MAPPING VALLEY NETWORKS IN THE NOACHIAN TERRAIN AROUND NAKTONG VALLIS, MARS: TOPOGRAPHIC CONTROL ON DRAINAGE DENSITY.

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Introduction: Most of the cratered uplands of Mars are dissected by networks of branching valleys, whose evolutionary history is still controversial [e.g. 1, 2]. The valleys show branching patterns closely analogous to terrestrial fluvial valleys, which may indicate that the valleys were cut primarily by surface runoff after precipitation [2]. However, short, stubby tributaries and amphitheater heads of valleys may favor another hypothesis, where the valleys are cut by groundwater emerging from below a thick cryosphere [3, 4]. In addition, Carr suggested mass wasting aided by the presence of groundwater at shallow depths mainly formed valley networks [4]. If groundwater migrations had controlled the formation of the valley networks, the source of water should be regionally supplied. In this case, the presence of valley networks hardly suggests anything on a Noachian climate condition.

The morphologic characteristics of valleys, such as U-shaped cross sections and relatively constant valley width downstream [5] were plausibly explained by all of these hypotheses, because the lithology and stratigraphy of early Mars were largely uncertain [2]. Thus, quantitative analyses of the distributions and spatial patterns of the valley networks, especially estimates of drainage densities, have been performed here to discuss the origin of the valleys [e.g., 6-12].

We focus on the variations of the drainage densities, because Craddock and Howard [2] qualitatively suggested the possibility that the mean slope is a dominant environmental factor for the drainage densities of valley networks. They suggested that correlation between drainage density and mean slope seems to exist, which might indicate that the particular spatial pattern of erosion involved precipitation, although their inspection was based on local area only and was not a quantitative analysis. Therefore, we test this hypothesis by mapping the valley networks of a larger region precisely in high-resolution images, estimating the drainage densities, and comparing them to local slopes.

Method: We identify the valley networks in the Noachian cratered upland, mainly using THEMIS-IR daytime images (100 m/pix). We also use the Viking MDIM 2.1 (231 m/pix) to cover the image gaps existed in THEMIS-IR and use the MOLA topography (about 300 m/pix) to avoid false positives and to determine drainage divides and local slopes. We integrate these data into a GIS-based software, Arc GIS 9.2, where all of the mapping procedures were performed.

The criteria we used for our mapping are: (1) A valley is a generally linear-shaped depression, which is traceable with its shadow; (2) a valley has an observable U- or V-shaped cross section, which is necessary to eliminate cliffs; (3) the length of a valley is at least twice its width, which is used to avoid mapping horizontally-short depressions; and (4) the valley length is longer than 5 km, which is required to exclude bumpy areas.

Each valley network is aerially separated from others, and appears to occur within distinct topographic drainage areas enclosed by topographic divides. Therefore, we can define a drainage area for each drainage network based on MOLA topography data.

Note that when we calculate the drainage area we exclude the area of the craters superimposed on the valley networks. If the impact occurred before the formation of the valley networks, the crater can be the site of a possible paleolake. Because within the drainage area water had been running and eroding, paleolake basins would have meant stagnant water and thus are not included in the drainage area. If the impact occurred after the formation of the valley networks, the valley networks, which may had been in the crater area, were destroyed by the impact. Thus, that area needs to be excluded from drainage area.

Results and Implications: The study area of this work is the northeast part of the boundary area between Arabia Terra and Terra Sabaea (Figure 1). The area includes 10 major valley networks, including Cusus Valles, Locras Valles, Naktong Vallis, and Verde Vallis. We mapped out more than 5000 individual valley segments, whose total length is about 36,000 km. Almost all of the valleys have observable flat floors and steep walls (Figure 2). The drainage areas range from 10,000 to 120,000 km^2, which are relatively larger compared with those obtained by a previous study [13]. In this study, we can identify significantly more valleys in the same region due to the better resolution of data.

The drainage densities estimated in this study are almost comparable to terrestrial drainage networks. We also find that there is strong positive correlation between the drainage densities and the mean slopes of drainage areas (Figure 3).

The correlation between the drainage densities and mean slopes suggests that, at least in the study area, the topographic relief is surprisingly well preserved for more than 3 billion years after the formation of the valley networks. That is, there has been no significant, detectable dynamic crustal movement since valley formation to modify slopes.

