Textural Characteristics, Mineralogy and Fauna in the Shore Zone Sediments at Rabigh and Sharm al-Kharrar, Eastern Red Sea, Saudi Arabia

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ABSTRACT. Thirty-nine sediment samples were collected along three profiles normal to the shore at Rabigh coast and beside the outlet of Sharm al-Kharrar. Samples were collected from beach, nearshore and offshore zones.

The textural criteria outlined in this paper together with information given by mineralogy and fauna provide new insight for the shore zone along the Saudi coast of the Red Sea.

Sediments in two of the three profiles studied have the coarsest grain size and the poorest sorting in the nearshore (breaker) zone, and improve in sorting both shoreward and seaward. Skewness generally tends to be negative in the breaker zone and positive shoreward. Coarse sediments are dominants along Al-Kassara bar due to the erosive power of waves. Probability cumulative grain size curves reflect the sedimentary process dynamics and suggest that the nearshore sediments have the highest content of surface creep material.

The nearshore sediments in the three profiles in concern are generally composed of carbonate grains rich with benthic foraminiferal fauna: Calcarina, Elphidium, Peneroplis, Amphistegina, Sorites, Spiroline, Triloculina and Ammonia arranged in a decreasing order of abundance. Micragnostorps and microplecypods are also abundant.

The heavy mineral suite has dominance of less stable minerals; amphiboles, pyroxenes and epidotes over the stable constituents; zircon, tourmaline and rutile which are mostly common in the shore-zone sediments of Rabigh coast. Few amounts of detrital quartz and feldspar grains are also encountered especially in the very light fine fraction.

Introduction

The present study is devoted for the comparison of nearshore sediments at Rabigh and those beside the outlet of Sharm al-Kharrar along the eastern Red Sea coast (Fig. 1).

The nearshore is a dynamic zone dominated by breaking waves and by wave-induced current. Breaking waves and surf are confined mainly to the Al-Kassara bar (Fig. 2) and to the edge of the beach. As waves approach the shoreline, their energy is used to rework the nearshore sediments and modify the topography.

Sedimentary processes associated with wave action are of interest to sedimentologists because of the need to understand coastal environments. Waves and longshore currents are responsible for deposition and erosion on sand beaches and small scale features including beaches, nearshore bars and ridges as well as tunnel topography are controlled by waves, longshore currents and tidal current.


The intent of this paper is to provide a background to the regional trends in the textural parameters, mineral associations and benthonic foraminifera along the shore-zone at Rabigh and at the outlet of Sharm al-Kharrar. Specifically, the purpose of this paper is to
Fig. 1. Location of studied profiles.

Fig. 2. Various geomorphologic features of beach profile at Rabigh.
investigate if there is a distinct differences in grain-size parameters, the heavy minerals suites and benthic foraminiferal species on the shore-zone profiles at Rabigh and the outlet of Sharm al-Kharrar. Beaches in these areas are narrow, poorly developed and rocky. Like most of the beaches along the Saudi Arabian Red Sea coast they are associated with raised terraces of the reef limestone.

Al-Kharrar lagoon lies on the coastal plain north-west of Rabigh on the western coast of Saudi Arabia (Fig. 1). It is connected to the adjacent Red Sea by a narrow channel on its northwestern side.

**Morphology**

The area under investigation lies between longitudes 38°45' & 39°00'E and latitudes 22°45' & 23°00'N. It extends for about 30 km along the coast. The study of the area was based on the investigation of ERTS Satellite, field and laboratory studies.

The area can be morphologically subdivided into lagoon, dunes, beach (backshore and foreshore), nearshore and offshore zones.

The nearshore zone is an area of shallow water spreading between 150 m wide at Rabigh and nearly 250 m wide at the outlet of Sharm al-Kharrar. It is characterized by steep shoreline as shown in the schematic representation of the profile near Rabigh (Fig. 2).

The sea floor of the nearshore zone is generally flat and is covered by a thin layer of unconsolidated sediments overlying the consolidated reefal limestone. The sediments are mostly composed of calcium carbonate; comprising skeletal and non-skeletal remains, and subordinate quartz sand grains.

The beach is poorly developed and composed largely of raised terraces of reefal limestone rocks covered by aeolian terrigenous constituents probably derived from the coastal erosion of the coralline limestone cliff as well as from the Tertiary mountains which dominate in the eastern coastal plain of the Red Sea.

