ISSN 1110-0354
Bull. Nat. Inst. of Oceanogr. & Fish., A.R.E., 1998. Vol. (24): 1 - 33

PALEOENVIRONMENTAL CONDITIONS AND SEALEVEL CHANGES IN SHARM EL-SHEIKH (GULF OF AQABA, EGYPT) BASED ON SEDIMENTOLOGICAL AND MINERALOGICAL STUDIES

By

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Key words: ***Paleoenvironmental, Sealevel, Gulf of Aqaba, Red Sea.***

ABSTRACT

Seven boreholes were drilled in Sharm El-Sheikh basin till depth of about -30 m. Using both of sedimentological and mineralogical characteristics, it was possible to determine the paleoenvironmental conditions, the paleohydrodynamic activities, the position of the paleoshoreline and the sealevel changes during the sedimentation periods.

The present study shows that, the subsurface shallow marine sediments had been deposited within and under beach environmental conditions. Some sediment belongs to inland dunes and subjected to aeolian deposition while the other subjected to both marine and fluviatile activities. The most probable sources of these sediments include stream discharges and sea cliff erosion.

The hydrodynamic conditions indicate that, rolling transports the majority of grains. The deeper parts are transported in presence of high to moderate turbulent energy as graded suspension.

The results show that, the paleoshoreline was at depths ranging from -16 to -20 meter in the eastern part and from -6 to -9.6m in the northern one

The mineralogical analysis reveals the presence of admixtures of carbonate and non-carbonate components. The siliciclastic minerals are confined to the lower parts of the subsurface sediments. derived mainly from the granitic cliffs.

The results of carbonate distribution are presented in a chronogram with three episodes of sea transgression separated by two distinct falls/stillstands. The first rise of relative sealevel began near – 29.5 meter since 8835years before present, while the second one started near – 16m from 7217 years ago, whereas, the last episode started at – 7.3m from about 4000 Y.B.P.

INTRODUCTION

The depositional environments of Red Sea have been recently studied by many workers e.g. Friedman (1965, 1968 and 1972); Loya and Slobodkin (1971); Goldberg (1970). Aylon (1976), in his study on the western coast of Gulf of Aqaba, has divided the area into four well defined heavy mineral provinces, one of which is the Sharm El-Sheikh region which is characterized with relatively high frequency of heavy minerals. The mineralogical assemblages are characterized by mixed sediments derived from two types of source rocks namely; Granite and Sandstone.

The present study aims at:

*Identification of the sedimentological characteristics as tools for, determination of depositional environments, hydrodynamic conditions and the old shoreline positioning.

*Identification of the mineralogical characteristics as tools to define both carbonate and non carbonate associations as well as to out line the possible changes of sealevel during the sedimentation periods.

Area of investigation:

Sharm El-Sheikh is semi-enclosed crescent form basin with an average depth of about 85 m. The northern side is shallower than the eastern one. The northern coast slopes gently seawards while its bottom is generally rough. Sharm El-Sheikh area is connected with the Red Sea proper at the entrance of Aqaba Gulf (Figs. 1a & 1b). Southwestwards of the study area, sandstone is

Fig. (1a)

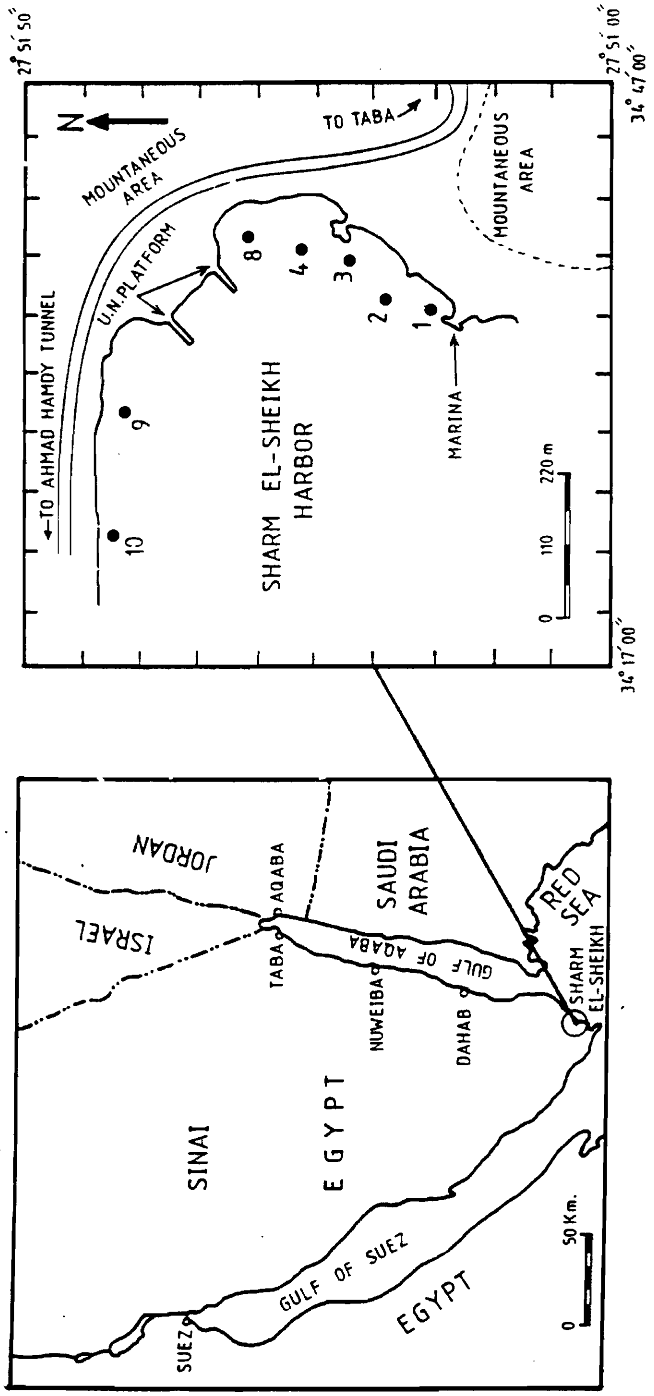

Fig. 1b.: Location map of Sharm El-Sheikh Harbor, (NIOF, 1993).

Fig. 1a: Gulf of Aqaba and study area.

overlaid by marine Miocene yellowish sandy limestone forms the upper half of the scarp of Gable El-Safra. East and northeastwards there is a number of flats topped Pleistocene raised beaches. The terraces consist of white coralline limestone (Omara, 1959).

Climatology and hydrography:

Gulf of Aqaba is characterized by high solar radiation and evaporation of about 1.0 cm/day (Assaf and Kessler, 1976). The annual average rainfall ranges from 5 to 25 mm, the majority of which is during a few days in winter whereas the flash floods contribute great amounts of terrigenous sediments as debris flow. Supratidal evaporites accumulate in supratidal flats. Interabasinal carbonates, principally coral reef, are formed seaward at Sharm El-Sheikh (Friedman, 1968).

Neumann and McGill (1962) reported that, the inflowing current in Gulf of Aqaba is less saline surface flow, whereas the more saline (denser) water sinks and forms a bottom counterflow. Wecht *et al.* (1992) found that, an annual cycle develops repetitively in the Gulf of Aqaba, in which the water column attains vertical homogenity in February, and a new thermocline begins to develop in March. Reiss and Hottinger (1984) gave a summary of earlier studies of the Gulf of Aqaba.

MATERIALS AND METHODS

A total of seven offshore borings were made using rotary type drilling mounted on floating platform. Subsurface samples were obtained with split spoon sampler at 1.5m interval till depth of about 30m. Boring locations are illustrated in (Fig. 1b). Boreholes No. 1, 2, 3 and 4 were taken along the eastern part, while boreholes No. 8, 9 and 10 were taken along the northern one. After field description and visual classification, all samples were transfered in air tight containers to laboratory and prepared for further analyses.

Fifty-six samples were air-dried, then splited to ensure that representative samples will be examined. About 50 g of each sample was washed thoroughly by distilled water and dried at 50° C (then kept in clean stoppered jars), ready for grain size and mineralogical analyses.

The statistical parameters were calculated according to Folk (1974) and the depositional environments were determined with respect to Sahu's equations (1964). These equations are applied to discriminate the different depositional mechanisms which took place in the area of investigation. The depositional conditions were determined using C-M pattern diagram, after Passega (1964) & Passega and Byramjee (1969).

For the mineralogical analysis, the samples were ground in mortar to pass through a 44 μ-mesh sieve (nominal diameter) then sprinkled on Vaseline on a glass slide to ensure random orientation. A Philips X-ray diffractometer Model 1060/80 with copper target tube and nickel filter was used. Diffraction was made at 40 Kv, 25 mA, chart speed 1°/min in the range of 20°~60° (2 θ), the operating sensitivity was 4x100 counts/sec and the chart speed at 1cm/min. The relative abundance of the minerals was determined by peak height analysis (Griffen, 1971).

RESULTS AND DISCUSSIONS

Sedimentological and mineralogical characteristics:

The data of grain size and mineralogical analyses were discussed as following:

Borehole No. 1 extends for about -23 m. The subsurface sediments range in size from gravel, principally, broken reef fragments and disintegrated limestone, to very coarse sand at different depth intervals with variable amounts of carbonate and noncarbonate components. Owing to the diversity of source materials, the majority of the subsurface sediments is shown to be poorly sorted (till depth of about -16.0 m), two exceptional sorting values were noticed at -18.8 & -23.4 m). Both values were recorded for almost pure siliciclastic sediments. The carbonate mineral content components has a maximum value (83.9%) at a depth of about -11.3 m. It is mainly due to the existence of fragmented coral reef as well as broken shells of marine organisms . The carbonate mineral association includes; aragonite, calcite, Mg-calcite and to lesser extent dolomite and ankerite (Fig. 2). However it seems that, the differentiation in the carbonate mineral association could be interpreted on the basis of physicochemical or biogeneic processes (Shata, 1987). The siliciclastic minerals attain its minimum value (16%) at -11.3 m and maximum value (99.7%) at -18.8 m. At depth level of -5.3 m the association of quartz, feldspars and clay suggests chemical weathering of granite.

