Delta J. Sci. 2007, 31: 100-120

GEOLOGY

SEDIMENTOLOGICAL AND MINERALOGICAL ANALYSES OF THE RECENT COASTAL SEDIMENTS ALONG AL-HODEIDAH – AL-URJ AREA, SOUTHERN RED SEA, YEMEN

Mohammed A. Gaashan

Al-Hodeidah University, Faculty of Marine science and Environment, Department of Marine Geology

(Received: 6- August- 2007)

Abstract: The present study describes the recent coastal sediments along Al-Hodeidah coast, Republic of Yemen. A total of 113 samples were collected from the onshore and offshore areas at four locations. The aim was to provide some information regarding the textural properties, mineralogical, and depositional environments of the sediments along Al-Hodeidah coast. Based on the sedimentological data it is suggested that most of the sediments are deposited in fluviatile conditions and in high energy active environments. The sediments are dominated by sand-mud size with calcareous particles. The occurrence of fine-grained carbonate mud is attributed to lagoonal environment. They are characterized by the occurrence of some mollusca species that signify normal marine and brackish waters. The sediments of El-Sheikh Younes and Ras Kathib areas are generally characterized by an increased amount of pebble sizes represented mainly by molluscan shells fragments, which increasing in abundance northward. The sediments also contain a considerable amount of gypsum, a large number of marine mollusca and few freshwater forms. The heavy mineral assemblages recorded from the sands consist of (in order of decreasing abundance): opaque, amphibole, zircon, epidote, rutile, garnet and tourmaline. The non-carbonate minerals are quartz, hematite, magnetite, halite and gypsum.

Introduction

Al-Hodeidah governorate is located on the coastal plains of Tehama extended along the Red Sea coasts, between latitude 13° 20' – 15° 45' N and longitude 42° 40' – 43° 15' E. Its coast extends about 300km from Al-Luhayah in the North to Al-Khawkhah in the south. There are several valleys in Al-Hodeidah governorate including: Wadi Mwr, Wadi Surdud, Wadi Siham, Wadi Rima, Wadi Nakhla, Wadi Zabid, Wadi Al-Qanawis, Wadi Al-Waga and Wadi A-Lawia. The climate of the area is semi tropical (warm and humid in the summer and moderate in winter). The highest temperature reaches 40 °C during the summer and it amounts to 24 °C in winter. The temperature is mildy by the seasonal monsoon winds. Generally, the area is characterized by its hot climate and calm winds.

The recent coastal marine sediments of the Yemeni coast have attracted little attention, and few limited studies were carried out such as Barratt *et al.* (1987), Al-Ahdel (1989), El-Sayad and Abdu (1990), El-Anbaawy (1993), El-Anbaawy and Al-Awah (1993), Dekker and Capelle (1994), Rushdi *et al.* (1994), Heba and Al-Mudaffer (2000), Heba *et al.* (2000), Al-Mayah and Heba (2001). The aim of the present work is to provide more information on the recent beach sediments along Al-Hodeidah coast, and to show the nature of these sediments, their textural properties, the factors affecting their distribution, the mineralogical and depositional environments.

Description of the study area

The study area comprises 50km stretch of the Red Sea coast that extending from Al-Urj in the north to Al-Hodeidah in the south. Al Hodeidah city is located in the eastern part of the Red Sea coast, between Ras Kathieb at the north to Al-Manzar area at the south and Zafran at the east. It is situated between latitude 43° E and longitude 14° 45' N, and above sea level about 10 meter. The studied area is a flat coastal plain characterized by sabkha sediments and salt marshes.

El-Sheikh Younes area is located southwest of Al-Hodeidah, between latitude 14° 43' N, and longitude 42° 58' E. It is coastal area that characterized by several geomorphological characters including barrier sand, marine spit, which are parallel to the coast, salt marshes and tidal flat. There are three wadis: Seham, Al-Aker and Rman, which are connected with the coastal area. Wadi Seham is considered the main and important wadi that poured its sediments in the area. Mangrove trees are well developed in the tidal flat areas.

Ras Al-Kathib, a 15km long sandy peninsula protruding north-westerly from the mainland coast about 5km north of Al-Hodeidah. It is located between latitude 14° 50' N and longitude 42° 45' E. Ras Kathib area is divided into two regions: 1) Construction region, which is characterized by low energy environment with continuous sedimentation and included marine spit and bay, 2) Destruction region, the area that exposed to wave and currents action, which reflect high energy environment.

Al-Urj is located at about of 40km north to Al-Hodeidah, between latitude 15° 06'N, and longitude 42° 52'E. Towards Al-Urj,. much of the coastline is a steep sandy beach backed by sand dunes and areas of bare salt flats. South of Al-Urj, the beach is split by a tidal inlet one kilometer long at the mouth of a dry wadi. Towards the shore, the extensive intertidal mud and sand flats support well-developed mangroves.

Materials and Techniques

Four locations were selected from the coastal area between Al-Hodeidah and Al-Urj, including 1) Al-Sheikh Yunes site, south of Al-Hodeidah, 2) Al-Hodeidah port area, 4) Ras Kathieb area and 4) Al-Urj area. 113 samples for sediment analysis were collected at each locality, starting from the onshore to offshore area. The samples were obtained by small shovel from upper 10 cm of the surface sediments.

Grain-size analysis was carried out on the sediments. Both the gravel and sand fractions of the samples were mechanically analyzed by dried sieving using a set of standard sieves with mesh openings of 4, 2, 1, 0, 0.5, 0.125, and 0,063 mm. For the fine fraction (< 4∟), the pipette method was used following the techniques described by Folk (1968). The weight percentages of different fractions (gravel, sand and mud) were calculated. The statistical parameters were calculated following the equations given by Folk and Ward (1957). Desegregation of samples and removal of iron oxides and carbonates were done using hydrochloric acid (Folk, 1974). The samples were dried at 100 ∟C and later sieved using a nest of screens and the sieving was operated for 15 minutes. The results of sieve analysis were tabulated. The statistical parameters (Folk and Ward, 1957) were calculated, which include the graphic mean size (Mz), the inclusive graphic sorting (▯ 1), the inclusive graphic skewness (SK1) and the inclusive graphic kurtosis (KG).

Tewnty sand samples were selected from the coast and subjected to heavy and light mineral separation. The very fine-sand fraction that separated by wet sieving was subjected to heavy mineral separation using bromoform, following the procedure recommended by Carver (1971). The heavy minerals were studied using the polarizing microscope and their relative proportion was determined by counting of 300 mineral grains within 10 traverses (Lewis and Mc Conchie, 1994).

