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GEOCHEMICAL APPROACH TO THE BEACH AND BOTTOM SEDIMENTS OF THE JUBAL AREA AT THE ENTRANCE OF THE GULF OF SUEZ, RED SEA.

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ABSTRACT

Geochemical investigation of the beach and bottom sediments of the Strait of Jubal area is given.

The sediments under investigation were chemically analyzed for their contents of carbonates, CaO, MgO, organic carbon, organic nitrogen, SiO_2, P_2O_5 and alkalies (Na&K). Factors controlling the accumulation of these sediments include: (a) Material supply of biogenic and terrigenous components for the bottom and beach sediments, respectively, (b) Hydrodynamic regime of the basin under investigation, and (c) Rate of oxidation of the organic matter in the bottom sediments.

INTRODUCTION

The Red Sea is unique among the seas of the world in the fact that no permanent streams or rivers flow into it. Biogenic activity might be regarded as the major source for its bottom sediments. Winds and rain-torrents are regarded as secondary sources for supplying the sea by terrestrial materials. The Red Sea occupies a large graben between the Arabian Peninsula and northeast of Africa. Physiographically, it consists of the main trough (over 550 m deep) which is best developed in the southern and central parts of the sea. At its northern end, it bifurcates into the Gulfs of Suez and Aqaba. The floor of the former is smooth and shallow (60-80 m deep) while it is irregular and deeper (over 1700 m deep) in the latter.

Considerable number of investigators have been interested in studying the various characteristics of the Red Sea sediments, among them: Crossland (1939), Milliman et al. (1969), Mohamed (1979 and 1980), El-Sayed and Hosny (1980) and Vincent de Vaugelas and Naim (1980).

The area under investigation, the Strait of Jubal and vicinity is the entrance to the Gulf of Suez and is lying between longitudes 33° 35' and 33° 55' E and latitudes 27° 10' and 28° N (Fig. 1). The Shadwan Island marks its eastern boundary, while in the south it is bordered by the Gaftun Islands. Since the Strait of Jubal is the entrance to the Gulf of Suez, it represents the transition from the wide and deep Red Sea proper to the narrow and shallow Gulf of Suez. The water body in this area is interrupted by some islands and many patches of coral reefs.

The aim of this study is to give the general features of the bottom topography, as well as the geochemical characteristics of the bottom and beach sediments of the Jubal area. The grain size and mineralogical characteristics of the beach and bottom sediments of the same area will be published elsewhere by the same authors.

SAMPLING AND ANALYTICAL TECHNIQUE

SAMPLING :

Thirty eight bottom samples were collected using Peterson grab sampler from the area under investigation. In the same time, data necessary for bathymetric study was obtained. Fourteen beach samples were collected from seven stations (every 6 Km); where supratidal and intratidal sediment samples were obtained from each station (Fig. 1).

CHEMICAL ANALYSIS :

The carbonate content was estimated using the calcimeter technique. The versenate method of Riley (1958) was adopted for the determination of calcium and magnesium as oxides. Organic carbon was determined as described by Allison (1935) and total organic matter was estimated by multiplying the organic carbon percentage by 1.8 (Trask, 1939). Organic nitrogen was determined using the microkjeldal technique described by Niederl and Niederl (1942). Total iron was determined as a ferrous oxide using the spectrophotometer at wavelength 510 nm. Phosphorus pentaoxide and silica were determined spectrophotometrically following the molybdenum blue method. Sodium and potassium were determined using an Atomic Absorption Spectrophotometer, Varian Tectron, model 1250 Automatic (Vigler et al., 1980).

RESULTS AND DISCUSSION

BATHYMETRY :

The bottom topography of the area under study is so complicated (Fig. 2). The bottom irregularity at the entrance of the Gulf of Suez is relatively lesser than that of the areas surrounding islands and reefs. Figure 3A is an E-W profile showing the bottom topography at the entrance of the Gulf. It shows that the western slope is less steeper than the eastern one and is interrupted by a series of coral reefs. Two other profiles have been made to the west of Shadwan and Jubal Sagheir islands (Fig. 3 B & C). They show that the bottom topography in these regions is complicated with very acute relief. The islands of Ranim, Um el Heimat, Tawila, Gaysum, Jubal and Shadwan which are considered as extensions of the basement ridges together with the haphazard distribution of reefal patches, contribute in disturbing the flatness of the bottom under consideration. In addition, the nature of the structural building of the Red Sea coast which is attributed to faulting, exaggerates the sharp slopes of the insular

