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STORMS AS AN ONSHORE DRIFT AGENT FOR COARSE SANDS, NILE DELTA COAST

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ABSTRACT

Onshore movement of coarse sands during storms is one of the most characteristic features of the Nile Delta coastal sediments. At the western side of Burullus and Damietta beaches, it is indicated that a lot amount of sediments are derived to the beach after server storms. These storm sediments are deposited and covered the beach zone at some locations with a thickness not exceeding 70 cm. This sand accumulation differs from the native beach materials; the derived sediments being coarser, less sorted, more rounded and cleanly washed than the native beach sands. The related characteristics of the storm sands on the beach may simply reflect derivation from similar source area under special physical conditions. In fact, correlation of the grain size distribution and texture of new materials added to the beach and that of the adjacent offshore indicates that onshore movement has occurred. It is significant that coarse sand from offshore sources is added to some beaches by wave action on the bottom during winter severe storms.

INTRODUCTION

During performing fluorescent sand tracer experiments along the Nile Delta coast, it was observed that a lot amounnt of coarse sediments is lying on some beaches and derived from outside sources. These sediments include mainly corse sands with some clay balls, small beach pebbles and shell fragments. Their thickness do not exceed 70 cm over the original beach sand and covers the area between beach face slope and backshore. These new sediments are observed to occur during the stormy period form November 1991 to April 1992 at the western side Burullus and Damietta coasts (*Fig. 1*).

West of Burullus outlet, the coast is sandy and flat. The mean grain size of beach sands ranges between 1.5 and 2.4 Φ. The barrier between the sea and Burullus lake is mostly a backshore plain. The plain is flooded during stormy conditions but it is not below sa level. At the shore, the beach sand is 2—3 m thick overlying lagoonal clay. The beach sand is therefore a thin wedge which disappears lakewards.

The coast west of Damietta mouth (Ras El Bar) has a wide and flat beach with small cusps. Progressive widening, along with the increasing length of Ras El Bar tongue have been occurred from 1800 until 1909. The coast is subjected to retreat from 1909 to the present. The mean grain size of beach sands ranges between 2.1 and 2.5 Φ.

During the past three decades many studies have been carried out concerning the continental shelf sedimentation processes and onshore transport (SHEPARD

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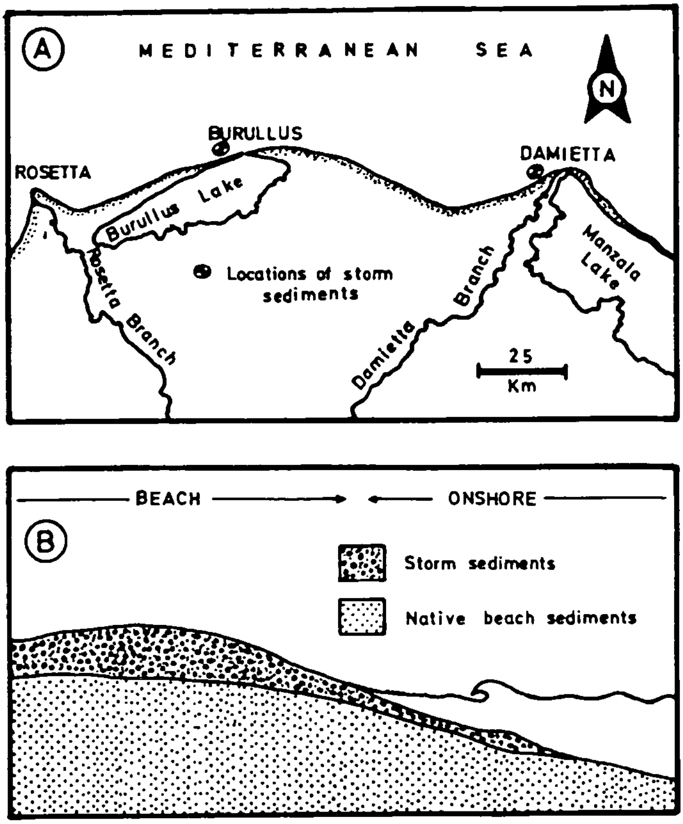

Fig. 1. A Location map showing the Nile Delta coast.
B Storm sediments on the beach.

