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# Mineralogy and Diagenesis of Coastal Sabkha Sediments of the Hypersaline Lagoons on the Eastern Coast of the Red Sea, Saudi Arabia

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ABSTRACT. Textural characteristics, gross mineralogy and diagenetic history of coastal sabkha sequences were studied in the tidal flats of two coastal lagoons; Shuaiba south of Jeddah and Sharm Al Kharrar northwest of Rabigh. The diagnostic features and mode of formation have also been deduced.

A comparison of the gross mineralogy of the two types of sabkhas showed considerable variation in the mineral proportions and the diagenetic alteration of the metastable minerals. The vertical variation of carbonate mineral components through sabkha sequence indicates dolomitization of the aragonitic sediments.

Shuaiba sabkha is characterized by carbonate-dominated sediments with high potential dolomitization and evaporate association, while Sharm Al Kharrar sabkha is marked by the abundance of land-derived material affecting the sedimentation regime and transition of it into siliciclastic sabkha. Attapulgite, kaolinite and swelling chlorite are the common clay minerals formed under humid subtropical conditions.

Red Sea coastal lagoons and sabkhas of Saudi Arabia have received little attention compared to those of the Arabian Gulf and Gulf of Aqaba (El-Sayed, 1987, Behairy *et al.*, 1991, and El-Abd and Awad, 1991). For example Ras Hatiba lagoon sediments and sabkha north of Jeddah have similar characteristic features resembling those found in the Gulf's of Suez and Aqaba (El-Sayed, 1987). High Mg-calcite, anhydrite and magnesite are the dominant minerals. Ras Hatiba sabkha follows the Gavish sabkha model, where aragonite is missing and gypsum is absent under certain environmental conditions (El-Sayed, 1987). Destruction of gypsum by sulphate reducing bacteria is suggested by Gavish *et al.* (1985).

The Saudi coastal stretch along the Red Sea extends for about 1800 km and has numerous coastal lagoons, locally known as sharms. The origin of these coastal lagoons is discussed by Rabaa (1988), Head (1987), Bralthwaite (1987) and Brown *et al.* (1989). They are formed by erosion in the pluvial Pleistocene and drowned by post glacial sea level rises where the present day seasonal streams (wadis) are still connected to these earlier erosional features. However, most of them are considered to be formed as collapsed structures resulting from the selective solution of the underlying Miocene evaporate beds. These coastal lagoons break the continuity of the Pleistocene reef complexes and most of them are remnants of a much larger body of water than that connected to the sea by a narrow tidal channel.

On the other hand, the near shore zone of the eastern coastal plain of the Red Sea is an area of a few tens of meters of shoreline and is almost flat and covered with a thin layer of Holocene unconsolidated reefal carbonate sediments. Most of the coastal lagoons act as a trap cutting off potential supply of material from the reef flat to the coast.

**Physiography, Climate and Oceanography**

Shuaiba lagoon is a representative hypersaline lagoon; located about 90 km south of Jeddah (Fig. 1). The lagoon comprises two basins extending for about 20 km with an average width of about 5 km and water depth varying between 3 and 2 m. The eastern and southern parts of the lagoon are bounded by extensive intertidal and supratidal flats with developing sabkha deposits.

The second lagoon named as Sharm Al Kharrar, lies north west of Rabigh city (Fig.1) within a narrow coastal plain parallel to the shoreline. The coast consists mainly of hard-consolidated reef limestone's as raised terraces covered with aeolian terrigenous constituents. The southern and eastern borders of the lagoon are bounded by extensive intertidal and supratidal flats that are backed by prominent escarpments nearly 1500 m high. These escarpments mark the uplift of the margins of both the Arabia and African shields. They represent the structural edge of the Red Sea rift area (Al Sayari and Zotl, 1978). The southern end of the lagoon is exposed to flash flooding, from ephemeral wadis during short periods of the year. Rainfall is very erratic and seasonal, usually occurring during the winter months. The temperature is very high with an average of 35.3$^{O}$C in summer.

In general, the coastal lagoons have an intensive dry climate. Tides are not so high and range from 6 to 9 cm in winter, but can reach to 17 cm in summer. Waves seem to break at the outer edge of the fringing reef then quietly enter the lagoon. The dominant wind direction is north and north west throughout most of the year (Morcos, 1970 and Durgaprasada Rao and Behairy, 1982).

