SABKHAS IN QATAR PENINSULA

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Key words: Qatar Peninsula, Sabkhas, Environmental parameters, Surface features, Anthropogenic interference.

Abstract
Sabkhas represent a very distinctive geomorphologic feature in the Qatar peninsula. They cover about 7% of the land surface. Investigations recognized two main types of sabkhas; the first is the Inland Sabkhas which is more mature. The second is the coastal sabkhas or supratidal flats which are more wide spread. Both types are characteristically flat containing a shallow water table, with highly saline ground water. This ground water may be either directly connected with the sea or with continental groundwater. Also surface water from tidal flooding and rainfall and run-off partially recharge the system. Sediments are mainly evaporates, quartz grains and mud, sodium chloride is very frequent on the surface. Beside the two main types a subsidiary type, not very well known are anthropogenic sabkhas near the inhabited areas and cultivated depressions. Detailed investigation revealed that the origin and evolution of sabkhas in Qatar are greatly influenced by: The low lying topography of the country, the shallow to very shallow coasts, the hot to very hot climate, sea level changes, ground water, geological setting, and anthropogenic interference.

Introduction
Sabkha (also sabkhab and sabkhat) a.a closed depression, with a saline surface (akin to a pan or playa), in an arid environment. b. A saline flat in arid areas that is above the mean high tide level but subject to periodic inundation. Both
terms are commonly used in Arabic countries. (David Thomas and Andrew Goudie, 3rd ed, 2000).

The Qatar Peninsula is located in the Arabian Gulf at the northeastern margin of the Arabian Peninsula land mass (Fig.1). Although Sabkhas have been studied in detail in some parts of the Arabian Gulf e.g. Perthusisot, 1977; Shin, 1973; Evans, 1966; Evans et al (1994 & 1969), Kendall et al. 1998, Kirkham 1997, Patterson & Kinsman 1981, Wood & Wolfe 1969 and in general e.g. Focke, 1987; Holm, 1960; I.D.T.C. 1980 and Kassler, 1973, Goudie et al. 2000, sabkhas in Qatar was not the focus of any detailed study. Because of the quick expansion of all activities in Qatar and the need for a suitable land use map, it was very important to study landforms in detail. In this respect a research project to study sand dunes in Qatar was implemented and executed by Embabi and Ashour (1983, 1985). Another project about the Sabkhas of Qatar Peninsula was implemented and executed by Ashour et al. 1991. Both projects were funded by Qatar University and published in Arabic.

(Fig. 1) Location map.

This paper summarizes the previously published work in Arabic dealing with the characteristics of the sabkhas in Qatar, i.e. spatial distribution, sediment analysis, surface features, environmental factors and evolution.

2. Spatial Distribution

Figure 2 shows the aerial distribution of Sabkhas in Qatar Peninsula. The two main types of sabkhas occupy almost 7% of the surface of Qatar. The first type is the inland sabkhas located away from the present shoreline and not connected with the sea. Examination of 1:50.000 topographic maps showed that there are 78

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inland sabkhas, covering an area of about 205 km. These sabkhas occupy depressed areas ranging in elevation between -3 and 4 m. It is worth mentioning that these sabkhas are located in a narrow strip of about 10 km wide parallel to the coast line which would suggest some type of relation between the sea and these sabkhas in the past. Another curvilinear belt lies at the southern borders of the Qatar peninsula extending from Khor El- Oudaid in the east to the southern tip of Salwa Bay in the west (Fig. 3). It seems that this belt is a relic of an abandoned embayment now disconnected from the sea, since the last subsidence of the sea 3000 years ago.

Fig. 2. Processed Land Sat Images showing landforms in Qatar Peninsula
1. Sabkhas are in blue color; 2. Sand Dunes are in a reddish color; 3. Hamada plain is in orange.
Fig. 3. The southern Inland belt of sabkhas, between the southern tip of Salwa Bay in the West and Khor el-Oudaid in the East. The surface level varies between -1 and +1m ASL. Extension and topography would suggest an embayment connected Salwa Bay and Khor el – Oudaid 3000 years ago, before the last drop of sea level.

