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GEOCHEMISTRY OF THE INNER-SHELF SEDIMENTS IN THE NORTHWESTERN RED SEA, EGYPT.

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ABSTRACT

The inner-shelf of the northwestern Red Sea in between Ras Jemsa at the north and Dishet El-Dabaa embayment at the south is covered with a moderately to poorly sorted sands. The organic carbon content of these sands varies from 1.98% to 0.21% with an average of 0.43%. The least amount of organic carbon is recorded in Dishet El-Dabaa embayment. The total phosphorus content in these sands ranges between 123 and 878 Ug/g with an average of 277 Ug/g. The amount of inorganic phosphorus in sediments is more than three times as much as organic phosphorus in these sediments. Terrestrial inorganic phosphorus is responsible for the total phosphorus in sediments of the inner-shelf of the northwestern Red Sea. Inorganic phosphorus content decreases in sediments northwards. The fine dust of phosphate rock falling to the bottom of the Sea during loading of ships with crude phosphate rock at port of Safaga as well as the waste resulting from processing (sorting and purification) of the phosphate rock nearby Safaga are the main sources of inorganic phosphorus to the bottom sediments in the northwestern inner-shelf of the Red Sea. The total carbonate content varies between 11.0% and 91.0% with an average of 58.1%. The carbonates off Hurgada Marine Biological Station are mainly composed of biogeneous origin, while carbonates at Jemsa Bay and Dishet El-Dabaa are mixed biogeneous and terrestrial in origin.

INTRODUCTION

Sediment samples collected during the Oceanographic survey of three embayments in the northwestern Red Sea area, were analysed for grain size, carbonate and organic matter contents and the different forms of phosphorus content. These embayments include Big Jemsa Bay, small Jemsa embayment, Dishet El-Dabaa embayment and off Hurgada Marine iological Station. They extend along the northwestern coast f the Red Sea for a distance of about 197 km (Fig. 1).

The grain size, organic matter, carbonate contents and phosphorus content of the bottom sediments of the Red Sea have been studied by many authors e.g. Shukri and Higazy,1944; Mohamed,1944; El-Wakeel and El-Sayed, 1978; El-Sayed and Hosny,1980; Beltagy and Moussa, 1984; El-Askary et al., 1986; El-Mamoney 1986; Nawar and El-Deghedy, 1989 and Mohamed, 1979 & 1980. All of these did not study the distribution of the different forms of phosphorus in bottom sediments of the Red Sea

It is therefore, the object of this paper to give a short account on the variation in concentrations of organic and inorganic phosphorus and their relation to the texture, organic matter and total carbonate contents in sediments of the inner-shelf of the northwestern Red Sea.

MATERIALS AND METHODS

Random samples were collected at depths ranging between 0-18 m, during the period 1-5 August, 1988. Six to seven samples were collected from each locality representing different depths of the studied area of inner-shelf of the Red Sea.

A portion of the washed and dried (at 60 - 70°C) samples was sieved using a standard set of sieves to separate it into the different fractions of sand. The residue (less than 62.5 u) was subjected to pipette analysis according to the method proposed by Krumbein and Pettijohn (1958). Standard statistical parameters were computed according to the method of Folk (1974).

The second portion of each sample was pulverized using an agate mortar. The organic matter content was determined by the method of El-Wakeel and Riley (1957), which consists of oxidizing the organic matter in the sample by a known quantity of chromic acid. The total organic matter was obtained by multiplying the organic carbon values by a factor 1.8 which was recommended by Trask (1932). The total carbonate content in sediment samples was determined gasometrically using the calcimeter technique. The inorganic, organic, and total phosphorus contents were determined by the method of Aspila et al. (1976).

RESULTS AND DISCUSSION

Texture :

The Jemsa Bay area includes two depositional environmets, the semiclosed sheltered small Jemsa embayment, and the open Big Jemsa Bay. The latter is subjected to the direct effect of Red Sea waves and currents.

Small Jemsa samples are dominated by medium sands with an average mean grain size of 1.890 ,and the average sorting value is 0.950. They are characterized by a wide range of variation in sorting, from poorly sorted to well sorted deposits, (Table 1).

The Big Jemsa Bay samples vary from medium to silty sand with an average mean grain size of 2.120 corresponding to fine sand. They have about the same average of sorting as Small Jemsa embayment (0.590) indicating that they are moderately sorted. This seems to mean that they receive sediments from one source area.

Hurgada M.B.Stn. samples have approximately the same range of variation in grain size as Big Jemsa Bay, but with lower degree of sorting averaging 1.490 meaning that they are poorly sorted.

