# GLOBAL DISTRIBUTION OF SMALL RAYED CRATERS ON MARS: SEQUENCES OF EJECTA RETENTION.

F. J. Calef III[1], R. R. Herrick[2], and V. L. Sharpton[2], [1]Jet Propulsion Laboratory, Caltech, Pasadena, CA 91109, fcalef@jpl.nasa.gov, [2]Geophysical Institute, University of Alasaka Fairbanks, Fairbanks, AK. rherrick@gi.alaska.edu, buck.sharpton@alaska.edu.

**Introduction:** Small rayed impact craters (SRC), whose diameter (D) is <1 km, should be distributed spatially and temporally random across Mars. Ejecta retention, the capacity of and time period impact excavated material remains in place around a crater, can serve as a proxy to understand global resurfacing rates and recent surficial processes. Ejecta retention depends on two factors: formation, where the target material is more conducive to creating ejecta rays, and retention, the erosion/deposition rate where ejecta are emplaced. This research aims to quantify the distribution of SRC on Mars, as well as develop a classification scheme for ejecta retention with correlations to known processes. Our ultimate goal is to better understand the retention environment over the "lifespan" of the rayed ejecta.

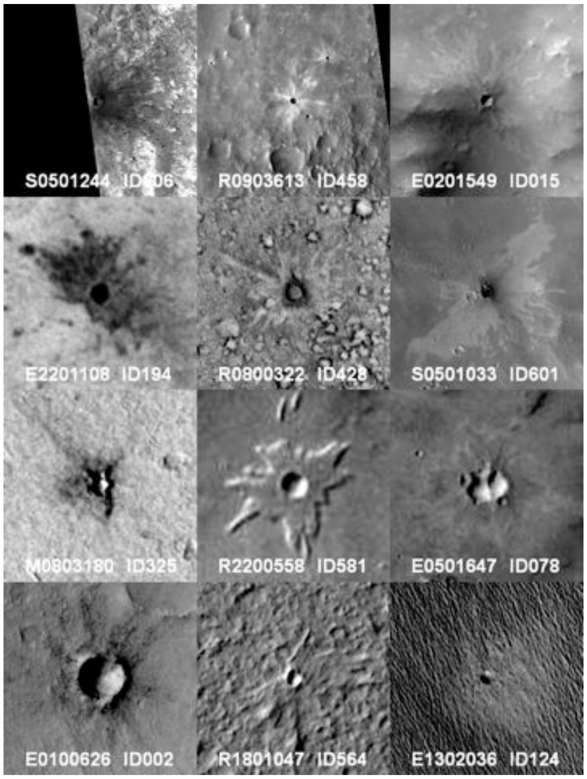


Figure 1: Twelve examples of small (sub-kilometer diameter) rayed craters (SRC) on Mars. Original MOCNA image name and identification number in white lettering. Crater diameters are from 20 m to 100 m. Images courtesy NASA/JPL/MSSS.

**Data Collection and Results:** We surveyed 4,264 panchromatic Mars Orbiter Camera Narrow Angle (MOCNA) images from a global random sample resulting in 200 images with 631 SRC (Figure 1). With a mean D = 71m, most SRC bound the equator between ±30° latitude (Figure 2). The paucity of SRC at higher latitudes correlates with near-surface ground ice affecting ejecta formation [1] and retention [2]. Ejecta retention ages in these polar regions are likely an order of magnitude lower than crater retention ages of 1-2 Ma at ~45° to 1 ka above 70° latitude[3].

