Assessing Spectral Evidence of Aqueous Activity in Two Putative Martian Paleolakes

T. L. Roush[1] , G. A. Marzo[2] , S. Fonti[3] , A. Blanco[3], V. Orofino[3], C. Gross[4] and L. Wendt[4]

[1]NASA Ames Research Center

[2]ENEA, Rome, Italy

[3]Dipartimento di Fisica, Università del Salento, Italy

[4]Freie Universität, Berlin, Germany

Introduction: Putative paleolakes in Martian impact craters have been discussed as valuable targets for exploration [1] and suggested as landing sites for *in situ* and sample-return missions as they represent environments capable of 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.

Site Selection and Background. Cankuzo (Ck, 19.39 S, 52.05 E) and Luqa (Lq, 18.23 S, 131.81 E) craters were selected based upon morphologic features suggestive of the ancient presence of standing bodies of water [2], and do not appear to have had major modification by subsequent impacts. Ck and Lq are not the focus of previous studies [3-9].

Data Analysis. CRISM is a spectrometer that provides ~18-200 m/pixel spatial sampling [10]. CRISM data indicate phyllosilicates at many locations with Al to Fe-Mg-rich chemistries [11,12]. CRISM data for Lq and Ck are shown in Fig. 1. We use the spectral parameters of [13] 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. A HRSC [14] image was used to evaluate the ages of regions at Ck. Two CTX [15] images were used to evaluate the ages at Lq. The modeled age was calculated from the cumulative crater size-frequencies at a reference crater diameter of 1 km, using the established cratering chronology model for Mars [16-17].

Results: Figure 1 shows the CRISM observations for Lq and Ck super imposed on simultaneous HiRISE [18] images. Average spectra of Lq and Ck with strong OL2 values [19] are shown in Figure 2a and can be compared (Fig. 2b) to reflectance spectra of olivines, low (LCP) and high (HCP) calcium pyroxenes. The minima near 1-, and 2.0-2.5 μm in the spectra are consistent with

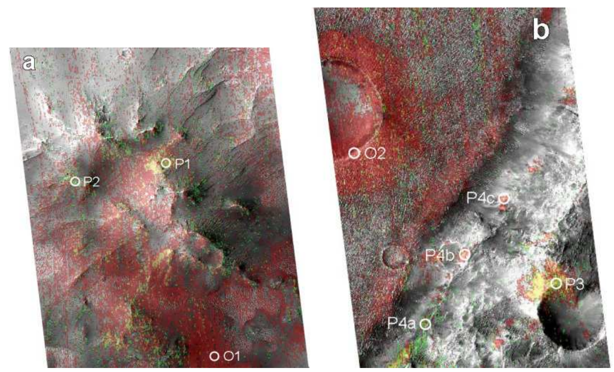

Figure 1. a) Overlay of Lq CRISM (FRT112C9) & HiRISE (ESP0135271615). All values >0.0, red=OL2, green= D2300, and yellow=both occur. Spectra are from P1, P2, & O1. b) Same as a, but for Ck (CRISM FRT11D18, HiRISE ESP0125411600). Spectra are from O2, P3, & P4a,b,c.

HCP and the different minimum positions in the 2-2.5 μm region suggests different HCP compositions. The 1 μm minimum width suggests a contribution from olivine, but the abundance and/or composition in Lq differs from Ck.

Average spectra of Lq and Ck with strong values of D2300 are shown in Figure 2c and can be compared to laboratory spectra of phyllosilicates (Fig. 2d). The Lq spectra exhibit minima, near 1.92 and 2.32 m (Fig. 2c, vertical dotted line) and the Ck spectra exhibit minima near 1.92 and 2.305 μm (Fig. 2c, vertical solid line). The former is attributed to molecular water and the latter to hydroxyl in mineral structures [20]. The minima positions from Lq and Ck are consistent with the laboratory saponite and pyrophyllite-talc spectra, respectively, although a mixture of the minerals can not be precluded. The CRISM spectra suggest the presence of secondary minerals (Mg- phyllosilicates) in both craters mixed with a primary ferrous-bearing component (HCP and/or olivine).

