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Sedimentology and Mineralogy of Jizan Shelf Sediments Red Sea, Saudi Arabia

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ABSTRACT. This study evaluates the texture, coarse fraction composition and mineralogical constituents of the bottom samples from the Jizan shelf, Red Sea, Saudi Arabia. Five sediment types were identified, namely muddy sand, sandy mud, silt, clayey silt and silty clay. It was found that most of the northern and central parts of the shelf are covered with muddy sediments, while the muddy sand and sandy mud sediments are restricted only to the southern part of the shelf and near shore areas. Based on the textural characteristics of the examined sediments, Jizan shelf environment can be divided into two energy zones: (a) low-energy zone, including most of the northern to middle shelf area; and (b) a moderate-energy zone, restricted to the southern part of the shelf and near shore areas.

The detailed mineralogical investigation of the various size classes of Jizan shelf sediments revealed that they are of polygenetic origin. Two main sources of the shelf sediments were recognized, namely: (a) autochtonous materials which are derived from the degradation of recent shells of various fauna, erosion of submerged ancient sediments and sub-recent coastal sediments; and (b) allochtonous materials, which are derived from the onshore alluvium deposits by the action of intermittent streams.

Introduction

Jizan shelf is a relatively large flat shoal in the southeastern part of the Red Sea. It lies between Farasan Islands and Jizan coast (Fig. 1) and covers an area of approximately 6000 km. Its maximum length is about 100 km and its maximum width is about 70 km.

Although the northern Red Sea bottom sediments have been a subject of numerous studies (e.g. Shukri and Higazy 1944a, b; Mohamed 1940b; Friedman 1968; Milliman *et al.* 1969; El Sayed and Hosny 1980), few published works are available on the Holocene sedimentology of the southern Red Sea in general and Jizan shelf in particular. The first geological studies on Farasan Islands was made by McFayden (1930a) and Cox (1931). Later, Bahafzallah (1984) investigated the beaches of the Farasan Islands and their benthic foraminiferal content. Also, the geological history and structure of Jizan coast and Farasan Islands have been summarized by Jado and Zotl 1984, (Fig. 2). Little terrigenous material is supplied from the adjacent coastal plain through the major wadis during flash floods caused by occasional cloud bursts (Al Sayari and Zotl 1978). Therefore, most of the sediments of the shelf are indigenous carbonates mixed with terrigenous clastics.