Sabkhat Dukhan (fig. 4) is an inland sabkha which lies near the western coast, occupies a synclinal depression of upturned L shape, its area is about 73 km², its width ranges between 2 and 4 km. The surface of the sabkha is almost flat, and most of it lies below sea level, solid in the west, buff and friable in the east. The lowest point in Qatar is found in this sabkha. The depression here is surrounded by limestone hills. The eastern side of the depression is linear and overlooks the sabkha with a steep slope. The northern side elevation varies between 3 and 12 meters with some isolated hills up to a maximum level of 27 m. We believe that this depression was an extension of Zikrit Bay before the last drop of the sea level 3000 years ago when the sea was +4 m higher than the present level. Drilling down to 9 meters before the rig started to sink in the sabkha deposits, the sediments are mainly sands and evaporates (fig. 5). Ground water in this sabkha is very saline found under pressure at depths varying between 2 and 120 centimeters, the source of the water is unknown, could be a direct underground connection with the sea probably in the north, or with a lower water aquifer. This sabkha hosts a number of surface features, such as sinkholes, elongated trenches, ring fissures, nebkhas, salt polygons, and salt saucers. Geomorphologically speaking it is believed that Dukhan Sabkha at present is at the late mature stage and it will not be long before the surface is covered with blown sand and the water level drops allow to develop into a flat sand sheet.
Sabkhat Dukhan: an inland sabkha lies near the coast of Salwa Bay. It occupies an upturned L shape depression. It is believed that this depression was extension of Zikrit Bay before the last drop of sea level 3000 years ago.

Geologically, the section in mainly composed of sands and crystalline gypsum.
Another example of inland sabkhas is Sauda Nithil Sabkha which lies on the south western borders of Qatar (Fig. 3). It occupies a NW-SE semi closed elongated depression of about 22.5 km². The surface level ranges between -1 and +1 meter. The borders of the depression are limestone and dolomite hills in the north, covered with sand dunes in the east, the south and the west. Sediments of this sabkha are sandier with a few gypsum layers and clays. Morphological characteristics of this sabkhas and others nearby ones would suggest that they were once connected with the Salwa bay before the last drop of the sea (Fig. 3).

The second type is the coastal sabkha. They cover about 590 km² divided between 42 sabkhas. Most of these sabkhas are concentrated on the eastern coast. This may be attributed to: 1. the flatness of west side, 2. drifted sediments particularly dune sands blowing from the North West to be downloaded in the shallow coastal areas, 3. the slow anticlockwise alongshore current which pass by the this side deposits its load in the very shallow water to develop into sabkhas after being lagoons cut off the sea. In some cases the development of spits and sand bars were the first phases of the development of sabkhas (Fig. 6)

![Fig. 6. A spit developed in the shallow water of the Eastern coast of Qatar.](image)

During our field investigation we were able to differentiate between three types of coastal sabkhas, they are: 1. sabkhas interrelated with the coastal embayments, 2. sabkhas behind sand bars, 3. sabkhas in the shadow of sand dunes. The first type are extensions of very shallow marine embayments represented by Fishakh Sabkha. This lies on the western coast, surrounded by the water of Fishakh Bay. Its area is about 18.5 km²; the surface level varies between zero meters at the coast and 2 m. on the outer borders of the sabkha. Algal mat and algal cones are will developed here. This could be explained by the very shallow and almost stagnant water that inundate the sabkha. The sabkha is surrounded by a 0.5 m. cliff. It is believed that this cliff is an old coast line (Embabi, 1984).
The second type of coastal sabkhas, lie behind sand bars, they are usually found at the shadow of spurs which face the sea. Waves and marine currents discharge their load forming saline flats to develop gradually into sabkhas. For example the sabkha that lies to the north of Khashm el-Nakhsh. Its area is about 11.4 km$^2$ of olive shape. Most of this sabkha lies at zero and +1 m level, separated from the sea by elongated sand accumulations of about 3 m. high. Sediments are very thin formed of a salt crust underlain a thin layer of sands and evaporates not more than 5 centimeters thick. Tide currents do not directly inundate its surface, but the high tide does.

