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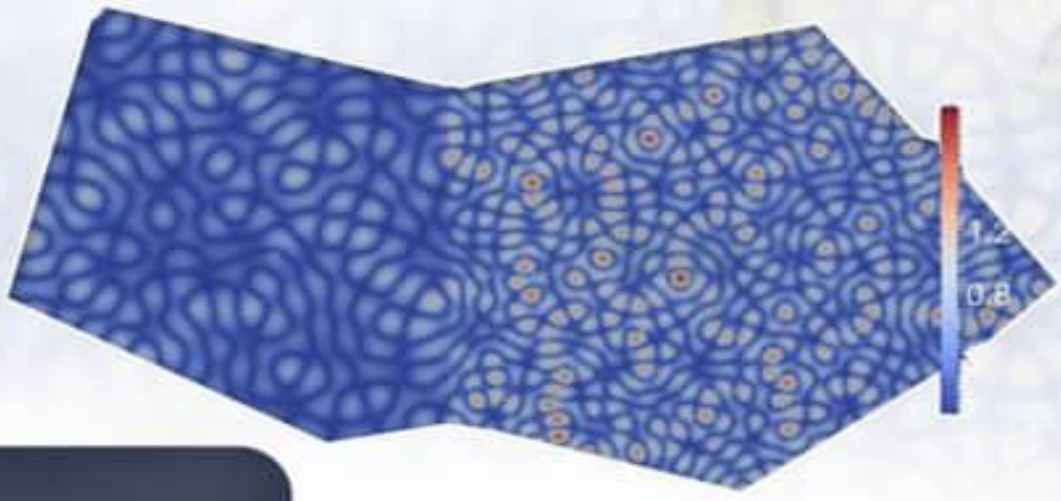

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Mode of Formation of the Coastal Sabkha Sediments in the Coastal Plain of Al-Dafna Plateau

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A B S T R A C T

Two types of sabkhas are distinguished in the study of coastal area; the first type was developed at the mouths of wadis where sea water enters the wadis through high tides; these include; Omm El-Shawesh, Wadi Al-Ain sabkha and Wadi Rizk sabkha. A generalized hydrodynamic model for the formation of this type of sabkha was constructed. The second type of sabkha is stretching behind the dunes, and is divided into a longitudinal strip from east to west where saline crusts appear in some parts and approach the groundwater level. These sabkhas are subjected to flooding during the winter and plant grows within this sabkha. Behind the shore sand hummocks, sea water enters the sabkhas area by seepage and mix with groundwater, and then rises upward to the surface through capillary action and evaporats. This type of sabkha include; Alaqila, Omm Rukbah and Wadi Al-Sawani. The generalized hydrodynamic model suggested for the formation of this kind of sabkha was constructed too.

1 Introduction

Sabkhas are widespread geomorphological features in the coastal landforms of the Mediterranean Sea of Libya Wadis sabkhas always subjected to flash floods during the rainy season in the main Wadis and/or recharge from tidal flow. A tidal pool partially filled with seawater during high tide flood seasonally and daily thus intertidal and supratidal sabkhas are developed. A marine sabkha is a near coastal salt dominated by marine-derived brines and processes; a continental sabkha is an inland salt flat dominated by continental brines and processes (Prudencio et al., 2007). According to Kleo and Al-Otaibi (2011) there are three types of geomorphic sabkhas which are as follows: 1) sabkhas that are connected to the coastal inlets; 2) sabkhas that are connected to the tidal flats and 3) sabkhas that lie behind the shore sand hummocks.

The study area is characterized by the presence of many geomorphological coastal landforms and bays. The coastline extends from the Wadi El-Shawash estuary in the west to the Ramla well in the east at the western border of the Arab Republic of Egypt. Sand dunes, sabkhas and pockets are abundant in this area (Al-Haram, 1997). Sabkha is an Arabic word for a salt-flat area found mainly along hot and arid climate typically formed on shoreline (coastal sabkhas) and inland present within the sand dunes areas. Marine sabkhas represent transitional environments between the land and the sea. Marginal marine sabkhas that bordered by tidal flats display a range of sedimentary features according to the frequency of flood by sea water and the providing of terrigenous material from nearby high mountains. A marine sabkha is a near coastal salt dominated by marine-derived brines and processes; whereas, a continental sabkha is an inland salt flat dominated by continental brines and processes (Prudêncio etal, 2007).