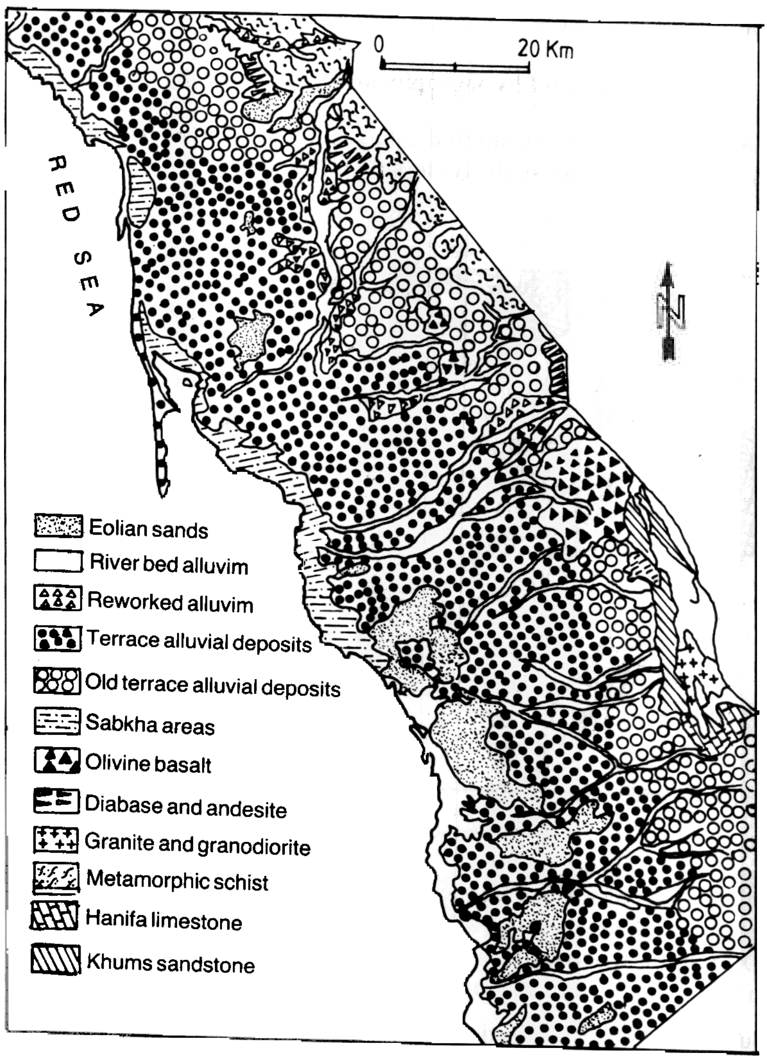

FIG 2. Generalized geology of Jizan coastal plain

39‰ in summer (Sharaf El-Din and Mohamed 1984). The direction of wind during the sample collection was south-southeast.

Sampling and Methods of Analyses

Thirty-five samples were collected from the bottom sediments of Jizan shelf area (Fig. 1). Samples were taken from the top 10cm of sediments using a Van Veen grab sampler. Grain-size analysis of these samples were made using standard sieving and sedimentation techniques (Folk 1974). Cumulative curves and histograms were prepared. The proportions of the main size fraction (sand-silt-clay) and the statistical size parameters for all study samples were calculated using the formula of Folk and Ward (1957).

Fifteen samples were chosen for the study of the composition of the sand fractions. The various mineral grain components in the very coarse, coarse, medium and fine sand fractions have been identified using a binocular microscope. The relative frequency percentage of each mineral grain was determined by counting a total of about 200 grain in each size fraction. The biogenic fragments were also studied in thin section.

Eleven samples were selected for the study of heavy minerals. The latter were separated from the very fine sand and coarse silt fractions using the standard bromoform method. Light mineral fractions were stained by alizarine red to facilitate identification of carbonate mineral grains.

For the study of "whole sediment" mineralogy, a portion of the dried sample was finely crushed and analysed by x-ray powder diffraction. Semiquantitative estimations of the minerals present in the "whole sediment" samples were made using the method described by Bush (1973).

The clay size fraction < 2 µm was separated by means of the sedimentation method. A suction-onto-ceramic disc method (Shaw 1971) was used for the preparation of oriented clay samples for x-ray diffraction analysis. The analyses were carried out on a powder diffractometer using nickel-filtered Cu-K radiation. The identification of clay minerals involved the standard pretreatments of glycolation and heating at 550C. The semi-quantitative estimates of the relative amounts of clay minerals were calculated by the method outlined by Schultz (1964).

Results

Textural Classes

The various textural classes of Jizan shelf sediments have been determined using Folk's classification (1974), which is based on sand-silt-clay percentages, with slight modification. Folk's mud textural class is divided into two textural classes, namely; silty clay and clayey silt. According to this classification five textural classes were obtained, namely; muddy sand, sandy mud, silt, clay silt, and silty clay. The average grain size composition and statistical size parameters of these textural classes are given in Table 1.

