Introduction: Valley networks provide the best evidence that water and fluvial processes were active at the surface of Mars sometime in the ancient past. Most networks are located in the Noachian highlands [1]; Hesperian terrain contains some sporadic valley networks systems [e.g., 2], while the Amazonian terrain contains valley networks system in localized places such as the flanks of volcanoes [1]. The omnipresence of valley networks in the Noachian highlands indicates that the global atmospheric conditions were different during the early history of Mars and much different than the dry and cold conditions today [e.g., 3]. However, the timing of Martian fluvial activity is not well understood. For example, we are not certain if all Noachian valley networks formed concurrently. It is also not clear if the valley networks in the highlands were active at the same time valley networks were forming on younger terrain. Are all Martian valley networks correlated in space and time? Are they correlated to a single climate phase?

Martian valley networks are small, linear features that do not easily lend themselves to age dating by conventional crater counting techniques [4]. Early efforts to age date Martian valley networks were based on Viking images [1] where the valleys were mapped at a global scale of 1:5,000,000. A more recent study [5] proposed crater counts on valley networks using a “buffered” crater counting technique on global image mosaic at around 200 m/pixel. Despite the different approaches, these studies indicate that there was a very active early stage of fluvial activity during the Noachian leading to more sporadic events during the Hesperian and Amazonian period. Yet, it is still not clear if there were regional or even local temporal variations in valley network formation.

In an effort to determine the possibility that there were temporal variations in valley network formation, we have applied a crater counting technique using small impact craters to several select regions on Mars where there is sufficient high-resolution imagery. Our efforts concentrated on highland valley network system emplaced on Noachian terrains and on valley networks emplaced on volcanic edifices. In the highlands we focused on two dense concentrations of valley networks in Noachis Terra and in Tyrrhena Terra and on two large valleys Evros Vallis and Nirgal Vallis, which are part of a larger valley network system. We also focused on the flanks of several volcanoes where some dense valley networks have been described [6], including Alba Patera (Amazonian) and Hecates Tholus (Hesperian).

Our results indicate that the use of small diameter crater populations may be helpful in discerning temporal variations in valley network formation.

Data Set and Method: Our preliminary work was supported by global MOLA topography and the released THEMIS daytime IR mosaic, which is at a resolution of 200m/pixel. The first step was to map the valley networks on MOLA data and the THEMIS IR daytime mosaics. The second step was to perform crater counts on the plains surrounding the valley networks using the THEMIS IR daytime mosaic as a base. For consistency, the crater counts were always performed on homogenous geological units as mapped by Tanaka [7]. These crater counts allowed us to assess the crater population larger than 2 km in diameter and provided us with a general age of the terrains where valley network formation occurred.
In a third step we measured the crater populations visible in high-resolution (~18 m/pixel) THEMIS VIS images, and determined crater counts for the valley network interior, including the trunk channel and tributaries. The resolution of the THEMIS VIS images was comparable in every location we investigated so that we assessed consistent crater populations between 200 m and 2 km in diameter. We were also careful to map only the impact craters postdating the valleys (see Figure 1). Our analyses provided us with both the age of the surrounding terrain as well as the age at which fluvial activity ceased.

Results: We analyzed 6 distinct areas on Mars (Figure 2) and found no temporal differences within the different Noachian locations despite the fact that the drainage basins we dated were separate, independent systems. In parallel, we also applied the same method to two dense valley networks on the flanks of volcanoes: on Alba Patera and on Hecates Tholus, two volcanoes located in the north hemisphere, at antipode location.

Evros Vallis: Evros Vallis is a ~200 m deep, ~2 km wide and ~600 km long valley network located in Noachis Terra that erodes through a single geologic unit [Npld; 9]. This valley network system also contains many tributaries along its length (Figure 3). The crater densities for the surrounding plain are presented in Figure 4 and are indicated by the blue squares (craters >2km). The crater size distribution is complex, implying that many resurfacing processes occurred. The age given by the larger craters indicates that the plain is ~4 Gy, which is in agreement with the geological mapping of Tanaka [7]. Resurfacing events occurred at 3.8 Gy (Noachian) and between 3.3 and 3.5 Gy (early Hesperian).

Figure 3b shows a sample of the smaller crater populations within Evros Vallis that are visible at higher resolution (18 m/pixel). The crater size distribution of impacts smaller than 2km as recorded in the high-resolution images are shown by red squares in Figure 4. The size-distribution follows an isochron slope indicating that valley network formation ceased between 3.3 and 3.5 Gy. This age is in agreement with the youngest resurfacing event recorded by the larger impact crater populations from the surrounding plains and suggest that the last episode of fluvial activity in this region occurred in the early Hesperian.

Figure 2. The location of our 6 study areas shown on a global map of Mars indicating the mapped location of valley networks (yellow) and outflow channels (red. Modified from [8]).

Figure 3. Evros Vallis System. A) MOLA map of the valley system. The black line where counts of small impact craters were performed B) THEMIS VIS image of the interior of Eros Vallis showing craters smaller than 2 km in diameter that post-date valley formation.

Figure 4. Crater populations in the Evros Vallis system. The counts are shown on the latest version of Hartmann’s diagram [9]. Blue squares correspond to counts done on the surrounding plain using 200 m/pixel images and red squares correspond to fine scale counting on the valley networks at 18 m/pixel.

Global Analyses: The global results that will be present at workshop. All the valley systems emplaced
on Noachian terrains demonstrate that the highlands were resurfaced by several major events; however, valley networks contained in these materials date to the early Hesperian. The valley networks located the flanks of volcanoes can be dated to a variety of ages. Geologic evidence suggests that Hecates Tholus was formed during the Hesperian [7], and we dated the last fluvial activity on its flanks at 3 Gy (late Hesperian). Similarly, geologic evidence suggests that Alba Patera was formed during the Amazonian [7]. We dated valley networks at the base of the volcano as early Amazonian in age where valley networks at the summit appear to be middle Amazonian in age. We date the last fluvial activity in our study areas at 1 Gy.

Discussion: This study reveals that all valley networks emplaced on Noachian terrains stopped their activity during early Hesperian regardless of geographic location. This would suggest that highland valley networks record temperate global climate conditions that ended by the early Hesperian. However, valley networks on the volcanoes are unrelated in time to other valley networks. This argues for more local conditions that may be related to the volcanic activity itself.

Valleys networks dated as late Hesperian in age have been found on the Echus plateau and appear to have formed by atmospheric precipitation [2]. In our analyses, however, we did not found evidences of such late Hesperian fluvial activity in other parts of Mars, suggesting that the Echus valley networks may

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References: