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Microbial signatures in sabkha evaporite deposits of Chott el Gharsa (Tunisia) and their astrobiological implications

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Abstract

This study investigates the geomicrobiological potential of Upper Pleistocene evaporite deposits of the Chott el Gharsa, a wide continental sabkha in southern Tunisia. Organic and inorganic-derived biosignatures are mostly contained in microcrystalline, laminated gypsum lithofacies consisting of light/dark alternations of concordant laminae, which have precipitated from high salt concentrated waters. These biosignatures include mineralized microbial-interpreted morphologies, such as mucilage, rods, and microfibers, and dumbbell morphologies in the hollow cores of dolomite crystals that are associated with sulfates. Mineral products that are induced by microbial activity and their organic compounds lead to the formation of lenticular-shaped gypsum crystals, with a high length/width ratio, dolomite precipitation and formation of pyrite framboids. Morphological and structural aspects of these biosignatures, and their composition, in laminated, dolomite-rich sulfate deposits could be detected through microscopic investigations and micro-analyses performed by the instrumentation that is planned for ongoing Mars sample return missions.

Keywords: Chott el Gharsa; Microbial biosignatures; Sabkha environment; Sulfate; Dolomite; Astrobiology

1. Introduction

The presence of water on Mars has been suggested ever since NASA's Viking mission. A large number of papers deal with the evidence for standing bodies of water and this evidence has recently been used to support the idea that Mars could have sustained life. Orbiting and landing missions did not, however, detect any hydrophile minerals. Only ESA's Mars Express and NASA's Mars Exploration Rover missions provided mineralogical data that supported the presence of liquid water on the surface of Mars (Elwood Madden et al., 2004; Hynek, 2004) and reinforced the hypotheses for past (or present) Martian life. One of the lines of evidence was the detection of sulfates (Christensen et al., 2004; Klingelhöfer et al., 2004; Vaniman et al., 2004; Langevin et al., 2005) that would in turn be the product of evaporation in ways similar to evaporite environments on earth, including sabkha and coastal lagoon settings (Gendrin et al., 2005). Therefore, terrestrial evaporite environments and their fossil equivalents throughout the geologic record should be carefully considered as key terrestrial analogues of Martian rocks in the search for biosignatures and the method for their recognition.

One such analogue is sabkha lake environment and associated evaporite minerals that occur in arid zones of earth adjacent to desert areas (Ori et al., 2001; Douglas and Yang, 2002; Douglas, 2004). Sabkhas seem to be good terrestrial analogues for Mars evaporites because a variety of salt deposits precipitate in dry conditions in surface and near surface locations with the twofold advantage of i) preserving traces of life (if any) within chemical precipitates, and ii) enabling relatively easy recognition and sampling in future landing missions (Ori et al., 2000). In hypersaline aquatic biotopes with very high salt

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concentration, such as in sabkha lakes, only extremely halophilic organisms may find suitable conditions for growth. Halophilic bacteria and archaea (halobacteria) include most of these salt tolerant taxa (Grant et al., 1998), although invertebrates, such as brine shrimp *Artemia salina*, and several species of green algae, such as *Dunaliella salina*, may locally be abundant. When waters approach saturation, however, their biology is dominated by halophilic archaea (halobacteria), the most halophilic biota (Rodriguez-Valera et al., 1981). Together with high salt concentrations, certain hypersaline environments also include periodic dilution, which, as in sabkha lakes, occurs during rainy seasons. As a consequence of the salinity fluctuations, conditions become less stable, and therefore, more difficult.

