HIGH RESOLUTION CRATER COUNTING OF SMALL AREAS ON MARS. N. H. Warner[1], S. Gupta[2], F. Calef[3], P. Grindrod[4]. [1]State University of New York at Geneseo, Department of Geological Sciences, Geneseo, NY 14454, warner@geneseo.edu, [2]Imperial College London, Department of Earth Science and Engineering, South Kensington, SW7 2AZ, UK, [3]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, [4]Centre for Planetary Science, UCL Birkbeck, London, UK.

Introduction: As resolution and spatial coverage of visible-light imagery improves for Mars, relatively small (10^2 to 10^3 km^2 by area) geomorphic terrains such as deltas, alluvial fans, crater ejecta blankets, lava flows, outflow channel floors, and small fluvial channels have become tempting targets for the crater counting method [1-6]. Some of these landforms, due to their association with liquid water, are ideal localities for exploration as they help us to better understand the planet's climate history and habitability potential. It has therefore become essential to understand where these high priority landforms place in the established, global chronostratigraphic framework.

However, the practical usefulness of the impact crater chronology method for achieving a true formation age for these areally-limited landforms is unclear. While the number of impact craters available for a count influences our age dating uncertainties on small landforms [4,7], we demonstrate here that the local and natural variability in the pattern of impact cratering, coupled with processes that resurface small craters, challenge attempts to date small landforms even when a statistically significant number of craters are present. In this analysis we utilize crater statistics derived from CTX imagery from four type Noachian (Noachis Terra), Hesperian (Lunae Planum and Syrtis Major), and Amazonian (Acidalia Planitia) terrains to address two primary questions regarding uncertainties in the use of small area crater counts:

(1) For terrains of different ages and different geologic histories, spanning the three epochs of Mars, how does spatial variability in the pattern of cratering influence the precision of crater-derived ages across a geologically uniform terrain?

(2) In the presence of processes that resurface small craters on Mars, do areally-limited crater counts record a significantly broad diameter range to reveal a population of craters that pre-dates resurfacing? By probability, images that cover small areas of the martian surface, or landforms that by themselves are small, may not have captured km-sized or larger impact craters. This may leave only the 10^2-m-diameter crater size for a crater count. Thus, when this diameter range provides the only available data, the derived ages may only reflect the timing of surface processes that influenced the uppermost crust or surface of Mars.

Methods: To address these two factors, we present a series of high-resolution impact crater statistics using CTX mosaics from different reference terrains. We quantify the impact crater statistics over geologically uniform areas of 10,000 km^2 for each terrain and highlight age variations across the larger area, recorded at spatial scales of 1,000 km^2 and 100 km^2 (Fig. 1). For each terrain region and each smaller area sample we determine: (1) the crater size frequency, (2) relative geologic age, and (3) absolute model age, derived from commonly utilized crater production and chronology functions. We also demonstrate the influence that small crater resurfacing has on providing systematically lower ages for the small area samples relative to the larger 10,000 km^2 sample, as well as previously published ages on geologic maps.

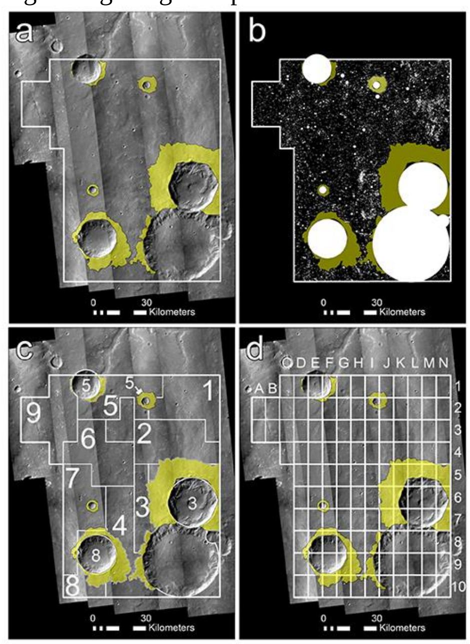

Fig. 1: Example areas and counts from Noachis Terra. (a) 10,000 km^2 area (b) crater counts (c) 1,000 km^2 areas (d) 100 km^2 areas.

Results and Discussion: We summarize the results from our crater area analysis with 4 major points.