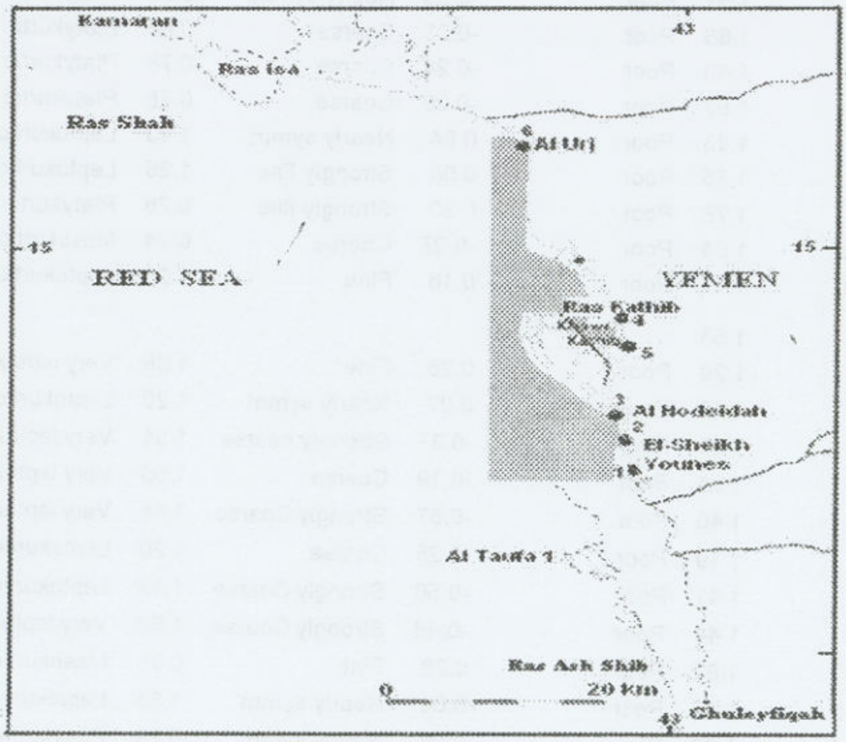

Figure 1: Location map of the studied Al-Hodeidah area

Table 1. List of the studied samples in El-Sheik Younes area is showing the calculated statistical parametrs from grain-size analysis.

	S. No.	Sorting φ		Skewness φ		Kurtosis φ	
Section 1	1	0.94	Moderate	0.77	Strongly fine	0.73	Platykurtic
	2	1.20	Poor	0.50	Strongly fine	1.17	Leptokurtic
	3	0.82	Moderate	0.32	Strongly fine	1.39	Leptokurtic
	4	0.96	Moderate	0.49	Strongly fine	1.54	Very leptokurtic
	5	1.4	Poor	0.14	Strongly fine	0.80	Platykurtic
	6	1.57	Poor	0.19	Coarse	1.04	Mesokurtic
	7	1.63	Poor	-0.01	Nearly symm.	0.90	Platykurtic
	8	1.70	Poor	-0.06	Nearly symm.	1.0	Mesokurtic
	9	1.68	Poor	0.36	Strongly fine	0.78	Platykurtic
	10	1.99	Poor	0.47	Strongly fine	0.79	Platykurtic
	11	1.48	Poor	-0.28	Coarse	0.96	Mesokurtic
	12	1.80	Poor	-0.07	Nearly symm.	1.02	Mesokurtic
	13	0.69	Moderately-well	0.14	Fine	1.14	Leptokurtic
	14	0.88	Moderate	0.25	Fine	1.05	Mesokurtic
	15	1.04	Poor	-0.36	Strongly coarse	1.55	Very leptokurtic
	16	0.85	Moderate	-0.07	Nearly symm.	1.08	Mesokurtic
	17	1.04	Poor	0.21	Fine	0.77	Platykurtic
	Average	1.29					
Section 2	1	1.37	Poor	0.19	Fine	1.09	Mesokurtic
	2	1.11	Poor	0.11	Fine	1.06	Mesokurtic
	3	1.57	Poor	-0.09	Nearly symm.	0.85	Platykurtic
	4	1.66	Poor	-0.23	Coarse	0.85	Platykurtic
	5	1.60	Poor	-0.24	Coarse	0.78	Platykurtic
	6	1.97	Poor	-0.29	Coarse	0.78	Platykurtic
	7	1.13	Poor	0.04	Nearly symm.	1.43	Leptokurtic
	8	1.75	Poor	0.56	Strongly fine	1.25	Leptokurtic
	9	1.78	Poor	0.36	Strongly fine	0.78	Platykurtic
	10	1.54	Poor	-0.27	Coarse	0.94	Mesokurtic
	11	1.41	Poor	0.16	Fine	1.28	Leptokurtic
		1.53					
Section 3	1	1.29	Poor	0.26	Fine	1.88	Very leptokurtic
	2	1.43	Poor	0.07	Nearly symm	1.20	Leptokurtic
	3	1.29	Poor	-0.37	Strongly coarse	1.51	Very leptokurtic
	4	1.24	Poor	-0.19	Coarse	1.56	Very leptokurtic
	5	1.40	Poor	-0.37	Strongly Coarse	1.68	Very leptokurtic
	6	1.19	Poor	-0.25	Coarse	1.20	Leptokurtic
	7	1.41	Poor	-0.50	Strongly Coarse	1.13	Leptokurtic
	8	1.44	Poor	-0.48	Strongly Coarse	1.52	Very leptokurtic
	9	1.62	Poor	0.28	Fine	0.95	Mesokurtic
	10.	1.17	Poor	0.03	Nearly symm	1.35	Leptokurtic
	11	1.66	Poor	0.06	Nearly symm	0.75	Platykurtic
	12	1.89	Poor	0.12	Fine	0.71	Platykurtic
	13	0.93	Moderate	-0.08	Nearly symm	1.26	Leptokurtic

Table 2. Showing the percentages of different grain-size fractions in the studied samples of El- Sheik Younes area.

