RECOGNITION AND CHARACTERIZATION OF CONTINUOUS DEPOSITS OBSERVED BEYOND LAYERED EJECTA RAMPARTS ON MARS. L. L. Tornabene[1], J. L. Piatek[2], N. G. Barlow[3], R. Capitan[1], A. S. McEwen[4], G. R. Osinski[1,5], S. J. Robbins[6], W. Watters[7], [1]Centre for Planetary Science and Exploration and Dept. of Earth Sciences, University of Western Ontario, 1151 Richmond Street, London, ON N6A 5B, (ltornabe@uwo.ca), [2]Dept. of Geological Sciences, Central Connecticut State Univ., New Britain, CT, [3]Dept. Physics and Astronomy, Northern Arizona Univ., Flagstaff, AZ, [4]LPL, University of Arizona, Tucson, AZ, [5]Dept. of Physics and Astronomy, University of Western Ontario, London, ON, [6]Southwest Research Institute, Boulder, CO, [7]Dept. Astronomy, Whitin Observatory, Wellesley College, Wellesley, MA.

Introduction: Continuous ejecta deposits are generally divided into two main morphologic types: "radial" and "layered". While radial ejecta represents the most common morphologic type on the Moon and Mercury [1], layered ejecta is the most dominant morphology for well-preserved craters on Mars (>90% for craters ≥ 5 km in diameter) [2,3]. Volatile or ice content within (or on) the target [e.g., 4], and/or effects from interactions between the ejection process with the atmosphere [e.g., 5], have all been proposed to explain the resulting layered ejecta morphology. Layered ejecta is also distinct from radial with respect to its morphometric profile [e.g., 6] including a distinctive terminal edge that manifests as a ridge or scarp, commonly referred to as a "rampart" [4,7-8]. Importantly, the layered ejecta rampart has often been assumed to be the terminus of the continuous ejecta and the start of discontinuous ejecta deposits.

Here we report on the recognition and characterization of subtle, relatively thin, but continuous deposit that flow off of, and terminate well beyond (up to 5 crater radii) the layered ejecta rampart of several of the best-preserved craters on Mars.

Background and General Methods: Emphasized in this abstract are observations and morphological mapping results based on HiRISE [9] and CTX [10] images for two of the best-preserved simple-to-complex transitional Single Layer Ejecta (SLE) craters on Mars: Resen and Noord. Resen is approximately 7.6 km in diameter and located in Hesperia Planum (108.88°E, 27.94°S). Noord is approximately 7.8 km in diameter and located in Noachis Terra (348.74°E, 19.27°S). These craters were selected based on the general characteristics outlined in [11-13], including similar sizes, different target materials (i.e., Hesperian-ridged plain materials – Resen; heavily-cratered higlands – Noord) and because they are two of the best-preserved craters that have experienced minimal post-impact degredation for their size class.

Although we emphasize results from the completed morphologic mapping of Resen and Noord here, we emphasize that similar patterns in HiRISE and CTX images of additional well-preserved craters on Mars have also been observed (~11 craters thus far; *e.g.*, Gratteri, Zunil, Corinto, Tooting, etc.). Improving HiRISE coverage and more detailed examinations of these craters are underway, so we include only some initial measurements of the extent of their "Beyond-Rampart Continuous Ejecta" (BRaCE) facies herein.

Beyond-Rampart Continuous Ejecta (BRaCE): Observations based on HiRISE images show that abundant flows that emanate from what are interpreted to be volatile-rich impact melt-bearing deposits that lie atop well-preserved layered ejecta (LE) blankets [14; see Fig. 16]. These abundant flows appear to coalesce into a continuous off-rampart deposit that is generally characterized as: relatively thin, smooth, sinuous and gently undulating with various quasi-radial features. There are three quasi-radial features observed associated with BRaCE: dense clusters of depressions, hummocky "islands" or patches, and lineaments with the best examples of these latter features occurring near the terminal edge of the BRaCE facies. Pit clusters are often sinuous, and are observed to divert and completely wrap around pre-existing obstacles – a behavior inconsistent with secondary crater chains. The pits are relatively shallow with respect to their diameters and have scalloped edges; as such, they are similar to the pits described by [14, 15], and even exhibit similar associations between the pit size and density to deposit thickness. This interpretation is further supported by the observed continuity with the ponded and pitted, and smooth and flowing deposits (i.e., impact melts) observed on the LE [see 14].

