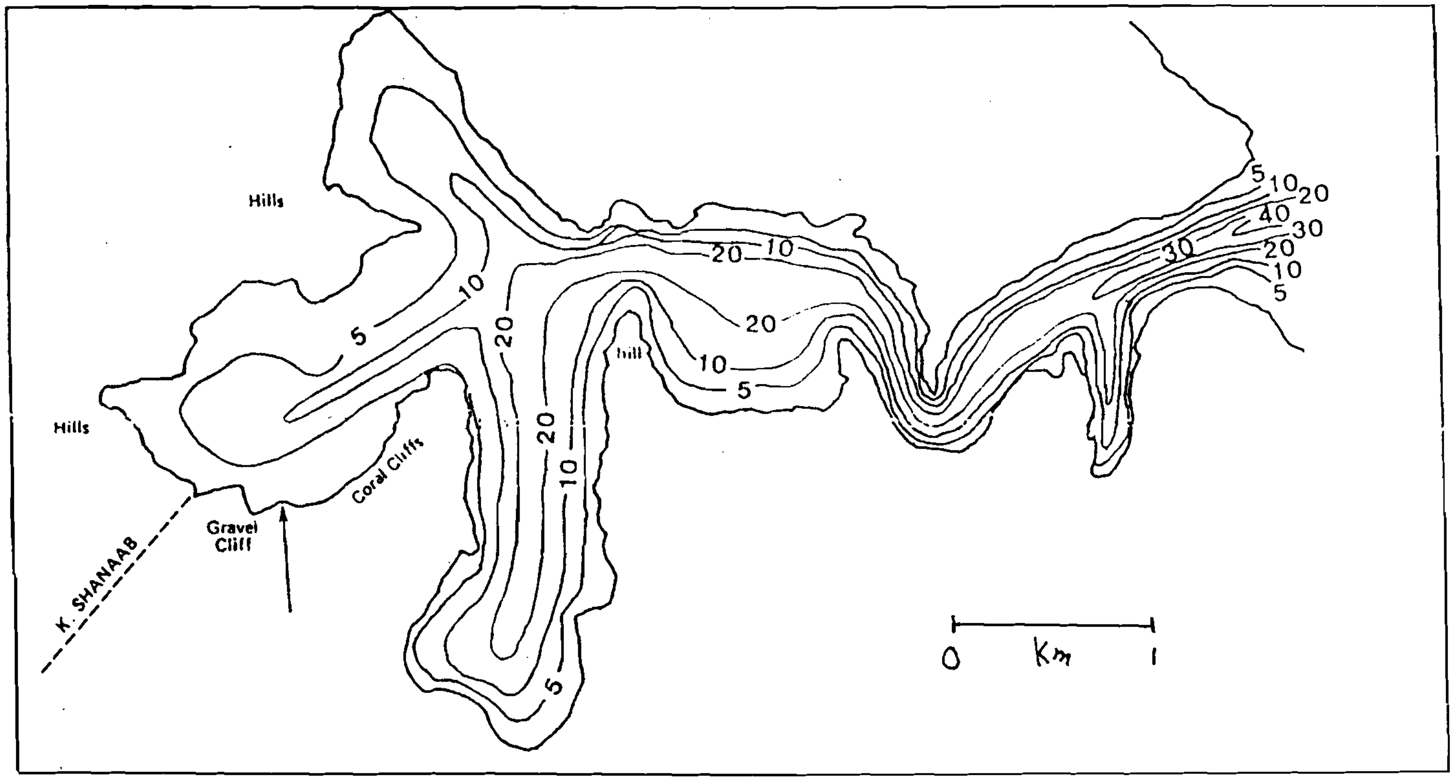

Fig. 3 : A map of Shanaab Bay showing bathymetry (m), coral cliffs, gravel cliffs, K. Shanaab and hills.