The area is subdivided into two geomorphic units; the northern scarped terrain is marked by the presence of many prominent scarps running in an ESE-WNW direction while the southern part of Al Bardia area is

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flat, monotonous plain (El Deftar and Issawi, 1977; Mazhar and Issawi, 1977; Sweedan and Issawi, 1977).

Coastal sabkha spreads within a boundary between the coastline and the interior at different distances depending on the topography of the surface. Sediments of sabkha were observed close to the mouths of some wadis at the northeast part of the studied area. It was subjected to all changes affecting the coastal plain because its development is closely related to coastal conditions (Ashour, M., 1993).

2 Techniques of Study

Two field trips were carried out on the coastal stretch of the Al-Dafna plateau in the summer and winter times (2017-2018) where six sites in the coastal area were chosen for collecting samples from intertidal and supratidal flat sediments developed at the mouths of different wadis; wadi Omm El-Shawesh, Alaqila, wadi Al-Ain, Omm Rukbah, wadi Riszk and wadi Al Sawani. Sankha features were described photgraphed, logged and samples.

3 Study Area

The study area occupies the northeastern part of Libya; where sabkhas are common in the coastal area of Al-Dafna plateau which extends from the mouth of Wadi Omm El-Shawash, in the west (east of Tobruk City), to Bir Al Ramla Well in the eastern border of Libya with Egypt for about 130 km long. The area lies between Latitude 31° 45" to 32° 21" N and Longitude between 24° 00" to 25° 08" E (Fig. 1). The study area has a Mediterranean climate where arid to semiarid conditions are dominant. The average temperature is ranging from 25 to 40° C in summer months and from 10 to 20° C during winter. The rainy season is limited and often concentrated in few showers from October to March. While December and January months are the wet.

The geomorphology of the Al-Dafna Plateau area occupy the eastern-north part of Libya. It extends from the Wadi Omm El-Shawesh, east of Tobruk City, to Bir Al Ramla Well in the eastern border of Libya to Egypt for about 130 km long. The total area included in this study is estimated to 5638.3 km^2 with maximum height of 223 m above the mean sea level. He further mentioned that the sabkhas are significantly spread along the coastal area, behind the sand dunes in Ras Azaz, Omm Rukbah, Mursi and Jazour. Sabkha is a shallow coastal area of marginal seas, particularly those in catchment areas of populated and industrialized regions, are endangered by the increasing of substances or heavy metals at a rate faster than the environment can accommodate (Saleh, 2013).

The supratidal and intertidal sabkha areas are flooded with sea water seasonally and daily. The main recharge to the sabkha area is from tidal flow and flash flood from different wadis. A tidal pool partially filled with seawater during high tide flood always occurs.

4 Study Objective

The objective of this paper is to construct the hydrodynamic model of sabkha formation.

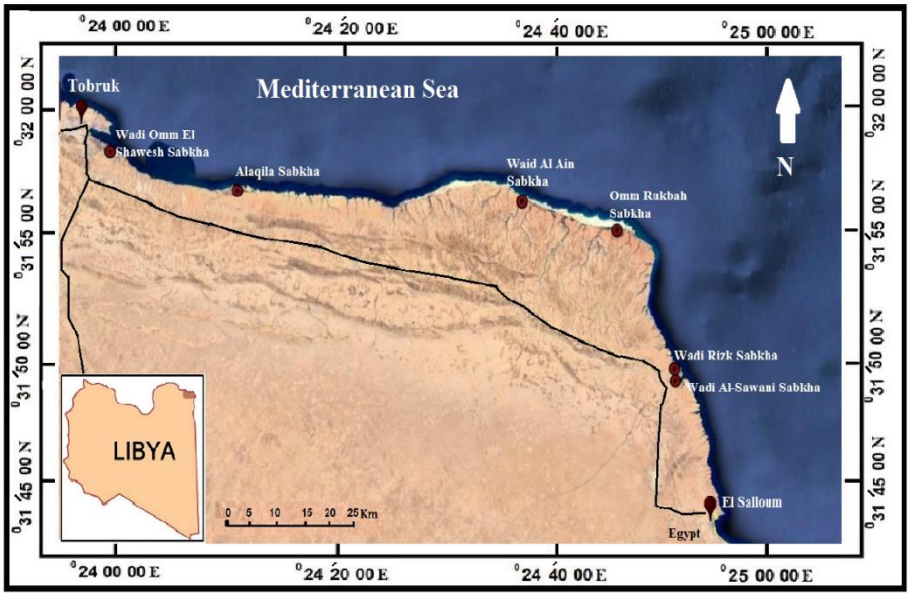

Figure (1). Satellite image showing the location of the studied coastal sabkhas in Al-Dafna plateau.

