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The Nature and Origin Of Mars Valley Networks

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Abstract

Valley networks are often cited as the best evidence that liquid water was stable on the surface of Mars early in its history [1]. However, geologic evidence is beginning to emerge indicating that the period of time valley networks were forming was actually short-lived and restricted primarily to the end of the Noachian/beginning of the Hesperian [2]. Other geologic features, such as modified impact craters, outflow channels, fluidized eject craters, putative evidence for ancient shorelines, and even volcanoes offer some evidence as to the ancient climatic conditions that may have existed on early Mars. These features suggest that the conditions were similar to the conditions that probably existed on the Earth when life was forming on our own planet. Valley networks are an important clue to the timing and intensity of fluvial processes that occurred on ancient Mars, but they must be placed into context with other features.

1. Valley Networks

A number of different observations indicate that a majority of valley networks are late Noachian to early Hesperian in age [3, 4, 5]. It is important to note that while crater ages provide an estimate as to when fluvial processes ceased and the surface became stable, they do not provide any clues as to when fluvial processes began. Instead, the evidence for when (or how long) valley network formation occurred comes from the drainage density, or maturity, of the valley networks. Because valley networks frequently lack smaller, space filling tributaries and many of the associated deposits, such as fans or deltas, can be explained in a few events, it is likely that valley network formation occurred during a "climatic optimum" at the end of the Noachian [2]. Valley networks are concentrated in a region located roughly between ±30° latitude. Preliminary climatic models that deduce the conditions on Mars while assuming that there was a hemisphere winters large monsoons would have been generated [6]. These monsoons would have moved south into the highlands, and rainfall would have preferentially occurred where valley networks are located [6]. Although a number of features, such as sapping canyons [7] and quebradas [8] have been proposed as analogs to valley networks, few features on Earth are good physical analogs. However, it is possible to use terrestrial fluvial features as processes analogs (Figure 1).

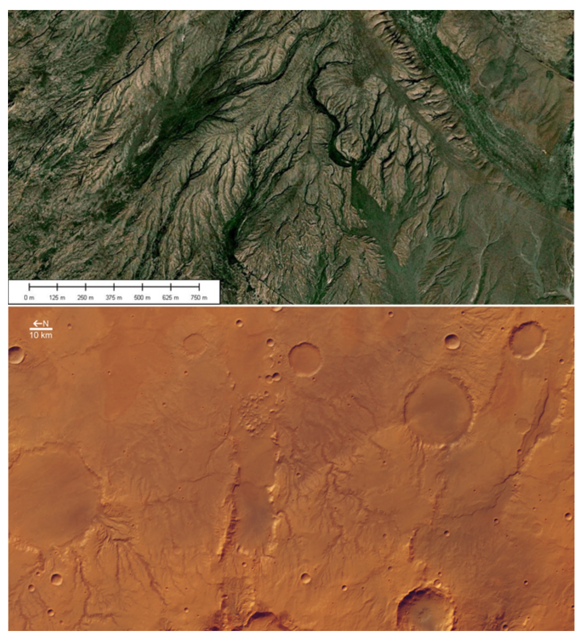

Figure 1: Although the scales are different, gullies formed in loose, friable basaltic tephra (top) have widths that vary independently with length. "Degraded" valley networks (bottom) share the same morphology, suggesting that the also formed in loose, friable materials with poor bank strength. Instead of implying temporal differences, valley network morphology may actually reflect local lithology.

2. Modified Impact Craters

Valley networks are only one group of features that record the history of fluvial processes on the Martian surface, and it is important to place our understanding of valley networks into context with these other features. One of the most important clues about the early climatic and geologic history of Mars comes from modified impact craters. These features often lack a raised rim or an ejecta blanket, and they often have flat floors and steep interior walls that have been incised by gullies. The only way to produce craters with these characteristics is through rainfall and surface runoff [9]. However, modified impact craters are preserved in various states of degradation and occur at all crater sizes. If crater modification occurred during a single, short-lived "climatic optimum," then it would be expected that modified craters would be preserved in a single degradational state with smaller craters being more eroded than larger ones. Instead, the geologic record indicates that crater modification persisted throughout the Noachian and into the early Hesperian [9]. This is important, because modified impact craters indicate that fluvial conditions predated the formation of valley networks. Because valley networks also breach modified impact craters [10], it appears that crater modification continued during valley network formation.

3. Summary and Conclusions

While it is probable that valley networks and modified impact craters formed in an arid to semi-arid climate, these features indicate that rainfall and surface runoff persistent throughout most of the early history of Mars. The only way for such conditions to have existed is if water in the atmosphere was in equilibrium [11]. Basically, rain cannot occur if it falls into dry vacuum. For any kind of erosion and sediment transport to occur from rainfall or snowmelt and runoff, there must have been standing bodies of water on Mars while these processes were occurring. It is possible that modified impact craters record the period when most of the volatile inventory on Mars still persisted as a steam atmosphere following accretion. As impact craters were forming, they were slowly being eroded by rainfall as the steam atmosphere condensed and precipitated down to the surface. Eventually enough of this atmosphere collapsed and precipitated to the surface to create the conditions necessary for a "climatic optimum" initiating valley network formation. The continued collapse of the steam atmosphere into the regolith eventually built up an aquifer with a sufficient hydraulic head to initiate outflow channel formation. Coupled with the increased volcanism during the Hesperian, it is possible that climatic conditions during this time period were the most favorable for life.

Acknowledgements

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