Dishet El-Dabaa samples are exclusively characterized by a wide range of variation in grain size from coarse to very fine sand with an average of 2.140. They have also the widest range of sorting from poorly sorted to moderately sorted sands with an average sorting value of 1.040 designating that they are dominantly poorly sorted as Hurgada samples.

The samples of the open areas (Big Jemsa Bay and Dishet El-Dabaa embayment) at less than six meter depth are more sorted than those at greater depths. This sharp contrast or difference in sorting may reflect the difference in physical conditions under which sediments are deposited in the Bay zones.

Statistical correlations of grain size against depth and sorting (Table 2) reveal the following (Fig. 2):

1) At the southern localities(Dishet El-Dabaa and Hurgada M.B.Stn., sorting of sediments decreases with depth.

2) In the relatively sheltered or semiclosed areas (off Hurgada M.B.Stn. and the Small Jemsa embayment) sediments decrease in grain size with depth, that may be attributed to the absence of turbulence in this environment of deposition and the dominance of sediments of biogenic origin.

3) The organic matter, organic and total phosphorus contents increase in sediments by the decrease of their sorting in the sheltered areas. This may be ascribed to the favourable conditions of relatively absent or less turbulence in these sheltered areas, and consequently the higher biological activity and rate of deposition of biogenic material.

Organic Matter Content

In general, the organic carbon in the sediments of the studied area ranges between 0.11 and 1.3% with an average of 0.43% (Table 1).

Samples off Hurgada M.B.Stn. show the highest average and the broadest range of variation in organic carbon content (average 0.60%). El-Sayed and Hosny (1980) attributed the high organic matter content in the shore sediments at Hurgada M.B.Stn. to the discharge of domestic sewage nearby the station.

Dishet El-Dabaa embayment sediments constitute the lowest average and the narrowest range of organic carbon (average 0.27%). This seems to assign the high current speed favourable for oxidation or removal of organic matter from sediments or the over supply of terrigenoue material contributed to the embayment.

In regards to texture-organic matter content relationship, there is a limited degree of systematic variation of organic carbon with the mean grain size (Fig. 3a & Table 2). Organic carbon is highly correlated with sorting of sediments. The less sorted sediments, the higher organic matter(organic carbon) content (Fig. 3b)

The organic carbon of sediments in different parts from the Red Sea has been determined by many workers. Mohamed (1949) stated that the average organic carbon in the Gulf of Suez is 0.39%, and in the Gulf of Aqaba is 0.10%. Beltagy and Moussa (1984) reported that the average of organic carbon in the Gulf of Suez is 0.55%. According to El-Askary et al, (1986) this average is 0.19% for beach sediments of Gubal area. Nawar and El-Deghedy. (1989) found that organic carbon in the nearshore sediments of Mersa El-Aat (Sinai) has an average of 0.15%. From the above data, it is seen that sediments in the inner-shelf of the northwestern Red Sea, excluding Hurgada M.B.Stn., have an intermediate average of organic matter between those in the Gulf of Suez and those in the Gulf of Aqaba.

Organic carbon is highly correlated with organic phosphorus in the sediment samples confirming their biogenic origin (Fig 3c).

Phosphorus Content

The total phosphorus in the inner-shelf samples of the Red Sea ranges from 123-878 Ug/g, with an average of 277 Ug/g. The inorganic phosphorus ranges between 109 and 812 Ug/g with an average of 215 Ug/g. Organic phosphorus ranges from 14 to 145 Ug/g with an average of 61 Ug/g.

Beus (1976) stated that the average phosphorus content in oceanic sediments is 0.14%. According to El-Wakeel and Riley (1861) the average phosphorus in ocean sediments is 0.15% $P_2 O_5$. The amount of total phosphorus in sediments is controlled by many factors from which the principals are: the concentration of dispersion of manganese and iron compounds in the sediment surface, the phosphorus contents of the mineralized source material, the biogenic matter and its chemical redistribution with the sediments. Riley and Skirrow (1965) and El-Wakeel and Riley (1961) reported that a large part of $P_2 O_5$ in biologically derived calcareous deep sea deposits contains an average of two times much as did the argillaceous sediments. They suggest that a large part of $P_2 O_5$ in the former is of biological origin. However, they did not find a correlation between $P_2 O_5$ and the total carbonate content of calcareous sediments.

The total phosphorus content in bottom sediments at Ras Jemsa off northwestern coast of the Red Sea was determined by El-Mamoney (1986) as $P_2 O_5$, it ranges between 0.27 and 1.9% with an average of 72%, and in beach sediments it ranges between 0.36 and 0.96%, with an average of 0.50%. El-Wakeel and El-Sayed, (1978) reported that the phosphorus content in beach sands from Alexandria region varies between 0.007 and 0.06%, and in bottom sediments between 0.08 and 0.18%. The above or previously mentioned results can not be compared with ours because of the different methods of analysis used.

