

Formation timescales of Amazonian-Hesperian aged Martian valley networks. R. S. Bahia¹ and V. Steinmann²,
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Introduction: The surface of Mars is incised by numerous valley networks, which are noted as evidence for surface run-off and past water cycles on ancient Mars [e.g. 1–3]. It is generally agreed that the majority formed as a result of precipitation-fed fluvial incision [4], however there is still great uncertainty in the duration, intensity and surface conditions that led to valley formation. The majority of these valleys formed during the Late Noachian – Early Hesperian period [e.g., 3], however younger valleys are observed incising Late Hesperian and Amazonian aged surfaces [e.g., 5], after the hypothesized loss of Martian atmosphere.

It is hypothesized that Mars' climate was warm and wet during the Late Noachian – Early Hesperian [6], conditions conducive for valley formation via precipitation-fed runoff. After the Early Hesperian valley network formation rapidly decreased as a result of the loss of Martian atmosphere and resulting vast increase in aridity. However, the presence of valleys incising young (Late Hesperian – Amazonian) surfaces indicate that fluvial incision locally persisted after global climatic conditions were no longer favorable.

Recent analysis of flat crater-bottom deposits within Hesperian – Amazonian aged craters has revealed that this period was not as arid as previously hypothesized [7]. Flat crater-bottom deposits are generally located downslope of alluvial fans, associated with fluvial activity. The extreme flatness of these deposits (a range of elevation of a few meters over kms) and location at the bottom of a crater indicates aggradation was controlled by an equipotential, most likely surface liquid water. The dimensions of these deposits, along with lake areas and drainage areas, can be utilized to calculate the hydrologic X-ratio, which is approximately equal to the aridity index (potential evaporation/precipitation) [e.g., 7, 8]. Utilizing this technique, it was found that the equatorial and northern mid-latitudes of Mars had wetter climates persisting after the Early Hesperian, with comparable aridity values. Further, the study revealed that the source of fluvial activity was likely not a result of localized impact triggers, as brief wet events would likely results in small/shallow craters filling more than big/deep craters, a trait that is inconsistent with their observations.

Calculating the duration of fluvial activity required to form Amazonian-Hesperian aged valley networks will further understanding of climatic conditions at this time. Additionally, paleohydraulic calculations (Hack's

Law and Flint's Law [9, 10] can reveal information about the origin and intensity of fluvial activity that formed the valley network.

In this study, we plan to map and perform detailed paleohydraulic analysis on 33 young Martian valley networks, at a range of latitudes, to gain a greater understanding of the origin and duration of fluvial activity required to form the valley networks. In turn, these findings will reveal information about the climatic conditions after the loss of the Martian atmosphere. Here we present the technique and results for a proof of concept valley network.

Data and Methods: Valley networks were initially identified using the Hynek et al. (2010) [3] valley map, and narrowed to those predominantly incising Amazonian-Hesperian [11]. ArcGIS Pro was used to perform detailed morphological analyses of these valleys, including high-resolution mapping (Context Camera images – 5 m per pixel).

To perform paleohydraulic and formation timescale calculations, digital elevation models (DEMs) are necessary. For this study, High Resolution Stereo Camera (HRSC) DEMs were used, and down sampled to ~ 100 m per pixel in resolution for consistency.

Several GIS software were used to obtain the required data; SAGA GIS was used to determine full water depth estimates and flow width via the multiply flow direction method; GRASS GIS was used to determine flow accumulation, flow direction, and upstream slope; ArcGIS Pro was used to perform spatially variable drainage area calculations for Hack's Law and Flint's Law calculations.

The formation timescale calculations build upon previous techniques [12, 13]. For the formation timescale calculation, the estimated volume (km³) of each pixel (result of the full water depth multiplied by the pixel resolution) was divided by the volumetric transport rate (km³/yr).

Initial Results: 33 valley networks incising Amazonian-Hesperian aged surfaces have been identified, from a range of latitudes (between 50 °S and 35 °N) and across all longitudes. Valleys on the rims of volcanoes have been avoided, as their origins are potentially lava flows [e.g., 14, 15].

At present, we have applied the technique to one of these valleys networks. This valley network is located north-east of Lowell Crater (49.82 °S 77.16 °W) with its source within the Middle Noachian highland unit;

however, the majority of the network incises an Amazonian-Hesperian aged impact unit. The valley network has a cumulative length of ~874 km, and a main valley length of ~123 km. The main valley has an almost linear profile with an average slope (dz/dl) of ~ 0.012. Based on a calculated average water velocity of 6.8 m/s and an average 12.25 m water depth, the average formation time for the whole study area is 23235.3 yr (1 sigma standard deviation = 39401.2 yr).

Discussion: The formation timescale for the examined young valley is ~ 20 to 63 thousand years. Given the near-linear profile and low slope of the valley it likely formed via ephemeral fluvial activity, indicating that the ~20 to 63 thousand years of formation may have been spread over a greater length of time.

Analysis of seven large Late Noachian – Early Hesperian Martian valley networks, with runoff similar to intense storms in arid regions on Earth, indicates that they have minimum formation timescales ranging from 10^5 to 10^7 [13]. In comparison, the examined young Martian valley is immature. However, it is apparent that thousands of years of fluvial activity were still required to form the valley in a period expected to have been extremely arid.

By applying formation timescale and paleohydraulic calculations to the 33 young valley networks of interest, we will be able to better understand the duration and origin of fluvial activity that formed them. This information will reveal information about the climatic conditions after the loss of the Martian atmosphere and perceived loss of a warm and wet climate.

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