**Sampling and Methods of Study**

Thirty-nine samples of unconsolidated sediments were collected along three profiles perpendicular to the beach, two at Rabigh and one beside the outlet of Sharm al-Kharrar. These profiles extend seaward from the backshore across the beach to the Al-Kassara bar at a depth of approximately 70 cm below sea level. Among these samples, four were collected from the offshore zone of profile no. 1 behind Al-Kassara at depths ranging from 15 to 25 m. The nearshore samples were collected at intervals of 10 m to 15 m front the base line.

The collected samples were spread on a paper sheet and allowed to dry in air then disaggregated and a known weight of each sample was washed by water to remove the soluble salts and dried at 80°C. About 100 g of each sample were taken for analysis using a mechanical shaker with a sieving time of 15 minutes. Sieve with class intervals (1.0, 0.25, 0.125, 0.05, 0.06, 0.035, 0.025, 0.0125) were used and the mean mean (M,), standard deviation (σ), inclusive skewness (Sk) and graphic kurtoisis (Ke) were obtained using Folk's graphic method (Folk, 1965).

Heavy mineral analysis was carried out on 25 samples representing two shore zone profiles. The mineral analysis was applied to the 0.125-0.063 mm size fraction. The heavy minerals were obtained by using a tetraethylenelmaleate separation technique, taking into consideration the precautions given by Carver (1971). The heavy mineral fraction was washed by alcohol, dried, weighed and heavy mineral percentages were calculated for each sample. Then the heavy mineral fraction was mounted in balsam on a glass slide for microscopic investigation. Counting was carried out for 400 mineral grains for each sample. The relative frequency percentages of the heavy mineral grains were calculated. The common heavy minerals have been described according to Milner (1962).

Micropaleontological investigation was carried out on the 0.5 mm size fraction of the sediment. The most common species in each sample were identified and the percentages of different genera were determined by a count of 300 specimens. Further investigation concerned with the abundance and distribution of genera of the benthic foraminifera in the other different size fractions to deduce their regional trend of variation.

**Results and Discussion**

**Textural Composition Variations**

It was found that the beach zone sediments at Rabigh (Profiles No. 1 & 2, Figs. 3 & 4) are composed mainly of medium-grained sand, rarely containing gravels and/or mud material. The nearshore sediments are composed of gravel and sand and in profile No. 1 are marked by increasing in coarser material seaward along the profile (Fig. 3).

The texture composition of the shore zone sediments at the outlet of Sharm al-Kharrar (Profile No. 3, Fig. 5) exhibits different trend containing sand towards the sea and more gravels near the beach.
Fig. 3. Variation of grain size fractions in the shore zone at Rabigh (Profile no. 1).

Fig. 4. Variation of grain size fractions in the shore zone at Rabigh (Profile no. 2).

Fig. 5. Variation of grain size fractions in the shore zone near the outlet of Sharm al-Khair (Profile no. 3).
In contrast to the nearshore zone at Rabigh, the offshore sediments, profile No. 1 are sandy (Fig. 3); gravel occurs in scarce amounts closest to the shoreface and the fine fraction increases seawards with increasing depth of water.

The variability in texture composition along the shore zone sediments profiles studied (beach, nearshore and offshore) seems to be attributed to the kind of sediment transport processes, reworking and marine wave mechanism originated by wind action which reduce the size of sediments toward the sea. However, one should not neglect the importance of longshore and rip currents in modifying the sediments in the nearshore zone (surf zone). In addition, Reineck & Singh (1975) believed that the bottom drawer for the backwash can transport the coarser sediments towards the breaker zone. However, at the same time sediments can be brought from the open sea towards the breaker zone. Therefore, the breaker zone is characterized by coarse-grained sediments. Moreover due to the gentle slope of the shore along the eastern Red Sea coast, the longshore currents appear strong enough to be able to transport the sediments parallel to the sea.

**Grain-size Data**

The grain size frequency data of the sediments in the three shore profiles were represented graphically as histograms shown in Figs. 6 to 9 and cumulative curves given in Figs. 10 to 13.

The shore zone sediments in the three profiles under study exhibit a wide modal variation; unimodal, bimodal and polymodal mostly varying with different microenvironments within the shore zone. Beach sediments (backshore and foreshore zones) have distinctly unimodal distribution, generally made up of one class falling in the medium sand fraction (See Figs. 6 & 7), whereas the sediments in the nearshore zone display asymmetric bimodal and polymodal distributions in which the coarse fractions predominant. The unimodal of grain size distribution of the beach zone sediments is probably an attribute of the differentiation in sorting produced by swash and backwash currents (Visher 1969). The bimodal and polymodal distributions are probably due to the increasing erosive power of waves generated by winds. The histograms constructed for the offshore sediments (Fig. 9) also show polymodal distributions probably reflections deposition of destructive material along Al-Kassara recid bar in the shoreface generally by rip currents.