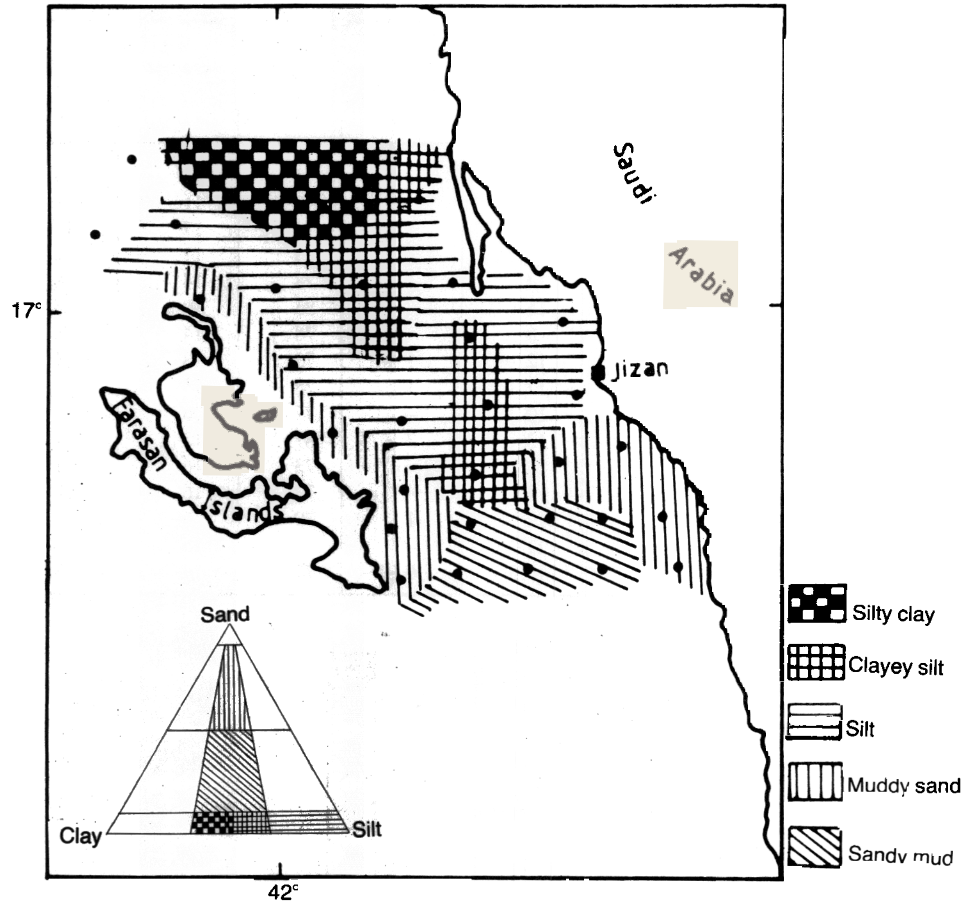

FIG. 4. Lithofacies map bottom sediments of Jizan shelf (1 = silty clay; 2 = clayey silt; 3 = silt; 4 = muddy sand; 5 = sandy mud).

Shells and shell fragments are the most dominant components, they constitute more than 70% of the sand fraction. They are generally represented by whole shells and shell fragments of pelecypods, gastropods, echinods, bryozoans, foraminifera, and ostracods. The relative abundance of these biogenic components are controlled to great extent by grain size and environment of deposition. They are generally more abundant in the coarser sand size fractions and decrease in the finer ones.

Biogenic grains in the very coarse sand fractions are mostly represented by fragments of gastropods and pelecypods shells and whole shells of microgastropods and micropelecypods. Echinoid plates and spines are also frequent in this size. Medium and fine sand fractions are characterized by the relative abundance of ostracodes and echinoids spines. Foraminiferal tests are mostly concentrated in the fine and very fine sand fractions.

Quartz is mostly represented by rounded monocrystalline grains which are commonly coated with thin, discontinuous shells of carbonates. Quartz is more frequent in the medium and fine sand fractions and less abundant in coarser fractions. Feldspars are present in subordinate amounts. Special distribution of the relative frequency percentages of both quartz and feldspar in the sand fraction of Jizan shelf sediments indicates that they are commonly more abundant in the southern area of the shelf. Pellets and oolites are present in noticeable amounts in the medium sand fraction.

Mineralogy of Very Fine Sand and Coarse Silt Fractions

1. Light Minerals

The light mineral assemblages of both very fine sand and coarse silt fractions of the investigated samples are chiefly composed of carbonate grains (mainly detrital calcite and allochems) quartz and feldspars. Gypsum, chert, and mica are present in traceable amounts (Table 3).

'ABLE 3. Relative frequency percentages of the light mineral grains in the coarse silt and very fine sand fraction in the Jizan shelf sediments.