(1) The majority of surfaces on Mars show some evidence for small crater modification, either in the form of abrupt resurfacing events or longer-term surface modification that have destroyed a Late Noachian-age population of < 1 to 5 km-sized craters. Because of this, the km-scale impact crater population that is often partially or completely preserved through the resurfacing process, tells a very different geologic story than the 10^2-m-diameter population.

(1) CTX mosaics covering 10,000 km^2 of a surface are more than adequate to capture a broad range of crater diameters on all age surfaces and provide similar relative and model ages to published geologic maps that utilize larger sample areas.

(3) The 1,000 km^2 samples show some variation in crater size frequency from sample to sample but often, broadly capture a similar relative age to the larger 10,000 km^2 sample. Taking into account the large differences between the different chronology systems [8,9], crater counts from the 1,000 km^2-scale samples can typically constrain a surface's age to within a specific epoch of Mars geologic time, and often to within the Early, Middle, or Late periods. Furthermore, the model age distributions for the 1,000 km^2 samples across the same terrain are relatively tight for their respective age, with a 1σ that ranges from just 0.08 Ga for Noachis Terra to 0.36 Ga for Syrtis Major. However, individual 1,000 km^2 regions sometimes exclude an appropriate number of pre-resurfacing km-sized craters for the model age fits. This is largely dependent on the magnitude of resurfacing over the 1,000 km^2 region and the age of the surface, which controls the mean distance between km-sized impact craters.

(4) 100 km^2 samples show significant variation in relative age across a region. In some cases, the N(0.2) and N(0.5) values provide plausible relative ages using the two different chronology systems that can span all three epochs of Mars geologic time (Fig. 2). Likewise, model ages vary dramatically from sample to sample for all terrains. We suggest that this range of ages is largely due to spatial variations in the cratering process where outlier cratering patterns, including clustered, random and dispersed distributions at the <100 km^2 scale, have a significant influence on the derived model ages. Furthermore, sample dimensions for a 100 km^2 area are more often than not less than the observed mean distance of km-size impact structures. Therefore, most crater counts at the 100 km^2 scale will typically miss the impact crater population that predates resurfacing.

Conclusion: Through an analysis of four type Noachian, Hesperian, and Amazonian-age terrains on Mars we have assessed the effectiveness of deriving relative and absolute model ages from different area samples at 100 km^2, 1,000 km^2, and 10,000 km^2. The results suggest that while the number of craters is an important factor that influences the reliability of small area crater counts, in terms of the absolute error of model age fits, a limited sample area provides two unique challenges to the crater counter. These include: (1) Random and non-random patterns in the cratering process generate spatial variability that has a strong influence on the derived model ages as the area

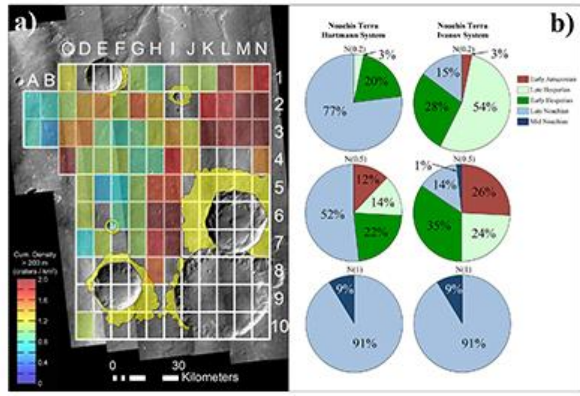

Fig. 2: Relative ages (N(0.2)) across Noachis Terra for 100 km^2 samples.

decreases. (2) Larger craters that have survived through some obliteration process are by probability excluded from crater counts as the counting area decreases. For Mars, complete resurfacing of < km-sized Noachian to Early Hesperian-age craters may have occurred globally [11,12,13] while resurfacing continued at a generally lower but significant rate throughout the Hesperian to Amazonian causing slope reductions in crater SFDs for < 10^2 m diameter craters. This suggests that the 10^2-m-diameter population that is commonly the only population available for a count on small area targets may consistently provide underestimates of formation age. Processes that destroyed craters by higher magnitude, more catastrophic events may also strongly influence even larger area crater counts (> 1,000 km^2) because the cut-off diameters of the SFD rollovers may exceed a few kilometers. We conclude that a high-resolution crater count, derived from CTX or HiRISE, should exceed 1,000 km^2 if possible with preference for counts that approach and exceed 10,000 km^2.

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