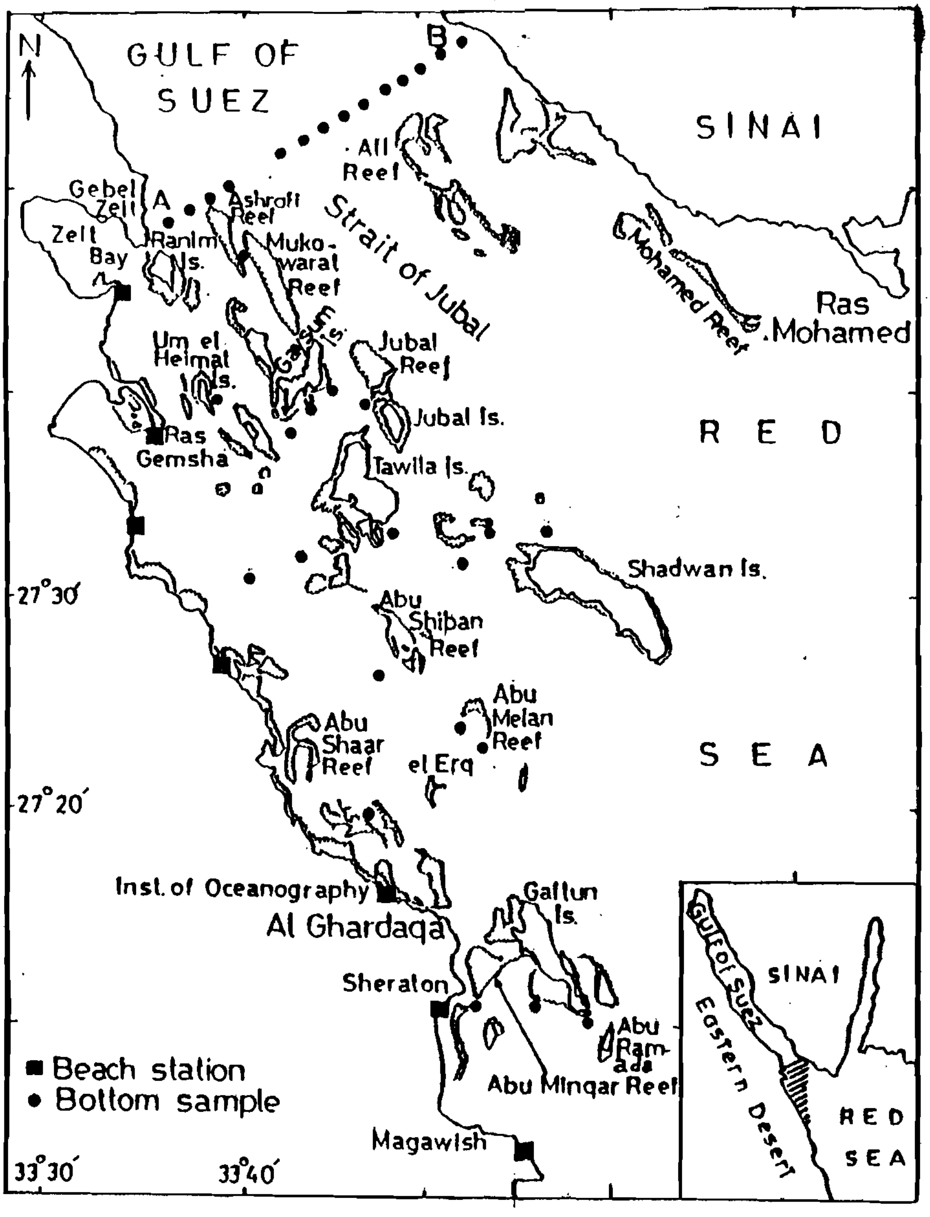

Fig. 1. The area of study and sample locations.