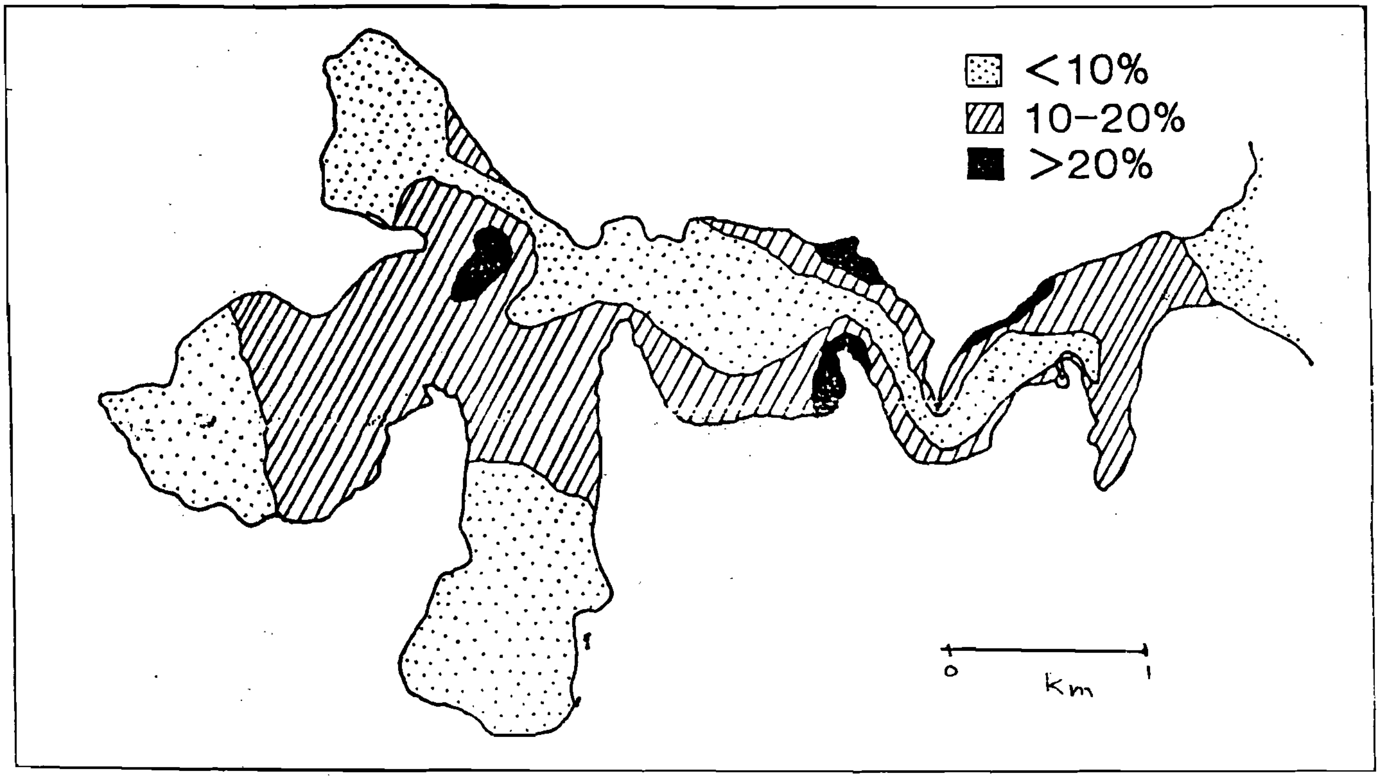

Fig. 4 : Areal distribution of pebbles (>2mm).