The analysis of probability grain size distribution curves of the type shown in Figs. 10 to 13 is a fruitful method of studying sedimentary process dynamics.

![Fig. 6. Histograms of shore zone sediments at Rabigh (Profile no. 1).](image-url)
Visher (1969) related the shape of such curves to the mode of transport.

A trial has been made herein to emphasize the significance of the distribution curve shapes constructed for the sediments in the three shore zone profiles. We notice, for example that the suspension population shown in Figs. 10 to 13 generally reflects mixing with and sometimes separate from the saltation population. This is related to turbulence in the overlying fluid and/or the presence of a boundary layer. However, mixing appears sometimes related to highly variable energy conditions.

The cumulative curves of the offshore sediments in front of Rabigh (Fig. 10) reflect similarity in the slope of the three populations denoting a strong mixing. Little sediment grains are moving by rolling transport.

The saltation population observed in Figs. 11 & 12 generally displays a wide range in grain size and has two distinct saltation sub-populations which differ in mean-size and sorting. Saltation normally characterizes the sediments in the beach zone where swash and backwash are active and this prevailed when opposing flows are active. Thus good sorting of the saltation population appears to reflect reworking or winnowing by waves in the swash and backwash zone. Therefore the steeper is the slope of this part of the distribution.

In contrast to the first saltation sub-population, the second saltation sub-population recorded in the cumulative curves of the nearshore zone sediments shown in Figs. 11 & 12 has poor sorting probably due the dumping from a highly turbulent graded suspension-traction carpet. A strong mixing between the saltation and suspension populations is further noticed. This would be the result of interaction of waves with strong tidal currents where the surface population has been removed possibly in the shallower water (Visher, 1969).

The cumulative curves of the nearshore sediments are further characterized by a large percentage of the surface creep population. The amount of this population is largely provenance controlled and wave conditions, so the finer grain sizes must be removed.

Cumulative curves of the nearshore sediments at the outlet of Sharm al-Kharrar (profile No. 3, Fig. 13) generally reflect mixing of the three populations with variable percentages of surface creep population probably due to the highly variable energy conditions.

**Distribution and Significances of Grain-Size Parameters**

Interpretations of the graphic grain size data of the sediments in the three shore profiles studied here are summarized in Tables 1 to 4.
Fig. 8. Histograms of shere zone sediments near outlet of Shurūm al-Kharrūr (Profile no. 3).
Fig. 12. Cumulative curves of shore zone sediments at Ralph (Profile no. 2).
Fig. 13. Cumulative curves of shore zone sediments near the outlet of Sharm el-Kharrar (Profile no. 3).
### Table 1. Interpretation of grain size parameters of Folk & Ward (1957) for the shore sediments at Rabigh coast (Profile No. 1).

<table>
<thead>
<tr>
<th>Distance from shore (m)</th>
<th>Mj</th>
<th>Description</th>
<th>0.1</th>
<th>Description</th>
<th>SK</th>
<th>Description</th>
<th>K3</th>
<th>Description</th>
</tr>
</thead>
<tbody>
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<td>Backshore</td>
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<td>V. well sorted</td>
<td>0.00</td>
<td>Near symm.</td>
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<td>Near symm.</td>
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<td>Near symm.</td>
<td>1.07</td>
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<td>V. coarse skewed</td>
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<td>V. platykurtic</td>
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### Table 2. Interpretation of grain size parameters of Folk & Ward (1957) for the offshore zone sediments at Rabigh coast (Profile No. 1).

<table>
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<tr>
<th>Depth (m)</th>
<th>Mj</th>
<th>Description</th>
<th>0.1</th>
<th>Description</th>
<th>SK</th>
<th>Description</th>
<th>K3</th>
<th>Description</th>
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<td>Near symm.</td>
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### Table 3. Interpretation of grain size parameters of Folk & Ward (1957) for the shore zone sediments at Rabigh coast (Profile No. 2).

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<td>Near symm.</td>
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Table 4. Interpretation of grain size parameters of Folk & Ward (1957) for the shore zone sediments near the outlet of Sharm al-Kharrar (Profile No. 3).

