Mineralogy and Provenance of Ash Shuqayq Coastal Sediments, Southern Red Sea, Kingdom of Saudi Arabia

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Abstract. A detailed mineralogical investigation was carried out on recent sediments from the different geomorphic environments at the Ash Shuqayq coastal area in the southern Red Sea. Ash Shuqayq coast is considered as a low-lying plain where sediment cover is generally thick and the distribution of the littoral sediments on the shoreface provide important information regarding not only the sources of the sediments but also the modes and pathways of transport. Polarizing microscope and XRD analyses were used to study heavy and light mineral fractions, bulk and clay mineral assemblages respectively. Mineral identification and provenance as well as sediment movement are established. Important conclusions concerning the influence of geology and coastal morphology on sediment distribution and transport along Ash Shuqayq shorelines are documented.

The distribution pattern of heavy minerals in Ash Shuqayq coastal environments shows their selective deposition with respect to their densities, sorting and winnowing processes prior to being deposited on the beach. On the other hand, the crescentic shape of the coastline and the occurrence of wadis play a considerable role enrichment of the beach by heavy minerals. Mica and carbonate minerals tend to accumulate in the deeper water (non-agitated areas) far from the shore.

Introduction

Ash Shuqayq coastal area lies 600 km from Jeddah on the southern Red Sea coastal stretch and extends from Al Huraydah to Itwad (Fig. 1). It lies between latitudes, 17°30' and 18°00'N and longitudes 41°48' and 41°15'E. Information related to sediment characteristics and transportation, beach processes, and geomorphology is available in Nabhan (2004).
The Red Sea is unique among the seas of the world as not many permanent streams flow into it and rainfall is very irregular. Mostly northwesterly wind and occasional rain-torrents contribute terrigenous sediments. In arid regions like Saudi Arabia, where riverine sediments are absent, aeolian and biogenic materials form a significant contribution to the marine realm.

In general, the eastern coastal plain and shelf area of the Red Sea is bound inland by the shield escarpment and seaward by the sharp break in slope marking the edge of the Red Sea trough (Brown, 1970). Detailed work along the coastal plain and the Red Sea marginal shelf can be found in the work of Karpoff (1957), Brown & Jackson (1960), Brown et al. (1962), Tooms (1971) and Skipwith (1973).

Numerous studies have dealt with the central and northern coastal zone of the Red Sea but few published works are available on the sedimentology of the southern Red Sea coastal plain (Tag, 1986, Abou Ouf et al., 1988, Abou Ouf & El-Shater, 1992, Gheith, 1999, Nabhan, 2004 and Al Washmi et al., 2005).

**Ash Shuqayq Coastal Area**

In general, the studied beaches in the Ash Shuqayq area are mainly beaches, with intermediate carbonate low-lying hard coral reef platforms, except the extremely northern stretch where the shore consists of high rocky cliffs with narrow arcuate pocket beaches. Along the low-lying Ash Shuqayq coast, beaches have received considerable sediments influx through the flash floods in the ancient wadis (Aramram, Nahab., Rim, Al Birk and Itwad; see Fig. 1). Sediment cover is generally thick, and distribution of the littoral sediments on the shoreface provides important information regarding not only the sources of the sediments, but also the modes and pathways of transport.

**Samples and Methods of Analyses**

Samples have been collected from the different geomorphic units characteristic of the Ash Shuqayq coastal zone including; nearshore, beach, coastal dune, sabkha and wadi environments (Fig. 1). Samples were subjected to extensive mineralogical investigations using a polarizing microscope and X-ray diffraction analyses for rock powdered material and the clay fraction. Distribution of both heavy and light minerals together with bulk and clay mineralogy have been also studied. Important conclusions concerning the source rocks and transportation history are documented.
Results and Discussion

A) Heavy and Light Mineralogy

1. Nearshore Sediments

The relative frequency percentage distributions of heavy minerals determined for Ash Shuqayq nearshore and far-shore sediments are expressed in variation distribution curves shown in Fig. 2 & 3. It was found that total heavy minerals in the nearshore sands range from 55 to 31% (av. 23%) and are higher than those of the offshore zone which range from 16 to 5% (av. 9.4%), probably due to the high energy processes operating in this littoral zone. Opaque minerals, including ilmenite, magnetite, hematite and limonite, occur in higher concentrations in the nearshore sediments than in the far-shore zone.

Amphibole, ZTR (zircon, tourmaline, rutile), pyroxene, mica and weathered minerals are the most abundant non-opaque minerals present in the heavy fraction of the nearshore sediments. Garnet occurs in lesser amount while epidote,
carbonates, kyanite and staurolite are rare. Far from the nearshore zone, the quantity of stable minerals ZTR are less, corresponding to an increase in carbonates and mica minerals. The non-opaque minerals are most useful in genetic interpretation (Carver, 1971).
Mica grains occur in considerable amount and are represented by biotite and chlorite. The flaky grains of subrounded brown biotite and green chlorite generally have parallel extinction. Micas and shells are used as indicators of energy level and depositional regime (Adegoke and Stanley, 1972). The enrichment of mica is related to its lightness and nature of the platy micaceous shape, which allows mica to be transported away from the shore especially in the non-agitated zone of deeper depths.

Amphibole grains are represented mainly by prismatic to subrounded green and brownish green hornblende varieties with small contents of actinolite-tremolite and anthophyllite. Amphiboles are the dominant transparent minerals and occur with percentages varying from 35 to 1% and averaging 13.5%. No spatial variation trend except a relatively greater abundance was observed in the north and south of the studied coastal area.

Pyroxenes are represented mainly by augite, diopside and rarely hypersthene. They vary between 21 and 4% with an average of 11%. Augite occurs as yellowish green and brownish green varieties, with subangular to subrounded grains.

Fig. 4. Lateral variation of light minerals in the nearshore sediments along Ash Shuqayq coast.

Concerning the light minerals, quartz, feldspars (potash and plagioclase) and carbonates are the principal mineral components found in the nearshore sands. Their lateral distribution curves are shown in Fig. 4 & 5. Quartz is the dominant
component in the nearshore zone and varies from 100 to 46%. Carbonate, the second most light mineral detected, occurs in amounts from 54 to 0%. Feldspars, including both potash feldspar and plagioclase, usually occur in minor amounts, ranging between 18% and 0%. The recorded fresh feldspar with clear twinning in the nearshore sands points to recent aeolian transportation from the volcanic and metamorphic terrains in the adjacent landmass. The roundness of the quartz grains indicates prolonged abrasion and suggests derivation from the sand dunes at the back of the beach zone itself. Far from the shore zone especially in the deeper water parts, carbonates predominate over quartz and feldspar with an average of 76%. This means that their sediments are essentially derived from local source erosion of the submerged reefal platform limestone.

2. Beach Sediments

The relative frequency percentages of the heavy minerals showed that opaques (iron oxides) range from 29% to 9% (Table 1). The non-opaque minerals arranged in a decreasing order of abundance include, amphibole, augite, ZTR, garnet, biotite, epidote and kyanite.

Amphiboles are represented by green to brown basaltic hornblende, colourless tremolite and grass green, thin prismatic actinolite. Augite occurs with dirty green, yellowish green and light brown varieties. The stable minerals zircon, tourmaline and rutile occur in high amounts indicating active sedimentary pro-
Table 1. Relative frequency percentages of heavy minerals in the beach sands of Ash Shuqayq.

<table>
<thead>
<tr>
<th>Station no.</th>
<th>Opaque</th>
<th>Hornblende</th>
<th>Augite</th>
<th>Epidote</th>
<th>Garnet</th>
<th>Zircon</th>
<th>Tourmaline</th>
<th>Rutile</th>
<th>Biotite</th>
<th>Chlorite</th>
<th>Kyanite</th>
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<td>1</td>
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<td>5</td>
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</tr>
<tr>
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<td>8</td>
<td>3</td>
<td>12</td>
<td>10</td>
<td>7</td>
<td>6</td>
<td>5</td>
<td>3</td>
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cesses due to swash and backwash (abrasion and winnowing). The recorded garnet and kyanite indicate derivation from weathering of high-grade metamorphic source rocks, while chlorite and biotite indicates derivation from lower grade metamorphic source rocks.

Most mineral grains in the beach zone reflect extensive reworking with a rounded to subrounded shape due to the abrasion and winnowing processes operating on the beach sediments. Grain sorting processes may concentrate the heaviest minerals on the beach surface due to the action of waves in the surf zone (Gheith et al., 1994). Waves and currents selectively sort and concentrate mineral grains according to their densities and sizes (Pettijohn, 1957). It is interesting to mention here that some areas in the Ash Shuqayq beach zone, especially near the mouths of wadis and where foredune sands back onto the beach, show significant anomalous zones of heavy minerals as placer deposits.

![Pie diagram showing the average percentage of light minerals in the beach sands of Ash Shuqayq.](image)

The light minerals identified in the beach sands show that quartz is the dominant light mineral (av. 71%, Fig. 6), while carbonate minerals occur in moderate amounts (av. 24%). Feldspars represented by plagioclase and potash feldspar but varieties occur in minor amounts (av. 5.61%). Association of carbonate with detrital quartz and feldspar indicates erosion of the submerged limestone platform and movement of weathered material by waves towards the beach where it is deposited.
Table 2. Relative frequency percentages of heavy minerals in the coastal sand dunes of Ash Shuqayq.

