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The Textural, Geochemical and Mineralogical Characteristics of Mangrove Sediments, South of Quseir City, Red Sea, Egypt

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Abstract. The characteristics of the sediments from a mangrove stand along the Red Sea coast have been studied and discussed. The sediments are characterized by the abundance of fine and very fine sands. The heavy metals contents in the mangrove sediments show close similarities to those of normal Red Sea sediments. The concentrations of metals in the mangrove sediments are controlled by four factors namely, coral debris-detrital sand factor, sorting factor, feldspar factor and textural factor. The calcareous constituent of sediment affects greatly the concentrations of total carbonate, calcium, barium, strontium, and cadmium. The effect of sorting of sediment particles is prominent and led to concentrate the fines in the southern part of the area. Iron, copper, zinc, potassium and manganese are associated with those fine sediments. The concentrations of sodium, potassium, chromium and magnesium are related to the feldspar content of the sediments. The grain size analysis of sediment samples showed that sediments of the mangrove area are finer than those of the surrounding substrate. The slightly higher concentrations of heavy metals in the mangrove sediments indicate their unique chemical behaviour and the existence of trapping mechanisms. Therefore, the mangrove areas prevent shore erosion by acting as buffers and catch finer materials, thus stabilizing the land elevation by sediment accretion that balance the sediment loss. A special attention should be devoted to the protection of the mangrove swamps by laying out balanced development policies.

Introduction

The ecological, environmental and socioeconomical importance of mangrove is now widely concerned. Apart from the well-known role of mangrove in the ecology of the nearshore environment, they act as sediment traps. The tidal currents in the mangrove areas are impeded by the friction caused by the high vegetation density and they are also complex comprising eddies, jets and stagnation zones (Furukawa and Wolanski, 1996). The sediments carried in suspension into the mangrove zones during tidal inundation are likely to be trapped as a result of turbulence created by the flow around the vegetation. As a result, the sediments trapped in the mangrove areas should be finer than those of the surroundings. If this is true, particular importance should be attached to the value of mangroves to reduce erosion. The present study investigates the geochemical and sedimentological characteristics of sediments of mangrove stands and verifies especially, the grain size characteristics.

Area of Study

The area of study lies about 34 km south of Quseir City along the Egyptian Red Sea coast. It ex-

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tends between Latitudes 25º51.8′N and 25º49.8′N and from the backshore area to the seaward reef edge, where the depth increases abruptly from about 14 meters to more than 50 meters (Fig. 1.)

Materials and Methods

The area under investigation was surveyed to determine the bathymetry using a combination of continuous recording echosounder (MACH1) and

