دراسة عن ميناء لبدة الأثري و خصائص الشاطىء، مدينة لبدة، ليبيا

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تم إنشاء ميناء لبدة منذ حوالي ٢٥٠٠ سنة خلال فترة الإمبراطورية الرومانية. أدى نمو حاجز رملي إلى إغلاق مدخل الميناء و اطماء حوض الدوران.

لوحظ وجود ظاهرات جيومورفولوجية ناتجة عن تأكل الشاطىء ممثلة أساسا بالجروف و الأرصفة البحرية و المسلات البحرية.

يتكون شاطىء ميناء لبدة البحري من رمال تتدرج في حجمها من الخشن حتى المتوسط، كما يتغير شاطىء الميناء من رملي إلى صخري شرق الميناء، حيث لوحظ زيادة في نسبة البيكربونات بالمياة الجوفية المتواجدة بالمنطقة الساحلية.

تم تعيين خصائص الأمواج و حالة البحر بمنطقة الدراسة و ذلك باستخدام المعلومات الرياحية و إتباع مقياس بيفورد، كما تم تعيين الاتجاة الذي يتخذة الشاطىء المتزن مع طاقة الأمواج ولقد تبين أنة شمال ٦٧° غرب – جنوب ٦٧° شرق. و لقد أوضحت القياسات و المشاهدات الحقلية أن خط الشاطىء الحجري المتآكل هو نفس الاتجاة الذي تم تعيينة للشاطىء المتزن.

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A STUDY ON ANCIENT LIBDA SEA PORT AND ITS BEACH CHARACTRRISTICS, LIBDA CITY, LIBYA

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ABSTRACT

Libda sea port has been constructed during Roman Empire, about 2500 years ago. Sea cliffs, sea platforms, wave related furrows and ridges and sea stacks are the most noticeable landforms which resulted from the erosion of the shore. The determined orientation of the equilibrium shoreline is N67W-S67E.

Sand bar blocked the access canal of the port and the rotation area was completely dumped. The beach sediments range in size from coarse to medium sand. Beach rocks were also observed at the sites with groundwater has relatively higher bicarbonate content along the hinter coastal area.

INTRODUCTION

Libda city lies about 130 Km east to Trapoli. One of the natural hazards threatening the beach of Libda city is coastal erosion (Fig. 1). Wind blowing over the sea surface forms waves, which transfer some of the winds energy to the shorelines (Plummer and McGeary, 1991). This energy is spent primarily in eroding and transporting sediments along the surf zone where waves are breaking and releasing energy (Tarbuch et al., 2000). Sea waves pick up sand grains and transport them along the shore by longshore current moving parallel to the shoreline. Usually, more sediments are carried by the longshore currents than that transported offshore by rip currents and storm waves or to backshore dunes by sea breezes (Chernicoff and Venkatakrishman, 1995). However, beaches are modified by erosion and accretion until become oriented at right angles to the onshore resultant of wind-generated waves (Bird, 2000).

Various studies such as those reported by the Intergovernmental Panel on climate change (Houghton et al., 1995) indicate that, global weather systems may be changing in part due to human activities. Coastal management plans as well as protection structures designed today to face conditions during their designed lifetime that are significantly different from their early history. Generally, engineering works deal with processes and interactions in human time. The engineer does not often design for time periods much longer than 100 years (Mathewson, 1981). The proper structural device must take into consideration the wave energy magnitude expected at the site.

Libda port was constructed during Roman Era, about 2500 years ago (Mathewson, 1981). The port inlet was stabilized with two jetties extending N52E – S52W (Fig. 2). The jetties secure the inlet and keep it from being closed (Merritts et al., 1997). The jetties were designed to intercept the incoming wave energy and provide an area of reduced energy.

According to the Meteorological Authority data of Al-Khums station, the climate of the coastal area in concern is semiarid (rainfall ranging between 200 to 250 mm/y). Summer is generally dray and hot with temperature ranging from 15 to 40^0 C while winter is occasionally rainy and cool with temperature ranging from 0 to 25^0 C. Humidity is ranging from 60% to 75%.

The present study intends to shed light on the beach erosion and accretion processes and the characteristics of the present dumped ancient Libda sea port.

MATERIALS AND METHODS

Detailed wind data for the years 2000-2001 were obtained from Meteorological Authority of Al-Khums station. The wind data represent the wind speeds every three hours for 36 wind directions.

The percentage duration (hours per month) of winds which produce waves that affect beaches are calculated. The sea state condition and the wave parameters are determined using the Beaufort Wind Scale of Thurman (1981).

Frequencies of the wind-generated waves (> 5.5 m / sec) are calculated and graphically presented after Bird (2000). The onshore resultant waves are obtained by drawing vectors of winds to which the coastline is exposed. The vectors are obtained by multiplying the frequency of winds in each Beaufort wind scale (> 3) category by the cube of the mean velocity (V^3) of that category in a directional diagram.

Beside field observations and measurements documented with photos, twenty one beach samples were collected at about 400 m interval (Fig.3). Grain size analysis was carried out using the standard sieving technique. Cumulative curves were prepared and statistical grain size parameters were calculated according to Folk and Ward (1957). Moreover, five groundwater samples were collected along the hinter coastal area (Fig. 3). Hydrogen ion concentration was measured in the field by using a pocket pH meter. Salinity was determined using an inductive salinometer. The major cations including Na^+, K^+, Mg^{++}, and Ca^{++} were determined using atomic absorption spectrometer. Major anions including Cl^-, SO_4^{--} and HCO_3^- were determined according to Adams (1990).

RESULTS AND DISCUSSION

Sea State

Wave parameters and annual sea state along the study area are given in Table (1). The waves that affect on Libda shore (with Beaufort

Scale > 3) have total duration of 23.89 % with highest wave up to 6.8 m (Table 1).

It is found that, the onshore waves have frequencies of 59.5 % and 40.5 % for the eastward and westward waves respectively and the net movement of the shore sediments is toward east (Fig. 4).

Annual frequency of onshore waves are given in Table (2).The onshore resultant wave energy is obtained by drawing vectors of wind generated waves to which Libda coastline is exposed (Table 3 and Fig. 5). The obtained onshore resultant wave energy is toward S23W. Therefore, the resultant orientation of the equilibrium shoreline is N67W-S67E.

Geomorphology

Libda beach is mainly unconsolidated sandy beach (Fig. 1). It may become rocky characterized by wave cut cliffs, wave related furrows and ridges, sea platforms and sea stacks (Figs 6, 7 and 8).

The steep cliffs are at or just landward of the shoreline and rise up to 1.2 m above the water level (Fig. 6). Sea platforms are planed off by waves and widened as the sea cliffs retreat (Fig. 6). Sea stacks result from a combination of wave energy forces with differences in resistance of rock to erosion. They are remnant rocks after the surrounding less-resistant materials have been eroded by wave activity (Fig. 7).