The third type are those sabkhas that lie in the shadow of sand dunes, where the sand dunes form the main source of sediments that built the sabkha. Umm-Said Sabkha is a very good example of this type (Fig. 7). It lies on the southeastern coast covering an area of about 350 km$^2$ (60 % of the total area of sabkhas in Qatar). Sediments here are more than 30 meters thick, mainly quartz and feldspars with fragments of dolomitic limestone, with few evaporates and occasionally thin algal mats in-between. It seems that these sediments were deposited in two cycles separated by a carbonate layer about 3 meters thick (Shinn, 1973). The surface is very flat varies in elevation between zero m at the shoreline and +3 m on the western border. Relicts of an old calcereets are found occasionally. These relics

Fig. 7. Sabkhat Umm-Said Geological Map.

The rural-urban fringe 16
represent an older level of the sea. Extensive parts of the surface are usually inundated with tidal currents leaving behind a thick crust of sodium chloride which could last for some months because of the location of this sabkha in the southeast at the forward site of the prevailing wind and its flat surface a large number of different size barchans sprinkle on its surface. Moreover humidity of the surface of the barchans slow down and may be trapped, to be developed into complex or even compound dunes. The ground water of this sabkha is the most saline compared with other sabkhas, due to the frequent inundation with the sea water and the high evaporation rate.

3. Sediment analysis
To assist in understanding the origin and evolution of the sabkhas the following sediment analyses were run:
3.1. Size analysis.
3.2. Grain surface micro features.
3.3. Mineralogy.
3.4. Geochemistry of sediments and water.

3.1. Size analysis:
Wet sieving of the sand fraction of 76 samples collected from 14. Profiles have shown the following results:
- The non-silicate components are generally higher at the top of the profiles decreasing towards the bottom;
- The mean size (MZ) of the samples ranges between 1.92 Φ (medium sand) to 2.43 Φ (fine sand) which indicates that the present sediments consist of a small range of sand sizes, This narrow range of sand sizes was also recorded from the sand dunes of Qatar (Embabi and Ashour, 1985);
- The mean size values increase downwards, suggesting a higher energy conditions (Visher, 1969);
- The standard deviation values range from 0.69Q (moderately sorted to 1.01 Q (poorly sorted) with an average value of 0.87 Q (moderately sorted). This data also show that there is a general decrease in the standard deviation value towards the lower samples indicating a better sorting downward;
- The skewness values fluctuate between coarse skew to near symmetrical which indicate that the energy varies from strong to moderate during deposition;
- The kurtosis value (KG), on the other hand, shows a wide range of variation as it fluctuates from platykurtic to very platykurtic to mesokurtic.

3.2. Grain surface micro features (S.E.M) (fig. 8):
These investigations aim at recognizing the ancient environments of the sediments. Investigations were carried on 8 samples of medium sand grains selected from different locations and levels.
Fig. 8a. Very Rounded grain, showing eolian abrasion and chemical erosion.

Fig. 8b. Longitudinal cracks.

Fig. 8c. Chemical erosion.
Fig. 8d. Upturned plates indicating Aeolian transportation.

Fig. 8e. V shapes indicating submarine erosion.

Fig. 8f. V shapes indicating aeolian erosion and submarine erosion.
The inspections show that:
  - most of the grains are rounded to sub-rounded (Fig. 8a), indicating Aeolian transport.
  - most grains taken at the surface or near the surface particularly of the inland sabkhas are affected by chemical deposition. This could be explained by the high temperature, humidity, and the high salt content. On the other hand the less chemical effect observed on the surficial coastal grains probably refers to the present effect of tide action.
  - Upturned plates (Fig. 8b) are a common feature on many grains indicating mechanical processes and Aeolian transport.
  - the very rounded grains affected by dish-shaped (Fig. 8c) features suggest an Aeolian transport.
  - the sub-rounded grains affected with v-shaped features(Fig. 8d) would reflect coastal conditions
  - one of the samples taken from Umm-Said coastal sabkha, sub-aqueous conditions were evident, reflecting sub-aqueous transport, thus we believe that the marine anticlockwise current was the transport agent, beside other agents.

As a conclusion, we would say that all sites show evidence of an aeolian transport history. A beach environment is not easy to select because of the chemical alteration at the grain surface. However, the sub-rounded rather than well-rounded nature would suggest that beach transport history was likely for all samples in addition to a wind transport history. At one of the sites in Umsaid coastal sabkha there is a strong evident for sub-aqueous activity whilst Aeolian grains were less numerous suggesting a great importance of the later environment for supplying sediment compared with wind transport.