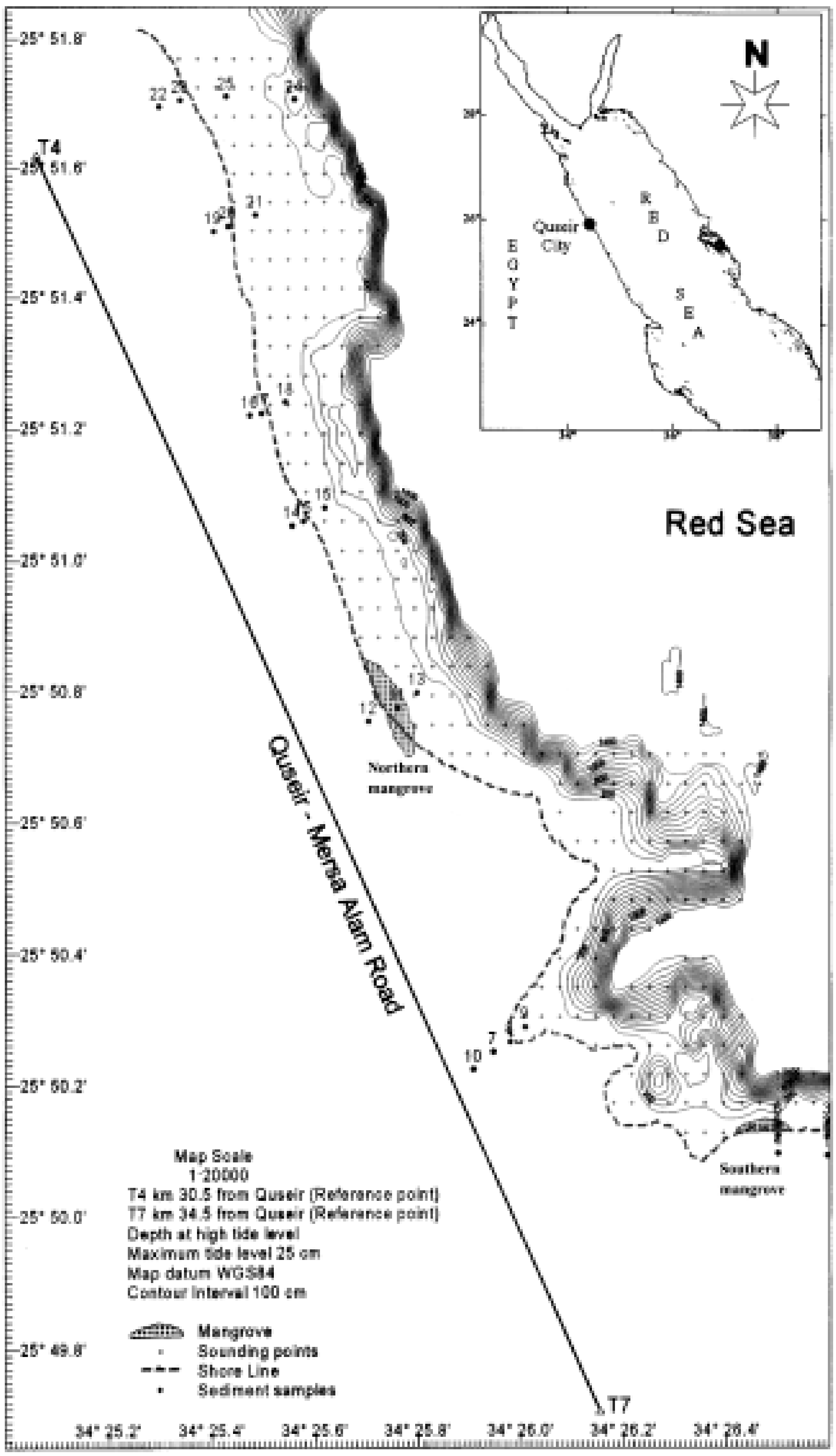

FIG. 1. A map showing the area of study, sampling locations and sounding contours.

SOKKIA SURVEY STATION together with two MAGELLAN PRO1000 GPS devices. The echo-sounding profiles are spaced 10 m apart and are perpendicular to the shore. The depths were corrected and adjusted for high tide level. The fauna and flora were identified during SCUBA diving. Sediments were sampled along profiles perpendicular to the shore. Representative samples were collected from the intertidal, beach face and foreshore zones as well as from the mangrove stands (Fig. 1). Sediment samples were analysed texturally using the method of Folk (1974). Chemical analyses included determination of total carbonate using the method of Molnia (1974). Metal constituents were measured on Atomic Absorption Spectrophotometer using the extraction method mentioned in Rifaat *et al.* (1992). X-Ray Diffractometry was applied to some samples to determine the mineral composition, qualitatively. The data were processed statistically applying the Factor Analysis technique to identify the factors influencing the spatial distribution of the variables measured.

Results and Discussion

The bathymetric survey shows a reef flat dips gradually from the shore/water mark to a depth of 2 m, where the depth increases steeply to 14 m and abruptly changes to more than 50 m marking the edge of the coral reef extent. The reef flat is occupied by two small lagoons one at the northern limit at latitude 25º51.7′N and the other at the southern limit at latitude 25º50.2′N (Fig. 1). Two distinctive mangrove stands are present, the first at latitude 25º50.2′N and the other at latitude 25º50.8′N. The shoreline shows a slightly landward-curved shape at the northern part of the area trending NW-SE, while it is irregular at the southern part trending W-E (Fig. 1). The beach sediments are composed of medium (1-2 phi) to coarse (0-1 phi) sand with the coarser sediments at the northern part and finer sediments at the south. The medium sand sediments of the intertidal zone are, relatively, finer than those of the proper beach, while the sediments of the mangrove stands and their surrounding parts are fine (2-3 phi) sands. At the southern end a sabkha deposit's flat marking the mouth of a wadi through which fresh water occasionally drain to the sea during the heavy rain seasons forming what is called a sharm (small submerged canyon). These sabkha deposits are characterised by their high salt content and the very fine grain size particles of their sands (3.11 phi). Table 1 shows the results of grain size analysis.