1963; GUILCHER 1963; PEVEAR and PILKEY 1966; MEADE 1969; WINDOM *et al.* 1971; PILKEY and FIELD 1972 and EL-FISHAWI and MOLNAR 1981, 1983). PIERCE (1969) estimated that 44,000 cubic yards of sand were supplied annually to the shoreline from sources on the continental shelf to meet the requirement for beach and barrier island maintenance.

METHODS AND TECHNIQUES

The Nile Delta coast was surveyed during the winter season from Nov., 1991 to April, 1992. Samples were collected from the coarse sediments which derived to some beaches after storms. Samples were also collected from the original beach sediments. The characteristics of offshore sands were obtained from FRIHY *et al.* 1990.

All samples collected were washed, dried and split. Mechanical analysis was carried out by the conventional sieving method with screens placed at one-phi intervals. About 100 gm of materials was taken for grain size analysis, using a mechanical shaker with a sieving time of 20 minutes. The data were plotted as cumulative curves on probability paper to ensure maximum accuracy in determining the grain size statistical parameters (FOLK and WARD 1957). The grain-roundness values for the collected samples were determined in each size fraction according to POWERS 1953.

STORMS AFFECTING THE NILE DELTA COAST

The Nile Delta coast, like the rest of the northern coasts, is subjecting to a number of quasi-periodic storms. These storms are mostly accompanied by heavy rains, high water level rise and high waves. Generally, these storms which are popular called "nawat", occur from October to April. The time and period of occurrence of the "navat" are summarized in Table 1.

TABLE 1.

Time and period of winter storms "Nawat" affecting the Nile Delta coast

Storm name	Time	period (days)
Saliba	Oct. 21	3
Kansa	Nov. 27	3
Kasem	Dec. 06	7
Faida Sugra	Dec. 20	2
Gatas	Jan. 11	3
Faida Kubra	Jan. 19	5
Karam	Jan. 29	2
Shams Sugra	Feb. 08	5
Hosoum	Mar. 10	8
Shams Kubra	Mar. 20	2
Aowa	Mar. 25	6
Khamasin	Apr. 30	4

During Dec., 25—31, 1991, surveying was carried out along the eastern part of the Nile Delta coast. It was severe stormy conditions which caused a big rise in the sea level. Many costs were subjected to damage (i.e. east of Damietta) where the other are drowned (i.e. Ras El Bar resort at west of Damietta). At the western part of the Nile coast, many inhabitants were much threatened due to this storm and some coastal areas and cultivated lands were drowned (i.e. Nobaria and Idku). The characteristics of this storms were similar to Nawat Kasem which lead to the conclusion that it is Nawat Kasem but only came lately that year. In fact, it was worst storm that occurred during the last 15 years, at least as far as the rise in water level is concerned. Similar conditions were reported at Ras El Bar resort in Nov., 1964 (SUEZ CANAL AUTHORITY 1965). For such storm surges, the rise in the sea water level was about 50 cm. The predominant wind direction was from W and WNW with maximum speed of 14.5 m/sec. The maximum wave height attained in the storm was 5.0 m with frequency period of 9—11 sec.

A great deal of attention has been given to the erosion effect of waves on beaches, and not nearly so much to the constructive work that waves are doing continuously on some beaches. In fact, the waves play an effective role in moving sediments up or along the beaches and extend some beaches into the present accumulation forms (bars, berms and spits). KING (1972) mentioned that low, flat waves with low frequency will move sediments landwards and build up the beach.

For many years, textural analysis has been used to determine sedimentary environments. New approaches and insights into the nature and significance of grain size distributions have been investigated. There are many physical criteria available to identify specific depositional environments and textural studies can provide a separate line of evidence to aid in interpreting clastic deposits.