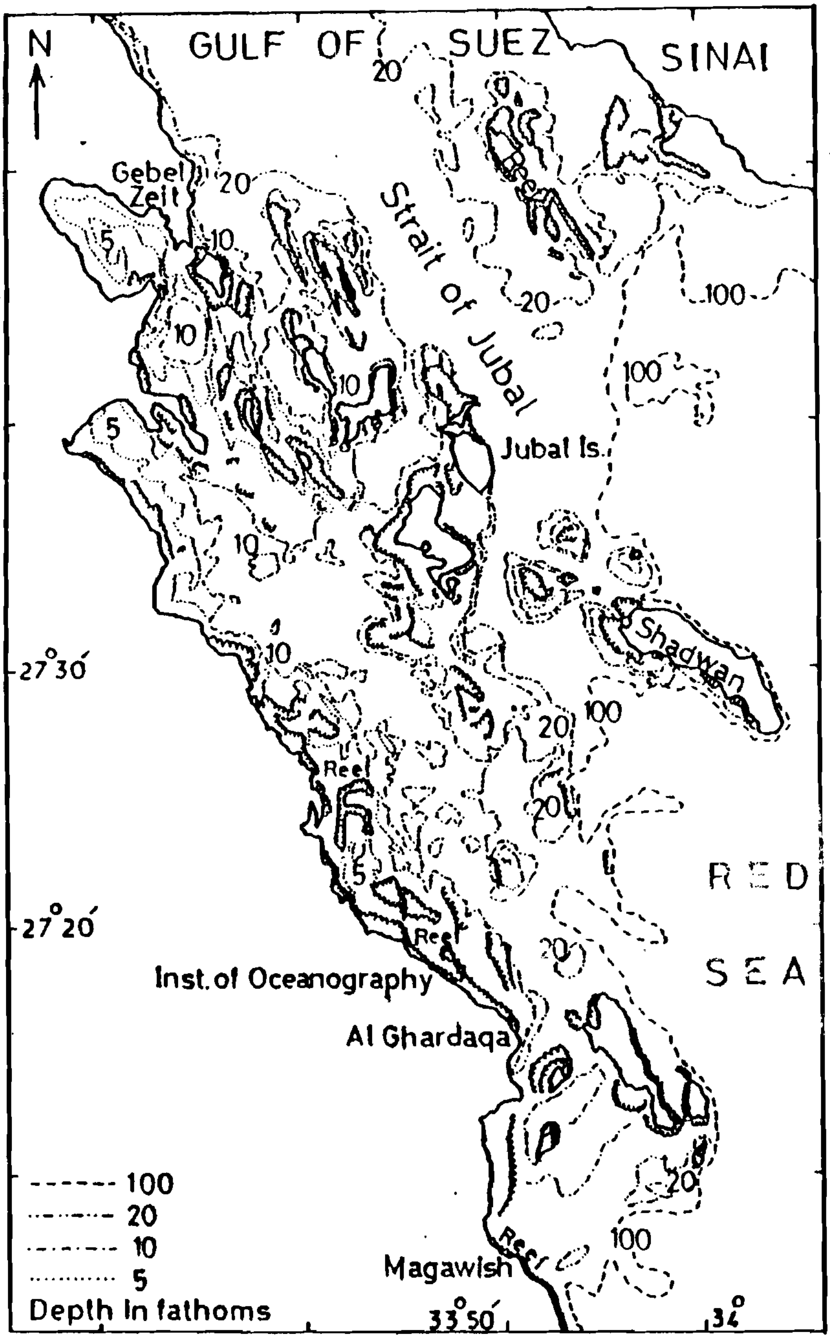

Fig. 2. Bathymetry of Strait of Jubal and Vicinity.

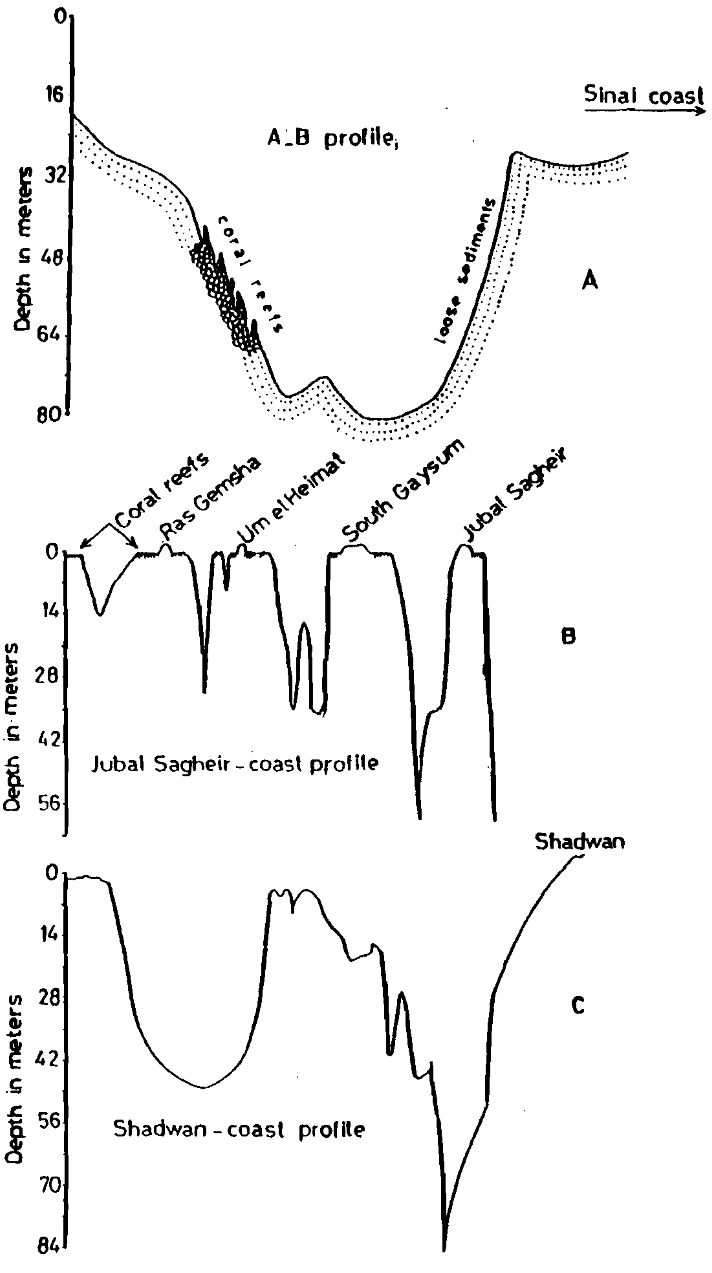

Fig. 3. Bathymetric bottom profiles in the studied area.

and reefal roots. The coral reef patches are present in two forms; one is attached either to the mainland or to the insular roots and forms a circular shape (fringing), while the other is independent reef and surrounded by water.