It is worthy to mention that, the determined orientation for the equilibrium shoreline is in agreement with that observed at present in the field. The sea cliff along the eroded rocky shore takes the direction of the obtained equilibrium beach orientation (N67W-S67E). Also, the erosional furrows and ridges, related to wave action in rocky beach are extending N23E-S23W parallel to the obtained onshore resultant wave energy (Fig. 8).

Field observations show that, a sand bar is well developed inside the access canal in between the port jetties (Fig. 9). Moreover, the rotation area is completely filled with sediments.

Sediment Characteristics

The grain size parameters and description of the studied beach sediments are given in Table (4) and Fig. (10). Mean grain size values range between 0.76 Ø (coarse sand) to 1.93 Ø (medium sand). The values of the graphic standard deviation range between 0.22 Ø (very well sorted) and 0.60 Ø (moderately well sorted). The inclusive graphic skewness ranges between -0.08 (near symmetrical) and 0.29 (fine skewed).

The grain size of beach sands is larger where the wave energy is greater (El-Fishawi and Molnar, 1983 and Bell, 1998). The studied beach sediments are subjected to different energy levels possibly due to the erosion and accretion processes east and west to Libda sea port respectively. The percentages of coarse sand fraction are up to 86 % and 60 % east and west to Libda sea port respectively (Fig. 11).

Hydrochemical Analysis

Slabs of beach rock exposed near high tide and slope seaward are composed of calcareous sandstone (Figs 6 and 8). According to Schwartz et al. (1989), beach rock formed as a layer of beach sand becomes consolidated by secondary deposition of calcium carbonate, precipitated from ground water in the zone between high and low tide. Precipitation of carbonates in the zone of fluctuating water table within a beach, related to rise and fall of tides, can cement beach sand into hard sandstone layers. Therefore, groundwater samples were collected from the hinter coastal area for determining their bicarbonate contents (Fig. 3).

The chemical analysis of ground water samples (Table 5 and Fig 12) show that, bicarbonate content of relatively higher concentrations are observed along the site of beach rock. This agrees with similar conclusion reported by Abdel Galil (2004) on the beach rocks of northern Sinai coast.

CONCLUSIONS

Libda port was constructed during Roman Era, about 2500 years ago. Nowadays, the port is blocked by sand bar and the rotation area is completely filled.

The most noticeable landforms due to erosion of the rocky coast are steep cliffs, wave related furrows and ridges, sea platforms and sea stacks. The beach sediments east to Libda port show relatively higher percentages of coarse sand fraction compared with that to the west possibly due to erosion process.

The waves affecting Libda shore have total duration of 23.89 % with highest wave up to 6.8 m and net movement of the shore sediments toward east. The estimated onshore resultant wave energy is toward S23W and the resultant orientation of the equilibrium shoreline is N67W-S67E.

The determined orientation for the equilibrium shoreline is in agreement with the field observation. The sea cliffs along the eroded rocky shore take the direction of the obtained equilibrium beach orientation (N67W-S67E). Groundwater bicarbonate contents of relatively higher concentrations are observed along the rocky beach.

Table (1): Annual sea state and description of wave parameters along Libda area.

Appearance of the sea	Small waves	Moderate waves	Large waves	Waves streaks	Total Duration %
Descriptive Term	Moderate breeze	Fresh breeze	Strong breeze	Near gale	
Beaufort Number	4	5	6	7	
Speed (Km /h)	20	30	40	50	
Average Height (m)	0.33	0.88	1.8	3.2	
Average Length (m)	10.6	22.2	39.7	61.8	
Average Period (Sec)	3.2	4.6	6.2	7.7	
Highest Waves (m)	0.75	2.1	3.9	6.8	
Duration %	17.76	5.72	0.35	0.06	23.89

Table (2): Annual frequency of onshore waves that have effect on Libda shore.

Beaufort Number	S 30 E ↘	S ↓	S 30 W ↙	S 60 W ↙	W ←
4	1.81	5.08	1.75	1.64	4.15
5	0.29	2.86	0.23	0.35	0.76
6		0.18			0.06
Total	**2.1**	**8.12**	**1.98**	**1.99**	**4.97**

Table (3): Onshore waves vectors (calculated after Bird,2000).

V	V^3	S 30 E ↘	S ↓	S 30 W ↙	S 60 W ↙	W ←
20	8×10^3	14480	40640	14000	13120	33200
30	27×10^3	7830	77220	6210	9450	20520
40	64×10^3		11520			3840
Total		**22310**	**129380**	**20210**	**22570**	**57560**

Table (4): Description of the beach sediments according to their grain size parameters.

Location	Sample Number	MZ	σ1	SK1	Description		
East	**1**	1.68	0.48	-0.06	Medium Sand	Well Sorted	Near Symmetrical
	2	1.57	0.43	0.03	Medium Sand	Well Sorted	Near Symmetrical
	3	0.92	0.57	0.28	Coarse Sand	Moderately Well Sorted	Fine Skewed
	4	1.22	0.45	0.24	Medium Sand	Well Sorted	Fine Skewed
	5	1.35	0.38	0.24	Medium Sand	Well Sorted	Fine Skewed
	6	1.13	0.45	-0.05	Medium Sand	Well Sorted	Near Symmetrical
	7	0.82	0.40	0.25	Coarse Sand	Well Sorted	Fine Skewed
	8	1.93	0.42	-0.05	Medium Sand	Well Sorted	Near Symmetrical
	9	1.21	0.32	0.02	Medium Sand	Very Well Sorted	Near Symmetrical
	10	0.76	0.22	0.05	Coarse Sand	Very Well Sorted	Near Symmetrical
	11	1.55	0.27	-0.08	Medium Sand	Very Well Sorted	Near Symmetrical
	12	1.15	0.51	0.00	Medium Sand	Moderately Well Sorted	Near Symmetrical
	Average	**1.27**	**0.41**	**0.07**	**Medium Sand**	**Well Sorted**	**Near Symmetrical**
Inside Libda Port	**13**	1.52	0.55	0.02	Medium Sand	Moderately Well Sorted	Near Symmetrical
	14	1.80	0.30	-0.02	Medium sand	Very Well Sorted	Near Symmetrical
	Average	**1.66**	**0.43**	**0.00**	**Medium Sand**	**Well Sorted**	**Near Symmetrical**
	15	1.47	0.38	0.09	Medium Sand	Well Sorted	Near Symmetrical
	16	0.87	0.59	0.03	Coarse Sand	Moderately Well Sorted	Near Symmetrical
	17	1.65	0.35	-0.01	Medium Sand	Well Sorted	Near Symmetrical
	18	1.27	0.34	0.28	Medium Sand	Very Well Sorted	Fine Skewed
	19	0.98	0.48	0.29	Coarse Sand	Well Sorted	Fine Skewed
	20	1.05	0.60	0.00	Medium Sand	Moderately Well Sorted	Near Symmetrical
	21	0.92	0.56	0.17	Coarse Sand	Moderately Well Sorted	Fine Skewed
West	**Average**	**1.17**	**0.47**	**0.12**	**Medium Sand**	**Well Sorted**	**Fine Skewed**

Table (5): Chemical analyses of ground water samples collected from the hinter coastal area.