The present study aims to detect the source of storm sediments. Therefore, it is better to correlate between: 1 — Native beach sands, 2 — Onshore drift sands during storms, and 3 — Adjacent offshore sands. The following methods of treating the grain size distribution of sands were applied : 1 — Frequency distribution curves, 2 — Cumulative frequency curves, 3 — CM diagram, 4 — Statistical poarameters, and 5 — Grain roundness.

Discriminate between native beach and onshore drift sands

The grain size distribution of native beach sands appears to be fundamentally different from those added to the beach during heavy storms. *Figures 2, 3* and *4* show the main differences and characteristic features.

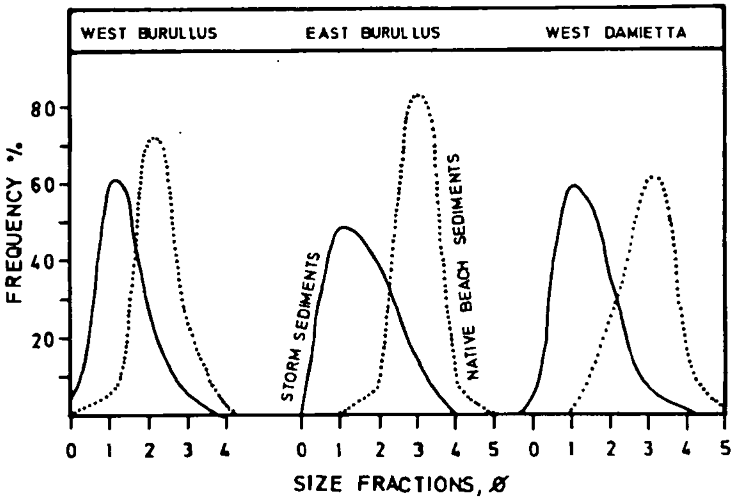

Fig. 2. Frequency distribution curves for native beach sands and storm sand.

The frequency distribution curves (*Fig. 2*) discriminate between these 2 types of sand. A visual inspection of the model classes and tails on the frequency curves can be used as a preliminary interpretation of the energy conditions within each type of sand. Native beach sands have a model class of 2 Φ unit at west of Burullus and 3 Φ unit at east of Burullus and west of Damietta. On the other hand, onshore drift sands (storm sediments) display a model in the 1Φ unit class. Thus, the storm sediments which added to the beach retain a higher percentage of coarser fractions than does the native beach sands. This indicates an increase in the energy level during onshore movement of coarse sands due to heavy storms.

Cumulative frequency curves drawn on probability paper were used to relate sedimentation dynamics to texture. Generally, there are 3 fundamental models of transport; traction, saltation and suspension. For the curves, the truncation points between these 3 models of transport reflect the physical conditions at the time of deposition, and hence give the true limiting value of grain size for each model of transport. It is also important to recognize a separate lognormal populations which relate to the position of truncation points and the degree of mixing between these populations. Morover, it is valuable to depend upon the degree of sorting as indicated by the shape of each population. *Fig. 3* shows the cumulative curves for native beach sands and onshore drift ones. Of special significance is the fact that the onshore drift samples are characterized by high percentages of sediment in the coarse rolling population. Size distribution curves indicate the three models of transport with a high degree of mixing. The positions of the coarse trunction are highly variable and the range is between 0—1 Φ (2—93%) of the distribution. It is clearly observed that mixing occurs between rolling and saltation populations. The saltation population has a size range between 1—3 Φ (50—99%). A suspension population has been defined between 3—4 Φ, it represents less than 1% of the distribution. On the other hand, the three modes of transport in the native beach samples are more pronounced, without mixing, and have better sorted populations than that in the onshore drift samples.