Section	S.No.	Gravel	Sand			T. Sand	Mud
			Coarse	Medium	Fine		
Section 1	1	0.2	15.9	50.5	31.5	97.9	1.9
	2	-	20.8	41.6	26.4	88.8	11
	3	0.8	47.8	37.4	13.7	98.9	0.2
	4	1.3	19.8	53.7	24.5	98	0.4
	5	0.7	23.1	18.4	53.7	95.7	3.1
	6	3.9	16.9	19.8	49.9	86.6	9.1
	7	2.1	23.3	19.1	46.4	89	8.7
	8	3.2	19.7	17.9	44.5	82.1	14.5
	9	2.3	23.1	16.4	42.8	82.3	15.2
	10	14.4	28.3	18.1	30.8	77.2	8.2
	11	1.7	11.7	14.6	51.3	77.6	20.5
	12	2.0	11.3	21.6	57.0	90	7.7
	13	-	34.1	54.9	10.9	99.9	-
	14	0.2	3.9	25.3	68.6	97.8	1.8
	15	-	7.7	9.1	74.7	91.5	8.4
	16	-	o.9	5.9	87.1	94.8	6.1
	17	3.1	82.6	5.6	5.3	93.5	3.4
Section 2	1	4.1	39.9	25.6	28.6	94.4	1.1
	2	0.5	24.1	39.3	34.1	97.6	1.8
	3	3.9	20.3	15.5	49.8	85.7	10.3
	4	6.2	26.3	17.2	43.5	87	6.6
	5	1.3	17.1	16.9	41.9	76	22.6
	6	1.4	17.5	18.1	43.9	79.6	18.9
	7	1.7	19.5	42.7	32.3	94.7	3.4
	8	3	36.3	32.3	19.7	88.3	8.6
	9	4.8	45.1	18.1	20.8	84	11.1
	10	0.4	16.8	15.7	44.6	77.1	22.3
	11	2.0	42.3	30.3	21.9	94.7	3.2
Section 3	1	1.6	42.1	21.7	34.1	97.9	0.5
	2	1.5	41.7	23.2	32.8	97.7	0.7
	3	0	6.7	11.4	61.2	79.3	20.6
	4	0	6.4	10.2	60.1	76.7	23.2
	5	0	5.8	4.9	55.5	66.2	33.7
	6	0	7.5	12.9	65.2	85.6	14.3
	7	0	12.1	11.2	55.1	78.4	21.5
	8	0	8.3	7.4	59.4	75.1	24.8
	9	2.4	32.1	29.6	26.4	88.1	9.4
	10	2.6	18.8	38.2	37.1	94.1	3.2
	11	13.2	33.4	16.4	22.7	72.5	14.2
	12	3.1	29.8	19.9	33.2	82.9	13.9
	13	1.8	34.9	47.2	15.7	97.8	0.3

Table 3. List of the studied samples in Al-Hodeidah area is showing the calculated statistical parametrs from grain-size analysis

	S. No.	Sorting ϕ		Skewness ϕ		Kurtosis ϕ	
Section 1	1	1.10	Poor	-0.04	Nearly symm	1.17	Leptokurtic
	2	1.32	Poor	0.07	Fine	0.64	Very platykurtic
	3	1.46	Poor	0.0	Nearly symm	0.78	Platykurtic
	4	1.36	Poor	-0.31	Strongly fine	0.78	Platykurtic
	5	1.59	Poor	-0.21	Coarse	0.69	Platykurtic
	6	1.51	Poor	-0.59	Strongly Coarse	0.77	Platykurtic
	7	1.28	Poor	-0.32	Strongly Coarse	0.91	Mesokurtic
	8	1.63	Poor	-0.37	Strongly Coarse	0.49	Very platykurtic
	9	1.29	Poor	-0.47	Strongly Coarse	1.20	Leptokurtic
	10	1.88	Poor	-0.15	Coarse	1.53	Very leptokurtic
	11	1.15	Poor	-0.49	Strongly Coarse	1.47	Leptokurtic
	12	0.8	Mod.-well	-0.31	Strongly Coarse	2.11	Very leptokurtic
	13	0.62	Mod.-well	-0.47	Strongly Coarse	0.96	Mesokurtic
	14	1.46	Poor	0.30	Fine	0.38	Very platykurtic

Table 4. Showing the percentages of different grain-size fractions in the studied samples of Al-Hodeidah area.

	S. No.	Gravel	Sand			T. Sand	Mud
			Coarse	Medium	Fine		
Section 1	1	0.0	3	5	49	57	43
	2	0.0	2.5	4.5	46	53	47
	3	0.0	12.5	19	47	78.5	21.5
	4	0.0	2	6	32	40	60
	5	0.0	5	11	36	52	48
	6	0.0	3.5	9.5	20	33	67
	7	0.0	3.5	11	36.5	51	49
	8	0.0	6	8	39	53	47
	9	0.0	7	7.5	22.5	37	63
	10	0.0	17	11	28	56	44
	11	0.0	7	4	22	33	67
	12	0.0	61	22	8	91	9
	13	0.0	3	30	60	93	7
	14	0.0	37	15	23	75	25

Table 5. List of the studied samples in Ras Kathib area is showing the calculated statistical parametrs from grain-size analysis.

	S. No.	Sorting ϕ		Skewness ϕ		Kurtosis ϕ	
Section 1	1	0.90	Moderate	0.008	Nearly symm	0.99	Mesokurtic
	2	0.84	Moderate	0.02	Nearly symm	1.08	Mesokurtic
	3	0.66	Moderate-well	0.05	Nearly symm	0.86	Platykurtic
	4	0.68	Moderate-well	-0.04	Nearly symm	0.98	Mesokurtic
	5	0.73	Moderate	-0.06	Nearly symm	1.02	Mesokurtic
	6	0.65	Moderate-well	-0.18	Coarse	2.23	Veryleptokurtic
	7	0.77	Moderate	-0.14	Coarse	1.14	Leptokurtic
	8	0.67	Moderate-well	-0.06	Nearly symm	1.02	Mesokurtic
	9	0.77	Moderate	-0.11	Coarse	1.22	Leptokurtic
	10	0.79	Moderate	-0.13	Coarse	1.21	Leptokurtic
Section 2	1	0.76	Moderate	0.05	Nearly symm	1.05	Mesokurtic
	2	0.72	Moderate	0.23	Fine	1.06	Mesokurtic
	3	0.64	Moderate-well	0.15	Fine	0.86	Platykurtic
	4	0.58	Moderate-well	0.19	Fine	0.86	Platykurtic
	5	0.64	Moderate-well	-0.02	Nearly symm	1.57	Leptokurtic
	6	0.72	Moderate	0.24	Fine	1.08	Mesokurtic
	7	0.63	Moderate- well	0.04	Nearly symm	0.82	Platykurtic
	8	0.77	Moderate	-0.07	Nearly symm	1.15	Leptokurtic
Section 3	1	0.67	Moderate-well	0.24	Fine	1.05	Mesokurtic
	2	0.62	Moderate-well	0.18	Fine	0.91	Mesokurtic
	3	0.65	Moderate-well	0.19	Fine	1.13	Leptokurtic
	4	0.77	Moderate	0.24	Fine	1.05	Mesokurtic
	5	0.75	Moderate	0.18	Fine	1.11	Leptokurtic
	6	0.59	Moderate-well	0.19	Fine	0.87	Platykurtic
	7	0.80	Moderate	0.17	Fine	1.15	Leptokurtic
	8	0.65	Moderate-well	0.14	Fine	0.76	Platykurtic

Table 6. Showing the percentages of different grain-size fractions in the studied samples of Ras Kathib area.