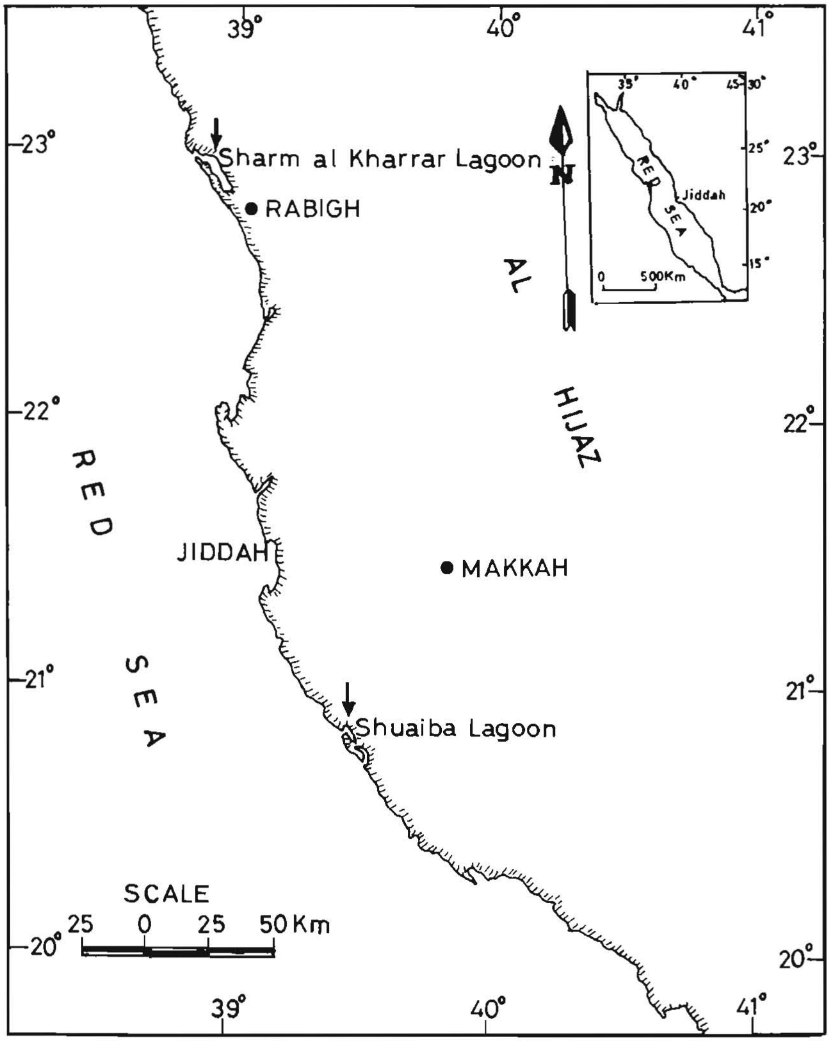


**Fig. 1:** Location map of the two coastal lagoons and study sabkhas. (Western coast of Saudi Arabia)

## Sampling and Techniques

Sabkha sediments were sampled from two different localities, one from the supratidal and intertidal flats situated at the eastern border of the Sharm Al Kharrar lagoon through six short cores (100 cm) along two profiles, by introducing a small hand auger into sabkha deposits. The other being collected from the upper 60 cm of the supratidal flats of Shuaiba lagoon through three small trenches. Twenty-nine samples were collected from the studied lagoon sabkhas and four bottom samples were collected from the two lagoons using a small grab sampler. These bottom samples represent primary marine sediments.

Dried samples were first analyzed for textural composition. Carbonate, sand and mud contents were determined. Portions of dried samples was powdered in agate mortar and then passed through a sieve 0.063 mm and mounted on a glass slide. Gross mineral composition of the powdered samples was identified by x-ray diffraction methods. The relative percentages of each mineral were calculated according to Carver (1971) and Milliman (1974). Mineral identification was based on the table of key lines listed by Pei-Yuan Chen (1976). The main mineral constituents of the clay fraction separated from the mud samples were also determined by XRD for oriented clay samples (Brown, 1972).

## Description of the Studied Coastal Plain Environments

Recognized coastal plain environments are shown in Plates 1 and 2, these include:

i) The intertidal zone: This occupies the area between mean low tide and mean high tide level. In Shuaiba lagoon, the intertidal zone (Plate 1, Photo 4) and is formed of recent carbonate sediments commonly of pellet carbonate mud, rich with gastropod shells (*Cerithidea*) and numerous burrows. All sediment deposited below mean low tide are refereed to as marine sediment (Lucia, 1972).

ii) The supratidal zone (Plate 1, Photos 1, 2 and Plate 2, Photos 3, 6) are a tidal flat sedimentation out of reach of the daily tides. It's elevation is higher than the mean high tide mark. It seems to be exposed subaerially for long periods of time and covered only by storm tides. Generally the arid climate allows sea water to evaporate and become saturated with respect to gypsum.

The Shuaiba lagoon environment is backed by extensive sabkha further toward the land, especially from the northern and eastern borders. Near the shore of the Red Sea, small groups of vegetative sand dunes are formed (Plate 1, Photo 5). These dunes extend parallel to the coast and contain high proportions of Pleistocene carbonate debris derived from the disintegration of coral reef terraces (Plate 1, Photo 6). The water bodies in the lagoon may continue to move landward by wind until they are depleted by evaporation and infiltration (Plate 1, Photo 4).

The Sharm Al Kharrar lagoon environment has a confined tidal flat zone bordered from the eastern side by Tertiary mountains parallel to the Red Sea coast (Plate 2, Photo 6). The supratidal zone consists mainly of brown muddy sand with salt crust on the surface (Plate 2, Photos 2, 3). Thickness of sabkha sediments in this zone seems to be thinning further to the east. Mostly, they were accumulated above the regression marine sediments. The seawater enters the lagoon through an inlet (Plate 2, Photo 1) that was formed on the continental shelf during the Late Pleistocene, after the sea regression.

**Texture of Sabkha Sediments**

The texture composition of Shuaiba sabkha sediments shown in Fig. 2 is distinguished by high carbonate concentrations with values ranging between 71% and 22.6%. Most of the samples lie in the carbonate class, while the remaining samples have calcareous muddy sand composition. In general, mud present, occurs in low amounts. It is evident that Shuaiba sabkha sediments have a biogenic origin.