Sample Number	pH	E.C. mmohs	T.D.S mgm/L	Unit	Na^{+}	K^{+}	Mg^{++}	Ca^{++}	Cl^{-}	SO_4^{--}	HCO_3^{-}	Beach Type
I	7.1	3.30	2350	ppm	377	19	113	244	836	527	232	Sandy
				epm	16.39	0.49	9.29	12.18	23.58	10.97	3.80	
				%	42.74	1.28	24.22	31.76	61.49	28.60	**9.90**	
II	7.2	2.77	1898	ppm	280	7.4	132	140	549	400	390	**Rocky**
				epm	12.17	0.19	10.36	6.99	15.48	8.32	6.39	
				%	40.28	0.63	35.95	23.14	51.28	27.56	**21.17**	
III	7.3	1.96	1350	ppm	160	12	105	99	272	392	306	**Rocky**
				epm	6.96	0.31	8.63	4.94	7.67	8.16	5.01	
				%	33.40	1.49	41.41	23.70	36.80	39.16	**24.04**	
IV	7.3	2.75	1670	ppm	368	9	54	126	660	214	239	Sandy
				epm	16	0.23	4.44	6.29	18.61	4.46	3.92	
				%	59.35	0.85	16.47	23.33	68.95	16.52	**14.53**	
V	7.2	1.94	1210	ppm	230	15	58	93	480	206	122	Sandy
				epm	10	0.38	4.77	4.64	13.53	4.28	1.99	
				%	50.53	1.92	24.10	23.45	68.33	21.62	**10.05**	

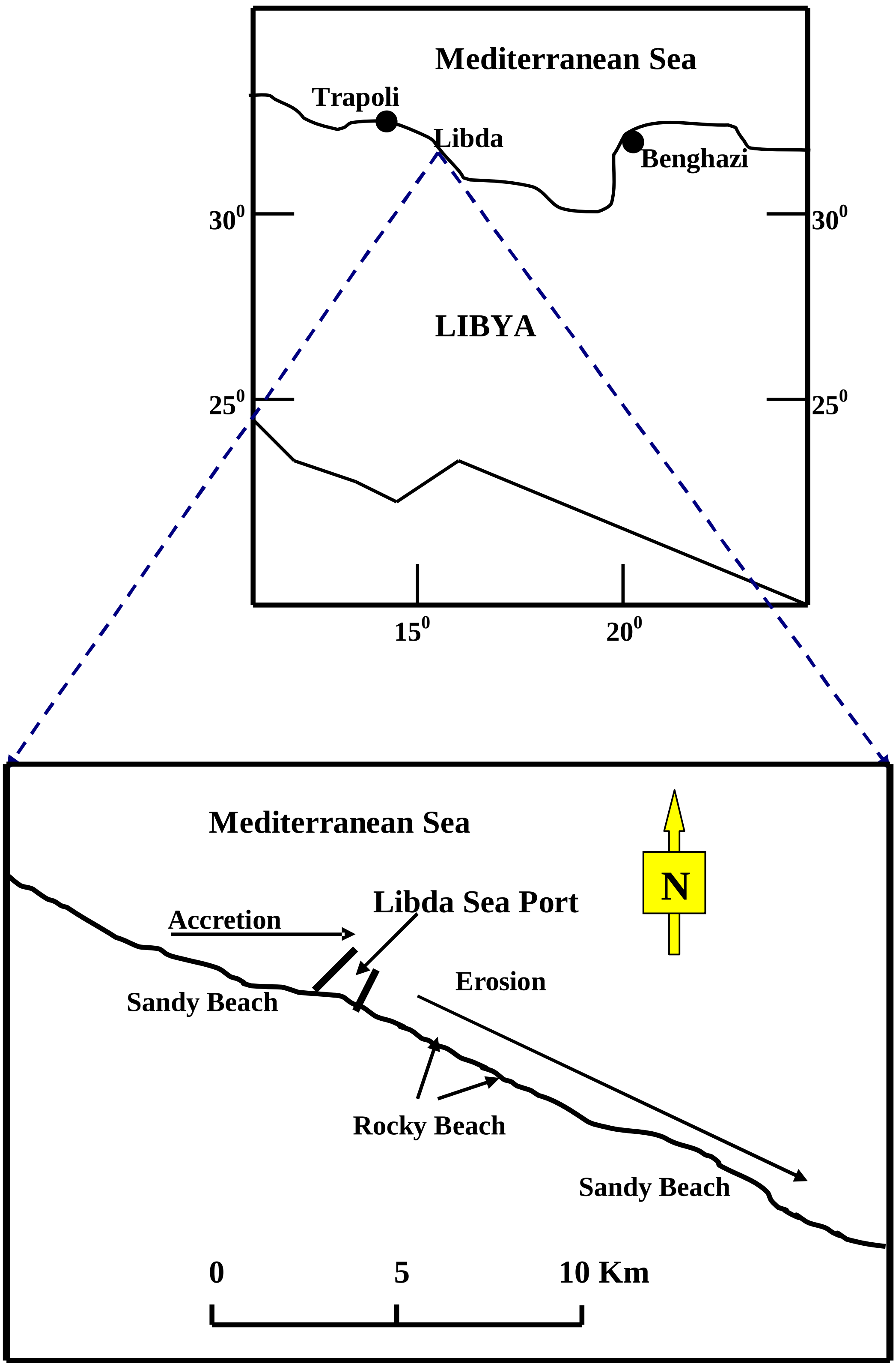


Fig. (1): The study area and the sites of erosion and accretion.