The coastal plain is wide and flat near the shore. It rises gradually landward, where the relics of the raised reefs run parallel to the shore. At the mouth of the wadi detrital volcanic and metamorphic rock fragments are predominant. Due to the extreme north latitude, *Avicennia marina* (mangrove tree) is the only tree species found in the area of study the case that is similar to the mangrove in Sinai Peninsula as noticed by Greenwood *et al.* (1998). The mangrove estuaries south of Quseir City are well developed, but are small and isolated from each other by extensive fringing coral reef lagoons similar to those in the Solomon Islands (Blaber and Milton, 1990).

The southern mangrove stand covers an area of 7,533 m^2 while the northern one has an area of 9,478 m^2 (Fig. 1). A total of 200 species of Algae, Crustacea, Echinodermata, Hard Coral, Mollusca, Soft Coral and fish were recorded from the two mangrove stands and the surrounding area (Table 2).

Table 3 summarizes the results of chemical analyses. Mineralogically, the sediments of the area under investigation are composed predominantly of quartz, feldspars, calcite, and aragonite together with traces of dolomite, ankerite, rhodochrosite and halite. The mean concentrations of metals in sediments of the study area could be compared with those of other areas. In spite of the slight mineralogical variations, the mean metal concentrations of the studied sediments showed no major differences with those of the different localities along the Red Sea (Beltagi, 1984; El-Sayed, 1984; El-Mamoney, 1995 and Rifaat, 1996) and the average carbonate sediments (Milliman, 1974) (Table 3).

The concentrations of metals in sediments of the study area are controlled by four factors namely, coral debris-detrital sand factor, sorting factor, feldspar factor and textural factor (Table 4). The calcareous constituent of sediment affects greatly the concentrations of total carbonate, calcium, barium, strontium, and cadmium. The effect of sorting of sediment particles is prominent and led to concentrate the fines in the southern part of the area. Iron, copper, zinc (Factor 2, Table 4) and potas-

TABLE 1. Results of grain size analysis (phi), total carbonate content (%) and type of the sediment in the area of study.

Sample no.	Mean size	Sorting	Skewness	Kurtosis	TCO_3%	Sample type
1	1.06	1.36	– 0.03	0.47	20.91	Beach
2	1.55	1.58	0.06	0.69	17.19	Beach face
3	1.01	1.23	– 0.21	0.72	26.62	Intertidal zone
4	1.16	1.41	– 0.18	0.83	19.76	Beach
5	2.53	1.65	– 0.57	0.92	38.65	Intertidal zone
6	1.86	1.83	– 0.35	0.60	32.29	Mangrove plant sediment
8	0.12	0.66	– 0.19	0.77	25.64	Beach face
9	2.83	0.78	0.02	1.01	21.23	Intertidal zone
10	3.11	1.34	– 0.10	0.69	28.85	Beach back sabkha deposits
11	2.28	1.71	– 0.58	0.73	34.97	Mangrove plant sediment
12	2.36	0.84	– 0.03	1.00	30.84	Beach
13	2.42	1.12	– 0.13	0.95	49.64	Intertidal zone
14	1.79	1.37	– 0.15	1.11	37.89	Beach
15	0.59	1.21	0.18	1.29	45.63	Beach face
15′	2.80	1.34	– 0.42	1.03	43.69	Intertidal zone
16	1.00	0.76	– 0.27	0.91	34.86	Beach
17	0.07	0.88	–0.85	0.66	59.89	Beach face
18	2.46	1.04	– 0.17	1.22	67.09	Intertidal zone
19	– 0.21	0.60	0.51	0.45	35.59	Beach
20	0.08	1.08	0.65	0.83	30.82	Beach face
21	0.46	1.24	0.35	0.71	79.87	Intertidal zone
22	0.44	1.05	0.85	0.55	23.88	Beach
23	– 0.03	0.85	0.45	0.80	62.51	Beach face
24	0.60	1.19	0.09	0.69	96.14	Intertidal zone pool
25	0.39	1.08	0.19	0.52	72.58	Intertidal zone

TABLE 2. Types of organisms in the area of study.

Taxa	Count
Algae	28
Crustacea	23
Echinodermata	7
Hard coral	31
Soft coral	10
Mangrove	1
Mollusca	21
Teleost	79
Grand total	200

TABLE 3. Metal composition of the mangrove sediments compared with other areas.