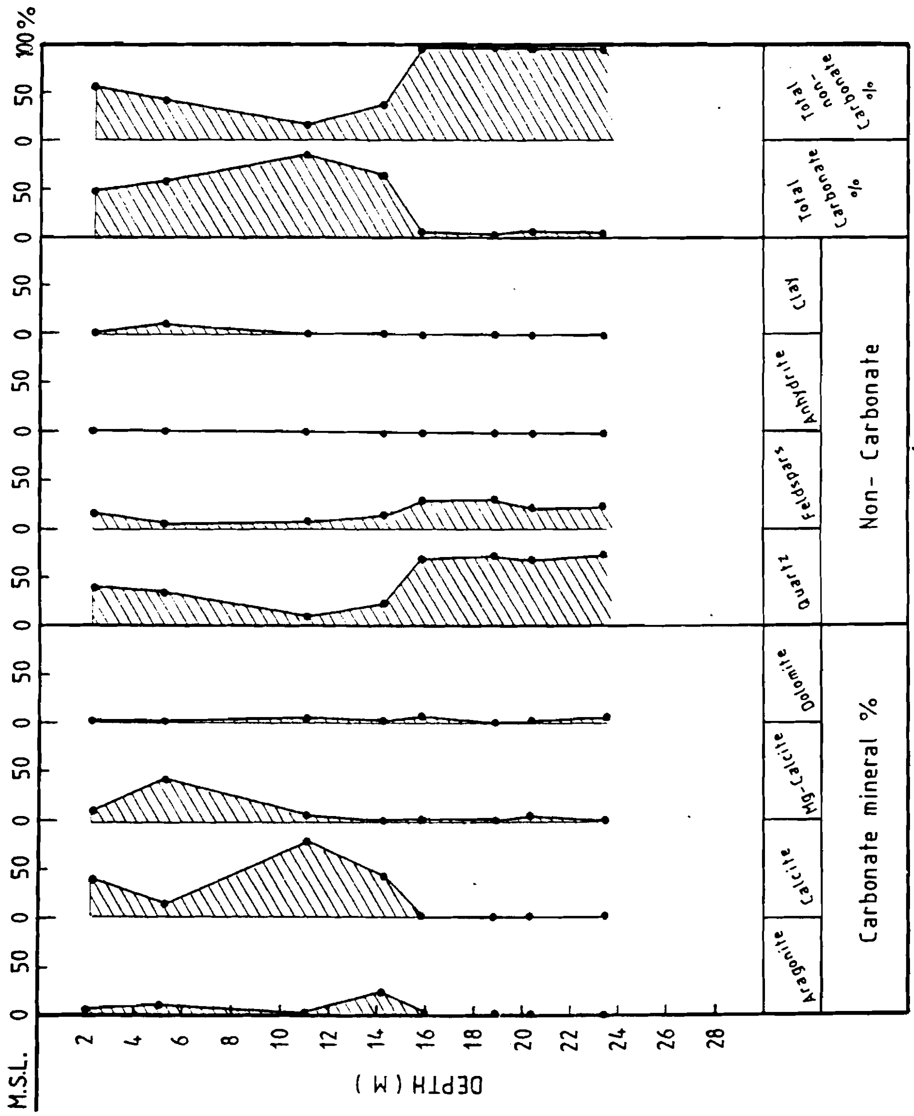

Fig. 2 : Vertical distribution of carbonate and non carbonate mineral contents of BH.1 subsurface sediments in Sharm El-Sheikh Harbor.

Borehole No. 2 extends for about -29 m. It comprises both biogenic and terrestrial components. The reefal colonies extend from depth of about -15 m to about -6.0 m upward. A layer of mixed carbonate and noncarbonate materials underlies these reefs. A layer of about 2 m in thickness (at -17 to -19 m) consists of medium sand sized sediments followed by another one of about 10 m thick of very coarse sand, mainly granitic grains with some coated reefal particles.

Mineralogically as shown in figure 3 that, the surface layer extends for about 3.0 m composed of nearly equal amounts of carbonate and siliciclastic materials. Underlying this surface layer, the sediment matrix is composed of pure coral reef of about 6.0 m in thickness Mg-calcite is the major carbonate component (57.4 to 72.1%) which could be interpreted in terms of homogenity of coral reef colonies in this locality. Directly under the coral reef terraces, the carbonates vary from 88.6% at -15.0 m to 12.4% at -27.1 m), The variation of this ratio can be explained on basis of the differential contribution of both terrestrial and marine environments (Shata, 1993). However the low potentiality of the carbonate content, in the lower part at a depth more than -15.0 m with the associations of dolomite and sometimes ankerite as well as magnesite, may reflect diminishing of the suitable conditions for normal carbonate sedimentation with depth. In contrary, another conditions favorable for diagentic processes were prevailed. This is evidenced by the presence of some sediments in the lower part which reveal chemical sedimentation of carbonate, where the siliciclastic material act as nucleii for concentric calcareous rings.

Borehole No. 3 extends for about -26 m. The upper part is composed of gravel sized sediments till depth of about -12.5 m followed by a layer of medium sized sediments consists mainly of medium to coarse shells of gastropods at depth of -13.7 m with moderate sorting value. The second major variation took place at -20 m, where sand sized sediments comprise relatively coarser dark gray limestone fragments admixed with fine clays. The sorting is poor all along the core with an exceptional value at a depth of about -13.7 m, which indicates deposition under quite energetic conditions.

As shown in figure 4 the carbonate minerals content attains its maximum value (98.6%) at about -15.0 m. depth, and represented only by calcite. This layer is characterized by grayish black color, as a result of weathering processes and is coated by a very thin clastic crust.

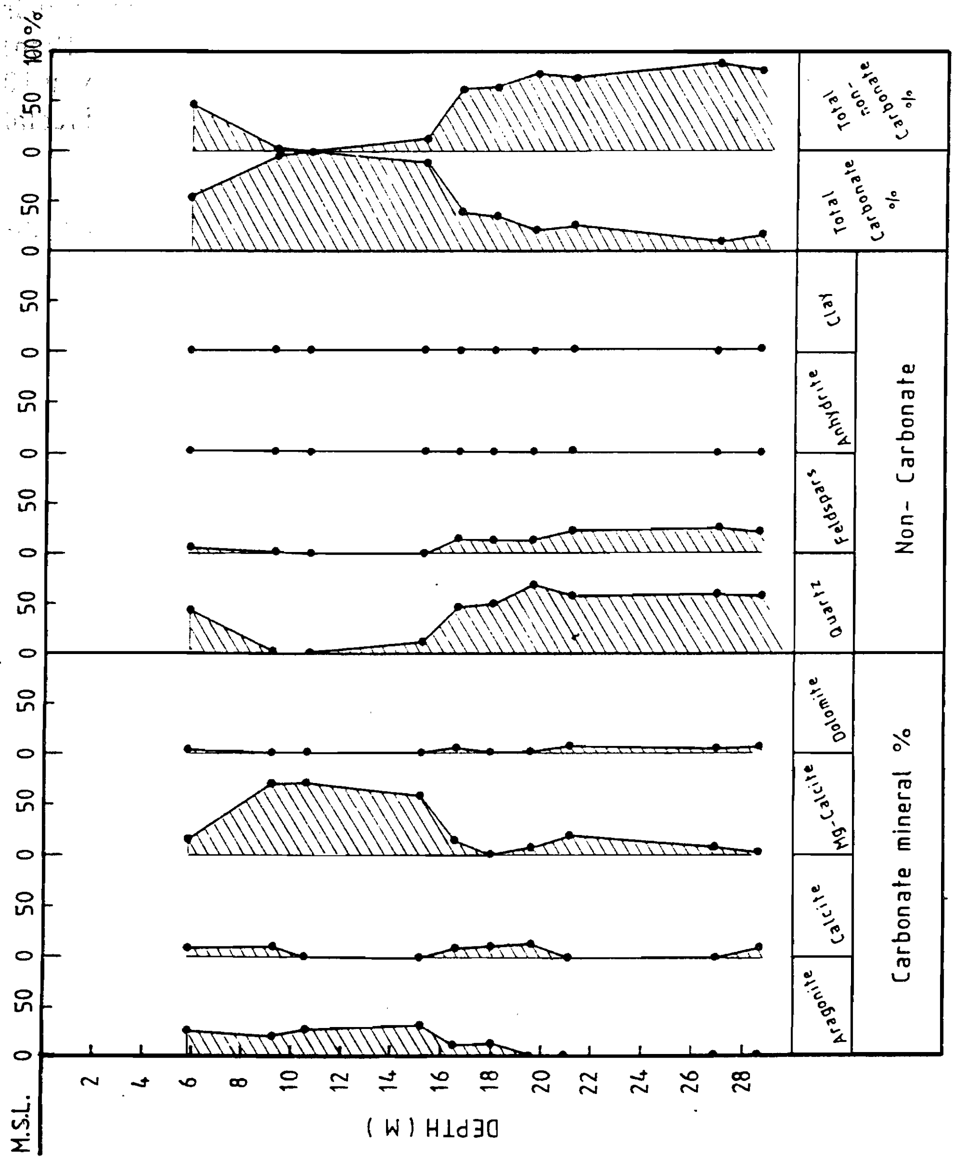

Fig. 3 : Vertical distribution of carbonate and non carbonate mineral contents of BH.2 subsurface sediments in Sharm El-Sheikh Harbor.