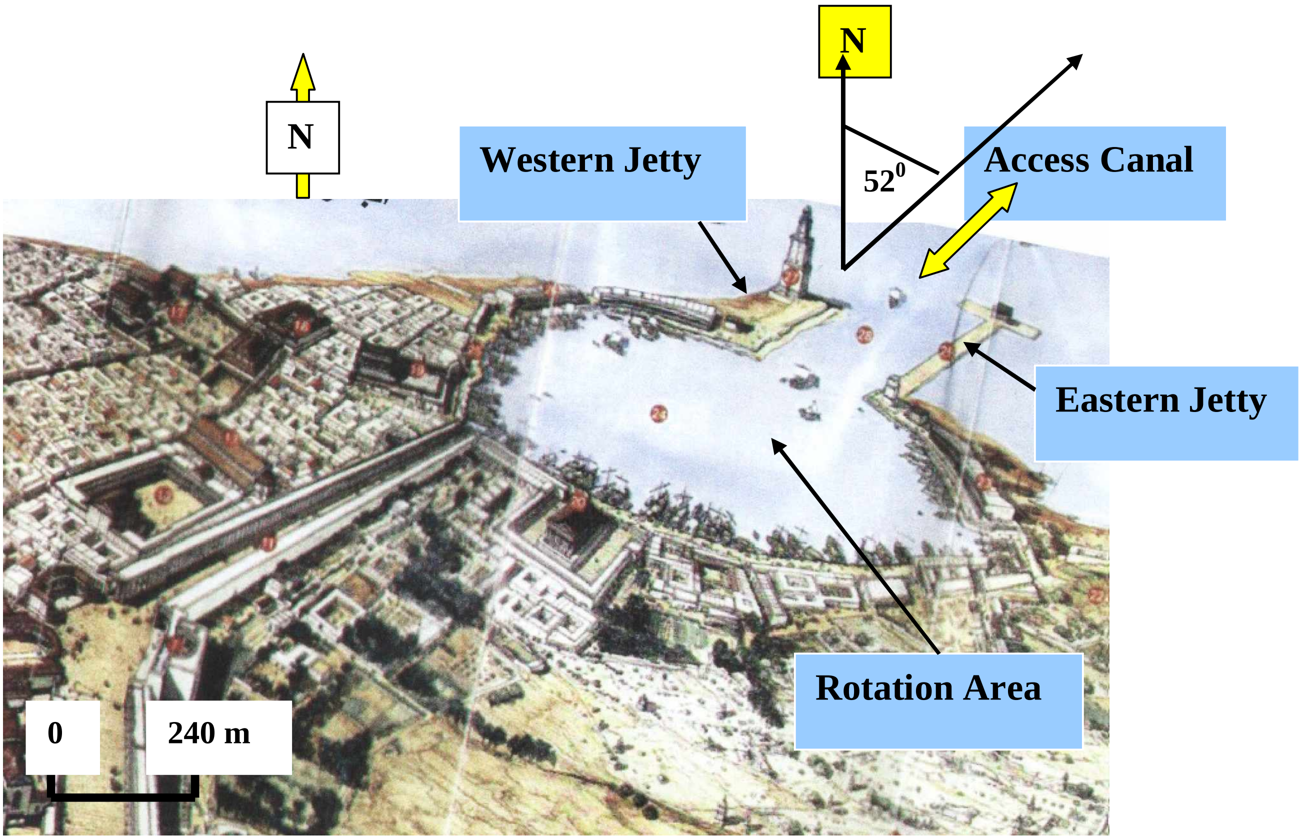


Fig. (2): A map of the ancient Libda sea port from the archeological document.

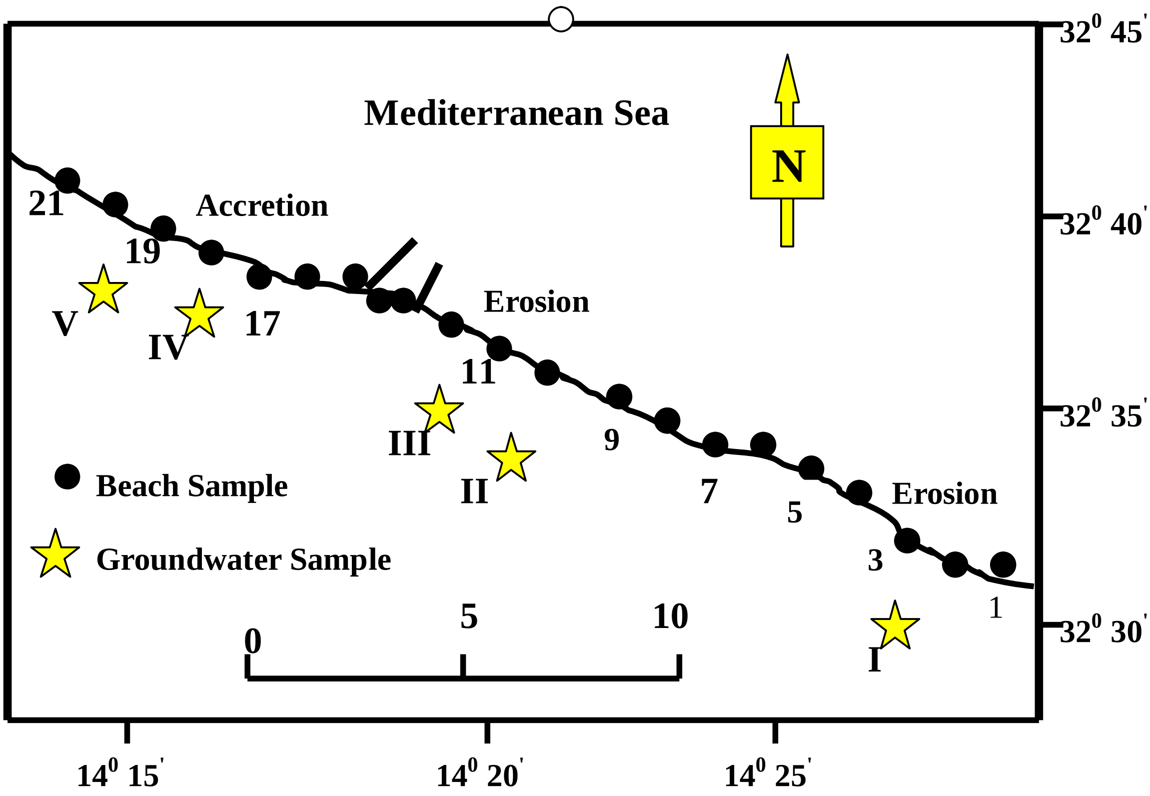


Fig. (3): The sites of the studied beach and water samples.

