NOACHIAN RESURFACING IN THE MARTIAN HIGHLANDS: ANALYSIS OF A NEW GLOBAL GEOLOGIC MAP AND CRATER DATABASE. R. P. Irwin III[1], K. L. Tanaka[2], and S. J. Robbins[3], [1]Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution, MRC 315, 6th St. at Independence Ave. SW, Washington, D.C. 20013 (irwinr@si.edu), [2]U. S. Geological Survey, Astrogeology Science Center, Flagstaff, Arizona 86001 (ktanaka@usgs.gov), [3]Laboratory for Atmospheric and Space Physics, 3655 Discovery Dr., University of Colorado, Boulder, Colorado 80309 (stuart.robbins@colorado.edu).

Introduction: Previous geologic mapping and analysis of impact crater populations have identified substantial Noachian resurfacing and loss of craters in the Martian highlands. Based on Mariner 4 data, [1] noted that older Martian craters were more degraded than those on the Moon and Mercury, and many small craters had been concurrently lost, a result that later studies confirmed [e.g., 2–5]. Global mapping of Mars at 1:5,000,000 and 1:25,000,000 scales based on Mariner 9 imagery included a distinction between rough ("hilly and cratered material") and smooth ("cratered plateau material") intercrater plains in the highlands, although the contacts were approximately mapped [6]. The Viking-based 1:15,000,000 global geologic map further subdivided the highlands into similar hilly, cratered, and subdued cratered units, as well as dissected, etched, and ridged units that were defined by secondary morphological features [7]. Both global maps also included mountain, basin rim, crater, and smooth plains units in the highlands.

The new 1:20,000,000 global geologic map of Mars divides highland units by age and thus has implications for the resurfacing history [8]. The map distinguishes rugged, high-relief outcrops of the Early Noachian highland unit (eNh) from the uneven to rolling, commonly layered Middle Noachian highland unit (mNh) and the plains-forming Late Noachian highland unit (lNh). These descriptions acknowledge the variable amounts of relief and resurfacing within the highlands, as prior maps had noted, but with better contact placement enabled by new mission datasets.

The purpose of this study is to evaluate highland resurfacing events and processes using the new global geologic map of Mars [8], a crater database that is statistically complete to 1 km diameter [9], and Mars Orbiter Laser Altimeter (MOLA) topography [10].

Methods: The contacts between the eNh and mNh units were commonly mapped at a break in slope separating high-relief, rugged surfaces (eNh) from sloping, less densely cratered plains (mNh) (Fig. 1). These contacts were mapped as certain along escarpments and approximate where the eNh outcrops had a less sharply defined margin. The lNh unit included buried to partially buried cratered surfaces that were typically confined to highland basins and delimited mostly by certain contacts [8, 11].

We examined the crater densities for these units in diameter (D) bins of D–D*$2^{0.5}$ km to determine if they had statistically distinct relative ages (i.e., the bin error bars, ± the square root of the crater count normalized to 1 million km^2, did not overlap). Craters that overlapped or contained unit contacts were assigned to one unit or another by inspection, and craters in the superimposed Amazonian and Hesperian impact unit (AHi) were reassigned to their subjacent unit. We used crater depth/diameter ratios from [9] and a single-factor analysis of variance to test whether crater degradation varied with unit relative age. The elevation distributions of the Noachian units in 500 m bins provided information on whether resurfacing was gravity-driven or independent of topography. Finally, we determined the relative ages of the Hellas, Isidis, and Argyre basins by counting craters superimposed on their respective highland massif units, in order to evaluate a possible link between resurfacing and basin ejecta [11].

Results: The eNh, mNh, and lNh units had statistically distinct crater retention ages in diameter bins >16 km, whereas their crater densities converged between 4 and 16 km (Fig. 2). At D<4 km, all three units had a mid-Hesperian age in Hartmann's scheme [5], consistent with the loss of all Noachian craters <4 km in diameter to ubiquitous resurfacing by that time.

Crater depth/diameter ratios were not significantly different between the eNh and mNh units. Craters in the lNh unit were mostly buried on highland basin floors, so this analysis was not done for that unit.

We confirmed mapping interpretations by finding found distinct and complex elevation differences between the units, associated with their regional and local spatial distributions. The eNh unit was concentrated in the high-standing Hellas basin annulus (within one inner ring diameter, 2400 km, of the inner basin ring) and in outcrops in the region of high crustal magnetization around 180º E, where the effects of Early to Middle Noachian basin-scale impacts were minimal. The mNh unit was extensive in Arabia Terra and in highland corridors between eNh outcrops.

The sequence of the largest impact basins was Hellas, then Isidis, and finally Argyre, consistent with prior work [12–14]. Hellas ejecta may have resurfaced the eNh unit, but other basins could not account for the age and full extent of Middle Noachian resurfacing.

