INSIGHTS INTO THE STRATIGRAPHY OF MARS' NORTHERN PLAINS FROM IMPACT CRATER MINERALOGY.

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Introduction: Impact craters on planetary bodies expose buried stratigraphy several kilometers deep in the crater walls, ejecta blanket and central peaks [1] and give insights into the crustal composition beneath the current planetary surface [2-3]. On Mars, the discovery of thousands of hydrated mineral outcrops using the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) implies that aqueous alteration of the southern highlands of Mars is widespread [4-5]. Unlike the southern highlands, the northern plains of Mars have a more obscure history due to dust- and sediment-mantling of older units [6]. Recent studies using CRISM data in the northern plains detected mafic minerals [7] and hydrated minerals [8] related to craters, hypothesized to be indicative of Hesperian lava flows on top of old hydrated Noachian crust. However, fundamental questions like the possibility of a global northern ocean [9] and post-impact hydrothermal activities [10] in Mars' northern plains still remain unsolved. To better understand the aqueous alteration history of northern lowlands, here we study the newest images acquired by CRISM to probe the buried stratigraphy of the northern plains and place the identified hydrated minerals and unaltered mafic minerals into geologic context using impact scaling models.

Method: We are performing spectral analyses on a list of CRISM targeted images compiled from comparing the Mars global crater database [11] to footprints of CRISM observations. We adopt the standard CRISM processing procedure to convert radiance cubes to I/F and perform geometric and atmospheric correction [12]. We apply a modified version of the noise reduction method from Carter et al. [13] adjusted to the northern plains dataset, which typically has higher background noise and dust cover. With calculated ratioed cubes and new spectral parameter maps we are able to distinguish weak spectral signatures of minerals. Mafic minerals, including low- and high-calcium pyroxene and olivine, are detected using broad absorptions due to electronic transition around 1 and 2 µm. Hydrated minerals are identified using H_2O overtone and combinations at 1.4 and 1.9 µm as well as metal-OH vibrations in 2.0-2.5 µm region.

Results: We have completed surveying CRISM targeted images in Acidalia Planitia (acquired through May 30, 2014), and have confirmed several detections outside of Acidalia reported in previous surveys [4-5] (Figure 1). The preliminary search has shown mafic minerals in craters of all sizes in Acidalia as well as diverse hydrated minerals in large craters (> 30 km), including Fe/Mg phyllosilicates, Al-phyllosilicates, hydrated silica, chlorite/prehnite, etc. In the initial survey, the hydrated mineral-bearing units are preferentially detected in the central peaks of large craters, while the mafic minerals can be found in craters with size ranging from >30 km to ~2 km. While mafic minerals in impact craters can form via local volcanic infill [14] or impact-induced decompression melting [15], the widespread mafic signatures in 182 impact craters in Acidalia on crater walls and ejecta blankets demonstrate a more contiguous unit, possibly buried lava flows [7]. For hydrated minerals on the other hand, due to the relatively small exposures [8] and the possibility of a post-impact hydrothermal system [10], the ques-

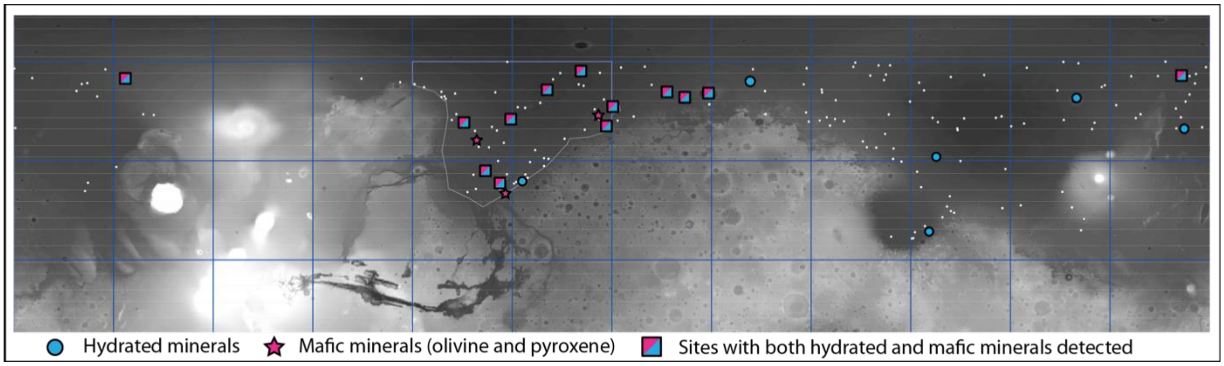

Figure 1: Summary of mineral detections in large craters in the northern plains of Mars south of 60° N. White dots show all the craters with diameter larger than 30 km (with or without CRISM coverage) [9]. Highlighted area with thin white lines is the main area for the study to date -Acidalia Planitia.