El-Mamoney (1986) found that the total phosphorus content increases in sediments southwards. This finding agrees with our results, where the minimum average of total and inorganic phosphorus is recorded at Small Jemsa embayment and the maximum average is found at Dishet El-Dabaa embayment. An anomaly of exceptionally high total and inorganic phosphorus of 878 and 812 Ug/g respectively are recorded at 5 m depth in Dishet El-Dabaa embayment. This seems to be attributed to the increase of the process of phosphatisation of calcareous deposits at this locality or may be an indicator of outcropping beds of phosphate rock.

Inorganic phosphorus shows the same phenomena of increase in concentration sediments toward the south. It forms about 3/4 of the total phosphorus content. This means that inorganic phosphorus is the main source of phosphorus content in sediments of the studied area. The increase in inorganic and consequently total phosphorus content in sediments toward the south seems to be attributed to: a) the fine dust of phosphate rock falling to the bottom of the Sea during loading of ships with crude phosphate rock at port Safaga (80 km to the south from Hurgada and 50 km to the south from Dishet El-Dabaa) , b) the suspended fine dust of phosphate rock in water resulting from purification and concentration of phosphates and c) phosphate rocks discharged to the sea through wadis draining the excavated upper cretaceous phosphate rocks in the area between Port Safaga and Quseir. Rich phosphate bottom sediments are transported northward, with gradual decrease of their phosphate content.

Organic phosphorus does not show any remarkable variation along the distance between Dishet El-Dabaa and Small Jemsa embayment. In the sheltered areas (Hurgada M.B.Stn. & Small Jemsa embayment) it is slightly higher than in the open areas. This may be due to the high rate of accumulation of sediments on the bottom of the relatively sheltered areas.

Results of statistical correlation of inorganic and consequently total phosphorus with texture of sediments (Table 2) showed that the phosphorus content increases to some extent with the decrease of the sediments grain size (fig.4 a) This property is more valuable in the sheltered areas. The total, inorganic and to some extent the organic phosphorus contents are correlated with depth (fig.4 b, c & d). The increase of phosphorus content in sediments with increase of depth seems to be attributed to the fact that fine grained sediments at these depths are capable of reserving their phosphorus content from leaching, under less turbulent condition.

Figure 4 c, shows that the total phosphorus is highly correlated with inorganic phosphorus, confirming that terrestrial inorganic phosphorus at Port Safaga is responsible for the total phosphorus content in sediments of the inner-shelf zone of the northwestern Red Sea, while phosphatization of calcareous detritals may play a secondary role.

Carbonate Content

The total carbonate content is represented in Table 1. It has a wide range of variation ranging between 11.0 and 9.0% with an average of 58.1%. The Hurgada M.B.Stn. samples are characterized by the narrowest range and the highest percentage of total carbonates (average 75.7%), in comparison with other areas.

The principal sources of carbonates in marine sediments are: a) authigenic resulting from inorganic chemical precipitation, b) residual from weathering of limestone rock on the sea floor, c) terrestrial from erosion of boundary limestone rock and d) biogenic from accumulation of skeletal parts of marine animals and plants. The latter of these is quantitatively the most important source of calcareous sediments at Hurgada M.B.Stn. The greater part of carbonates in other studied areas seems to result from more than one source, i.e. mixed from b,c and d.

Results of correlation coefficient of carbonates with texture, organic carbon, and phosphorus showed that the total carbonates are moderately correlated with sorting, whereas the less sorted sediments constitute the higher content of carbonates (Fig. 5a) Carbonates are not correlated with organic carbon. They are negatively correlated with inorganic and total phosphorus (Fig. 5 b) in the southern half of the area of study (Dishet El-Dabaa and Hurgada M.B.Stn.). Shukri and Higazy, (1944) recorded that organic matter in bottom sediments of the northern Red Sea increases with decrease of carbonates. El-Sayed (1974), Nasr (1978) and El-Mamoney (1986) found no relationship between organic matter and carbonates in bottom sediments of both Alexandria area (Arab's Bay) and at Gubal strait area respectively, which agrees with our results.

CONCLUSION

The inner-shelf sediment samples of the northwestern Red ea (between Jemsa Bay to the north and Dishet El-Dabaa to he south) are dominantly formed of poorly to moderately orted medium sands, whose mean grain size varies between .58 and 3.5 , and sorting ranges between 0.45 and 1.57 . neir grain size and sorting coefficients decrease with ncrease of depth.

