

A CRATER-EXPOSED BEDROCK DATABASE FOR MARS WITH APPLICATIONS FOR DETERMINING THE COMPOSITION AND STRUCTURE OF THE UPPER CRUST. L. L. Tornabene¹, A. S. McEwen¹, C. Caudill¹, G. R. Osinski², J. J. Wray³, G. A. Marzo^{4,5}, J. F. Mustard⁶, J. R. Skok⁶, J. A. Grant⁷, and S. Mattson¹, ¹LPL (University of Arizona, Tucson, AZ; livio@pirl.lpl.arizona.edu), ²Dept. of Earth Sciences (University of Western Ontario, London, ON), ³Dept. of Astronomy (Cornell University, Ithaca, NY), ⁴Bay Area Environmental Research Institute (Sonoma, CA), ⁵NASA Ames (Moffett Field, CA), ⁶Dept. of (Brown University, Providence, RI), ⁷CEPS, (Smithsonian Institute, Washington DC).

Introduction: We are compiling a database (DB) of crater-exposed bedrock (CEB) on Mars using data primarily derived from instruments on Mars Odyssey (MO) and 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) images (~25 cm./pixel) [3]. Not all craters have well-exposed bedrock due to a variety of factors (e.g., degradation, infilling, dust mantling, surface coatings, impact melt coatings, other deposits, etc.), making a DB of the craters that do have good exposures is a first step. The new CEB DB will be used to understand the origin and geology of spectral units derived from the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) [4] dataset, which suggests aqueous alteration products specifically correlate with CEB – some of which may represent some of the oldest rock exposures on the surface, and thus recording early conditions on Mars [2]; the CEB DB will also be used in a companion study by Skok et al. [5] to study some of the oldest exposures of unaltered materials.

From 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 or Context Camera (CTX; ~5 m/pixel) [6] 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 [7] for the identification of additional candidate CEB. Any candidate lacking HiRISE or CTX coverage is entered into the HiRISE target DB via the web-based targeting tool [see 8].

The CEB DB. Detailed examinations of HiRISE images covering 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 stratigraphy (IS) have also been observed. For this reason, the MB DB evolved into the CEB DB as the expression of these textures in crater rims, wall-terraces or central uplifts, gives us an indication of the pre-impact target stratigraphy and geologic history. In addition to CEB texture, we are augmenting the emerging DB by noting geographic region, occurrence, exposure 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”. Spectral characteristics are specifically based on the IR (1.00-3.92 microns) spectral summary products [9] 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.) [9]. 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”, “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 impact melt deposits, small patches of other bedrock types).

Discussion: *Preliminary insights into upper crustal structural:* The general significance of the distinction of textures in CEB is that 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 [10,11], typically 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 fracturing, faulting, rotations and in-place/incipient brecciation [10]. 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 (e.g., heavily impacted area – MB; areas of infrequent impacts and rapid deposition – IS). The 40-km Toro crater provides a good example [12]; 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