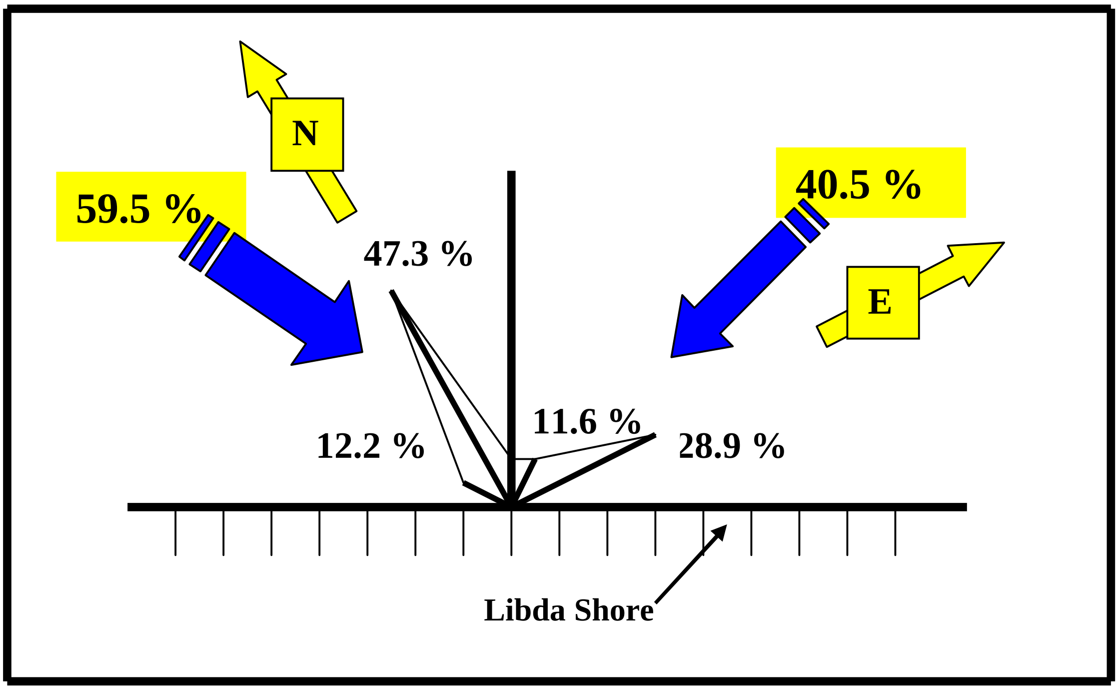


Fig. (4): Frequencies and directions of the onshore waves. Note, the net movement of the sediment is toward east.

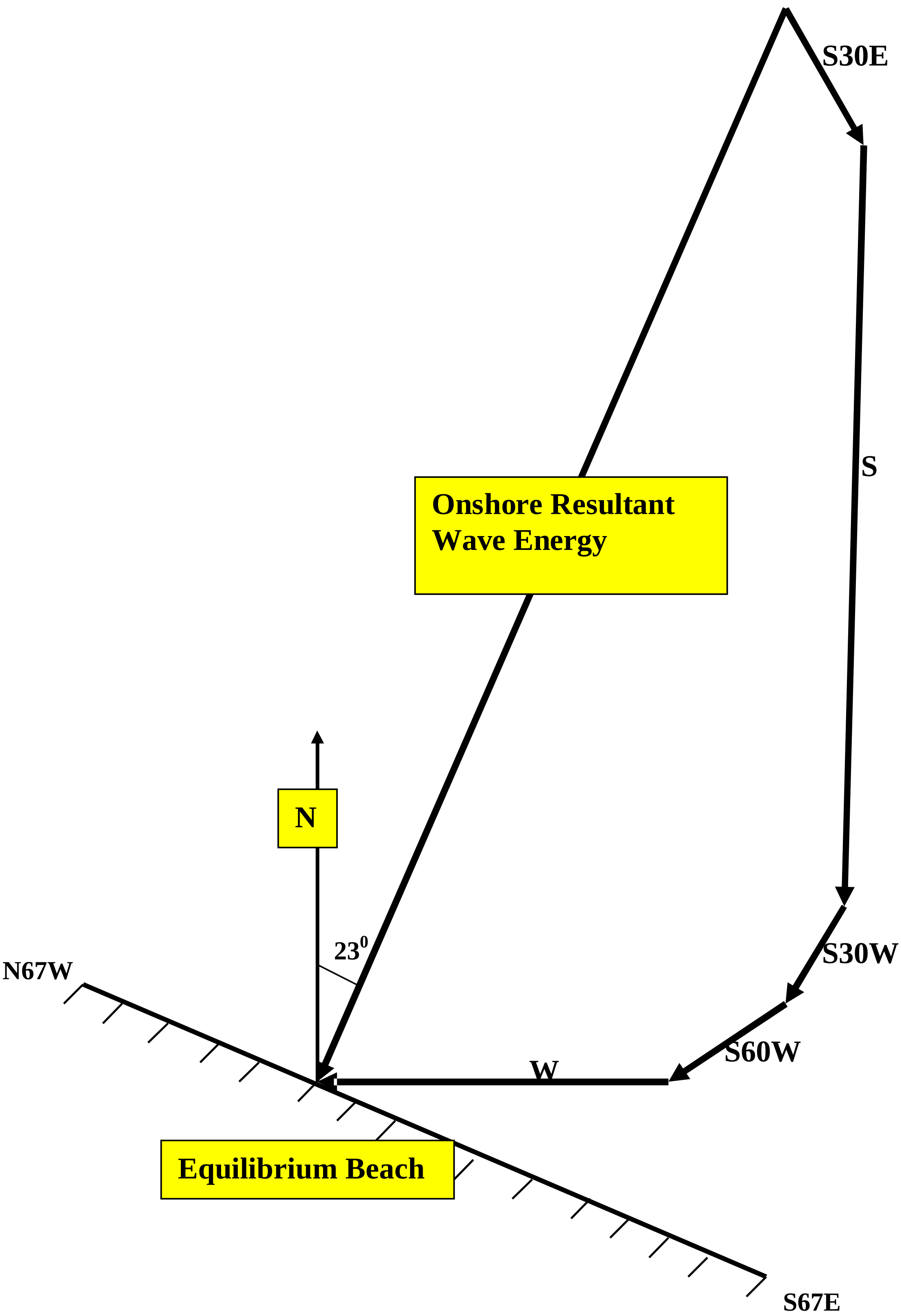


Fig. (5): Onshore resultant wave energy at Libda area. The beach will be modified by erosion and accretion until oriented N67W – S67E, at right angle to the onshore resultant wave energy.