The studied area constitutes two zones of deposition differentiated at five meter depth. The upper zone is identified by coarser and more sorted sands, where the winnowing effect of waves and current is effective. Sediment samples of this horizon are characterized by lower percentage of organic matter, carbonate content, and phosphorus content. The deeper zone (more than five meter depth) is distinguished by finer less sorted deposits, that change into more coarser grains at the boundary of coral reefs. They constitute relatively higher percentages of organic matter, carbonates, and phosphorus contents.

The studied inner-shelf area constitutes two different depositional environments. Small Jemsa embayment and to some extent the offshore area of Hurgada Marine Biological station represent the semiclosed or sheltered environment. Dishet El-Dabaa embayment and Big Jemsa Bay give the example of the open depositional environment which is subjected to the direct activity of sea waves and currents.

In general, the northwestern Red Sea inner-shelf sediments are clearly discerned by an intermediate organic natter content in comparison with the Gulf of Suez and the ulf of Aqaba. Their organic carbon content varies between .11 and 1.3% with an average of 0.43%. Sediment samples off irgada M.B. Stn. are identified by distinctive higher rcentage of organic carbon (averaging 0.60%), even at 14 m pth. This is attributed to two factors, the domestic sewage discharged nearby the station, and the high phosphorus content of their sediments. Dishet El-Dabaa embayment sediment samples constitute the least percentages of organic carbon content(average 0.27%) which is attributed to oxidation and leaching of organic matter from sediments by high velocity currents entering the embayment, as well as the over supply of terrigenous detritals. Organic matter in the studied area is not correlated with the total carbonate content.

The organic phosphorus content in the sediments of the studied area ranges from 14 to 145 Ug/g with an average of 61 Ug/g. The inorganic phosphorus content varies between 109 and 812 Ug/g, with an average of 215 Ug/g. The total phosphorus ranges between 123 and 878 Ug/g with an average of 277 Ug/g. Inorganic phosphorus constitutes about three quarters(3/4)of the total phosphorus content. This implicates the dominantly terrigenous origin of phosphorus in sediments of the studied area. The inorganic and consequently the total phosphorus contents increase in sediments southwards, confirming that phosphorus is supplied to the area of study from the south. The upper cretaceous phosphate rock excavated in the area between Port Safaga and Quseir(80 km to the south from Dishet El-Dabaa) is the main source of phosphate rock in area of study. Organic phosphorus is highly correlated with organic carbon content.

The sheltered parts of the studied area(Small Jemsa embayment and Ghardaqa M.B.Stn.) are characterized by relatively higher organic phosphorus content, which is assigned to the higher rate of biological activity, and accumulation of sediments under less turbulent conditions.

The carbonate content in sediments of the Red Sea inner-shelf samples varies from 11.0 to 91.0% with an average of 58.1%. Samples off Hurgada M.B. Stn. constitute the maximum average of carbonates. They are principally of biogenic origin. Sediments of Dishet El-Dabaa and Jemsa Bay as whole constitute a mixed residual, terrestrial and biologically derived deposits. Carbonates are moderately negatively correlated with inorganic and total phosphorus in the southern part of the area of study(Dishet El-Dabaa and off Hurgada M.B.Stn, indicating the probable phosphatization of calcareous detritals in these areas.

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TABLE 1

Results of analysis of texture, organic matter, phosphorus and totalccarbonatecontents in sediments samples from the inner-shelf of the north western RED SEA.

