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Obliquity-related Ice Deposition in the Glaciated Martian Crater Greg, and Progress on Crater Chronometry

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Abstract

Crater count chronometry continues to be a valuable tool in interpreting Martian surface history and geological processes. We apply this and other techniques to analyze the important crater, Greg, east of Hellas. We present a new technique to discuss ages of strata and geological processes as a function of depth. Topography in the upper meters of Greg is controlled by obliquity-driven climatic episodes producing ice-rich mantles, and modulated by the solar longitude of perihelion.

1. Introduction

Detections of new, decameter-scale craters on Mars continue to give primary crater production rates overlapping rates used in isochron diagrams developed at PSI and by Neukum et al. [1, 2]. This increases opportunities to interpret geological processes affecting Martian formations. We combine techniques of crater chronometry, geomorphology, and climate modeling to investigate the remarkable glacial flow structures and mantling of the crater Greg, east of Hellas, in an area already known for debris apron flow features (Fig. 1).

2. Dataset and Method

We conducted geomorphologic analysis and crater counts on images at a variety of scales, including imagery from HRSC, THEMIS, CTX, and HiRISE. We also made DEMs from HRSC imagery to measure slopes and thicknesses of glacial and mantle features. Counts on dense, cratered terrain and the ejecta blanket indicate an age of some 10^9 y for Greg (Fig. 2), but counts on mantled terrain and the glaciers give much younger ages (Fig. 3).

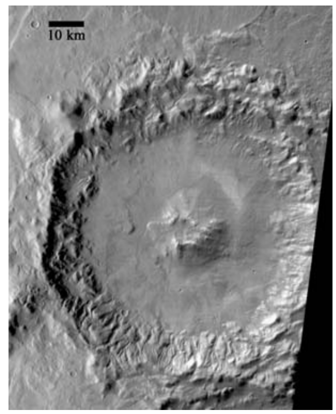

Figure 1: Crater Greg, showing fluvially dissected south wall. (THEMIS mosaic, Frank Chuang.)

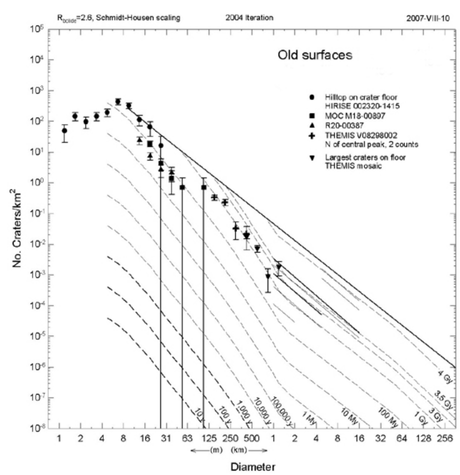

Figure 2: Crater counts on the most densely cratered terrains, at D>100 m, indicate model ages of a few 10^9 y for the crater itself.

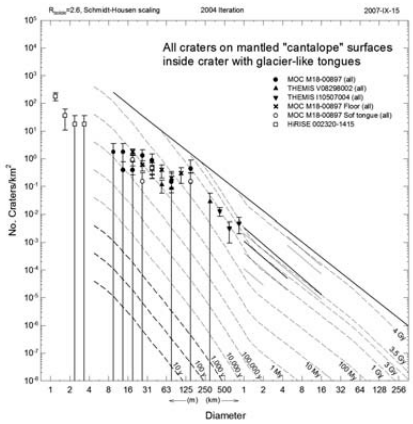

Figure 3: Craters on mantled terrain give model ages of ~10^9 y at D>125 m, but give ages of only some 10^6 y at D<31 m; i.e., shallow craters have short survival lifetimes.

3. Results

Greg is a few 10^9 y old, and shows evidence of ancient (Noachian? Hesperian?) fluvial erosion on the walls, but the decameter-scale topography, especially on ice-rich features is much younger, as young as 10^6-10^7 y old. The surface has been mantled by initially ice-rich material, to depths ~30-60 m, consistent with earlier work on mantling [3, 4]. Glacial structures range 5-85 m deep, and may be quite old, but the upper meters are young.

Here we see a new technique, implicit in the last 50 years of crater count analysis, but not sufficiently utilized, in which we can gain information about geological history and processes as function of depth. Figure 4 shows a plot of model age versus depth d. (Diameter D is shown on the top axis. We find that on the surfaces involving ice and ice-rich mantling, craters of D≲30 m (depth d≲10 m) date back only to the last few episodes of high-obliquity. Forget and others have shown that at high obliquities, dramatically different climate environments can exist, compared to what we see today [5]. They show that under some conditions of high obliquity, as modulated by the solar longitude of perihelion of Mars's orbit, H_2O ice build-up on the south pole and summer burn-off of the ice cap can result in massive ice deposition in the region east of Hellas – exactly the region where we see the unusual and dramatic glacial features of crater Greg, and nearby debris aprons, which have been proven to be ice-rich by Holt et al. [6]. These results offer dramatic support for the validity of global climate modelling as a tool for understanding planetary environmental evolution.

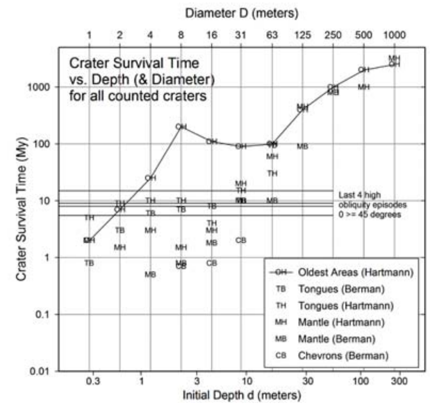

Figure 4: A variety of crater retention ages, or crater survival times (as in Figs. 2-3) are plotted vs. crater depth bottom) and diameter (top), for various surfaces inside Greg. We find that (excepting mantle-free surfaces shown in top solid line) craters shallower than ~10 m survive only after the last few high-obliquity mantling episodes (horizontal solid lines, 5 to 20 My ago). This suggests that topography shallower than ~10 m has been obliterated during the last major episodes of mantling.

4. References

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