On the other hand, Sharm Al Kharrar sabkha sediments are composed mainly of calcareous muddy sand (Fig. 2). In general, it appears poor in carbonate with values ranging from 4.26% to 28.5%. Sand present is dominant over mud. Sabkha deposits of Sharm Al Kharrar lagoon have a largely terrigenous origin.

**PLATE 1.**

Photo 1. Supratidal flats (sabkha) with salt crust of Shuaiba lagoon.

Photo 2. Trench in supratidal zone, lamination in a shelly evaporative deposit.

Photo 3. Algal mats on the intertidal zone of Shuaiba lagoon.

Photo 4. Lagoon water becomes depleted by evaporation and infiltration.

Photo 5. Small groups and sand dunes with vegetation parallel to the shoreline of the Red Sea.

Photo 6. Coral reef terraces exposed on the Red Sea coast near the outlet of Shuaiba lagoon.

**PLATE 2.**

Photo 1. Inlet of Sharm al Kharrar lagoon with strong tidal current enters the lagoon from the Red Sea.

Photo 2. View of Sharn al Kharrar lagoon with heavy mangrove vegetation.

Photo 3. Supratidal flat sediments with dark brown color.

Photo 4. Intertidal zone on the eastern border of Sharm al Kharrar lagoon.

Photo 5. Coring in the intertidal zone. Notice the coarser surface sediments.

Photo 6. Supratidal zone with salt crust surrounded by high tertiary mountain chains further inland.

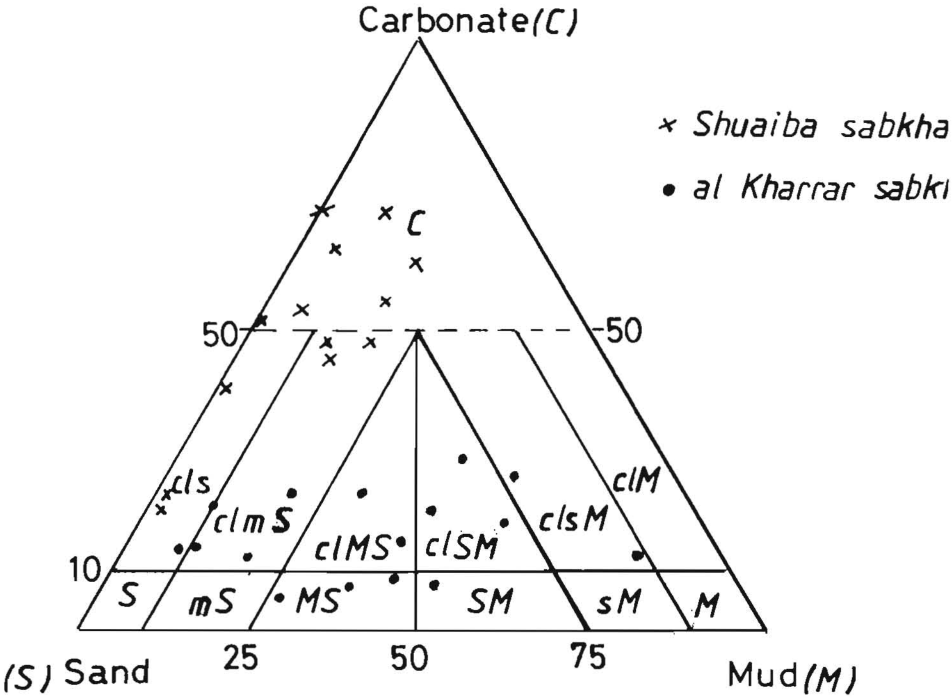


**Fig. 2.** Compositional triangular diagram of carbonate sand mud for coastal sabkha sequences. *(according to Fuchtbauer and Muller, 1970)*

## Gross Mineralogy of Coastal Sabkhas

In general, the mineralogy of any sabkha deposit is considered the guide for understanding the mode of formation, the diagenetic process and kind of source rocks of the different detrital components. While surface bottom samples of the lagoon refer to the primary mineralogy of the sediments before they become buried and react with the concentrated sabkha brines. The bulk mineralogy of the whole sabkha sediments was determined by x-ray diffraction analysis (Figs 3 and 4). The data obtained is summarized in Tables 1 and 2. Vertical variation in bulk mineral composition of Shuaiba sabkha is shown in Fig. 5.

X-ray analysis indicated that the gross mineralogy of Shuaiba sabkha comprises primarily carbonates and quartz with subordiante amounts of feldspars, evaporates and few pyrite. Evaporites, gypsum and halites are present. The carbonate minerals are dominated by dolomite with different proportions of calcite, aragonite and high Mg-calcite. Despite its absence in a few number of samples, dolomite is the most common carbonate mineral. It occurs with a maximum concentration of about 55.7%.