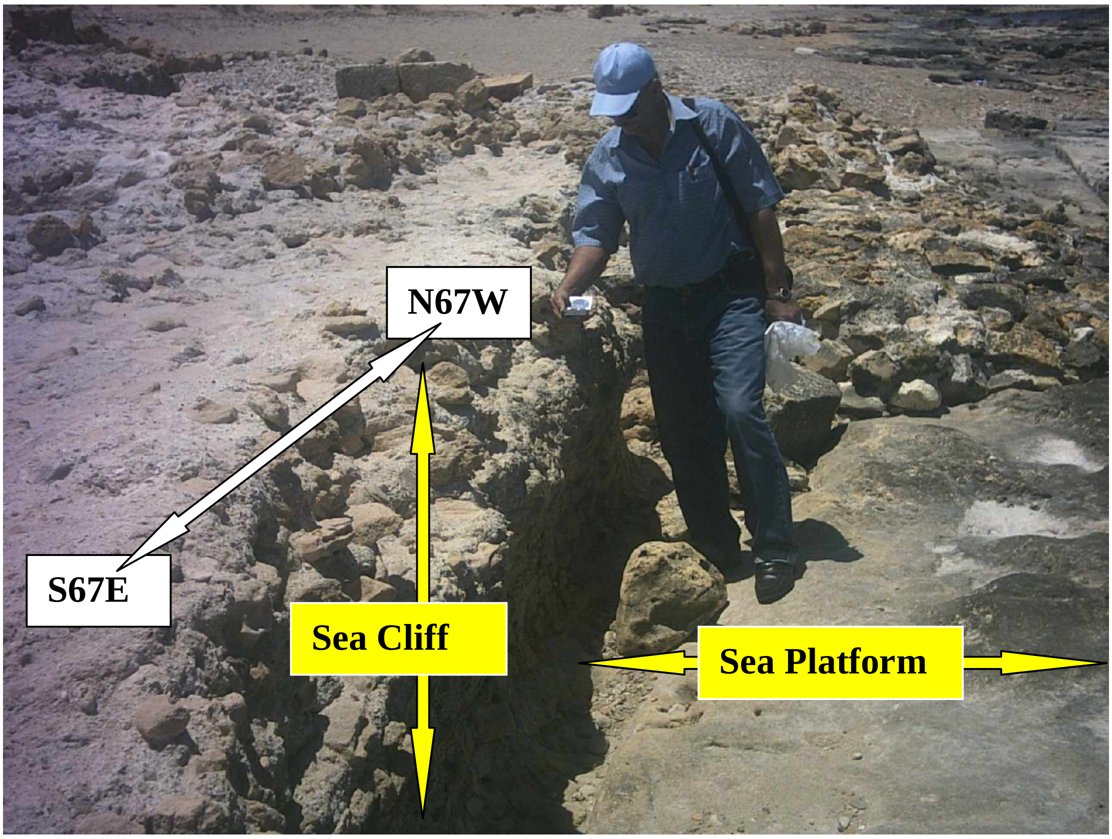


Fig. (6): Sea platform planed off by waves and widens as the sea cliffs retreat.

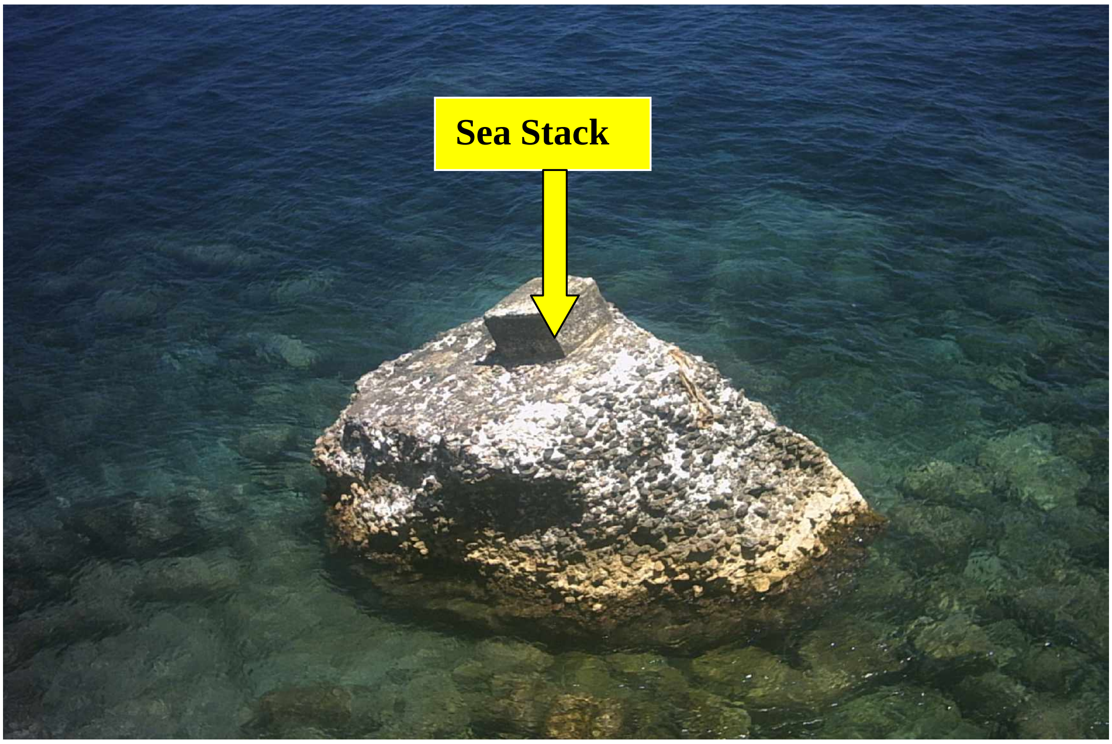


Fig. (7): Sea stack resulted from differential erosion.

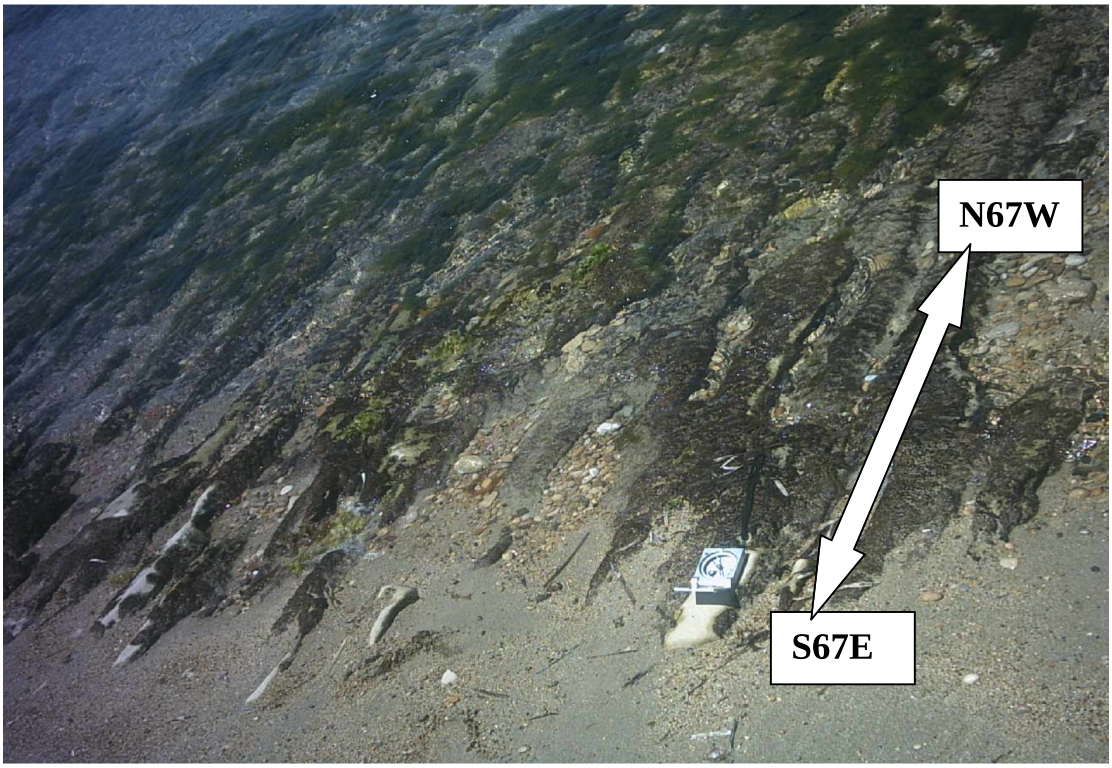


Fig. (8): Erosional furrows and ridges in rocky beach are extending parallel to the obtained onshore resultant wave energy.