Metal	Quseir City present study			Jeddah[1]		Northern Red Sea[2]		Ghardaqa[3]		Red Sea[4]		Carbonate[5]	
	Mean	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Ca %	5.50	2.10	10.10	30.50	35.90	13.10	39.00	7.00	20.00	7.30	32.70	27.00	41.00
Mg %	0.10	0.03	0.20	0.90	2.40	0.60	2.00	1.00	3.00	–	–	0.01	7.20
Sr %	0.10	0.04	0.26	0.35	0.63	–	–	0.20	1.00	–	–	0.01	1.00
Ba ppm	2609.5	835.5	6559.7	–	–	–	–	–	–	–	–	1	530.00
Cd ppm	2.57	1.04	4.85	1.80	6.00	–	–	–	–	0.48	1.10	0.05	2.80
Fe ppm	457	74	1018	–	–	–	–	–	–	4800	18000	1	7700
Mn ppm	85	16	199	9	39	2	418	73	2012	21	619	1	392
Cu ppm	2.1	0.6	4.1	1.3	25.1	3.0	79.0	5	18	6	23	0.29	443
Zn ppm	8.5	3.5	19.0	5.3	30.6	10.0	230.0	7	59	12	40	2	470
Cr ppm	4.6	1.6	8.1	–	–	–	–	–	–	7	126	1	23
Na ppm	427	131	797	20	467	–	–	488	1629	6700	17000	800	5300
K ppm	462	173	1359	2	397	–	–	543	706	1300	11000	100	6900

[1]Rifaat (1996).
[2]Beltagi (1984).
[3]El-Sayed (1984).
[4]El-Mamoney (1995).
[5]Milliman (1974).

TABLE 4. Factor analysis of the observed variables in sediments of the study area.

Variables	Factor 1	Factor 2	Factor 3	Factor 4
Mean size	– 0.33	0.49		0.67
Sorting		0.80		
Skewness		– 0.54		– 0.39
Kurtosis				0.91
TCO_3	0.96			
Ba	0.98			
Sr	0.98			
Cd	0.91			
Cu		0.79		– 0.34
Fe	– 0.52	0.68		
Zn	– 0.44	0.70		
Cr			– 0.39	0.52
Mn	– 0.87			
Na			0.91	
K	– 0.40		0.85	
Ca	0.94			
Mg	0.30		0.75	
Eigenvalue	6.77	2.94	2.33	1.72
Pct of var	39.8	17.3	13.7	10.1
Cum pct	39.8	57.2	70.9	81.0

Kaiser-Meyer-Olkin measure of sampling adequacy = 0.58758.
Loadings < 0.25 are eliminated.

sium-manganese (Factor 1, Table 4) are associated with those fine sediments as also noticed by Badarudeen *et al.* (1996) along the southwestern coast of India. The concentrations of sodium, potassium, magnesium (Factor 3, Table 4) and chromium (Factor 4, Table 4) are related to the feldspar content of the sediment, which in turn are related to the fine fraction of the sediments.

The grain size analysis of sediment samples showed that the sediments of the mangrove area are finer than those of the surroundings. Badarudeen *et al.* (1996) reported that the mean size of sediments of a tropical mangrove ecosystem is fine to very fine sand the case that is also noticed by Ramanathan *et al.* (1999) in mangrove areas of southeast coast of India, who pointed out that heavy metals are enriched in the mangrove sediments, indicating their unique chemical behaviour and the existence of trapping mechanisms. The ability of mangrove trees to trap sediment particles is noted by many authors, *e.g.* Wolanski *et al.* (1998) and Furukawa and Wolanski (1996). The sea area off the mangrove is characterised by the existence of a high turbidity zone. This high turbidity zone is restricted to a narrow band along the coast and was named "the coastal boundary layer" by Wolanski and Ridd (1990).

The water in the boundary layer, shared between the mangroves and the sea, mixes very slowly with offshore waters and thus provides a buffer between the mangroves and offshore waters (Wolanski *et al.,* 1990). The formation of the boundary layer is due to the effect of bottom friction in shallow coastal water (Wolanski *et al*., 1998). The stagnant conditions prevailing around the mangrove trees led to the settling of the fine sedimentary particles and the formation of newer sedimentary bank.

The mean grain size of sediments from the mangrove stands in the study area ranges between 2.28 and 2.53 phi (fine sand) whereas the surrounding sediment' grain size ranges between 0.21 and 1.5 phi (coarse to medium sand) (Table 1). This means that the mangrove trees trap finer sediments and are thus not opportunistic trees colonising mud and sand banks but actively contribute to the creation of mud and sand banks. Therefore, they prevent shore erosion by acting as buffers and catch finer materials, thus stabilizing the land elevation by sediment accretion that balance the sediment loss. In addition to that, mangrove communities filter out pollution, hold nutrients, and provide food, nesting and nursery areas for many animals.