<table>
<thead>
<tr>
<th>Station no.</th>
<th>Dune type</th>
<th>Garnet</th>
<th>Hornblende</th>
<th>Opaque</th>
<th>Zircon</th>
<th>Augite</th>
<th>Biotite</th>
<th>Tourmaline</th>
<th>Chlorite</th>
<th>Kyaneite</th>
<th>Rutile</th>
<th>Epidote</th>
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<td>1</td>
<td>Barchan</td>
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<td>18</td>
<td>8</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>Seif</td>
<td>21</td>
<td>20</td>
<td>24</td>
<td>5</td>
<td>5</td>
<td>22</td>
<td>2</td>
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<td>Seif</td>
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<td>14</td>
<td>20</td>
<td>17</td>
<td>5</td>
<td>22</td>
<td>22</td>
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<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>Seif</td>
<td>19</td>
<td>16</td>
<td>20</td>
<td>13</td>
<td>8</td>
<td>22</td>
<td>3</td>
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<td>2</td>
<td>32</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>Dune ridge</td>
<td>19</td>
<td>10</td>
<td>28</td>
<td>14</td>
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<tr>
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<td>22</td>
<td>23</td>
<td>3</td>
<td>0</td>
<td>0</td>
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</tr>
</tbody>
</table>
3. Coastal Sand Dune

The opaque grains vary between 35 and 10% (Table 2) and consist mainly of magnetite, ilmenite and limonite. The dominant non-opaque heavy minerals identified in the coastal sand dunes of Ash Shuqayq include hornblende, augite, biotite, garnet, ZTR, kyanite, epidote and chlorite. Most of the mineral grains are rounded to subrounded. The association of metamorphic minerals, (biotite, garnet, hornblende and kyanite) prove derivation mainly from both low-grade and high-grade metamorphic source rocks. Micas (biotite + chlorite) occur with percentage varying from 34 to 14% and represent the essential heavy minerals recorded in the coastal sand dunes studied. Zircon, rutile and tourmaline occur in smaller amounts, together with a considerable content of augite that proves derivation from acidic to basic igneous source rocks.

Quartz and carbonates are found to be the principal light minerals identified. Feldspars are rare. Quartz have average 69% (Fig. 7), while carbonate occurs at an average of 30%. The recorded carbonate material in the light fraction proved its derivation from the beach zone where winds picked up and moved grains to form part of the sand dunes at the border of the beach.

![Pie diagram showing the average percentage of light minerals in the sand dunes of Ash Shuqayq.](image_url)
B) Bulk Mineralogy

1 – Nearshore Sediments

The gross mineralogy determined by X-ray diffraction from powdered samples of the marine nearshore environment consists mainly of quartz, feldspar and carbonate minerals with minor amounts of clay minerals and amphiboles (Fig. 8 & 9). Quartz, the dominant detrital mineral occurs in amount ranging from 77 to 0% with an average value of 39%. Feldspar is the second dominant component in the marine sediments where plagioclase (av. 23.3%) is always higher than potash feldspar (av. 4.6%). Illite-chlorite and amphibole are recorded in minor amounts.

Fig. 8. Lateral variation of bulk minerals in the nearshore samples along Ash Shuqayq coast (Data from XRD analysis).

Fig. 9. Lateral variation of bulk minerals in the far-shore samples along Ash Shuqayq coast (Data from XRD analysis).
The carbonate minerals identified include aragonite, high Mg-calcite and calcite. Dolomite is rare while halite occurs in very small amounts in most of the samples. Quartz and feldspar are abundant along the whole stretch of the Ash Shuqayq coast except in the most northern part, where carbonate minerals increase. Far from the shore, carbonate minerals play a considerable role in the distribution of the bulk components.

In general, the enrichment of the marine nearshore zone with detrital minerals (quartz, feldspars amphiboles and clay minerals) indicate derivation from weathering of the uplifted igneous and metamorphic rocks in the hinterland. The presence of illite and chlorite are often taken to indicate high latitude climatic conditions where mechanical weathering prevails (Singer, 1984).

2 – Wadi Sediments

Five wadi samples were analysed by X-ray diffraction for bulk mineralogy (Table 3). It was found that quartz and feldspar are the principal components where plagioclase is always higher than the potash feldspar. Quartz occurs with values more than 50%. Illite, chlorite and amphiboles are present in small amounts indicating that the supplied clay material from high relief metamorphic and volcanic source rocks.

Most of the wadi sediment were supplied by active wadis during the late Quaternary when sea level was lower than the present level. The high escarpments on the Red Sea coastal border consist mainly of crystalline Precambrian and Tertiary rocks. In addition, aeolian transportation provides the nearshore zone with detrital quartz and fresh feldspars. On the other hand, the considerable content of the carbonate minerals in the offshore zone indicates derivation from the erosion of fringing coral reefs which characterizes the shelf area. Thus the Ash Shuqayq marine environment represents a dynamic basin for receiving detrital material. On the other hand, microscopic observation revealed that most of the nearshore sediments contain small amounts of biogenous components such as coral, coralline algae and shell fragments that originated from the disintegration of coral reef platforms. Ash Shuqayq beaches are sandy with clastic gravels of different origin. The gravels have flatten shapes indicating derivation mainly from metamorphic rocks, whereas quartz pebble came from an acidic igneous source. In conclusion, the Ash Shuqayq shore zone represents a dynamic coastal environment on the eastern Red Sea which reflects complex interactions of numerous environmental variables.

3. – Coastal Sabkhas

X-ray diffraction analysis of two sabkha samples collected from the backshore proved that they are composed mainly of evaporite minerals; anhydrite, gypsum and halite with considerable amount of terrigenous minerals: quartz, feldspar and clay minerals (Table 4). Carbonate minerals (high-Mg calcite, dol-
Table 3. Bulk mineralogy of the raw samples from Ash Shuqayq wadis (Data from XRD analysis).

<table>
<thead>
<tr>
<th>Wadis</th>
<th>Terrigenous minerals</th>
<th>Evaporate minerals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Illite (%)</td>
<td>Chlorite (%)</td>
</tr>
<tr>
<td>Itwad (WI\textsubscript{1})</td>
<td>7%</td>
<td>6%</td>
</tr>
<tr>
<td>Albirkah (WB)</td>
<td>4%</td>
<td>0%</td>
</tr>
<tr>
<td>Rim (WR\textsubscript{3})</td>
<td>8%</td>
<td>6%</td>
</tr>
<tr>
<td>Aramram (WA\textsubscript{1})</td>
<td>4%</td>
<td>0%</td>
</tr>
<tr>
<td>Nahab (WN\textsubscript{3})</td>
<td>4%</td>
<td>0%</td>
</tr>
</tbody>
</table>

Table 4. Relative frequency distribution of total minerals in the sabkha deposits from Ash Shuqayq coastal area (Data from XRD analysis).

<table>
<thead>
<tr>
<th>St. no.</th>
<th>Depth (cm)</th>
<th>Terrigenous minerals</th>
<th>Carbonate minerals</th>
<th>Evaporate minerals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mont.</td>
<td>Illite</td>
<td>Kaolinite</td>
</tr>
<tr>
<td>Sk\textsubscript{1}</td>
<td>0 - 2</td>
<td>1</td>
<td>1.2</td>
<td>1.8</td>
</tr>
<tr>
<td>SK\textsubscript{2}</td>
<td>2 - 5</td>
<td>1.3</td>
<td>3.2</td>
<td>4.4</td>
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</table>
omite) are scarce. The clay minerals identified in the sabkhas include montmorillonite, illite and kaolinite indicating derivation from weathering of metamorphic and volcanic basaltic rocks and red soils of the coastal mountains. Significant differences have been noticed in the occurrence and proportion of evaporite and carbonate minerals. The surface of the sabkha is characterized by the dominance of halite and gypsum indicating high evaporation rates. While under the surface, the sabkha exhibits dominant anhydrite and little halite with the absence of carbonate and gypsum minerals indicating high degree of dehydration processes.

In contrast, the recent sabkha in the northern Red Sea (Gavish, 1980) and Ras Hatiba sabkha (El-Sayed, 1987) in the central Red Sea are characterised by the absence of gypsum and aragonite. In contrast, Al Lith sabkhas in the southern Red Sea (Basyoni, 1997) are mainly arenaceous, composed of fine to medium sand with clay lenses. Carbonates are present in the form of aragonite, dolomite and calcite, while evaporites are in the form of gypsum, halite and anhydrite. Gavish et al. (1985) suggested that the lack of gypsum accumulation is due to destruction by sulphate-reducing bacteria. Gheith (1999) found Shuaiba sabkhas, south of Jeddah, were dominated by carbonate minerals with high potential for dolomitization, while Al Kharrar sabkhas north of Jeddah are dominated by siliceous constituents. In general, Ash Shuqayq sabkha seems to be similar to Abu Dhabi sabkha (Patterson and Kinsman, 1982) and Al Lith sabkha (Basyoni, 1997).

4 – Ash Shuqayq Marine and Coastal Sediment Sources and Transport

The coastal area of Ash Shuqayq was very active during the Late Pleistocene and Holocene periods when sea level was lower than present, and streams eroded up and down the uplifted coastal terrain, bring to the marine shelf huge amounts of terrigenous materials. When sea level rose again, most sediments were captured on the shelf and subjected to the marine dynamic processes, then distributed and transported along the beach and nearshore zone.

The beach sediments are sorted, redistributed and accumulated in the beach zone by the wave action and littoral drift. Heavy minerals are enriched more in dunes and backshore area than in the foreshore. The formation of placer deposits depends on the variations in the transportation energy and existence of suitable sedimentary environment such as Ash Shuqayq beaches. Thus the Ash Shuqayq beach zone represents a dynamic coastal environment which reflects complex interaction of numerous environment variables.