In the closed basins extending outward in southern Tunisia, along the northern margin of the Sahara Desert, waters with strong salt concentrations characterize the environments of continental sabkha, locally called "chotts". In the wide and flat Chott el Jerid stands of shallow, ephemeral waters and the formation of salt crusts in slightly alkaline conditions depend on the annual alternation of dry and rainy seasons (Gueddari et al., 1983). In the smaller Chott el Gharsa there are outcrops of sabkha deposits of the Upper Pleistocene age (Swezey, 2003). At Chott el Gharsa, most of the evaporites consist of gypsum deposits that outcrop along the southern and eastern parts of the chott (Ori et al., 2001; Barbieri et al., 2003). The advantage of the chotts area is that both modern and fossil sulfate evaporites, and their microbial communities, can be considered for tracing the preservation potential of the microbial-derived fabrics and products. This paper presents the results of the investigation of preserved, microbial-interpreted morphologies in the evaporite deposits of the Chott el Gharsa. The goal is to test the potential of fossil lacustrine evaporites, in spite of the negligible amounts of preserved organic compounds, of recording biological morphologies and other inorganic (mineral) elements that are useful as microbial signatures in an exobiological perspective.

1.1. Chott el Gharsa

Connected to the Mediterranean Sea about 90 ky ago (Causse et al., 1989), or perhaps in much earlier times (Richards and Vita-Finzi, 1982), the chotts of southern Tunisia are characterized by a variety of environmental and depositional settings. The 620 km^2 wide depression of the Chott el Gharsa is located at the Tunisia–Algeria border, south of the Metlaoui Mountains. The east–west trending basin that makes up the Chott el Gharsa hosts aeolian, lacustrine, and evaporite deposits (Swezey, 1996, 2003). The investigated area (Fig. 1) is from the eastern part of the depression, where evaporite (gypsum) deposits comprise the tops of the cliffs of the mesas (terraces) produced by the erosion of wadies and runoff (Fig. 2A). A recent, comprehensive review of the Quaternary geology and stratigraphy of Chott el Gharsa is provided by Swezey (2003).

2. Methods

For the investigation of microfacies and microbial-derived morphologies, standard thin sections (5 × 4 cm) obtained from resin-impregnated blocks of rock, fractured portions of selected thin sections, polished slabs and freshly cut surfaces from unaltered (non-impregnated) rock samples were examined with transmitted light microscopes, and scanning electron microscopy (SEM). Reflected-light microscopy also enabled an evaluation of the size and organization of mineral grains, and the minerals–sediments relationships at the microscopic scale. Measurements

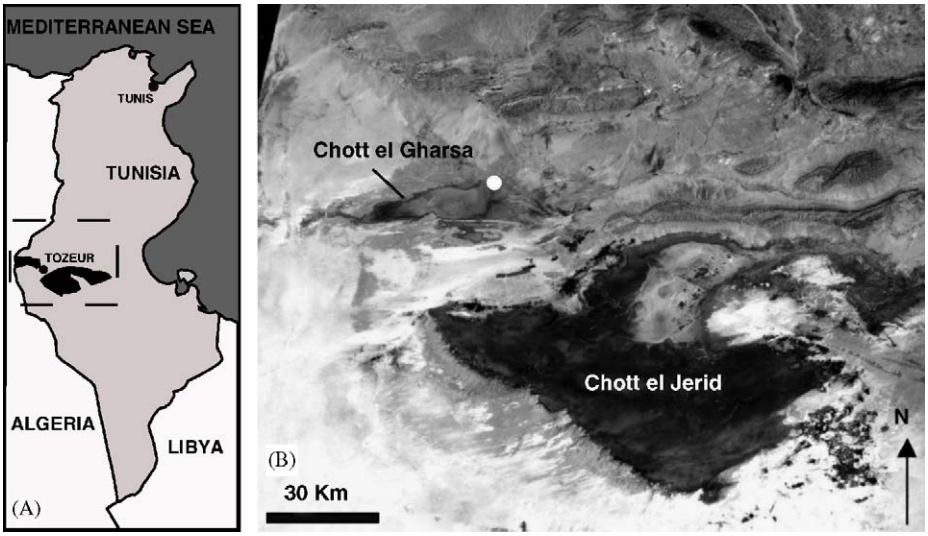

Fig. 1. (A) Location map. (B) Satellite view (LANDSAT panchromatic mosaic) of the Chotts region, southern Tunisia. The white dot locates the study area.