The systematic increase in the drainage density with the mean slope suggests that the maturity of valley networks depends largely on the local slope. This strongly indicates that local water sources for the formation of valley networks are unlikely. On the contrary, if the water is supplied by precipitation at much the same rate, the mean slope of the precipitated area generally controlled the velocity of the resultant surface runoff, which largely influences the efficiency of erosion and eventually determines the maturity of the drainage density. Therefore, we suggest that the most likely source of water for the formation of valley networks in the study area is precipitation.

Also, hypotheses which suggest that the valley networks were formed by groundwater have difficulty in explaining the strong correlation between mean slopes and drainage densities, because the hydraulic head does not necessarily depend on the mean slope.

We cannot exclude the possibility that the correlation between drainage densities and mean slopes indicates that valleys were degraded after fluvial activity corresponding to topographic relief, and we cannot discuss the origin of the valley networks based on this correlation. However, Figure 2 shows that the morphological drainage patterns differ between networks that have low vs. high slopes. Network 8, which has the lowest drainage density and slope, consists of several main trunk valleys and many short tributaries, whereas network 4, which has the highest drainage density and slope, shows less clear distinction of main trunk valleys from tributaries. This morphological tendency is consistent with the control of slope on the origin of the valley networks, which supports that precipitation-fed surface runoff eroded the valley networks.

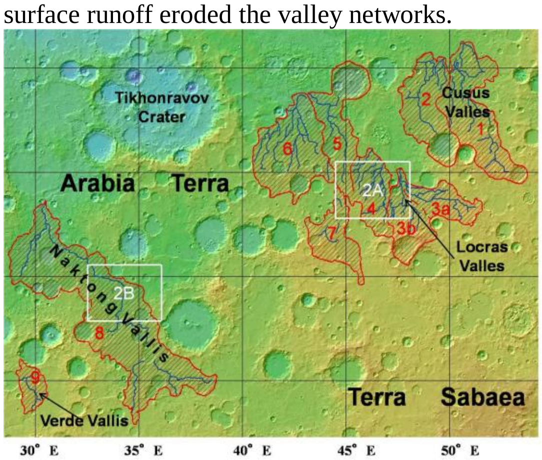

Figure 1. The study area on MOLA topography. The red lines indicate the boundaries of the 10 drainage areas (red numbers).

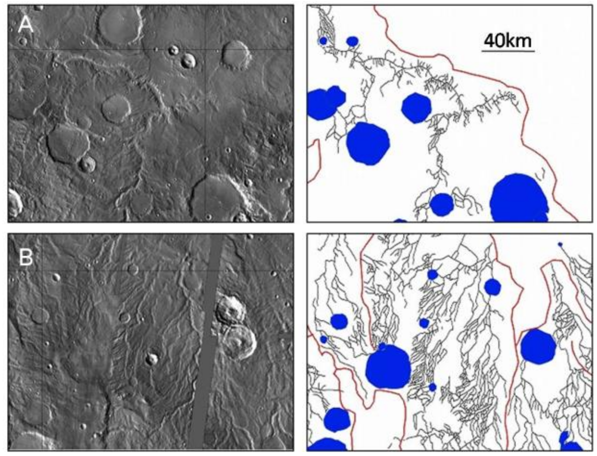

Figure 2. Paired (left) THEMIS IR day mosaics and (right) mapped valleys (black lines), craters superimposed on valleys (blue circles), and boundaries of the drainage areas (red lines). (A) Part of network 8. (at 2A in Figure 1). (B) Network 4. (at 2B in Figure 1).

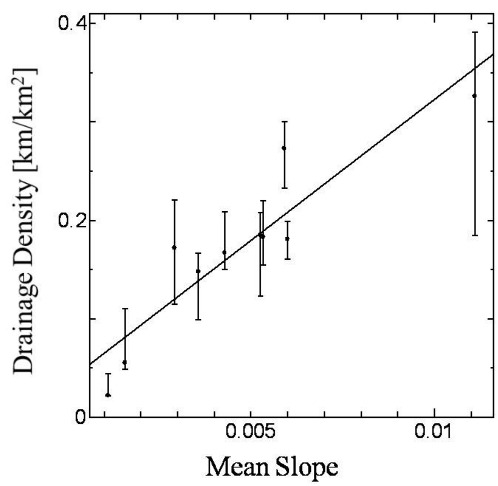

Figure 3. Drainage density vs. mean slope of the drainage areas.

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