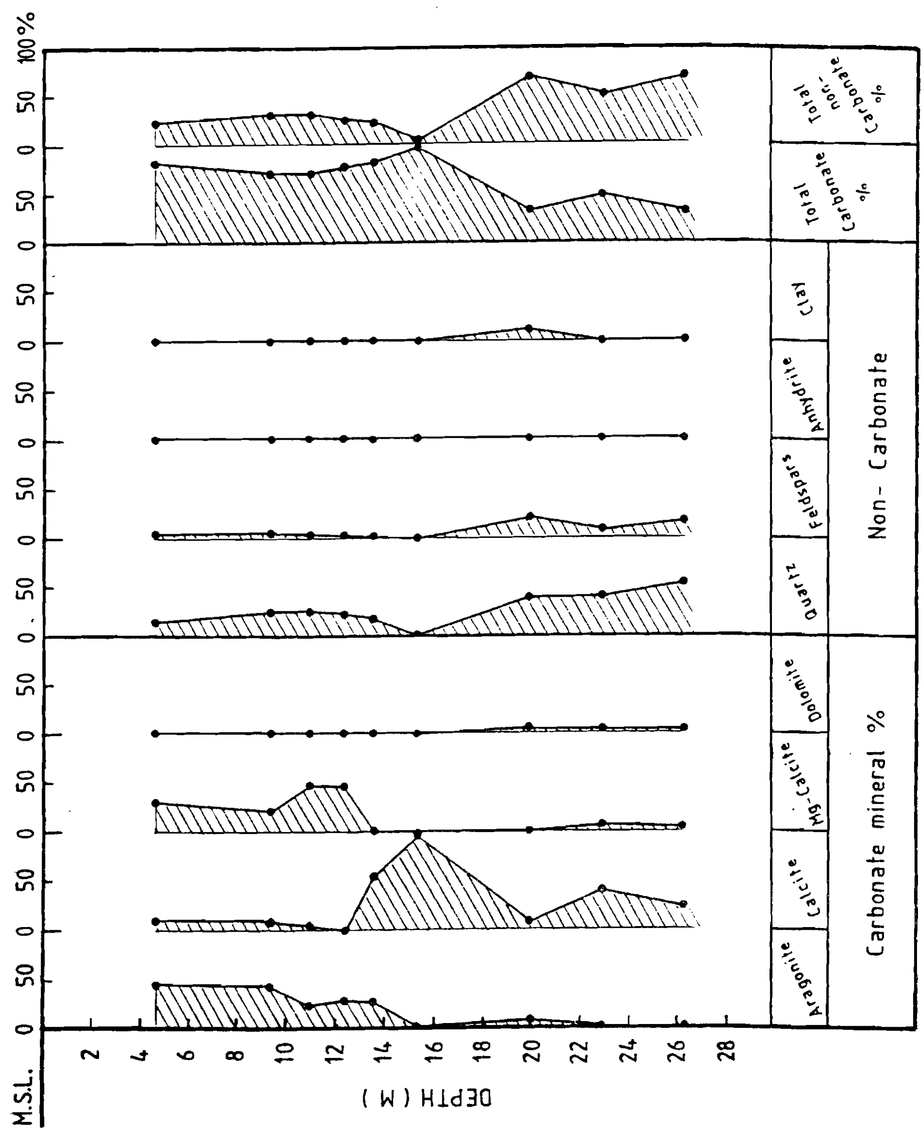

Fig. 4 : Vertical distribution of carbonate and non carbonate mineral contents of BH.3 subsurface sediments in Sharm El-Sheikh Harbor.

In the upper layer, which extends for about 10 m, the carbonate association includes aragonite, Mg-calcite and calcite respectively. It is of interest to note that, the occurrence of both of dolomite and magnesite are limited in the lower part of BH.3. This may be attributed to prevailing suitable conditions for dolomitization as well as to biogenic processes. This idea is supported by Patterson and Kensman (1982) who reported that dolomite is formed mostly by replacing aragonite and or via an intermediate high Mg-calcite phase as documented by Katz and Mattews (1977).

Borehole No. 4 extends for about -29.5 m. Also the upper part is occupied by reefal colonies with fragmented shells of gastropods and bivalves. The lower part extends for about 15 m with a marked deficiency in carbonate materials. The terrestrial components composed mainly of Nubia sandstone (Omara 1959, Abd-El-Wahab, 1991). The Nubia sandstone of the lower part of this borehole ranged from poorly sorted fine sand at the depth intervals of -16 to -20 m, to moderately sorted very fine sands at depth of -26 m.

As shown in figure 5, the upper part of this borehole is occupied by reefal sediments and also characterized by a chemical precipitation of carbonates where the concentric calcareous rings act as a coat, or thin crust, for terrestrial nucleii. A marked deficiency of carbonate minerals are observed and represented by tinny patches of broken shell fragment. Foraminiferal tests of "***Soritus*** *sp.*" is noticed at depth levels of about -26.0 m which reflects marine environmental conditions of the intertidal zone that had been prevailed at this location.

Borehole No. 8 the carbonate layer extends for a depth less than -9 m. The coarse fraction composed of fragmented limestone and disintegrated coral reef residues with few amounts of abraded granite grains. The medium sand sized sediments consist of shell fragments of gastropods, in addition to foraminiferal tests of ***Soritus*** *sp.* characteristics to the intertidal zone. A thick layer of mainly Nubia sandstone underlying the previously mentioned layer extends for about 17.0 m from -9.6 to -26.9 m. The variation in sorting values from moderately well sorted at the bottom to poorly sorted at -9.6 m may reflect variation in the kinetic energy and/or the depositional environment as proposed by Wilgey (1961).

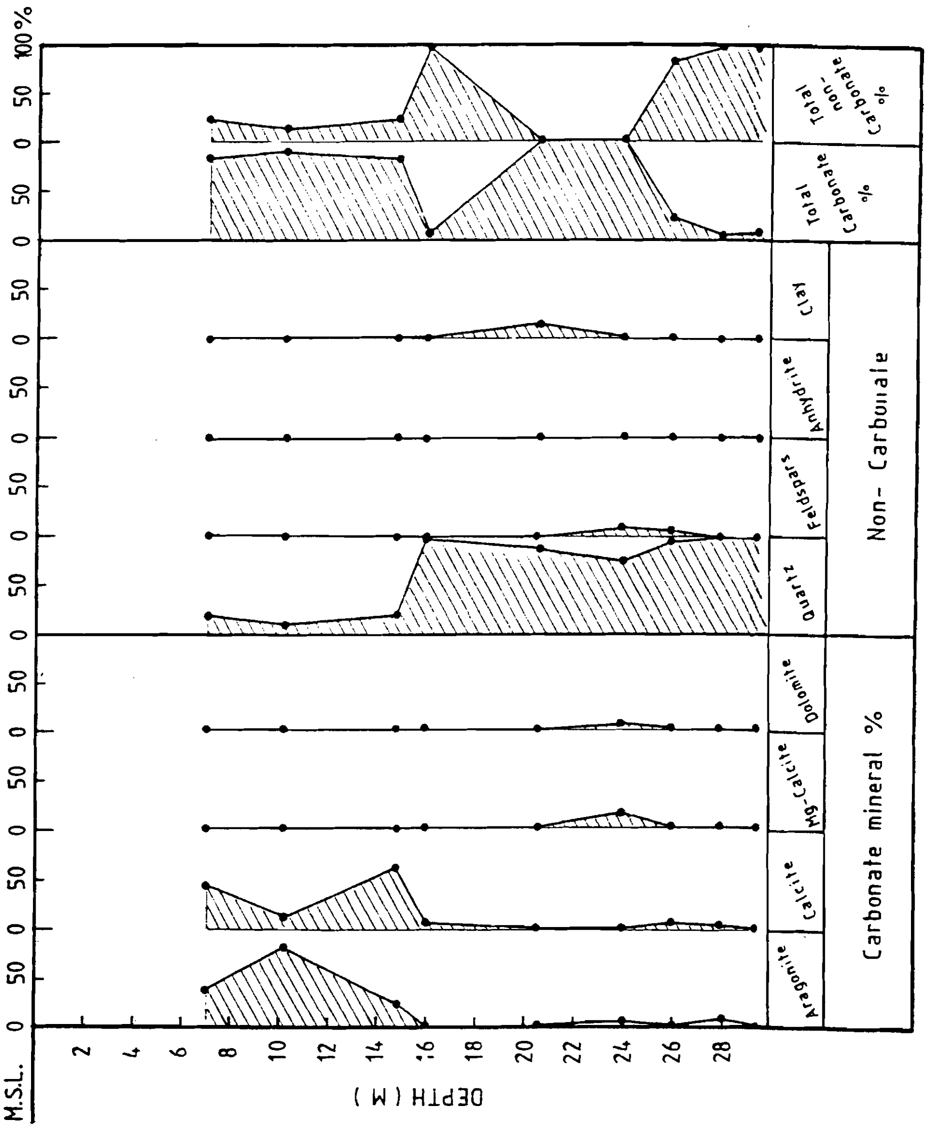

Fig. 5 : Vertical distribution of carbonate and non carbonate mineral contents of BH.4 subsurface sediments in Sharm El-Sheikh Harbor.

As shown in figure 6 the surface layer is composed of carbonate and siliciclastic components. However, the carbonate components are as twice much as the siliciclastic ones. The presence of traceable amounts of broken shell fragments and foraminiferal tests, at different depth levels in pure sandstone, may indicate the beginning of carbonate sedimentation period and/or the prevalence of intertidal conditions.

Borehole No. 9 the carbonate layer extends for about 6 m and varies from medium to fine sand sized sediments. The roundness and coarseness of foraminiferal tests of ***Soritus*** *sp.* suggest prevailing of lower energetic conditions. Directly under this layer, there is another one of medium size Nubia sandstone. A layer of about 1.5 m extends for a depth of about -7.5 m showing major variations in grain size; it consists of fine sand sized sediments probably represents an interruption in the sedimentation pattern of the whole succession of the medium sands. A layer of uniform size of moderately sorted sandstone at -11.7 m interrupts the whole succession of poorly sorted sediments.

As shown in figure 7 the surface layer exhibits lower content of carbonate than in the upper parts of boreholes (1, 2, 3 and 4). Moreover, the sediment matrix includes both sidirite and ankerite as accessory minerals. The sediment matrix includes also anhydrite that shows irregular downward increase.

Borehole No. 10 extends for about -26 m. The biogenic carbonate includes broken shell fragments of gastropods as well as foraminifers. The calm conditions in this locality are suitable to activate the physicochemical processes such as precipitation of carbonate rings with quartz nucleii. Directly under this layer, there is another one comprising coarse granitic grains.

