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Groundwater upwelling and wind erosion in the Makgadikgadi pan, Botswana: analogies with the equatorial layered deposits of Arabia Terra, Mars

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Abstract

Arabia Terra, in the equatorial region of Mars, is characterized by layered deposits, known in literature as ELDs (Equatorial Layered Deposits). These deposits have been interpreted as playa deposits fueled by regional groundwater upwelling [1-3]. The ELDs in Arabia Terra host peculiar mounded morphologies that have been interpreted as evidences for past water occurrence on Mars [2, 4]. Important clues on the mechanisms of formation of these mounds come from analogous layered mounds from the Makgadikgadi pan of Botswana. These mounds are in fact similar in shape and size (Fig. 1) and are formed in an arid playa environment by the overlap of groundwater upwelling and wind erosion.

1. Introduction

The Makgadikgadi in the North-Eastern Botswana is the largest evaporitic basin in the world (16,000 km^2) and consists of several ephemeral lakes (pans). Large (up to >1 km across) mounds have been identified raising from the flat surface of the pan in the north-western regions. These mounds have been interpreted by various authors as aeolian features, lake bed morphologies or spring mounds, linked to water upwelling processes. However, to date their true origin remains debated and this research aims at addressing their origin starting from the assumption that these morphologies might be analogue of those described in Arabia Terra since i) they are fueled by regional groundwater upwelling whereby water reach the surface in an otherwise arid environment; ii) their morphologies are strongly influenced by wind erosion; iii) they are characterized by evaporitic deposition of minerals.

2. Results and interpretation

The morphologies and lithological composition of selected mounds from the north-west of the Makgadikgadi pan have been investigated and coupled with hydrogeological and geophysical data aimed at identifying the role of groundwater in the surface processes of the area.

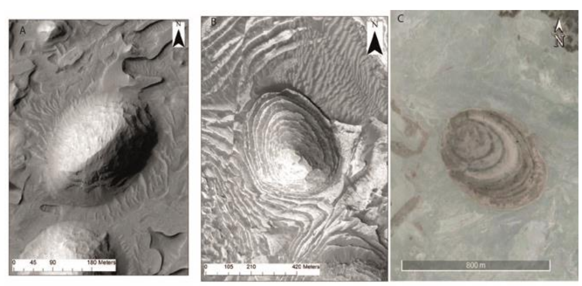

Figure 1: Comparison between mounds within the ELD in Firsoff Crater (A, B) and their analogues from the Makgadikgadi pan (C).

Mounds in the Makgadikgadi pan range from few tens of meters to > 1 km in size showing dimensions compatible with the mounded morphologies described on Mars (Fig 1). From satellite, they present a clear layering and asymmetrical shape (Fig. 1C). These mounds are made up by detrital silica and pedogenic carbonates often cemented by authigenic quartz and calcite cements. An important component of the mound buildups is made by authigenic clay minerals. Sedimentological studies carried on drill cores collected from 3 selected mounds showed that these buildups rest directly on a pavement of indurated evaporites (clay and carbonate mainly).

Three electrical resistivity profiles have highlighted the presence of a capillary fringe that raises under the mound well above the pan floor. This indicates that higher water content in the sediments of the mounds may foster the precipitation of minerals (cements) and lead to a stronger resistance to wind erosion of the mounds.

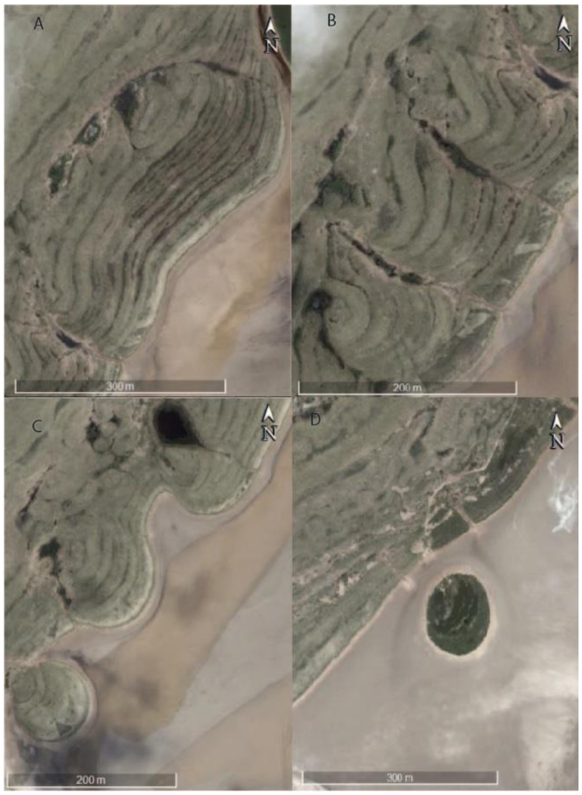

Figure 2: Satellite images of evolving strandline (Google Earth: A) layered sediments exposed along the strandline; B) layered deposits cut by perpendicular furrows; C) differential erosion isolates lobes of the strandline; D) isolated mound.

More conclusive evidences for the genesis of these mounds come from satellite imageries of the coast line of the Ntwetwe pan. The coastline (strandline) shows a peculiar banded toning interpreted as layering of the sediments (Fig. 2A). These layered sediments are Pleistocene lacustrine deposits that are undergoing erosion due to the change in the drainage system occurred in the Mid-Late Pleistocene [5]. The mounds might be formed by selective erosion of the paleo-coastline through several steps. First, small streams and furrows fed by small artesian pools (Fig. 2B-C) cut perpendicular to the strandline. Then the sectors of the strandline cut by the streams eventually evolve into isolated mounds that maintain the layering inherited by the coastline deposits (Fig. 2C-D). The presence of hundreds of isolated mounds on the pan floor suggests that this process might have been protracted for long dry periods when the mega-lake was shrinking [5].

3. Summary and Conclusions

This new data set highlights the importance of groundwater upwelling and wind deflation as main processes for the formation of layered morphologies in arid environment. These mounds have the potential to contribute understanding the analogous layered deposits on Mars which are allegedly formed by cyclical upwelling of the groundwater that have precipitated evaporite deposits subsequently eroded by wind action.

Acknowledgements

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