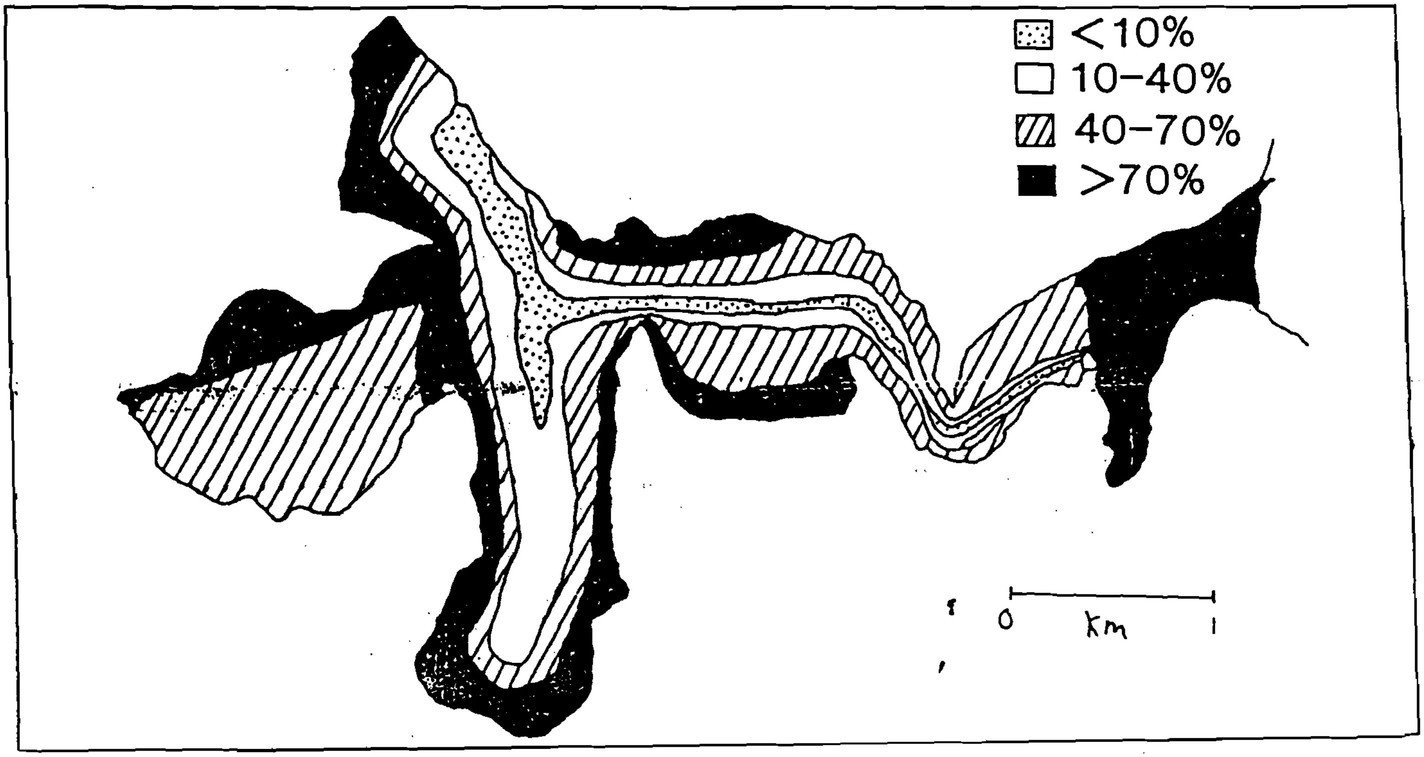

Fig. 5 : Areal distribution of sand (2-0.02mm).

