IMPACT CRATER DEPTH AND DIAMETER CHANGES ON NOACHIAN MARS. Y. Matsubara[1], R. P. Irwin III[1], R. A. Craddock[1], A. D. Howard[2], and L. Bandeira[3], [1]Center for Earth and Planetary Studies, NASM Smithsonian Institution, Independence Ave. at 6th St. SW., Washington, D.C. 20013, (matsubaray@si.edu), [2]Department of Environmental Sciences, University of Virginia, [3] CERENA, Instituto Superior Técnico.

Introduction: Impact craters are essential in planetary studies for two main reasons. First, craters and crater populations provide an essential tool for assessing the relative ages of geologic units and surface features on planetary bodies. As for the Moon and Mars, rough estimate of absolute ages can be acquired based on the crater population and rock samples retured by the Apollo missions. The martian surface dating models are based on the lunar crater populations with adjustments for gravity, bolide frequency, and atmospheric effects [1, 2] assuming that the size distribution and flux of impactors are the same for the Moon and Mars.

Secondly, because craters formed universally throughout the history of the Solar System and have fairly consistant, simple initial geometry, any changes in geometry are record of environmental conditions they experienced over time. On Mars, the best insights into long-term environmental conditions have come from studies of crater degradation [e.g., 3–5] and the interaction of cratering with other processes in shaping the Noachian landscape 6–8]. When looking at Noachian craters on Mars, it can easily be noted that they come in various degradation stages and that degradation is not dependent upon crater diameter. Many of the Noachian craters <20–40 km in diameter (D) have been lost from the surface record [e.g., 9], including nearly all Noachian craters D<4 km [10]. Some of the larger craters were degraded to a rimless and shallow form, requiring substantial lateral erosion and infilling [e.g., 11, 12]. This observation indicates that more prolonged erosion is required than can be explained by late, short-lived events, because otherwise the craters of similar size would all be degraded equally and have similar morphology, and larger craters would be less degraded than smaller ones. It is also evident that crater degradation rates by fluvial processes decreased drastically after the Noachian Period [e.g., 5, 13].

To date, published chronologies have not addressed the loss of smaller craters from the surface record or the increase in diameter that is caused by fluvial erosion of martian crater rims. The erosional widening of Noachian craters that occurred during modification is unlike anything seen on the Moon [5, 14, 15], and thus, modification complicates determination of the absolute ages surface units on Mars.

The objective of this study is to analyze crater morphometry changes due to fluvial processes over time using a simulation model to estimate minimum initial diameters for observed degraded craters.

Crater Degradation: Relative to impact craters on the Moon and Mercury, Noachian craters on Mars generally have distinct cross-sectional profiles, with relatively flat floors and eroded rims. Their depth/diameter ratios are significantly reduced relative to fresh martian craters or craters on the Moon and Mercury [e.g., 15–17]. Furthermore, as previously mentioned, many small Noachian craters have been lost from the surface record [10]. Martian impact craters were not strongly modified after the Noachian Period [4, 15, 18–20], implying possible loss of a thicker atmosphere (e.g., [21]). Originally, it was suggested that aeolian deposits [22] or lava flows [23] are responsible for the observed morphology. However, infilling by lava flows or aeolian deposits does not affect the rim structure; hence, the heavily eroded rim observed on Noachian craters is likely the result of aqueous weathering and fluvial erosion, with other processes playing lesser roles.

For this study, we are only focusing on the crater degration by fluvial processes, because of the climatic implications and it is the only process that affect the crater diameter.

Methodology: We used the MARSSIM landform evolution model in order to understand how craters of specific diameter degrade over time under the influence of different climatic conditions. The MARSSIM landscape evolution model was developed by Alan Howard and can simulate variety of geomorphic processes and impact cratering on planetary surfaces. To date the MARSSIM model has been applied to study various planetary bodies, including Mars, the icy satellites of Jupiter and Saturn, and Pluto [8, 24–26].

The effectsof fluvial processes can be tested by adjusting mainly two parameters: evaporation scaling ($X=(E-P)/RP$) and discharge exponent (α in $Q=\kappa A^{\alpha}$), where E is the mean annual evaporation (m), P is the mean annual precipitation (m), R is the fraction of annual precipitation that results in surface runoff, Q is the discharge, k is a constant, and α is the discharge exponent that measures the effectiveness of precipitation to produce surface runoff. X is the ratio of the net lake evaporation rate to runoff depth per year and larger value of X represents more arid condition (Table 1). The value of α can show the dependency of surface runoff on contributing drainage area can be varied

from 0 to 1.0. The discharge is well-correlated with drainage area when α =1. The terrestrial value of α is about 0.3 for arid regions and 0.7 for a typical humid region [26, 27].