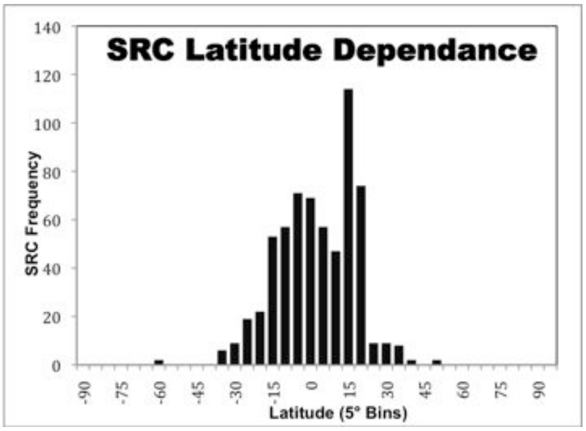


Figure 2: Latitude dependence of the global SRC population. Note the peak of SRC at ~15°-20°N (top); this coincides approximately with the latitude of Zunil, a large primary known to have produced an extensive secondary cratering field [4].

To investigate equatorial retention processes, a t-test for statistical significance of SRC presence/absence versus albedo [5], dust occurrence (DCI) [6], MOLA elevation [7], thermal inertia [8], and water equivalent hydrogen (WEH) [9] was performed. At a 95% confidence interval ($\alpha = 0.05$), three physical parameters yielded statistically significant correlations with SRC: albedo, DCI, and WEH. Albedo had a two-tail probability (P-value) of 0.007 (t-value (t) = 2.72, degrees of freedom (df) = 3211). DCI scored just below our $\alpha$ at P = 0.015 (t = -2.43, df = 3211), while WEH had the highest significance ($P < 0.001$, t = -18.78, df = 1838). Elevation (P = 0.176, t = 1.36, df = 240) and thermal inertia (P = 0.67, t = 0.43, df = 239) were revealed to be highly insignificant.

Since albedo is a surrogate for dust content on Mars, dust deposition appears to be the dominant factor in ejecta retention in the equatorial latitudes (Figure 3). WEH's role in ejecta retention is debatable, but correlates with presence of a unique class of excess ejecta SRC (e.g. see 2nd column, 3rd row in Figure 1).

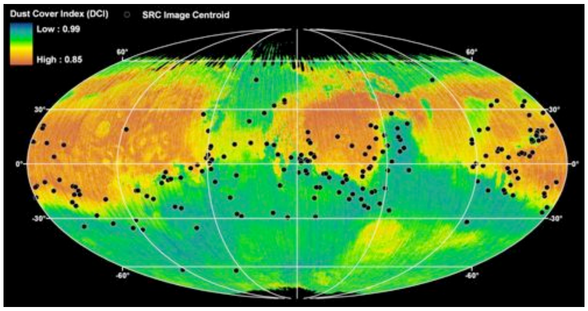
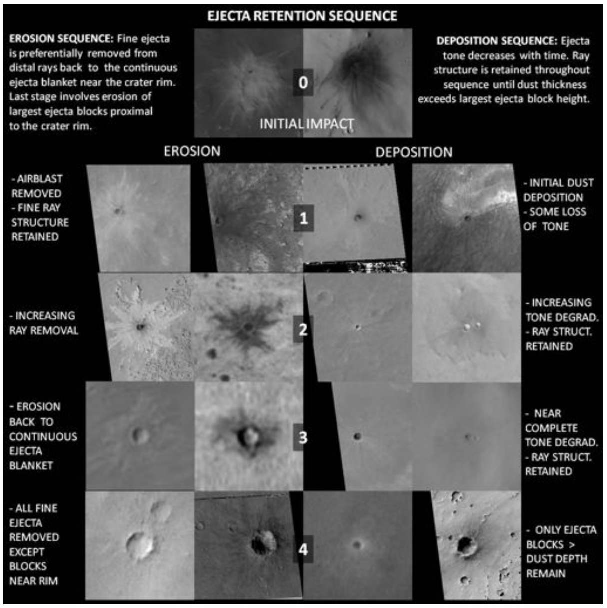


Figure 3: SRC occurrences with dust deposition. Albedo bright areas correlate directly to high dust concentrations (low DCI values), while albedo dark areas are indicative of less dust deposition (high DCI values). SRC appear absent in ‘bright and dusty’ regions (P = 0.015, t = -2.43, df = 3211, α = 0.05). DCI values from [6]

**Discussion:** Two ejecta retention sequences were observed: erosion and deposition (Figure 4). Each sequence has four stages representing increasing removal or burial of ejecta until only a few large remnant blocks remain along the crater rim.

