New Estimates of Martian Erosion Rates from Crater Obliteration Statistics

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Abstract

- Geologists and planetary scientists have confirmed the existence of water on Mars over the past 50 years.
- How much water has existed on Mars throughout time?
- We can zoom in on Mars's glacial and fluvial histories and use erosion rates and latitude as a proxy for extent of hydrologic activity.
- I will extract crater-frequency distributions for each unit to determine the age of the unit and its long-term erosion rate and compare these rates across latitudes.

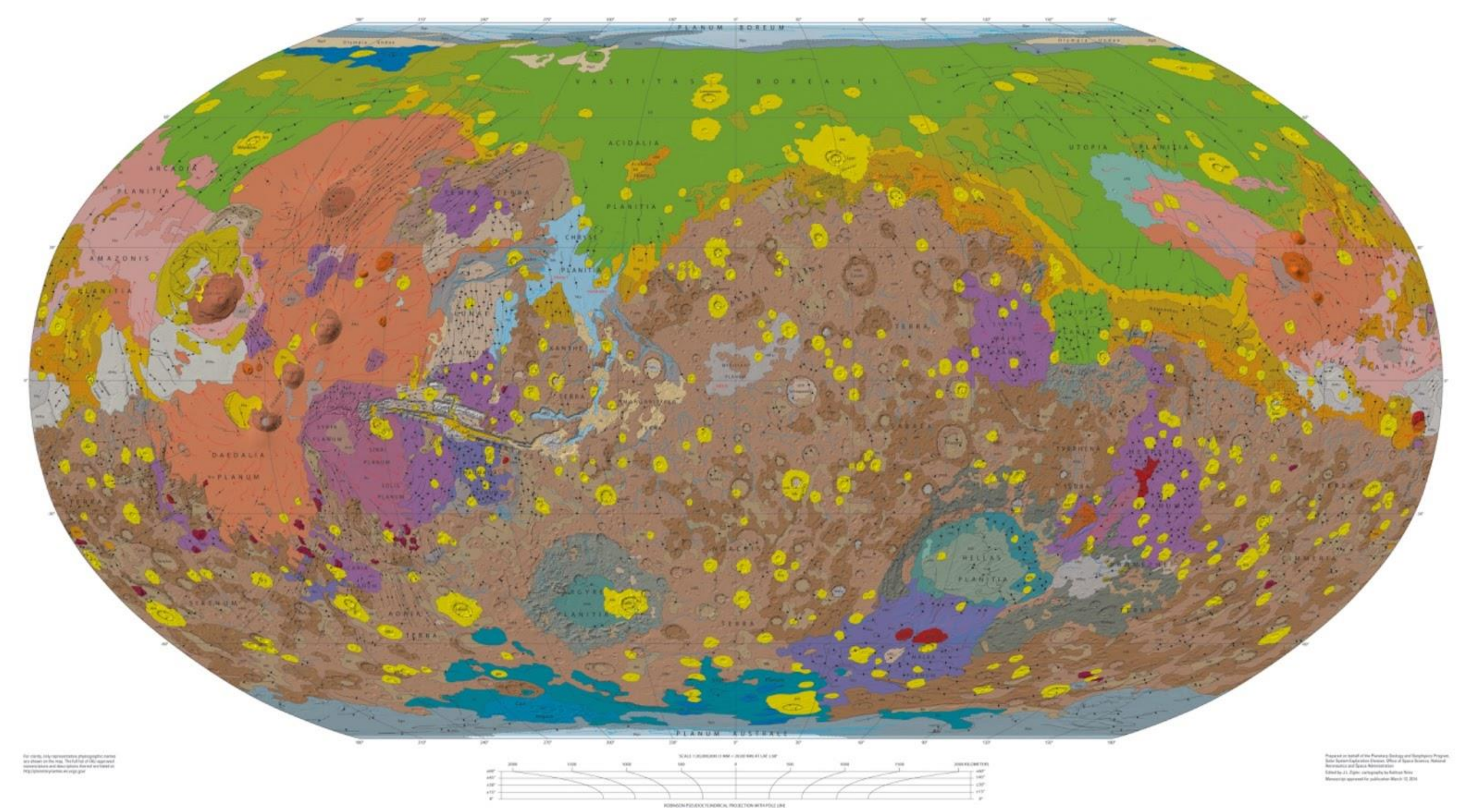

Figure 1. Geologic Map of Mars. Colors represent geologic unit, which are areas categorized by the rock's age, mineralogy, and structural features (Tanaka et al., 2014).

Introduction

- In 1971, Mariner 9 enabled the discovery of both sinuous and dendritic channels on Mars, polar water and carbon dioxide ice, and many other Earth-like geological features in Mars' surface.
- The source of such a large amount of water needed to carve these Martian channels was not immediately evident – theories included release from the atmosphere, polar caps, and ground ice (Plescia, 1990).
- In order to understand Martian history, we need to constrain the ages of its geologic features. Without rock samples, we must rely on dating methods using imagery, like crater counting (Hartmann and Neukum).
- Isochrons relate impact crater densities and diameters to age the underlying surface, leading to the creation of geologic maps of Mars (Figure 1).
- Smith et al. (2008) argue that Martian crater counting models must be adjusted for crater obliteration (Figure 2), and formulated an equation relating abundance of measured craters (N) at a time (t), crater production rate (p), loss rate (λ), crater diameter(d), and erosion rate (β).
- We can fit craters to these updated isochrons, and determine the erosion rates of each geologic period, and therefore, each geographical area of the planet.
- Combining our new erosion rates with previously published geomorphic maps, we can determine the relative importance of glacial vs fluvial processes on shaping the Red planet.

