HIGH-RESOLUTION TEXTURAL, STRUCTURAL AND SPECTRAL CHARACTERISTICS OF CRATER-EXPOSED BEDROCK ON MARS: INSIGHTS IN TO THE PETROGENESIS, STRATIGRAPHY AND GEOLOGIC HISTORY OF THE MARTIAN CRUST.

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Introduction: On Earth, geologists heavily rely on uplifted and exposed bedrock at the surface to access older rocks than those currently present or recently formed in the near surface environment. Because older, underlying rocks form under a variety of geologic settings and conditions, the mineral composition, texture, structures and stratigraphic relationships of such uplifted and exposed bedrock provide geologists the means to access information about the past geologic and climatic history. Typically, tectonic events and erosional processes exposes thick sections of older terrestrial rocks at the surface. On Mars, a lack of complex tectonics and lower erosion rates make tectonic exposures rare to virtually non-existent. Impacts, however, generate localized displacements and structural uplift of target rocks that exposes bedrock within the crater rim, walls, terraces and central structural uplifts. Imagery from the High Resolution Imaging Science Experiment (HiRISE) [1] of this "Crater-Exposed Bedrock" (CEB) reveals unprecedented meter to decameter textural and structural detail [2]. In this study we are seeking to ascertain the spatial and temporal distributions of CEB textures and compositions on a global scale and attempt to characterize them lithologically. Our initial work revealed that not all craters are well exposed (due to impact melt coatings and ongoing degradation, infilling, and mantling of crater rims, floors and walls) [2-4], and because texture identification is a function of the quality of exposure, our primary objective is to construct a deteailed database (DB) of craters with fair to excellent exposures. As such, the emerging global CEB DB will be specifically used to focus on spectral units that specifically correlate with CEB textures, structures and stratigraphic relationships, with emphasis on data from the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) [5] in order to identify possibly lithologies and their relationships at a local, regional and global scale.

The results from our preliminary CRISM survey indicates that both unaltered mafic signatures and aqueously altered phases correlate correlate with CEB. In regards to aqueous alteration, it is vital importance to note, and try to delinate, alteration that either predates or post-dates the exposing crater's formation; however, a recent detailed study reveals that altered materials may both pre- and post-date crater formation [6]. We hope to further investigate this issue in particular via multiple examples and detailed analyses similar to those in [6]. We also note here that some of these CEB lithologies, altered or unaltered, may represent some of the oldest rock exposures on the surface, and thus record early conditions on Mars [4]. Therefore, our resulting CEB database will also be useful for seeking early alteration on Mars as well as the identification of the oldest unaltered exposures of crustal materials (see our companion study by Skok et al. [7]).

From megabreccia (MB) to CEB DB: Martian MBs are fragmental, typically poorly sorted deposits that consist of large (m- to dkm-scale) angular to subrounded lithic megaclasts in a fine-grained matrix. Initially, any HiRISE [1] or Context Camera (CTX; ~5 m/pixel) [8] image containing what appeared to be MB were noted and was then later input into a digital DB to note their regional and global distributions. We also initiated a global systematic survey (ongoing) of central peaks that appear warm in the THEMIS nighttime thermal infrared (nTIR) global mosaic [9] for the identification of additional candidate CEB. Any candidate lacking HiRISE or CTX coverage is kept in a separate DB and also entered into the HiRISE targeting DB via the web-based targeting tool [10].