	S.No.	Medium	Gravel	Sand			T. Sand	Mud
				Coarse	Medium	Fine		
Section 1	1	1.9	0.2	9.5	44	45.5	99	0.7
	2	2	0.4	9.8	45	44	98.8	0.8
	3	2	0.5	6.9	47	45	98.9	0.6
	4	2.3	0.1	5	35	59.4	99.4	0.5
	5	1.98	0.1	14	40.5	45	99.5	0.4
	6	1.8	0.3	10	31	54.6	95.6	4.3
	7	2.4	0.2	3.5	28	64.4	95.9	4.0
	8	2.4	0.1	6.3	23.7	64.8	94.8	5.1
	9	2.4	0.1	9.4	31.2	57.2	97.8	2.2
	10	2.3	0.0	7.6	34.2	57.9	99.7	0.3
Section 2	1	2.1	0.2	5.3	47	45	97.3	2.5
	2	2	0.0	6	51	40.7	97.7	2.3
	3	1.9	0.0	4.6	50	44	98.6	0.4
	4	2	0.1	4.5	8.5	84.5	97.5	2.4
	5	1.8	0.0	5	50	44.5	99.5	0.5
	6	2	0.0	5.4	41.7	51.1	98.2	1.8
	7	2.1	0.0	8.3	37.6	52	97.9	2.1
	8	2.4	0.0	6.7	34.2	57.3	98.2	1.8
Section 3	1	1.9	0.0	5	50	41.9	96.9	3.1
	2	2.0	0.0	5.6	54.4	37.1	97.1	2.9
	3	1.9	0.0	5.4	55.2	38	98.6	1.4
	4	2	0.0	6.3	56.7	36.7	99.7	0.2
	5	1.9	0.2	4.5	58	37.3	99.8	0.2
	6	2	0.0	6.3	51.5	42	99.8	0.1
	7	2	0.1	4.2	49.3	44.1	97.6	2.3
	8	1.9	0.0	5.4	50.7	43.5	99.6	0.4

Table 7. List of the studied samples in Al-Urj area is showing the calculated statistical parametrs from grain-size analysis.

	S.No.	Kurtosis ϕ		Skewness ϕ		Sorting ϕ	
Section 1	1	1.1	Poor	0.26	Fine	1.79	Very leptokurtic
	2	1.5	Poor	0.5	Strongly fine	0.83	Platykurtic
	3	1.2	Poor	-0.23	Fine	1.12	Leptokurtic
	4	1.0	Moderate	-0.76	Strongly coarse	0.55	Very platykurtic
	5	0.88	Moderate	-0.89	Strongly coarse	1.12	Leptokurtic
	6	0.78	Moderate	-0.62	Strongly coarse	2.7	Very leptokurtic
	7	1.7	Poor	0.16	Fine	2.2	Very leptokurtic
	8	0.92	Moderate	0.23	Fine	0.42	Very platykurtic
	9	0.85	Moderate	-0.19	Coarse	1.36	Mesokurtic
	10	0.57	Moderate-well	-0.15	Coarse	0.81	Platykurtic
		1.05		-0.17			
Section 2	1	0.61	Moderately well	-0.12	Coarse	0.97	Mesokurtic
	2	2.94	Very poor	-0.04	Nearly symmetrical	0.97	Mesokurtic
	3	1.03	Moderate	-0.23	Fine	1.35	Mesokurtic
	4	1.24	Poor	-0.38	Strongly coarse	1.90	Very leptokurtic
	5	1.27	Poor	0.19	Fine	1.12	Leptokurtic
	6	1.09	Poor	0.42	Strongly fine	1.27	Leptokurtic
	7	1.20	Poor	0.30	Fine	1.80	Leptokurtic
	8	1.20	Poor	-0.03	Nearly symmetrical	4.39	Extremely leptokurtic
	9	0.78	Moderate	-0.16	Coarse	1.23	Leptokurtic
	10	0.70	Moderately well	-0.34	Strongly coarse	0.94	Mesokurtic
	11	0.49	Well	0.0	Nearly symmetrical	0.82	Platykurtic
	12	1.06	Poor	0.22	Fine	0.35	Very platykurtic
		1.13					
Section 3	1	0.80	Moderate	-0.40	Strongly coarse	1.24	Leptokurtic
	2	1.0	Moderate	-0.55	Strongly coarse	1.38	Leptokurtic
	3	1.20	Poor	-0.30	coarse	1.17	Leptokurtic
	4	1.75	Poor	-0.37	Strongly coarse	0.62	Platykurtic
	5	0.8	Moderately well	-0.27	coarse	0.65	Platykurtic
	6	1.30	Poor	-0.33	Strongly coarse	1.12	Leptokurtic
	7	1.1	Poor	-0.15	coarse	0.93	mesokurtic
	8	1.4	Poor	-0.12	coarse	0.98	mesokurtic
	9	1.1	Poor	-0.23	coarse	1.1	mesokurtic
	10	1.0	Poor	-0.21	coarse	1.14	Leptokurtic

Table 8: Showing the percentages of different grain-size fractions in the studied samples of Al-Urj area.

