DEGRADATIONAL MODIFICATION OF VICTORIA CRATER, MARS.

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Introduction: Victoria crater (2.05°S, 354.51°E) is 750 m in diameter (Fig. 1), surrounded by an annulus dominated by dark sand, and displays a low, serrated rim characterized by embayments or "bays" separated by promontories or "capes." Dunes partially cover the crater floor and the present depth/diameter ratio is 0.1, less than the 0.2 expected for a pristine primary crater [1]. Observations by the Opportunity rover and assessment of a digital elevation model (DEM) produced using High Resolution Imaging Science Experiment (HiRISE) stereo images (26-52 cm/pixel scale) enables us to constrain Victoria's degradation state.

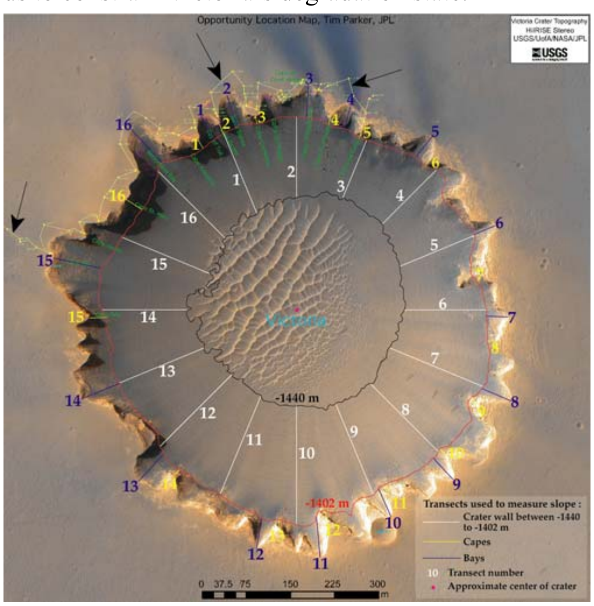

Figure 1. HiRISE image (PSP_004289_1780 IRB) of Victoria crater showing the location of transects along capes, bays, and the crater floor used to derive slopes. Black arrows point to Opportunity rover's traverse. North to top of image.

Degradation Processes: Victoria's small depth/diameter ratio, the serrated rim, and interior dune field, imply it has been enlarged and infilled. Surfaces in the bays slope an average of 19° (range from 15° to 26°), below the repose angle, suggesting limited ongoing mass-wasting. Some rocks lining the bays appear planed off and are ventifacts eroded by sediments blowing out of the crater. Other rocks narrow at their base due to scour by wind blown sediments. These examples highlight the ease with which rocks at Victoria are eroded by wind blown sediments.

Slope profiles down the capes average 41° (range from 31° to 48°), but locally are vertical. Although mass-wasting is more important on these steeper wall segments, most capes are not flanked by much talus and the bases of many are notched and wind-scoured.

Ongoing degradation of Victoria crater involves mostly wind erosion by sediment transported into, eroded within, and transported out of the crater. The result is net infilling over time and erosion is fastest where lithology and/or structure expose relatively weaker materials. Hence, the bays may reflect enhanced erosion along structural weaknesses (e.g., tear faults). Eolian scour of bounding capes causes oversteepening and collapse, but the low strength of talus enables rapid breakdown by saltating sand, thereby leaving slopes exposed to continued back-wasting.

Mass-wasting may have been more important in the past and it is possible that the bays reflect slumps and/or spur and gully topography since enlarged by eolian erosion. However, there is no topographic evidence for any resultant mass wasting deposits on the lower wall and floor, bay spacing is fairly regular, there are few examples of coalesced bays, and some bay heads are angular (in plan view) rather than rounded. Subsequent eolian erosion/burial required to mask any associated mass-wasting signatures is significant and further highlights the importance of more recent eolian modification. Ongoing mass wasting, mostly along the steeper capes, is enabled by eolian scour and subsequent disintegration of resulting talus.

Materials eroded from the walls contribute to net infilling, though some are transported out of the crater. Dark basaltic sands in the crater and in wind streaks indicate additional eolian transport into and out of the crater from other sources [2]. Slopes along the lower walls and floor (outside the dune field) are 12° to 20° and relatively free of talus, consistent with mostly eolian infilling. The diminished expression of the rim, planed-off appearance of the near-rim ejecta, paucity of exposed blocks, and wind streaks [2] further implies efficient eolian modification that is consistent with erosion of nearby craters [3]. There is no evidence suggesting the crater was filled and subsequently exhumed [4] or for degradation by water-related processes. If such processes occurred, associated signatures were destroyed by later erosion.

Victoria Crater's Original Size: The amount of crater modification can be assessed by comparing observed versus expected pristine morphologic parameters. These parameters include the crater depth and diameter, width of the raised rim, extent of ejecta, and height of the rim due to contributions from ejecta and uplift. Rim relief and relative contributions from ejecta and uplift were derived by measuring outcrops viewed by Opportunity and a using a 1 m contour map derived from the DEM. Both methods yield similar results. If the original crater diameter was a primary and ~750 m in diameter, then the initial depth (no infilling) would be ~150 m and the raised rim should be ~110-260 m wide and ~29 m high (Table 1). Instead, the crater is only ~75 m deep and possesses a rim ~150-225 m wide and 4-5 m high (~3 m ejecta and 1-2 m of uplift).

