MAPPING AND INTERPRETING THE CRATERING RECORD IN THE COLUMBIA HILLS WITH SPIRIT.

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Introduction: High resolution Mars Orbiter Camera (MOC) views of the Gusev plains and Columbia Hills (CH) at the MER-A landing site afford the opportunity to examine the role of cratering in the geomorphic evolution of these terrain elements, and to propose hypotheses that may be tested with observations made by the the Spirit rover. In fact, a simple examination of MOC produces a mystery: the plains, which appear superposed on the CH, have more craters, in the 100 m size range in particular, than do the hills (Figure 1). Addressing this mystery, and a desire for a thorough mapping of CH craters stems from our desire to provide a proper structural geologic context for the many rock types, and bedrock exposures, being found by Spirit.

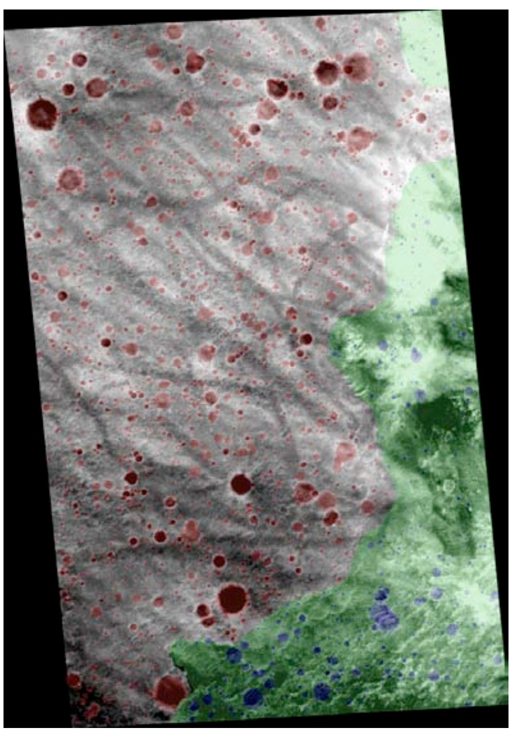

Figure 1. MGS MOC image R13-01467 with 1.47 m/pixel, north up, swath width 2.94 km. The Columbia Hills are shaded green. The plains/hills contact generally follows maps produced by the Athena Science Team during the MER mission [1,2].

Explaining the mystery: There are several hypotheses that can be proposed to explain the "lack" of craters in the Columbia Hills.

(a) We imagined that the human eye and brain are fooled by the crater distribution. So we tested whether the apparent lower crater population in the CH holds up statistically. It does. Crater counts in two MOC images, R13-01467 (Figure 1), and E03-00012 bear it out (Figure 2). The counts for the plains craters in MOC image R13-01467 lie on or very near the saturation line for crater sizes below 100 m [3]. Open triangles and filled circles in Figure 2 show counts in the CH from images R13-01467 and E03-00012 respectively, and show that there is a reduced decameter-to-hectometer crater population in the CH. The difference between counts in the two images is that counting was more "aggressive" in the higher resolution R13-01467. Further, adding more tentative large craters ("degradeds") in the E03-00012 count raises the numbers to be more similar to that in R13-01467. The roll-offs in all counts in Fig. 2 at small crater sizes are crater-counter-laziness effects.

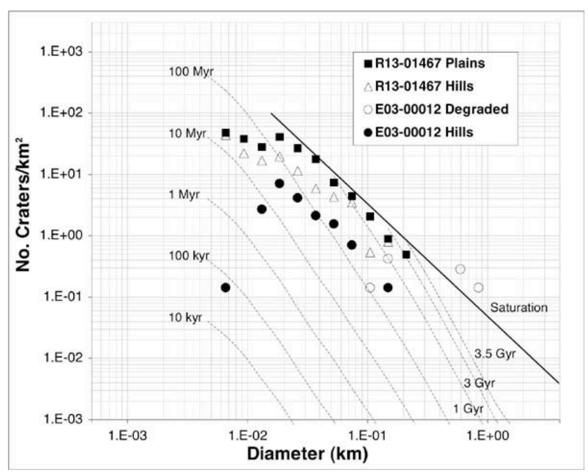

Figure 2. Crater counts on MOC images plotted over isochrons [3] to illustrate relative ages. Solid boxes for plains craters in R13-01467 lie on or very near the saturation line for crater sizes below 100 m, while the counts for the Columbia Hills do not appear saturated.