3.3 Mineralogy: (Table 1)

X-Ray diffraction analyses run on sediments less than 0.063 mm in 69 samples representing 14 profiles in the main 4 sabkhas, which are, Dukhan, Suda Nethil, Umm-Said and Khor-elOudaid, results are as follows:
  - quartz is the main mineral constituent in all sections and all horizons, except the top horizon. This is due to the abundance of the mineral in both solid rocks and surficial deposits in the area. gypsum, anhydrite and halite are also frequent particularly in top horizons. Source of such minerals could be the limestone rocks which constitute a large part of the geological section in Qatar, or it may be the underground water rich in sulfurs and chlorides.
  - Feldspars are also frequent in all horizons due to the weathering of sandy and calcareous deposits which contain the mineral.
  - Magnetite is found occasionally in some places as a result of chemical weathering processes.
- Existence of goethite in some horizons of few profiles refers to hydration of magnetite in humid conditions.

Table 1: Mineralogical Analysis of Sabkha Sediments %.

<table>
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<tr>
<th>Sabkha</th>
<th>Quartz</th>
<th>Halite</th>
<th>Gypsum</th>
<th>Feldspar</th>
<th>Calcite</th>
<th>Dolomite</th>
<th>Anhydrite</th>
<th>Other</th>
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<td>14</td>
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</table>

s = Surface   m = Middle   b = Bottom

3.4. Geochemical analysis (Table 2)

A number of geochemical analyses have been run on 76 samples representing all sabkhas in Qatar Peninsula. The main constituents are as follows:

- Silica SiO₂: differs between 18 and 79 %, it is highly concentrated in the lower horizons and it is less in the upper horizons of all profiles. It was noticed that the percentage is very irregular in the horizons; this could be explained by irregular wind regime during deposition.

- Aluminum in the form of Al₂O₃: It varies from 0.56% and 6.55%. The analysis shows that there is a cumulative correlation between the percentage of silica and the percentage of aluminum regardless the type of sabkha or the depth of the sample. In this context we should expect higher percentage of aluminum in the sabkhas lying in the shadow of sand dunes or sand sheets e.g. Sabkhat UmmSaid in the southwest.

- Calcium Carbonates CaCO₃: it ranges between 6 and 18.2%. Calcium carbonates found would be attributed to the widespread calcareous rocks in Qatar. It was noticed that the percentage of the CaCO₃ is higher in coastal sabkhas and increases downwards in most profiles.
Sulfates $\text{SO}_3$: sulphate substance in sabkhas is found as a result of the evaporation of water rich in sulphates, and this is considered to be the first stage, whereas sulphide is a late stage and is found as a result for reduction factors. The most important factors are the deterioration of organic organisms as well as gasless bacteria. Such factors lead to the formation of hydrogen sulphide with its distinguished odour (rotten eggs). There are two main sources of sulphates in the environment surrounding sabkhas in Qatar peninsula which are: Gypsum found among sediments of Ross formation and sea water that contains sulphates 3 to 6 grams/liter. The most important sulphate sediments in the areas of evaporate and sabkhas areas are gypsum and anhydrite. The year average for such ratio in Dukhan Sabkha (39 samples in five profiles) is about 14%. It is also noticed that sulphate percentage increases with the increase of calcium to form calcium sulphates or gypsum and decreases with the increase of silica. On the other hand it is noticed also that sulphates in sabkhas is lesser under the surface of underground water.

This high percent of sulphates in inner sabkhas than coastal sabkhas reflects the existence of a rich source of sulphates that has an effect on the inner sabkhas. This reality attracts our attention to the importance of underground water in the formation of evaporates in the inner sabkhas in Qatar Peninsula.

Chlorides: It appears in the results of sabkhas samples that the percentage of chlorides varies totally in the one sector and from one sector to another and from one sabkhas to another and this reflects that these salts are greatly affected by the climate factors due to the fact that it needs dryness factors for long period of time.