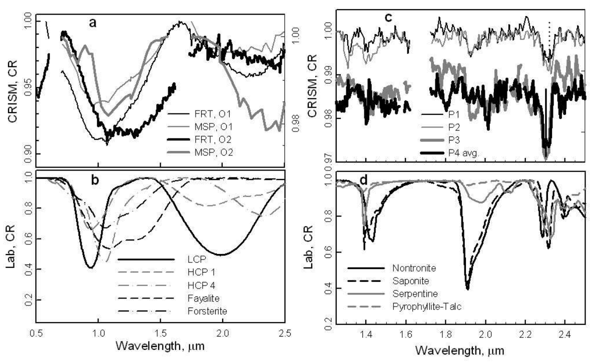

Figure 2. a) Continuum removed (CR) CRISM spectra for Lq (left axis) and Ck (right axis). Black (gray) lines are for CRISM FRT (MSP) observations. O1 and O2 are averages extracted from areas in Figs. 1a & 1b. b) CR laboratory spectra of olivines (dashed & dash-dot black lines) LCP (solid black line), and HCP (gray lines). c) CR CRISM averages for Lq (left axis) and Ck (right axis). P1, & P2, are from Fig. 1a and P3 & P4 avg from Fig. 1b. Vertical lines indicate the minimum in the 2.2-2.35 m region. d) CR laboratory spectra of Fe-Mg-bearing phyllosilicates.

Using crater statistics, the age of Lq is 2.93± 0.32/0.62 Ga and for the external ejecta, a resurfacing event occurred with an age of 245±48 Ma (Fig 3a,b). Ck crater statistics gives an age of 3.79±0.09/0.27 Ga and displays a clear resurfacing at 3.37±0.08/0.14 Ga of the basin floor fill (Fig 3e). The surface to the NW of Ck has an age of 3.4±0.06/0.10 Ga (Fig 3c). This nearly contemporaneous age suggests that the eroded surface to the west likely delivered the infilling material seen on Cks floor between 3.79 and 3.4 Ga.

At Lq, secondary minerals chiefly occur near the central uplift with limited distribution elsewhere. During the impact, buried, pre-existing sediments can be emplaced in central peaks [21] or dehydrated by transient temperatures [22-23]. However, the areas with high D2300 values are along ridges, at tops of cone shaped deposits, and are perpendicular to lineaments suggestive of bedding near the central peak. The observed distribution is consistent with alteration due to localized hydrothermal circulation along weak zones induced by the residual heat from the impact [22-23]. Neither formation scenario requires a standing body of water in Lq. The distribution of minerals within Lq suggests more than one geologic unit and the derived age is inconsistent with previous determination [24], suggesting mapping of this area be revisited.

Discussion: There is significant spatial extent of primary minerals in both craters with restricted spatial extent of secondary minerals. The spatial distribution of secondary minerals is different in the two craters.

