PARAUTOCHTHONOUS MEGABRECCIAS AND POSSIBLE EVIDENCE OF IMPACT-INDUCED HYDROTHERMAL ALTERATION IN HOLDEN CRATER, MARS. L. L. Tornabene[1], G. R. Osinski[2], and A. S. McEwen[1], [1]Lunar and Planetary Lab, University of Arizona, 1541 E. University Blvd., Tucson, Arizona, 85721, USA (livio@pirl.lpl.arizona.edu, [2]Dept. of Earth Sciences, University of Western Ontario, London, Ont., Canada N6A 5B7.

Introduction: Megabreccias have been recognized in meter-scale images from the High Resolution Imaging Science Expermiment (HiRISE) and are commonly associated with large (10's to 100's of km in diameter) craters [1, 2]. Terrestrial impact megabreccia is often, but not always, a poorly sorted deposit that is commonly lithified and consists of large (m-scale) angular to subrounded clasts [e.g., 3]. The geologic context of the Martian examples (i.e., often found associated with impact craters in Noachian terrains) suggests that they are likely impact megabreccias. Those that occur within central uplifts may generally consist of bedrock that pre-dates the impact, but possible produced by previous impacts. These deposits have been commonly associated with phyllosilicate phases detected by Compact Reconnaisance Imaging Spectrometer for Mars (CRISM) [2, 4-5]; however, to date, its not clear whether or not the alteration is a result of the impact event, post-date the event, or whether the phyllosilicates represent resampled altered materials uplifted and exposed by the impact event.

Here, we combine the hyperspectral capabilities of CRISM with the high resolution and signal-to-noise of HiRISE, and report on the detection of Fe–Mg phyllosilicates (CRISM) that are strongly correlated with dikes interpreted to be breccia injection dikes within parautochthonous megabreccias (HiRISE) originating from the deeply eroded and now well exposed basement of Holden crater. Our observations suggest that the alteration event is consistent with impact-induced hydrothermal circulation of fluids within the densely fractured basement of Holden.

CRISM and HiRISE: CRISM calibration, processing and spectral parameters as defined by [6] were used to assess the spectral variability in locations throughout Holden crater. These spectral parameters are sensitive to both undulations in CRISM spectra in addition to diagnostic absorptions indicative of altered and non-altered mineral phases. As a consequence, extraction and inspection of spectra from a CRISM cube are necessary steps to confirm the presence of a mineral class (e.g., phyllosilicates) or specific phase (e.g., nontronite). Once confirmed, we used a combination of Ground Control Points (GCPs) to warp a CRISM R-G-B spectral parameter image to HiRISE. Next, a Hue Saturation and Value (HSV) transform is used to overlay the color information precisely on a HiRISE red mosaic image [see 7]. This precise combination of the two datasets (despite the differences in spatial resolution) allows detailed morphological and spectral analysis to ascertain correlations between mineral detections from CRISM with meter-scale geologic features and infrared color (IRB) variations from HiRISE.

Holden Megabreccia deposits: We have inspected MOC and HiRISE images in and around Holden crater (326°E, -26°N, D~154 km) and have only observed megabreccia outcrops at two basic localties. These two localities are associated with Uzboi Valles, which breeches the crater rim on the southwest side of Holden. They are: 1) on the deeply incised wall-terrace region just within the crater [see 1] (325.23ºE, -26.91ºN), and 2) within Uzboi Valles just outside of Holden (324.68ºE, -27.45ºN – ~32 km from the rim).

Impactites can be classified based on their location within the crater and lithologic characteristic [e.g., 3]. Based on HiRISE color observations, we define one megabreccia unit (MBu) in Holden that can be divided into two basic types or facies: a megaclast facies and breccia dike facies – MCf and BDf, respectively. The indiviual clasts of the MCf have dimensions ranging from 10's to 100's of meters and appears to be monomict (i.e., a single rock type) parautochthonous breccia based on HiRISE color IRB images (Fig 1.).

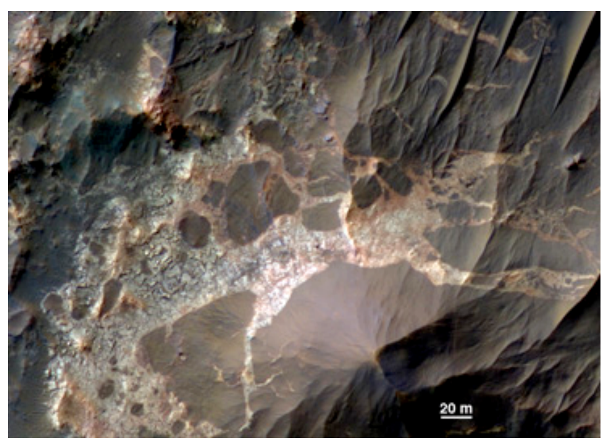

Fig. 1. HiRISE IRB color image (PSP_008338_1525) of outcrops of parautocthonous megabreccia (MBu) in Uzboi Valles ~x km from the rim of Holden crater.