The average of chloride in inner sabkhas and coastal sabkhas is as follows:
- Sabkhat Dukhan (39 sample) 4.4%;
- Sabkhat Sauda-Nithil (8 samples) 6.2%;
- Sabkhat Um-Said (23 sample) 7.8%;
- Sabkhat Khor El-Oudaid (4 samples) 2.7%.

Magnesium: The average of magnesium oxide is as follows:
- Sabkhat Dukhan 3.3%;
- Sabkhat Sauda-Nithil 2.4%;
- Sabkhat Umm-Said 1.2 %;
- Sabkhat Khor El-Oudaid 1.2%.

It is obvious that the percentage of magnesium in inland sabkhas is more than the magnesium found in the coastal sabkhas. De Groot (1973) shows that the lower percentage of magnesium in Umm-Said Sabkha is due to the slow formation of dolomite.

The Nitrogen and organic matters: The concentration of ion hydrogen in the inland sabkhas ranges between 7.8 and 9.9 whereas the concentration in the coastal sabkhas ranges between 8.5 and 9.3. This increase may be explained due to the increase of aluminum in the coastal sabkhas as the hydration of aluminum leads to the formation of aluminum hydroxide which is very alkaline.
Sources of nitrates in the soil are the oxidation of organic matters made by organisms. As a matter of fact the percentage of the contained nitrogen in sabkhas samples is very low as it ranges between traces and 0.013. Higher values are recorded in inland sabkhas.

### Table: 2. Geochemical Analysis of Sabkhas Sediments

<table>
<thead>
<tr>
<th>Sabkha</th>
<th>SiO₂</th>
<th>Al₂O₃</th>
<th>Fe₂O₃</th>
<th>MnO</th>
<th>CaO</th>
<th>MgO</th>
<th>Na₂O</th>
<th>K₂O</th>
<th>CO₂</th>
<th>SO₃</th>
<th>Cl</th>
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<td>19.27</td>
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</table>

s = Surface  m = middle  b = bottom

### 4. Sabkhas Surface Micro features

Although the sabkhas surface is generally flat, a number of micro features are well developed on the surface, namely:

4.1. The patterned relief i.e.

1) Salt polygons
2) Salt saucers.
3) Blister like.

4.2. Salt karst holes.

4.3. Longitudinal trenches.

4.4. Ring fissures.

4.5. Nebkas.

Field investigations showed that these features are very susceptible to changes. Such observations agree with other studies (Neal, 1972). Their formation is a function of soil texture, salt content, ground water level, temperature, rainfall, and tide flooding in the case of coastal sabkhas. Flatness of the sabkhas surface may be attributed to the slow movement of tide waves in the case of coastal sabkhas as well as the level of ground waters almost at the same level in each sabkhas, this level controls the effect of wind erosion. In case of sabkhas
accumulated in depressions the flat surface could be the result of the very slow rate of deposition.

4.1. The patterned Relief: (fig. 9)

These are symmetrical forms of the same characteristics such as, form size, composition, hardness, compactness and development. Field investigation revealed three forms:

![Fig. 9a. A secondary salt polygons superimposed on older generation.](image)

4.1.1. Salt polygons (fig.9a): They are mainly 6 sided, few are 4 and 5 sided. Borders are irregular and many are curved. Sides lengths vary between 10 cm. and 100cm. Some of the polygons are separated by bridges made of salts which go up to about 30 cm in many cases. The surface could be flat and very compact in the case of a high mud or clay content, where in other cases the surface is puffy and friable when the gypsum content is high, however it would be crumbling and cracked in the case of high salt content. It is believed that these polygons develop in four consequent stages: 1. Inundation and saturation of the sabkha surface by high tide sea water in the case of coastal sabkhas and by rain water in the case of inland sabkhas; 2. Dissection of the surface, contraction, and cracking, forming the polygons during the summer hot and dry summer days; 3. concentration of salts content at the surface by evaporation and capillarity; 4. expansion of salt crystals and the formation of higher edges bordering the polygons. This cycle could last for two consequent different seasons, the winter with abundant water and the summer with hot dry weather. During winter the polygons will vanish by dissolving salts to rebuilt during summer time.
Superimposed polygons are well developed in inland sabkhas, it is believed that they are the result consequent dry seasons without any rainfall capable of dissolving the accumulated salts forming them.