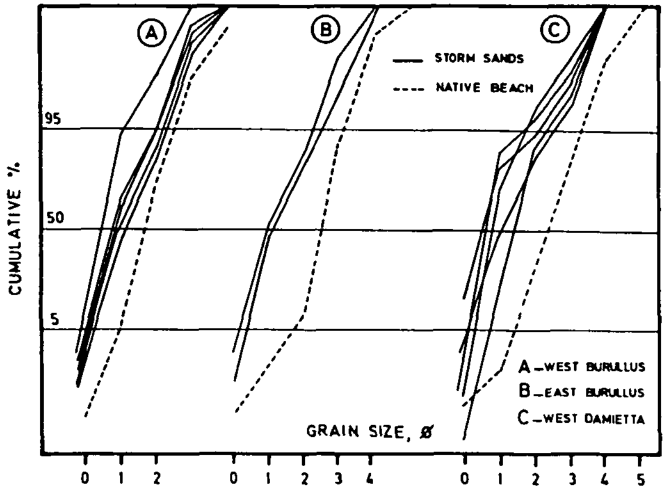

Fig. 3. Cumulative frequency curves for native beach and storm sands.

CM diagram is constructed by plotting the one percentile particle diameter (C) versus the fifty percentile particle diameter (M) in µm on bilogarithmic paper. The texture of a clastic sediment represented in this way is characteristic of the depositionale agent. The transport mechanism that built up the deposit can be suggested on the basis of the shape and the arrangement of the pattern of the sample points in a CM diagram (*Fig. 4*). It is indicated that combinations of C and M permit distinction between native beach and onshore drift sands. Depending on the spreading C with relation to the M values, the native beach samples are formed essentially by particles with C values of 500—616 µm and M values of 177—308 µm. On the other hand, onshore drift samples are coarser, with C values of 732-1275 µm and M values of 366—707 µm. The change from a pattern parallel to the CM line (suspension) to a pattern parallel to the C axis (rolling) corresponds

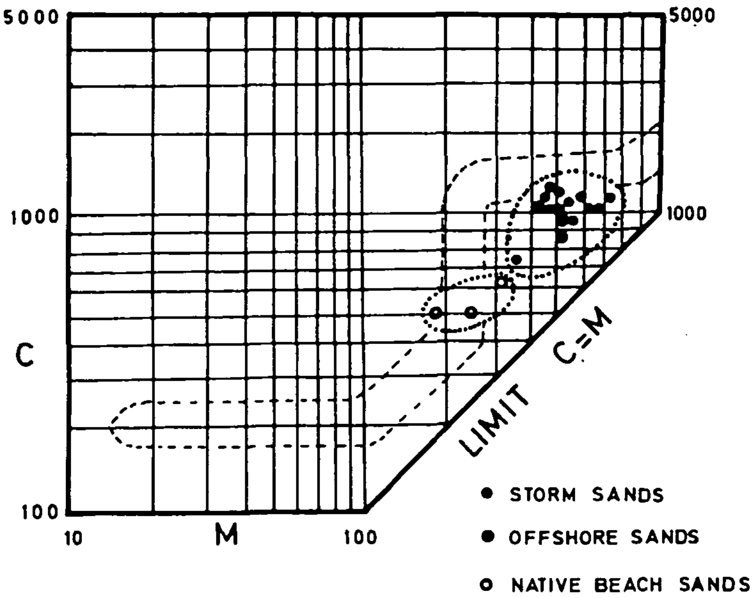

Fig. 4. C M diagram for native beach sands and storm sands (onshore drift)

to a difference in mode of deposition. Native beach points are distributed parallel to the limit of C=M, indicating an area of good sorting and transported by suspension. The majority of the onshore drift points are situated at a considerable distance from the limit C=M and can be related to the C axis. Therefore, they are poorly sorted and moved by means of rolling. The action of the tractive current caused by the waves during storms is responsible for onshore drift of coarse sands. The maximum value of C in the pattern is an indication of the maximum turbulance caused by waves during storms.

The mean grain size and the inclusive standard deviation (sorting) yielded an optimum discrimination (Table 2). Onshore drift sands are largely coarser and less sorted than the native beach ones. For example, the average mean grain size of onshore drift sands at west of Burullus was found to be 0.91Φ while it was 1.72 Φ for the native beach sands. The sorting values were 0.55 and 0.47 Φ for the onshore drift and native beach sands, respectively.

Grain roundness was used to investigate the depositional environment of sands in question. At first site, it will be seen that a difference in grain roundness was found between onshore drift storm sands and native beach ones (Table 3). The onshore drift grains are more rounded (0.52—0.58) than those of the native beach (0.41—0.43).

