

CHANGES IN NEW IMPACT BLAST ZONES OVER THREE MARTIAN YEARS. I. J. Daubar¹, P. E. Geisler², A. S. McEwen¹, C. M. Dundas², S. Byrne¹, P. S. Russell³, and G. D. Bart⁴. ¹Lunar & Planetary Lab, University of Arizona, Tucson, AZ, 85721 (ingrid@lpl.arizona.edu), ²U.S. Geological Survey, Flagstaff, AZ, ³Center for Earth & Planetary Studies, Smithsonian, Washington, DC, ⁴University of Idaho, Dept. of Physics, Moscow, ID.

Introduction: New, dated craters on Mars [1, 2] are the freshest examples of impact processes and some of the only recently-modified surfaces with constrained dates for the initial disturbances. HiRISE [3] has now been monitoring these sites for as much as three Mars years. The rates and characteristics of changes at these sites help us understand the initial impact processes, the modification processes that have occurred since, and the ultimate fate of these features.

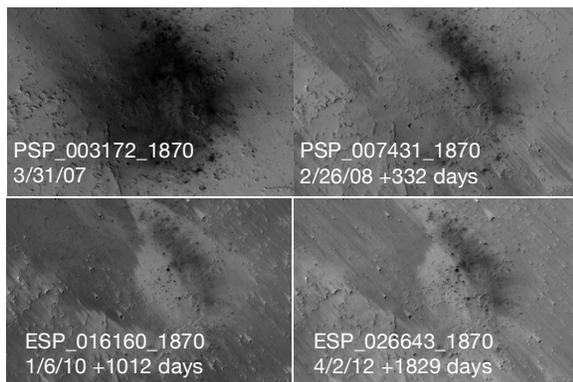


Fig. 1. Dated impact site at 6.99°N, 247.91°E. HiRISE RED RDRs with North up. NASA/JPL/University of Arizona.

Description: As a result of a detection technique that uses lower-resolution repeat imaging over dusty areas [2], almost all known new impacts have an extended “blast zone” (BZ) consisting of an area with (usually) lower albedo surrounding the craters. Features within the BZ vary by site and include diffuse dark halos; arcuate, parabolic, or radial rays; light and dark-toned ejecta; slope streaks; and complex combinations thereof.

Hypothesized formation mechanisms for the disparate features within BZs include removal and/or disturbance of high-albedo surface dust by atmosphere/surface interactions of the shock waves associated with the descent and impact of the bolide and ejecta [1]; straightforward impact ejecta (depositional) processes, shock effects on small-scale surface texture, interactions between shock waves from separated fragments of an impactor [4], and seismic shaking from the impact [5]. The various BZ features may very well have different origins, and in future work we aim to distinguish the fading behavior of different types of features to illuminate their formation mechanisms and relative lifetimes. For now, we use the general term “blast zone” to encompass all of these albedo changes associated with the initial impact, without implying

specific formation processes, nor that they all share a single formation process.

Fig. 1 shows examples of the variation in BZ features, and the types and intensity of changes observed. Selected BZs have been measured to range from 20-95 times larger than the craters themselves [6], up to 400 times larger at some sites [4].

Previous work: In [7] we reported that out of 14 sites with repeat imaging at that time, surprisingly only one site showed significant changes thus far (Fig. 1), even after the 2007 global dust storm. In [10] we reported on qualitative changes at 57 sites.

We now expand that to include 254 images at 79 non-polar sites with repeat images ranging from 5 days to 3 Mars years apart. In addition, we demonstrate a technique to measure changes quantitatively in order to estimate fading lifetimes. We do not include sites northward of 50° latitude, where different processes, e.g. dust and ice deposition and polar cap sublimation, are at work erasing BZs on seasonal timescales [11].

Changes: Types of changes observed, in order of most to least common: (A) Diffuse halos fade and approach surrounding albedo. (B) Extended discrete rays and filamentary features fade, shorten, and disappear. (C) Small outlying dark spots disappear completely. We attribute these first three types of changes to airfall of dust returning the features to the surrounding albedo. (D) Dust devil tracks appear/disappear (these features are not caused by the impact event, but, interestingly, are more visible over previously-disturbed areas). (E) Brightening of previously dark BZs above surrounding albedo (rare). (F) Disappearance of blocks near crater rim – only observed at one high-latitude site, this is thought to be due to sublimation of icy ejecta blocks [11].

Intensity of changes: We made qualitative evaluations of the amount of change in each repeat image of each site. Images were manually coregistered and stretched to match background areas. Changes were assessed by blinking between images and classified using these categories: 0: no detectable change, 16 images, 14%; 1: subtle changes that may be due to differences in lighting or atmospheric effects, 45 images, 39%; 2: definite changes, 37 images, 32%; 3: dramatic changes (e.g. the BZ has disappeared entirely), 17 images, 15%. Surprisingly many still show no detectable changes after three martian years. In comparison, rover tracks fade on timescales of one martian year [8], and slope streaks fade over decades [9].

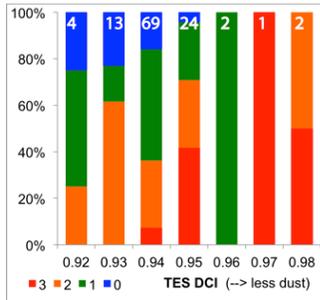


Fig. 2. (left). Percentage of images showing change levels with different TES DCI values [12]. Number of images in each bin are at column tops. Disregarding sparsely populated bins, more change occurs in areas with less dust cover.