**4.1.2. Salt saucers** (Fig. 9b):

They are initially formed as salt polygons in the same sequence of formation mentioned above, but because of high content of salts and the very hot weather a salt crust of 2-3 cm is formed at the surface and the borders developed to be salt bridges of about 30 cm height in some cases. In the case of higher bridges two or three separated generations of successive bridges or layers are found, due to light showers of rain which are capable of dissolving some salts to build a new bridge underneath the first one or the first ones.

![Fig. 9b. Salt saucers, Sabkha Dukhan, separated by salt bridges of about 30 cm height. The bridges may hide underneath another one or two generations of salt bridges.](image)

**4.1.3. Blister-like features:** (fig. 9c).

Field observations detected three types: ripple-like forms, network features and faint small polygons. They are usually developed in the low lying interdune sabkhas covered with aeolian sand, they may extend to cover sand dune slopes after rain showers or when the surface water or the ground saturated waters is available. They can be found also in the flat sandy coastal sabkhas. It is worth mentioning that these form because they are mostly friable and relatively tinny they are susceptible and may vanish and reform in few days during successive dry and wet short events.
4.1.3.1: The first type is formed of small ripples perpendicular to the prevailing wind and arranged in the same form of the micro sand ripples found in any sand accumulation. The width of each ripple varies from 7 to 10 cm. while the height is about 5 cm. It seems that these ripples are formed initially as sand ripples and is consolidated or cemented by evaporates.

4.1.3.2: Networks: They are of different sizes, made of salts mixed with sand, found in most of coastal sabkhas and sometimes in interdune sabkhas.

4.1.3.3: The faint small polygons: They are quite similar to the salt pans but relatively smaller, developed at the bottom of the many small depression (Locally known as Rawdat) scattered all over the surface of Qatar Peninsula. The soil in such locations is formed of fine to medium sand mixed with calcium carbonates and evaporates. Worth mentioning here is that these types of sabkhas were developed during the last 40 years where the cultivable lands were desertified with the excessive pumping of underground water misused for irrigation.

4.2. Salt karst holes or semi karst holes (Fig. 10):
They may be circular or irregular in shape, developed in inland sabkhas only in puffy soil sections. Their apparent depths vary between some centimeters and +3 meters. It is believed that the development of such features is mainly attributed to the solution of underlain evaporates and the subsidence of the surface at some points which could be the intersection of two joint systems of the underlying solid rocks.

It is believed that when the water level drops after excessive pumping, the meteoric water moving downwards takes large amounts of soluble salts producing solutional features or collapse structures like sinkholes and dolines. Again this
another feature is mainly attributed to man’s activity particularly after the seventeenth of the last century and the unplanned withdrawal of huge quantities of ground water.

Fig. 10a. Salt karst hole, in the Middle Eastern part of sabkhat Dukhan. About 2 m wide and +3m in depth, very saline water is near the surface.

Fig. 10b. Salt karst hole, found in the eastern part of sabkhat Dukhan, notice the Irregular shape of the hole, the nearly separated block and the distribution of vegetation around the hole. Water level is quite near the Surface.

4.3. Ring fissures:
These are clearly detected from aerial photographs and observed in the northern part of Dukhan Sabkha. They are very circular of about 200 meters in diameter with a vegetated smaller circle in the middle. It is assumed that these features were developed in four consequent stages (fig.11): 1. Existence of matured halophytic plants on the surface of the sabkhas; 2. loss of underlying subsurface
water by evapotranspiration or subsidence of water table after the excessive extraction of the ground water; 3. Deterioration and death of plants but not those at the centre of the circle which absorb more water creating a subsidized circular dry area around them; 4. deflation of soils of the dry sector leaving a whitish or grayish patch with high concentration of salts. Such assumption agrees with the model suggested by Neal (1972).