Correlation between onshore drift and offshore sands

The sands on most parts of the inner shelf are generally coarser than what the Nile mouths used to discharge in the present time (COASTAL EROSION STUDIES 1976). Terrigenous sands that make a patchy belt on the middle shelf are relict and can be related to some of the former Nile branches (*Fig. 5A*). The sands of western Abu Quir Bay occur north of the Canopic mouth. The sand patches of the west

TABLE 2.
Grain size fractions and parameters for native beach, storm (onshore drift) and affshore sands.

Stretch	Features	% of grain size fractions						Mz	σ I	C	M
		ø 0	ø 1	ø 2	ø 3	ø 4	ø 5	ø	ø	µm	µm
West of Burullus	Storm sands	3.99	60.08	29.47	6.31	0.09	—	0.91	0.55	1193	555
	Native beach	0.05	5.43	72.23	21.53	0.74	0.01	1.72	0.47	616	308
Just east of Burullus	Storm sands	1.61	48.17	37.20	12.37	0.64	0.02	1.18	0.65	1111	483
	Native beach	0.12	1.03	7.31	83.35	8.11	0.07	2.50	0.42	500	177
West of Damietta	Storm sands	2.97	58.82	31.21	6.10	0.90	—	0.94	0.47	993	545
	Native beach	0.19	0.97	25.92	61.36	11.31	0.25	2.35	0.57	500	196
Off Burulluss (offshore sands)	No. 9/2	0.38	54.60	43.60	1.37	0.02	—	0.95	0.39	871	500
	15/2	1.15	70.16	27.60	0.87	0.20	—	0.79	0.36	966	555
	25/1	0.40	46.56	52.74	0.30	—	—	1.03	0.38	1035	467
	Average	0.64	57.11	41.32	0.86	0.07	—	0.92	0.38	957	507

TABLE 3.
Roundness values for native beach, storm (onshore drift) and offshore sand grains.

Size fraction Φ	Burullus		Damietta		offshore sands
	Storm sands	Native beach	Storm sands	Native beach	
0	0.69	0.56	0.72	0.46	0.68
1	0.65	0.48	0.57	0.43	0.63
2	0.61	0.41	0.48	0.41	0.49
3	0.52	0.35	0.41	0.37	0.44
4	0.43	0.33	0.40	0.36	0.41
Total mean	0.58	0.43	0.52	0.41	0.53

Burullus inner shelf lie to the N and NW of the traces of the Saitic and associated branches. North of Burullus outlet, the N-S tongues of coarse sand are rather suggestive of an ancient stream, their location could be on the continuation of the Sebennytic branch. The sands that lie on Gamasa and Damietta terraces may have come from an old mouth at Gamasa. Some evidences for the old Atribic branch near Gamasa have been found by BARAKAT and IMAM (1976). these branches were probably more active in Pleistocene-Holocene times.

In 1989, exploration survey has been done for the area of Burullus using cores and vibrocores. The objects were to identify and evaluate the suitability of offshore borrow materials for beach nourishment. The survey covered the inner shelf zone off Burullus coast (*Fig. 5B*). The textural analysis of the sediment corings identified coarser sand at distance of 2—9 km from the coast and water depth between 8 and 15 m (FRIHY *et al.* 1990). Table 2 shows that the offshore sands has a mean size of 0.92 Φ and sorting of 0.38 Φ . The total volume of the identified borrow areas is estimated to be 22 million cubic meters within one meter subbottom layer.