	S.No.	Gravel	Sand			T. Sand	Mud
			Coarse	Medium	Fine		
Section 1	1	1.0	8.3	41.6	43.8	93.7	5.3
	2	21	9.1	28.6	36.2	73.9	5.1
	3	10	4.9	41.7	39.2	85.8	4.2
	4	4.7	2	31	55.1	88.1	7.2
	5	-	12.3	40.1	45.5	97.9	2.1
	6	0.3	8.2	38.7	52.6	99.5	0.2
	7	1.0	1.7	31.6	60.4	93.7	5.3
	8	13	8.4	23.7	41.8	73.9	5.1
	9	8.9	11.4	33.2	41.2	85.8	4.2
	10	3.5	10	40.2	37.9	88.1	7.2
Section 2	1	8.2	5.8	36.5	41.5	83.8	7.9
	2	9.8	6.1	37.1	42.3	85.5	4.7
	3	-	2.7	26.1	50.7	79.5	20.5
	4	-	2.4	23.9	51.2	77.5	22.4
	5	-	2.9	19.8	48.8	71.5	28.5
	6	-	2.4	20.3	49.8	72.5	27.4
	7	-	2.6	20.5	49.2	72.3	27.6
	8	-	2.3	19.7	51.5	73.5	26.4
	9	-	2.1	17.9	50.4	70.4	29.5
	10	-	8.9	45.2	41.7	95.8	4.2
	11	-	9.6	48.5	40.6	98.7	1.3
	12	-	7.3	49.3	39.5	96.1	3.9
Section 3	1	4.2	6.8	39.5	43.5	89.8	5.9
	2	3.2	6.1	38.1	43.3	87.5	9.2
	3	-	1.5	20.3	50.7	72.5	27.4
	4	-	2.5	21.8	51.2	75.5	24.4
	5	-	2.7	19.9	49.7	72.3	27.6
	6	-	2.4	21.6	53.1	77.1	22.8
	7	-	1.3	20.1	50.2	71.6	28.4
	8	-	2.3	19.5	51.7	73.5	26.5
	9	-	2.1	22.4	50.9	75.4	24.6
	10	-	1.9	31.2	46.7	79.8	20.2

Results and Discussion

The recent marine deposits of Al-Hodeidah coast along 50 Km from El-Sheikh Younes at south to Al-Urj at north offer a wide range of characteristics and features which are of sedimentological interest. The beach deposits of the coast are composed mainly of unconsolidated sand consisting of small shells and worm shell fragments, which accumulate above the high water mark by wave action, particularly during periods of high tides. The mud fractions present in considerable amounts. The carbonate producing organisms are dominated by mollusca, followed by corals, foraminifera and bryozoa.

Grain-Size Analysis

The grain size of sediment is an important textural parameter which measures the energy of a depositional environment. For that purpose, 113 samples from Al-Hodeidah coast were subjected to grain size analysis by sieving (Folk, 1974). The grain-size parameters (δI, SKI and KG) were calculated according to the equations and verbal limits given by Folk and Ward (1957).

Sheikh Younes area

The data derived from the grain-size analysis of sediments from three sections in El-Sheikh Younes area, and the calculated statistical parameters show that the mean size of sediments ranges from coarse sand to mud fractions. Gravel fraction is recorded in some samples by few percentages. The sorting of the samples in section 1 ranges from 0.82ϕ (moderately sorted) to 1.99ϕ (poorly sorted), except only one sample no. 13 has value 0.69ϕ (moderately-well sorted), with an average sorting for all samples of 1.29ϕ, which means that the samples are poorly sorted. In section 2, all samples show poorly sorted with sorting value ranges from 1.11ϕ upto 1.97ϕ, with mean average of 1.53ϕ. As well as, the samples of section 3 show poorly sorted with sorting value varies from 1.17ϕ to 1.89ϕ, except only one sample no. 13, which indicate moderately sorted with value of 0.93ϕ.

Sample skewness is varied within each section. In section 1, the skewness of samples ranges from -0.36ϕ (strongly coarse fractio) to – 0.07ϕ (nearly symmetrical) for offshore samples, and strongly fine fraction (0.14ϕ - 0.77ϕ) for onshore samples. In section 2, four samples are skewed towards the coarse fractions (-0.24ϕ - -0.29ϕ), two samples are nearly symmetrical or neutral (0.04ϕ - -0.09ϕ), three samples are fine (0.11ϕ - 0.19ϕ) and two samples are skewed towards strongly fine fractions (0.36ϕ - 0.56ϕ). In section 3, four samples show strongly coarse fraction, two samples are coarse, four samples are nearly symmetrical and three samples are skewed towards fine fractions. The kurtosis of samples in the studied sections ranges from platykurtic – mesokurtic to very leptokurtic catigories.

The sediments are composed of three main fractions (gravel, sand and mud sizes). The sand – size particles are most dominant, ranging from 72.5% upto 99.9%, with an average value of 87.6%. The ratio of gravel size is very low, ranges from 0.2% to 14.4%, with an average 2.4%, while the mud fraction varies from 0.2% to 33.7%, with an average value of 10.24%.

Through grain – size analysis of sediments, El-Sheikh Younes area can be divided into three distinct sediment facies, each one has characteristic features. 1) Fluviatile facies represented by different sand sediments and appeared in section 1 and 2, samples 1-4; section 3, samples 1-2) Tidal flat facies, which is composed of gayish black fine sand, silt and clay dominant by mangrove trees. This facies is represented by samples 5-16 (section1), 5-8 (section 2), 7-8 (section 3). Some regions are characterized by dominant of gray to black mud enriched with organic matter and has H2S odor. 3) Barrier sand facies that represented by samples collected from the spit, and including samples 17-18 (section 1), 9-11 (section 2), and 5-6, 9-13 (section 3). This facies consists of sand gravels and mollusca shell fragments, friable, well sorted. The origin of sand may be from the sand dunes that located in the back shore area

It is obvious that, the source of sediments in first and second facies is fluviatile origin, come from the hinterland by rivers through wadi Seham, and formed first in backshore area and then transported into the coast to form the tidal falt facies by high tide water current. El-Sheikh Younes area is suffered from some pollution that comes from the sewage, which poured to the coast from the adjacent area without treatment. There are three principal wadis: Seham, Al-Aker and Rman which are connected with the coastal area. Wadi Seham is considered the main and important wadi that poured its sediments in the area. Mangrove trees are well developed in the tidal flat areas that characterized by fine sand with dominant mud, quiet water and enriched with organic matter.

Al-Hodeidah area

The sediments in Al-Hodeidah area site are consist mainly of grayish to black fine sand with mud, which are covered in some places with surficial evaporitic deposits or sabkha. The grain size analysis of sediments shows that the sorting of the samples is poor, ranging from 1.10ϕ up to 1.88ϕ, except two samples (12 and 13) from the barrier sand, are moderately well sorted with sorting value of 0.62ϕ - 0.80ϕ. The average sorting of 1.32ϕ, which indicate that the studied samples are poorly sorted. Their skewness ranges from -0.04ϕ to 0.30ϕ. Seven samples (4,7,8,9,11,12,13) are skewed towards the strongly coarse fraction; two samples (5,10) are coarse; four samples (1,2,3,6) are nearly symmetrical or neutral, while one sample (14) is skewed towards the fine fraction. The kurtosis of samples varies from very platykurtic – platykurtic – mesokurtic to very leptokurtic.

