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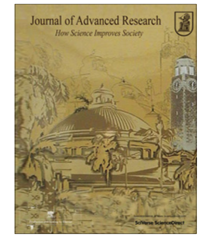

ORIGINAL ARTICLE

Microbially induced sedimentary structures in evaporite–siliciclastic sediments of Ras Gemsa sabkha, Red Sea Coast, Egypt

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ABSTRACT

The coastal sabkha in Ras Gemsa, Red Sea coast with its colonizing microbial mats and biofilms was investigated. The sabkha sediments consist mainly of terrigenous siliciclastic material accompanied by the development of evaporites. Halite serves as a good conduit for light and reduces the effect of intensive harmful solar radiation, which allows microbial mats to survive and flourish. The microbial mats in the evaporite–siliciclastic environments of such sabkha display distinctive sedimentary structures (microbially induced sedimentary structures), including frozen multidirected ripple marks, salt-encrusted crinkle mats, jelly roll structure, and petee structures. Scanning electron microscopy of the sediment surface colonized by cyanobacteria revealed that sand grains of the studied samples are incorporated into the biofilm by trapping and binding processes. Filamentous cyanobacteria and their EPS found in the voids in and between the particles construct a network that effectively interweaves and stabilizes the surface sediments. In advanced stages, the whole surface is covered by a spider web-like structure of biofilm, leading to a planar surface morphology. Sabkha with its chemical precipitates is a good model for potential preservation of life signatures. It is worthy to note that the available, published works on the subject of the present work are not numerous.

Introduction

Many studies on microbial mats, the oldest and most successful microorganisms, showed that metabolic activity of cyanobacteria and heterotrophic bacteria in carbonate marine environments induces the precipitation of carbonates, which in turn form a microbial buildup named stromatolites [1–3]. Recent studies have shown that microbial mats are also of paleoenvironmental significance in shallow siliciclastic shelf settings through much of Earth history. Increasingly, microbial communities are recognized for playing a potentially important role in defining and modifying surface sediment characteristics in various settings, ranging from terrestrial, through marginal marine to continental margins [4]. Siliciclastic microbially induced sedimentary structures MISS [5–10] is adding to our knowledge about both present and past life. Systematic studies, leading from modern to increasingly older deposits, have revealed that fossil MISS occur in tidal flat and shelf sandstones of Phanerozoic, Proterozoic, and Archean ages and appear to have shown very little changes since at

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least 3.2 Ga [9,11–13]. The morphologies and paleoenvironmental distribution of such structures record the former presence of photoautotrophic microbial mats.

Sabkhas or "salt flats" are among the most saline natural environments that form under arid or semiarid climate. Their level is dictated by the local level of the water table and forms an equilibrium geomorphological surface, which may be periodically inundated by water [14,15]. Capillary evaporation leads to an increase in salinity of the interstitial waters and thus favors the formation of evaporites. The study of sabkha is important for several fields. Biologists were increasingly interested in the study of hypersaline ecosystems as amazingly high primary productivities are supported by such systems. Geologists became aware of the fact that many metal–sulfide deposits are associated with paleosabkha conditions [16,17]. Moreover, sabkhas have received many recent studies as they form important permeability barriers in both aquifers and hydrocarbon reservoirs [18].

In modern tidal flat environments, e.g. sabkhas, where high salinity restricts metazoans grazing, microbial mats tend to flourish. Siliciclastic sediments are widely overgrown by a great variety of benthic microorganisms, especially cyanobacteria which are most abundant in the upper intertidal and lower supratidal zones [19]. Cyanobacteria are blossoming in wet sandy environments and secrete sufficient extracellular polysaccharides (EPS). The EPS are adhesive mucilage that enables the benthic microorganisms to attach themselves to solid substrates such as the surface of a quartz grain, to transport nutrients toward the cell, and to buffer the microbes against the changing salinities in their microhabitat [20].

A biofilm is a collection of microorganisms, and their extracellular products bound to a solid surface termed as substratum [21]. It can be also regarded as microbially stabilized water [22] that glue and fix the surface sediments in a process known as biostabilization which increases stability against erosion [23–26].