CHEMISTRY OF SEDIMENTS

In order to get sufficient information about the environment to evaluate the role of the chemical sedimentary processes acting therein, the following chemical parameters will be discussed:

CARBONATES :

The carbonate content in the bottom sediments shows a more or less uniformal distribution but sometimes is interrupted by silicate contribution from the beach and islands to the nearby sediments. In general, the sediments are carbonate-rich having carbonate content ranging between 41.31 and 96.61 % with an average of 84.62 %. Due to the high rate of carbonate production, the distribution of carbonate is a function of the hydrodynamic regime and the magnitude of physical energy which might affect the degree of breakdown of skeletal materials and their subsequent redistribution. The carbonate content in the beach sands is significantly decreased relative to the bottom sediments. It ranges from 4.65 to 29.92 % with an average of 19.29 % indicating the over supply of terrigenous materials. The distribution of the type of carbonate either calcium or magnesium varies according to the biological communities incorporated in the sediments and the amount of disintegrated particles from the magnesium calcite cement. The calcium oxide in the bottom sediments varies between 19.93 and 50.83 % with an average of 44.64 %, while the magnesium oxide varies between 1.46 and 4.36 % with an average of 2.54 %. These data give an average Ca/Mg ratio in the bottom sediments of 16.69. In the beach sediments, the calcium oxide varies between 2.38 and 13.95 % with an average of 8.68 %, while the magnesium oxide ranges from 0.69 to 3.11 % averaging 1.92 % and the Ca/Mg ratio is 4.05. Correlation study showed that there is a slight tendency for increasing magnesium oxide as the calcium oxide increases in both the beach and bottom sediments (Fig. 4 & Table 1). This relationship has been also detected by El-Sayed (1984) in the reefal sediments of Al-Ghardaqa. On the other hand, Anwar et al. (1984) pointed out to the slight tendency for increasing calcium oxide as the magnesium oxide decreases in the oolitic carbonate sediments of the Arab's Bay, West of Alexandria.

Organic Matter

Organic matter, whether living or detritic, is generally composed of light-weight materials. Sedimentation of these materials follows same laws as those of fine particles, both accumulate in calm zones. Therefore, there is a close connection between the presence of fine sediments and their content of organic matter. Accumulation of organic matter in sediments is affected by the size of the basin, the width of the continental platform, the bottom rlief, and other morphological features. Physical (temperature, light, oxygen,...) and biological characteristics (variety of ecology, competition among species, reproduction) are critical factors in the establishment and maintenance of the species inhabiting a sediment

TABLE 1.

Correlation coefficient matrix of results of the chemical analysis.

	O.M.	T.C.	SiO_2	I.O.	CaO	MgO	P_2O_5	Na	K
O.M.	1.00								
T.C.	0.45	1.00							
SiO_2	-0.48	-0.89	1.00						
I.O.	-0.35	-0.61	0.62	1.00					
CaO	0.44	0.98	-0.86	-0.59	1.00				
MgO	0.18	0.41	-0.39	-0.18	0.46	1.00			
P_2O_5	-0.02	0.19	-0.18	0.42	0.22	0.12	1.00		
Na	-0.38	-0.79	0.72	0.26	-0.74	-0.22	-0.02	1.00	
K	-0.39	-0.76	0.92	0.47	-0.71	-0.19	-0.18	0.71	1.00

(O.M. = Organic matter, T.C. = Total carbonate and I.O. = Iron oxide)

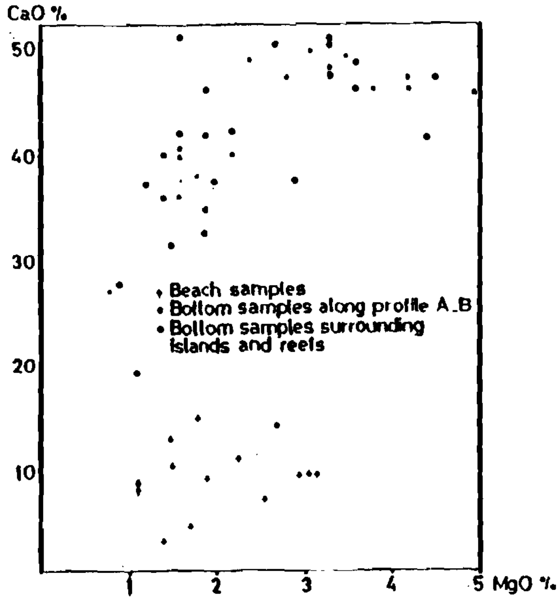

Fig. 4. Relation between calcium and magnesium oxides.

(Boucher, 1979). The results of the organic matter analysis showed that the organic carbon content of the bottom sediments varies between 0.2 and 1.1 % with an average of 0.4 % and the organic nitrogen varies between 0.019 and 0.075 % with an average of 0.041 %. Similarly, the beach sediments contain from 0.06 to 0.57 % organic carbon and from 0.005 to 0.026 % organic nitrogen with an average values of 0.19 and 0.014, respectively. The variation in the organic matter content of the bottom sediments is primarily due to local hydrodynamic influence which transport and scatter particulate organic materials brought from inside the Gulf of Suez. From the other side the variation in the organic matter content of the beach sediments is mostly due to local contamination by hydrocarbons, i.e., tar balls thrown out to the beach by waves.

The average C/N ratio of the beach sediments is 11.11 with variation from 3.33 to 26.0. These high ratios and wide variation are attributed to the contribution of carbon offered by tar balls in some sample stations. The low C/N ratio at some beach localities refers to the predominance of faunal remains over plant remains as well as the absence of oil hydrocarbons . The C/N ratio of the bottom sediments ranges from 3.19 to 16.55 with an average of 10.37. In contrast with the previous determinations of C/N ratio for the same area of study, the C/N ratio of the present study is found double. This can be attributed to the use of different analytical methods and to the recent effect of oil pollution. The calculated averages of both Shukri and Higazy (1944) and Mohamed (1949) are 4.48 and 4.26, respectively. Mohamed (1949) considered his C/N ratio lesser than the counterpart ratios for sediments from other oceanic regions. He determined the C/N ratio for the different regions of the Red Sea, the average being: the Gulf of Suez 7.7, the southern approaches of the Gulf of Suez 4.3, the Gulf of Aqaba 4.0, the southern approaches of the Gulf of Aqaba 3.6, and the Red Sea proper 5.6. Mohamed (1949) attributed the regional differences of the C/N ratio to the different conditions influencing the chemical make up of organic matter deposited in each region. Figure 5A shows that nitrogen slightly increases with increasing of carbon (correlation coefficient is 0.57).