<table>
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<tr>
<th>Distance from shore (m)</th>
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<th>Description</th>
<th>S&lt;sub&gt;1&lt;/sub&gt;</th>
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<th>K&lt;sub&gt;r&lt;/sub&gt;</th>
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</table>

**Mean Size**

With regard to variation of mean grain size (M<sub>j</sub>), the sediments in the shore zone at Rabigh (Profile No. 1, Fig. 14), show a marked increase in M<sub>j</sub> from fine and medium sand in the beach zone to coarse and very coarse sand in the nearshore zone followed by rapid decrease in size toward the offshore zone. In contrast, the mean size pattern of sediments in profile No. 2 at Rabigh shows no consistent trend (Fig. 15). It generally oscillates between coarse sand and medium sand especially in the nearshore zone. A conspicuous very coarse sand is recorded near the beach probably due to the winnowing of the finer grain-size population by wave and current action in the nearshore environment as proposed by Mason and Folk (1958), Duane (1964) and Friedman (1961 & 1967).

A general seaward decrease in mean-size is exhibited by the sediments of the shore zone profile at the outlet of Sharm al-Kharrar.

**Standard Deviation**

Concerning sorting distribution, the pattern exhibited by the sediments of profile No. 1 at Rabigh (Fig. 14) indicates good to moderately good sorting for the beach sediments and a general poor sorting for the nearshore and offshore sediments. The sorting variation probably results from small energy fluctuations. A similar behaviour of sorting distribution is exhibited by the sediments in the nearshore zone of profile No. 2, (Fig. 15) and profile No. 3, (Fig. 16).

It is noticed that the sorting commonly improves with decreasing grain size (Fig. 14). Whereas the converse is true for the sediments in the beach zone of Sharm al-Kharrar. It is known in general that sediments on beaches receiving considerable sediments influx will be more poorly sorted than sediments in beaches receiving little sediments influx (Folk, 1965). However, the major cause of the grain size difference is the effect of the lag graviels on sorting formed by the accumulation of shell fragments.

The general poor sorting and polymodal grain size distribution of the nearshore sediments indicate that the wave processes and tidal currents are not intense enough to rework and sort the sediment.

**Skewness and Kurtosis**

Data of skewness and kurtosis given in Tables 1 & 3 show that the beach sands in profiles 1 or 2 at Rabigh are near symmetrical and mesokurtic in grain size distribution consistent with Folk’s (1965) observation that most beach sands tend to have fairly normal curves. In contrast, the nearshore sediments exhibit a wide range of skewness and kurtosis values varying from very coarsely skewed to very finely skewed and from platykurtic to leptokurtic.
Fig. 14. Variation of grain size parameters in the shore zone sediments at Rabigh (Profile no. 1).

Fig. 15. Variation of grain size parameters in shore zone sediments at Rabigh (Profile no. 2).

Fig. 16. Variation of grain size parameters in the shore zone sediments near outlet of Shum al-Khurrut (Profile no. 3).
The variability in kurtosis values (Tables 1 to 4) appears to be strongly related to the variability and energy of the wave regimes. Further going seaward, the sediments in the offshore zone at Ratigh is coarsely skewed and mesokurtic.

Conversely, the shore sediments at the outlet of Sharm-al-Kharrar appear mostly negatively skewed with kurtosis dominantly mesokurtic and slightly platykurtic (Table 4). The fine material was probably removed due to winnowing, indicative of erosion along this part of the Red Sea coast.

Discrimination of sedimentary environments using bivariate plots of statistical grain size parameters has been employed on recent and ancient sediments by many authors (Friedman, 1961 & 1967; Moiola and Weiser, 1968; Mason and Folk, 1958; Stewart, 1958 and Passiaga, 1957, 1964).

It was found that application of these plots to our data of the shore zone sediments is not suitable because it doesn't yield interpretable results. However, plotting the standard deviation versus mean size succeeded to distinguish the beach sands from the nearshore sands (Fig. 17).

**Mineralogy of the Heavy Fraction**

Heavy mineral analysis was carried out on 24 samples representing two shore profiles, one at Ratigh and the other at the outlet of Sharm-al-Kharrar. The 0.125-0.0063 mm fraction of the heavy minerals concentrate was used for mineralogical analysis. The non-opaque minerals are most useful in genetic interpretation (Carver, 1971) so they are recalculated to total 100%, thereby excluding opaques. The relative frequency percentages of heavy minerals encountered in the two profiles were given in Tables (5 & 6).

The main constituents of heavy minerals are opaques, amphiboles, pyroxenes, epidotes, clinopyroxene, hornblende, and rutile arranged in decreasing order of abundance. Garnet, chlorite, staurolite, kyanite, biotite, and sphene are found in smaller amounts.

In general, opaques are surrounded by well-rounded grains of feldspar and magnetite, some of which are partially and/or completely altered to hematite. We observed that opaques dominate the heavy minerals in the shore sediments of Ratigh. They vary between 70.8% and 28%, whereas ranges between 30.45% and 13% in the shore sediments at the outlet of Sharm-al-Kharrar.