The aim of the present work is to characterize different sedimentary structures induced by the microbial activity in evaporites and siliciclastic sediments in the coastal sabkha hypersaline environment, also to discuss the fossilization potential of microbes in evaporites. It is worthy to note that these structures are documented for the first time in this particular area of Egypt. In this respect, the detailed characteristics of their formation are given, especially in the absence of many published works on the subject.

Study area

The study area is the coastal sabkha of little Gemsa on the western side of the Gulf of Suez along the Red Sea coast Fig. 1. The Gulf of Suez is a large elongated embayment which is part of the rift system dividing the African and the European Asian plates. The modern Gulf of Suez occupies the central trough of the Suez rift which is only 50–70 m in depth [27]. A relatively wide gently sloping, coastal plain exists along this Gulf. The shoreline comprises a low-angle siliciclastic carbonate ramp depositional system that passes onshore into an extensive coastal sabkha environment. The sabkha extends over a large area and displays a low slope with isolated patches of high salt tolerant vegetation. It has no surface connection with the sea but a subterranean one, fluctuating with the tide in the open sea.

Ras Gemsa is located between 27°39′0″N and 33°34′60″E and covers an area of about 10 km^2. Gemsa forms two tongues

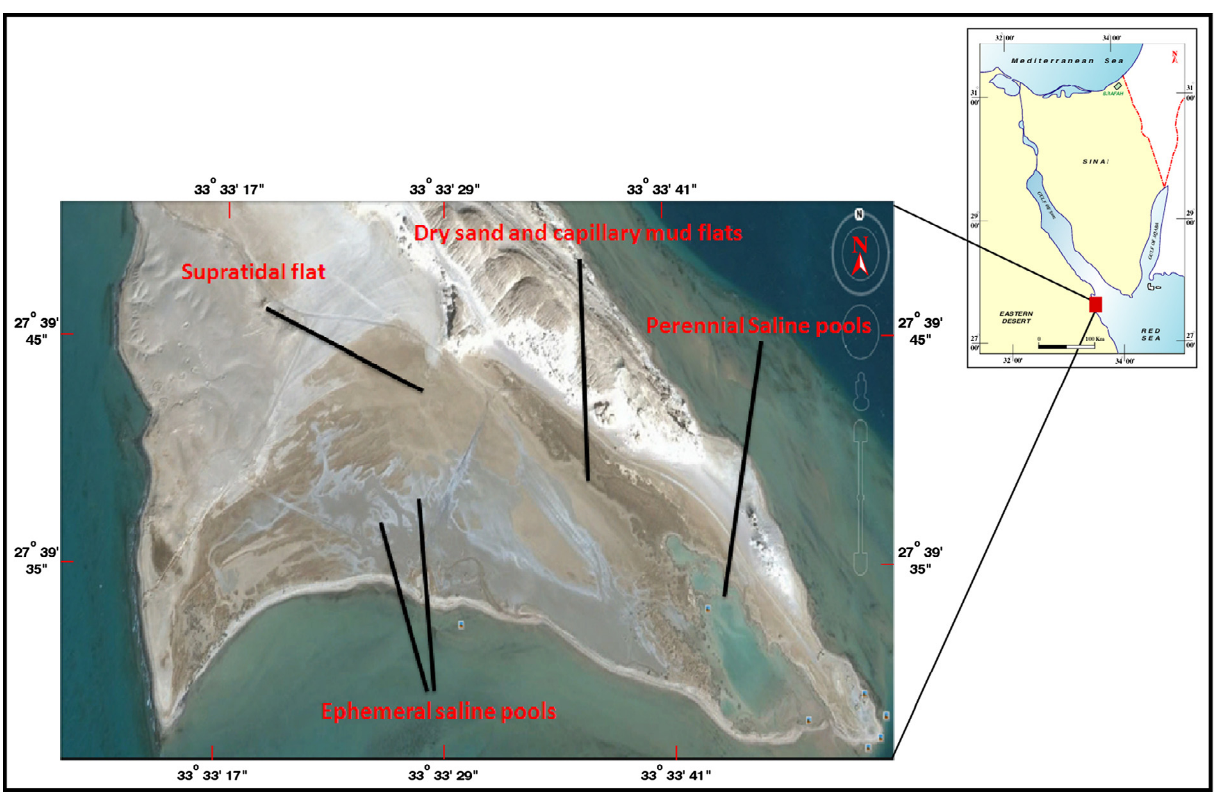

Fig. 1 Location map of the study area.