Sample No.	Carbonate		Quartz		Feldspars		Mica		Chert		Gypsum	
	V.F.S.	C.S.	V.F.S.	C.S.	V.F.S.	C.S.	V.F.S.	C.S.	V.F.S.	C.S.	V.F.S.	C.S.
2	51.1	62.1	25.1	21.4	11.5	8.3	6.2	8.6	8.1	6.2	1.8	2.1
6	52.3	58.4	27.4	24.3	13.6	7.8	5.2	8.0	6.2	3.9	2.4	3.1
8	48.4	57.7	28.3	26.4	12.3	9.3	7.0	3.2	5.0	3.8	0.9	1.7
9	48.6	60.3	24.3	22.1	11.2	12.7	8.9	2.5	4.3	2.7	0.7	1.2
11	47.6	66.0	20.2	17.2	8.6	11.4	4.1	5.1	3.6	2.0	0.0	0.8
14	49.1	61.3	21.3	19.4	9.7	12.9	7.5	12.2	4.0	3.1	1.1	0.6
16	44.8	59.6	29.0	27.8	12.1	9.7	5.3	5.8	3.8	4.0	0.0	0.3
19	39.8	57.1	28.9	26.3	14.3	8.4	3.6	10.6	5.2	2.2	0.2	0.1
24	48.3	55.4	27.7	23.9	11.9	9.0	6.4	5.7	4.9	1.8	1.2	1.1
28	53.2	53.9	26.3	23.8	12.4	8.1	2.0	4.9	4.1	1.6	0.0	0.0
31	50.1	54.3	25.7	20.6	13.2	9.4	7.9	4.7	3.3	1.8	0.0	2.7
Average	48.5	58.7	25.8	23.0	11.9	9.7	5.9	6.7	4.8	3.0	0.8	1.3

Note: V.F.S. Very Find Sand; **C.S.** Coarse Silt.

Carbonate grains constitute an average of 54% of the light fraction which generally forms an average of about 89% of the studied samples of both the very fine sand and coarse silt fractions. They are mainly represented by detrital calcite grains and allochems. The latter are composed of fragments of various marine fauna shells (pelecypod, gastropod, echinod, and bryozoa) and whole shells of ostracods, foraminifera and other microfauna. The microfaunal shells and echinoid spines form a considerable portion of the very fine sand fraction. Foraminiferal shells are usually filled with black organic matter and pyrite. Some of the pyrite-filled foraminiferal shells are present with the heavy fraction of the very fine sand and coarse silt. Detrital calcite is present as rounded to subrounded monocrystalline grains and as well-

TABLE 4.a. Relative frequency percentages of the heavy minerals in the very fine sand fraction of Jizan shelf sediments.

Sample No.	Opaques	Transparent heavies	Transparent heavy minerals (100%)									Wt % of heavy minerals
			Amphiboles	Epidotes	Mica	Staurolite	Andalusite	Zircon	Tourmaline	Pyroxene	Others*	
2	13.8	86.2	70.0	22.6	1.2	1.3	0.3	1.0	0.2	2.2	1.2	12.3
6	12.1	87.9	73.7	20.6	1.7	0.3	0.3	0.8	–	1.8	0.8	8.4
8	16.3	83.7	68.4	21.8	2.4	2.0	0.9	1.2	–	3.0	0.4	10.1
9	15.00	85.0	68.9	23.2	3.2	0.8	0.6	0.4	0.1	1.2	1.5	12.7
11	14.2	85.8	65.3	24.3	4.0	1.7	1.1	0.6	0.2	1.4	0.7	11.5
14	11.4	88.6	67.5	26.9	2.7	0.5	0.3	0.9	–	1.0	0.2	14.6
16	10.8	89.2	70.0	20.7	3.0	1.2	0.6	0.4	–	2.9	2.0	10.8
19	12.4	87.6	70.3	25.4	2.9	1.0	–	–	–	1.8	0.6	13.2
24	15.3	84.7	67.9	24.5	3.7	0.9	1.0	0.2	–	1.5	0.4	9.7
28	17.0	83.0	68.6	22.0	2.5	2.1	0.8	0.7	0.3	2.4	1.3	8.9
31	11.5	87.5	70.8	22.8	1.7	1.6	0.4	0.4	–	1.1	1.2	14.0
Av.	13.6	86.3	70.2	23.0	2.6	1.2	0.6	0.6	0.1	1.8	0.9	11.5

Other : apatite, sphene, rutile, and sillimanite

TABLE 4.b. Relative frequency percentage of the heavy minerals in the coarse silt of Jizan shelf sediments