The main consituents of sediments are sand and mud sizes. The sand size particles ranging from 33% upto 93% with an average value of 57.32%, while the mud fraction ranges from 7% upto 67% with an average value of 42.7%. Data from the grain-size analysis illustrate that Al-Hodeidah sediment site belonging to fluviatile origin, which characterized by dominant medium to fine sand with mud. These sediments are characteristic tidal flat facies, which has larger extent in the area studied and covered by surficial sabkha deposits, like those found in El-Sheikh Younes area.

Ras Kathib area

The type of sediment in Ras Kathib area is composed mainly of medium to fine sand graines and mud. From the grain-size analysis of sediments; the sorting of all studied samples ranges from 0.59ϕ to 0.90ϕ (moderately-well to moderate). The skewness of samples is nearly different between the studied three sections. In section 1, the skewness of samples ranges between nearly symmetrical (0.08ϕ) to coarse fractions (-0.18ϕ). In section 2, four samples are skewed to nearly symmetrical and other four are skewed towards the fine fractions; while in section 3, all samples are skewed towards the fine fractions, with skewness value ranges from 0.14ϕ to 0.24ϕ. The kurtosis of samples in the three sections varies between platykurtic (0.76ϕ - 0.86ϕ), mesokurtic (0.91ϕ - 1.05ϕ) and leptokurtic (1.13ϕ - 1.22ϕ), except only one sample no. 6 in section1, which shows very leptokurtic of kurtosis value 2.23ϕ.

It is obvious that most of the studied samples indicate fluvial sand environment, except few samples that point to coastal sand. Therefore, there are two main sources of sediments in Ras Kathib area including River and coastal sources. The fluviatile source may be periodically through interrupted intervals and attributed to the flooding of the wadi that poured its sediments in this area. The marine source results from the impact of marine currents, waves, tides and somewhat sea level changes, which lead to movement of sediments into the shore area. The increased foreshore area of Ras Kathib spit indicates that there is continuous sedimentation, where the thickness of sediments increased towards the khore and form small spites within this area. This may due to quiet currents, beside the continuous sedimentation by the wadi. Therefore, Ras Kathib area is divided into two regions: 1) Construction region, which is characterized by low energy environment with continuous sedimentation and included marine spit and bay, 2) Destruction region, the area that exposed to wave and currents action, which reflect high energy environment.

In the tidal flat area, there is a thin layer of non-crystallized halite and died algae found on the surface of the sand sediments. This layer is formed during the high tide and covered the foreshore area and then exposed to evaporation, which led to form evaporitic surface sediments. Generally, In Ras Kathib area, the ratio of clay increased gradually from the middle of the spit ranges from (91-44.1 %) of the heavy fractions (average 69.9 %), whereas in Al-Urj coastal samples range from (90.7-15.3 %) with the average value 65.9 %. The opaque minerals are represented mainly by magnetite with few ilmenite and hematite minerals. The sediments of Al-Urj coast are relatively enriched in opaque compared with others sites (69.9 % versus 65.9 %).

Non opaque heavy minerals

The non-opaque minerals of the studied samples are composed of amphibole, zircon, epidote, rutile, garnet, staurolite and tourmaline. The ultrastable group consists of zircon, tourmaline and rutile (abbreviated ZTR). The unstable group comprises epidotes and amphiboles. The remaining staurolite and garnet are considered the metastable heavies. The ratio between unstables and ultrastables has been used as a crude measure of the mineralogical maturity or the complexity of the heavy mineral assemblage (El-Shahat, 1993b).

Amphiboles

Amphiboles are the most common non-opaque minerals recognized in the samples. They are represented mainly by hornblende and biotite. The ratio of amphiboles in El-Sheikh Younes area ranges from (4.8-69.4 %) with the average value 32.2 %; in Al-Hodeidah site (6.3-64.5%); in Ras Kathib coasts (5.9-73.8%), whereas, Al-Urj coast ranges from (2-100 %), with the mean value 32.3 %.

Zircon

Zircon is the second most common non-opaque heavy minerals in all samples. It is known as one of the most stable minerals, which persist through several sedimentary cycles and diagenesis, as well as, through metamorphism. In the studied samples, it occurs as colourless grains in different shapes elongated, rounded to subrounded or as euhedral with bipyramids termination, subhedral, and zoning were frequently observed. Euhedral zircon is generally drived from intrusive granitiods, whereas rounded shape, especially high rounded index, is regarded as a criterion of detrital origin and occasionally may be caused magmatic corrosion (Mange and Maurer, 1992). Zircon is relatively found in El-Sheikh Younes coast and it reaches up to 53.4 % with a mean value 14.7 % and 28.6 % with a mean value 15.2 % in the other coasts.

Epidotes

They include common pistachite and rare zoisite. Pistachite is represented by lemon yellow to yellowish green varieties. These minerals are mainly the yellowish green varieties and are in the form of anhedral, irregular prismatic grains, rounded to subrounded and show weak pleochroism. Epidotes reach up to 30.8 % with a mean value 13.0% in the Ras Kathib coast and in Al-Urj coast reach up to 35.2 % with a mean value 14.5 %.

Rutile

Rutile occurs in deep red, golden yellow, orange and brown varieties. The deep red variety is the most common. Rutile is present as subhedral, rounded to subrounded with frequent pleochrism. It is recorded in about 11.9 % of the examined samples, reaching up to 38.5% in the Ras Kathib coast and reach up to 35.2 % in Al-Urj coast with a mean value 9-6 %.

Tourmaline

Tourmaline is present as subangular to rounded elongated prismatic grain. It has various coloures ranging from yellowish brown to green with strong pleochrism. The tourmaline content is relatively enrich in the studied sediments of Al-Urj area.

Staurolite

Staurolite occur as platy grains with irregular outlines and uneven fractures, ranging in colour from golden and brownish yellow to pale reddish brown. They display a strong pleochrism and a few grains contain opaque inclusions. The average of staurolite is lightly constant in the sediments of Al-Urj coast (10.2, 10 %)

Garnet

Garnet occurs as colourless, pink to purple rounded grains and its average content reaches 11.3 % of the total non-opaque in the Al-Urj coast and it is recorded in the most samples.

PROVENANCES

Examination of the light fractions in the studied samples reflects the predominance of quartz and frequent amounts of rock fragments with minor feldspars. Quartz grains suggest their derivation from acidic igneous and metamorphic rocks. Therefore, the exposed volcanic rocks of the Yemeni Desert that close to Tihama plain might be considered, in part, as a reasonable source for those detrital sands.