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The sabkhas are significantly spread along the coastal area behind the sand dunes. Supratidal and intertidal sabkhas are developed in the wadis mouths in the coastal area of Al-Dafna plateau where desiccation in the tidal flat areas causes precipitation of gypsum and halite.

Sabkhas are subjected to all changes affecting the coastal plain because its development is closely related to coastal conditions. Sediments are composed of fine to medium sand and muds with gypsum. They are deposited by wind and water carried by the valleys to the sea sabkha areas. Fine sediments can brought to sabkhas through the tidal currents and storm waves too. Marshes and plants (halophytes) are well developed in the study area where groundwater covers some sabkhas. The water table rises in winter due to the tyranny of the sea with the rising waves, in addition to the water of the floods brought by wadis. While in summer, the high temperatures and the high evaporation rate cause lowering of water table. Depending on the topography of the surface, coastal sabkha spread between the coastline and the interior of the land. Sabkha sediments were observed close to the mouths of some wadis at the northeast part of the studied area.

The wadis draining the inland part of the surrounding limestone terrain wash in this flat surface fine-grained terrigenous materials admixed with the almost stagnant sea water. Evaporation helps the formation of sediments which consist of very fine calcite sand and salt grains with various components of clay. Gypsum and salt form a thin cover on the sabkha surface in dry season; and saline crusts in some parts appear frequently.

5 Results and Discussion

The recognized sabkhas are subdivided into intertidal and supratidal sabkhas. These sabkhas are occurred either in mouth of wadis or behind the costal sand dune. Each type has its characteristic textural and mineralogical composition. The dunes cover very small patches at the central part of the area with 2 m rise from the surrounding surface. It is composed of quartz sands mixed with carbonate particles.

Sabkhas developed in these areas are formed under complex hydrochemical system includes sea water seepage, groundwater percolation, and surface drainage water. Wadis sabkhas always subjected to flash floods during the rainy season in the main wadis and/or recharge from tidal flow, thus intertidal and supratidal sabkhas are developed. Tidal flats are desiccated and are marked by mud cracks with the growth of gypsum and halite crystals in muds according to Boggs (1987), especially in arid and semiarid regions. In correlation with the Trucial sabkha, gypsum and anhydrite are the dominant evaporite minerals (Kinsman, 1969). Although there is a common tendency to regard tidal flats as primarily sites of siliciclastic deposition, carbonate sediments, and evaporites accumulate on many modern tidal flats. On the other hand, Kleo and Al-Otaibi (2011) distinguished three types of geomorphic sabkhas; these include, sabkhas that connected to the coastal inlets, sabkhas connected to the tidal flats and sabkhas lie behind the shore sand hummocks.

The studied area of the sabkha is a flat and shallow embayment filled with sea water during high tides. Lands filled with water are formed throughout the year as a result of the decline and exposure to rain water during the winter and spread the edges of some veneers salt. Evaporation helps the formation of sediments which consist of very fine calcite sand and salt grains with various components of clay. Gypsum and salt form a thin cover on the sabkha surface in dry seasons.