The erosion sequence begins with the initial removal of the air blast associated with the most recent impacts [10], but retains most of the fine ray structure with some distal disconnected ejecta segments (stage E1). Stage E2 removes the distal component and begins to erode ejecta rays back towards the continuous ejecta blanket, sharpening the ejecta transition with background target. At stage E3, the rays have been reduced to the continuous ejecta, leaving only a few crater radii worth of the thickest part of the ejecta. The final part of the sequence, stage E4, leaves only the largest ejecta blocks in place with all other fine (<sand size?) ejecta having been preferentially removed, leaving the slow(er) ventifact process to eventually erode the blocks in-situ down to the level of the rim. In general, we consider the erosive process to be predominately eolian, though we cannot rule out periglacial processes at higher latitudes.

The deposition sequence progresses as a gradual decrease in ejecta tone (i.e. darkness) as successive dust layers blend the visible ejecta with the surrounding target reflectance. Ray structure is retained up until the last stage (stage D4) where dust has effectively buried the fine ejecta and only the largest blocks protrude from the proximal ejecta blanket near the rim. These blocks are visible until the dust depth matches the block height and eventually covers them. The crater floor should also experience burial, but will still retain some depth as block height should be a couple factors less than crater depth. For Mars, depostion dominates in dusty (albedo bright) area while erosion dominates in non-dusty (albedo dark) areas.


EJECTA RETENTION SEQUENCE

EROSION SEQUENCE: Fine ejecta is preferentially removed from distal rays back to the continuous ejecta blanket near the crater rim. Last stage involves erosion of largest ejecta blocks proximal to the crater rim.

DEPOSITION SEQUENCE: Ejecta tone decreases with time. Ray structure is retained throughout sequence until dust thickness exceeds largest ejecta block height.

Figure 4: Observed SRC ejecta retention sequence on Mars. Both bright and dark rayed craters appear to experience the same morphologic changes of retention for both erosion and deposition. SRC at ‘stage 0’ were first discovered by [9] and are not incorporated into our study. Stages E1-E4 are listed on the left side of the figure, and D1-D4 on the right.

**Conclusions:** Observations from a global sampling of MOCNA images reveal a spatial distribution of SRC constrained by active surface processes. Properties of formation poleward of ±30° latitude play a substantial role in ejecta retention. Modeling has shown that wind stress decreases with surface brightening [11], allowing SRC to be rapidly buried within high dust concentration areas at lower latitudes. In contrast, intermediate albedo/DCI areas represent a middle ground where winds are strong enough to keep most dust aloft, but removing only a minimal amount of larger particle ejecta material. From the observed Martian SRC distribution, dust is covering ejecta at a faster rate than erosion removes it over +-30° latitude. Based on ejecta retention ages, this has likely been true over the last 100 ka [12].

**References:** [1] Byrne, S. et al. (2009) *Science, 325,* 1674. [2] Kreslavsky A. et al. (2009) *LPSC XLI,* #2311. [3] Maine A. et al. (2010) *LPSC XLI,* #1556. [4] McEwen A. S. et al. (2005) *Icarus, 176*, 3561-381. [5] Christensen et al. (2001) *JGR, 106*, 23823-23872. [6] Ruff and Christensen (2002) *JGR, 107(E12)*, 5127. [7] Smith et al. (1999) *Science, 284*, 1495-1503. [8] Putzig and Mellon (2007) *Icarus, 191*, 68-94. [9] Feldman et al. (2004) *JGR, 109*, E09006. [10] Malin M. C. et al. (2006) *Science, 314*, 5805. [11] Fenton L. K. (2007) *Nature, 446*, 646-649. [12] Calef et al. [2011] SRC Retention Age, *LPSC XLII,* this conference.