Numerous discontinuous rougher and higher-standing hummocky "islands" or patches are also observed within the BRaCE facies. They are almost identical in apperence to hummocky terrains that are larger and more abundant within the LE, but also show distinct similarities to the overall morphology of radial ejecta deposits observed around well-preserved simple craters. When completely mapped, these hummocky patches are notably radial, occur circumferentially, and are within a confined range to the primary. They are also observed to be coated, embayed and sometimes partially buried by the smooth and pitted flow portions of the BRaCE facies; as such, they must predate the emplacement of these smooth and pitted flow materials. For Resen in particular, we note that pre-impact target-surface features are rare and often absent within the margins of the BRaCE facies. Pre-existing terrain has a comparatively smoother and muted appearance when compared to these hummocky patches. As such, we interpret them to be portions of an initial emplacement of radial ejecta deposits that crop out of the smooth and pitted flow materials that comprise the bulk of the BRaCE facies.

The most diagnostic feature of BRaCE facies is the marked scarcity of herringbone features and a distinct absence of secondary crater chains crater-ward from its margins. Indeed, abundant pre-existing target-surface features, and both partially buried and scoured herringbone features and secondary crater chains, are only observed beyond the terminal striated lobes of the BRaCE facies. With increasing distance from this boundary, the secondaries notably become progressively less buried and scoured in appearance, until they are at the best-expressed in appearance (i.e., sharpest, deepest). This is consistent with the ejecta becoming progressively discontinuous away from the BRaCE margin. We suggest that the emergence of these features marks the true contact between continuous ejecta and discontinuous ejecta for LE craters, and not the rampart.

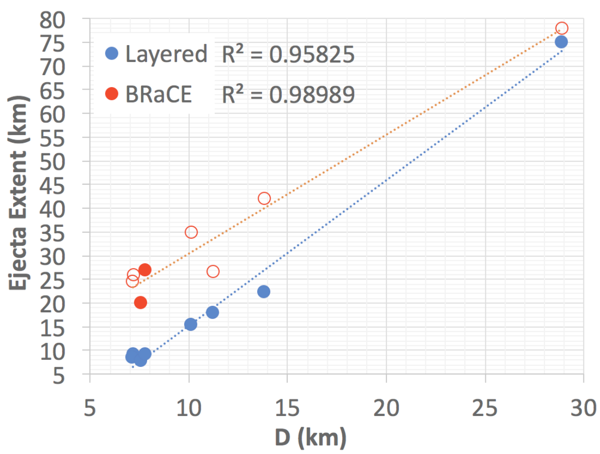

Fig. 1. Plot of the maximum ejecta facies extent vs. crater diameter (D, km) for layered ejecta (LE) in blue, and beyond-rampart continuous ejecta (BRaCE) in red.

While most of our measurements are preliminary (hollow circles in Fig. 1), due to the sparse availability of HiRISE images that currently cover BRaCE, Fig.1 shows the BRaCE facies extends generally ~2-5 crater radii away from the LE rampart and generally increases with crater diameter. Another issue with providing maximum extents instead of averages, which requires more coverage and complete mapping, is that the terminal edge of the deposits around Resen, Noord and other craters are notably quite sinuous (~1.92 or more [e.g., 18]) with some lobes extending further than others, and especially where they are observed influences from pre-existing topography, slopes, and in one such case (Canala), a low-angle impact trajectory.

The BRaCE is somewhat similar, and is likely related to, Low-Aspect Ratio Layered Ejecta (LARLE), which were proposed to form as a ground-hugging base surge [18-19]. However, unlike LARLEs, all craters with BRaCE deposits have generally shorter runouts (<6 crater radii), are notably superior in preservation, and occur equator-ward of the mid-latitudes. Indeed, some LARLEs are found at lower latitudes, but these are much rarer (11; ~8%) and occur very specifically in deposits interpreted to be altered ash deposits [18] (e.g., Medusa Fossae Fm.). Thus, we suggest that LARLEs and pedestal craters are not unique ejecta classes, but may merely be expressions of various degrees of preferential preservation of the BRaCE facies with their enhanced run-out distances and differences in preservation likely attributed to target properties and local conditions, respectively.

Conclusions: We have identified a continuous, relatively thin, smooth and pitted ground-hugging flow facies of ejecta that is observed well beyond the terminal rampart of some of the best-preserved layered ejecta craters on Mars. Despite similarities to LARLEs, the clear relationship of these beyond-rampart deposits to volatile-rich impact deposits observed on the layered ejecta suggests an important role not only for target volatiles in their formation, but also for impact melt-production and emplacement. The recognition of these continuous beyond layered ejecta rampart deposits calls into question how we define the ejecta (continuous vs. discontinuous); as such, these deposits warrant further detailed study to make additional constrains on ejecta classification and how ejecta blankets form and degrade on volatile-rich bodies.

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