On the basis of the relative abundance and distribution of heavy minerals, two essential sources can be recorded: regional provenance formed of low to high grade metamorphic and igneous volcanic source rocks and a local source consisting of carbonate reefal limestone.
C) Mineralogy of the Clay Fraction

The clay mineral assemblages in the marine nearshore and wadi sediments have been determined by X-ray diffraction analysis. Mineral identification is based on Brindley & Brown (1980), Pierce & Siegel (1969) and Carroll (1970).

The reflections used for identification of the different clay minerals present in the studied samples are given as follow:

**Illite**: Is recognized by a strong first order basal reflection at 10 Å, which remains unchanged after glycolation or heating.

**Kaolinite**: Is identified by its basal reflection at about 7 Å which remains unchanged by glycolation, but is destroyed at a temperature of 550°C and the mineral becomes amorphous to X-rays.

**Chlorite**: Chlorite is identified by first and second order basal reflection at 14 Å and 7 Å respectively. Chlorite remains unchanged after glycolation but thermal treatment will cause a small shift in position to 13.8 Å and an increase in the intensity of the 14 Å reflection.

Significance and Genesis of Clay Minerals

The clay minerals found in the nearshore environment are composed mainly of illite with lesser equal amounts of kaolinite and chlorite (Table 5). In contrast the clay minerals found in the wadi sediments are composed essentially of illite and kaolinite with subordinate amounts of chlorite (Table 6). They are highly uniform and no clear variation was observed for comparison with the varied geological formations in the source areas. The climatic conditions seem to control the kind of clay minerals rather than the nature of the source rock. Singer (1984) determined the paleoclimatic conditions and source areas from studying detrital clay minerals in marine sediments.

Illite occurs in the nearshore sediments and also in the wadi sediments with maximum contents equal to 55% and 60%, respectively, and reflects continental input. Illite concentration in marine sediments bears a close relation to riverborne sediments. The Ash Shuqayq coastal area is traversed by many wadis that extend several kilometers inland to the pediments of the fringing mountains. These wadis were active during lowered sea level when supply of terrigenous sediments to the shelf area was greater.

The presence of chlorite in Ash Shuqayq marine sediments is indicative of the prevailing mechanical weathering and dry climate. Chlorite in the Ash Shuqayq coastal area is derived from the low-grade metamorphic green schist and basic volcanic igneous terrains common in the hinterland. The occurrence of
kaolinite as a second dominant clay mineral reflects more intense leaching and chemical weathering.

Table 5. Relative percentages of clay minerals in the nearshore sediments of Ash Shuqayq area (Data obtained from XRD).

<table>
<thead>
<tr>
<th>Station no.</th>
<th>Depth (m)</th>
<th>Chlorite %</th>
<th>Illite %</th>
<th>Kaolinite %</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>6</td>
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<td>54</td>
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Table 6. Relative percentages of clay minerals in the wadi deposits of Ash Shuqayq area (Data obtained from XRD).

<table>
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<th>Station no.</th>
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<th>Illite %</th>
<th>Kaolinite %</th>
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<td>6</td>
<td>//</td>
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</tbody>
</table>

Most previous studies on the mineralogy of the coastal sediments were concentrated around Jeddah (Behairy, 1980; Bahafzallah & El-Askary, 1981; Durgaprasada Rao & Behairy, 1984; Gheith, 1999 & 2000 and Gheith & Abou Ouf, 1996). Behairy (1980) found that kaolinite, mixed layer chlorite-vermiculite and illite as the clay minerals that constitute the modern and Quaternary reef sediments in the coastal plain north of Jeddah. They were derived from weathering of low-grade metamorphic rocks and volcanic basalts of the Jeddah groups. Durgaprasada Rao and Behairy (1986) found abundant kaolinite, swelling chlorite and minor illite in the clay minerals that constitute the modern and Quaternary reef sediments in the coastal plain north of Jeddah. They were derived from weathering of low-grade metamorphic rocks and volcanic basalts of the Jeddah groups. Durgaprasada Rao and Behairy (1986) found abundant kaolinite, swelling chlorite and minor illite in the Jeddah-Yanbu nearshore sediments, while Schneider and Schumann (1979) found an abundance of chlorite, kaolinite, illite and small amounts of montmorillonite, sepiolite and palygorskite in the normal Red Sea sediments.

The general climatic conditions on the west coast of Saudi Arabia are classified as arid to semi-arid (Skipwith, 1973). On the other hand, the red soils developed on the eastern coastal plain reflect evidence for a hot and humid environment. Though most of the clay material in the nearshore zone is transported
from these regions either by flash floods in the ephemeral wadis caused by the occasional rains or by aeolian transport. Behairy et al. (1985) distinguished two clay mineral assemblages in the aeolian dust in the coastal area north of Jeddah: one is composed of kaolinite, and chlorite and the other is formed of montmorillonite and kaolinite. The minerals chlorite and montmorillonite have been mixed in the nearshore environment giving rise to swelling chlorite.

It is concluded that significant latitudinal variation in the type and proportion of clay minerals along the Red Sea coast. Kaolinite and swelling chlorite with minor illite are predominant along in the northern Red Sea coast, while illite with subordinate chlorite and kaolinite predominate in the southern Red Sea coast. There is also a wide range in sediment texture, composition and nature of sediments along the coastline which reveals varying energy conditions. Further variability depends on the sources of the sediments, topography of the shore zone and reworking processes operative in the littoral zone.

Conclusions

The distribution of heavy minerals in Ash Shuqayq coastal subenvironments show selective deposition of these minerals with respect to their densities, sorting and winnowing processes prior to their final deposition on the beach. The total heavy minerals tend to concentrate in the littoral zone.

The composition of the heavy mineral assemblages found in the nearshore sediments shows a dominance of amphibole, mica, tourmaline and pyroxene indicating derivation from mainly metamorphic and partly igneous volcanic sources. Beach and dune sands show enrichment of garnet also indicating metamorphic source rocks.

Carbonate and mica minerals are dominant especially in the deeper offshore zones where they accumulate in non-agitated areas. The enrichment of Ash Shuqayq marine sediments with detrital quartz and feldspar, indicates transportation from the hinterland toward the sea by the ancient wadis which were active during the Late Pleistocene. Another local source in the marine environment is the erosion of the submerged reefal limestone platform.

The clay mineral assemblages determined either in the nearshore sediments or in wadis are highly uniform and do not show any clear difference that can be correlated to the varied geological formations in the source area. Climatic conditions probably played a considerable role in the clay mineral composition in both the marine and coastal plain sediments. The large amount of illite and its association with chlorite and kaolinite indicate an influx of detrital material from high to low relief source rocks that suffered active tectonic uplift leading to erosion in up- and down-stream areas.
References


المكونات المعدنية وأصل الرواسب الساحلية للشقيق

بجنوب البحر الأحمر، المملكة العربية السعودية

أمين مصطفى غيث، وحمد عبدالله الوشمى، وعبد الله إبراهيم نهان
كلية علوم البحر - جامعة الملك عبد العزيز
و* المساحة الجيولوجية - القسم البحري - جدة - المملكة العربية السعودية

المستخلص. تشمل هذه الدراسة على فحوصات معدنية مفصلة
للرواسب الحديثة المكونة لمختلف البيئات الجيولوجية الشائعة في
المنطقة الساحلية للشقيق بجنوب البحر الأحمر. يعتبر شاطئ الشقيق
سهل منخفض، حيث يغطي برواسب سميك، وللذا فإن توزيع الرواسب
الشاطئية في صدر الشاطئ تزودا معلومات مفيدة عن مصدر تلك
الرواسب وأسلوب ومسار نقلها.

ولقد تم استخدام الميكروسكوب المستقطب، وجهاز حيود الأشعة
السمية لدراسة المعادن ومنطقة الأصل واستنتاج معلومات مهمة، عن تأثير الجيولوجيا ومورفولوجية الساحل على توزيع الرواسب، بطريقة
تلتها على طول خطوط شواطئ الشقيق.

هذا وأوضح نتائج توزيع المعادن الثقيلة في البيئات الساحلية للشقيق،
ترسب مفصل للمعادن على أساس الكثافات، ودرجة الفرز، وعمليات
الغريلة وإعادة ترسبيها على الشاطئ. ومن الوجهة الأخرى، فإن
الشكل الهلالي لخط الشاطئ، ووجود الودودان قد لعب دورًا رئيسيًا في
إثارة الشاطئ، ببعض المعادن الثقيلة، بينما تسببت معادن الميكا والكربونات في
الأماكن العميقة غير المضلحة بعيدة عن الشاطئ.
The Effect of Redox Potential on the Stability of Some Heavy Metals in the Bottom Sediments of the Gulf of Suez, Egypt

A.E. Rifaat*
National Institute of Oceanography and Fisheries, Alexandria, Egypt

Abstract. The relationship between pH and Eh values and the content of some heavy metals in 27 bottom sediments from the Gulf of Suez has been studied. The sediment samples are mainly composed of carbonate-sand and silt. Three main factors control the behaviour of the examined metals in sediments.

Factor 1 represents a pH-Eh factor that reveals the influence of redox potential on these metals in sediment. Carbonates are insoluble at high pH and Eh values and hence the metals in the carbonate debris are stable under such redox conditions. The strong positive loadings on mud (silt and clay), organic carbon, iron and manganese indicate to the close relationship of these components in the marine environment. The inverse relationship between these components and pH and Eh, indicates that the decay of organic matter tends to lower the pH of the sediments – but not far below pH 7.35 – and consumes the oxygen, and hence lowers the Eh too. The process of organic matter decay may release part of the iron and manganese content that is associated with organic debris.