Parameters for pristine craters between 500 m and 700 m in diameter were compared to what is observed and predicted at Victoria crater (Table 1). A pristine primary crater 625 to 650 m in diameter and ~125-130 m deep that is eroded to 750 m and infilled best matches the present Victoria profile. Craters larger than 650 m would posses a rim of uplifted rocks (no ejecta) after the crater was enlarged to 750 m and the rim was eroded to the observed 5 m relief. By contrast, pristine craters smaller than 625 m yield a rim height and width below what is observed if enlarged to 750 m. For a pristine crater 625-650 m in diameter, ~8-11 m of rim relief is expected ~50-70 m beyond the original crest and corresponding to the present rim location. The observed ~5 m rim preserves ~3 m of ejecta, consistent with ~3-6 m planation at the current rim.

Based on these comparisons, Victoria's pristine form has been modified by a 100-125 m increase in diameter (consistent with bays extending 25-83 m into the rim) and 50-55 m of infilling (consistent with dunes n the crater). This coupled with the modified rim form and evidence for infilling suggests the crater is a modified primary rather than secondary. Evidence for sediment transport into and out of the crater precludes a detailed mass-balance evaluation of degradation.

Origin of the Annulus: The annulus surrounding Victoria extends an average of 760 m from the rim (ranges from 470 m to 1100 m) and may have formed by a variety of processes. Because it surrounds the crater and there is a lack of relief across the contact with the surrounding terrain, an origin related to a regional geomorphic or geologic boundary seems coincidental. More likely, it reflects some aspect of the ejecta from Victoria, as the average extent is close to what is expected for a crater originally 625-650 m in diameter. Nevertheless, there is a paucity of exposed blocks and relief and no apparent transition from continuous to discontinuous ejecta at ~325 to 675 from the rim as predicted [1]. Given the evidence for efficient eolian modification of the crater, it appears the annulus reflects an eroded ejecta surface that is capped by basaltic sand and a resistant lag of hematite concretions [6]. Persistence of the annulus well beyond the expected limit of the continuous ejecta suggests the lag is formed after minimal (~1 m) erosion. Otherwise, extent of the annulus would be less.

References: [1] Melosh, H. J. (1989), *Impact Cratering*, 245 pp., Oxford Press, NY. [2] Geissler, P.E., *et al.,* 2008, LPSC XXXIX (this issue), LPI, Houston, TX. [3] Grant, J.A., *et al*., 2006, *JGR*., 111, doi:10.1029/2005JE002465. [4] Edgett, K.E., 2005, *Mars*, 1, doi:10.1555/mars.2005.0002. [5] Wilhelms, D. E., 1987, *The Geologic History of the Moon,* USGS Pap. 1348, US GPO, Wash. DC, 302p. [6] Sullivan, R., *et al*., 2007, LPSC XXXVIII, 2048, LPI, Houston, TX.

Table 1- Some Calculations, Parameters, and Predictions for Victoria crater

Victoria crater is currently ~750 m in diameter (D) and ~75 m deep (d) and yields a d/D = 0.1, but if Victoria is pristine and a primary crater, then a d/D ratio of ~0.2 is expected [Melosh, 1989]. Obvious evidence for infilling (e.g., dunes) and enlargement (e.g., serrated rim plan) suggest the crater was initially deeper and smaller in diameter:

	Possible Original Depth	d/D Ratio for 750 m crater	Initial Diameter for d/D =0.2
Scenario 1	100 m	0.13	500 m
Scenario 2	125 m	0.16	625 m
Scenario 3	130 m	0.17	650 m
Scenario 4	140 m	0.19	700 m

Comparision Between Victoria Crater Today and an Initially Smaller Crater (Scenarios 1-4 Above)

	750 m/Current Parameters	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Diameter (D)	750 m	500 m	625 m	650 m	700 m
Transient Crater Diameter	630 m	420 m	525 m	546 m	588 m
Depth (d)	75 m	100 m	125 m	130 m	140 m
d/D ratio	0.1	0.2	0.2	0.2	0.2
Initial Rim Crest to Annulus Edge	760 m*	885 m	823 m	810 m	785 m
Current Rim to Ejecta Limit**	750 m	125 m	580 m	600 m	675 m
Predicted Extent Continuous Ejecta ***	~325-675 m	~200-450 m	~260-590 m	~265-600 m	~300-665 m
Observed Rim Uplift	~1-2 m****	~1-2 m****	~1-2 m****	~1-2 m****	1-2 m****
Observed Ejecta Thickness	~3.2 m*****	~3.2 m*****	~3.2 m*****	~3.2 m*****	~3.2 m*****
Observed Width of Raised Rim	150-225 m	150-225 m	150-225 m	150-225 m	150-225 m
Predicted Pristine Rim Height at Crest	29 m	19 m	25 m	26 m	28 m
Predicted Rim Uplift at Present Rim	~15m	<0.5 m	~3 m	~4.5 m	8 m
Predicted Ejecta Thickness at Present	~14 m	~1.3 m	~5.7 m	~6.5 m	9 m
Observed vs Predicted Rim Height at	~5 m******	~2-3 m	~8-9 m	~11 m	~17 m
Predicted Rim Width at 750 m Diameter	~110-260 m	~0-50 m	~30-150 m	~50-175 m	~80-220 m

* Average of 8 Transects (Range 470 m and 1100 m), ** Assumes Ejecta Extends ~1D Beyond Initial Rim [5], *** Calculated Using Equations in [1], **** Inferred from Difference Between Rim Height and Thickness of Ejecta at Rim, ***** Based on Measurements Cfrom the Opportunity Rover and HiRISE DEM (yield similar results), ****** Rim Height Averages 5 m (Ranges 4 and 6 m) From Four Transects on N and S and Regional Slope Removed