The heavy minerals have been extensively used in the reconstruction of paleogeography and history of the source and depositional areas. The observed ferromagnesian minerals (epidotes and amphiboles) are the major constituents of the non-opaque heavy mineral assemblages. These detrital minerals are important constituents of the intermediate and basic igneous rocks, and high grade metamorphic rocks. This may support the partial contribution from the adjacent igneous rocks of Tihama plain.

The stable minerals are represented by zircon, tourmaline (originally derived from acidic igneous rocks), ilmenite, magnetite, rutile (usually indicating basic igneous rocks), garnet and staurolite (detrital from metamorphic sources). This assemblage involves the contribution from different sources by the active wadis. However, the presence of some rounded grains of ultrastable zircon, tourmaline and rutile is attributed to derivation from earlier sedimentary rocks and deposition under energetic conditions.

Non Carbonate Minerals

Non-carbonate minerals such as: quartz, magnetite, halite and gypsum are detected in the coastal samples of the studied area. The data showed that, detrital quartz is abundant in all studied samples and it is the most stable mineral under various sedimentary environments. The majority of quartz grains are derived from plutonic granitoid rocks, acid gneisses and schists.

Quartz

Quartz is one of the most common detrital minerals in the studied samples. It is identified microscopically. The percentage of quartz in the samples of Ras Kathib ranges from 4 to 35.9 % with a mean value 14.5 %, while in Al-Urj samples it ranges from 0.0 to 55.3 % with a mean value of 18.8 %. The maximum values of quartz were recorded in El-Sheikh Younes samples.

Magnetite

Magnetite is common in most of Al-Urj samples. Its percentage ranges from 0.0 to 3.6 % with a mean value 1.7 %, while it ranges from 0 to 2.3 % with the average value 0.7 % in El-Sheikh Younes area.

Evaporites

Only two evaporite minerals (gypsum and halite) are recognized in the studied samples. The geological evidences and present-day occurrence show that gypsum and halite could be precipitated during arid periods where the sediment supply was low and the rate of evaporation was high. Halite mineral was deposited under subaqueous condition possibly in a lagoonal environment and subaerilly in coastal areas. Although, halite is more common than gypsum in the studied samples and it ranges from 0.0 to 1.6 % with a mean value 0.2 % in the Ras Kathib samples, whereas it ranges from 0.0 to 1.8 % with a mean value 0.4 % in the El-Sheikh Younes samples.

Conclusion

Overall, from the results of grain-size analysis of sediments that distributed along 50 km of Al-Hodiedah coast and the comparison of the data resulted from all the studied sections, it is clear that the studied coastline of Al-Hodeidah area is affected by several factors that caused the different sedimentary characters. Of these factors, Terrestrial origin, this is represented by weathering products that transported by means of water or winds through the wadis into coastal area. These terrigenous sediments are fluviatile origin, which transported by rivers and their thickness or amounts based on the rainfall rate on the hinterland. Other sediments are of eolian origin, where the sand garins are transported by wind from the neibouring sand dunes along the coastline and help in formation of sand beach.

The studied area is also affected directly by some coastal processes that result from the influence of tides, sea currents, wave action and sea level change. Tidal processes play an important role in the form of sediment characters and its distribution along the area studied. During the high tide, sea water covered large flat area such as in Ras Kathib, El-Sheikh Younes and Al-Hodeidah site, when sea water is regressed during the low tide, some water remains in these mud flatsand exposed to evaporation due to increasing temperature, which lead to form salt marshes or sabkha deposits. However, longshore currents transport of sediments from area to other parallel to the shore and these currents lead to redistribution of sediments along the coast. Wave action has important role in the distruction and construction processes along the coast.

REFERENCES

Al-Ahdel, A. O. (1989): Geophysical studies on the Wadi Surdud area, Tihama plain, Republic of Yemen. Unpubl. M.sc. thesis, Sana'a University, Yemen, 200 pp.

Al-Mayah, A. and Heba, H. M. A. (2001): Application and environmental study for plains along coastal of Red sea Yemen, Marine Mesopotamia Iraqi 16 (2), p. 169-186.

Barratt, L., Dawson, S., A., Ormand, R. and McDowell, R. (1987): Yemen Arab Republic Marine conservation survey, volume, Distribution of habitats species along the Y.A.R. coastline, unpublished report International Union for servatio of Nature and Natural Resources.

Beltagy, A. I. (1984): Elemental geochemistry of some recent marine sediments from Red Sea. Bull. Inst. Oceanogr and Fish., ARE, Vol. 10, p. 1-12.

Blatt, H. (1967): Original characteristics of clastic quartz grains. Jour. Sed. Petrology, Vol. 37, p. 401-424.

Carver, R. E. (1971): Procedures in sedimentary petrology, Wiley-Intersciences, 653pp.

Coleman, R. G. (1974): Geological background of the Red Sea. In: Burk, C. A. and Drake, C. L. (Ed.) The geology of continental margins. Springer-Verlag, p. 743-51.

Dekker, H. and Capelle, F. G. C. (1994): Survey of Yemen Red Sea Shells collected by TBIA-1 Expedition, 1993. Dekreukel jrg 30nrs, 7-10, p. 79-147.

Dill, H.G. (1998): A review of heavy minerals in clastic sediments with case studies from the alluvial-fan through the nearshore-marine environments. Earth Sci. Rev., 45, p. 103-132.

Duane, D. B. (1964): Significance of skewness in recent sediments, Western Panlico Sound, North Cerolina, Jour. Sed. Petrology, Vol. 34, p. 864-874.

El-Anbaawy, M. I. H. (1993): Reefal facies and digenesis of Pleistocene sediments in Kamaran Island, Southern Red Sea, Republic of Yemen. Geol. Soc. Egypt, Vol. 37, p. 137-151.

El-Anbaawy, M. I. H. and Al-Awah, M. A. H. (1993): Opaque mineralogy of some beach sands, Yemen Red Sea coastal area. Geol. Soc. Egypt, Vol. 37, p. 39-52.

El-Sayad, A. A. Y. and Abdu, A. (1990): Geomorphologic study of wadi Surdud Basin, West Central Yemen Arab Republic, Faculty of Arts, University of Sana'a, Vol. 11, p. 3-20.

Folk, R. L. (1954): The distinction between grain size and mineral composition in sedimentary rocks: Journal of Geology, Vol. 62, p. 344-359.

Folk, R. L. (1959): Pratical petrographic classification of limestones: Bulletin of American Association of Petroleum Geologists, Vol. 43, p. 1-38.

Folk, R. L. (1974): Petrology of sedimentary rocks. Hemiphills, Sec. Ed., 182 pp.