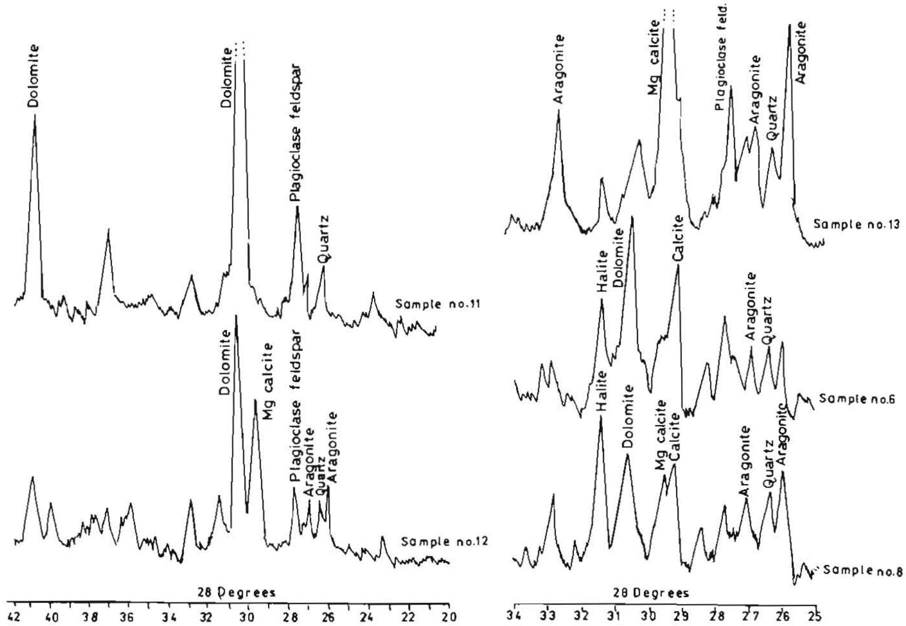


**Fig. 3:** Typical X ray diffraction patterns of some bulk sabkha sediments from Shuaiba area.

The detected pyrite in the Shuaiba sabkha sediments indicates an anaerobic environment. Authigenic pyrite is formed during shallow burial through the reaction between detrital iron minerals and hydrogen sulphide produced by the bacterial reduction of interstial dissolved sulphate (Berner, 1970). Depletion of oxygen in such a microenvironment allows anaerobic bacteria to begin the sulphate reduction process after organic matter has been buried.

Sabkha mineralogy of Sharm Al Kharrar is characterized by higher concentrations of terrigenous material and evaporites, than those of Shuaiba (Fig. 4). Carbonate minerals are absent in some samples, if present it occurs in minor quantities and include; calcite and dolomite. Evaporite minerals occur as gypsum, anhydrite and halite.