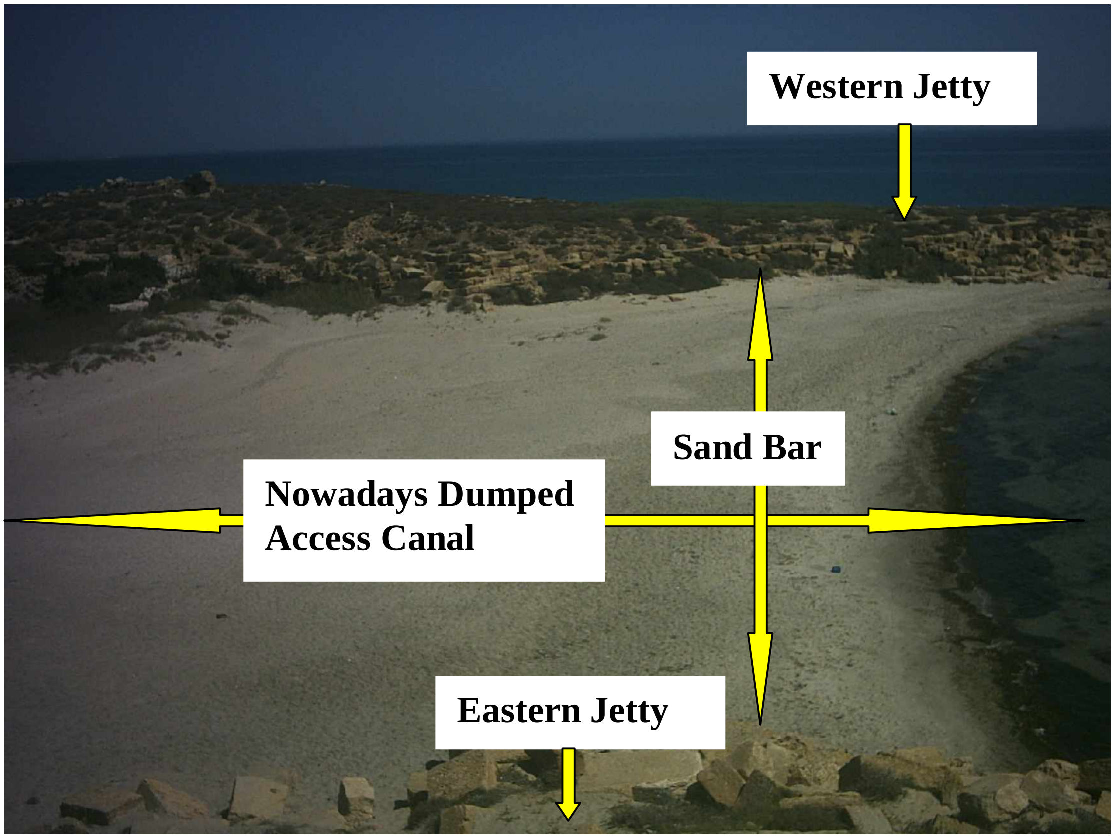


Fig. (9): The nowadays dumped ancient Libda port. Note, the sand bar completely blocked the access canal. Looking toward the north.

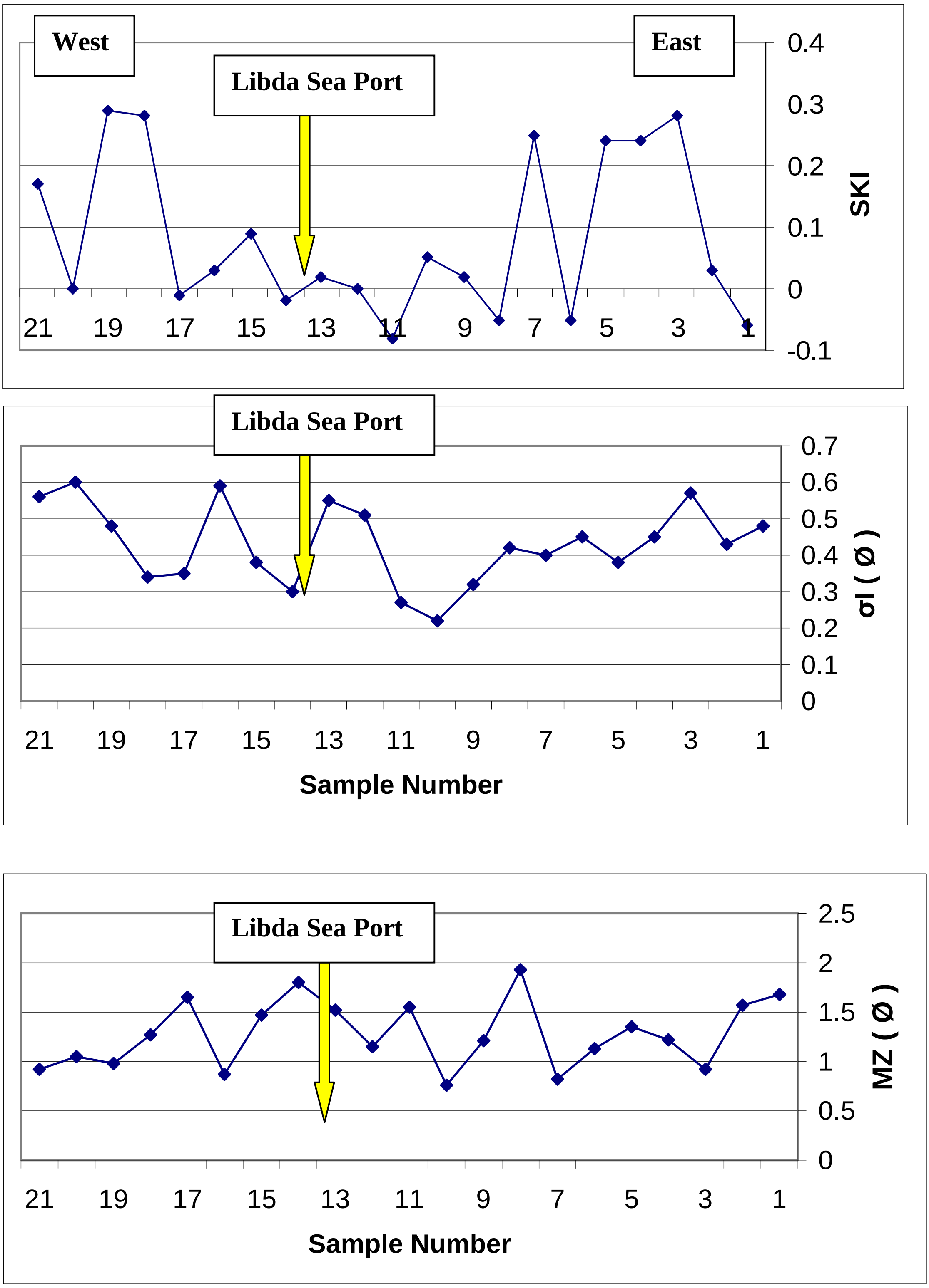


Fig. (10): Schematic illustration showing variations in mean size, standard deviation and skewness of the studied beach sediments.