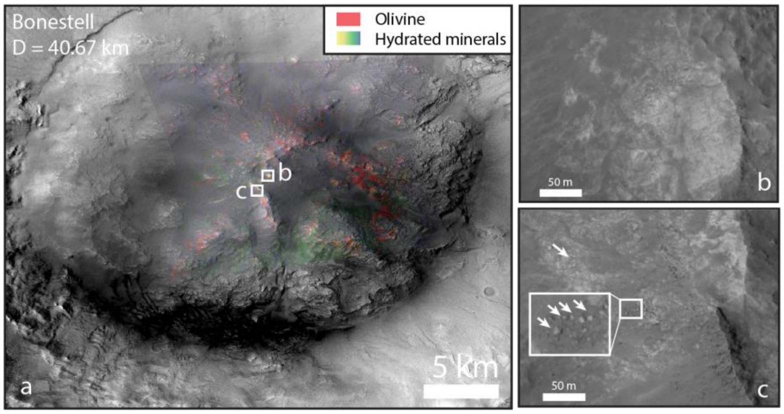

Figure 2: Bonestell crater central peak image: a) CRISM color composite mineral map (R: OLINDEX2, G: BD1900R; B: D2300) overlay on Context Camera (CTX) image. b-c) HiRISE image (PSP_008733_2225_RED) on bright rocky ridges with hydrated mineral detection, with white arrows pointing to several meter-sized boulders.

tion of whether these minerals formed pre-impact or through later alteration processes after the impact requires more detailed analysis.

We have examined several craters closely to better determine the timing and environment of the formation of hydrated minerals. The hydrated and mafic minerals in the central peaks are often associated with uplifted rocky outcrops (e.g. Fig 2). In Bamberg crater, some clay detections are distinctly associated with exposures of uplifted stratified blocks within the central peak [16]. In the central peak of Bonestell crater we also find exposed rocky ridges with strong 1.9 μm absorption related to H_2O (Figure 2 b-c). Davies crater shows similar mineralogy in the central peak, crater walls and ejecta blanket. The observations at these specific sites strongly support the pre-impact alteration of the crustal materials to be the origin of these hydrated minerals.

Impact crater excavation depth scaling: We apply established scaling relationships from lab experiments and simulations to estimate the maximum excavation depth from the rim-to-rim diameter of the craters in this study. The maximum excavation depth is estimated as 1/10 of the diameter of the transient crater [1]. Using different scaling models [1, 17-18], we calculate that the craters we investigated excavate materials from ~1-4 km. The craters in which hydrated minerals are found to penetrate stratigraphy >1.5 km (Figure 3). Under the assumption that the surface mineralogy of Acidalia craters represents previously buried stratigraphy, this information can be used to provide constraints on the stratigraphy of the subsurface.

Conclusions and future work: From the ongoing survey, we have identified mafic minerals and hydrated minerals in impact craters in Acidalia Planitia and across the northern plains. Preliminary work on the occurrences and formation of the hydrated minerals shows that they are detectable only in the craters that excavate >1.5 km. For future work we will look at the detailed stratigraphy of each of these to establish pre- vs. post-impact origin (e.g. Fig. 2; [19]). We will also determine the minimum depth of origin of the central peaks, which could give a second depth probe for craters with central peak detections. Continued survey will help build a complete database of the mafic and hydrated minerals in the subsurface of the northern plains and place upper and lower bounds on the thicknesses of different stratigraphic layers. Using these impact craters, we will be able to decipher the changing aqueous alteration history of the northern lowlands in time.

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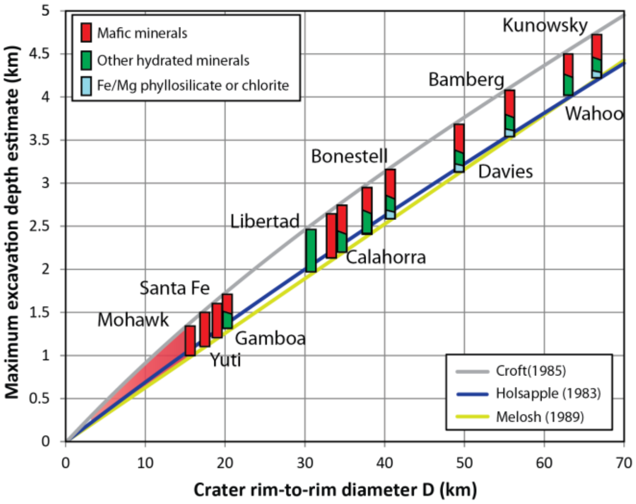

Figure 3: Scaling of the maximum excavation depth of impact craters using methods of Holsapple (1993), Melosh(1989) and Croft (1985). Colored bars of each crater represent the detected minerals therein.