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Microbial Mats from the Khor Al-Adaid Sabkha, Qatar: Morphotypes and Association with Authigenic Minerals

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The sabkhas (i.e., salt flats) of Qatar are among the rare places on Earth where carbonate and sulfate minerals similar to those constituting economically important hydrocarbon reservoirs are still forming today, under the arid conditions that characterize the coastline of the country. Since the 1960's, the sabkhas of Qatar have been studied with great interest as a modern analogue for ancient sedimentary sequences (e.g., Wells, 1962; Illing & Taylor, 1995; Alsharhan & Kendall, 2003). The results of these studies provided important insights for formulating stratigraphic models of subsurface hydrocarbon reservoirs. Notable examples of gas and oil reservoirs that formed in arid, evaporitic environments include the Permo-Triassic Khuff (which is estimated to contain about 15–20% of the world's gas reserves and is of fundamental importance for the economy of Qatar), the Jurassic Arab formations, and the Triassic Kurra Chine, all of the Middle East, and the Permian Zechstein of Northern Europe. Although extremely valuable, most of these early studies were based on purely physical and chemical approaches, which may have not fully captured the complexity of the mineralization processes occurring in the sabkha environment. Indeed, research conducted in more recent years has shown that microorganisms play an important and, as yet, poorly understood role for the mineralization processes occurring in these evaporitic environments (Bontognali et al., 2010; Bontognali et al., 2012; Bontognali et al., 2014; Brauchli et al., 2015; Paulo & Dittrich, 2013; Strohmenger et al., 2011).

Here we present the results of a field campaign conducted in the Khor Al-Adaid sabkha, which is located in the southeast of Qatar, in a large tidal embayment composed of two shallow inland lagoons. The main goal of the field

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campaign was to identify regions of the intertidal zone that are particularly rich in microbial mats, and that represent ideal sites at which to study microbe-mineral interactions. Three sites of interest have been defined.

Site 1 is characterized by the presence of microbial mats that develop in a restricted pond where abundant precipitation of gypsum takes place. This site is an ideal place to look for geochemical or mineralogical signatures of microbes in the gypsum crystals. This, in turn, may allow for the definition of new proxies for identification of microbially-mediated gypsum in ancient sedimentary sequences. Because gypsum and anhydrite are common seals of hydrocarbon reservoirs, a broad understanding of the mechanism of their formation is of unquestioned interest in the field of hydrocarbon exploration.

Site 2 is characterized by the presence of thick (more than 5 cm) microbial mats. Spherical authigenic carbonate minerals are visibly forming in association with the extracellular polymeric substances constituting these mats. X-ray diffraction analyses revealed that dolomite is among the carbonate minerals forming at this site. Thus, the mats will be studied with the goal of providing new insights helpful in solving the long-standing enigma surrounding the origin of sedimentary dolomite. Dolomite is a common mineral in ancient sedimentary sequences (including many hydrocarbon reservoirs) but historically it has been very difficult to form in laboratory experiments that simulate Earth's surface conditions. For this reason, the mechanism of its formation remains highly debated. It has been proposed that microorganisms play a key role for overcoming the kinetic barriers that prevent dolomite formation at low temperature (Vasconcelos et al., 1995). Because this "microbial hypothesis" is not unanimously accepted, the mats present at site 2 represent an ideal material to study for better understanding and further demonstration of the existence of this biomineralization process.

Site 3 is characterized by the presence of well-layered, domical microbial mats. Gas is produced in abundance within the mats, which likely influences pore-water chemistry and might, in turn, influence the rate and the type of mineral precipitation.

Work is currently in progress to characterize the microbial diversity of the three sites through "next generation sequencing" methods, as well as characterization of the mineralogy and the isotopic composition of the carbonate and gypsum forming within the microbial mats. The ultimate goal is the better understanding of what role microbes play in the formation of ancient evaporitic sequences.

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