Two types of sabkhas are distinguished in the study coastal area; the first type was developed at the mouths of wadis where sea water enter the wadis through high tides; these include Omm El-Shawesh, Wadi Al Sawani sabkha and Wadi Rizk sabkha (Fig. 2). A generalized hydrodynamic model for the formation of this type of sabkha is shown in (Fig. 3). The second type of sabkha is stretching behind the dunes, and is divided into a longitudinal strip from east to west. Saline crusts appear in some parts and approach the groundwater level. In meantime, these sabkhas may subject to flooding during the winter and plant grow within this sabkha. Behind the shore sand hummocks, sea water enters the sabkhas area by seepage and mix with groundwater, and then rises upward to the surface through capillary action and evaporats. Sometimes this sabkha subjects to flooding of wadis through rainy season. This type of sabkha include; Alaqila, Omm Rukbah and Wadi Al-Ain (Fig. 4). The generalized hydrodynamic model suggested for the formation of this kind of sabkha is demonstrated in (Fig. 5). During the winter season rainfall results in the increase of the flow of groundwater through wadis and thus the level of water table is increased. This mechanism is reversed through summer season, where the increase of evaporation rate causes lowering of the water table, this leads to evaporative concentration of near surface water and displacive grow of the gypsum and halite crystals. The occurrence and abundance of evaporite minerals are controlled by local environmental factors such as topography of the sabkha, emergence or submergence of tidal areas and contribution of meteoric water as a result of floods from the adjoining mountains.

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Furthermore, during the rise of groundwater part of the old gypsum is dissolved and redeposited again at the ground surface under arid climate. This is probably modified by dissolving some of the lagoon gypsum under the sabkha (Ali; 1981, Ali and West, 1983). In addition, there is a role of active wind deflation which eroded the surrounded high carbonate outcrops then transported and deposited into the sabkha basin. The carbonate minerals present in the sabkha deposits are formed of calcite and dolomite that occur as sand and mud material resulted from weathering products.

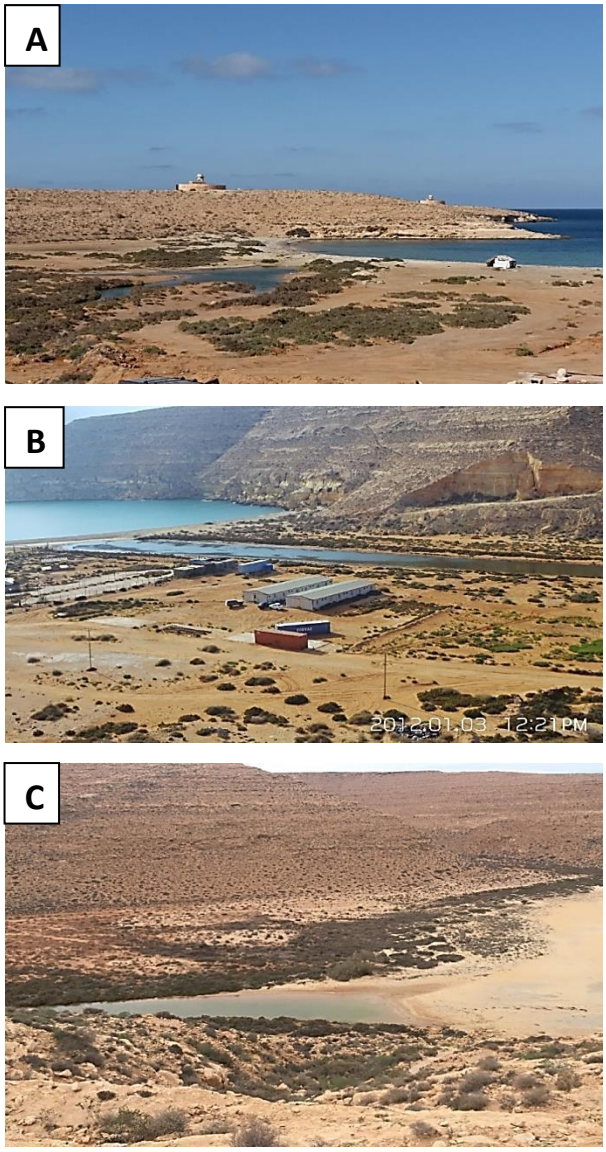

Figure (2). First type of sabkha formed at the Wadi mouths, where sea water enter sabkha basin during the high tide. (A) Omm El-Shawesh sabkha, (B) Al Sawani sabkha, (C) Wadi Rizk sabkha.

