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Detailed mapping and statistical analyses of martian valley networks: Topographic controls on their drainage densities

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In this study, the martian valley networks are focused, because 1) dendritic pattern of tributaries may show the formational process related to water cycle rather than episodic flood, and 2) they are possibly omnipresent in Noachian terrains and thus they can reveal the water cycle at a global scale. Previous investigations, however, focused on valley networks at local to regional scales, which includes geologic evidence of precipitation, and to assess whether valley formation was related to global phenomena, including climate-induced activity, has scarcely been done. Thus, we investigate the distributional patterns of the valley networks in detail and the global tendency of the characteristics of the valley networks, to infer the formational processes and the martian paleoenvironment.
Using THEMIS IR and Viking MDIM2.1 images and MOLA topography data, we mapped the clusters of valley networks in five Noachian drainage basin regions, which are spatially separated, and 7 post-Noachian dissected volcanoes. Based on this mapping, the parameters indicating individual valley network shape are measured and calculated, such as drainage area, drainage density, mean elevation, and mean slope. These parameters are used in statistical analyses.
217 major valley network systems, which occur within Noachian and post-Noachian terrains, are identified in the study regions, and total identified valley length exceeds 300,000 km. The drainage densities range from 0.02 to 0.98 km-1, which compare with terrestrial values. The geologic mapping-based results, which includes statistical analyses, point to precipitation under a warm and wet climate during the Late Noachian to Early Hesperian Epochs with possible groundwater sapping contributions. The evidences are 1) the valley heads near the sharp ridge crests, which exist in all of the five Noachian drainage basin regions, 2) the mean values of drainage densities for each region ranging from 0.2 to 0.4 km^{-1}, which is compared to terrestrial typical value, 3) no significant correlation among drainage density and mean elevation, which has difficulty to be explained by pure groundwater sources, and 4) strong and positive correlation among drainage density and mean slope for all of five Noachian drainage basin regions, which is consistent with precipitation-fed surface runoff and/or groundwater sapping.
Although what drove the atmospheric water cycle during Noachian Epoch has not been revealed, the paleoocean and lakes possibly existed in northern plains and Hellas and Argyre basins can have been contributor to the formation of valley networks. This hypothesis can explain why no large drainage basin exists within the Region 1 (Terra Sirenum and Southern Terra Cimmeria region), which is distant from both northern plains and Hellas Basin. Instead, if local heat sources accompanied by tectonism, volcanism, magmatism, or impact, led to precipitation at local to regional scales, these activities would have changed significantly the topography of the region and thus the correlation among drainage density and mean slope would not be detected.
The correlation among drainage density and mean slope does not detected in post-Noachian volcanoes, which is consistent with the hypothesis where the global climate changed at Noachian/Hesperian boundary, but further study is needed to ascertain the reliability of this result because of the possibility that not sufficient number of post-Noachian valley networks have been analyzed statistically.

Keywords: Mars, valley networks, drainage density, water cycle, precipitation, statistical analysis