Factor 2 is a pH factor that clearly reveals the relationship of pH with iron, copper, zinc and cobalt. The increase of pH is associated with similar increases in the content of these metals in sediments. This factor shows that these metals are more stable in the solid phase under more alkaline conditions.

Factor 3 is a metal-carbonate factor where cadmium, nickel, cobalt and lead are mainly present in the carbonate constituents of the sediments.

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Introduction

The heavy metals in sediments of the Gulf of Suez (GOS) have been studied by many authors, e.g. El-Moselhy and Gabal (2004), El-Moselhy et al., (1999), Abd El-Azim, (1996) and Hamed (1992). Their investigations showed an increase in the concentrations of some heavy metals in the sediments with time. Such increase has been attributed to pollution due to increased dumping of sewage and industrial wastes into the Gulf (El-Moselhy and Gabal, 2004). The hazardous effect of a metal is determined by its instability in the marine sedimentary compartment (solid phase). The redox state of the sediment controls the solubility, or bioavailability of heavy metals (Kehew, 2001). The hydroxides, oxides, carbonates and phosphates of all of the trace metals are insoluble under alkaline conditions (Lindsay, 1979). The dissolution of these metal salts is strongly dependant on the pH of the system (McLean and Bledsoe, 1992). Also, the redox state can greatly affect the transport of a metal from the solid phase to the dissolved phase. Oxidizing conditions favor retention of metals in the solid phase (sediments) while reducing conditions contribute to the accelerated migration of metals from sediments to seawater (Clark et al., 1998). The present work is focused on the distribution of pH and Eh (redox state) of GOS bottom sediments and their influence on the stability of some environmentally important metals.

Area of Study

The Gulf of Suez (Fig. 1) is a semi-enclosed basin that is 280 km long and its width varies between 20 and 40 km. It occupies a wide valley and lies between the wide plains of low relief of the Eastern Desert in the west and Sinai Peninsula in the east. It has no significant terrestrial input of water. The mean monthly air temperature at the Suez Meteorological Station, based on the average of records in the years 2001, 2002, and 2003, varies between 14ºC in January and 30ºC in August. The atmospheric pressure increases gradually from 1007mb in July to 1020mb in January and decreases afterwards until July. The mean wind speed is minimum (3.5-6 knot) in January and December and its maximum value recorded in August and September (7-11 knot). Local storms occur frequently. The direction of dominant wind on GOS is mainly north and northwest. The sea surface temperature in the Gulf, ranges between 19.3ºC in winter and 26.2ºC in summer. Horizontal decrease of water temperatures from south to north and from east to west is a pronounced feature of the Gulf that is due in part to the cooling effect of the north and northwest winds. The north-south increase in water temperature is associated with a decrease in water salinity (42.5 in the north and 40.5 in the south) (Rifaat et al., 1996). According to Shepard et al. (1992), the rapid cooling of surface water in winter and the increased evapo-
The Effect of Redox Potential on the Stability of Some...

Ration lead to a rise in the salinity causing a steep salinity gradient along the Gulf. The regional current system in the Gulf is characterized by northward flowing surface waters and a southward flowing bottom waters except near the shore where it has a gyratory character. The bottom topography of the Gulf is almost flat with a maximum depth of 70 m at its southern end. The near shore zone is mostly occupied by coral reefs. The Gulf appears to be spreading and exhibits normal faulting. The bottom sediments are predominantly carbonate-sands and -silty sands. The carbonates are composed of calcareous debris of corals, coralline algae, molluscan shell fragments and other organisms; terrestrial deposits are minor (Shepard et al., 1992). The terrigenous component of the sediments is composed of quartz, orthoclase, plagioclase, micas, opaque minerals, and traces of heavy minerals (Nawar, 1981).

**Materials and Methods**

Figure (1) shows the locations of 27 bottom sediment samples collected from the Gulf of Suez. The pH and Eh of these samples were measured in situ using pH-Eh-meter (Model wtw pH 315i). Buffer solutions of pH 4, 7, 9 and Zobell’s solution were used as standard solutions for testing the redox instruments. The detailed method for measuring pH and Eh is mentioned by Wild and Radtke (2004).

![Fig. 1. The study area and locations of sampling stations.](image-url)
The percentages of sand, silt and clay of collected samples were determined using Shimadzu SALD 3001 Laser Particle Analyzer. Total carbonates were determined using the method of Molnia (1974). Organic Carbon content was determined colourmetrically after the method of Sims and Haby (1971). The trace metals iron, copper, manganese, zinc, cadmium, cobalt, and lead were extracted from the collected samples using the method mentioned by Rifaat et al., (1992) and their concentrations were determined using Atomic Absorption Spectrophotometer (Model Varian A250). The data obtained were analyzed statistically using the Varimax Rotated Factor Analysis technique (Davis, 1973) to decide upon the factors controlling the stability of these metals in the GOS bottom sediments.

Results and Discussion

The bottom sediments of the Gulf of Suez are mainly of carbonates that are composed of calcareous debris of corals and other marine shells and shell fragments. The carbonate content in the examined sediments ranges from 41.9% to 97.4% with an average of 69.3%. The distribution of carbonate content (Fig. 2) shows a relative increase towards west and south while the northern part of the GOS has a lower carbonate percentage. The distribution of organic carbon (Fig. 3) is inversely correlated with carbonate distribution. Organic carbon ranges between 0.92% and 6.84% with an average of 3.58%. The central and northern parts of the Gulf of Suez show the greatest amounts of organic carbon in sediments while the southern part sediment has a relatively low organic carbon content. Most of the examined samples are sand to sandy silt. The northern part of the GOS bottom is covered by sandy silt sediments whereas sediments of the southern part are mainly sands to silty sands (Fig. 4). Table (1) shows the data obtained including the values of pH and Eh, percentages of carbonate and organic carbon and the concentration of Fe, Cu, Mn, Zn, Cd, Ni, Co, Cr and Pb given in ppm.

The distributions of pH and Eh in the sedimentary environment of the GOS are presented in Fig. (5) and (6). The pH of the bottom sediments ranges from 7.35 and 8.05 with an average of 7.62 (slightly alkaline medium). It shows two pH zones. The northern and southern parts of the GOS are dominated by sediments having pH values between 7.35 and 7.75 while its central part is dominated by sediments of pH values greater than 7.75 indicating more alkaline conditions than that of the northern and southern parts (Fig. 5). The Eh values of the GOS bottom sediments vary between 112.74 and 470.24 mV (oxidizing) except at GOS24 at the southeastern part where Eh decreases to –76.81 (reducing). The four general ranges of redox conditions as suggested by Patrick and Mahapatra (1968), which may be encountered in soils are at pH 7, oxidizing > 400 mV, moderately reduced from +400 to +100 mV, reduced from +100 to –100 mV.
Fig. 2. Distribution of carbonate content in the bottom sediments of Gulf of Suez.

Fig. 3. Distribution of organic carbon in the bottom sediments of the Gulf of Suez.
Table 1. The determined parameters in the bottom sediments of the Gulf of Suez.

|       | pH   | Eh   | CO3 % | O.C. % | Fe   | Cu   | Mn   | Zn   | Cd   | Ni   | Co   | Cr   | Pb   |
|-------|------|------|-------|--------|------|------|------|------|------|------|------|------|------|------|
| GOS01 | 7.45 | 112.7| 60.2  | 5.0    | 601.7| 4.7  | 93.3 | 14.8 | 5.1  | 34.8 | 37.5 | 2.9  | 56.2 |
| GOS02 | 7.70 | 211.6| 72.1  | 3.4    | 527.7| 3.6  | 54.1 | 8.9  | 4.7  | 37.2 | 43.3 | 3.6  | 73.6 |
| GOS04 | 7.45 | 279.5| 70.1  | 2.4    | 494.1| 2.1  | 64.4 | 8.5  | 2.8  | 33.0 | 35.6 | 4.9  | 71.9 |
| GOS05 | 7.40 | 413.5| 71.5  | 4.8    | 725.7| 3.1  | 100.3| 16.6 | 4.6  | 45.6 | 39.9 | 1.6  | 51.9 |
| GOS06 | 7.55 | 470.2| 65.3  | 1.0    | 427.8| 1.4  | 69.1 | 7.6  | 5.4  | 34.6 | 36.7 | 9.8  | 68.6 |
| GOS07 | 7.55 | 423.0| 53.7  | 6.8    | 768.3| 4.4  | 146.0| 20.3 | 3.4  | 39.5 | 37.1 | 14.8 | 53.2 |
| GOS08 | 7.55 | 384.6| 58.6  | 4.8    | 903.8| 4.5  | 126.9| 18.4 | 5.7  | 32.7 | 40.9 | 11.8 | 54.8 |
| GOS09 | 7.65 | 419.5| 55.6  | 6.1    | 829.0| 4.2  | 151.6| 24.3 | 4.3  | 30.1 | 36.2 | 7.9  | 59.4 |
| GOS10 | 7.75 | 434.4| 64.5  | 2.2    | 439.0| 0.8  | 68.5 | 6.9  | 3.8  | 33.9 | 36.6 | 1.2  | 43.0 |
| GOS11 | 7.35 | 463.5| 61.6  | 4.9    | 826.3| 2.8  | 140.8| 19.5 | 4.1  | 31.5 | 40.6 | 16.9 | 52.5 |
| GOS12 | 7.70 | 468.2| 79.1  | 2.7    | 384.1| 2.3  | 68.8 | 6.1  | 4.8  | 29.6 | 31.7 | 6.0  | 65.5 |
| GOS13 | 7.60 | 224.4| 70.0  | 3.1    | 365.9| 3.2  | 113.9| 7.7  | 4.0  | 26.3 | 40.7 | 2.4  | 55.0 |
| GOS14 | 7.35 | 130.9| 68.6  | 5.3    | 621.5| 4.0  | 110.8| 17.6 | 2.5  | 39.5 | 36.0 | 3.7  | 51.8 |
| GOS15 | 7.70 | 184.4| 57.9  | 5.1    | 902.6| 8.7  | 157.0| 25.9 | 2.5  | 23.5 | 48.0 | 3.5  | 57.5 |
| GOS16 | 7.65 | 372.8| 78.5  | 2.6    | 323.4| 3.4  | 41.6 | 5.7  | 4.1  | 29.3 | 28.7 | 1.9  | 69.2 |