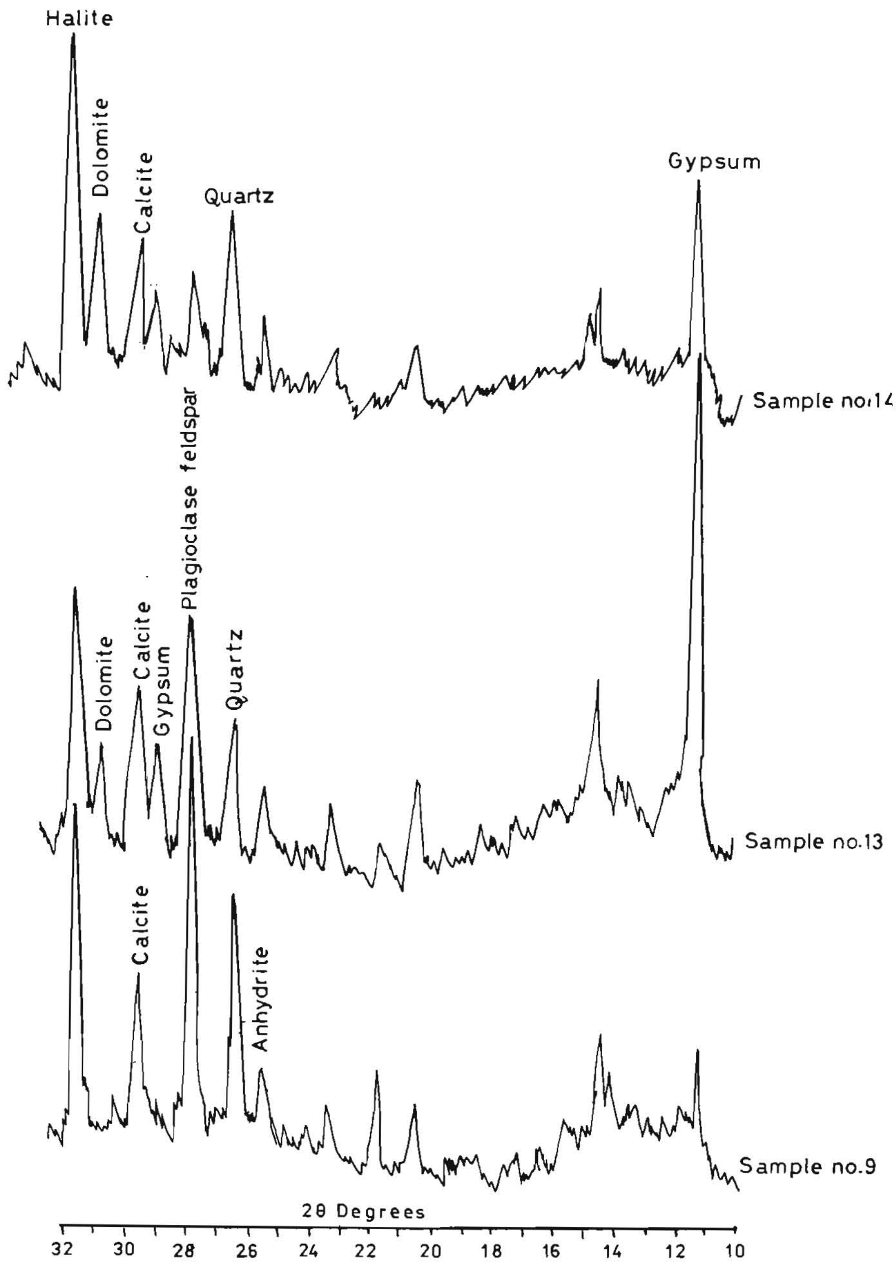


**Fig. 4.:** Typical X ray diffraction patterns of bulk sabkha sediments from Sharm al Kharrar area.

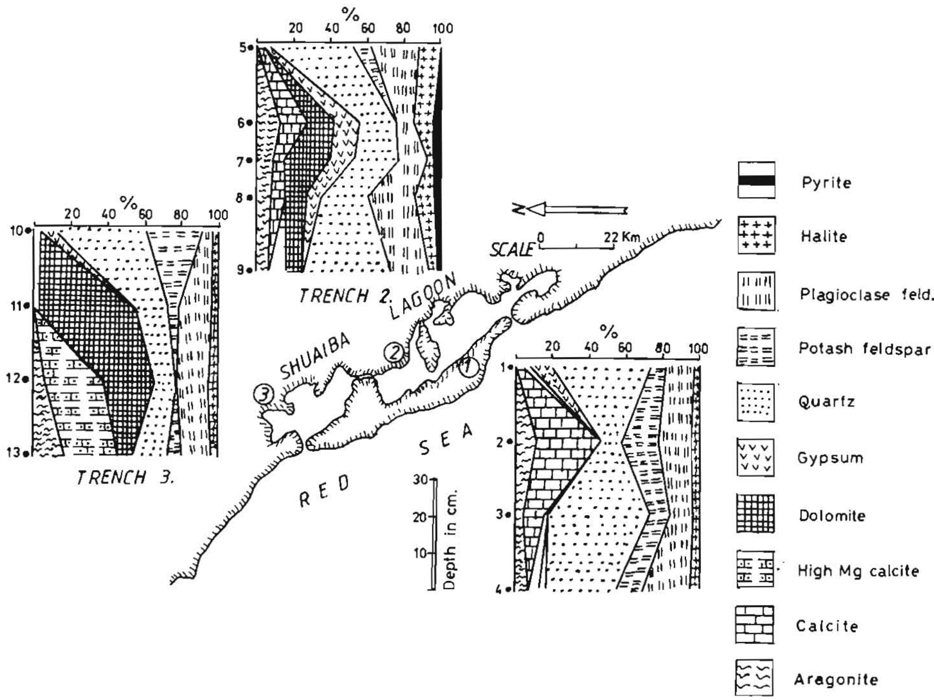


**Fig. 5**: Vertical variation of bulk mineral components *TRENCH 1* in Shuaiba sabkha sequence.

In comparing the two sabkah sediments, significant differences in the bulk mineral proportions were found to exist; Sharm Al Kharrar sabkha have terrigenous components (fine sand and mud) dominating over carbonates. Aragonite being absent, while dolomite is uncommon and anhydrite is associated with evaporate minerals.

On the other hand, lagoon bottom sediments studied, are characterized by higher aragonite and high Mg-calcite concentrations relative to the sabkha sediments (Table 2). Therefore, Sharm Al Kharrar lagoon sediments are similar in composition to the shallow marine skeletal carbonate sediments of the Red Sea which are composed generally of coral fragments, molluscs, peloids, algal grains, halimeda and benthic foraminifera (Durgaprasad Rao and Behairy, 1984). However, dolomite and calcite are present in minor amounts in Shuaiba lagoon bottom sediments (Table 1). In contrast, the recent sabkha in the northern Red Sea (Gavish, 1980) and Ras Hatiba sabkha in the central Red Sea coast (El-Sayed, 1987) are characterised by the absence of gypsum and aragonite. Gavish *et al.* (1985) related to the lack of gypsum accumulation by its destruction by sulphate-reducing bacteria.

**Tabie 1:** Bulk mineral components of Shuaiba sabkha sediments (from X-ray siffraction analysis).

| Trench. No. | Sample no. | Depth (cm) | Aragonite % | Calcite % | Mg-calcite % | Dolomite % | Quartz % | Potash feldspar % | Plagioclase feld. % | Gypsum % | Halite % | Pyrite % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Trench no. 1 | 1 | 2 | - | 4.9 | - | 2 | 53.5 | 8.8 | 14.4 | 12.1 | 4.3 | - |
| | 2 | 20 | 11.5 | 33.2 | - | - | 12.8 | 19.1 | 18.3 | - | 5.1 | - |
| | 3 | 40 | 4.3 | 10.9 | 2.2 | - | 55.8 | 9.7 | 13.3 | - | 3.6 | - |
| | 4 | 60 | 7 | - | 7 | 2.3 | 38.9 | 13 | 27.2 | - | 4.7 | - |
| Trench no. 2 | 5 | 2 | - | 2.9 | - | - | 45.8 | 9.4 | 27 | 3.1 | 11.9 | - |
| | 6 | 20 | 13.8 | 13 | - | 14.3 | 20.2 | - | 9.4 | 14.3 | 10.8 | 4.3 |
| | 7 | 30 | 9.5 | 5.7 | - | 23.7 | 23.7 | - | 15.8 | 14.2 | 3.5 | 3.8 |
| | 8 | 50 | 7.9 | 7.6 | - | 12.2 | 25.4 | - | 25.4 | 7.6 | 10.7 | 3.1 |
| | 9 | 60 | 6.3 | - | 10 | 9 | 47.3 | - | 20.9 | - | 4.8 | 1.8 |
| Trench no. 3 | 10 | 2 | - | - | 1.9 | 1.3 | 48.7 | 29.1 | 5.8 | 9.7 | 3.5 | - |
| | 11 | 20 | - | - | - | 55.7 | 17.3 | 6.2 | 17 | - | 3.7 | - |
| | 12 | 40 | 6.3 | - | 31.4 | 28.1 | 12.5 | - | 15.5 | - | 6.3 | - |
| | 13 | 60 | 18 | - | 28.4 | 6 | 20 | 7.5 | 16 | - | 4.1 | - |
| Bottom samples | 14 | - | 10.5 | - | 9.6 | - | 38.2 | 6.2 | 28.1 | - | 1.9 | - |
| | 15 | - | 16.8 | 17.5 | - | 10.2 | 34.7 | - | 6.1 | - | 10.2 | - |