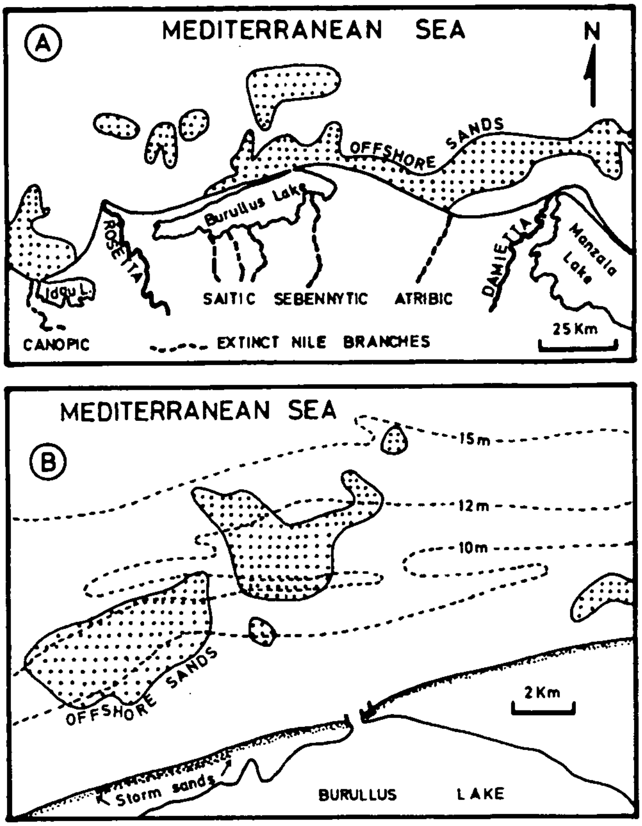

Fig. 5. A Position of extinct Nile branches in relation to the areas of sands on the offshore (after El-Fishawi *et al.* 1976).
B Offshore coarse sands in adjacent of Burullus coast (after Frihy *et al.* 1990).

In fact, the similarities between the new material added to the beach during onshore drift and the offshore sands are indicated by textural analysis (*Fig. 6* and Table 2). The two types of sand are coarse, moderately well sorted and have nearly similar roundness values. Morover, the presence of index rosy quartz grains indicate close correlation between these two types of sands.

Thus, the evidences show that a reasonably close correlation exists between the nature of offshore sands and those added to the beach during onshore movement at some stretches of the Nile Delta coast. This similarity between the two types of sand is assumed to be due to the fact that the offshore area is acting as a source region for onshore movement of sand to some coastal areas during winter heavy storms. The evidence being that the only possible source of coarse, moderately well sorted sands with similar roundness values and rosy quartz grains which added to the beach is the offshore. The offshore and onshore drift sands are mostly free from heavy minerals and since the present mouths at Rosetta and Damietta are believed not to be contributing sand at present, the correlation may reflect onshore tranpsort of offshore sediments under special physical conditions.

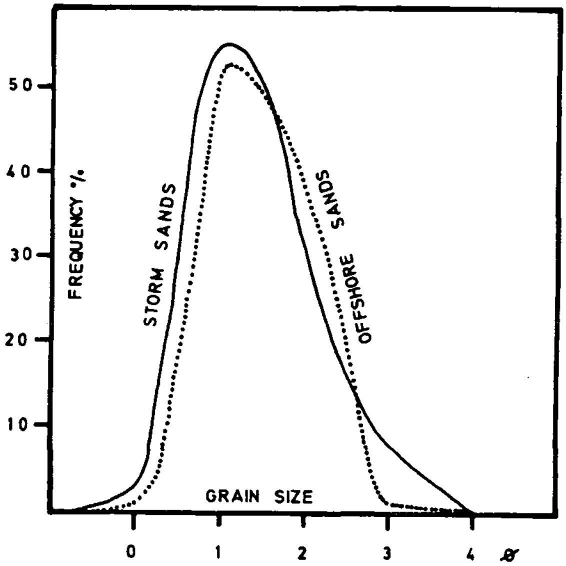

Fig. 6. Correlation between storm sands and adjacent offshore sands.