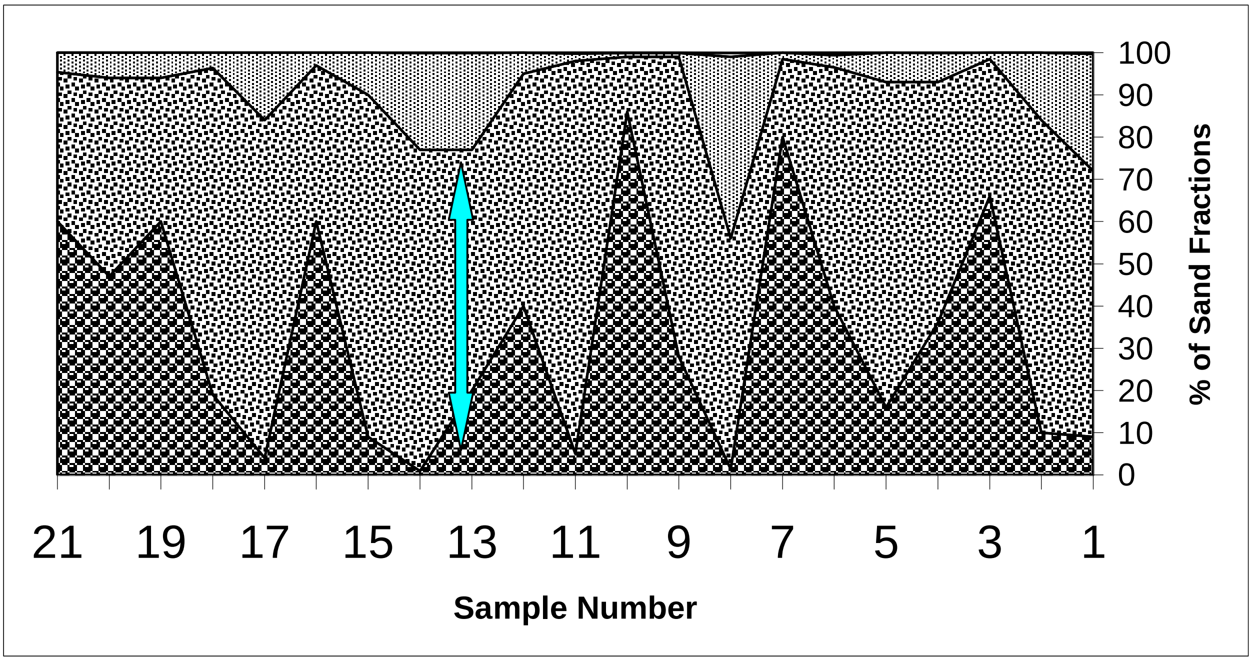
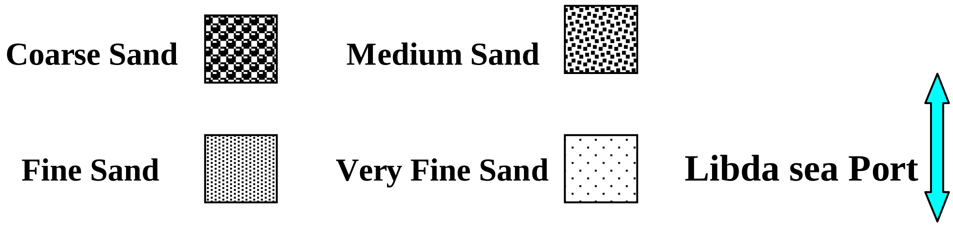


Fig. (11): Variation of beach grain size around Libda sea port.



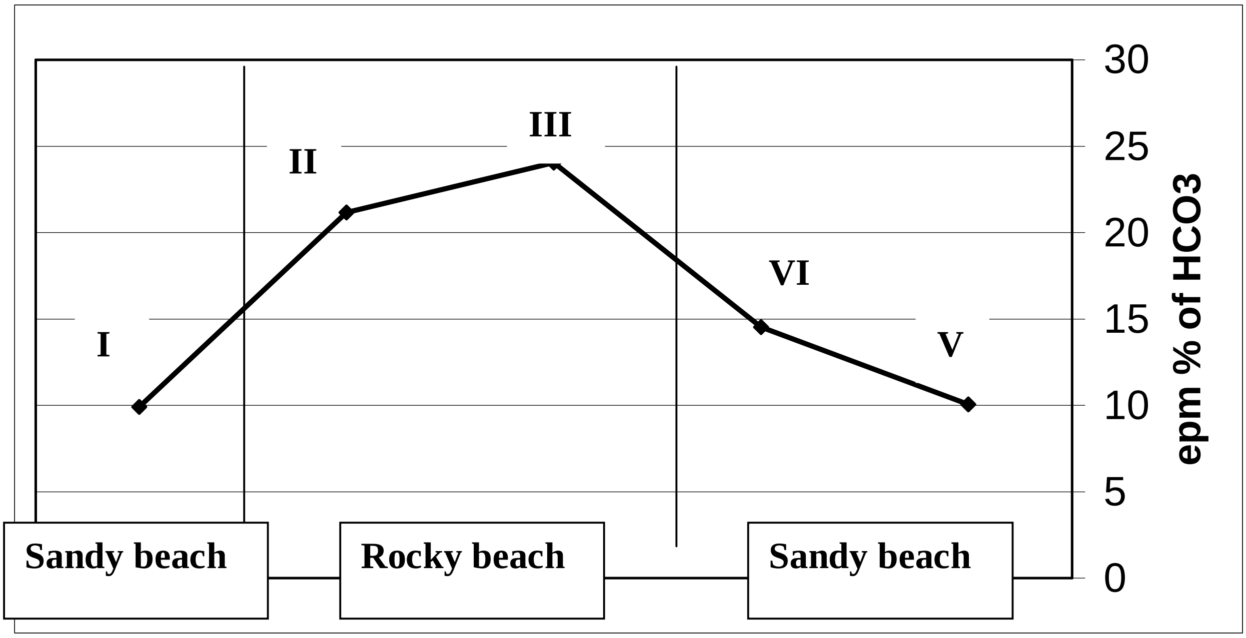


Fig. (12): Distribution of the ground water bicarbonate content along the hinter coastal area.

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