As shown in figure 8 the whole succession of BH.10 has the same mineralogical characteristics as BH. 9, the carbonate component comprises 30% while siliciclastics 70%. Anhydrite exists with lesser amount than in BH. 9

The processing of both sedimentological and mineralogical data leads to the following determinations: -

I. Lithological characteristics:

The results of grain size and mineralogical analyses as well as field standard penetration test (SPT) have been compiled and interpreted to get a tentative

Fig. (6)

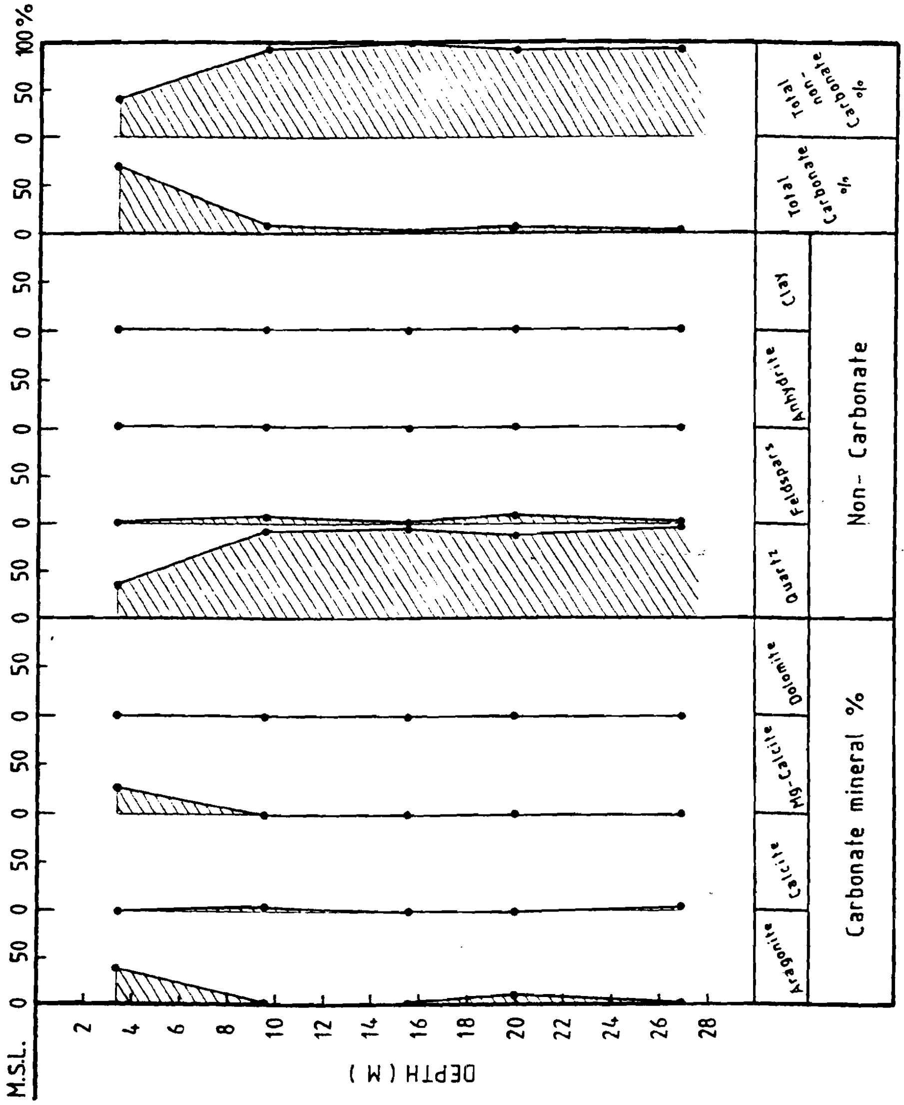

Fig. 6 : Vertical distribution of carbonate and non carbonate mineral contents of BH.8 subsurface sediments in Sharm El-Sheikh Harbor.

Fig. (7)

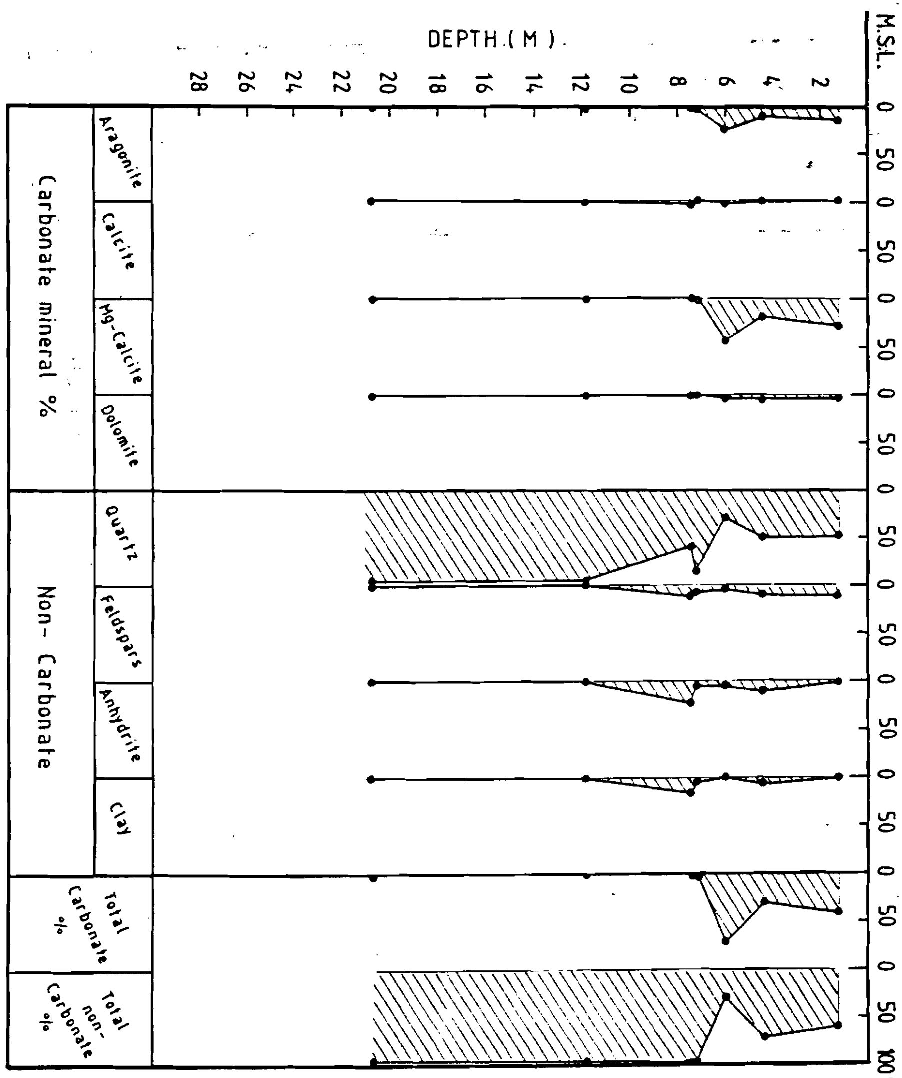

Fig. 7 : Vertical distribution of carbonate and non carbonate mineral contents of BH.9 subsurface sediments in Sharm El-Sheikh Harbor.

Fig. (8)

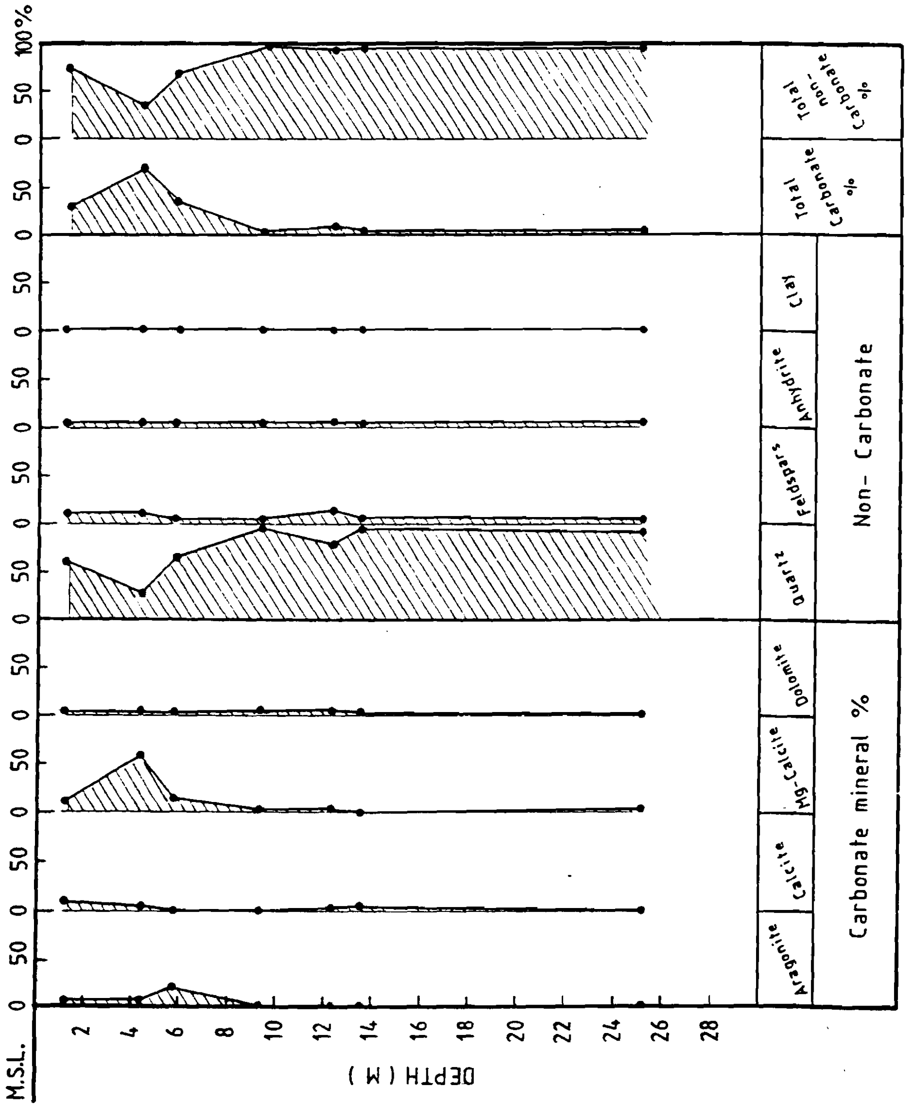

Fig. 8 : Vertical distribution of carbonate and non carbonate mineral contents of BH.10 subsurface sediments in Sharm El-Sheikh Harbor.

lithologic section (Fig. 9), along the seven boreholes, inspection of this section shows that it includes 8 different lithologic features which are described and summarized in table 1.

The existence of some lens structures (layer No.4, 5, 6 and 8) indicates the paleoenvironmental conditions of fluviomarine origin. The compiled section shows the effect of the two shallow fractures F_1 & F_2 together with the small features of deeper ones f3 and f4.