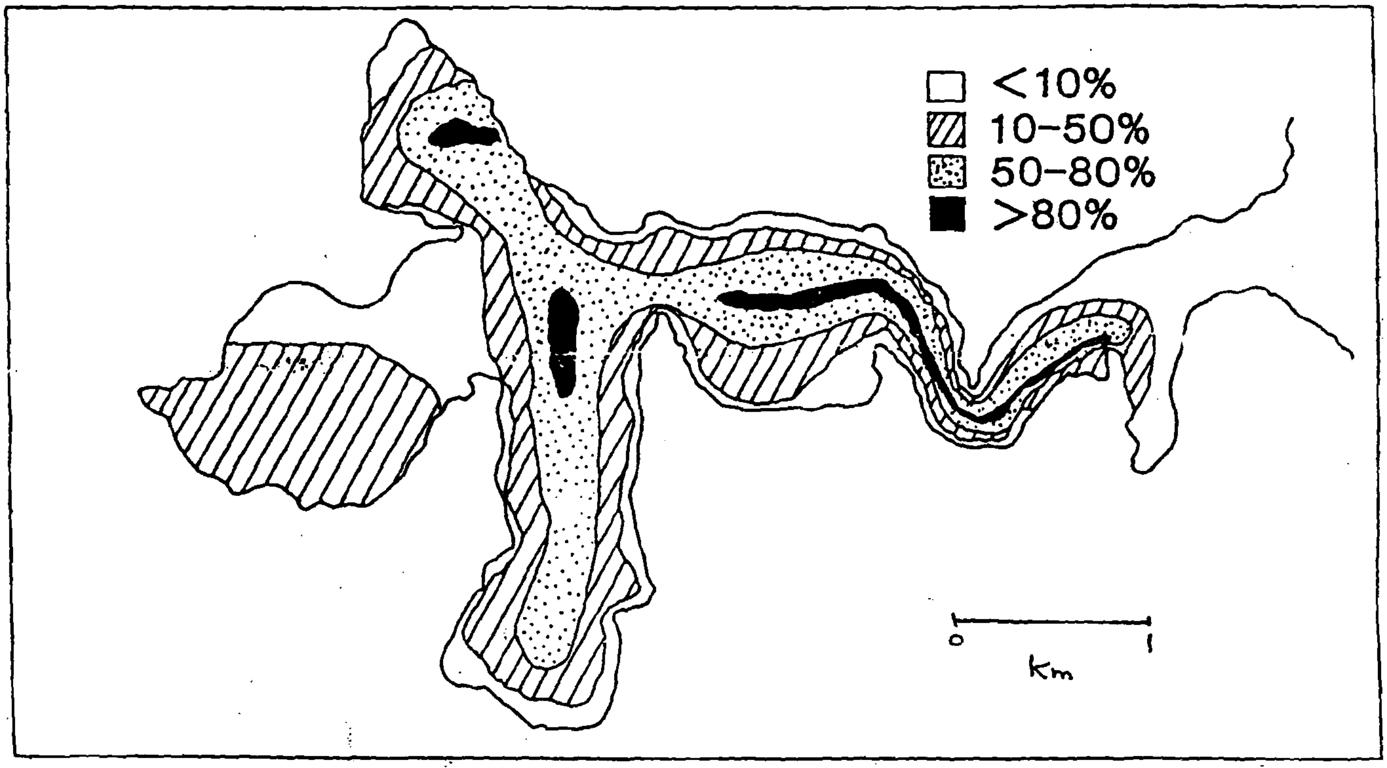

Fig. 6 : Areal distribution of silt & clay (<0.02mm).