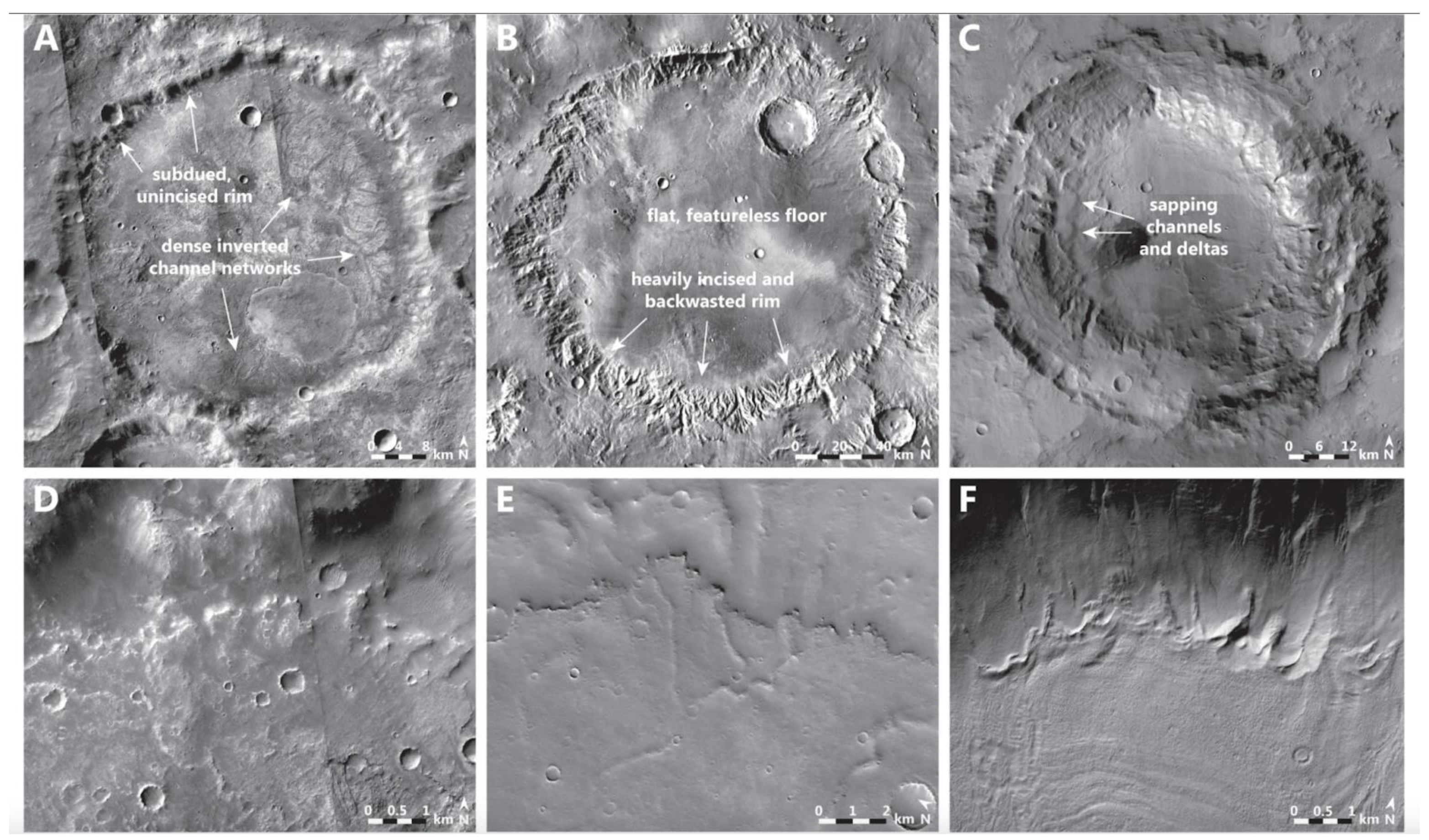

Figure 2. Geomorphology of degraded craters. Over time, Martian craters will shallow. The rims erode and infill into the basins, decreasing relief (Boatwright and Head, 2021).

Methods

- Data: Robbins Crater Database and Martian Global Geology, Contacts, and Structures map in GIS format.
- First, in ArcGIS, I will group the craters by their unit. Next, I will plot the craters using isochron code from Palucis et al., comparing overall area of the geological unit to its crater-frequency distribution, and receive an erosion rate output. I plan to invert for best-fit age and erosion rates via a Markov Chain Monte Carlo approach.
- Finally, I will group units by latitude bands and observe the relationship between erosion rates and latitude, as glacial erosion is thought to be the dominant erosional force at the poles of Mars, whereas fluvial erosion is more likely to exist closer to the tropics, the region around the equator.

$$N = \frac{1000}{\psi\beta} p(d)\xi(1 - e^{\frac{-\psi\beta t}{1000\xi}})$$

Figure 3. Smith et al. formula for crater abundance (N) based on crater production (p) and obliteration rates (λ), along with crater diameter (d), and erosion rate (β) (Smith et al., 2008).

Results

- Erosion rates are thought to have quickened in time periods and locations with more water available. During the Noachian epoch, Mars's climate was relatively warm and wet, whereas today it is extremely cold and hyperarid. However, there are highland paleodrainage systems that indicate hydrological activity during the Amazonian epoch (Salese et al., 2016).
- I expect to observe significant variations in erosion rates across time periods (Noachian, Hesperian, Amazonian) and latitudes, along with higher erosion rates at the poles and tropics on Mars.

