Pacing Wind-Induced Saltation Abrasion on Mars: Using Crater Counts to Constrain Aeolian Exhumation

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Motivation
Estimates of surface erosion rates and knowledge of how they vary over space are needed in order to better understand various aspects of Mars’ landscape evolution:

- Test models of past wind shear stress [1]
- Test models of sedimentary rock mound formation [2,3]
- Provide input to models of organic matter preservation potential [4]

Relatively small, shallow craters are preferentially obliterated as a landscape undergoes erosion [5], so the size-frequency distribution of impact craters in a landscape undergoing rapid, steady exhumation will develop a shallow power-law slope [6].

Here we present preliminary results from our effort to map impact craters for sedimentary rocks across Mars and estimate their corresponding obliteration rates.

1. Data and Methods

We used map-projected image data from the HiRISE red channel as the basis for crater mapping. Analysts counted craters on selected areas of HiRISE images using ArcMap and CraterTools

Crater Counting

Six analysts (University of Chicago undergraduates) were given 2 hours of classroom training on martian impact crater morphology, with examples primarily drawn from HiRISE image data, followed by ~6 hours of hands-on training mapping impact craters on 2 HiRISE images using ArcMap and CraterTools.

Following training, the analysts independently mapped craters in pre-selected areas of ~40 HiRISE images. Portions of the images containing dunes or other landforms of apparently unconsolidated material were masked out.

2. Results

Impact craters were mapped by ≥3 analysts in 18 HiRISE images showing sedimentary rocks (Figure 1). The incremental frequency plots of craters agreed upon by ≥2 analysts from each image display a shallower power-law slope than that of an isochron (Figure 4), indicating that these areas have experienced resurfacing.

Obliteration Rate Estimation

We estimated crater obliteration rates, \( \dot{f} \), for each size bin \( i \) using the following equation:

\[
\dot{f}_i = \frac{f_i H_i}{N_i}
\]

where \( H \) is the expected flux of craters onto a unit surface per 1 Ga (Table 1 in Ref. 10), \( N_i \) is the observed density of craters in the size bin \( i \) is an assumed resurfacing depth sufficient to obliterate a crater (i.e. make it unrecognizable as a crater in HiRISE image data) (Figure 3). We set \( f = 10\% \) of the crater bin log center.

For small, fresh craters on Mars, the crater depth to diameter ratio, \( d/D = 0.2 \), therefore our assumed resurfacing depth is 50% of the depth of the original crater.

3. Discussion

Crater Counts

Most studies involving crater counts rely on a single experienced analyst to identify craters. Ref. [11] compared lunar crater counts from 8 expert analysts to those 1000s of non-specialist volunteer and found that, on average, non-specialists are able to identify craters as well as expert analysts are. There can also exist considerable variability between individual analysts’ crater counts, even among experts (review in [11]).

This work took an intermediate approach by providing 6 non-specialists with ~8 hours of intensive training. However, a key remaining uncertainty is the effect of inter-analyst variability on the crater counts.

In an effort to provide an expert reference to the non-specialists’ counts, the authors counted craters on 2 of the HiRISE images (we mapped 42 and 35 craters, respectively, with 32 craters in common).

The false positive rate is ~3% (~0%) for features agreed upon by ≥2 (≥3) analysts. The false negative rate is ~33% (~55%) for features agreed upon by ≥2 (≥3) analysts. We chose to calculate obliteration rates based on the ≥2-agree case because it represents the smallest combined error rate relative to the expert reference.

4. Conclusions

- Crater size-frequency distributions in the studied sedimentary rock regions are not well-fit by isochrons.
- We estimate crater obliteration rates of 0.1-0.2 μm/yr based on craters agreed upon by ≥2 analysts.
- These crater obliteration rates represent an upper limit on surface erosion by landscape lowering.
- A key remaining uncertainty on obliteration rate estimates is the effect of crater count variability between non-specialist analysts and between images.
- Future work will involve using estimated erosion rates to assess organic matter preservation potential [4,12].

References


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