Sample No.	Depth m	Texture	Mean M_z	Sorting σ_I	Skewness S_k	Kurtosis K_G
1	14	Silty sand	2.48	1.57	0.08	1.16
2	8	Silty sand	2.88	1.46	-0.29	0.97
3	7.5	Fine sand	2.00	1.50	0.03	2.13
4	5	Medium sand	1.18	1.50	-0.10	0.91
5	6	Medium sand	1.01	1.42	-0.00	0.89
Mean of		(Hurgada M.B.St.)	1.91	1.49	-0.06	1.20
6	0.5	Coarse sand	0.58	0.74	-0.14	1.29
7	10	Fine "	2.03	1.23	-0.38	0.66
8	18	Silty "	2.36	1.19	0.61	1.06
9	5	Medium "	1.26	1.36	-0.05	1.02
10	6	Very fine "	3.02	0.77	-0.33	1.33
11	5	" " "	3.20	0.72	-0.23	1.26
12	9	Silty "	2.50	1.26	-0.35	1.11
Mean of	(Dishat El-Dabaa)		2.14	1.04	-0.12	1.10
13	0.5	Fine sand	2.24	1.17	-0.28	1.15
14	10	Medium "	1.67	1.18	0.25	0.85
15	15	Fine "	2.41	0.56	-0.25	1.89
16	0.5	Medium "	1.80	0.76	0.09	1.12
17	9	Silty "	2.90	1.46	-0.32	0.96
18	12	Medium "	1.35	1.24	0.03	0.99
19	6	Fine "	2.49	0.45	-0.05	1.27
Mean of	(Big Jemsa Bay)		2.12	0.79	-0.02	1.18
20	10	Medium sand	1.61	0.92	0.07	1.25
21	Beach	Medium "	1.28	0.38	-0.06	1.23
22	14	Silty "	3.18	1.28	-0.24	1.24
23	0.5	Medium "	1.79	1.28	-0.13	1.51
24	0.5	Medium "	1.28	0.89	0.14	1.45
25	0.5	Medium "	1.66	0.96	0.12	1.13
Mean of	(Small Jemsa embayment)		1.89	0.95	-0.02	1.31

Sample No.	Organic carbon%	Organic matter%	Inorganic	Phosphours Organic	Total Ug/g	Tot car
1	1.3	2.35	282	145	427	68
2	0.49	0.88	346	19	383	43
3	0.47	0.85	218	72	290	91
4	0.38	0.61	127	60	187	84
5	0.36	0.65	176	39	215	90
	0.60	1.07	233	67	300	75
6	0.18	0.23	115	65	180	35
7	0.29	0.52	218	54	272	64
8	0.41	0.73	184	69	253	80
9	0.46	0.82	141	85	226	86
10	0.25	0.46	211	59	270	74
11	0.16	0.29	812	66	878	17
12	0.13	0.24	322	22	344	38
	0.27	0.47	286	60	346	56
13	0.38	0.69	137	34	171	78
14	0.29	0.53	265	42	307	83
15	0.14	0.24	129	27	156	11
16	0.45	0.81	137	49	186	55
17	0.60	1.07	187	63	250	59
18	0.34	0.62	216	69	285	88
19	1.10	1.98	246	128	374	32
	0.47	0.85	188	59	247	58
20	0.32	0.57	136	87	223	81
21	0.11	0.21	109	14	123	5
22	0.94	1.69	216	109	325	59
23	0.39	0.70	159	69	228	49
24	0.30	0.57	150	17	167	27
25	0.41	0.78	124	50	174	47
	0.42	0.75	157	66	233	52

Table(2)

Correlation matrices of textural parameters, organic matter, phosphorus, and carbonate contents in:
A) The inner-shelf of the northwestern Red Sea,
B) Small Jemsa embayment, C) Big Jemsa Bay,
D) Hurgada M.B.Stn., and E) Dishet El-Dabaa embayment.
D= Depth, M_z= Mean grain size, σ_I=Sorting, OC=Organic matter content %, IPH=Inorganic phosphorus, OPH=Organic phosphorus, and TPH=Total carbonate content.

A

	D	M_z	σ_I	OC	IPh	OPh	TPh	TC
M_z								
σ_I								
OC								
IPh		0.5489						
OPh				0.8021				
TPh		0.5638			0.9749			
TC			0.6842					

B

	D	M_z	σ_I	OC	IPh	Ph	TPh	TC
M_z	0.7428							
σ_I		0.6869						
OC	0.7469	0.9754	0.7531					
IPh	0.6983	0.9651	0.7811	0.9251				
OPh	0.8505	0.7009	0.7473	0.7871	0.7127			
TPh	0.8382	0.8986	0.8245	0.9232	0.9246	0.9261		
TC	0.6915		0.6563			0.8547	0.6832	

C

	D	M_z	σ_I	OC	IPh	OPh	TPh	TC
M_z								
OPh				0.9275	0.5832			
TPh				0.6954	0.9324	0.8373		
TC	-0.5789	0.7930						

D

	D	M_z	σ_I	OC	IPh	OPh	TPh	TC
M_z	0.6991							
σ_I	0.7491							
OC	0.9747	0.5139	0.8247					
IPh	0.5647	0.9428						
OPh	0.8043		0.8984	0.8878				
TPh	0.8700	0.9259	0.5359	0.7696	0.8863			
TC		-0.8250			-0.8829		-0.7186	

E

	D	M_z	σ_I	OC	IPh	OPh	TPh	TC
σ_I	0.5252							
OC			0.5725					
IPh		0.6503						
OPh				0.6879				
TPh		0.6279			0.9968			
TC			0.5630	0.8776	-0.6909	-0.6627		