Folk, R. L. and Robles, R. (1964): Carbonate sands oflsla Perez Alacran reef complex, Yucatan. J. geol., Vol. 72, p. 255-292.

Folk, R. L. and Ward, W. C. 1957: Brazos River bar, a study in the significance of grain size parameters. Jour. Sed. Petrol., v. 27, p. 3-26.

Friedman, G. M. (1961): Distribution between dune, beach and rivers sands from their textural characteristics. Jour. Sed. Petrol., p. 31-51.

Friedman, G. M. (1967): Dynamic processes and statistical parameters compared for size frequency distribution of beach and river sands. Jour. Sed. Petrology, Vol. 37, p. 327-345.

Friedman, G. M. (1971): Staining in procedures in sedimentary petrology (Ed. By R. E. Carver; Jhon Wily and Sans), New York, p. 511-530.

Heba, H. M. A. and Al-Mudaffer, N. (2000): Trace metals in fish, mussles, shrimp and sediment from the Red Sea coast of Yemen. Bull. Nat. Inst. Oceanogr. & Fish, ARE, Vol. 26, p. 151-165.

Heba, H. M. A., Maheub, A. R. S. and Al-Shawafi, N. (2000): Oil pollution in Gulf of Aden/Arabian Sea Coasts of Yemen. Bull. Nat. Inst. Oceanogr. & Fish, ARE, Vol. 26, p. 139-150.

IUCN (1987): Preliminary coast zone management and recommendations for the Yemen Arab Rebuplic. Marine conservation survey, IUCN/Red Sea and Gulf of Aden environment program, Gland Switzerland and Jeddah, Saudi Arabia VII, 70 pp.

Lewis, D. W. and Mc Conchie, D. (1994): Practical sedimentology (2nd Ed.). Chapman, Hall. Ehr. New York, 213 pp.

Moiola, R. J. and Weiser, D. (1968): Textural parameters, and evaluation. Jour. Sed. Petrology, Vol. 38, p. 45-53.

Nordstrom, K. F. (1977): The use of grain size statistics to distinguish between high and moderate energy beach environment. J. Sed. Petrol., Vol. 47/3, p. 1287-1294.

Passega, R. (1964): Grain size representation by CM patterns as a geological tool. Jour. Sed. Petrology, Vol. 38, p. 830-847.

Passega, R. and Byramjee, R. (1969): Grain-size image of clastic deposits. Sedimentology, Vol. 13, p. 133-252.

Pettijohn, F. J. (1975): Sedimentary rocks. Harper and Row Publishers, New York, 628 pp.

Pettijohn, F. J., Potter, P. E. and Siever, R. (1972): Sand and sandstone. 1st edition. Springer-Verlag, New York, 618 pp.

Picard, M. D. (1971): Classification of fine-grained sedimentary rocks: Journal of Sedimentary Petrology, Vol. 41, p. 179-195.

Rushdi, A. I., Abubakr, M. M. and Heba, H. M. (1994): Marine environment of Yemen policy and strategy preconditions and requirements for Arab world conference. Yarmouk Univ. 48 pp.

Sahu, W. D. (1964): Depositional mechanisms of clastic deposition. Am. Ass. Petrol. Geol. Bull., Vol. 34, p. 73-83.

Voggenreiter, W. R., Hotzl, H. and Jado, A. R. (1988): Red Sea related history of extension and magmatism in the Jizan area (southwest Arabia): Indication for simple-shear during early Red Sea rifting. Geol. Rdsch., Vol. 77, p. 257-274.

دراسات ترسيبه ومعدنيه على الرواسب الشاطئية فى منطقه الحديده- العرج- جنوب البحر الاحمر- اليمن

محمد جاشان

تتناول الدراسة الحالية وصف دقيق للرواسب الشاطئية لساحل مدينة الحديدة التى تطل على البحر الأحمر بالجمهورية اليمنية. لقد تمت الدراسة على 113 عينة رسوبيات سطحية جمعت من اربعة مناطق بحرية ابتداء من منطقة الشيخ يونس جنوب الحديدة ثم بالقرب من ميناء الحديدة ، ورأس كثيب ومنطقة العرج شمال مدينة الحديدة. وكان الهدف من الدراسة هو القاء الضوء على نوعية الرواسب الشاطئية وصفاتها النسيجية وتكوينها المعدنى وبيئة الترسيب. ومن التحليل الحجمى للرواسب اتضح ان معظم الرواسب الشاطئية المتواجدة على ساحل الحديدة ترسبت تحت ظروف نهرية وفى بيئة ذات طاقة عالية حيث ان الرواسب مكونة من رمال مختلطة بقليل من الطين مع جزيئات من الهياكل الجيرية للعديد من الكائنات البحرية وخاصة الفورامنفرا ومجموعة الرخويات بالأضافة الى هياكل الطحالب السليسية، كما ان وجود الحبيبات الكربوناتية الدقيقة يرجع الى ان البيئة قد تكون لاغونية. كما أن الدراسة أوضحت أن مصادر هذه الرواسب قد تكون

1- رواسب فتاتية مصدرها نهرى ومن المحتمل أن تكون دورية أى خلال فترات متقطعة وسمك هذه الرواسب يعتمد على معدل سقوط الأمطار فى المناطق المجاورة.

2- رواسب ذات أصل رياحى حيث انتقلت حبيبات الرمال بواسطة الرياح من الكثبان الرملية المجاورة للشاطىء وتساعد على تكوين الرمال الشاطئية

3- رواسب شاطئية ناتجة من تأثير التيارات البحرية والأمواج والمد والجزر وتغير منسوب البحر والذى بدورهم يقومون بنقل الرواسب الى الشاطىء.

وأوضحت الدراسة ان العمليات الشاطئية تلعب دورا هاما فى تكوين النسيج الرسوبى وتوزيع الرواسب على المنطقة الشاطئية ، كما أن نشاط الأمواج لها دور هام فى عمليات البناء والهدم على طول الساحل.

ومن دراسة المحتوى المعدنى للرواسب وجد أن مجموعة المعادن الثقيلة تتواجد بوفرة بالرواسب وتشمل معادن الأمفيبول، الأبيدوت، الزيركون، الروتيل ، الجارنت والتورمالين والتى تكون مشتقة من الصخور النارية والبركانية المتواجدة بالقرب من سهل تهامة وتنقل عبر الأودية الى المنطقة الشاطئية ، بالأضافة الى معادن الكوارتز، الهيماتيت ، المجناتيت، والمتبخرات مثل الهاليت والجبس.