The relative concentration of heavy minerals in the beach sediments at Ratigh is probably due to the relative sorting by wave during storms which produce heavy mineral placer in the backshore region (Reitbek & Singh, 1975). However, the nearshore sediments show an appreciable content of heavy minerals indicating an active storm waves. In addition, wind action plays an important role in heavy mineral concentration.

**Amphiboles**

Other than opaques, amphiboles are the abundant heavy minerals. They are mainly represented by hornblende and fibrous tremolite-actinolite which occur as subrounded or prismatic grains. Hornblende is found in many varieties; yellowish green, dark
### Table 5: Relative frequency percentages of heavy minerals in the shore zone sediments at Rabigh coast (Profile No. 1).

<table>
<thead>
<tr>
<th>Sample no</th>
<th>Distance from shore (m)</th>
<th>% Total MIN</th>
<th>Ilmenite</th>
<th>Pyrope</th>
<th>Anorthosite</th>
<th>Epidote</th>
<th>Zircon</th>
<th>Rutile</th>
<th>Tourmaline</th>
<th>Garnet</th>
<th>Kyanite</th>
<th>Chlorite</th>
<th>Biotite</th>
<th>Smectite</th>
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<tbody>
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<td>78.83</td>
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<td>32.63</td>
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<td>3.08</td>
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### Table 6: Relative frequency percentages of heavy minerals in the shore zone sediments near the outlet of Sharm al-Khattat (Profile No. 3).

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<th>Distance from shore (m)</th>
<th>% Total MIN</th>
<th>Ilmenite</th>
<th>Pyrope</th>
<th>Anorthosite</th>
<th>Epidote</th>
<th>Zircon</th>
<th>Tourmaline</th>
<th>Ilmenite</th>
<th>Garnet</th>
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<td>7.87</td>
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<td>2.15</td>
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<td>4.12</td>
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</tr>
</tbody>
</table>
bluish green and brown hornblende. Amphibole range in abundance from 17% to 60.6% and from 28.86% to 64.86% in the shore sediments of Rabigh and at the outlet of Sharm al-Kharrar, respectively.

**Pyroxenes**

Both monoclinic (augite and diopside) and rhombic members (hypersthene and enstatite) of the pyroxenes series are found. Augite is the most common and includes greenish yellow and brownish violet varieties. Enstatite, hypersthene, diopside and aegirine are also noticed. Pyroxenes range in abundance from 14.3% to 46.5% in the shore sediments of Rabigh and from 15.65% to 63.4% in the shore sediments at the outlet of Sharm al-Kharrar.

**Epidote**

Epidote grains are found in appreciable amounts and are represented mainly by pisteicite, chinozoite and zoisite. They occur as rounded to subrounded grains and constitute 3% to 23% of the heavy mineral concentrate in the shore sediments of Rabigh and 2.79% to 16.13% at the outlet of Sharm al-Kharrar.

**Zircon, Tourmaline and Rutile**

These three minerals are ultrastable grains that constitute up to 35% of the non-opaque heavy minerals in the shore sediments of Rabigh. Zircon is recorded in considerable amounts in the shore zone of Rabigh. It reaches in abundance up to 29.67% and 6.96% in the beach zone of Rabigh and at the outlet of Sharm al-Kharrar, respectively. Zircon grains are almost prismatic with angular to subrounded terminations. Euhedral grains are also encountered.

Tourmaline occurs as highly pleochroic brown and green varieties, and attains its maximum frequency of 7.87% in the beach sediments of the outlet of Sharm al-Kharrar. Rutile is represented by yellowish to reddish brown varieties with the characteristic high relief.

The frequency distribution of the non-opaque heavy minerals (Figs. 18 & 19) demonstrates that two different heavy mineral associations characterize the shore zone sediments of Rabigh. A stable association consists of zircon, tourmaline and rutile and an unstable association consists of amphibole, augite and epi-

---

**Fig. 18.** Distribution of the non-opaque heavy minerals in the shore zone sediments at Rabigh.

**Fig. 19.** Distribution of the non-opaque heavy minerals in the shore zone sediments near outlet of Sharm al-Kharrar.
doe. In contrast, the shore zone sediments at the out-
let of Sharm al-Kharraz are distinguished mainly by 
the unstable heavy mineral association and to a lesser 
extent by the stable one.