Fig. 4. Sediment type on the bottom of Gulf of Suez.
Table 1. Contd.

|       | pH  | Eh   | CO3 % | O.C. % | Fe   | Cu   | Mn   | Zn   | Cd   | Ni   | Co   | Cr   | Pb   |
|-------|-----|------|-------|--------|------|------|------|------|------|------|------|------|------|------|
| GOS17 | 7.75| 347.4| 57.7  | 0.9    | 174.3| 2.6  | 38.4 | 3.1  | 3.1  | 24.9 | 25.2 | 3.0  | 36.8 |
| GOS18 | 7.65| 137.5| 56.4  | 6.7    | 433.0| 5.0  | 117.7| 20.2 | 3.7  | 33.7 | 27.5 | 6.1  | 43.7 |
| GOS19 | 7.85| 430.1| 89.2  | 2.3    | 388.3| 4.9  | 70.9 | 5.6  | 4.6  | 39.1 | 39.4 | 2.1  | 67.7 |
| GOS20 | 7.55| 151.0| 66.9  | 6.1    | 745.6| 6.3  | 109.4| 20.0 | 3.8  | 30.0 | 35.6 | 7.4  | 72.7 |
| GOS21 | 8.05| 421.6| 90.9  | 3.1    | 885.5| 6.2  | 91.5 | 48.6 | 5.2  | 45.2 | 47.4 | 10.2 | 52.1 |
| GOS22 | 7.65| 375.0| 41.9  | 2.4    | 622.8| 5.4  | 83.6 | 11.1 | 2.6  | 18.5 | 27.9 | 21.9 | 38.8 |
| GOS23 | 7.90| 467.6| 77.0  | 1.1    | 245.5| 3.6  | 28.8 | 4.3  | 3.9  | 32.3 | 29.7 | 6.1  | 46.8 |
| GOS24 | 7.45| –    | –     | –     | 512.6| 5.0  | 62.1 | 14.3 | 3.0  | 24.2 | 30.8 | 10.9 | 40.8 |
| GOS25 | –   | –    | 85.3  | 2.7    | 435.4| 6.1  | 25.0 | 6.1  | 4.2  | 33.1 | 43.2 | 7.9  | 53.9 |
| GOS26 | 7.70| 389.3| 95.5  | 2.2    | 198.2| 4.6  | 17.9 | 4.8  | 1.9  | 29.3 | 40.1 | 5.4  | 37.1 |
| GOS27 | 7.55| 399.9| 97.4  | 2.2    | 162.6| 2.4  | 15.1 | 44.5 | 4.6  | 35.2 | 38.2 | 9.0  | 58.5 |
| Average| 7.62| 321.4| 69.3  | 3.6    | 536.3| 4.1  | 83.4 | 15.1 | 3.9  | 32.6 | 36.7 | 7.0  | 55.1 |
| Min.  | 7.35| –    | 41.9  | 0.9    | 162.6| 0.8  | 15.1 | 3.1  | 1.9  | 18.5 | 25.2 | 1.2  | 36.8 |
| Max.  | 8.05| 470.2| 97.4  | 6.8    | 903.8| 8.7  | 157.0| 48.6 | 5.7  | 45.6 | 48.0 | 21.9 | 73.6 |

Fig. 5. pH distribution in the bottom sediments of the Gulf of Suez.
and highly reduced from –100 to –300 mV. Clark et al., (1998) considered all values of Eh greater than +100 mV as oxidizing and all Eh values lower than –100 mV as reducing environments. Accordingly, the entire GOS bottom is covered by oxidized sediments except in the southeastern part at station GOS24 where the Eh of sediments is –76.81 mV (Fig. 6). The prevailing pH and Eh conditions recorded in the bottom sediments of the Gulf of Suez favour trapping of the metal precipitates in the solid phase rather than releasing them to the surrounding seawater.

Table (2) shows the factors controlling the examined metals in the bottom sediments of GOS.

Factor 1 contains two associations; the first is a negative association of Sand (loading = –0.95), pH (loading = –0.67), Eh (loading = –0.40), and Carbonate content (loading = –0.67). The second one is an inverse association as indicated by the positive loadings on Silt (loading = 0.93), Clay (loading = 0.77), Organic Carbon (loading = 0.88), Iron (loading = 0.73) and Manganese (loading = 0.85). This factor represents the interaction of coarse-grained sediments that are composed of calcareous debris and fine-grained sediments that are associated with organic carbon and iron-manganese oxides. It denotes that the pH and Eh of the sediment are the fundamental influence behind this factor. Carbonates are insol-
The Effect of Redox Potential on the Stability of Some...

Table 2. Factor Analysis of the obtained data in Table (1).

<table>
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</table>

Kaiser-Meyer-Olkin Test = 0.6

uble at high pH and Eh values and hence the metals content of the carbonate debris are stable under such redox conditions. The strong positive loadings on mud (silt and clay), organic carbon, iron and manganese metals indicate the close relationship of these components in the studied marine environment as observed by many authors (Gibbs, 1973, Armstrong et al., 1976, Rifaat et al., 1992 and El-Sayed et al., 2002). The inverse relationship between these components and both pH and Eh values indicates that the decay of organic matter tends to lower pH of the sediments, but not far below pH 7.35 and consumes the oxygen, and hence lowers the Eh too. The process of organic matter decay may release part of the iron and manganese content that is associated with organic debris (Förstner and Wittmann, 1981).
**Factor 2** is a pH factor that reveals the relationship of pH with iron, copper, zinc and cobalt contents. The increase of pH is associated by similar increase in the content of these metals in the sediments (Galloway *et al.*, 1975 and Dillon *et al.*, 1977). This factor shows that these metals are more stable in the solid phase under more alkaline conditions.

**Factor 3** is a metal-carbonate factor where cadmium, nickel, cobalt and lead are present in the carbonate constituents in the examined sediment which means that the carbonate minerals are the main host of such metals in the sediments as also noticed by Beltagy (1984) in his work on the sediments from the northern Red Sea.

**Conclusion**

The bottom sediments of the Gulf of Suez are mainly composed of carbonates-sand and -silt. The pH values of these carbonate sediments showed two distinctive zones. The northern and southern parts of the Gulf of Suez are dominated by sediments having pH values ranging between 7.35 and 7.75 while the central zone sediments have pH values greater than 7.75. The entire Gulf of Suez sediments are oxidizing except at the southeastern part. The prevailing redox potential in the Gulf of Suez sediments favours trapping of the metal precipitates rather than releasing them to the ambient seawater.

**References**


تأثير الجهد الأكسدي-الاختزالى على ثبات بعض العناصر الثقيلة
في رواسب قاع خليج السويس

أحمد السيد محمد رفعت
المعهد القومي لعلوم البحار والبحار - الإسكندرية - مصر

المستخلص. أوضح أن الدراسة التي تمت على 27 عينة من رواسب قاع خليج السويس بالبحر الأحمر، وجود علاقة وثيقة بين كل من الأس الهيدروجيني والجهد الأكسدي الاختزالى من جهة، ودرجة ثبات بعض العناصر الثقيلة في تلك الرواسب. تتكون رواسب قاع خليج السويس في الغالب الأعم من الرمال والغراني الكليسي (الرمال والغراني المكونة من كربونات الكالسيوم والمجفف). وقد تم التوصل إلى أنه هناك ثلاثة عوامل رئيسية تحكم في ثبات العناصر تحت الدراسة في الرواسب، العامل الأول هو درجة الأكسيد هيدروجيني - والجهد الأكسدي الاختزالى، وحيث إن معظم رواسب قاع خليج السويس تتكون من الرمال والغراني الكليسي، فإنها لأنذرب تحت معدلات عالية من الأس الهيدروجيني (الوسط الفاعلي) والجهد الأكسدي الاختزالى (الوسط المؤكد). وما أن هذه الرواسب الكليسي تحتوي على معظم الفلزات، فإن اتباعها إلى الوسط المائي المحيط عبر طريق الذوبان المباشر غير وارد. على الصعيد الآخر، فإن العلاقة العكسية بين المحتوى العضوي وكل من درجة الأس الهيدروجيني والجهد الأكسدي الاختزالى، توضح أن ثبت المواد العضوية في الرواسب يقلل من فلوسيتها ويسهل الأكسجين مكسباً رواسب جهد اختزال أعلى. العامل الثاني هو الأس الهيدروجيني، والذي يتحكم في وجود عناصر الحديد والنحاس والزنك والكوبالت، وهو يظهر علاقة هذه العناصر بدرجة قلوية الرواسب، حيث كثلاً زادت قلوية الرواسب زادت درجة وجود هذه العناصر وثباتها. أما العامل الثالث فهو يوضح وجود عناصر في صورة كربونات، كما هو واضح من علاقة الأكاديميوم والنيكل والكوبالت والرصاص بالكربونات الكلية في رواسب خليج السويس.
Geomorphological Features, Sediment Distribution and Transport Along Ash Shuqayq-Al Huraydah Coastal Area, Southern Red Sea, Saudi Arabia

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Abstract. The coastal area under investigation stretching from Al Huraydah in the northwest to Itwad in the southwest. It lies about 600 km south of Jeddah on the southern Red Sea coast. It extends inland more than 40 km and is bordered by the shield escarpment. The geomorphologic features, shoreline configuration, sediment characteristics and dynamics has been established for understanding the processes that influence the coastal environments. The shoreline of the studied area is not linear and smooth, instead it is complexed by arcuate beaches, sharms, inlets, lagoons, barriers and rocky hills. The width of the coastal plain varies widely, it is wide and featureless towards south of Ash Shuqayq while being narrow and bounded by resistant sea cliffs towards the north.