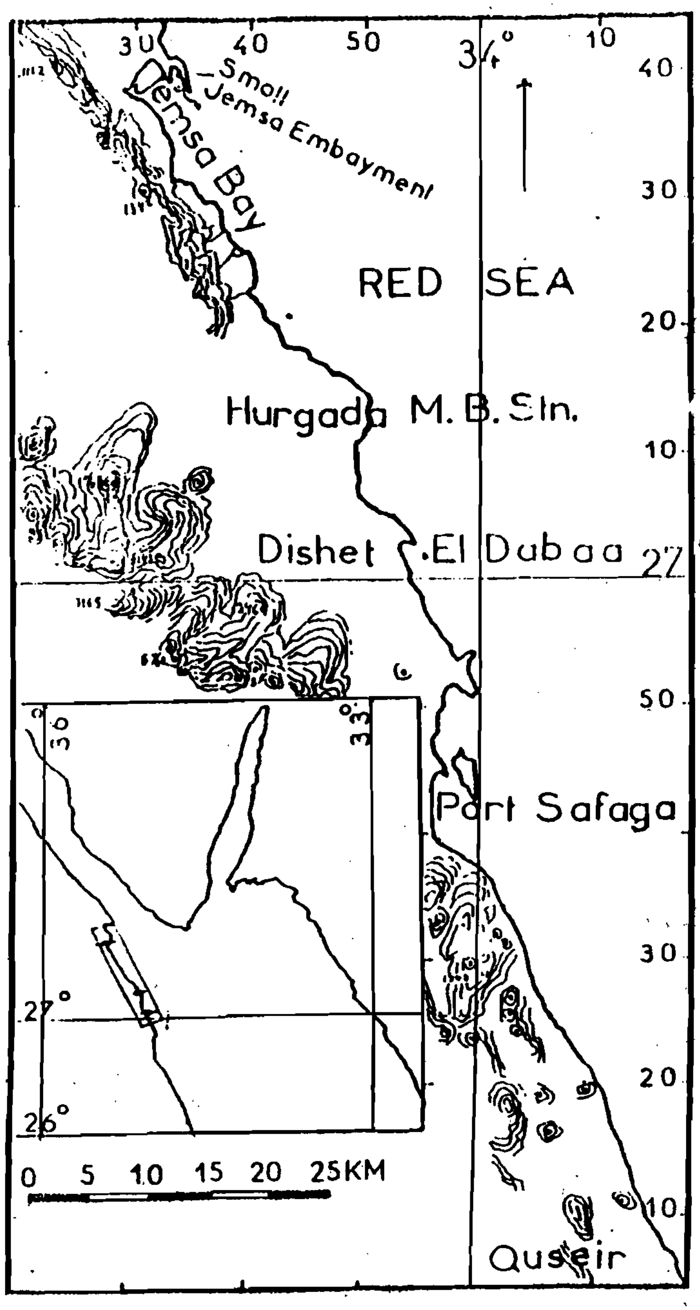

FIG. 1- Location map of the studied ares in the northwestern Red Sea.

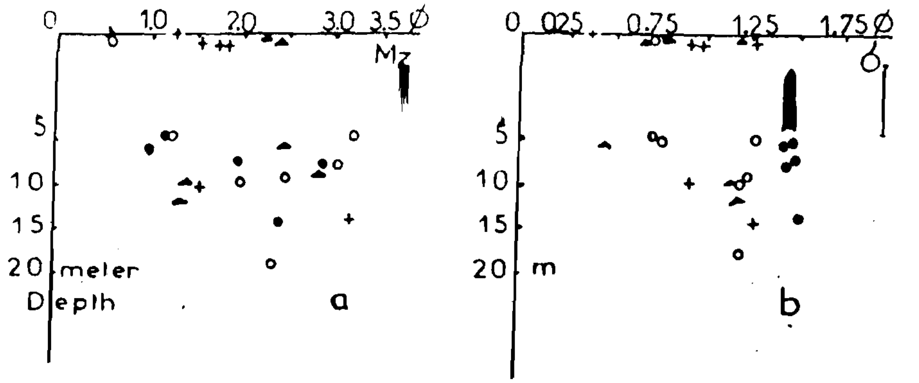

FIG.2- Variation of the mean grain size & sorting of the north-western Red Sea inner-shelf sediments with depth.