Fig. 11. Aerial photograph of the Northern part of Qatar showing Ring fissures

4.4. Longitudinal Trenches (Fig.12):

Fig. 12. Longitudinal Trench, marked by vegetation. The trench is 120 m long, 1m Width and +0.5 m deep. It is found on the eastern margin of sabkhat Dukhan. Saline water are found at the bottom.
They are longitudinal subsidized forms observed in the field on the eastern border of Dukhan sabkhas in a soft, dry, porous, puffy surface. One of these trenches was 120 meters long in a curve linear shape; its width varies between 0.5 and 1.0 m. The bottom is almost covered with material similar to those forming the surrounding surface. Small plants and saline water are found in the deepest parts of the trench. The sides are nearly vertical suggesting a fresh stage of formation, many karst holes are spreading in the vicinity suggesting subsidence of ground water. Providing these circumstances it appears that these longitudinal trenches were formed after desiccation of the dried sediments due to declined water level in the area and intensified aridity which increased surface evaporation.

4.5. Nebkas (fig. 13):

13A. a side view of a nebka of about 1 m height, 3-5 m long and 1.5m wide, composed of fine sands accumulated and trapped by plants.
13B. a front view of the nebka.
13C. Stages of Nebka development:
   C1. a tiny plant appears on the sabkha surface;
   C2. accumulation of sand trapped by the plant;
   C3. as the mound builds up the plant grows;
   C4. deterioration of the plant;
   C5. remnants of decayed roots and small heap of sand.

They are phreatophyte mounds formed as a result of the trapping of sands and silts at the shadow of plants, structureless, totally or partially covered with a thin veneer of salts. They are wedge like shapes, their narrow side points to the wind ward direction. The height varies between few centimeters and 150 centimeters where Length varies between some centimeters and 5 meters.
observation revealed that these nebkhas develop in a triple stages model: 1. in the young stage: a tiny plant grows on the sabkhas surface (plant type, size ,and shape are function of soil texture ,salt content, and ground water level). Moving sands and silts are trapped by the growing plant forming a mound; 2. As the mound builds up, the plant continues to grow extending its roots and branches system in all directions to catch water and sun light trapping more sand and silts. This would be the mature stage; 3. In the old stage the mound grows to the limit that the water is no longer reach the branches, the plant deteriorates gradually, and the salt crust dissected leaving the friable material of the mound to be driven by the prevailing wind at last the mound collapses gradually leaving remnants of dried and decayed roots and small heaps of sands (Ashour, 1991).

**Environmental Factors**

Investigations show that the origin and evolution of sabkhas in Qatar are greatly influenced by the following environmental factors: 1) The topography and morphology of the surface; 2) The very shallow to shallow coasts; 3) The hot desert climate; 4) Quaternary sea level changes; 5) Ground water; 6) Geological setting and; 7) Anthropic interferences (Ashour et al, 1991).

5.1. **Topography and morphology of the surface**

The land surface of Qatar is generally of low relief with a maximum height of 103 meters ASL in the southwestern hilly corner and a minimum of 3 meters below sea level in Sabkhat of Dukhan at the middle of the western side of the peninsula. It has a slightly undulating surface covered by a thin sheet of surfacial deposits and stippled by a large number of scattered shallow depressions locally known as Rawdat. Most of these depressions receive the discharges of the very shallow and short wadis running around. They are occasionally cultivated by pumping underground water to develop the soil there into a very alkaline un productive sabkhas (Ashour and Elkassas, 1986). Aeolian sands accumulations of different types and patterns cover a considerable area of the country particularly in the southern part. Some dunes end at the coast line to pour their sands in the subtidal flats converting them into supratidal flats (sabkhas).

5.2. **The very shallow to shallow coasts:**

The coastline of Qatar Peninsula is gently emergent and presents an uneven outline with numerous islands, reefs, capes, bays and extensive areas of supratidal flats or sabkhas.

The coastal water of the eastern coast is very shallow to shallow. The -5 meters contour line lies some km away from the shore line while the – 10 meters contour line lies on a distance varies between 1 and 12 km. This shallow sea floor beside high tide action which varies between 0.92 cm on the western coast of the Peninsula and 3.9 m on the eastern coast and sand invading the sea with the very slow anti- clockwise marine current encourages the
formation of sand bars, spits, lagoons and reefs which form the primary stages of coastal sabkhas.