Sample No.	Opaques	Transparent heavies	Transparent heavy minerals (100%)									Wt % of heavy minerals
			Amphiboles	Epidotes	Mica	Staurolite	Andalusite	Zircon	Tourmaline	Pyroxene	Others*	
2	14.7	85.3	78.1	16.2	0.9	–	–	1.2	0.6	2.1	0.9	8.5
6	15.1	84.9	76.4	12.3	0.7	–	–	1.6	–	1.2	1.7	10.6
8	11.0	81.0	72.3	20.9	1.5	–	–	0.5	–	2.8	2.0	9.5
9	9.2	91.8	73.8	19.1	1.3	0.7	–	0.9	–	2.9	1.3	11.3
11	16.7	83.3	72.9	21.6	2.1	0.2	–	–	0.4	2.0	0.8	8.8
14	14.3	85.7	77.2	15.6	3.2	–	–	1.7	–	1.7	0.6	9.2
16	12.1	87.9	80.1	.2.7	1.9	0.2	–	1.9	0.9	2.3	1.0	13.0
19	13.5	86.5	79.0	14.1	2.7	–	–	–	–	3.0	1.2	10.1
24	17.2	82.8	75.3	16.6	2.3	–	–	1.3	0.8	3.2	0.5	13.2
28	19.4	80.6	72.11	19.8	1.3	–	–	2.0	–	2.6	0.7	7.0
31	13.6	86.4	82.9	13.2	0.5	–	–	–	–	3.0	0.4	12.5
Av.	14.3	85.1	76.4	16.6	1.7	0.1	–	1.1	0.2	2.4	1.0	10.3

* Other : apatite, sphene, rutile, and sillimanite.

Pyroxene grains usually occur as euhedral to subhedral prismatic crystals. They are represented mainly by hypersthene, enstatite and augite

The nature of the Recent-Sub-Recent coastal sediments also affects the textural characteristics of the Jizan shelf sediments. The occurrence of calcarenitic beach sediments (Sub-Recent raised beaches) along Jizan coast and around the Farasan Islands are responsible for the relative abundance of sandy sediments in the western, southern and eastern part of the shelf. The action of waves generated by the prevailing S-SE winds also play an important role in the development of these sediments.

The biogenic components of the sand-size fractions in the studied sediments, whole shells and shell fragments, are mostly derived from both the living fauna within the shelf and the ancient shells from the coastal Sub-Recent-raised beaches. These shells, Recent and Sub-Recent, are subjected to mechanical breakdown and reworking in the intertidal area of the shelf and then transported by the action of dynamic factors of tidal currents and waves towards the offshore area. Biological breakdown of shells and shell fragments through the micritization and borrowing processes could be responsible for the development of silt and clay-size calcareous particles.

The coarse fragments of these shells will be transported in traction and saltation mode and deposited in the near-shore areas; while the finer grains (silt size) are most probably transported as suspended matter and then deposited in the quite low-energy offshore area as calcareous mud. Shells of the in situ benthic microfauna, foraminifera and ostracoda, contribute to the whole sediment budget by direct accumulation, especially in the muddy areas.

The abundance of aragonite and high-Mg calcite in Jizan shelf sediments could be attributed to the suitability of this area for chemical and biochemical precipitation of these carbonate minerals or to the type of indigenous fauna.

With regard to the transparent heavy minerals, it can be noticed that Jizan shelf sediments are similar to the Recent coastal sediments of the southeastern Red Sea (Tag 1986) in the abundance of amphiboles, epidotes and mica. Therefore, the composition of these heavy-mineral suites indicates that they are mainly derived from the desintegration of metamorphic rocks and partly from basic igneous rocks.

The distribution pattern of smectite fits well the Tertiary and Quaternary volcanic rock occurrence in the coastal region (Jado and Zotl 1984; Fig. 2). Alteration of volcanic material under the influence of relatively higher rainfall contributed smectite-rich sediments to the Jizan shelf. In Al-Qunfudah-Al-Lith coast, which is the northern limit of the monsoon influence and bordering the studied area, low intensity chemical weathering associated hot desert climate and abundant metamorphic schists supplied chlorite-dominant sediment load Durgaprasada Rao *et al.* 1987). These chlorite-rich sediments of Al Qunfudah-Al-Lith shelf may be the main source of chlorite in sediment of the Jizan shelf, where chlorite is more abundant in the northern part and roughly decreases towards the south (Table 5). Kaolinite is considered to have been derived from the soils formed under paleo-humid climates in the west coast of Saudi Arabia (Durgaprasada Rao *et al.* 1987); but the absence of palygorskite and deficiency in kaolinite suggest that the wind-transported sediments from the west coast of Saudi Arabia (Behairy *et al.* 1991) are not deposited in the

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