CRATER-EXPOSED INTACT STRATIGRAPHY BLOCKS AND VOLCANOGENIC ORIGIN. C. Caudill[1], L. Tornabene[2], A. McEwen[1], [1]Lunar and Planetary Lab, University of Arizona, Arizona, USA (caudill@email.arizona.edu), [2]Center for Earth and Planetary Studies, Smithsonian Inst., Washington, D.C., USA.

Introduction: Typical terrestrial uplift and exposure of layered and stratified rocks are usually not oriented at a high enough tilt to easily infer their geometries from aerial or orbital remote sensing techniques. However, when layers are brought to the surface in crater central stratigraphic uplifts, they are tilted at such high orientations (>45) as to be useful for such determinations as thickness, strike, dip, etc. Here we use a variety of Martian datasets to identify (THEMIS IR, MOLA) and classify (CTX and HiRISE) these unique bedrock exposures and textures in Martian craters [1]. A global survey of 868 Martin craters reveals three distinct classifications of bedrock textures, which includes uplifted and overturned strata that are exposed from depth. Crater-exposed bedrock provides a unique opportunity to not only understand the underlying mineral compositions within the Martian crust, but also gain insight into past geologic processes of Mars. Of the 868 craters surveyed, 210 have bedrock outcroppings that are sufficiently exposed and extensive enough to determine their overall textures. Of these, we classified 39 as Intact layered Stratigraphy (IS) (i.e., uplifted and inverted bedrock consisting of strongly layered and intact blocks of stratigraphy with layers ranging from meter to decameter scales in HiRISE images as seen in Figure 1). As seen in Figure 2, a strong correlation exists between the location of IS craters observed and the major volcanic provinces and mapped Hesperian flood lavas and ridged plains (purple units), generally interpreted as flood lavas [2]. Here we couple the geologic context and textures observed from depth with the measurable thickness and cyclicity of the layers, which alternate between competent and less competent layers within a given uplifted megablock, to better understand and relate past geologic events and processes across vast regions of Mars.

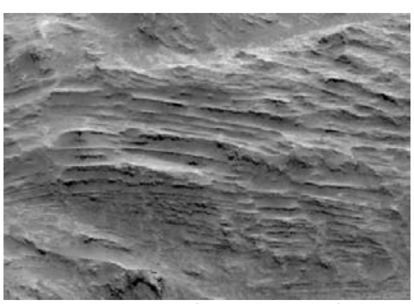

Figure 1. (A) Subset of HiRISE DTM of exposed bedrock in the central uplift of an unnamed crater (-16°N, 296°E), exhibiting intact layered stratigraphy (IS), also see Figure 3.

Depth measurements: By measuring the estimated depths of these bedrock textures based on crater scaling estimates and comparing with other classified textures observed (see abstract by L. Tornabene, et al.) we can make inferences regarding the spatial and temporal extent of volcanics, but also the geologic history of provinces including plutonic, impact, and volcanic events. Thereby, applying crater scaling relationships to IS craters ranging from ~10 – 125 km diameter provides a unique opportunity to make constraints on the extent and kilometer-scale thicknesses of volcanics in these provinces.

During formation of complex craters, bedrock is brought to the surface from an estimable depth in central uplifts [4]. The estimate for stratigraphic uplift (SU) used here is SU=0.086D^1.03, where D is the final rim diameter [5]. The SU estimate is then subtracted from the average height of the crater central uplift as estimated from MOLA elevation data to derive a baseline sampling. We have evaluated bedrock depths for crater central uplifts globally and compared them on a regional basis to assess the upper and lower limits of observed bedrock textures. Preliminary assessments include the volcanics in Hesperia Planum, in which we used 4 HiRISE images. As expected, a thick section of IS is found near Tyrrhena Patera in Hesperia Planum, where Trinidad crater (D=29.5km, -23°N, 109°E) was found to sample IS in HiRISE image PSP_009427_1565 at a depth of -2819.5m. To the west, two other craters in Hesperia Planum expose IS as seen in HiRISE image ESP_017603_1550 (D=34.9km, -25°N, 95°E) and ESP_018895_1540 (D=14.3 km, -26°N, 101°E), where the volcanics are expected to be thinner is measured as -2290.0m and -821.25m, respectively. A fourth nearby crater, also west of Hesperia Planum, (D=34.1km seen in PSP_007252_1615 at -19°N, 99°E) does not sample IS, but now samples MB (Megabreccia). The lack of IS exposed here, as well as the lack of IS exposure continuing west from Hesperia Planum, suggests that this crater has sampled outside of the volcanics of this region. Although our study is limited by available bedrock outcroppings, such craters may represent geographic extent of the underlying volcanics. The depth measured for this re-sampled MB is -2632.0m, indicating a lower limit for the depth of lava stacks in the western portion of this region.