**Tabie 2:** Bulk mineral components of Sharm al Kharrar sabkha sediments (from X-ry diffraction analysis)

| S. no. | Core no. | Depth cm | Aragonite % | Calcite % | Mg-calcite % | Dolomite % | Quartz % | Potash feldspar % | Plagioclase feldspar % | Gypsum % | Anhydrite % | Halite % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 1 | 80 | - | - | 2.23 | - | 57.43 | 7.93 | 27.2 | 2.03 | - | 3.18 |
| 3 | 2 | 80 | - | - | - | - | 52.18 | 10.55 | 28.31 | 3.26 | - | 5.7 |
| 4 | 2 | 100 | - | - | - | - | 48.27 | 7.84 | 37.95 | - | - | 5.9 |
| 7 | 3 | 80 | - | - | - | - | 66.59 | - | 24.51 | 2.12 | 1.55 | 5.23 |
| 8 | 1` | 20 | - | - | - | - | 58.44 | 7.30 | 14.37 | 5.09 | - | 14.8 |
| 9 | 1` | 60 | - | 8.54 | - | 2.17 | 39.86 | - | 32.87 | 2.8 | 2.17 | 11.59 |
| 13 | 2` | 80 | - | 9.5 | - | 5.51 | 25.97 | - | 24.7 | 21.53 | 2.53 | 10.26 |
| 14 | 2` | 100 | - | 8.97 | - | 9.59 | 39.43 | 4.76 | 8.84 | 10.6 | 3.53 | 14.82 |
| 15 | 3` | 20 | - | - | 9.82 | - | 36.67 | - | 21.28 | - | 5.5 | 26.72 |
| Bottom sample | | | 53.9 | - | 46.1 | - | - | - | - | - | - | + |
| " | " | | 50 | - | 26.5 | - | 11.8 | - | 11.8 | - | - | + |

## Clay Mineralogy of Sabkha Sediments

Due to the high proportion of terrigenous mud material in Sharm Al Kharrar sabkha, ten samples of clay fractions were separated and analyzed by x-ray diffraction. The obtained data is summarized in Table 3 and their x-ray diffraction patterns are shown in Fig. 6.

**Table 3**: Relative frequency percentages of the clay minerals in Sharm al Kharrar sabkha sediments

| S. No. | Core no. | Depth (cm) | Swelling chlorite | Attapulgite | Kaolinite |
|---|---|---|---|---|---|
| 1 | 1 | 20 | 14.72 | 40.73 | 44.55 |
| 5 | 3 | 20 | 8.89 | 39.05 | 52.06 |
| 6 | 3 | 40 | 18.2 | 56.8 | 25 |
| 7 | 3 | 80 | 8.34 | 70.88 | 20.78 |
| 10 | 1` | 100 | 8.77 | 44.09 | 47.14 |
| 11 | 2` | 20 | 13.49 | 47.63 | 38.88 |
| 12 | 2` | 40 | 26.6 | 46.8 | 26.6 |
| 14 | 2` | 100 | 29.13 | 45.42 | 25.45 |
| 15 | 3` | 20 | 6.94 | 72.24 | 20.82 |
| 16 | 3` | 40 | 23.5 | 34.5 | 4.2 |