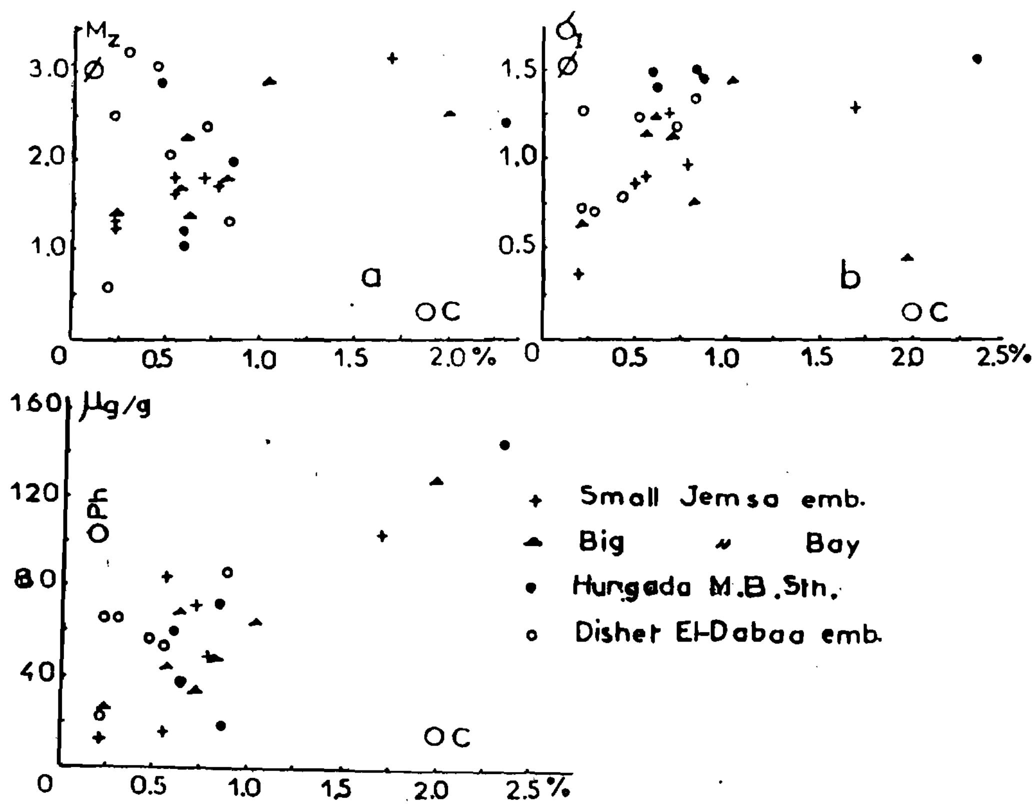

FIG.3 Variation of organic carbon (OC)with:a)mean grain size, b)sorting of sediments,c)organic phosphorus (Ph).