A comparison of the distribution of heavy minerals in 
the two zone profiles (Figs. 18 & 19) reveals an increase of pyroxene, tine corresponding to 
decrease of amphibole in the shore zone sediments at 
the outlet of Sharm al-Kharraz (Fig. 19).

In general, amphiboles and pyroxenes are the most 
abundant constituents in the examined sediments, 
while calcite, tourmaline and rutile constitute a sig-
ificant position of the total non-opaque in the shore 
zone sediments of Rabigh.

A comparison of mineralogy between beach and 
nearshore sediments proved the enrichment of beach 
zone by ZTR and opaques than the nearshore zone 
which displays high content of amphiboles.

Possible Source Rocks

The stable heavy minerals (zircon, tourmaline and 
rutile) were possibly derived from acidic igneous 
source rocks. The recorded euhedral shape of some of 
these minerals and their abundance suggests their re-
cent derivation from a nearby igneous source rock;
while the rounded varieties refer to their derivation 
from pre-existing sedimentary rocks, probably from 
the Tertiary mountains bordering the coastal plain.

Amphibole, pyroxene, biotite, epidote, garnet and 
tourmaline are derived from metamorphic and andite 
to basic source rocks. Contributions from the And 
by wind action plays additional role of transportation 
and concentration of heavy minerals in the shore zone 
se diments of Rabigh.

However, a large portion of the nearshore sedi-
ments is originated in the areas of accumulation gener-
ally by shore erosion for the consolidated Pleistocene 
rectal limestone.

Micropaleontological Investigation

As a part of our study we made a micropaleontolo-
gical investigation of the coastal sediments that was 
primarily concerned with the abundance and distribu-
tion of the genera of the benthic foraminifera in the 
shore zone sediments at Rabigh coast and at the outlet 
of Sharm al-Kharraz. In addition, the relationship be-
tween their abundance and grain size fractions as well 
as depth of water has been studied.

Several micropaleontological studies have been car-
ried out on the eastern Red Sea coast, north and south 
of Jeddah region (Bahalzallah, 1979, Bahalzallah and 
El-Askary, 1981; Yusuf, 1984; Abou Ouf et al. 1988 
and Abou Ouf, 1992). However, little detailed work 
has been done on distribution and abundance of 
benthonic foraminifera in the shore zone profile 
(beach, nearshore and offshore zones).

Functal investigation was carried out mainly on the 
0.5 mm size fraction which was found suitable for 
counting most of the genera present. Further identifi-
cation has done in size fractions; 1 mm, 0.25 mm 
and 0.125 mm in order to follow the general trend of 
distribution of the benthic foraminifera. The percent-
egages of each subgroup and the recognized taxa were 
calculated for each sample.

The samples studied are composed mainly of coral 
debris, coraline algae, molluscan shell fragments, 
microgranules, microcalcites and benthonic foraminifera in addition to detrital quartz sand grains. 
The backshore samples are almost devoid of foraminifera which is in agreement with Bahalzallah 
(1979).

The benthic foraminifera encountered in the shore 
zone sediments at Rabigh and at the outlet of Sharm 
al-Kharraz are represented mainly by two suborders; 
Miliolida and Rotalinida, while Textulariida is rare.

In general, the most dominant suborder is the 
Rotalinida especially in the nearshore and offshore sedi-
ments of Rabigh coast (Fig. 28) while Miliolida pre-
valued in the shore zone sediments of the outlet of 
Sharm al-Kharraz (Fig. 21). A noticeable local in-
crease of Miliolids is recorded in the beach zone of 
Rabigh. It is observed that Rotalids are more abun-
dant than Miliolids with increasing depth of water. 
The behaviour of distribution agrees with the findings 

The most common species identified in the two sub-
orders; Miliolida and Rotalinida are summarized in 
Table (7). Their abundance and distribution are 
shown in Figs. 22 & 23. Certain characteristic trends 
are observed in the profile sediments at Rabigh where 
Calcarina calcar prevailed the benthic foraminiferal 
assemblage encountered in the nearshore zone (Fig. 
22). The other species constitute only a minor propor-
tion. In the offshore sediments, Elphidiium spp. and 
Ampithistea spp. prevailed while Calcarina calcar 
disappeared and Ammonia beccarii appeared among 
the characteristic assemblage of the offshore zone.

Another distinctive feature noticed along the shore 
zone sediments of Rabigh is the remarkable seaward 
decrease in Sorites, Peneroplis and Spirulina.

The highest content of Elphidiium in the offshore 
zone sediments probably indicates Elphidiium
spp. favours areas of weak currents as indicated also by Yusuf (1984). However Elphidium spp. appears also among the assemblage encountered in the nearshore sediments at the outlet of Sharm al-Kharrar (Fig. 23).