Ash Shuqayq coastal landforms include; marsh system, inlet and swamps, wave swash, dunes, shoreline processes, beach bars, spit system, wadi systems and sabkha systems. Conditions on such beaches change rapidly.

In conclusion, the coastal area of Ash Shuqayq can be divided into two principal geomorphic zones: (i) The northern zone stretching from Al Huraydah is characterized by rocky highlands, very rugged with high sea cliffs and small pocket beaches that disrupt wave induced longshore sand transport. (ii) The middle and southern zone stretching from Ash Shuqayq to Itwad southward, is generally broad low relief depositional coastal plain. The shore zone profile is featureless-wide beaches backed by extensive and longitudinal foredunes fixed by coastal vegetation. Sediment cover is thick with numerous wadis drained in the area and contributed the vast majority of the total input of sediments to the coastal zone.
Introduction

In general, little attention has been paid towards the geomorphology of the coastal stretch in the eastern Red Sea coastal plain, among the researchers interested in mapping of the coastal area of the Red Sea were Brown and Jackson (1960). The coastal plain towards the southern Red Sea coast has more than 40 km wide shelf, and extremely vast coastal plain, and even wider further south to the Yemen. North of Ash Shuqayq, the coastal plain is interrupted, where the basement occurs, represented by a large area of plateau basalt and Pleistocene alluvial terraces.

Limited information is available from the published papers dealing with the geomorphologic features and sedimentologic aspects of coastal area of the Red Sea (Jado & Zotl, 1984; Tag, 1986; Tag et al., 1990; Abou Ouf & El Shater, 1992; Gheith & Abou Ouf, 1996; Basyoni, 1997 and Gheith, 1999). Brown (1970) and Brown et al., (1962) have dealt with the geomorphology and geology of the shield area of western Saudi Arabia, geology of the Arabian Peninsula and coastal structures in Saudi Arabia. While Coleman (1993) reported on the geologic evolution of the Red Sea. He described the shelf segments of the Red Sea as shallow and flat. South of 21ºN, the shelf merges imperceptibly with the coastal plain, however, north of this latitude the shelf becomes narrower and is interrupted by rather sharp topographic breaks. Onshore, the coastal plain broadens south of 21ºN, reaching a width greater than 50 km, and in restricted areas may be covered by recent lava flows. North of this latitude, the coastal plain is narrower and contains raised terraces that represent older shoreline. These features indicate emergence (or uplift) in the north, and submergence combined with rapid deposition in the south.

Red Sea relief is related to tectonic movement resulting from the opening of the Red Sea. The climate is arid and the erosional processes play a dominant role in the development of the present landscape (Coleman, 1993). The marginal shelf of the Red Sea is composed of coral banks and reef limestone that is covered by a veneer of carbonate sand. The morphology of the Red Sea shelf in the western coast of Saudi Arabia has been controlled mainly by the effect of coral growth. Separating the shelf from the coastal plain along most of the coastline is a 3 m raised littoral surface of reef limestone. This littoral depositional surface between Yemen in the south and the vicinity of Al Wajh in the north is almost continuous band of emergent reef terraces between 0.5 km and 10 km wide. In land from the coast, the plain rises into an eastern plain consisting largely of a pediment with alluvium and outwash sands and gravels on Tertiary or crystalline rocks and hence to the basement hills. In the south, there is no relief to the flat coastal plain other than the Jizan salt dome, which rises 50 m above sea level and the volcanic lava flow between Hali and Ash Shuqayq.
So the study of local geology helps the authors to understand how coastal geomorphology, lithology and tectonics influence the distribution and transport of littoral sediment in the nearshore along low topography shoreline.

**Area of Study**

Ash Shuqayq-Al Huraydah coast is situated about 600 km south of Jeddah. It is about 40 km wide bordered by flat narrow beach 10 m wide followed by sand dune ridges, swamps, tidal flats and sabkhas. In general, the coast of Ash Shuqayq is flanked to the east by high hills and mountains with peaks more than 2000 m high. The bed rock consists of mainly metamorphic and igneous rock types in addition to many basaltic volcanic rocks. The area covered during this field work was approximately 80 km², stretching from Al Huraydah in the northwest to Itwad in the southeast (Fig. 1).

**Objectives**

The objective of the paper is to describe the geomorphic coastal features and to delineate sediment transportation and its distribution along the Ash Shuqayq-Al Huraydah coastal area in the southern Red Sea.
Sample Collection and Methods of Study

A reconnaissance survey of the Ash Shuqayq coastal area was carried out to collect and describe different geomorphic environments characteristic of the coastal zone. These include; nearshore, shoreline, beach, beach bars, sand dunes, tidal inlets and flats, sabkhas, lagoons and wadis. From these environments samples were collected and landforms were classified and described and photographed. Influence of geology and coastal morphology on sediment distribution and transport are interpreted. Sediment samples from various geomorphic environments between Al-Huraydah (north of Ash Shuqayq) and Itwad (south of Ash Shuqayq) have been collected. A summary of this collection is given in Table (1). Samples collected were texturally analyzed and classified. Sand fraction has been mechanically analyzed by sieving technique adopted by Folk (1962). Graphic grain size parameters were computed by following Folk & Ward (1957).

Table 1. Samples collected from different geomorphic environments of the Ash Shuqayq coastal area.

<table>
<thead>
<tr>
<th>Environment</th>
<th>Station numbers</th>
<th>Collected samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 – Nearshore</td>
<td>1 - 94</td>
<td>94</td>
</tr>
<tr>
<td>2 – Beach</td>
<td>B1 - B10</td>
<td>10</td>
</tr>
<tr>
<td>3 – Sabkha</td>
<td>SK1 - SK6</td>
<td>6</td>
</tr>
<tr>
<td>4 – Wadis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>i – Wadi Itwad</td>
<td>WI1 - WI3</td>
<td>12</td>
</tr>
<tr>
<td>ii – Wadi Al Birk</td>
<td>WB</td>
<td></td>
</tr>
<tr>
<td>iii – Wadi Rim</td>
<td>WR1 - WR2</td>
<td></td>
</tr>
<tr>
<td>iv – Wadi Aramram</td>
<td>WA1 - WA3</td>
<td></td>
</tr>
<tr>
<td>v – Wadi Nahab</td>
<td>WN1 - WN3</td>
<td></td>
</tr>
<tr>
<td>5 – Lagoons</td>
<td></td>
<td></td>
</tr>
<tr>
<td>i – Ash Shuqayq</td>
<td>L1 - L5</td>
<td></td>
</tr>
<tr>
<td>ii – Masud</td>
<td>ML1 - ML3</td>
<td></td>
</tr>
<tr>
<td>iii – Sharm At tanah</td>
<td>Shi1 - Shi5</td>
<td></td>
</tr>
<tr>
<td>6 – Sand Dunes</td>
<td>D1 - D10</td>
<td>10</td>
</tr>
<tr>
<td>7 – Sand spit</td>
<td>SP1 - SP3</td>
<td>3</td>
</tr>
</tbody>
</table>

Results and Discussion

General Description of Ash Shuqayq-Al Huraydah Coastal Area

Ash Shuqayq coast is about 40 km wide and bordered by complex sand dunes, swamps, tidal flat and sabkhas on the north eastern side. The shoreline north and south of Ash Shuqayq is not linear and smooth, but instead comprises arcuate beaches, sharms, inlets, rocky hills, barrier, spits and lagoons. Moreover, Ash Shuqayq coastal plain is also cut across by many wadis, lagoonal outlets, tidal inlets and tidal channels, which act as protected areas, where mainly
coarse-grained material is deposited. North of Ash Shuqayq near Al Hurayda region lies Sharm At Tanah and Jabal Al Raqabah while south of Ash Shuqayq lies Ras Suwad and Ras Masud.

Ash Shuqayq coast can be describe as a broad, low relief depositional coastal plain, while Al Huraydah coast (north of Ash Shuqayq) is an emergent shoreline with rocky headlands giving rise to pocket beaches and disrupts wave-induced longshore sand transport or littoral drift in the surf zone. Along the low-lying Ash Shuqayq coast sediment cover is generally thick, the distribution of the littoral sediments on the shoreface provides important information regarding not only the sources of the sediments but also the modes and pathways of transport. However, some parts of the beach consist of low-lying hard coral reef platform, have a very thin to non-existent sediment cover.

