HYDROTHERMAL ACTIVITY RECORDED IN POST NOACHIAN-AGED IMPACT CRATERS ON MARS. S. M. R. Turner[1], J. C. Bridges[1], S. Grebby[2] and B. L. Ehlmann[3]. [1]Space Research Centre, Dept. of Physics and Astronomy, University of Leicester, UK (smrt1@leicester.ac.uk), [2]British Geological Survey, Nottingham, UK, [3]Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, USA.

Introduction and Aim of this Study: Here we aim to characterise the mineralogy of post Noachian-aged impact craters on Mars. This study draws on research conducted by Bridges and Schwenzer [1], who showed that the parent rocks of the nakhlite Martian meteorites were altered by a hydrothermal brine at ≤200 °C [1] in the last 670 Ma [2]. This may have occurred in the setting of a short-lived impact-induced hydrothermal system in the ice-bearing crust of Mars. Although the nakhlite secondary assemblage formed rapidly e.g. <1 year [1], such systems have the potential to last for up to ~10 Myr [3], resulting in various phyllosilicate alteration phases [4]. The hydrothermal brine that altered the nakhlites also contained elements necessary for life [1], therefore a consequence of this research is the identification of past habitable environments in post Noachian Mars.

Data Analysis Approach: 144 post Noachian-aged impact craters ≥7 km diameter and 14 smaller craters 3-7 km diameter were selected using the most recent Mars crater database [5] and the latest geologic map of Mars [6]. CRISM data for this subset of impact craters was then obtained.

Hyperspectral imagery (362–3920 nm; 544 bands) acquired by the CRISM instrument onboard Mars Reconnaissance Orbiter [7], was processed using the CRISM Analysis Toolkit ENVI extension [8] to remove instrumental, photometric and atmospheric effects, along with striping and spiking image artifacts. Summary products were then derived to highlight regions of interest, resulting in the extraction of spectra that were compared to reference library spectra for mineral identification [8,9].

Results: Results suggest that 3 impact craters (of various diameters) out of the 158 analysed show signs of hydrated minerals, whereas the rest exhibited a variety of spectral signatures not consistent with hydrated minerals (Figure 1 and Table 1) [10]. Although dust coverage is an issue in some regions, these findings are consistent with the general understanding of the Martian Amazonian-epoch.

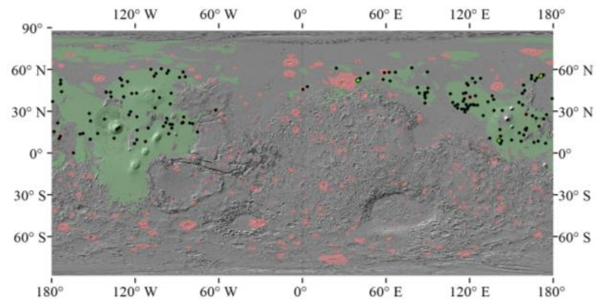

Figure 1. Grayscale MOLA map showing the impact craters analysed in this study. Amazonian-Hesperian terrains are highlighted in green, with Amazonian-Hesperian Impact (AHi) units highlighted in red (only AHi units overlying Amazonian-Hesperian terrains were considered in this study; map units from [9]). Black dots indicate impact craters that did not show hydrated minerals; green dots indicate impact craters that contain hydrated minerals.

Unnamed Crater in Ismenius Lacus: The unnamed impact crater central uplift shown in Figure 2 is located in Amazonian / Hesperian terrain [9], dated as 0.3 Ga with crater counts by [11]. Summary products derived from CRISM FRT0000BFA6 indicated absorptions at ~1.9 μm and ~2.3 μm in materials in the central structure, both in rocky materials and in alluvial fans on the central uplift of the impact crater (outlined in Figure 2). Further analysis of continuum-removed CRISM spectra (Figure 3) revealed a 1.92-1.94 μm absorption, indicating the presence of molecular H_2O, in addition to an absorption centred at 2.35 μm and a shoulder at ~2.2-2.3 μm for spectra of fan #1and megabreccia material. The spectra for the fan #1 material also has an absorption at ~1.48 μm that together with the other absorptions present in this spectra suggest the possibility of prehnite. For all spectra present in figure 3, the absorptions indicate the presence of Fe/Mg phyllosilicates, possibly Fe-serpentines or chlorites. A broad absorption centred near 1.25 μm indicates the presence of iron, either in an Fe-bearing igneous mineral or in the Fe/Mg phyllosilicate phase. The hydrous signatures are confined to the central structure, including probable megabreccia blocks, rocky alcoves at the head of each of the gullies, and alluvial fans (Figure 3) but do not extend on to the crater floor. Sands within the crater are enriched in mafic minerals.

