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Spectral Evidence of Aqueous Activity in Two Putative Martian Paleolakes

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Abstract

CRISM observations of putative paleolakes in Cankuzo and Luqa craters exhibit spectral features consistent with the activity of water. The spatial distributions suggest different formation scenarios for each site. In Cankuzo the distribution suggests post-impact alteration whereas in Luqa there are hints of possible formation of a layer of phyllosilicate materials.

1. Introduction

Putative paleolakes in Martian impact craters have been discussed as valuable targets for exploration [1]. They have been suggested as landing sites for *in situ* and sample-return missions since they should provide information about the dynamics of the sedimentary processes, the climate under which they were formed, and represent environments providing conditions favorable to preserving evidence of biomarkers. Here we investigate CRISM observations of putative paleolakes on Mars to evaluate the evidence for the presence of mineral spectral signatures indicative of the past presence of water at these sites.

1.1 Site Selection and Background

Cankuzo (19.39 S. Lat., 52.05 E. Long.) and Luqa (18.23 S. Lat., 131.81 E. Long.) craters were selected based upon morphologic features suggestive of the ancient presence of standing bodies of water [2]. These craters do not appear to have undergone major modification by subsequent impacts. Cankuzo and Luqa are not included in the studies of [3-6], and are in regions where sheet silicates are reported [7]. It is unclear if Cankuzo and Luqa were investigated by [8] and they were not studied by [9].

1.2 Data Analysis

CRISM is a spectrometer that from orbit provides ~18-200 m/pixel spatial sampling [10]. CRISM data have been interpreted to indicate the presence of several phyllosilicates at many locations and the range of associated chemistry include Al- to Fe-Mg-rich materials [11,12]. The available CRISM data for Luqa and Cankuzo craters are shown in Figures 1a and e. The CRISM data were converted to apparent I/F, divided by the cosine of the incidence angle [10,12] and the atmospheric contribution addressed using the volcano-scan correction of [13]. A de-spiking and de-striping algorithm [14] was applied and geo-referencing allows comparison with other maps of the area. We focused on the spectral parameters of [15] associated with hydrated/hydroxylated silicates, sulfates, and carbonates. Each parameter map is visually evaluated for spatial coherence and when identified, confirmation involves extraction of individual spectra.

3. Results

Figure 1 shows the observations for Cankuzo (MSP_40A8, MSP_81C2, MSP_74C8, and FRT_112C9) and Luqa (MSP_3238, MSP_64DF, FRT_11D18 and FRT_1192C) craters, illustrating high values of the OLINDEX_2 [OL2, 16] and D2300.

Average spectra of Luqa and Cankuzo where a strong OL2 value (O1 and O2) was detected are shown in Figure 2a. These can be compared to laboratory reflectance spectra of olivines (Fig. 2b), low calcium pyroxene (LCP, Fig. 2b) and high calcium pyroxenes (HCP, Fig. 2b). The local minima near 1 μm and between 2.0 and 2.5 μm in the Cankuzo and Luqa spectra are consistent with a HCP. The different minimum position in the 2-2.5 μm region suggests the HCP compositions in Cankuzo and Luqa are different. The width of the minimum near 1 μm in the spectra suggests a significant contribution from olivine, although in Luqa the olivine is either less abundant or more Mg-rich than in Cankuzo.

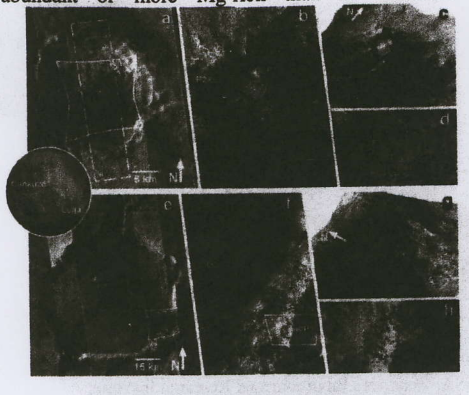

Figure 1: Inset shows locations of Cankuzo and Luqa. a) Thin/thick solid lines are CRISM MSP/FRT observations of Luqa. Red is OL2 and green D2300. Dashed line is HiRISE observation ESP_0135527_1615. b) Overlay of CRISM and HiRISE, dashed/solid line areas are in panel c and d, respectively. Spectral data were extracted at points P1, P2, and O1. c) CRISM observations of Luqa on MOLA topography, the regions from panel b and d are shown. d) dune field in panel b enlarged, values of OL2 are high in areas surrounding the dune field. e) Same as panel a, but for Cankuzo. f) CRISM observations at Cankuzo crater on HiRISE ESP_012541_1600. The dotted line indicates a series of out-crops, the solid line is an area in panel h. CRISM spectra were extracted from points O2 and P3. g) CRISM observations of Cankuzo on MOLA topography. Dotted line outcrops on the crater wall (panel f) and the outline the position of the region shown in panel h. h) Small crater outside the Cankuzo.

