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New impact craters and meteoroid densities on Mars

B. Ivanov (1,2), H. J. Melosh (2), A. McEwen (3) and HiRISE Team

(1) Institute for Dynamics of Geospheres, Russian Academy of Science, Moscow, Russia (baivanov@idg.chph.ras.ru / Fax: +7-495-137-6511), (2) Departments of Earth and Atmospheric Sciences, Purdue University, Civil Engineering Building, Room 3237, 550 Stadium Mall Drive, West Lafayette IN 47907, (3) University of Arizona, Department of Planetary Sciences, Tucson, AZ, 85721

Abstract

Repetitive high-resolution imaging of Mars revealed new small impact craters with known dates of formation (see [1, 2] and references in [2]). After ~2006 the discovery rate became a linear function of time, so we can use the discovery rate as a proxy for the modern bombardment rate. The low-mass Martian atmosphere is dense enough to shatter roughly half of the meteoroids, resulting in the crater clusters. Separation distances in these clusters put some constraints on the density and strength of meteoroids. The atmospheric deceleration and breakup of meteoroids complicate the Mars/Moon comparison and attempts to verify the crater related timescale (e.g. [3]). At the same time observations of impact sites with known formation dates allow us to analyze the rate of modern surface changes due to wind/dust interaction.

1. Small craters and clusters

To date about 200 new impact cites (e.g. Figure 1) are recognized in dusty areas of Mars (mostly by comparison of CTX and HiRISE images) [4]. For the first ~20,000 orbits 164 impact sites are verified and analyzed.

117 impact sites with nominal formation dates after 2008 demonstrate the ~50/50 sharing between events forming a single crater and events forming multiple craters. In ~50% of falls meteoroids traveled through the lower atmosphere as fragments. Hence, the atmospheric drag and ablation were more effective than for a single body. The available estimates for atmospheric correction [3] should be reconsidered to take into account the atmospheric breakup. Before such a correction we use the cube root of the sum of diameters cubed $D_{eff}=(\Sigma D_i^3)^{1/3}$ as a simple measure of an effective crater that would be created by a single impact without atmospheric breakup. This effective diameter is used to plot Figure 2.

The long time HiRISE operation brings a few observations which allow us to verify and to improve available models of atmospheric break up. An example of a possible cascade fragmentation is shown in Figure 1. Sometimes positions of craters in a cluster make possible to estimate angle of impact and to constrain the meteoroid effective density (Figure 2).

2. Summary and Conclusions

Linear discovery rate in different diameter bins allows us to use the discovery rate as a proxy for the impact rate and to compare HiRISE observations with the Moon-derived chronology [3, 4]. The comparison may be complicated with incompleteness of small new impact detection [4] as well as (partially) from a complicated interplay of the atmospheric breakup and enhanced (for smaller individual fragments) deceleration and ablation. The observation of widely-dispersed crater clusters at high altitudes (5 to 10 km, Figure 2) prompt us to discuss in a future the presence of low density (porous?) meteoroids in the modern bombardment flux.

Acknowledgements

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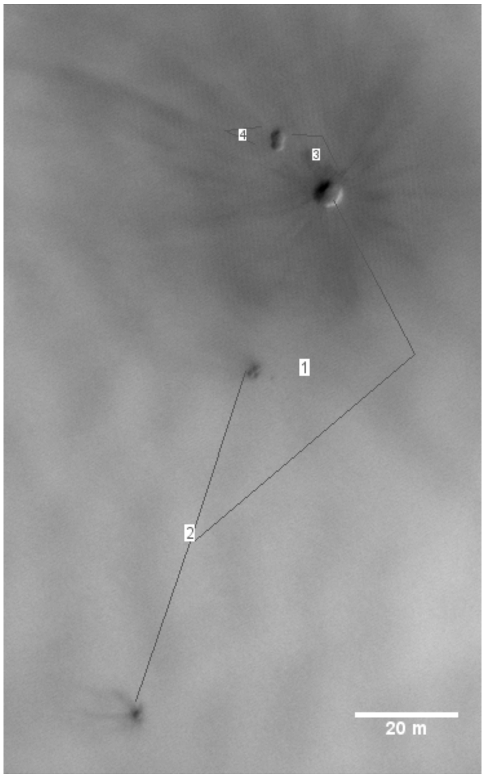

Figure 1: ESP_016200_1740. North is up. The impact crater cluster is formed between May 2007 and January 2009 at the surface elevated ~ 5.4 km above zero level. One can assume that 5 fragmentation events are visible here: (1) the “south” fragment detached from the main body and later (2) was divided in two smaller fragments. (3) The “NW” fragment detached from the main body. (4) The “NW” fragment is broken, and after separation at a meter or so strikes the surface. (5) The “northern” of two “South” fragments is shattered in 3 pieces, striking the surface with ~1 m separation. If the altitude of the surface would be well below 5.4 km fragments would have more time for separation and finally we would see a cluster at least of 7 craters while with the smaller separation above 5.4 km altitude we would see 4 craters only. In addition more fragmentation events could happen during the flight through denser atmosphere below the altitude of 5.4 km.

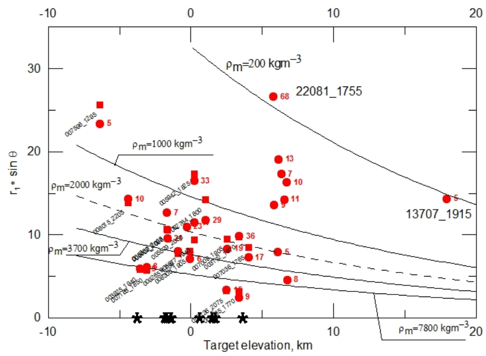

Figure 2: Model dependent estimates for an effective meteoroid densities vs. elevation of the target surface. The model assumes the optimum breakup altitude for each assumed value of meteoroid density (black solid and dashed curves). Observations are processed assuming the estimated impact angle (from the elliptic shape of the strewn field), the cascade fragmentation assumption (see Figure 1), and the standard separation coefficient for an elementary breakup in two pieces [2]. While the majority of clusters allow assuming the “normal” density below 2000 kgm^{-3}, a dozen of recorded events demands as low effective density at breakup as 200 kgm^{-3}. Red numbers (to the right of red points) are for the effective crater diameter in meters.

References

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