The key to recognizing parautochthonous megabreccias, defined as a breccia formed virtually in place, includes: 1) incipient brecciation and a non-chaotic distribution of the megaclasts (i.e., MCf), 2)

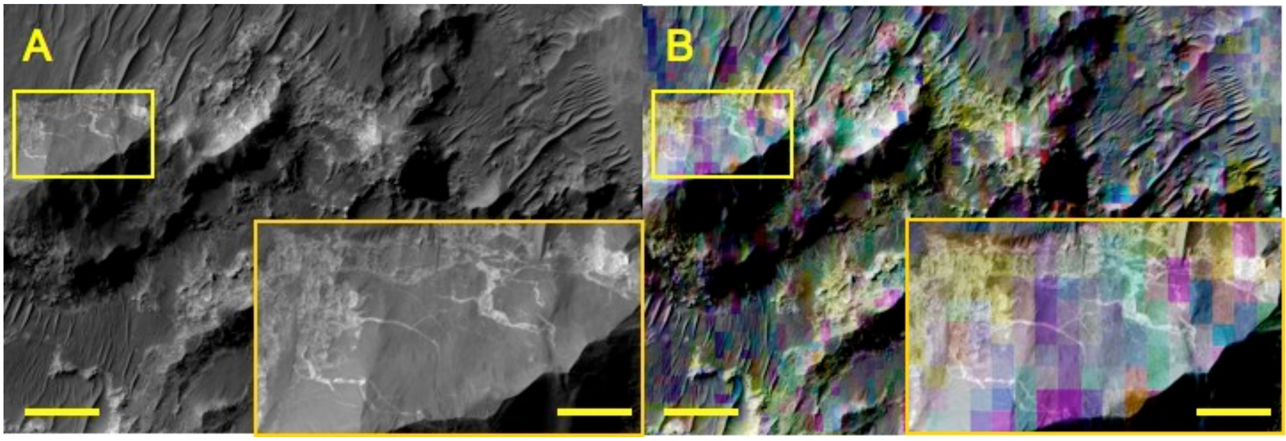

Fig. 2. Outcrops of parautocthonous megabreccia (MBu) in Uzboi Valles ~32 km from the rim of Holden crater. A) HiRISE (PSP_008338_1525) red mosaic of outcrops of MBu exhibiting incipient brecciation with megaclasts (dark) and dikes interpreted to be breccia injection dikes (light-toned with smaller darker clasts. B) CRISM spectral parameters 2300R, 1900R and 2100 in R-G-B overlain precisely on the HiRISE red mosaic. Areas of contiguous yellow pixels represent lithologies rich in Fe-Mg phyllosilicates while darker pixels represent unaltered mafic to ultramafic lithologies and aolian deposits (also observed by THEMIS). Yellow scale bars represent 100 and 25 meters, respectively.

the occurrence of smaller scale breccia injection dikes between the megaclasts (i.e., BDf), and 3) the location and horizon (or erosional level) within the crater [e.g., 3]. Incipent breciation manifests as breccia dikes that have only partially to fully propagated through a target lithology as to give the apperence of partial to fully formed megaclasts that are neither chaotic nor randomly mixed, but that can be "refitted back together" with the "closing" of the dikes (Figs. 1 & 2). Both locations of the MBu (both within and outside the crater rim) are located where Uzboi Valles has deeply eroded into the crater. Profiles derived from the MOLA gridded Digital Elevation Model (DEM) indicates that the MBu originated from at least ~1 km with up to ~2 km depth near the crater rim. The MBu outside of Holden would have originated from beneath the Holden ejecta (based on the incision depth of Uzboi with respect to the surrounding plains – i.e., Holden ejecta). The location of the MBu and such estimated depths (compared to estimates of ejecta thickness for a crater the size of Holden [8]) suggest that it is likely that in these two outcrops of the MBu represent the Holden crater basement (i.e., sub-crater floor), consistent with the occurrence of parautochthonous breccias in terrestrial craters [see Fig. 3.13 in 3].

The BDf appears to be a polymict breccia (multiple rock types) according to different color clasts observed in HiRISE IRB images. This is also supported by the detection of an olivine signature in THEMIS images, which like the CRISM phyllosilicate signature, correlates with MBu in THEMIS, but more specifically in the BDf and not in the MCf in HiRISE IRB images. This suggests that BDf may sample deeper sources in the target sequence.

Discussion and Conclusions: We suspect that remobilization and deposition of altered Noachian crustal and surface materials could be largely responsible for the clay signatures detected in Holden carter [1]. However, the exclusive occurrence of alteration phases, specifically Fe–Mg phyllosilicates (the most abundant hydrothermal phase in over 60 terrestrial impact structures [9-10]), within breccia injection dikes (BDf), and not within the megaclasts (MCf), along with the geologic context and evidence from terrestrial analogs, is consistent with alteration that most likely occurred following the formation of Holden and as a consequence of impact-induced hydrothermal alteration.

Impact-induced hydrothermal systems may have been critical habitat on early Mars. With Holden as one of the final Mars Science Lab (MSL) candidates, testing the potential of a such a setting would be consistent with one of the major goals of the mission (i.e., assess habitability).

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