II. The position of the old shoreline:

The investigation of the studied boreholes for the vertical grain size distribution reveals that, major variations occurred in the eastern flank at depth intervals of -18.8, -18, -20 and -16 m respectively. The dominant grain size at these levels tends to be fine sand. The lithology of the sediments at these depth levels indicates variation from almost pure siliciclastic in BH.1 to mixture of siliciclastic and carbonate components in BH.2, BH.3 and BH.4. The mineralogical study of the investigated area illustrates presence of traces of anhydrite as well as dolomite at these levels. Accordingly the old shoreline was at these levels at times prior to the extensive carbonate production of reefal colonies (Fig. 10).

In the boreholes of the northern flank (BH.8, BH.9 and BH.10), the major variations in the mean grain size distribution could be detected at depth levels of -9.6, -6.0 and -9.3 m respectively. Also the presence of foraminiferal tests and finally the significant occurrence of evaporitic minerals (see table 1) define the position of the old shoreline at these depth intervals.

III. The depositional environments:

According to Sahu (1964) the depositional mechanisms from the grain size analysis of clastic sediments have been defined through statistical method. Each depositional environment assumed to have its characteristic energetic conditions. He could differentiate between the different environments with different formulae.

Fig. (9)

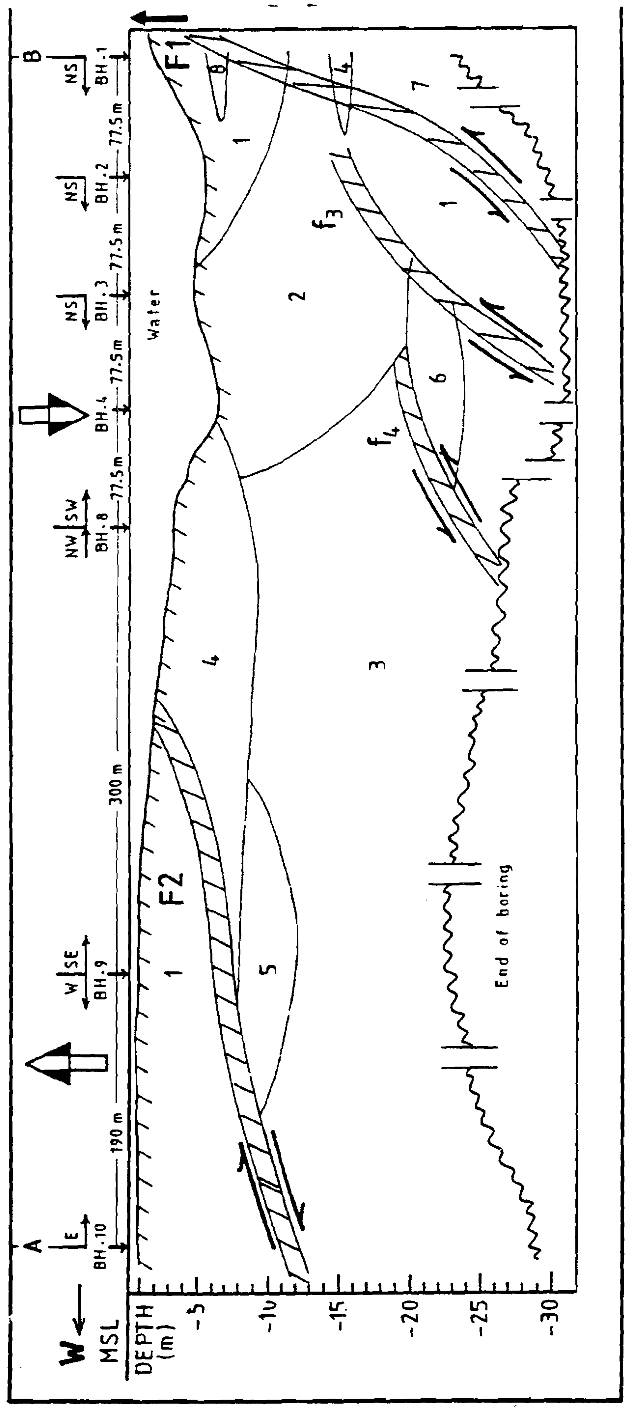

Fig. 9 : Compiled lithologic section of Sharm El-Sheikh basin.

Fig. (10)

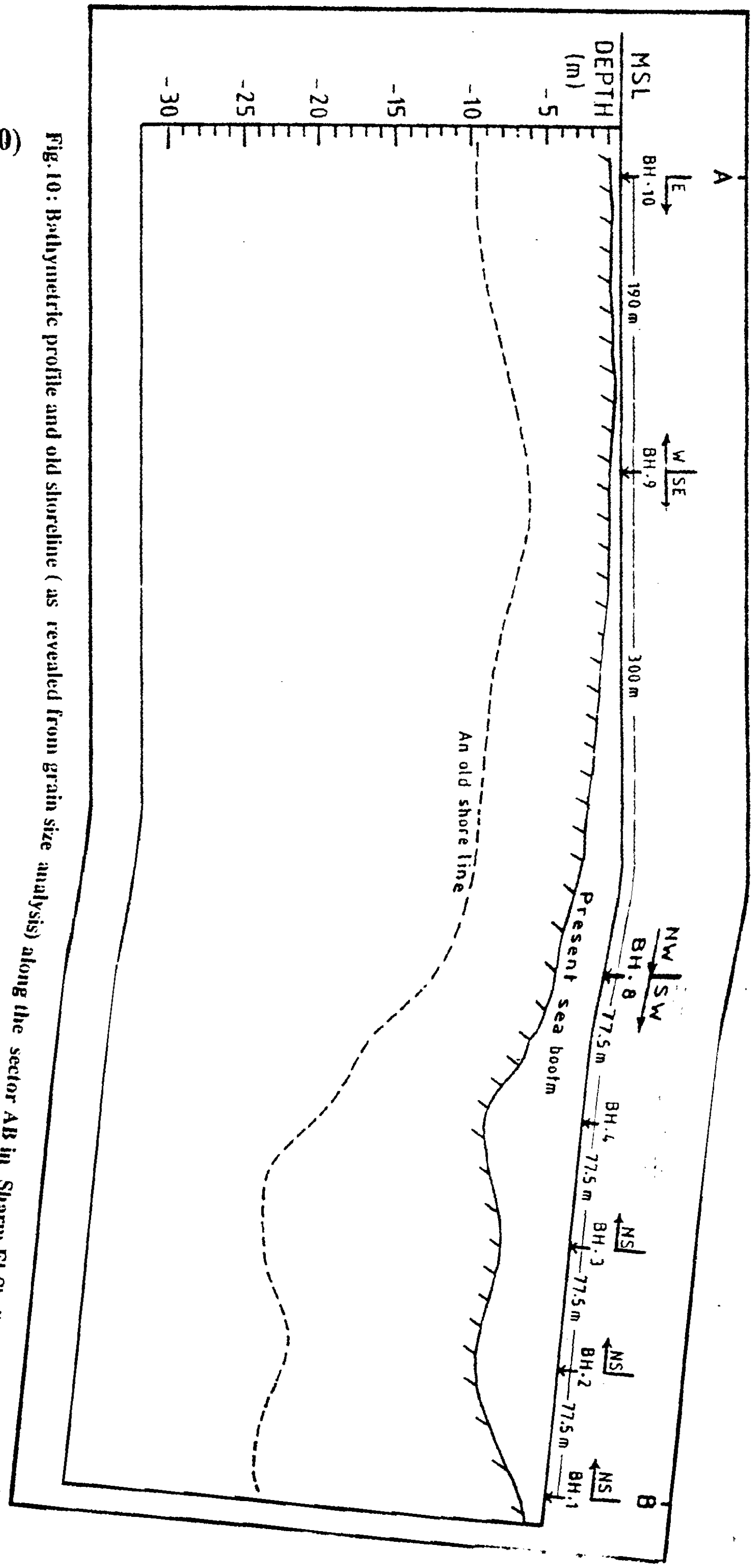

Fig.10: Bathymetric profile and old shoreline (as revealed from grain size analysis) along the sector AB in Sharm El-Sheikh Harbor.

Table (1): Compiled Lithologic description of subsurface layers in Sharm El-Sheikh.

Layer.	Lithology
1	well rounded granite grains with pink to brown color, shell fragments of gastropods with white, yellowish brown to brown colour, patches of coral reef and foraminiferal tests of different sizes. Medium to fine sand, traces of (dolomite, siderite, ankerite and heavy mineral). Carbonate/non carbonate ratio 1/2, N 25
2	mainly pure carbonate sediments. Coral reef fragments of gravel size. Little amount of Qz. granite grain, shell fragments of yellowish to white colour, poorly to medium sorted. Carbonate/non carbonate ratio 1/0.0, N 30:40
3	mainly clastic of Nubia S.S deposits, coarse to very fine sand sized, brownish yellow to yellow color. Traces of feldspars, anhydrite, ankerite, shell fragments, few amount of granite grains, heavy minerals, foramineferal tests (intertidal zone). Carbonate/non carbonate 0.0/1.0. N 125:150.
4	coarse fragments of L.S. shells of gravel size of gastropods, bivalves, foramineferal tests, coral reef fragments, dark colour due to heavy minerals, poorly sorted with medium sand size, little amount of fine sand of greywish white colour with pink granite, it is considered as the lower boundary of the carbonate layer. Carbonate/non carbonate 2/1. N 20:25
5	Lens structure of reddish brown Nubia sandstone deposited as Sabkha sediments (13.6% clay + 2.0% anhydrite) mainly clastic sediments, poorly sorted with medium sand sized, traces of carbonate minerals (dolomite, ankerite). Carbonate/non carbonate 0.0/1, N 150
6	Lens structure of fine sand poorly sorted clastic minerals, brownish silt fraction, traces of L.S. of black color as coarse fraction, clay as kaolinite 13.3%. Carbonate/non carbonate 0.0/1.0. N 150:175.
7	Composed mainly of granite grains of very coarse sand sized poorly to moderately sorted with reddish brown to pink color with traces of coral reef fragments. Carbonate/non carbonate 0.0/1.0. N 40:50.
8	Small lens, composed of coral reef fragments, broken shell fragments, granite grains, clay 8.5%, poorly sorted. N 50:60.

N = Number of blows per each 6 inches (from SPT).

In the present study, Sahu's equations (1964) were applied on the sediments of the lower parts of the examined boreholes. They consist mainly of siliciclastic components. It has been found that, all sediments of this succession had been deposited within beach environment. This agreed with the previously mentioned data about the position of the paleoshoreline.

