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Desert spring mounds: a potential analogue to Martian arid environments?

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Abstract

Spring carbonates have been often considered as putative analogues of Martian arid environments. On Earth these are believed to form by the interaction of highly saline water and microbial communities, which favor the formation of authigenic micrite. Here we present new data from spring mounds in the western Makgadikgadi Pan (Botswana) and the Great Artesian Basin (South Australia). In both areas, upwelling of ground water give rise to mounds and layered deposits which are close morphological analogues of landforms documented on Mars. The authigenic carbonates and evaporites associated with the spring mounds retain evidence of microbial microfabric founded elsewhere, pointing to the potential existence of similar microbial in the extreme Martian conditions.

1.Introduction

Earth geological record preserves fossil of living systems that show adaption of life to extreme and unique environments [2] such as desert spring mounds (Fig. 1 A, B). The study of these systems provides insight into the nature of rock/life interactions on Earth [1], and may give clues to life forms could have been preserved in the rock record of Mars [13]. Occurrences of alleged spring mounds have been recently reported for the equatorial region of Mars [4, 9, 11] (Fig. 1C). These landforms are commonly exposed within major craters filled by sedimentary units collectively referred to as Equatorial layered Deposits (ELDs). It has been hypothesized that ELDs have been deposited by cyclical groundwater upwelling [4].

Similarly to other continental microbially induced, carbonates, desert spring mounds exhibit micrite and microsparite layers suitable for petrographic and geochemical investigation at micro- to nano-metre scale [5]. Critically, crystallization pathways in the presence of microbes, seem to occur via non-classical nucleation and growth through mechanism common both to inorganic and bio-mediated processes. However, purely inorganic carbonates, where organic compounds are absent, seem to be characterized by diagenetic ripening [5]. This implies that the characterization of the spring mound carbonates potentially provide insight on their formation.

2.Study area

Spring sediments in arid regions of Botswana and South Australia (Fig. 1A, B) occur along the western margin of the Makgadikgadi Pan (MKP) [8] and along the western margin of the Great Artesian Basin (GAB) [3, 6, 7], respectively. There, the groundwater flux reaches the surface favoring deposition of carbonates and evaporites organized in mounds characterized by tufa (Fig. 1B) and travertines [3, 6].

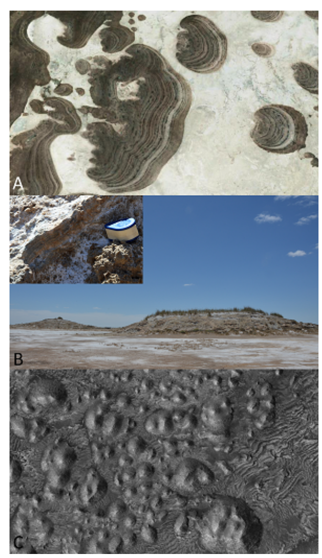

Figure 1: A) MKP mounds (Google Earth). B) GAB mounds characterized by tufa (inset). C) Firsoff crater mounds (ESP_020679_1820).

3.Methods

The present research has commenced by scrutinizing the outer morphologies of the mounds. Satellite imagines (Google Earth) of terrestrial landforms were compared with remote sensing data. The NASA Context Camera (CTX) images were combined with high-resolution HiRISE (High Resolution Imaging Science Experiment on Mars Reconnaissance Orbiter) and High Resolution Stereo Camera (HRSC) data.

Preliminary field work was carried by FF in October 2016. Samples of sediments and rocks have been collected and preliminary investigated by X-ray diffraction (XRD), standard optical microscopy and Scanning Electron Microscopy (SEM-EDS). This is the basis for the next step, which will include High Resolution Transmission Electron Microscopy and elemental mapping.

4.Results and Discussion

Along the western margin of the GAB, where groundwater reaches the surface microbialite (Fig. 1B), travertines and phytoherm framestone tufa occur. Mounds consist of aeolian dust cemented by variable amounts of calcite and dolomite. The evaporation rates in the area average 2.5 m/yr with a volume of water loss through evapotraspiration ranging between 6% and 33% [6]. GAB spring water is highly alkaline (high Na^+ and Cl^- and low HCO_3^- contents), although strongly acidic spring water (pH<2.5) have been also described [7]. In analogy to Triassic and present evaporative and alkaline environments, nucleation and growth of micrite, and specifically dolomicrite, is likely to be favored by organic compounds [10]. The poorly known MKP mounds from Central Botswana (Fig. 1A), which were thought to be wind dunes, bear evidence of cyclic groundwater upwelling [8] potentially conducive to microbial bio-mediated precipitation of salts.

Whilst the terrestrial springs mounds under investigation mostly consist of wind dust, carbonates and evaporite minerals, Mars spring deposits are dominated by sulphates and minor amount of carbonates [12] precipitated by cyclical upwelling of saline groundwater [4]. Outcrop-scale investigation of Martian sedimentary rocks [12] revealed that aeolian sediments are cemented by evaporite mineral deposited in a playa-lake setting. Therefore, if we seek an understanding of life on Mars, it becomes crucial to unravel processes that shape spring deposits on GAB and MKP.

5.Conclusions

Spring sediments deposited in terrestrial arid environments of MKP and GAB are morphological analogues of landforms which are believed to be formed in playa-like environments on Mars. GAB spring carbonates preserve micromorphologies and mineral associations which is typical of those of arid environments of Pangaea “microbialites”.Preliminary data reveal that layering of carbonates may reflect a change in the mineralization, and, likely, changes in the influence of microbial activity. Detailed micro and nanostructural study of these carbonates will shed light onto both bio-mediated and inorganic processes conducive to the formation of Martian-like mounds.

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