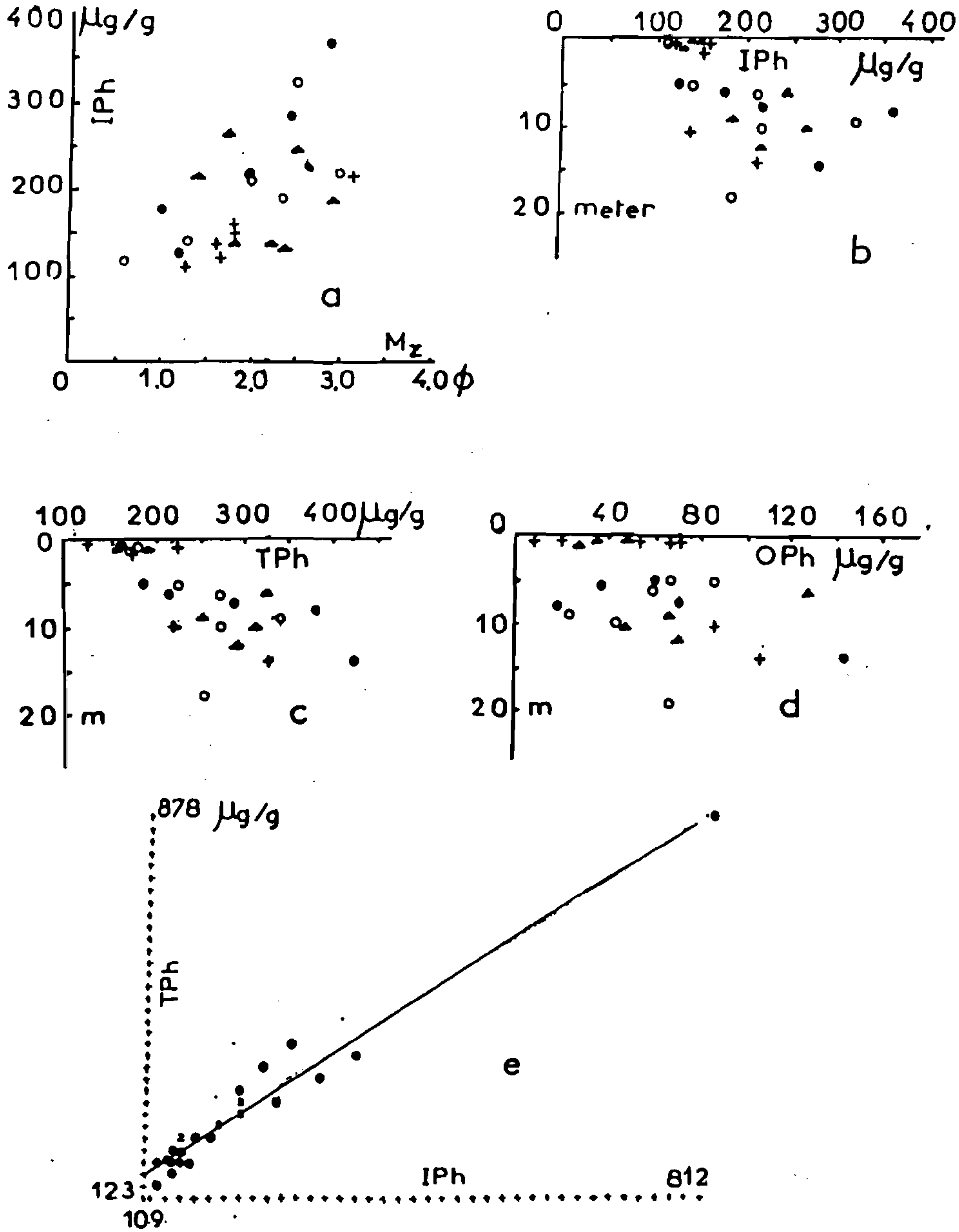

FIG.4-Relationship between a)Inorganicpphosphorus(IPh)and mean grain size(M_z),b),c)&d) Depth and the different forms of phosphorus,e) Inorganic and total phosphorus(TPh), in sediment samples from the northwestern Red Sea inner-shelf.

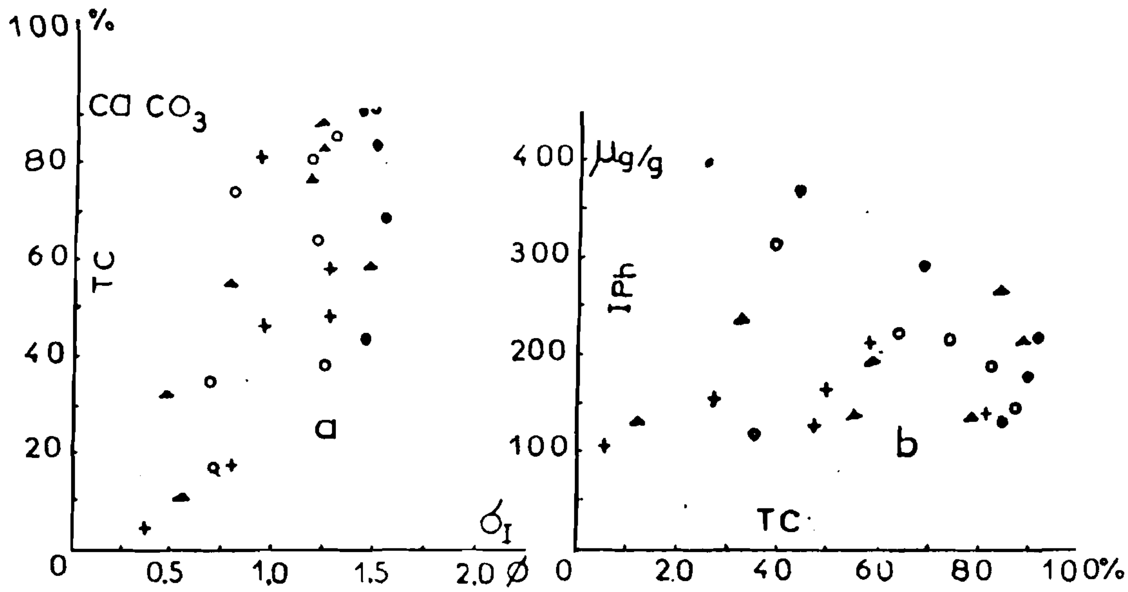

FIG.5- Relationship between the total carbonates(TC)and a)sorting,b)inorganic phosphorus,in sediment samples from the northwestern Red Sea inner-shelf.