Finally, to differentiate the origin of the siliciclastic sediments of the lower parts of the boreholes, two models of Friedman (1961) and Miolia and Weiser (1968) have been examined. Figure 11 reveals that, some sediments belong to the inland dune transported to the site of deposition by wind, whereas the other deposited from coastal dunes under the combined effects of both marine and fluviatile activities.

VI. Hydrodynamic conditions:

Visher (1969) showed that, the position of the fine truncation point might reflect turbulent energy at the depositional interface, low turbulent energy would produce truncation at a fine point, and high turbulent energy at coarse truncation point.

In the present investigation, the cumulative curves of the lower part of the examined boreholes reveal nearly absence of coarse truncation at BH.4, BH.8, BH.9 and BH.10 (Figs. 12 & 13). This suggests the presence of lower turbulent energy in comparison with those existed in the eastern flank (BH.1, BH.2 and BH.3).

The cumulative curves of the lower parts of siliciclastic sediments of BH.4, BH.8, BH.9 and BH.10 mostly have from two to three populations (i.e.) saltation, suspension and traction. Emery (1955) mentioned that, there are four main possible sources of beach pebbles; sea-cliff erosion, stream discharge, sea-floor erosion and long shore transport from one or more of the first three primary sources. It is supposed that, the possible sources in the area of investigation include stream discharge and sea cliff erosion.

Analysis of hydrodynamic conditions of sedimentation is conducted by plotting C (one percentile in micron) against M (Medium-diameter in micron) on logarithmic paper (Passega and Byramjee, 1969). Fig. (14) reveals that, the

Fig. (11)

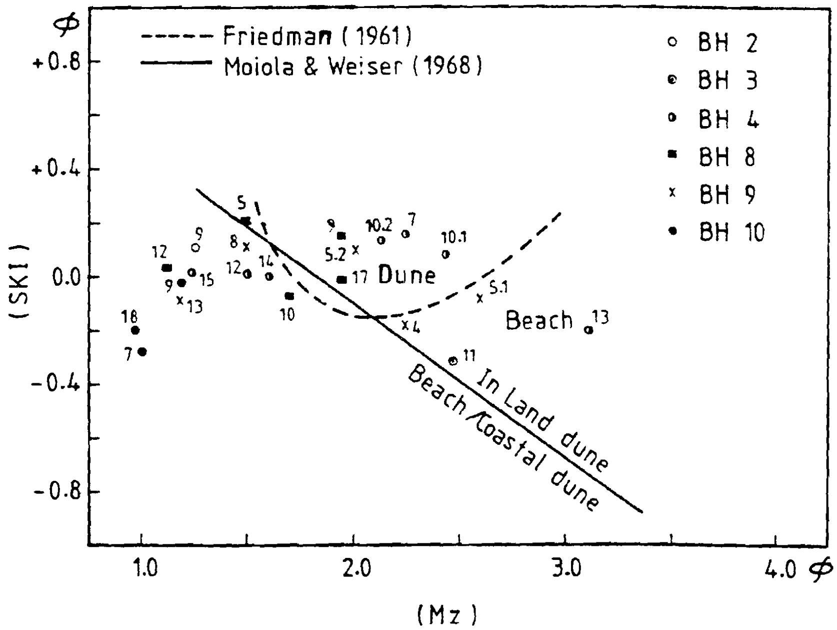

Fig. 11: Tentative diagram showing the depositional environments in the area of study.

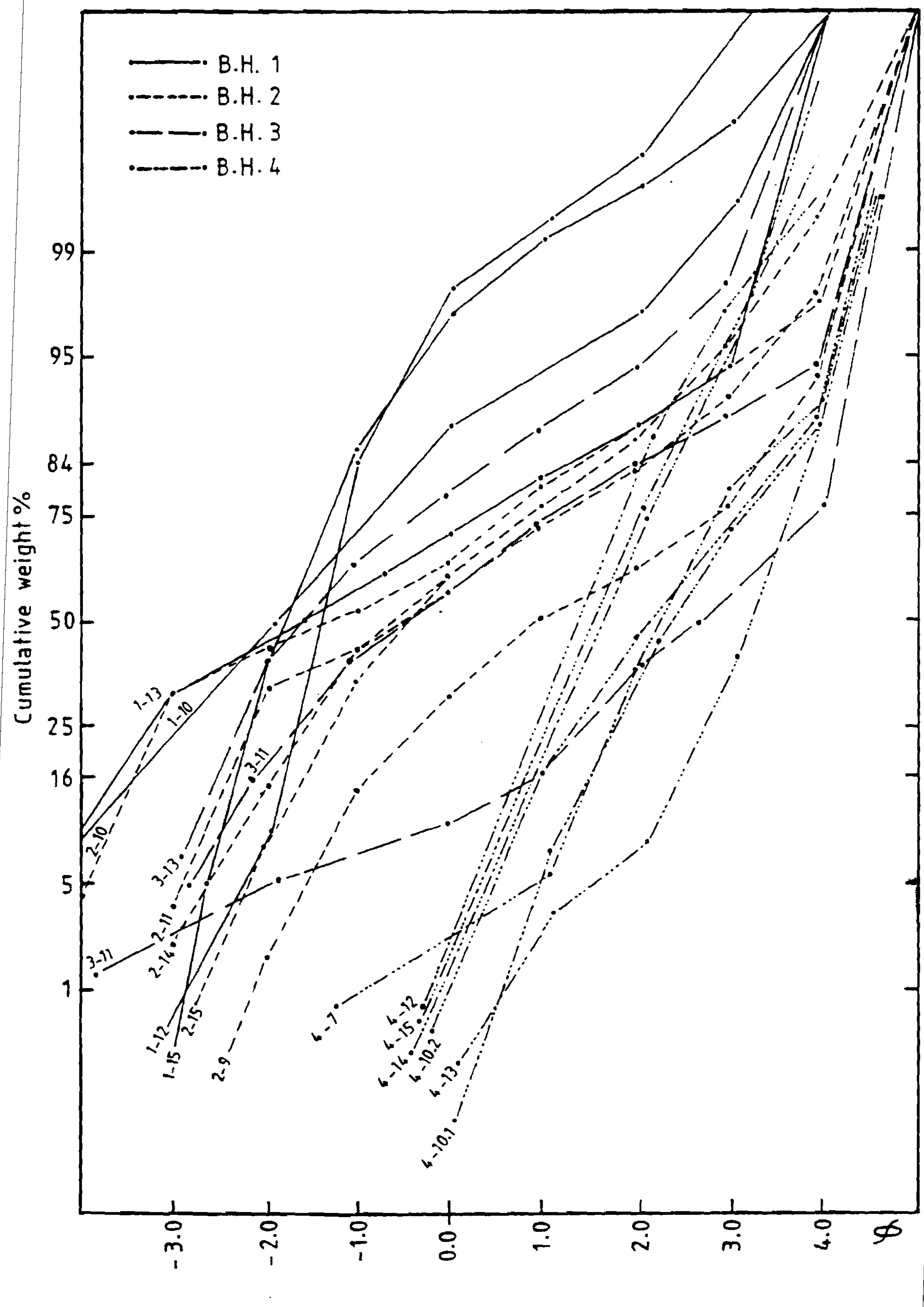

Fig. 12 : Cumulative curves of sediment samples of boreholes (1.2.3 and 4) located at Sharm El-Sheikh Harbor.

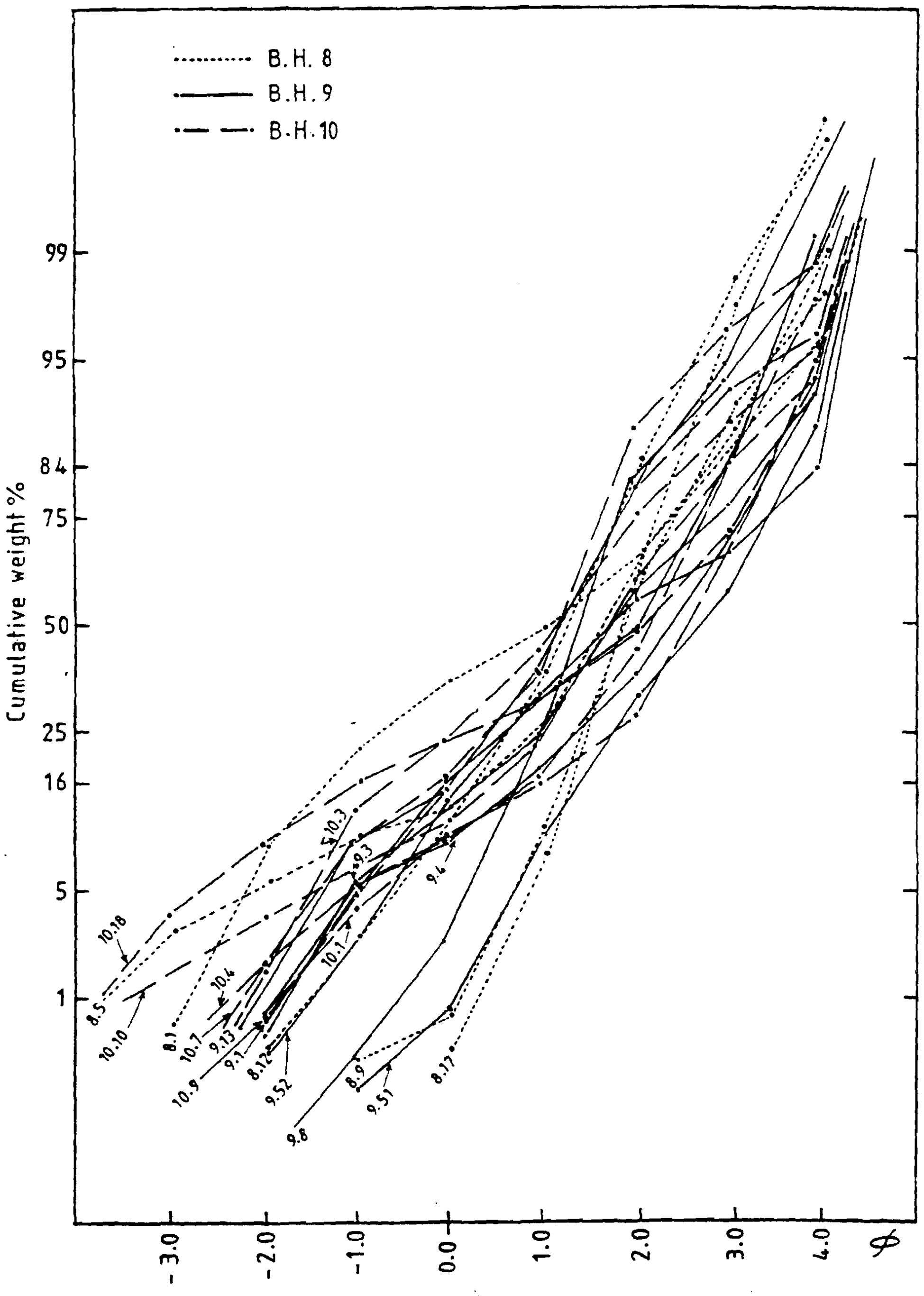

Fig.13: Cumulative curves of sediment samples of boreholes (8, 9 and 10) in the study area.

