A CRATER-EXPOSED BEDROCK DATABASE FOR MARS WITH APPLICATIONS FOR DETERMINING THE COMPOSITION AND STRUCTURE OF THE UPPER CRUST.

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Introduction: We are compiling a database (DB) of crater-exposed bedrock (CEB) on Mars using data primarily derived from instruments on the Mars Reconnaissance Orbiter (MRO). This DB is based on a previous effort to document megabreccias (MB) [1,2] observed in High Resolution Imaging Science Experiment (HiRISE; ~25 cm./pixel) and Context Camera (CTX; ~5 m/pixel) images [3,4]. The current CEB DB consists of 150 entries spanning 60˚N to 50˚S and includes terrains of all types and ages. This evolving DB will be key to understanding the origin and geology of the upper Martian crust, and specifically towards deciphering spectral units derived from the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) [5] dataset, which suggests aqueous alteration products specifically correlate with CEB – some of which may represent some of the oldest rock exposures on the surface, recording early conditions on Mars [2]; the CEB DB is currently being used to study the volcanic history of Mars [6] and to study some of the oldest exposures of unaltered bedrock materials [7].

Database summary: Detailed examinations of HiRISE images covering central uplifts (CUs), including some of the entries in the previous MB DB, revealed that MBs are not always the most abundant expression of CEB. In addition to MB, massive fractured bedrock (FB) and intact-layered stratigraphy (IS) (or Layered Megablocks - LMB [6]) are also observed. For this reason, the MB DB evolved into the CEB DB and specifically records the expression of these textures in CUs. In addition to CEB texture, we are augmenting the information in the emerging DB by noting geographic region, geologic unit, exposure, CU type, and spectral categories. Geologic units are based on the predominate surface geologic unit that the exposing crater occurs within [8]. "Exposure" is a subjective assessment of how well exposed and recognizable the CEB texture is: "very good", "good", or "fair". We include Dust Cover Index (DCI) [9] to assess our qualitative exposure category. CU types include peak, peak pit (summit pit), pit and complex (i.e., difficult to determine as one of the former). Spectral characteristics are specifically based on the IR (1.00-3.92 microns) spectral summary products derived from high-resolution (~18-36 m./pixel) hyperspectral (438 IR bands) CRISM targeted observations (FRT, HRL, HRS). The summary products include indices for the preliminary identification of mafic (e.g., olivine and pyroxenes), and hydrated phases (e.g., phyllosilicates, hydrated sulfates, etc.) [9]. Instead of recording whether each parameter indicates the presence of a specific phase, we document the spectral character for each summary product (e.g., "strong", "diffuse", or "no" for no detection). Note that these detections from the summary products recorded in the DB are not validated until cube-extracted spectra are inspected and analyzed in detail. We are also including a notes category in the DB to include any addition information that is pertinent to geologic interpretations (e.g., presence of features such as impact melt deposits, dikes, etc).

Discussion & Results: Studies of terrestrial craters show that the bulk of the underlying rocks of the CU originate from rocks that are displaced and uplifted from their original place in the pre-impact stratigraphy (a.k.a., parautochthonous). As such these rocks generally reflect and preserve the bulk of the original structures and textures of the target despite impact-induced fracturing, faulting, rotations, in-place/incipient brecciation, and the injection of impact melt and breccia dikes [10]. Thus, CUs provide an excellent means to observe bedrock, especially on a planet where craters are abundant and tectonic exposures are scarce, but also they provide the most convenient means to observe layered materials from orbit due to the crater-related faulting and rotations, which orient layers to almost vertical positions [6, 11]). However, with the exception of easily identified layering, there are some complications with identifying CEB textures from orbit, especially with respect to the FB and MB classes. In addition to the aforementioned dikes, bedrock of the CU is often coated by impactites, which are captured during the formation of the uplift as it arises from the impact melt- and breccia-lined transient cavity floor. Based on our observations, most craters on Mars do not have well-exposed bedrock due to obscuration by impactites, but also a variety of factors including dust mantling, aeolian deposits, and other mantles or deposits. Thus, it is important to distinguish impact-related (allochthonous) and post-impact deposits on CUs from pre-impact bedrock (parautochthonous) when determining the CEB texture. Stereo-derived anaglyphs and Digital Terrain Models, were key to make such determinations based on the observed textures, morphologies and stratigraphic relationships between the deposits and bedrock exposed on CUs.