Trask (1932 and 1939) mentioned that the organic matter content of sediments increases more or less progressively as the constituent grains become finer. This concept coincides with the result of some of the present samples containing relatively more fine particles and slightly agrees with the majority of samples lacking the fine fraction in their sediment composition (Fig. 5B).

It is evident that the organic matter content in the area under study shows no relationship with the corresponding depth, except in deep areas (more than 40 m), where conditions (calm and non-oxidative medium and abundance of fines) permit a considerable accumulation of organic matter (Fig. 5C). Shukri and Higazy (1944) stated that organic matter contents of bottom deposits from the northern Red Sea remain more or less constant at different depths, except at depths of about 100 m where an increase in organic matter contents was apparent. They also found that the organic matter accumulates more in basins than on slopes and ridges. El-Sayed (1974) and Anwar et al. (1984) found that organic matter contents increase with depth along the western Egyptian continental shelf of the Mediterranean Sea. They attributed this phenomenon to removal of organic matter from the nearshore zone by high turbulance caused by the prevailing waves and associated rip and longshore currents especially during stormy conditions.

Very weak relation is detected between the organic matter and the carbonate content of the bottom sediments (correlation coefficient is 0.40), while the beach sediments show a kind of proportional relation among them (correlation coefficient is 0.77) (Fig. 5D). Shukri and Higazy (1944) observed that the organic matter contents of bottom deposits from the northern Red Sea increase with the decrease of carbonate content. El-Sayed (1974) recorded no relationship between the organic matter and carbonate contents in the bottom sediments off Alexandria. Anwar et al. (1984) also detected no relation between these two constituents in sediments of the Arab's Bay, west of Alexandria.

Generally, the areal distribution of the organic matter shows an increase in the central part and a decrease in both the outside parts of the area under investigation (Fig. 6). The distribution of the organic matter in the sediments is dependent upon : (a) The organic material supply which is either particulate transported from the Gulf of Suez or oil materials thrown out to the beach by waves, (b) The temperature and aeration of sediments (rate of oxidation of the organic matter), and (c) The hydrodynamic regime.