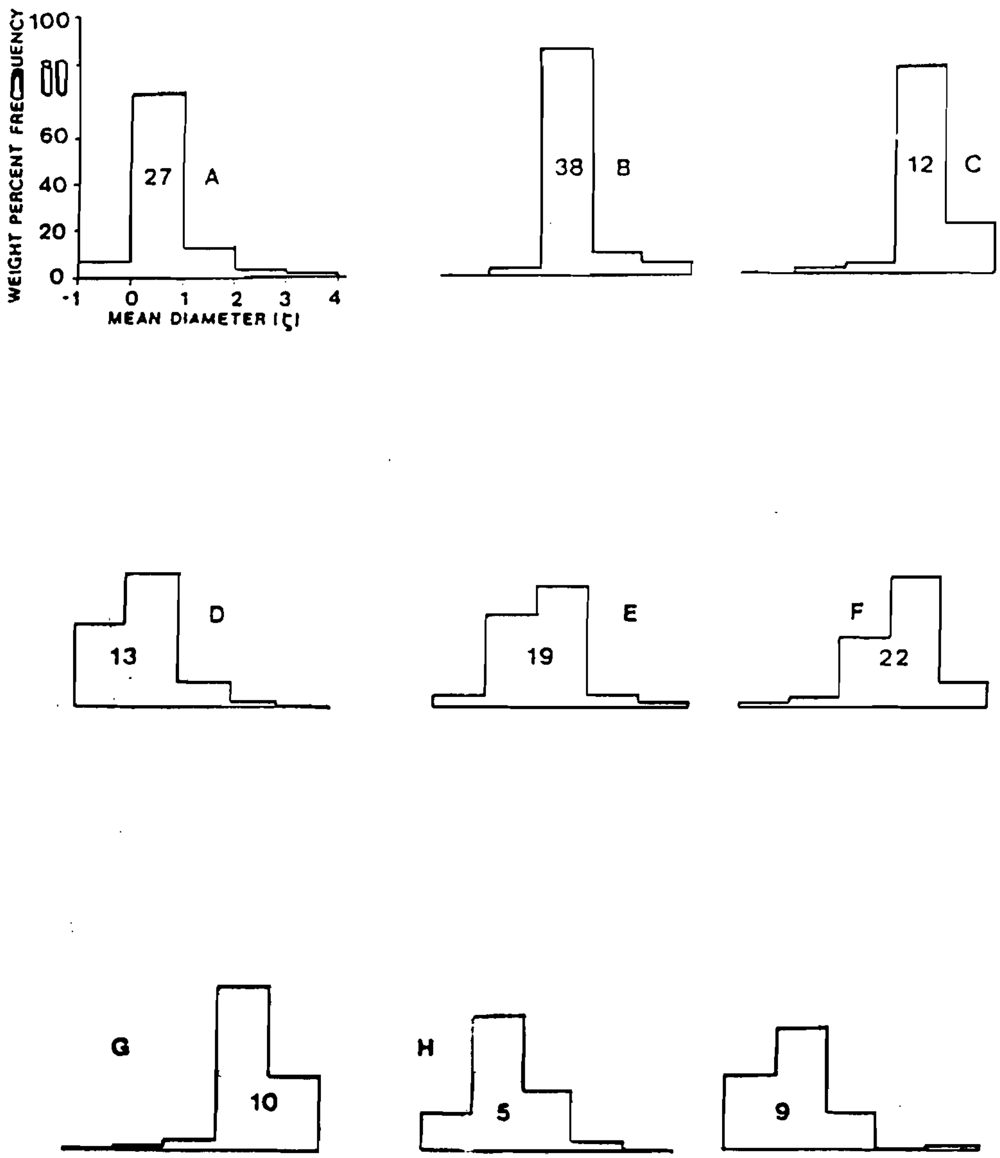

Fig. 7 : Histograms showing representative grain-size variation.

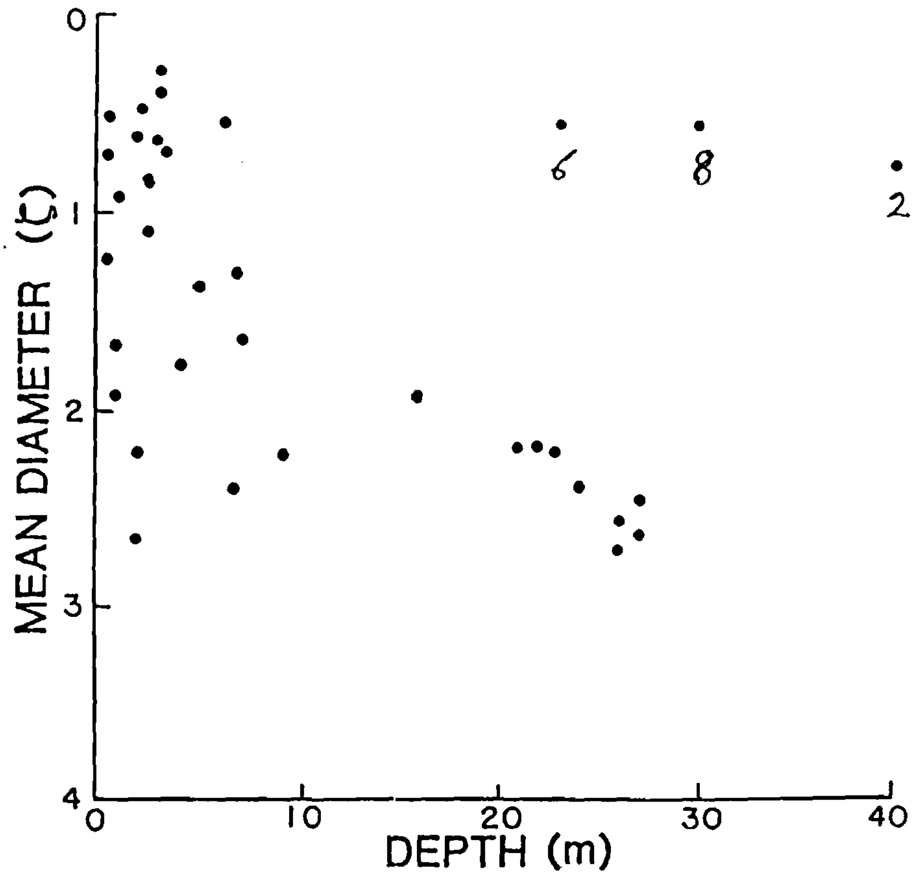

Fig. 8 : Mean diameter versus depth (r = 0.391).