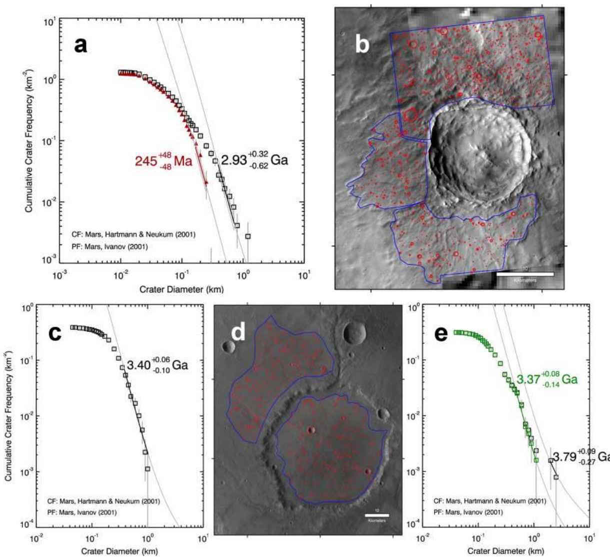

Figure 3. Areas (blue outline) used to determine ages in (b) Lq (CTX P13006196XN17S228W & B060120371616 XN19S228W) and (d) Ck, (HRSC H72250010). Red circles are craters and scale bars are 10 km. (a) Cumulative crater frequencies that determine the age for Lq are from the eject blanket (black pts. = base age, red pts.= resurfacing age), and for Ck from the plains to the NW (c) and within Ck (e, black pts.= base age, green pts.= resurfacing age).

The age of Ck is consistent with the surrounding unit [24]. The OL2 unit is abundant throughout the floor and the age is consistent with, although its distribution appears to extend closer to the crater wall, when compared to previous mapping [24]. CRISM observations do not reveal a similar unit to the south or north, suggesting the OL2 unit is not of aeolian origin. Supporting this interpretation is the close temporal association with the resurfacing event, documented to the NW (Fig. 3c), initiated by aqueous activity, whose age is consistent with an event emplacing the crater floor fill (Fig. 3e, green points).

The largest spatial occurrences of the D2300 at Ck are a small external crater and as a layer in the SW basin wall (Fig. 1b). However, existing data do not reveal whether the phyllosilicates were produced prior or subsequent to the formation of Ck. In either case fluids could have circulated within the layer, and no standing body of water is required. The small crater excavates to the same altitude as the wall layer where spectra suggest similar materials (Fig. 2c).

References: [1] N. Cabrol & E. Grin, 1999 Icarus 142, 160. [2] V. Orofino *et al.*, 2009 Icarus 200, 426. [3] J-P. Bibring *et al.*, 2006 Science 312, 400. [4] D. Tirsch *et al.*, 2008 39th LPSC, abst. #1693. [5] J. Carter *et al.*, 2009 40th LPSC, abst. #2058. [6] J. Wray *et al.*, 2009 Geology 37, 1043. [7] K. Stockstill *et al.*, 2005 JGRE 110, 10.1029 /2004JE002353. [8] K. Stockstill *et al.*, 2007 JGRE 112, 10.1029/2005JE002517. [9] J. Bandfield, 2002 JGRE 107, 10.1029/2001JE001510. [10] S. Murchie *et al.*, 2007 JGRE 112, 10.1029/2006JE002682. [11] J. Mustard *et al.*, 2008 Nature 454, 305. [12] S. Murchie *et al.*. 2009 JGRE 114, 10.1029/2009JE003342. [13] S. Pelkey *et al.*, 2007 JGRE 112, 10.1029/2006JE002831. [14] G. Neukum *et al.*, 2004 Mars Express: The Scientific Payload, ESA SP-1240, ESA Publ. Div., ESA, Joordwijk, the Netherlands, 17. [15] M. Malin *et al.*, 2007 JGRE 112, E05S04, 10.1029/ 2006JE002808. [16] W. Hartmann & G. Neukum, 2001 Space Sci. Rev. 96, 165. [17] B. Ivanov, 2001 Space Sci. Rev. 96, 87. [18] A. McEwan *et al.*, 2007 JGRE 112, 10.1029/2005JE002605. [19] M. Salvatore *et al.*, 2009 40th LPSC, abst. #2050. [20] R. Clark, *et al.*, 1990 JGRE 95, 12653. [21] T. Kenkmann *et al.* 2005 Utah. Geol. Soc. Am. Spec. Pap. 384, 85 [22] G. Marzo, et al (2010) Icarus 208, 10.1016/j.icarus.2010.03.013. [23] A. Farien *et al.*, 2010 Pub. Natl. Acad. Scis., 10.1073/pnas.1002889107 [24] R. Greeley & J. Guest, 1987 Geological Map of the Eastern Equatorial Region of Mars, USGS map I-1802-B.