Average spectra of two locations in Luqa (P1 and P2) and one spectrum of Cankuzo (P3) where strong values of D2300 were detected are shown in Figure 2c. These spectra are compared to laboratory spectra of phyllosilicates (Fig. 2d and the associated inset). The two Luqa spectra exhibit minima, near 1.92 and 2.32 µm (Fig. 2c, vertical dotted line) and the Cankuzo spectrum exhibits two minima near 1.92 and 2.305 µm (Fig. 2c, vertical solid line). The former can be attributed to molecular water and the latter to hydroxyl in mineral structures [17]. The minima positions from Luqa and Cankuzo are consistent with the laboratory saponite and pyrophyllite-talc spectra, respectively, although in both cases a mixture of the minerals shown in Fig. 2d can not be precluded. We interpret the CRISM spectra as suggesting the presence of secondary minerals (Mg-bearing phyllosilicates) in both craters mixed with a primary ferrous-bearing component (HCP and/or olivine).

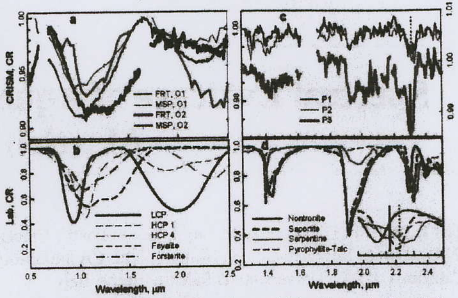

Figure 2. a) Spectra for Luqa (thin lines, left axis) and Cankuzo (thick lines, right axis). b) Laboratory spectra of olivines (dashed and dash-dot black lines), LCP (solid black line), and HCP (dashed and dash-dot gray lines). c) Spectra for Luqa (thin lines, left axis) and Cankuzo (thick line, right axis) craters. The solid and dotted vertical lines indicate the minimum in the 2.2-2.35 µm region. d) Laboratory spectra of Fe-Mg-bearing phyllosilicates. The inset enlarges the 2.26-2.38 µm region with major/minor tick every 0.04/0.01 µm. The solid and dotted vertical lines correspond to the positions of the same lines shown in panel c.

4. Discussion

There is a significant spatial extent of the primary mineral signatures in both craters with restricted spatial extent where both primary and secondary minerals occur. The spatial distribution of the secondary minerals is significantly different in the two craters.

At Luqa, the secondary minerals occur in the central uplift with limited distribution throughout the crater floor region (Figs. 1a-1c). This is reminiscent of a pattern interpreted to suggest post-impact hydrothermal activity in Toro crater [18].

There is an occurrence of the unit indicated by the OL2 that lies outside Cankuzo and appears associated with the small crater near the southeast rim (Figs. 1f-1h) and this is where the D2300 parameter is strong (Fig 1f-1h). MSP observations to the north and south do not reveal any additional major occurrences of D2300 suggesting aeolian activity is not the source of the material. There is a lineament delineated by the OL2 in the southeast crater wall (Figs. 1f and 1g) and continues to the southwest where a concentration of the D2300 unit occurs (Fig. 1f-1g) raising the possibility the D2300 unit indicates a layered deposit. The spatially coherent D2300 pattern near the small crater suggests an underlying layer exposed by the impact process and the depth of this small crater extends to about the same level as the lineament defined by OL2 and D2300 identified in the wall of Cankuzo. Thus one speculation is that during the impact process the small crater excavated the same material from depth that is exposed in the wall of Cankuzo.

The lineament in the wall of Cankuzo suggests two possible genetic scenarios. Both involve the presence of a layer prior to the impact of Cankuzo crater. In the first scenario alteration and/or deposition of the phyllosilicate layer predates the formation of Cankuzo and the unit has been exposed by the cratering process. In the second scenario a pre-existing permeable, or semi-permeable, layer predates the impact and the phyllosilicates were formed by post-impact hydrothermal alteration occurring along this pre-existing layer. Although the pyrophyllite-talc mineralogy associated with the spectra of Cankuzo suggest an elevated temperature during formation of the phyllosilicate phase, this fact alone does not favor selection of either scenario. This is due to relatively close proximity of Cankuzo to the rims of the older Huygens crater (~170 km) and Hellas basin (~750 km). Impacts associated with both of these larger craters could easily emplace ejecta deposits of pre-existing materials, or induce significant hydrothermal systems due to the energy associated with the large impact events.

Acknowledgements

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