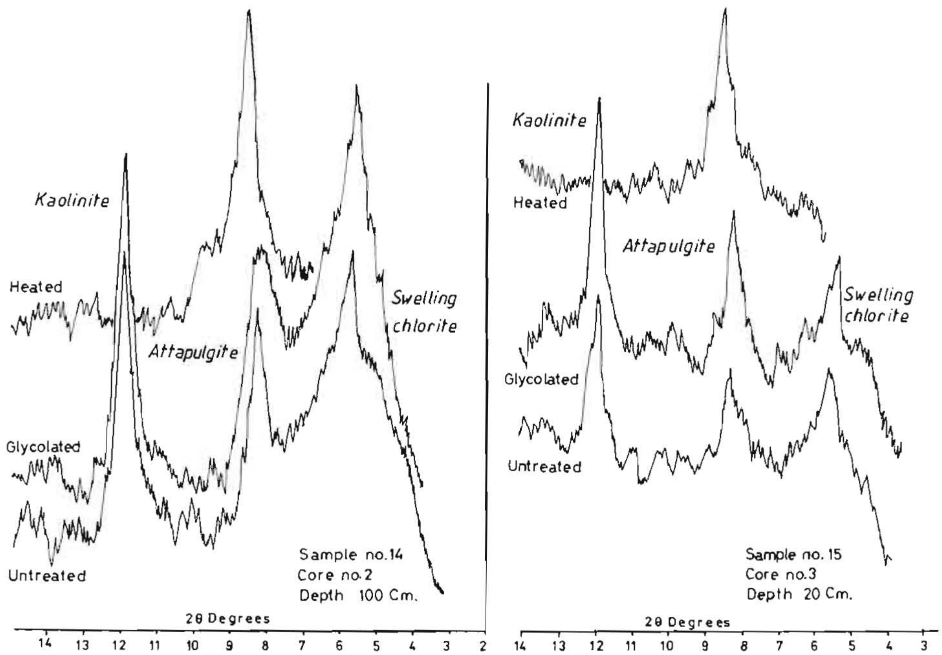


**Fig 6:** X-ray diffraction patterns of some clay fractions in Sharm al Kharrar sabkha sediments

Clay minerals found in these subtropical sabkha deposits are attapulgite, kaolinite and swelling chlorite in decreasing order of abundance. While the clay mineral assemblage determined in the modern and Quaternary reef sediments in the coastal plain north of Jeddah were composed mainly of kaolinite, mixed layer chlorite-vermiculite and illite. They originated from weathering of the low-grade metamorphic rocks and volcanic basalts of the Jeddah group (Behairy, 1980).

The recorded swelling chlorite (14A) in the studied sabkha exhibits properties intermediate between normal chlorite and montmorillonite and vermiculite-type minerals. Only a small portion was expanding to about 17A, with the major portion remaining at the same place. Such minerals are seen to be interlayered mixtures (Carrol, 1970 and Brindley, 1961). Swelling chlorite was formed by a mechanical mixture of chlorite and montmorillonite derived from the metamorphic chlorite schist and igneous rocks of the Tertiary mountains bordering the coastal plain (Durgaprasada Rao and Behairy, 1986).

Attapulgite (10.5A), is the most common clay mineral in the sabkha deposits probably formed in an alkaline environment of mixed marine and fresh water. Its origin has been ascribed to authigenesis (Singer and Norish, 1974).

Authigenic attapulgite may be formed either from alteration of montmorillonite (Yaalon and Wieder, 1976) or by direct precipitation from solution (Singer and Norish, 1974). However, if montmorillonite has been altered to attapulgite, illite is expected to survive. Thus the most likely origin of attapulgite in sabkha deposits is neoformation, i.e. direct precipitation from solution with high Mg/Ca ratio. Si, and to a lesser extent AI, corroded from quartz and feldspar grains, are also mobilized, fulfilling in addition to Mg, the requirements of attapulgite neoformations.

Kaolinite, the second dominant clay mineral in the studied sabkha, is a common mineral in red soils formed on the surface of coastal mountains under humid climatic conditions.

It can be concluded that the limited variation in the clay mineralogy suggests that the clay fraction in sabkha sediments is ultimately derived from one major source. Climatic conditions control the nature and composition of clay minerals formed in a humid subtropical region and it is not controlled by the kind of the source rock.

**Diagenetic History in Coastal Sabkha Sequence**

It is known that, progressive evaporation of marine and continental waters drives sabkha pore fluids to gypsum saturation and leads to the precipitation of aragonite and gypsum.

There are indications of both subaerial exposure and diagenetic alteration in the gross mineralogy of the sabkha sequence studied. Aragonite and calcite are most common in the intertidal zone together with gypsum and pyrite while dolomite and high Mg-calcite are considered the dominant carbonate minerals in the supratidal zone of Shuaiba lagoon. A noticeable change in carbonate mineralogy at depth exists where dolomite is dominant (Fig. 5). The upper limit of diagenetic dolomite occurs at a depth of about 40 cm where the other carbonate minerals diminish through the dolomitized part of the section.

The dolomite forming today under surface evaporative marine conditions generally contains excess calcium, and is termed calcian dolomite (Land, 1985 and Reeder, 1983). Levy (1977) suggested that the interaction of normal marine brines with pre-existing calcium carbonate minerals leads to the formation of diagenetic dolomite. Dolomitization in Shuaiba coastal sabkha is associated with lithification and takes place at depth, and not at the surface similar to Abu Dhabi (Patterson and Kinsman, 1982 and McKenzie *et al.*, 1980).

Aragonite in Shuaiba sabkha varies inversely with that of the dolomite so, aragonite is consumed in the production of dolomite. However, partly dissolved aragonitic cerithid shells provide direct evidence of aragonite loss. It was also noticed that dolomitization occurs farther inland agreeing with McKenzie *et al.* (1980). Association of authigenic pyrite in Shauiba sabkha indicates that dolomitization only proceeds under reducing conditions consistent with Patterson and Kinsman (1982). As the water bodies move inland, evaporation causes a loss of calcium through gypsum precipitation and causes a dramatic increase in the $mMg^{++}/mCa^{++}$ ratio of the pore fluids and favorable for the formation of diagenetic dolomite (McKenzie, 1981) and/or by direct interstitial precipitation (Hardie, 1987). However, Patterson and Kinsman (1982) assumed that to form diagenetic dolomite, a significant rate of flow of fluids with high $Mg^{++}/Ca^{++}$ ratios exists through sediments. In fact, the greater groundwater limit, the greater production and preservation of evaporates in the supratidal zone. The heavy hypersaline water moves down from the supratidal surface and dolomitizes the underlying sediments (Luccia, 1972). In addition, Purser (1973) suggested that the active sabkah is underlain by porous sediments that supply groundwater as well as marine water to keep pace with the water lost through evaporation of the sabkha surface.