The distribution pattern of the benthonic foraminiferal assemblage in the shore zone sediments at the outlet of Sharm al-Kharrar differs from that found at Rabigh coast. Peneroplis planatus and Ammonia beccarii are the most dominant species (Fig. 23), while Spirotaenia and Triloculina occur in moderate amounts and Soyuras are present with least content.

Dealing with the distribution of benthonic foraminifera in the different size fractions the different genera are arranged in a decreasing order of abundance as shown in Table (8).
Fig. 22. Variation of the most common species in the profile sediments at Rabigh.

Fig. 23. Variation of the most common species in the profile sediments near the outlet of Shuqaiq al-Khairat.
<table>
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<td></td>
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</tr>
<tr>
<td>塔利肯达洛群岛</td>
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</table>

The benthonic foraminiferal genera shows significant variation. Sorting is the dominant genus in the coarser fraction (1 mm), while Elphidium and Triboloculina are the most abundant assemblage in the finest fraction (0.125 mm).

Harting (1971) and Yosuf (1983) assumed that light and water depth are the main factors affecting the distribution of benthic foraminifera. However, the occurrence or disappearance of Calcarina calcar along the shore zone sediments in our study is not related to water depth. The dominance of Amphistegina in the offshore zone agrees with the assumption of Larsen and Drooger (1977).

The relationship between the mean size of the sediments and the suborders Rotulina and Miliolina is further studied and shown in Figs. 24 & 25. It is noticed that Rotulina decrease while miliolids decrease with increasing mean size (Figs. 24 & 25). Murray (1972) stated that the abundance of Miliolids is related to the hypersaline and normal marine tropical and subtropical shallow water environment.

In general, the dominant wall composition of the encountered genera, Triboloculina, Peneroplis, Spirulina and Sorites is calcareous porcelaneous; typical hygiene is confined to the Calcarina calcar, Elphidium and Amphistegina. Alou Guf (1992) found a positive correlation between the porcelaneous fauna and the total carbonate content. So, Gricier (1989) assumed that porcelaneous fauna required water supersaturated with calcium carbonate.

In conclusion, the benthonic foraminiferal content shows significant variation between the different sub-environments along the shore profile. This is due to differences in the grain size fraction, hydrographic conditions and other ecological parameters.

**Conclusions**

The shore zone sediments at Rabigh and at the outlet of Sharm al-Khairat along the Eastern Red Sea coast have been sampled through three profiles normal to the present shoreline and extending seaward. The variations in textural parameters, heavy mineral constituents and benthic foraminiferal assemblages have been investigated. The following conclusions are recorded:

1. **Textural criteria**
   1. The nearshore sediments (breaker zone) are characterized by the coarsest grain size and the poorest sorting and improve in sorting both shoreward and seaward. Shoreness generally tends to be negative in the breaker zone and positive seaward.
   2. Beach sediments appear of unimodal distributions, whereas the nearshore and offshore sediments have bimodal to polymodal distributions. These are related to winnowing processes, erosive power of waves and deposition of destructive material along al-Kaissara reef's bar in the shoreface by rip currents respectively.
   3. Probability cumulative curves constructed for the sediments in the three profiles reflect the sedimentary process-dynamics:
      i. The suspension population appears mixing with and sometimes separate from the saltation population due to highly variable energy conditions.
      ii. The saltation population of the sediments in the beach zone has two distinct saltation subpopulations which differ in mean-size and sorting where swash and backwash are active in contrast to the second saltation subpopulation of the nearshore sediments which has poor sorting.
due to dumping from highly turbulent graded suspension-traction carpet.

iii) The third surface creep population generally characterizes the nearshore sediments with large percentages and depends largely on the provenance controlled.

4. The major cause of grain size difference is the effect of the lag gravels on sorting formed by the accumulation of shell fragments.

b - Mineralogical criteria

1 - Opales, amphiboles, pyroxenes, epidotes, zircon, tourmaline and rutile are the main heavy minerals encountered in the shore zone sediments.

2 - Opales and ZTR are enriched in the beach zone while hornblende dominates in the nearshore sediments of Rabigh probably due to the sorting processes and the active aeolian transportation.