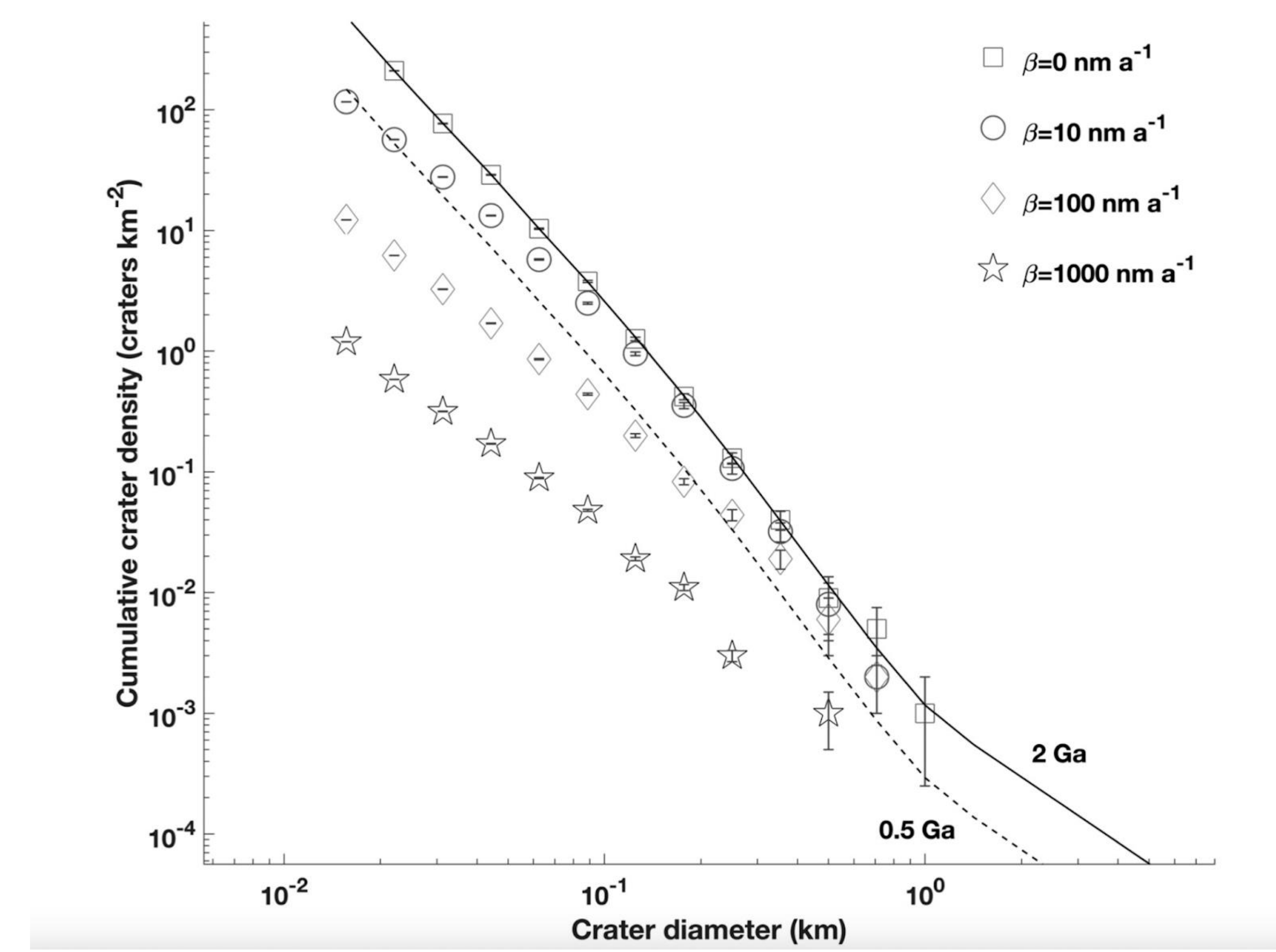

Figure 4. Crater isochrons with varying ages and resulting erosion rates. With higher rates of erosion, there are fewer small craters observed due to obliteration, resulting in shallower isochron slopes (Palucis et al., 2020).

Discussion

- The implications of water and ice on Mars are massive, particularly when considering the habitability of Mars for water-based life.
- In terms of comparative planetology, studying Martian systems teaches us about ancient terrestrial patterns.

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