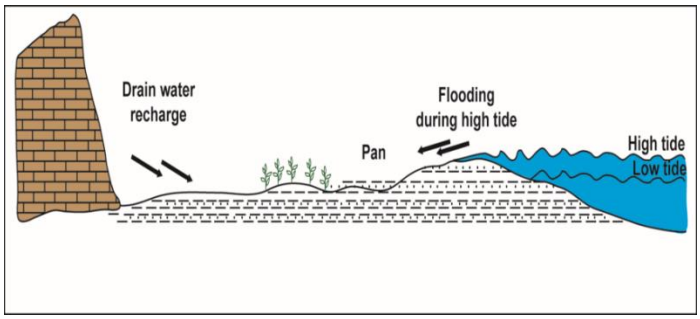

Figure (3). Hydrodynamic model of the first type of sabkha formation

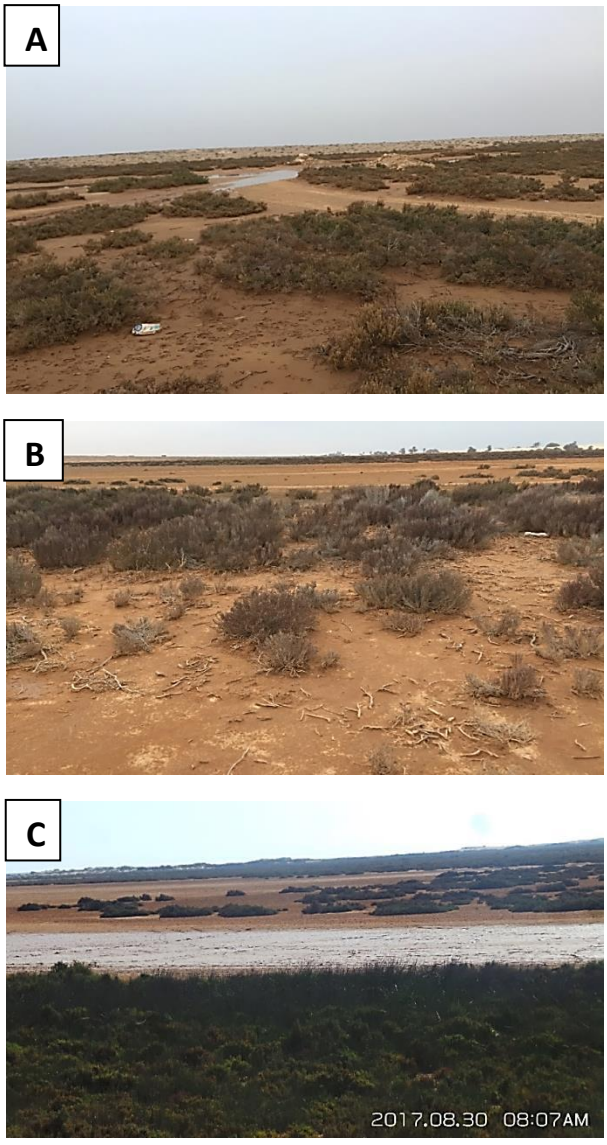

Figure (4). Second type of sabkha formed behind sand dunes, where sea water seepage and mix with groundwater. (A) Alaqila sabkha, (B) Omm Rukbah sabkha, (C) Wadi Al-Ain sabkha.

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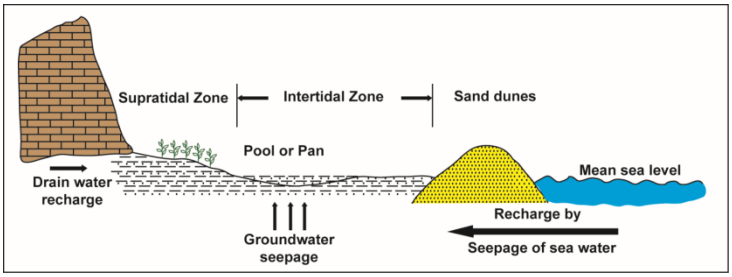

Figure (5). Hydrodynamic model of the second type of sabkha formation

6 Conclusion

Three mechanisms were suggested for the formation of sabkha deposits in the coastal area of Al-Dafna Plateau:

1) Direct influx of the sea water during the high tides into the low land with probability of mixing with drainage surface water, later then evaporated.
2) Seepage of seawater through the very permeable sediments under the coastal dune sediments which formed the groundwater brines that upward raised by capillary movement, then subjected to evaporation.
3) Downward flow of concentration brines moving through the sediments enriched with residual Mg^{++} and formation of dolomite crystals.

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