Fig. (14)

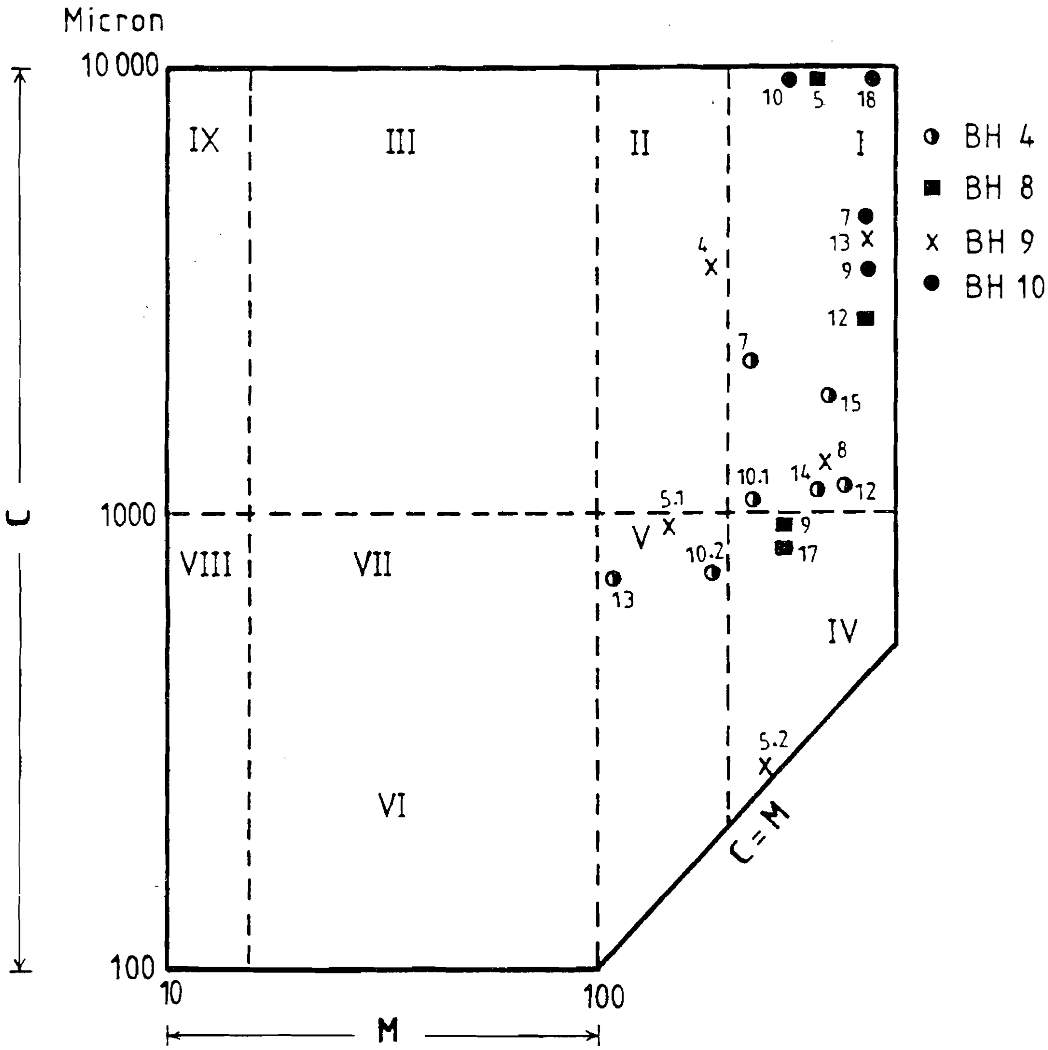

Fig. 14: C-M Pattern diagram showing the hydrodynamic conditions of sedimentation in the study area (Passega and Pyramjee, 1969).

majority of grains are transported by rolling, whereas the lower parts of BH.4 & BH.8 and the upper part of BH.9 are transported in presence of high and moderate turbulent energy as graded suspension.

V. Possible sealevel changes:

The delineation of the subsurface sediments in the study area is based on the percent carbonate (Fig. 15). Carbonate layers in BH1 dominate above about -16 m, whereas underlying layers of siliciclastic sediments derived primarily from granitic grains contain only 0 to 6 % carbonate. In BH2 and BH3, carbonate dominates above -16 and -17m. respectively. However, between 12 and 50 % carbonate is present below in both borings. In BH4 carbonate dominates above -15 m, but it is absent or rare below.

The bottom topography northward (BH8) and westward (BH. 9 and BH. 10) shows that, the carbonate layers confined in this part to shallower depths. essentially above -6m.

The bathymetric configuration (Fig. 16) indicates formation of a drowned fluvial valley. This might be took place during the Late Pleistocene. The area was completely exposed, and relative sea level was near -120 to -130m, about 18,000 Y.B.P. (Kennet, 1982).

As the Holocene transgression started, the seawater reached the Sharm and began to accommodate and maintain marine conditions favorable for the carbonate precipitation.

The vertical distribution of the carbonate percent shows that, the sedimentation occurred at two stages; -

(a) The pre-final stage which extends downward from a depth of about -15 m below present mean sea level with lower rate of carbonate sedimentation and

(b) The final stage, which is concerned with formation of recent reefs and extends from a depth of -5 m downward to -15 m with a high rate of carbonate sedimentation.

The gradient of percent carbonate was employed to infer relative changes of Holocene sea level. The low gradient is attributed to an event related to a past

Fig. (

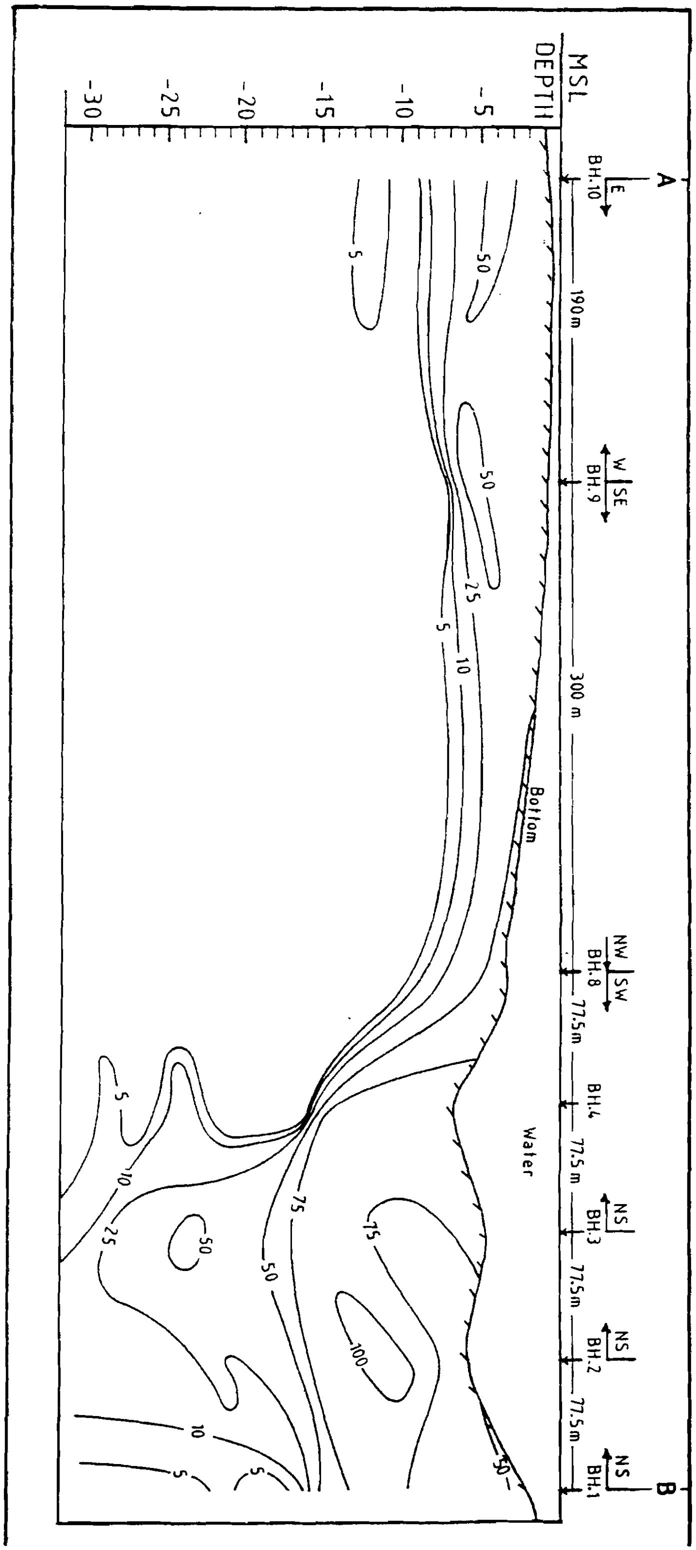

Fig. 15 : Vertical contour section showing the variation of carbonates % of subsurface sediments in Sharm El-Sheikh Harbor.

