GROUNDWATER CONTROL ON THE SULFATE-BEARING LAYERED DEPOSITS OF KOTIDO CRATER, MARS.

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**Introduction:** Light-toned sulfate-bearing layered deposits (LTD) are widespread in many areas of Mars and their formation is still matter of discussion [e.g., 1,2,3,4,5,6,7,8,9]. These deposits appear to be stratigraphically constrained from the Noachian-Hesperian transition up to the lower Hesperian, so to postdate the clay-bearing deposits of Noachian age [e.g., 10,11]. Such transition would mark a major environmental change in Mars history from alkaline to acidic conditions, which makes the understanding of the physical/chemical characteristics of the environment(s) of LTD deposition crucial in understanding the climate evolution of Mars. Moreover, many sulfate-bearing environments on Earth have been shown to be potentially conductive to life, which makes of LTD potential targets for future *in situ* missions.

Arabia Terra represents a crucial target to explore LTD geological history because it shows several well-exposed successions in different physiographic settings (i.e., craters of different size/geometry and plateau). Moreover, the presence of groundwater potentially controlling LTD deposition has been proposed by many authors [e.g., 4,5,7] and here physiography shows a very gentle slope connecting the Highlands to the Lowlands that is ideal to observe the potential groundwater presence effects reflected in the sedimentary record.

Accordingly we focused on Kotido crater (centered 9.1\(^\circ\)W, 1\(^\circ\)N), because of the excellent exposure of the deposits and of the good CTX, HiRISE an CRISM data coverage, including an HiRISE stereo pair almost crossing all the crater length that allow to constrain the depositional geometries.

**Results:** Kotido crater is a roughly 40 km large complex crater (Figure 1) with a basin infill thickness can be roughly estimated to be about 1 km [12]. We produced a detailed geological map [12], in order to constraint the stratigraphic framework of the basin, but also the heterogeneity within the LTD deposits.

The LTD stay nonconformably on top of the ‘Middle Noachian highland unit’ [13]. They consist of light-toned deposits, dark-toned deposits, and interspersed mounds (Figure 1). The light-toned deposits form meter-thick layers, according to the smallest structures resolved by HiRISE images/DTMs and might correspond to single beds or at most probably bedsets. They are fragmented into polygons on average about 5 meters in diameter and display very sinuous margins and undulated surfaces, often incised by quasi-circular depressions (Figure 2a). Aeolian erosion might explain some of these morphologies, but bedsets do not always show iso-oriented boundaries and sometimes the geometries are not consistent with a formation by erosion from a unidirectional wind. This suggests that at least part of these morphologies may be depositional. The light-toned bedsets are interbedded with bedsets of darker-toned deposits (Figure 2c). Dark-toned bedsets display a smoother texture and fill and adjust the irregularities left by the undulated surfaces and the quasi-circular depressions of the light-toned deposits. Moreover, they appear to be more easily preserved in topographically more protected/deeper parts of the basin, which suggest that they consist of relatively easily erodible materials.

Both light- and dark-toned bedsets gently drape the older succession lying almost horizontally, although with undulation and folds at a smaller scale. In particular, Two gentle antiforms are present close to the crater margins, possibly reflecting the existence of a buried

![Figure 1 - Geological map of Kotido crater. A schematic geological section is reported in the bottom-right box.](image-url)
terraced rim which constrained the layers geometries (Figure 1, inset).

![Image](https://example.com/image1.png)

**Figure 2 - Characteristics of the deposits inside Kotido crater.**

Mounds form in lateral continuity with the layered light- and dark-toned deposits [9]. They are rounded in plain view and sometimes display an apical pit at their top (Figure 2d). Most of the mounds do not show no asymmetry which might suggest a formation from aeolian erosion. Accordingly, we interpret that at least part of the mounds might represent remnants of depositional landforms.

LTD are frequently associated with linear, layered, positive relief features that appear structurally controlled and can reach kilometer scales (Figure 1a); we interpret these as fissure ridges. Sometimes mounds (both rounded and elongated) are visible on the top of these landforms.

**Discussions and conclusions:** we interpret the Kotido basin infilling as formed by a combination of spring mounds and playa precipitation alternating with clastic transport phases and/or residual materials formed by dissolution of the evaporitic materials (Figure 3). Salt-rich fluids would have been sourced from a pressurized aquifer through fissure ridges and mounds to precipitate evaporites immediately along the mounds’ flanks or more distally forming the layered deposits. Mounds have been interpreted as the results of fluid-expulsion in other places in Arabia because of their conical shape, the presence in certain cases of an apical pit and because of their texture and/or layer attitude [8,9,12].

![Image](https://example.com/image2.png)

**Figure 3 - Conceptual model of LTD formation.**

Alternatively, groundwater might have provided fluids rich in salts to favor the diagenesis of already deposited clastic sediments. In this case, sediments might have been deposited through aeolian, dust/airfall, or volcanlastic processes. Still, this formal process would imply much more laterally and vertically relatively uniform textural and morphological characteristics, which contrast with the observed variability and morphologies such as mounds and fissure ridges, but also the cross-bedding bearing duneforms shown in the nearby plateau [9].

The light-toned deposits show characteristics consistent with evaporite deposition, including the quasi-circular depressions, the undulated surface, the sinuous margins and the polygonal pattern. The fluid expulsion processes, possibly depending on the varying relative ratio between fluid, clasts and salts, might alternatively led to clastic (darker-toned deposits) and evaporite deposition (light-toned deposits).

These processes would be controlled by groundwater emplacement and fluctuations, in turn controlled by climatic changes, and interactions with the fractures related to the crater formation which allowed the actual upwelling from a pressurized aquifer.

**References:**