Correlations: We explored correlations between rankings and various factors: elapsed time (not shown; more change over longer times, as would be expected), latitude (no correlation), elevation (no correlation, despite atmospheric density varying widely at different elevations on Mars), and TES Dust Cover Index (DCI) [12] (Fig. 2). The latter shows a puzzling trend of less change where the DCI indicates there is more dust.

Locations of changes were also compared to global albedo changes (Fig. 3). Sites with no change are mostly located in areas where there were few or minor visible surface albedo changes 2000-2009. However, sites that did change are located in all areas, including many places with little history of regional albedo changes.

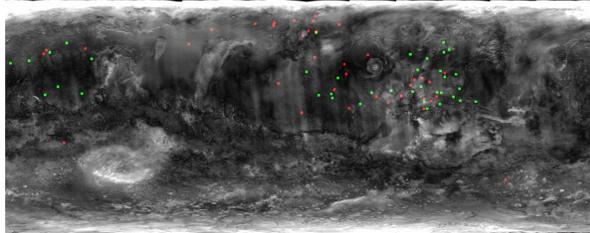


Fig. 3. Sites with changes (red; levels 2 and 3) and no changes (green; levels 0 and 1) on a map of surface albedo changes from 2000-2009. Map created from MOC WA and MARCI data at L_s 330°. Bright areas changed greatly in albedo over this period; dark areas changed little.

Quantifying change: We have also developed a technique to measure albedo change in successive images. Albedos are calculated from samples of RED HiRISE RDRs taken with HiView [13]. After making a simplified atmospheric correction, BZ albedos are ratioed to a background albedo distant from the impact. Such relative albedos (A_{rel}) are more accurate [14] and to first order are independent of lighting conditions.

A_{rel} is plotted over time (Fig. 4) and a linear trend projected forward to $A_{rel}=1$. This yields an estimated fading lifetime (from $t=0$ of the first image) for that particular site. Results for several sites are shown in the table. Since the original impacts occurred at various times before the first HiRISE image, these are not absolute lifetimes. These estimated lifetimes assume a linear fading over time, which may or may not be appropriate, perhaps as in the example shown in Fig. 4.

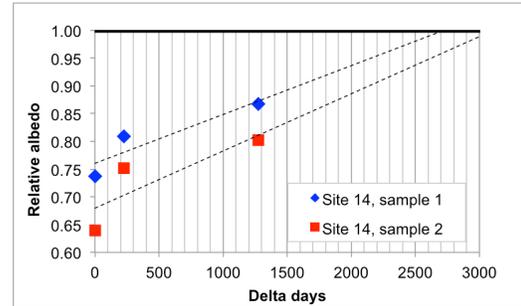


Fig. 4. Example of relative albedo change over time at two samples within the blast zone of a single dated impact. Dotted lines show linear fits projected to estimated lifetime ($A_{rel}=1$).

Observation IDs	Lifetime (days)
PSP_002764_1800, PSP_005665_1800, ESP_019154_1800	~2,700-3,100
PSP_003754_1815, PSP_008237_1815	~900-1,200
ESP_019830_2215, ESP_024221_2215	~450

Conclusions: Many new martian impact blast zones have changed drastically over relatively short timescales, but ~half show no or only subtle changes, despite being freshly-disturbed sites in areas with evidence of other aeolian activity. The qualitative amount of change observed is correlated with the amount of time elapsed and inversely correlated with the amount of dust cover. The frequency and magnitude of regional albedo changes are poor predictors of whether a young impact crater will fade quickly or not. We will also explore relationships between quantitative changes and additional factors such as BZ and crater sizes.

Quantitative changes in albedo yield estimated lifetimes of BZs. These vary widely in the few examples measured so far, but are 1-2 orders of magnitude shorter than the lifetimes of slope streak fading [9]. However, these particular sites were chosen because they were observed to be fading over shorter timescales, so the fading lifetimes of the overall populations may yet be similar. These lifetimes will be useful for evaluating the accuracy of measurements of the current impact rate based on BZ detections [2].

References: [1] Malin M.C. *et al.* (2006) *Science* 314, 1573-1577. [2] Daubar, I.J. *et al.* (2013) *Icarus* 225, 506-516. [3] McEwen A.S. *et al.* (2007) *JGR* 112, 5. [4] Ivanov B.A. *et al.* (2010) *LPSC* 41, abs. 2020. [5] Burleigh K.J. *et al.* (2012) *Icarus* 217, 194-201. [6] Bart, G.D. & P. Spinolo (2013) *GSA* abstract. [7] Geissler, P.E. *et al.* (2010) *LPSC* 41, abstract 2591. [8] Geissler, P.E. *et al.* (2010) *JGR* 115, E00F11. [9] Bergonio, J.R. *et al.* (2013) *Icarus* 225, 194-199. [10] Daubar, I.J. *et al.* (2012) *AGU* abstract. [11] Dundas, C.M. *et al.* (2014) *JGR*, in press. [12] Ruff S.W. & Christensen P.R. (2002) *JGR* 107, 5127. [13] <http://www.uahirise.org/hiview/> [14] Delamere, W.A. *et al.* (2010) *Icarus* 205, 38-52.