Concerning the Sharm Al Kharrar sabkha, recent sediment on the intertidal and supratidal flats consists mainly of clastic materials transported by wind (highly rounded quartz grains) and flash floods through ephemeral wadis from the surrounding coastal mountains (Fig. 7). Nodules of gypsum and pore filling crystals are formed within the sediments under standing bodies of water. The carbonate minerals present here, being rare and uncommon, include mainly dolomite and Mg-calcite. Evaporites occur in considerable amounts. The precipitation of gypsum and anhydrites produces a dolomitizing fluid which moves down through the underlying sediments. However, the presence of anhydrite minerals indicates that gypsum loses water due to the high temperature.

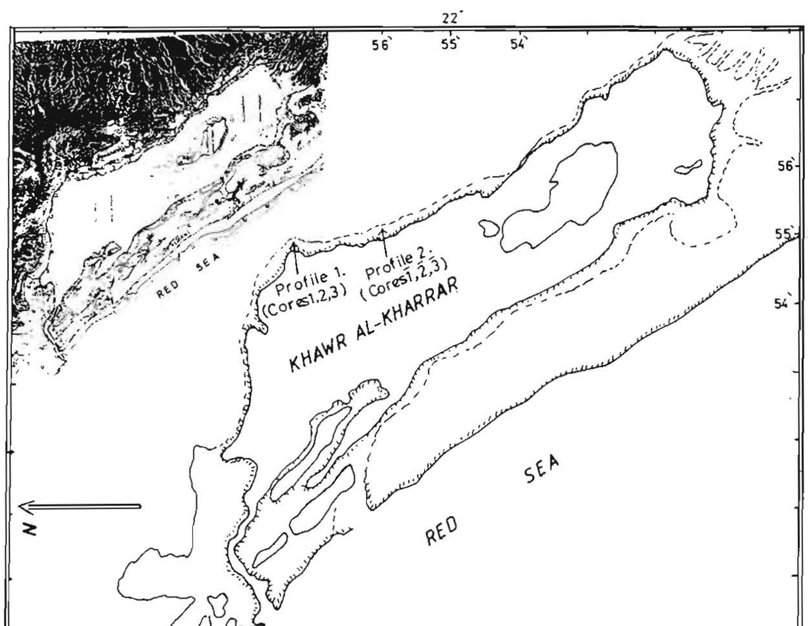


**Fig 7.** Khawr Al-Kharrar area

## Conclusions

Sabkha deposits around two hypersaline lagoons on the Red Sea coast are markedly different; one is dominated by carbonates with high potential dolomitization and the other by siliceous clastic sediments.

The former includes the intertidal and supratidal flats of Shuaiba lagoon and is composed chiefly of carbonates (mostly dolomite, aragonite, calcite and high Mg-calcite) with subordinate amounts of quartz and feldspar, few gypsum and pyrite. It reflects diagenetic alteration in the gross mineralogy and shows dolomitization as well as lithification in the upper limits of the sequence farther inland. The abundance of carbonate minerals in the Shuaiba sabkha is primarily attributed to the biochemical precipitation from lagoon water and subsequent coastal erosion and breakdown of reefal limestone terraces. Fine material seems to be diminished probably due to removal of such material by current action, which leaves only coarser fractions on the tidal surface as lag deposits.

The later includes the intertidal and supratidal flats of the Sharm Al Kharrar lagoon which is marked by silicate-dominated sediments (quartz, feldspar and clay minerals) with minor amounts of carbonates (dolomite and calcite) and little gypsum, anhydrite and halite. The clay minerals present are marked by the dominant attapulgite, kaolinite and swelling chlorite. They are distinguished by the siliciclastic sabkha formed under humid subtropical conditions.

The abundance of terrigenous minerals in the Sharm Al Kharrar sabkha is attributed to aeollan material transported as bed load and/or suspended load from local sources particularly the Tertiary mountains bordering the coastal region and parallel to the Red Sea. However, flash floods in ephemeral wadis probably are also important contributors to the fine clay fraction of the sabkha.

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# الدلائل المعدنية والتاريخ التحورى لتتابعات السبخات الساحلية للبحيرات الفوق ملحية على الشاطئ الشرقي للبحر الأحمر ، المملكة العربية السعودية

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**المستخلص** : درست الصفات النسيجية ، المعادن الكلية والتاريخ التحورى لتتابعات السبخات الساحلية في المسطحات المدية لبحيرتين ساحليتين هما ، الشعيبة جنوب جدة وخور شرم الخرار شمال غرب مدينة رابغ . كما تم إستنتاج المعالم التشخيصية وطريقة التكوين .

وبمقارنة المعادن الكلية في نوعى السبختين، أعطت تغييراً كبيراً في تناسب المعادن والتغيرات التحورية للمعادن الشبة ثابتة .

وقد تميزت سبخة الشعيبة بسيود رواسب الكربونات ، بينما تميزت سبخة شرم الخرار بغزارة المواد الفتاتية المشتقة من اليابس والتي حولتها إلى سبخة سيليسية.

إن التغير الرأسى في مكونات معادن الكربونات خلال تتابع السبخة ، برهن على تدلمت رواسب الأراجونيت. كما أظهرت سبخة الشعيبة وفرة معدن الدولوميت التحورى وصحبات معادن المتبخرات .