In general, the geomorphology of Ash Shuqayq-Al Huraydah coastal area has complex landforms, these include sand dune processes, marsh and inlet systems, sabkha systems, carbonate systems, wadi systems, sea cliffs and wave swash processes. Conditions on such beaches change rapidly. Coastal marshes and inlets as well as sand dunes are common components of Ash Shuqayq coast. The location of the studied landforms characteristic for the studied coastal area is represented in a geomorphologic map shown in Fig. (2).

![Map of Ash Shuqayq area showing different geomorphic environments](image)

**Fig. 2.** Constructed schematic map showing the different geomorphic environments along Ash Shuqayq area.
Generally, the beach sediments in most part of the Ash Shuqayq coast are backed by eolian sands arranged in the form of complex sand dunes or in the form of longitudinal bar or ridge parallel to the shore and constitute the youngest recent material in the study area. It is well known that the energy input by waves, currents and tides is linked to the landforms of the coast by coastal sediments. The shape of the various coastal landforms is a response to the energy inputs (Pethick, 1984). Coastal landforms reflect the materials from which they are made. On the other hand, the rate of the sea level change has an important effect on the stability and survival of many coastal forms. Two other strong factors control these coastal changes; sediment availability and the intensity of wave processes (Carter, 1991).

Inland, the coastal plain of Ash Shuqayq is characterized by vast areas of low-lying table lands which are thought to be remnant of flood plain deposits of clayey silt composition.

The width of the coastal plain varies widely, it looks wide toward south of Ash Shuqayq (Fig. 3A) and narrow towards north of Al Huraydah and is bounded by resistant headlands as sea cliffs (Fig. 3B).

It was observed that many wadis were drowned in the coastal area and contributed the vast majority of the total input of sediments to the coastal zone probably during the Late Quaternary period at the time of lowered sea level. Many of the paleo-drainage of these wadis stopped to carry significant discharge or sediments due to the heavy road and building construction in the area. Thus the majority of the drainages observed have since been infilled, thus retarding local erosion and decreasing the supply of sediments to the beaches.

Coastal Landforms Characteristics of Ash Shuqayq-Al Huraydah Area

1) The Beach

Beaches are accumulation of sediment deposited by waves and currents in the shore zone and extend from the upper most limit of wave action to the low-tide mark. They are typically composed of sand and/or pebbles. In general, sandy beaches are formed from the material partly eroded from adjacent parts of the coast, partly by fluvial sediment and partly by sand carried shoreward from the sea floor (Bird, 1984). The topographic configuration of Ash Shuqayq beach includes the following units; backshore, foreshore and sand dunes. North of Ash Shuqayq, pocket beaches are noticed. South of Ash Shuqayq the beach is much wider and longer and is distinguished by lower gradient shore-face and low-lying marine reef platform.

Sediment on the beach is coarser than the intertidal sediments as fine sediments are dispersed seaward due to wave action in that area. There is a wide
range in sediment texture exhibited by the Ash Shuqayq beach, which reflects varying energy conditions in the study area. Further, variability in the sources of the sediments and the reworking processes operative in the littoral zone have also been observed in grain size.

The coarse-gravelly sand bed material (Fig. 3C) results as runoff down the wadis, during flash floods (Al Sayari and Zotl, 1978). These flash floods are highly localized and of variable intensity. The terrigenous sediments from the wadis are mixed with in situ available skeletal carbonate material in varying proportion in the beach and littoral zone, such mixing and subsequent reworking by the near-shore processes gave rise to the variation in texture. Generally, along the whole beach zone foredune ridge sands are arranged in the form of complex sand dunes parallel to the shore and constitute the youngest recent material in the study area.

2) **Beach Ridge**

A beach ridge is a continuous linear mound of coarser sediment near high water line (Reineck & Singh, 1975). In front of a beach ridge a sandy beach is always present. Ash Shuqayq beach ridges are made up of sand and gravel. They developed mainly during rainy storms and deposited at the mouths of the wadis then redeposited by wave processes. It is mainly horizontally laminated sand and gravel layers (Fig. 3D).

3) **The Shorelines**

In general, the shoreline of Ash Shuqayq area can be divided into three principal geomorphic zones namely: (i) The northern zone stretching from Al-Huraydah area is characterized by rocky headlands (Fig. 4A); is very rugged with high sea cliff formed of basaltic rocks and alluvial terraces with small pocket beaches. (ii) The middle zone is generally wide containing sandy to coarse-grained beaches backed by dunes. The coarse-grained laminated beach sediments may be considered as recent most features that formed by modern periodic fillings. Numerous wadis are responsible in contributing the vast majority of the total input of sediments to the coastal zone. Hence Ash Shuqayq has the thick sediment covered shoreline. (iii) The southern zone of the shoreline which starts just south of Ash Shuqayq and includes wide sandy beach interrupted in some parts by coralline platform as low-lying terraces (Fig. 4B).

4) **Sand Dunes**

Ash Shuqayq coast is distinguished by extensive and various coastal sand dunes. In general, the occurrence of dunes on the coast is directly related to sand supply and a favorable wind regime (Davis, 1985).
Fig. 3(A). Wide low-lying coast, south of Ash Shuqayq.

Fig. 3(B). Narrow, short and rugged rocky beach with pocket boulders-sandy beach north Al Huraydah coast.
Fig. 3(C). Coarse-grained sandy beach north of Ash Shuqayq coast.

Fig. 3(D). Beach bar or ridge consists of conglomeratic sandy layers.
Fig. 4(A). Rocky coastal hills shoreline north of Al Huraydah.

Fig. 4(B). Transgressive shoreline formed of coarse grained biogenous materials disrupted by coral reef platform.
Fig. 4(C&D). Low-lying foredunes set along the beach and fixed by abundant coastal vegetation.
The foredunes set along the beach are continuous and fixed by abundant coastal vegetation (Fig. 4C&D) with low-lying relief, whereas others show evidence of movement with high topographic relief and include seif and barchan dunes.

In general, it was observed that along most coastline of Ash Shuqayq, active dune systems are common, where the foredune marks a boundary between hydrodynamics and aeolian environments. Initiation and evolution of these dunes and their interactions with the processes include vegetation influences that act upon them.

5) Tidal Inlets

Tidal inlets along the Ash Shuqayq coast cut across through weak beach zones and points of the mouths of the ancient wadis and they are maintained by tidal currents. During high tide, salt marshes are common in the Ash Shuqayq plain as a short term process at the scale of tidal cycles. In general, the inlets join the lagoons of Ash Shuqayq to the Red Sea and are merely a gap in a weak section of the low-lying shore known as tidal inlets (Fig. 5A).

6) Tidal Sediments

They are formed in coastal backwaters where they form a sort of dumping ground for the detritus collected on open coast and transported into these sheltered bays (Fig. 5B). These backwaters may be loaded with mud and constitute only ephemeral coastal landforms.

7) Salt Marshes and Sabkhas

Ash Shuqayq coastal plain is characterized by many vegetated mud flats, sabkha deposits and salt beds (Fig. 5C&D). The coastal sabkhas are characterized by the presence of evaporite minerals which have accumulated on the top to form a hard crust, followed by a soft or loose soil zone. In general, the sabkha surface is very flat with no physical obstacles. These sabkhas extend for approximately more than 1 km from the waterline. In general, Ash Shuqayq coastal sabkhas are mainly siliciclastic in origin due to the dominance of quartz and feldspar over carbonate (Nabhan, 2004).

8) The Wadis

Ash Shuqayq coastal plain is traversed by many ancient wadis named as Itwad, Al Beark, Rim, Nahab and Aramram (Fig. 6A&B) from south to north. They extend several kilometers inland ranging from 29 to 52 km in length.
Fig. 5(A). Tidal inlet connects Ash Shuqayq lagoon with the Red Sea.

Fig. 5(B). Submerged wadi Rim during high tide and deposition of collected fine detritus in sheltered bays.
Fig. 5(C&D). Deposition of mud flats and sabkha deposits in a wide low-lying coastline south of Ash Shuqayq.
Fig. 6(A&B). Submerged wadi Nahab and wadi Aramram during high tide. Concentration of heavy minerals (placer deposits) is due to sorting processes (tidal backwash).
These drowned valleys were formed during lowered sea level events of the Late Quaternary time. The wadis are ephemeral and active sediments supply channels only during flash floods (Al-Sayari and Zotl, 1978). These seem to be localized and of variable intensity which can transport even gravel sized sediments noticed in the beach zone.

9) The Reef Limestone Platform

Some parts of Ash Shuqayq area exhibit low lying reefal limestone platform (Fig. 6C) which extend from the nearshore zone toward the beach, and sometimes are covered by alluvial deposits of sand and mud materials. These reef limestones were formed in the Late Pleistocene and are associated with the last period of higher sea level in the western coast of Saudi Arabia (Skipwith, 1973 and Behairy1983).

10) The Nearshore Shelf Zone

The nearshore shelf zone of the Red Sea coast is considered an active carbonate depositional region with wide spread fringing coral reefs, Ash Shuqayq nearshore zone represent a dynamic basin which receives detrital constituents.

The shallow nearshore zone surface gently slopes seaward up-to the edge of reefal flat. It is covered by thin fine to coarse grained sediments. These terrigenous materials are composed mainly of sandy mud to gravelly sand mud with little fragments of coral, coralline algae and mollusks. Eolian activity may have contributions of some fine sediments to the shelf from the adjacent landmass.