HYDRODYNAMIC FORCES AND ONSHORE MOVEMENT

The primary source of energy affecting the nearshore region is that of waves. According to MANOHAR (1976), two types of waves are predominant; the storm waves of the winter season (November — March) and the swells of the summer season (July — August). Records of the storm waves show that the waves rarely exceed 3.5 m in height, and the swells are generally 40—75 cm heigh. With average periods not exceeding 6-8 sec, the storm waves do not affect the bottom at depths more than 50 m. In general, the predominant direction of waves is NNW and NW. This means that all the time there is wave movement (75% of the time waves are over 75 cm), and the zone between 0 and 5 m depth is affected. During moderate storms (waves up to 1.5 m), the bottom is actively stirred to a depth of at least 12 m. The swells and the bigger waves during heavy storms can affect the bottom of continental shelf to a depth of 50 m by what is known as bottom current velocities (KORGN *et al.* 1970, KING 1972; MCCLENNEN 1973). This depth limit includes all the sand patches of the Nile Delta inner shelf (*Fig. 5*).

Therefore, during heavy storms the bottom currents are capable of moving coarse sediments from NW direction to feed the coast. Many evidences indicate the offshore-onshore transport of sediments (PILKEY and FIELD 1972; SUMMERHAYES and MARKS 1976; EL-FISHAWI and MOLNAR 1981). The distribution of the beach pebbles along Burullus coast is closely related to the position of the Rosetta and Burullus offshore banks. These pebbles reached storms (EL-FISHAWI and MOLNAR 1981). There is many evidence of large objects reaching the coast from known places even many km away from the shore (SHEPARD, 1963; BASCOM, 1964). In a similar way, as the beach pebbles have come from submarine ridges as far as 20—25 km to the NW of Burullus, could also have come the coarse sands from offshore sources to nourish some coasts. Time series analysis of mean grain size at Burullus area indicate that coarse sand is periodically added to the coast

(EL-FISHAWI and MOLNAR 1983). West of Burullus outlet, the barrier between sea and lake is narrow and the beach is a thin wedge (3—6 m thick) over lagoonal clays, so that the coarse sand found to nourish the coast should come from outside. On the other hand, for the beaches east of the outlet, the source of coarse sand is available in the land itself (backshore and dunes).

Although in the profiles of west Burullus the percentage of coarse sand decreases rapidly seaward and no more is found after 100 m from the shore (BADR 1990) it is indicated that during the storms a lot of offshore sediment is in suspension, and coarse sand is then derived shoreward.

RATE OF SAND DRIFT DURING STORMY CONDITIONS

Monthly field experiments, using fluorescent-dyed grains, were performed at the beaches located east and west of Damietta mouth. The experiments were carried out during the period from January to December, 1991 to trace the sand movement and to estimate the rate of drift. In fact, such period represented different sea conditions during summer and winter seasons. The field and lobarotory techniques were made according to INGLE (1966).

At the western side of Damietta coast, where the storm sediments are occurred, pattern of tracer sand dispersion indicated the tendency of a large percent of tracer sand to move eastwards. Most waves are approaching the coast from NW and consequently cause dominant eastward drift. During stormy conditions in November and December, the velocity of the eastward current may exceed 90 cm/sec.

The drift rate yielded a wide range of variety due to seasonal effect and surf conditions prevailing during tracer tests. The rate of drift at west Damietta ranges between 48,100 and 111,900 cubic meters per month. Generally, it is indicated that the rate of drift tends to be higher in winter season than that in summer one. At west of Burullus, it ranges between 76,000 and 100,000 cubic meters per month during stormy conditions.

CONCLUSION

A deposition of coarse sediments took place during storms, covering the beach and surf zone at the western side of Burullus and Damietta. Textural analysis indicates that these storm sands are coarse, less sorted and more rounded than the native beach sands. It is apparent that the storm sands added to the beach and adjacent offshore sands closely correspond to one another with regard to grain size distribution and texture. Therefore, the coarse sand accumulation which took place during storms are derived from the adjacent offshore sources. Possible mechanisms of onshore movement include the wave action on the bottom and strom-induced current.

The ivestigation has presented evidence indicating onshore movement of coarse sands from offshore sources at a distance of about 2—9 km and 8—15 m water depth. Rosetta and Damietta branches are not contributors of sand to the coast at present due to the construction of the Aswan High Dam. Furthermore, litoral current do not introduce new material to the beach but rather redistribute the quantities already present. Therefore, on a regional scale, only coastal erosion and onshore movement are the potential sources for generation of present day Nile Delta coastal sands.

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