The mangrove areas along the Red Sea coast have been given legal protection because of the increased understanding of their environmental importance. As development continues along the Red Sea coast, however, so will the pressure to destroy more of this important native community, the case that dictates more restrictions on the dredge and fill projects that alter the characteristics of the coastal environment. Government policy needs to devote as much attention to sustainability issues. A balanced development policy would include training and education monitoring and enforcement, managing land use within the coastal zone, more community involvement, and government reorganization to eliminate overlapping jurisdictions among agencies.

Conclusion

From the above study it could be concluded that:

1) The sediments of the studied area are composed of quartz, feldspars, calcite, aragonite and traces of dolomite, ankerite, rhodochrosite and halite that are similar to the sediments along the Egyptian Red Sea coast.

2) In spite of the slight mineralogical variations, the mean metal concentrations of the studied sediments showed no major difference with those of the different localities along the Red Sea.

3) The concentrations of metals in sediments of the study area are controlled by four factors these are: 1) Coral debris-detrital sand factor, 2) Sorting factor, 3) Feldspar factor, and 4) Textural factor. The calcareous constituent of sediment affects greatly the concentrations of total carbonate, calcium, barium, strontium and cadmium. The effect of sorting of sediment particles is prominent and led to concentrate the fines in the southern part of the area. Iron, copper, zinc, potassium and manganese are associated with those fine sediments. The concentrations of sodium, potassium, magnesium and chromium are related to the feldspar content of the sediment which in turn are related to the fine fraction of the sediments.

4) The mean grain sizes of the mangrove sediments in the study area are finer than the surrounding sediments .The mangrove trees trap finer sediments and act as buffers, thus stabilizing the land elevation by sediments' accretion that balance the sediment loss.

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الخصائص النسيجية والجيوكيميائية والمعدنية لرسوبيات منطقة نبات الشورى جنوب مدينة القصير ، البحر الأحمر ، مصر

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المستخلص . تتناول هذه الدراسة الخصائص النسيجية والجيوكيميائية والمعدنية لرسوبيات إحدى مناطق نمو أشجار نبات الشورى على الجزء المصرى من ساحل البحر الأحمر . وتتميز هذة الرسوبيات بتزايد مكونها من الرمال الناعمة والناعمة جداً ، ويتحكم فى تركيز العناصر الفلزية فى رسوبيات منطقة الدراسة أربعة عوامل ، هى:

١. نسبة فتات الشعاب المرجانية والرمال المنقولة .
٢. درجة تصنيف الحبيبات المكونة للرواسب .
٣. نسبة تركيز معادن الفلسبار .
٤. التوزيع الحجمى لحبيبات الرواسب .

وجد أن المكونات الكلسية فى الرواسب تؤثر على كل من نسب تركيز الكربونات والكالسيوم والباريوم والسترونشيوم والكادميوم . فى حين تؤثر درجة تصنيف الحبيبات فى توزيع الرسوبيات ، بحيث تتركز الرسوبيات الناعمة فى الجزء الجنوبى من المنطقة . ويرتبط توزيع كل من الحديد والنحاس والزنك كليًا والبوتاسيوم والمنجنيز جزئيًا بنمط توزيع الرسوبيات الناعمة السابق ذكرها بينما يرتبط توزيع الصوديوم والمغنسيوم والكروم كليًا والبوتاسيوم جزئيًا بتجمع معادن الفلسبار . وقد أظهرت الدراسة أن حجم حبيبات رسوبيات نطاق نمو أشجار الشورى أقل من رسوبيات المنطقة المحيطة ، مما يدل على وجود عملية ترسيب فى نطاق هذه المنطقة . ولذلك فإن نباتات أشجار الشورى تمثل منطقة حماية للشاطئ ضد عوامل النحر والتآكل ، حيث يعمل التجمع الجذرى والخضرى للنباتات على احتجاز الرواسب حوله ويعادل من تأثير عمليات النحر .

وعلى هذا فإنه يجب الاعتناء بمناطق نمو أشجار الشورى وحمايتها من جور الأنشطة الأخرى عليها ، وذلك بوضع سياسات تنمية متوازنة تضمن حمايتها من التعرية وكذا محاولةالإستزراعها فى الشواطئ المهددة بالنحر .