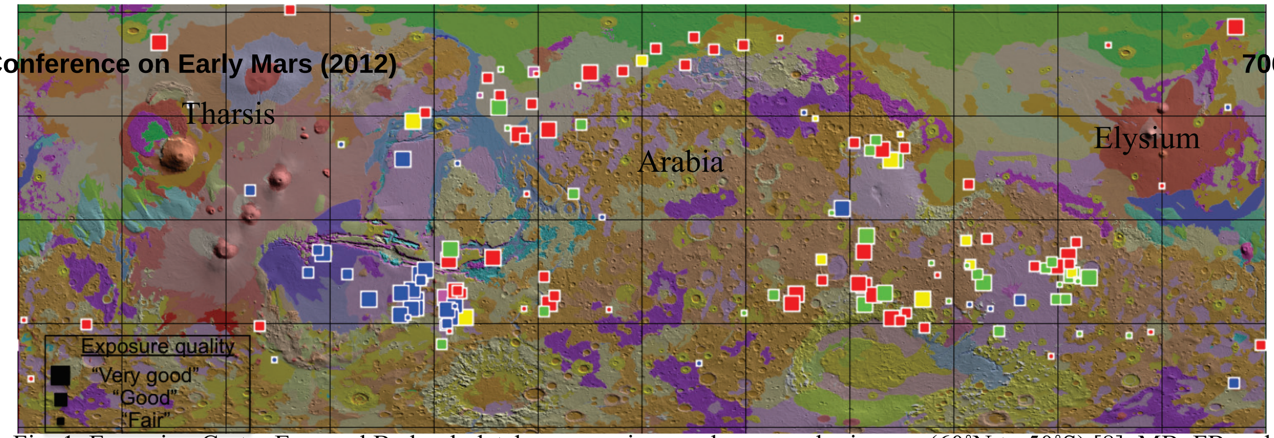

Fig. 1. Emerging Crater Exposed Bedrock database superimposed on a geologic map (60˚N to 50˚S) [8]. MB, FB and IS are color-coded as green, red and blue, respectively. Yellow (R+G) and Magenta (R+B) represent mixed textures of the former. Three sizes of squares are used to indicate the exposure category (largest = "very good", smallest = "fair"). The lack of CEB detections in heavily dust-mantled regions (e.g., Arabia) is apparent in the emerging DB.

Despite its subjectivity, the quality and extent of exposure category in our DB is key as a qualifier for the texture identification of each CEB DB entry. Although dust is not solely responsible for obscuration of CUs on Mars, DCI was used to provide some quantitative constraints on our exposure category. Average DCI is in general agreement with our qualitative exposure assessments as the average decreases from "very good" (0.973), to "good" (0.967), to "fair" (0.956) (Note: Low DCI suggests higher dust concentrations [9]). This is consistent with an increase in obscuration from "very good" to "fair".

Fig. 1 shows the current state of the CEB DB, which currently contains 150 entries carefully assessed in the above fashion. The texture of parautochthonous rocks in CUs is not only informative with respect to the pre-impact target structure and stratigraphy, but also appears to correlate with the overall geology and impact history of a locale or region. For example, MB occurrences are generally consistent with craters into heavily impacted surfaces. Over 77% occur in heavily cratered Noachian terrains, while the remaining 22% are craters into lavas or plains materials that are overlaying or embaying heavily cratered ancient terrains. Fifty perecent of IS craters occur specifically within the Hesperian Ridged plains unit (Hr), and an additional 25% occur in terrains interpreted to be lavas or volcanic in origin. As such, we suggest that areas of infrequent impacts and rapid emplacement of volcanics or sedimentary deposition appear to be key to the occurrence of IS [6]. FB occurs within a variety of circum-volcanic and -basin terrains spanning all ages, and interestingly appears to dominate the northern plains.

As an example of how even a single crater can shed some insight into the local/regional geology, we present here a summary of the 40-km Toro crater [12]; Toro occurs within the northernmost volcanic flows of Syrtis Major and ~150 km (or ~3 crater diameters) south of the ancient bedrock exposures of the Nili Fossae region. The crater possesses extensive MBs in the CU, but also includes a large (D~500 m) megablock of IS in the outer portion of the eastern CU complex and exposed in wall-terraces. This suggests that layered materials comprise the uppermost portions of the pre-impact target, with ancient, previously brecciated materials likely comprising the lower (deepest) portion of the target. This is supported by the regional geology and stratigraphy (i.e., Syrtis Major layered volcanics unconformably overlying ancient bedrock of Nili Fossae – some of which may represent impact-churned Isidis ejecta materials [13,14]).

Conclusions & Future work: Bedrock exposed in the CUs of Martian craters can provide pre-impact target structure and stratigraphy, and reflect the overall geology and impact history of a locale or region. Crater scaling relationships will be used to shed further insights into the spatial relationships of the textures expressed in CUs, and their relationship to surface geology, if any. The observations from these central peaks are also expected to be informative with respect to the impact process as well (e.g., uplift formation and impactite emplacement).

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