Table 1. Terrestrial examples of *X*-values. The LGM (the Last Glacial Maximum) conditions were estimated by [28].

	Warm Desert						Moderate	Cold
	Western UT		Western NV		Death Valley, CA		Central VA	Northwestern Canada
	Present	LGM	Present	LGM	Present	LGM		
X Ratio	8.21	1.8	8.74	4.5	20.75	6.8	-0.92	-0.83

Thus far we have simulated the degradation of individual craters from 10–100 km at a 10 km size interval under semi-arid conditions (α=0.3–0.5, X=10), because our previous studies indicated that it was the condition that most likely represented the Noachian climate [29, 30]. For each simulation, we used an initial condition with a single crater at the center of a square area, each side equal to three crater diameters wide and at the resolution of 600 m/pixel. This initial condition is a geometric representation of an impact crater based on fresh crater morphology; we did not model the impact process itself. We calculated the average crater diameter and depth at each time interval by averaging the four cross-sectional profiles (Fig. 1).

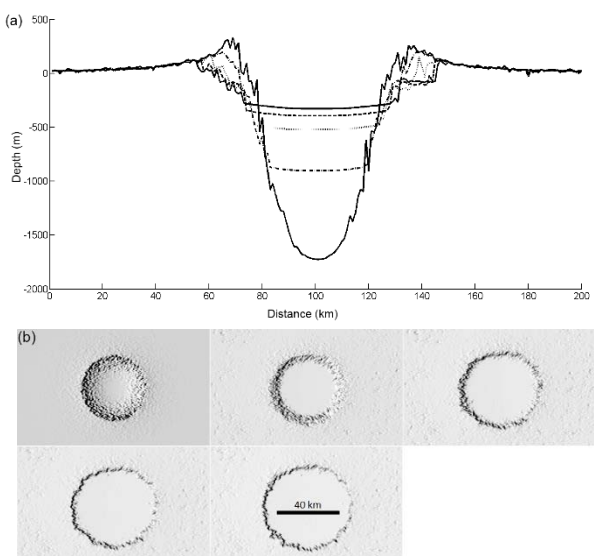

Fig. 1. Example of crater degradation simulation results using α=0.5, *X*= 10. Both cross-sectional (a) and aerial (b) view show widening of the crater and smoothing/infilling of crater floor over time.

Preliminary Results and Discussions: We plotted the changes in crater diameter and depth for each initial crater diameter (Fig. 2). This graph shows how crater depth and diameter changed over the simulated time interval. The results clearly depict that craters get wider and shallower over time under fluvial erosion. The shape of the curves for each initial crater diameter are very similar with high R^2 value. Craters initially get filled in as crater rim gets eroded away and then widens rapidly through backwasting of crater wall.

This graph can be used as a look-up table for initial crater diameter. One can look at current depth and diameter and see if it falls on any of the modeled lines. Knowing initial diameter could be used to evaluate the effects of crater degradation on crater chronology.

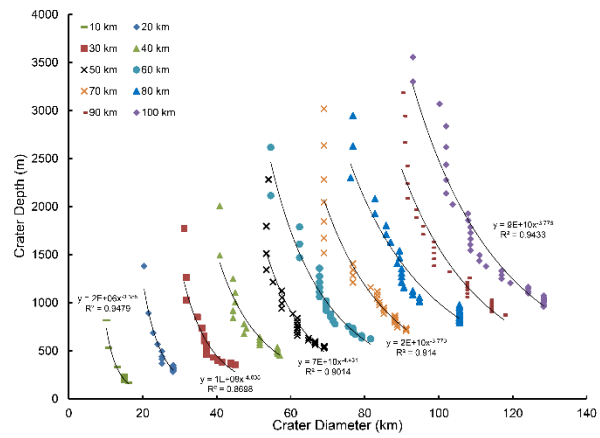

Fig. 2. Relationship between crater diameter (km) and depth (m) as a crater degrades over simulation time for initial crater sizes of 10 km to 100 km. This was obtained by running the simulation with one crater in the center and plotting the changes in diameter against depth over time.

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