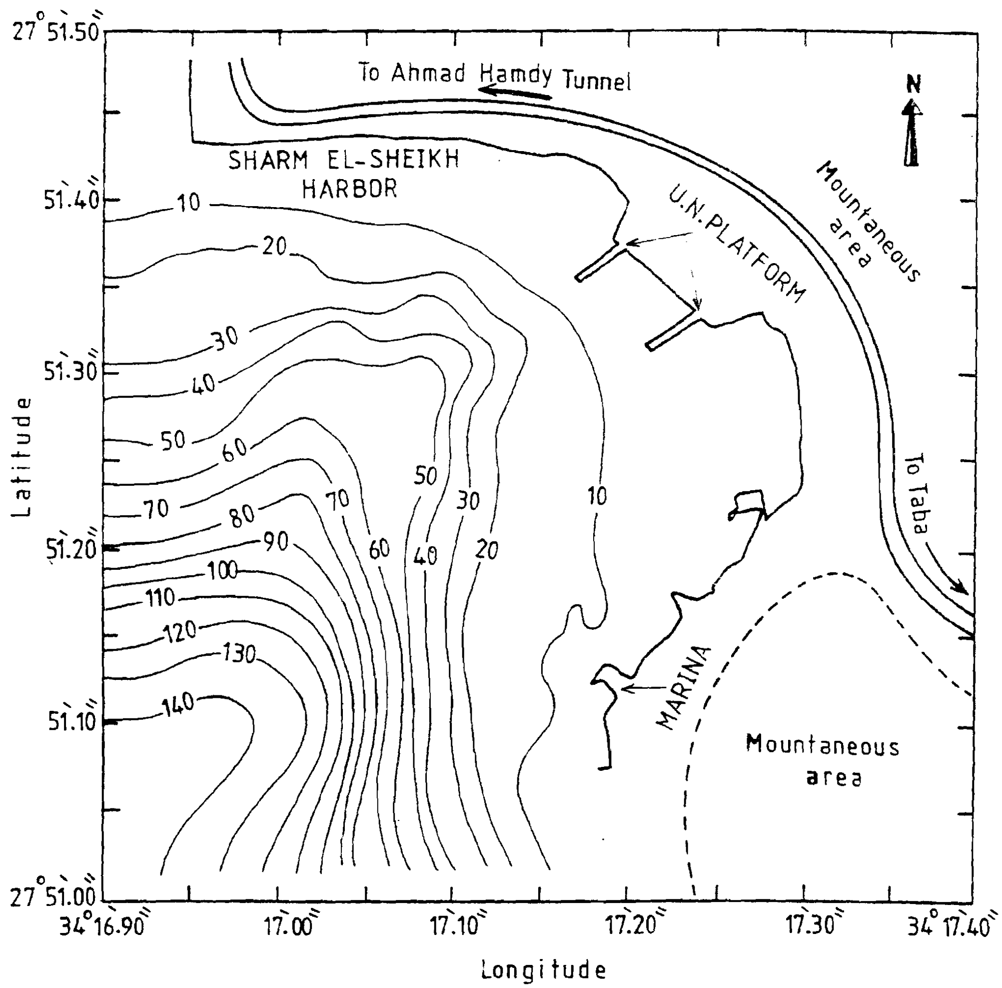

Fig.16: Bathymetric chart of Sharm El-Sheikh basin.

sea level rise, thereafter, it would pass through a still stand period, then followed by sea level fall which is contributed by high gradient of percent carbonate. The data may suggest a continuous rising of sea level, interrupted by two distinct falls, at -14.7 to -16.0m and -5.7 to - 7m have taken place below the present sea level.

The analyses were carried out comparatively in relative dependence on a chronogram of relative Holocene sea level changes (Fig. 17), as revealed from seismic stratigraphic analysis of Sharm Abhur, Saudi Arabia, Red Sea, (El-Abd and Awad, 1992) taking the dashed line representing the present sea level as reference zero. The comparative study showed that, the two sea level falls can be marked at about 7217 and 4000 Y.B.P.

The present work suggests a chronogram (Fig. 18), which indicates three sequential subcycles of transgression, which had been intermittent by the above two distinct falls.

The first one is shown at a relative sea level -29.5m below present sea level since 8835 Y.B.P., the second one had started at a relative sea level -16.0m below present sea level since 7217 Y.B.P. while the third one had started at a relative sea level -7.3m below present sea level since 4000 Y.B.P. Their corresponding relative rates of carbonate sedimentation are 9.2, 2.9 and 1.4 mm/y, for the three subcycles respectively with an overall average 3.33 mm/y.

The obtained chronological results match well the global one obtained by Fairbridge (1961), Kraft (1976) and Kennet (1982).

However, this approach needs further analyses (such as C_{14} dating and seismic stratigraphic correlation) to get more precise overview of Holocene sea level variation in the Gulf of Aqaba.

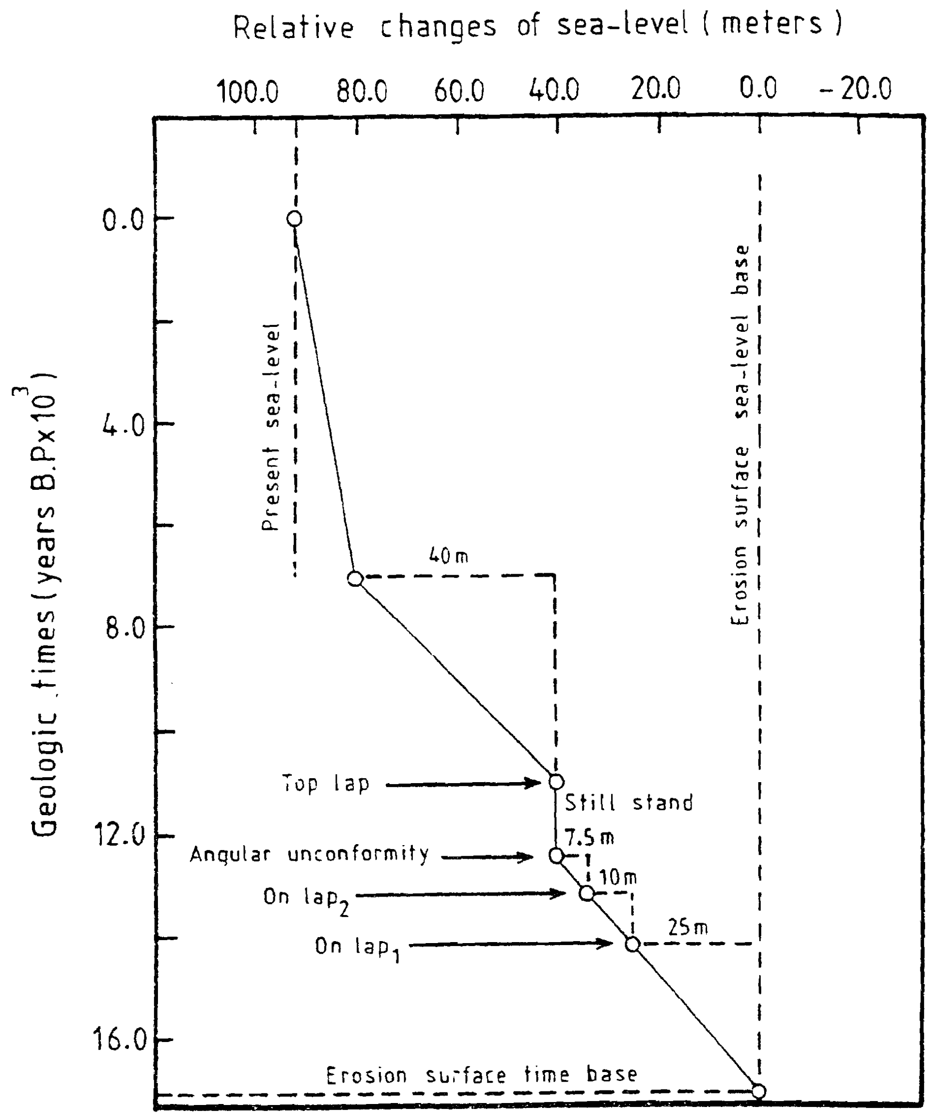

Fig. 17 : Chronogram of Holocene sea level variations in Sharm Obhur, Red Sea, after (El-Abd & Awad, 1992).

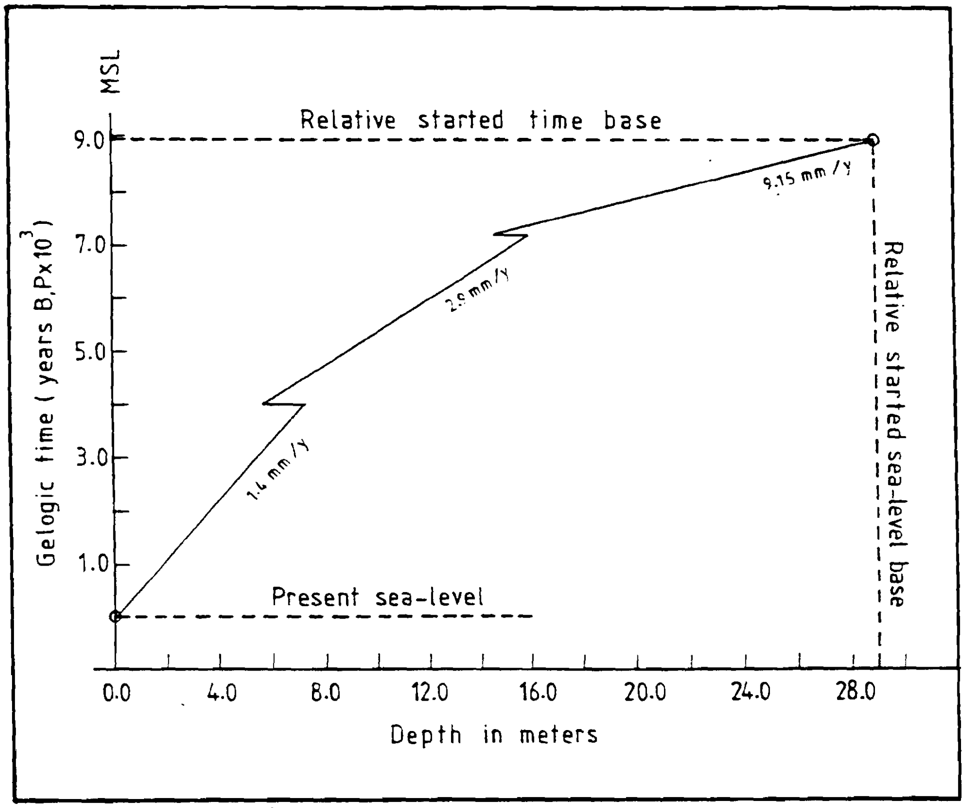

Fig. 18 : Tentative chronogram showing relative changes of sea level in Sharm El-Sheikh Harbor, Red Sea.

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