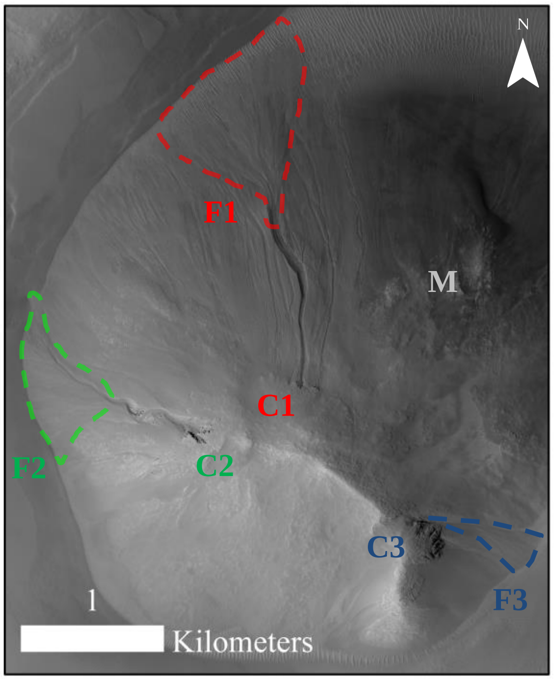

Figure 2. HiRISE PSP_009561_2325_RED showing gullies and fans in the central uplift of unnamed 20 km impact crater located in Ismenius Lacus, with areas of CRISM spectral extraction annotated. Fan 1 (F1), Fan 2 (F2) and Fan 3 (F3) are sized 0.73 km^2 (1817 CRISM pixels), 0.28 km^2 (705 CRISM pixels) and 0.14 km^2 (358 CRISM pixels), respectively. Megabreccia is denoted by M.

Conclusions: Gullies, alluvial fans, and uplifted breccia in the central uplift of an unnamed 20 km diameter impact crater (located at 52.42°N, 39.86°E in the Ismenius Lacus quadrangle) show spectral evidence for a chlorite or Fe-serpentine that may have formed through erosion and redeposition of impact-induced hydrothermal mineral assemblages during the Amazonian epoch, although the exposure of pre-existing secondary minerals cannot be completely ruled out. [10]

In summary, three out of 144 of these impact craters showed spectral features that suggest a hydrated mineralogy with some similarities to the nakhlite secondary mineralogy (Table 1) [10]. However, lack of clear spectral signatures, caused by small regions of interest and surface dust coverage, has hindered the investigation.

Crater Name	Latitude (°N)	Longitude (°E)	Diameter (km)	Crater Type
	8.93	141.28	50.77	Complex
	52.42	39.86	20.01	Complex
Stokes	55.62	171.29	62.49	Complex

Table 1. The three craters of interest, where CRISM analysis suggests a hydrated mineralogy.

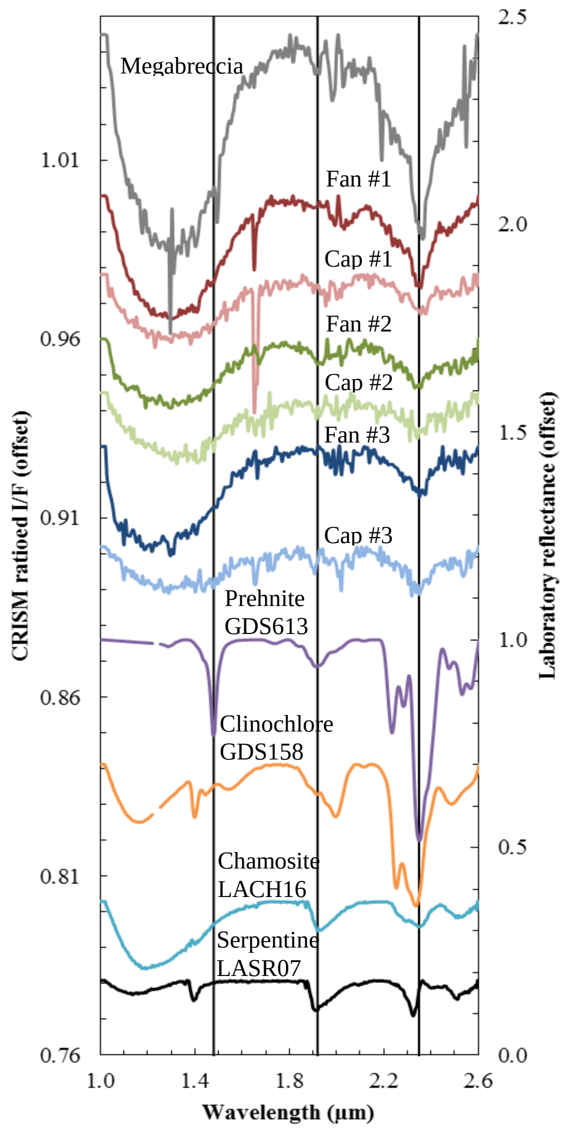

Figure 3. CRISM continuum-removed spectra extracted from FRT0000BFA6 of fans and megabreccia shown in figure 2 1.92-1.94 µm and 2.351 µm absorptions indicate the presence of chlorite / Fe-serpentine / prehnite.

References: [1] Bridges J. C. and Schwenzer S. P. (2012) *Earth and Planetary Science Letters, 359*, 117–123. [2] Swindle T. D. et al. (2000) *Meteoritics & Planet. Sci, 35*, 107-115. [3] Abramov O. and Kring D. A. (2005) *JGR, 110*, E12S09. [4] Schwenzer S. P. and Kring D. A. (2009) *Geology, 37*, 1091-1094. [5] Robbins S. J. and Hynek B. M. (2012) *JGR: Planets, 117*, E05004. [6] Tanaka K. L. et al. (2014) *USGS Sci. Inv. Map 3292.* [7] Murchie S. et al. (2007) *JGR, 112*, E05S03. [8] MRO/CRISM Data Users' Workshop (2012) LPSC. [9] Pelkey S. M. et al. (2007) *JGR, 112*, E08S14. [10] Turner S. M. R. et al. (2015), *JGR: Planets*, in rev. [11] Sun V. Z. and Milliken R. E. (2015) *JGR: Planets*, doi:10.1002/2015JE004918.