11) Rocky Cliff and Pocket Beaches

This type of beach is common in north Ash Shuqayq, at Al Huraydah. It consists of nearly 60 m high hills of basaltic rocks on the shoreline (Fig. 6D). In between, pocket beaches are also noticed. These rocky hills indicate volcanic eruption which built up a thick succession of lava associated with the tectonics of the Red Sea region.

12) Lagoons

Ash Shuqayq lagoons are considered as shallow depressions which remain water filled even at low tide. Few of the lagoons developed at the mouth of the ancient wadis, while others in the tidal regions which gradually develop into tidal flats. Small part of the coastline is changed to a barrier coastline which opens into Red Sea by inlet. However, the size and number of inlets of a lagoon depends upon the quantity of water, which flows through it during a given time
Fig. 6(C). Low lying reefal limestone platform in the nearshore zone south of Ash Shuqayq.

Fig. 6(D). Ash Shuqayq lagoon separated from the Red Sea by sand barrier.
(Reineck & Singh, 1975). The amount of water is controlled by tidal range, number of tides per day.

Some of the coastal lagoons of Ash Shuqayq are hypersaline, as no fresh water comes into the lagoons except mouths of the wadis, which are flooded during rainy storm by fresh water drained into the lagoon, causing decrease in salinity. Most of the lagoons with normal salinity show faunal similarity with those of the open sea (Abou Ouf, 1996), however, with change in salinity, fauna get impoverished. Mangrove vegetation are present due to the tropical climate, along with algal mats. During dessication, mud cracks are usually developed.

**Sediment Characteristics of Coastal Landforms**

Analyses of sediment samples from coastal landforms are important for any geomorphologic work in the study area. Along low-lying Ash Shuqayq coast, beaches received considerable sediments influx through many ancient wadis (Aramram, Nahab, Rim, Al Beark and Itwad) as indicated by the dominant terrigenous materials. Texture variation and transportation of the sediment is discussed in the following:

1 – **The Nearshore Sediments**

The nearshore sediments of Ash Shuqayq can texturally be classified as dominantly muddy sand, along with gravelly muddy sand at few places. Carbonate content varies between 2 and 93% with an average of 21%. Carbonate concentration appears to be very low near the shore, especially in front of wadi mouths, due to dilution by the terrigenous material. In the extreme north gravel content shows an increase.

The nearshore sediment sources appear to be a combination of material eroded from the basaltic cliffs and alluvial terraces by wave action, relict sediment originally from the ancient wadis in the area and transported onshore by northwesterly waves or wind during sea level low stands. Littoral source for this sediment is supported by its calcareous composition character and similarly to coral reef sediments. Under high energy or storm conditions, part of the beach sediments typically is eroded and carried to offshore.

2 – **The Beach Sediments**

Beach or shore landforms include well developed foreshore and backshore. Beach bar or ridge is common and consists of coarse-grained gravelly sands. This bar occurs between mouths of wadi Aramram and wadi Nahab as remnant or more recent shore feature that formed by modern filling.
Beach sediments are mainly composed of sand fraction, however, gravel size fragments of well rounded and flatty shape are seen everywhere besides the mouths and wadi channels. Reworking of ancient wadi deposits by marine processes is probably a more important contributor to the gravel coarse fraction in the beach zone. Graphic grains-size parameters determined by Nabhan (2004) indicate that the beach zone is composed mainly of medium to fine-grained sand especially in the intertidal zone and sometimes gravel, with moderately sorted to moderately well sorted sediments in the backshore zone.

The processes of coastal sediment transport are evaluated whereby the energy input by waves, currents and tides are linked to the landforms of the coast by coastal sediments. The shape of the various coastal landforms reflects the material from which they are generated either detrital grains (clastic sediments) or calcium carbonate grains (chemical and/or biogenic). In addition, the wide range in sediment texture along the beach stretch of Ash Shuqayq reveals varying energy conditions in the different environments. Further variability is recorded in the sources of the sediments due to the different composition.

3 – Sand Dune Sediments

Sand dunes are identified as high coastal seif and barchan dunes which move landward side. Extensive low dunes field, scanty vegetated and parallel to the shoreline as a foredune ridge is the characteristic feature of the beach zone. Aeolian material transported as a drag from local sources and as a suspended load from regional sources is another important source. Graphic grain size parameters determined by Nabhan (2004) proved that Mz varies between medium-grained and fine-grained. While sorting values fit into moderately well sorted to well sorted. It is concluded that sorting is related to dune morphology; where the dune ridge has better sorted coarse-grained sand than the inland barchan and seif dunes indicating sediment derivation from the beach zone.

4 – Wadi Sediments

Ash Shuqayq coastal area is cut across by five wadis, namely from south to north; Itwad, Al Beark, Rim, Aramram and Nahab. These wadis affect the deposition in the shelf marine environment, since they provide the area by huge amounts of detritus material derived from the adjacent high fringing Tertiary mountains. These wadis get occasionally flash floods at a time when the rainfall is extensive in the region.

The texture analyses of selected samples from these wadis show that they are mainly composed of muddy sand, sand and sandy mud. Gravels constitute low amount however, one can see many boulders, cobbles and pebbles everywhere
at the mouths and in the channels especially at wadi Nahab probably due to proximity of rocky hills on the path way of the wadi.

5 – Lagoon Sediments

Ash Shuqayq, At Tanah and Masud lagoons were formed due to the presence of gap in weaker sections of the shore through tidal inlet. Their sediments analyses exhibit various textural range; muddy sand, muddy gravelly sand, gravelly sand and sand. At Tanah have relatively finer sediments (sandy mud and sand).

Conclusion

The study area of Ash Shuqayq can be divided into the following units; fore-shore, backshore, swamps, tidal inlets, tidal flats and sand dunes. Sea cliffs, coral reef platform, ancient wadis are the major factors controlling the development and changes in the area. Sometimes, the beach appears as ridge. This make shoreline marked as sand bar which was formed by the flooding of wadis through rainy seasons. Patches of gravels are present near mouths of wadi Nahab and wadi Aramram. Along the low lying Ash Shuqayq coast, sediment cover is generally thick and the distribution of littoral sediments on the shore-face provides important information regarding not only the sources of the sediments but also the modes and pathways of transport.

Ash shuqayq coastal area can geomorphologically subdivided into northern and southern geomorphic provinces:

1 – The northern province (includes Al Huraydah area): Study area tends to be narrow short and poorly developed beaches, rocky cliffs of volcanic basalt with pocket beaches. Erosion and abrasion of these rocks fill material and rocks by waves and currents are believed to represent the most important source on the intertidal sediments, especially the coarse fraction.

2 – The southern province (include the middle and south of Ash Shuqayq area): Beaches are much wider and longer with low-lying topography and cut across by many wadis. The wadi sediments are generally muddy to gravelly sand. Most wadis contribute much terrigenous sediments to the coastal zone as evident from the long stretches of sand, that overlies the fringing reefs. The terrigenous sediments from the wadis, mixed with locally produced carbonate in the littoral zone are subsequently affected by reworking, due to the near-shore processes. The fine grained sediments were dispersed seaward by wave energy.
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References


الأولى الجيولوجية وتوسيع وحركة الرواسب
على طول المنطقة الساحلية للشقيق والخريضة
بجنوب البحر الأحمر - المملكة العربية السعودية

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المستخلص. تقع منطقة الدراسة الساحلية بين الخريضة والشقيق على بعد 600 كم من جدة على الساحل الجنوبي للبحر الأحمر. اتساع المنطقة يصل إلى حوالي 40 كم وطول قدره 250 كم، يحفظها من ناحية البابس سلسلة جبال البحر الأحمر.

لقد تم استنباط كل المعلومات الخاصة بالظواهر الجيولوجية، وشکل خط الشاطئ، وحركة وميزات الرواسب، فهم العمليات المؤثرة على البيئة الساحلية. ولقد لوحظ أن خط الشاطئ غير مستقيمة ولا ناعم، بل معقد بواسطة شواطئ منحنية. هذا ويتكون عرض السهل الساحلي اختلافاً واضحًا، فهو يبدو متسعًا ومستويًا ناحية جنوب الشقيق، بينما يضيق ويعتقل بالجروف البحرية في الشمال.

وتضمن الأشكال الأرضية الساحلية كلاً من: نظم المستنقعات، والمداخل والإتجاهات، وغسيل الأمواج، والكتفيات الرملية، وعمليات خط الشاطئ، والخواجز والألسنة والأودية والسبخات، هذا وتتغير الظروف سريعاً في تلك الشواطئ.

ولقد تم تقسيم المنطقة الساحلية للشقيق إلى منطقتين:

- الجيولوجيات أساسيات:
  - المنطقة الشمالية للشقيق، وهي متقدمن من الخريضة، وتمتاز بالرووس الأرضية المرتفعة الوعرة، التي تشمل الجروف البحرية، والخيوط
الشاطئية الصغيرة، مما يؤدي إلى إعاقة نقل الرواسب على طول الشاطئ.

2- المنطقة الوسطى والجنوبية للشقيق، وهي تمتد من الشقيق حتى عتود جنوبًا، حيث يتسع ويعرض الشاطئ، فبيدو عديم الظواهر، كما يتميز بوجود تراكمات من الكثبان الرملية المتصلة، والثابتة بالنباتات على طول الشاطئ. الغطاء الرسوبي بوجه عام سميك نتيجة لوجود الأودية التي ذهدت المنطقة الشاطئية بكميات هائلة من الفاتنيات.