Similarly, depth and geographic boundaries are defined by craters in Bosphorous Planum, at the transition between the mapped Hesperian-aged flows [3] south of Valles Marineris and heavily cratered Noachis Terra to the east. Fractured Bedrock (FB) is estimated to originate from depths of -8807.0m (D=79.1km, -29°N, 309°E) to -1871.25m (D=28.3km, -20°N, 307°E), while Megabreccia (MB) is estimated to originate from -1549.0m (D=22.2km, -36°N, 302°E), possibly marking the southern geographic extent of the flow in this narrow region, and then IS being re-sampled between -1454.5m (D=18.7km, -29°N, 305°E) and -1092.0m (D=15.4km, -30°N,

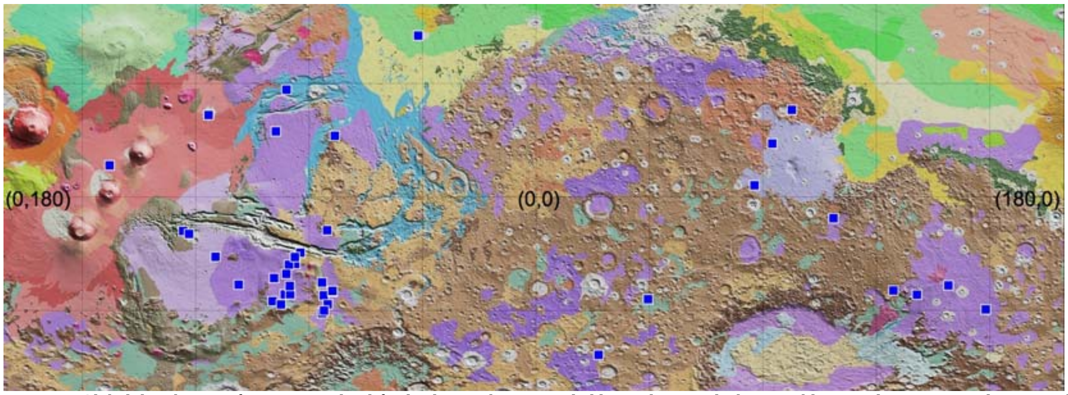

Figure 2. Global distribution of crater central uplifts displaying the re-sampled layered material, shown in blue, overlain onto a geologic map [3]. Purple units are Hesperian ridged plains and reddish units are Amazonian volcanics.

304°E). These estimates indicate that massive-textured bedrock, possibly plutonic, is at greater depths represented by FB, and then MB suggests heavily cratered terrain being re-sampled from intermediate depths, followed by volcanics represented by IS.

Bedding cyclicity and thickness measurements: The cyclic nature of the IS is clearly recognizable as alternating higher-standing and lower-standing layers throughout the length of the intact block. The apparent differences in height are suggested to be a function of the difference in competency of the materials and their relative resistance to erosion post-exposure. Measurements of this apparent competency are one way that we can relate these layers over a region as well as globally. Here we use the spatial information taken from a HiRISE DTM (1m/pixel resolution) of Martin crater (D=58.5km, -21°N, 291°E) analyzed as elevation profiles across IS outcroppings where a line was fitted to the competent, high-standing layers. When analyzed with a structural map of Martin [6], preliminary results suggest that bedding orientations measured at a dip of 45 degrees or less have an average deviation from the line of 7.39m for the less competent, more eroded alternate layers. Figure 3 shows a diagram of this process for an unnamed crater ~400km NE of Martin with less competent layers deviating an average of 7.74m, which closely matches thereby suggests a common origin for the IS materials sampled in both craters.

The thickness of the bedding of these inverted IS blocks provide another means of determining if the layers are of similar or differing origin within and across regions. The availability of HiRISE-derived DTMs, which are best for such measurements, is currently limited. In this study, we are seeking to derive bedding orientations and thicknesses from HiRISE image stereo pairs, wherein mapping layers can yield the 3-D spatial information. In addition to analyzing the morphology, we will undertake CRISM spectral analysis to determine mineral and lithologic compositions, in the hopes of gaining inferences into whether composition can place further constraints of the relationships of layers over broad areas.

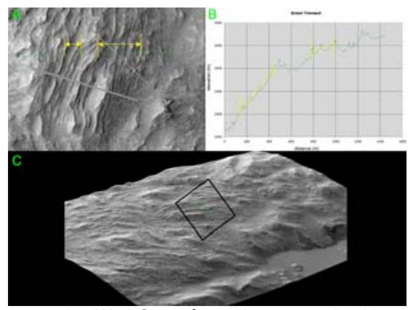

Figure 3. (A) Subset of HiRISE image PSP_005201_1640, peak pit of unnamed crater. Profile drawn across a unit of cyclic competent and less competent layers. Yellow arrows indicate two sections of this unit, which are grouped based on a consistent slope within each section created by underlying topography. (B) Elevation profile of the green transect shown in the image (A) and overlain on the DTM (C) based on HiRISE stereo pair PSP_005913_1640. Yellow lines again indicate the two sections of layers used for competency measurement.

Spectral signature comparisons: Using the CRISM spectral summary products, we have begun to make a preliminary VNIR spectral assessment of IS exposed craters in Tharsis and Kasei Valles, including Oudemans crater in Valles Marineris. Oudemans crater (D=123.5km, -9°N, 268°E) and Fesenkov crater (D=86.1km, 21°N, 273°E), though 1900km apart, both sampling several km in depth, show similar patterns in spectral summary parameter images, which indicates the presence of olivine, LCP, and HCP, accompanied by weaker signatures of phyllosillicates. These need to be verified with further detailed analysis (extraction of spectra), but if these phases are indeed present, it may suggest (coupled with other measurements in this study) that an early period of voluminous volcanic resurfacing is being re-sampled at a depth of up to ~8km depths and may span up to or greater than 2000km in distance, laying down layers that are cyclical, of similar thickness, and alternating in competency.

References: [1] Tornabene et al. (2010) *LPSC* 41, #1533. [2] Tanaka, K.T., et al. (1992) in Mars, Kieffer et al., Eds. 345-382. [3] Skinner et al. (2006) *LPSC* 37, #2331. [4] Wunnemann and Ivanov (2003) *Planetary and Space Science*, 51, 841. [5] Cintala et al. (1998) *Meteoritics and Planetary Science* 33, 1343. [6] Poelchau et al. (2009) *Journal of Geophysical Research Planets*, 114, 14.