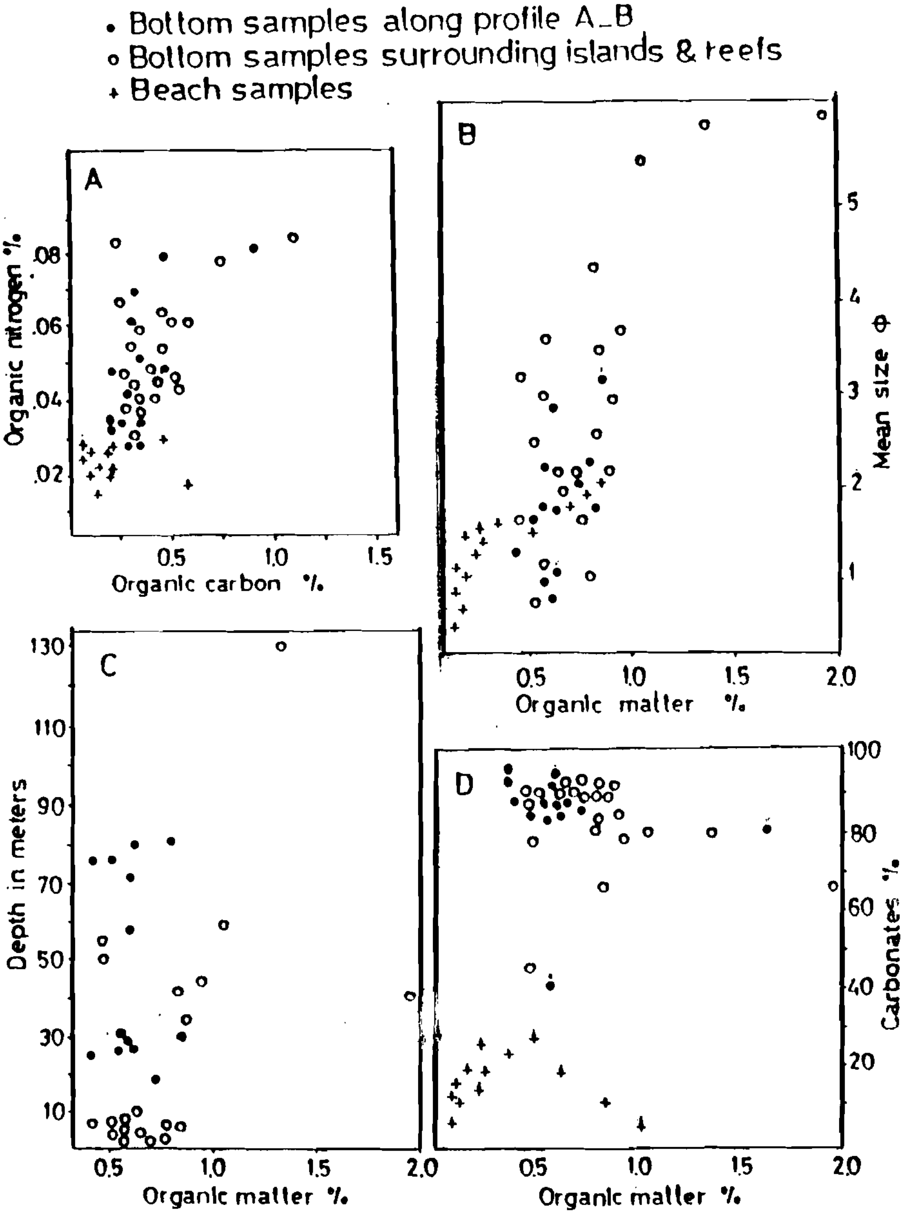

Fig. 5. Relation between organic matter and organic nitrogen, mean size, depth and carbonates.

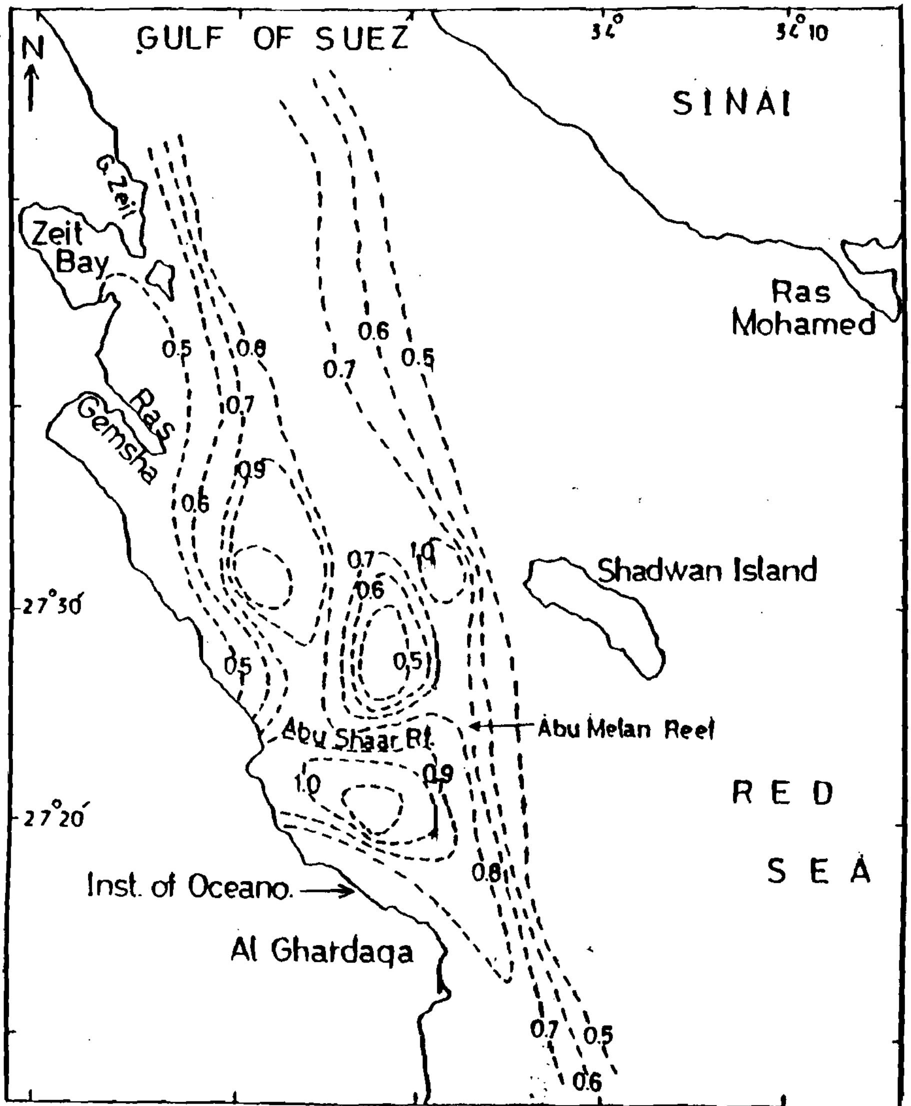

Fig. 6. Areal distribution of organic matter content. (Contour values are percentages)

IRON:

Iron in sediments has many diverse sources, but the iron derived from biologic sources has been focused on by many authors, e.g., Clark and Wheeler (1922), Bradley and Bramlette (1942) and Revelle (1944). El-Wakeel and Riley (1961) recorded certain highly calcareous sediments having high concentration of iron. Hall (1938) and Brenon and Orloff (1956), Alexander et al. (1964) and Maxwell et al. (1965) found that limestone contains 2.20, 0.31 and 0.80 % iron, respectively. Beus (1976) stated that deep-sea carbonates may contain up to 1.84 % iron.

The FeO content of the bottom samples in the vicinity of the islands and reefs ranges from 0.02 to 0.60 % and averages 0.19 % while in those at the entrace of the Gulf of Suez, it ranges between 0.14 and 1.33 % and averages 0.56 %. In the beach sediments FeO is relatively more concentrated (0.50 - 2.58 % with an average of 1.45 %). These values together with the relations shown in figure 7 indicate the parallel increase of iron content with the amount of terrigenous materials including mafic minerals. Other mechanisms such as incorporation in organometallic (organic matter) complexes and shell (carbonates) structures are insignificant.