(b) Is the superposition of the plains over the CH correct? Spirit's observations of the contact between the plains and the CH convince us that it is [1,2]; the plains surface is as old or younger than the CH. This hypothesis has a corollary which reinforces the mystery: there have been as many or more impacts in the hills as in the plains.

At least three further hypotheses can be formed, and tested to some extent if not fully with Spirit's observations in the CH, so:

(c) *Slopes modify the distribution of ejecta from craters*. This effect has been consider for previous planetary studies [4], buy appears not to have been extensively researched with ground truth. Additionally, illumination and slope effects may also confound orbital observations.

(d) *Target properties of the CH are different than for the plains*. Softer rocks, observed by Spirit may form more poorly expressed craters record that escape detection in orbital imagery. This effect is known from lunar surfaces [5].

(e) *Crater degradation is enhanced on martian slopes*. The wind helps degrade craters on the plains [6], and its effects should be more pronounced in the CH, softening morphology, or masking it more quickly.

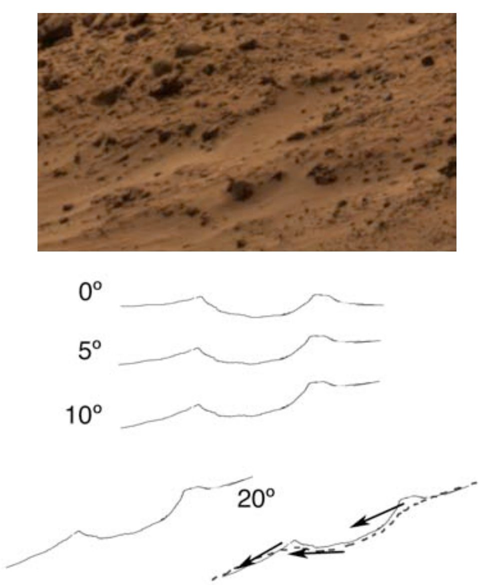

Figure 3. upper: excerpt from the Cahokia pan showing a candidate slope crater missing down-slope rim and with fines filling. Lower: sketch model to illustrate slope dependence of this geomorphic form.

Observations: Comparing Spirit observations with MOC, we observe anti-correlation of slope and small crater occurrence in the CH, where our "hollow"-counting technique's robustness is confirmed by plains experience [2]. What is different is the morphology of "steeper hollows".

Simple Model. We are developing a model of geomorphic slope control for crater morphologic expression (Figure 3). Observations of artillery in mountains suggests that gravity can come to control the later excavation stage and subsequent modification stage. We propose that the geomorphic control over whether a crater in the hills will resemble a flat-terrain crater is the relief of the pre-crater slope relative to the potential crater relief for the crater's size. A limit-case thought-experiment of an impact on a vertical wall implies that gravity can dominate the modification stage of ejecta distribution to control crater morphologies on steep slopes.

Outlook: The mystery is not then "where are the craters?" but is more correctly stated as "what do small craters look like in the CH?" Further tests are being pursued with Spirt data and will be presented at the meeting: (1) Quantitative "ground-truth" mapping to estimate the size and position of (candidate) impact craters within the CH to compare directly with MOC data of the CH, and with Spirit data from the Gusev plains. (2) Hectometer diameter crater numbers (viewed with orbital data or from Spirit) will be compared with quantitative slope information to evaluate, and perhaps refine, our slope cratering model including target [7] and ejecta [8] properties.

More generally, in this new era of bedrock planetary geologic mapping, the planetary geologist needs more refined models of cratering structural geology to interpret details of lithologic history. Only meters of erosion/redistribution in the CH is also consistent with preservation of what appears to be basaltic ejecta on many surfaces and with the rock count data [9]. Thus, the form of the Columbia Hills may be largely unchanged since at least Hesperian and maybe since formation.

References: [1] Crumpler L. et al. (2005) *Geology*, *33*, 809–812. [2] Golombek, M.P. et al. (2006) *JGR* doi:10.1029/2005JE002503. [3] Hartmann, W.K. (2005) *Icarus*, *174*(2), 294-320. [4] Robinson, M.S. et al. (2003) *LPS XXXIV,* Abstract #1696. [5] Schultz, P.H. and J. Spencer (1979) *LPS X,* 1081-1083. [6] Grant, J.A. et al. (2006) *JGR* doi:10.1029/ 2005JE002465. [7] Hörtz, F. and M. Cintala (1997) *Meteor. Planet. Sci.*, *32*, 179-209. [8] Cohen, B.A. (2006) *LPS XXXVII.* [9] Grant et al. (2005) *AGU Abstract#P21A-031*.

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