The CEB DB. Detailed examinations of HiRISE images covering the entries in our intital MB DB revealed that MBs are not always the most abundant expression of CEB, although its important to note that some MB is always present in the form of crater-formed MB (i.e., not resampled MB that existed before crater formation). In addition to MB, our preliminary results suggest that CEB can be classified into two additional basic textural categories, 1) Intact layered Stratigraphy (IS), and 2) a massive textured Fractured Bedrock (FB). For this reason, the MB DB evolved into the CEB DB. In addition to CEB texture, we are augmenting the emerging DB by also noting secondary textures, geographic region, occurrence, exposure, extent and spectral categories. "Occurrence" records the CEB morphologic features that contain the exposures (central uplift, etc.). "Exposure" is a subjective assessment of how well exposed and recognizable the CEB texture is in terms of "excellent", "good", fair, or "poor". We recognize the qualitative and subjective nature of this category, and therefore we are currently seaking ways to quantify this particular attribute by including a measurement of the exposures "extent" (e.g., area of the exposure vs. the area of the crater or central peak). Spectral characteristics are specifically based on the IR (1.00-3.92 microns) spectral summary products [5, 11] derived from high-resolution (~18-32 m./pixel) hyperspectral (438 IR bands) CRISM gimbaled 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.) [5,11]. Instead of indicating whether a individual parameter indicates the presence of these phases, we are recording the spectral character for each summary product (e.g., "strong", "weak", "diffuse", or "no" for no detection). Note that the presence of a signal in one of these summary products is not validated until cube-extracted spectra are inspected and analyzed in detail [5,11]. However, the summary parameters provide a rapid means to be able to focus on the craters with the best spectral signatures for further detailed analysis. 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 impact melt deposits, small patches of other bedrock types).

Discussion: *Preliminary insights into the geology of the upper crust:* The general significance of the distinction of CEB textures is that we can gain some insights into the provanace and origin of certain texures based on there location, or oocurrence in the crater. For example, MBs are not usually extensive in crater rims, wall-terraces and central uplifts in terrestrial impact structures. The rocks exposed in these areas represent the parautochthonous zones of the crater [12,13], which is characterized by bedrock that has been displaced and uplifted from their original place in the pre-impact target. These rocks generally preserve most of their original structures and textures as they generally suffer from lower shock decompression resulting in fracturing, faulting, rotations and some in-place/incipient brecciation [12]. Therefore, the differences in the texture of these parautochthonous zones of an individual crater, or groups of craters, are not only informative with respect to the pre-impact target structure and stratigraphy, but also the overall geology and impact history of a locale or region. The 40-km Toro crater provides a good example [6]; Toro occurs within the northern most 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 central peak, but also includes a large (D ~500 m) megablock of IS in the outer portion of the eastern central uplift complex and exposed in wall-terraces. This suggests that layered materials (likely volcanic) comprise the uppermost portions of the preimpact target, with ancient, previously brecciated materials likely comprising the lower (deeper) portion of the target. This is supported by the regional geology and stratigraphy (i.e., Syrtis Major layered volcanics conformably overlying ancient bedrock of Nili Fossae – some of which may represent impact-churned Isidis ejecta materials [14,15]).

The FB texture was initially confused as MBs, as many exposures of CEBs are patchy due to surface coatings (e.g., impact-melts are noted to drape/coat central uplifts). At present, the distribution of MB and FB is still being re-assessed. Also, we are carefully noting that some MBs is expected due to brecciation along faults, mass wasting, and fall-back breccia deposition, as well as the emplacement of breccia dikes into the rocks of the parautochthonous zones [12,13]. Such distinctions are currently being noted and recorded in the new CEB DB via use of HiRISE or CTX anaglyphs or DTMs.

Our emerging CEB DB also indicates a group of IS craters (Ds ~15-120 km) within and on the outskirts of southeast Tharsis (Thaumasia, Solis and Sinai) as well as other volcanic regions (e.g., Hesperia Planum). Our preliminary interpretation of this cluster of IS craters is that it represents a sequence of layered volcanics (pyroclatics, ash and lavas) that were deposited in these regions during a period of high effusivity and lowe impact frequency. When the exposing craters formed, instead of sampling deep-setaed plutonic rocks or heavily cratered materials, they sampled layered lithologies in their central uplifts (see HiRISE images of Oudemans, Martin or Mazamba) [see companion abstract by C. Caudill, this conference].

Our preliminary results demonstrate that trends in the spatial distributions CEB may be used to not only assess subsurface composition, but also as a "window" into regional and global geologic histories. Each textural classification is informative with respect to a specific geologic setting or possible set of histories (e.g., late-heavy bombardment, cyclical volcanism and sedimentation). Therefore, we predict that as our DB continues to gain statistical significance, we be able to make inferences regarding the petrogenesis, evolution and geologic history of the upper Martian crust at regional and possibly global scales. As such, CEB sites may prove to be exceptional targets for future lander, roving missions or even sample return.

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