PHOSPHORUS:

Marine sediments may contain phosphorus either incorporated in organic materials or as phosphate ions bound to various sediment components like aluminosilicate minerals and iron and manganese oxides. Therefore, distribution of phosphorus in the marine sediments is controlled mainly by the phosphorus contents of the minerogenous source material, the concentration and state of dispersion of manganese and iron compounds on the sediment surface, and the biogenous matter and its chemical redistribution within the sediment (Riley and Skirrow, 1965). The average phosphorus concentration in oceanic marine sediments is 0.15 % P_2O_5 (El-Wakeel and Riley, 1961).

The phosphorus content was found to be higher in the samples at the entrace of the Gulf of Suez, where P_2O_5 ranges from 0.28 to 1.93 % and averages 1.06 %. In the samples around the reef complex, it ranges from 0.27 to 1.34 with an average of 0.50 %. In the beach sediments, it varies between 0.36 and 0.96 %. Statistical data indicate that phosphorus might be derived from terrestrial source and/or due to phosphatization of calcareous skeletons.

SILICA:

Silicon binds most of the oxygen in the lithosphere by forming very stable and mobile tetrahedral complexes. Riley and Skirrow (1965) have pointed out that with the exception of quartz, the silicate minerals of igneous and metamorphic rocks are not resistant to weathering. Four types of organisms contribute significant quantities of siliceous skeletal remains to pelagic sediments. These are diatoms, radiolarians, sponges and silicoflagellates (Riedel, 1959). According to El Wakeel and Riley (1961) the average silicon content in pelagic sediments may be estimated as 20.5 %, while in carbonates it is 3.40 % (Beus, 1976). The average

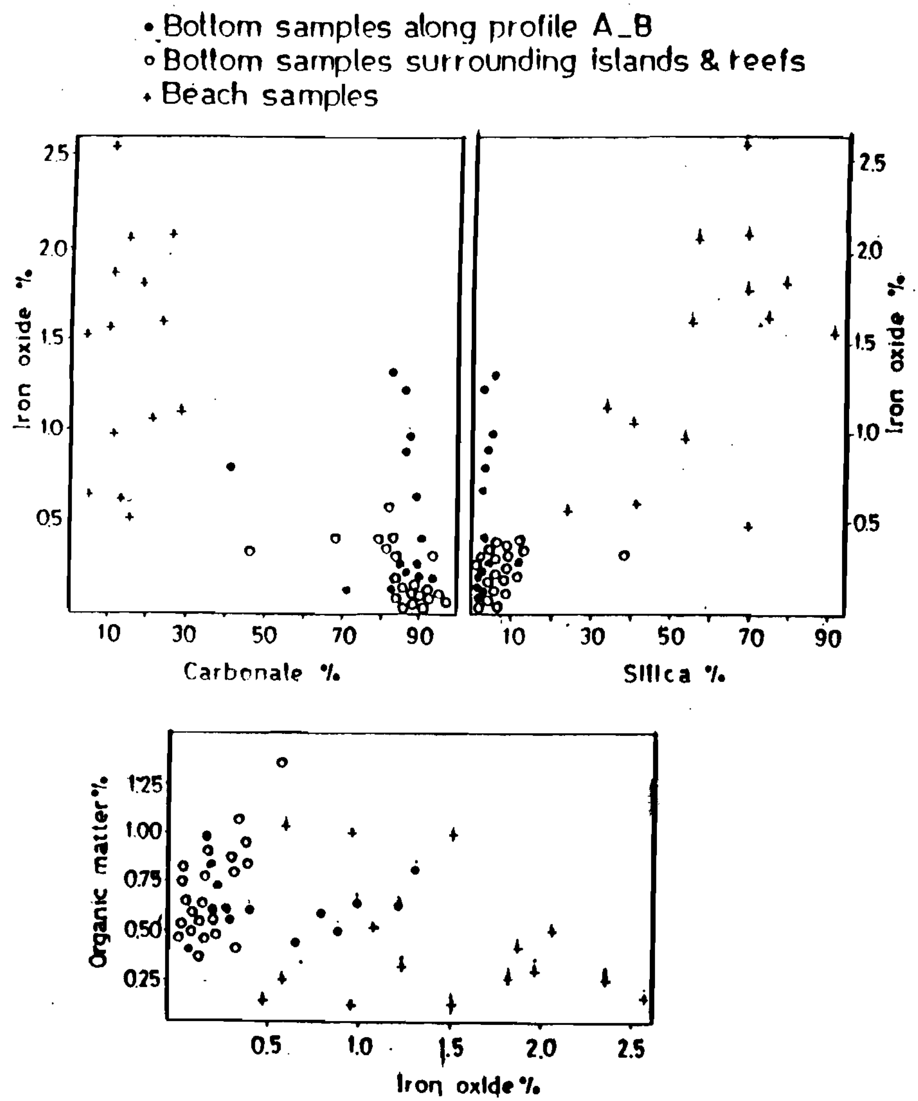

Fig. 7. Relation between iron oxide and silica, carbonate and organic matter contents.

silica content in sea water is 4 mg/l (Chester, 1965). Hirst (1962) stu... recent sediments from the Gulf of Paria and found that silicon conte... varies inversely with the clay mineral contents. In those sediments silicon may be present in the "free SiO_2". Chester (1965) stated that silica released by the weathering of the earth's crust enters the ocean in various forms : (a) in solution, some of which will be removed from sea water by biological precipitation, (b) silica incorporated into the lattices of silicate minerals, which incorporate as detrital or altered silicates, or (c) silica in the form of quartz transported by wind, water or ice.