5.3. **The hot Desert climate:**

Climatologically, Qatar is classified as being among the world’s most arid regions. Daily temperature ranges from 12.7°C to 41.2°C. The absolute minimum temperature in January is 3.8°C and absolute maximum in June is 49°C. The rainfall is characterized by its irregularity and variability in both time and space. It is usually concentrated in the winter and spring seasons with annual average of 50-80 mm. The relative humidity varies between 45 and 98% averaging 61.7%. The prevailing wind, locally known as al-Shamal, is blowing from NNW at NW directions, while about 20% of the winds blow from various directions mainly the SE, S and SW. Such climatic conditions prevailed since the end of the last glacial period supported evolution of evaporates and development of sabkhas.

Fig. 14A. 10m, marine cliff on the western side of the Qatar peninsula, showing a former marine platform at 10 m level and marine notches at 7, 5, 3 and 1-2m level indicates the present tide and high waves action.
5.4. **Sea level changes:**

During deglaciation of the major ice sheets the level of the sea within the Arabian Gulf rose above its present level in two successive periods. In the first, the sea attained a level of 7 and 3 meters above the present level (Fig. 14). These marine transgression form part of the well-known flandrian sea level rise. Evidence from Qatar is reported by Taylor and Illing (1969) who argued that the age of the strand lines in Qatar which heights vary between +1.5 and 2.5 m. range between 3930+130 and 4340+140 years B.P. in age. Evans (1969) in his analysis of beach deposits from the coastal sabkha in Abu Dhabi concluded that the Arabian gulf water level exceeded the present level by 7 meters above sea level during the period between 6000-7000 years B.P. It was believed that at this level of the sea water led to a number of the depressions such as Dukhan and Sauda Nethil. Since 3750 years B.P. sea level appears to have fallen to 3 meters above sea level (Abu el Enin, 1986). Subsequently sea level dropped to its present level leaving behind a marine platform at 3 meters above sea level and the previously inundated depression to be inland sabkhas.

5.5. **Ground Water:**

It is found that the quality of ground water in Qatar is generally deteriorating at a rate of 5% per year (Eccleston, Pike and Harhash, 1981). Due to several reasons including, seawater intrusion particularly in coastal areas, upward diffusion of deeper saline water as a result of over extraction of the ground water and the very low rate of recharge and recirculation of low-quality irrigation water which may develop secondary Stalinization (Ashour and Elkassas, 1986).

5.6. **Geological setting:**

The greater part of Qatar Peninsula is mainly composed of a remarkably uniform limestone horizon of middle Eocene age. In some parts, this limestone horizon is breached and eroded where underlying older rocks of early Eocene age are exposed. On the other hand, the limestone horizon is overlain by younger strata of Middle and late Miocene age followed by Pliocene formation. Quaternary and Recent surficial deposits are widely distributed and they consist of various detritus among which sabkhas cover about 7% of the surface of the Peninsula.

Structurally, the Peninsula of Qatar is considered as a wide anticlinal dome having a general elliptic configuration with a North –South axis. This domal structure is gently wrapped, slightly folded and separated by a syncline (occupied by Dukhan Sabkha) from the more pronounced, narrow and elongated Dukhan anticline trending in the same direction.

5.7. **Anthropogenic Factors:**

Qatar being a rich petrol country since the seventies of the last century, the mode of life changed, the population increased many folds, Doha the capital, towns and villages expanded, many activities were created. As a result of these changes huge quantities of ground water were extracted for domestic use and irrigation of...
newly cultivated areas. The water level dropped. With the drop of the water level
the saturated water moved to be replaced by more fresh water and karst features
were formed on the inland sabkhas.

On the other hand desalinization of the sea water and consumption of large
quantities of water for domestic use particularly in the newly built areas
developed ponds of seepage water around inhabited areas creating a new type of
sabkha (Fig. 15).

Fig. 15. A very recent pond of water in Rayan district (a new inhabited area) during winter
season, the pond changes during summer very hot days to be a sabkha or a saline flat.
Source is sewage water, and excessive garden irrigation water.

6. Conclusion
Sabkhas in Qatar Peninsula were developed under certain environmental
factors. Of these factors, the sea level and anthropogenic impacts, these factors
would be more effective in the near future. With the global sea level rise it became
evident that wide coastal areas particularly those flat or gently sloped would be
inundated by sea water creating new sabkhas, which may extend to cover wide
areas needed for development. It is also expected that the man made sabkhas would
expand around inhabited areas creating environmental problems.

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