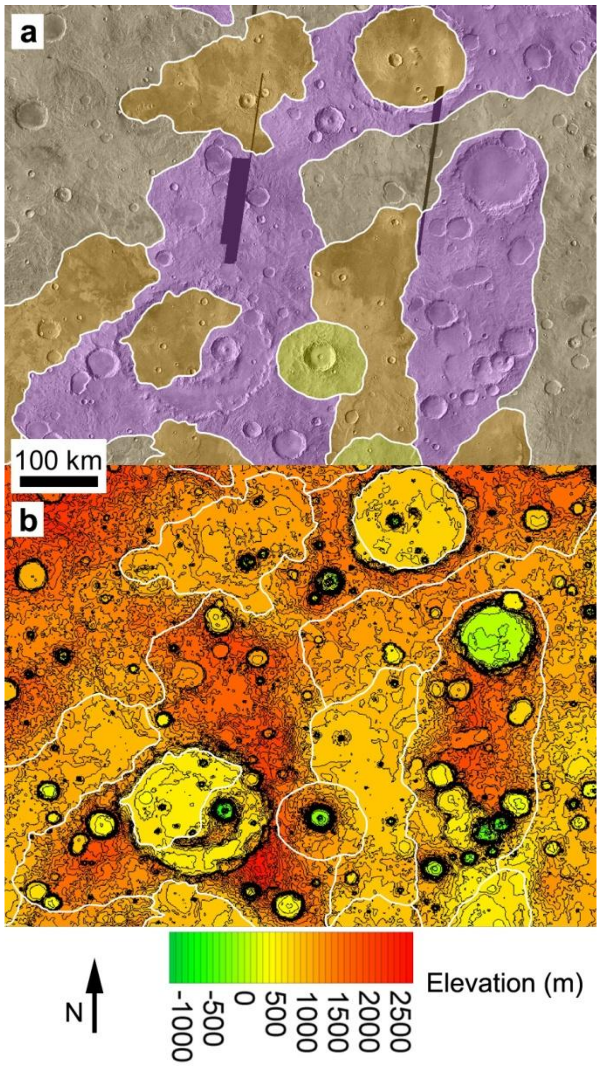

Fig. 1. (a) Example of map units eNh (purple shade), mNh (dark brown), lNh (orange-brown), and AHi (yellow) at 20–30ºS, 145–158ºE in Terra Cimmeria. (b) Same area on MOLA contour map, 100 m interval.

Discussion: The distinct relative ages of the units show that Noachian resurfacing was not spatially uniform. The lack of a relationship between crater infilling and crater density in the eNh and mNh units suggests that age was not the only important factor in crater degradation. The regional concentrations and elevation differences among the units show that Middle Noachian resurfacing was more significant in certain regions (Arabia Terra, Argyre vicinity, dichotomy boundary) and in lower-lying areas of the highland plateau than it was in higher-standing areas, as noted qualitatively during mapping. Although Early Noachian Hellas ejecta resurfaced much of Mars, the Early to Middle Noachian Isidis and Middle Noachian Argyre impacts had more limited effects.

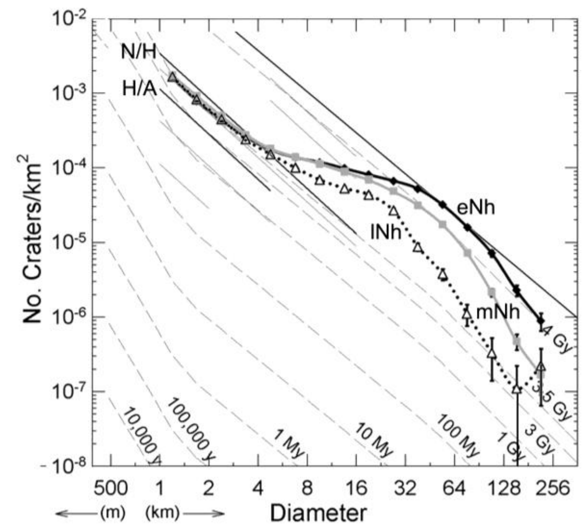

Fig. 2. Crater populations for highland units, shown on Hartmann isochron plot [5]. The Noachian/Hesperian (N/H) and Hesperian/Amazonian (H/A) boundaries are labeled. Figure adapted from [11].

These relationships and the concentration of lNh outcrops in basins are consistent with preferential erosion of highs and deposition in lows, i.e., a gravity-driven resurfacing process. Uniform airfall mantling on a regional scale is plausible (but not uniquely so) on the widely resurfaced Arabia Terra [15], however it does not appear to have been important on most of the highland plateau. Evidence for Noachian or Hesperian glaciation is lacking in the equatorial region. The most suitable candidate resurfacing processes for the mNh and lNh units are fluvial erosion and volcanism, likely with contributions from aeolian sand transport.

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