As generally known, silicate minerals are dominant constituents of terrigenous materials, so the beach sediments, as expected, are notably enriched in silica than the bottom ones. They have silica content ranging between 50.43 and 89.39 % and the average being 64.03 %, while the silica content in the bottom sediments at the entrace of the Gulf.of Suez varies between 2.51 and 38.32 % with an average of 7.89 % and those around the reef complex show similar values ranging from 0.26 to 37.86 % SiO_2 (average 7.93 %). The positive correlation between silica content and FeO (Fig. 7), and sodium and potassium (Fig. 8) from one side and the negative correlation with carbonates and organic matter on the other side indicates a terrestrial origin of silica.

ALKALIES:

Chemical analysis for alkalies shows that the average concentrations of sodium in the beach and bottom sediments are nearly double that of potassium ones, (0.93 and 0.46 %, respectively). The sodium contents in the bottom sediments range between 0.51 and 1.27 % with an average of 0.70 %, while potassium ranges between 0.03 and 1.23 % with 0.22 % average concentration. The beach sediments contain relatively higher concentration of sodium and potassium, where the sodium concentration ranges between 1.14 and 1.81 % with an average of 1.57 % and the potassium concentration ranges between 0.16 and 1.74 % with an average of 1.19%. These data are similar to those reported by Chester (1965) for oceanic sediments. In general, carbonate sediments have lower sodium and potassium contents in comparison with terrigenous sediments. However, the investigated bottom sediments, in spite of their calcareous nature, they show some increase in their sodium content which can be attributed to the replacement of calcium by sodium in calcareous shells. Riley and Skirrow (1965) showed that sediments with considerable contents of calcium carbonate have a corresponding low potassium and relatively high sodium contents. They attributed the high sodium contents to the ability of certain organisms to concentrate sodium. A strong correlation (0.92) between potassium and silica, and moderate one (0.72) between sodium and silica are obtained (Table 1). These results indicate the main role played by terrigenous sources for the derivation of sodium and potassium to the sediments under investigation.

SUMMARY AND CONCLUSION

As a geographical and environmental features, the area of study is already subdivided into beach and bottom zones. Bathymetrically, the bottom

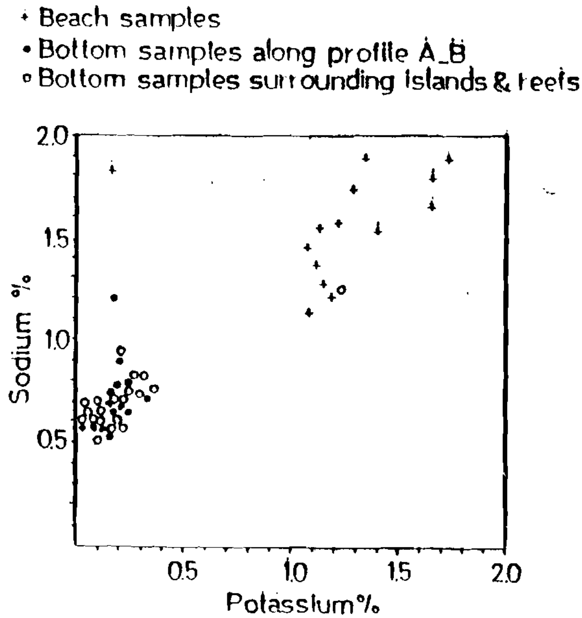

Fig. 8. Relation between sodium and potassium contents.

relief is very complicated due to scattering of some islands and several reefal patches. The reefal patches are present in two forms; one is attached either to the mainland or to the insular roots and forming a circular shape (fringing), while the other forms independent reef surrounded by water.

Beach and bottom sediments from the study area were chemically analyzed for their contents of carbonates, CaO, MgO, organic carbon, organic nitrogen, SiO_2, Fe-oxide, P_2O_5 and alkalies (Na & K). The following conclusions could be arrived at:

- The bottom sediments are carbonate-rich while the beach ones contain lesser amounts of carbonate. The composition of the skeletal materials, the close source of carbonate production, and the hydrodynamic energy are the main factors which control the carbonate content in the sediments.

- The distribution of organic matter in the sediments is dependent upon the organic material supply, the rate of oxidation of the organic matter and the hydrodynamic regime of the basin.

- A parallel increase of iron content with the amount of terrigenous materials had been observed.

- The source of phosphorus is believed to be terrestrial and/or due to phosphatization of calcareous skeletons.

The positive correlation between silica content and FeO, sodium and potassium from one side and the negative correlation with carbonates and organic matter on the other side indicate the terrestrial origin of silicates.

- The statistical data reveal that sodium and potassium are of terrigenous source. Moreover, a part of the sodium is probably related to other phases which seem to be a result of Ca replacement by Na in calcareous shells.

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