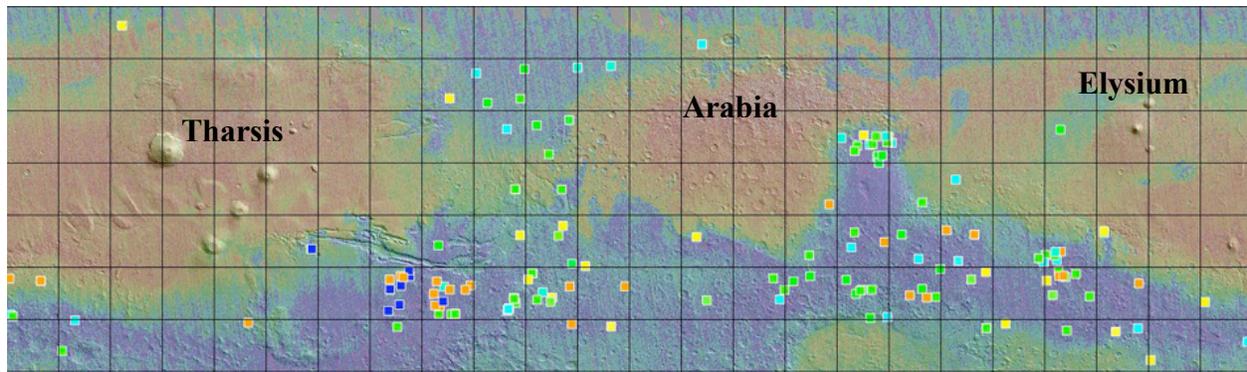


Fig. 1. Emerging Crater Exposed Bedrock database superimposed on TES-derived dust cover index and MOLA shaded relief map (60°N to 45°S). MB, FB and IS are color-coded as green, light blue and blue, respectively. Yellow squares represent poor exposures, which are examples that are difficult to make a positive identification of the bedrock texture. Orange squares (27) are candidates currently targeted for HiRISE acquisition. The lack of CEB detections in dust-mantled regions is apparent in the emerging DB.

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 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 conformably overlying ancient bedrock of Nili Fossae – some of which may represent impact-churned Isidis ejecta materials [13,14]).

Fig. 1 shows the current state of the CEB DB, which currently contains 161 entries. In many cases, FBs were initially confused as MBs, as many CEBs are generally patchy due to various types of surface coatings (e.g., impact-melts are often noted to drape/coat central uplifts of well-preserved craters). At present, MB (green) entries are still being re-assessed; at the time of writing, we've only re-examined ~25%. Also, we are taking note that some MBs are always expected associated with the crater central peaks due to brecciation along faults, mass wasting, fall-back breccia deposition, and also the emplacement of breccia dikes into the rocks of the parautochthonous zones [10,11]. Such distinctions are currently being noted and recorded in the new CEB DB.

The emerging CEB DB indicates a group of eight craters (Ds ~15-120 km) bearing IS (blue) in their central uplifts occur in outskirts of southeast Tharsis (Thaumasia, Solis and Sinai). Our preliminary interpretation of this cluster of IS craters is that layered volcanics (pyroclastics, ash and lavas) deposited in these regions occurred relatively rapidly during a period of less frequent impacts. When these craters formed, instead of sampling heavily cratered materials (i.e., a megaregolith/megabreccias), they sampled layered materials in their central uplifts (see HiRISE images of Oudemans, Martin or Mazamba). Based on

Oudemans, Martin or Mazamba). Based on crater scaling [11], the deepest materials in their central uplift originated from a maximum depth of ~1.3-11.9 km.

Preliminary Spectral Analysis: One of our primary goals, is to assess whether hydrated silicate spectral signatures associated with CEBs are re-sampled pre-existing target materials, the result of impact-induced alteration, or both [see 15]. We have commenced an in-depth CRISM spectral analysis of some of the CEBs from a subset of craters spanning several regions across Mars. Preliminary analysis indicates the presence of a variety of both unaltered mafic materials (both high and low calcium pyroxenes, olivine) and hydrated silicates (Fe-Mg smectites, chlorite/prehnite, Al phyllosilicates, zeolites and hydrated amorphous silica or opal). We will present the final results from our analysis at the conference.

References: [1] Grant J. A. et al. (2007) *Geology*, 36, 195–198. [2] McEwen A. S. et al. (2008) *AGU*, P43D-03. [3] McEwen A.S. et al. (2007) *J. Geophys. Res.*, 112, doi: 10.1029/2005JE002605. [4] Murchie S. et al. (2009) *J. Geophys. Res.*, 114, doi:10.1029/2009JE003344. [5] Skok J. R. et al. (2009) *LPSC XLI, this conf.* [6] Malin M. C. et al. (2007), *J. Geophys. Res.*, doi:10.1029/2006JE00280. [7] Christensen P. R. et al. (2004) *Space Sci. Rev.*, 110, 85-130. [8] Beyer R. et al. (2009) *LPSC XLI, this conf.* [9] Pelkey S. M. et al. (2007) *J. Geophys. Res.*, 112, 10.1029/2006JE002831. [10] French B. (1998), *LPI-Contribution*, #954. [11] Melosh H. J. (1989), *Oxford press*, 345 pp. [12] Marzo G. A. et al. (2010) *ICARUS*, submitted Oct 2009. [13] Tornabene L. L. et al. (2008) *J. Geophys. Res.*, 113, doi:10.1029/2007JE002988. [14] Mustard J. F. et al. (2009) *J. Geophys. Res.*, doi:10.1029/2009JE003349, in press. [15] Tornabene L. L. et al. (2009) *LPSC XL # 1766*.