3 - The relative sorting by water during storms at...
ways produces heavy mineral placers in the backshore and
formation of a region at Shahm al-Kharrar. However, wind
action plays an important role in heavy mineral con-
centrations.
4. A comparison of the distribution of heavy min-
erals in the two shore zone profiles reveals an increase
of pyroxene seaward corresponding to a decrease of
amphiboles in the shore profile at the outlet of Shahm
al-Kharrar.
5. Contribution from the land by wind action plays
additional role of transportation and concentration of
heavy minerals in the shore zone sediments of Rabigh.

c – Vaunal criteria
1. The benthic foraminifera are represented by
two suborders; Rotalina and Milollina. Rotalids are
the most abundant in the nearshore zone sediments of
Rabigh, whereas Milollids prevail in the nearshore
zone sediments at the outlet of Shahm al-Kharrar.
2. Calcarina calcar prevailed the benthic forami-
niferan assemblage of the nearshore zone sediments
of Rabigh while Elphidium and Amphipectenina domi-
nate in the offshore sediments.
3. Peneroplis planus and Ammonia beccari are
the dominant species in the nearshore sediments at the
outlet of Shahm al-Kharrar.
4. The relationship between the abundance and
distribution of the benthic foraminifera in the diffe-
rent size fractions proved that Sorters are concentrated
in the coarser fraction while Elphidium and
Triloculina are abundant in the finer fraction.
5. Rotalina increases as the mean size increase,
while Milollina displays a reverse behaviour.
6. The nearshore sediments at the outlet of Shahm
al-Kharrar are distinguished by dominance of high
Milollina which is typical of shallow water, subtemporal
carbonate-rich environments.
7. Genera variations along the shore zone profile
are related to variation in size fraction, hydrographic
conditions and ecological parameters.

References
Abou Ouf, M. (1992) Benthic foraminifera in carbonate facies of a
from littoral sediments of Al-Lib Al-Qun-
fishah, southeastern Red Sea. Indian Journal of Marine Sci-
ence, 17: 217-221.
———, and El-Shater, A. (1995) Black benthic foraminifera in
carbonate facies of a coral sabkha, Saudi Arabian Red Sea
Babaitallah, A.A.K. (1979) Kafran benthic foraminifera from Jed-
———, and El-Ashary, M.A. (1980) Sedimentological and mic-
32.
———. (1983) Marine transgressions in west coast of Saudi
Arabia between Mid. Pleistocene and present. Marine Geol-
history of evaporitic sediments in a coastal lagoon and
No. 145-407.
Arab Environment, 80-89.
Interscience, New York.
ical variation in the unconsolidated sediments of El Qus-
tul, north of Jeddb, West coast of Saudi Arabia. Com-
nunal Shelp Research, J.A. No. 4: 489-498.
Folk, R.L. (1955) Petrology of sedimentary rocks. Hemphill, Au-
sin, Texas.
Grémer, G.O.G. (1969) Benthic foraminifera environmental fac-
and eolian flat environments by size analysis, Mustang Is-
Molda, R.J. and Weiser, D. (1968) Textural parameters, reevalua-
Passeri, R. (1957) Texture as characterized by slope deposi-
Reecker, H. and Singh, L. (1975) Depositional sedimentary envi-


المميزات السماوية والمغذية والحفرية في روانس القطاع الشاطئي

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المشتمل: يتضمن البحث أشياء من طرق فنية ترتبط بثلاثة فترات زمنية: الأولى ضمن تفسير أبعاد النسيج، الثاني ضمن تفسير أبعاد النسيج، الثالث ضمن تفسير أبعاد النسيج.

والأخير: وفقاً لدور التعصيف، فإن الوقائع المختلفة ترتبط بثلاثة فترات زمنية: الأولى ضمن تفسير أبعاد النسيج، الثاني ضمن تفسير أبعاد النسيج، الثالث ضمن تفسير أبعاد النسيج.

كما تمت روانس نطاق القطاع الشاطئي، بناءً على تفسير أبعاد النسيج، في ثلاث فترات زمنية: الأولى ضمن تفسير أبعاد النسيج، الثاني ضمن تفسير أبعاد النسيج، الثالث ضمن تفسير أبعاد النسيج.

وكما تمت روانس نطاق القطاع الشاطئي، بناءً على تفسير أبعاد النسيج، في ثلاث فترات زمنية: الأولى ضمن تفسير أبعاد النسيج، الثاني ضمن تفسير أبعاد النسيج، الثالث ضمن تفسير أبعاد النسيج.

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كما وردت الطرق السماوية والأرضية للجدران الرملية في المحور البسالي بقناطر النسيج، الأشجار النباتية مثل النسيج، البذور النباتية مثل النسيج، الأعشاب النباتية مثل النسيج.

وإلى ذلك، يمكن إعداد رواية السماوية في القطاع الشاطئي، بناءً على تفسير أبعاد النسيج.