PROPERTIES OF MARTIAN HIGHLANDS DRAINAGE FROM THEMIS IMAGES AND MOLA TOPOGRAPHY.

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Abstract. Valley networks are mapped from mosaics composed of 100 m/pixel THEMIS images for 8 sites in Martian highlands. The sites are subdivided into individual drainage basins using 500 m/pixel DEMs co-registered with image mosaics. Terrain parameters are calculated for each basin with area $> 10^3$ km^2. Drainage densities of individual basins are 0 - 0.29 km^{-1}. There is a moderate (r=0.5) correlation between values of drainage density and relief, no other terrain parameters are correlated. Within a given site, the basins show evidence of past integration disrupted by subsequent cratering. Morphologically, the basins are divided into 5 classes. There is no clear correlation between basin's morphologic class and the value of any of the terrain parameters. In particular, heavily dissected and undissected basins are found in all morphological classes.

Introduction. We map valley networks in eight large ($\sim 10^5$ km^2) Noachian sites using mosaics of 100m/pixel THEMIS daytime images. The results are compared to previous mapping [1] based on 256m/pixel global mosaic constructed from MOC images. They are also compared to results of automatic mapping [2] based on 500m/pixel digital elevation models (DEMs) constructed from topography data collected by MOLA instrument. The DEMs are also used to divide each site into constituent drainage basins. Overall, 83 non-crater basins having areas $> 10^3$ km^2 are extracted from all eight sites. For each basin we calculate several terrain parameters including a drainage density. Drainage density is calculated using our new manual mapping of valley networks. We study the issue of integration of drainage basins by subdividing the sites into progressively smaller basins. Finally, we compare quantitatively morphologies of drainage basins using the circularity function method [3]. The 83 basins are classified into five morphologic classes on the basis of similarity between their circularity functions. We study correlations between pairs of basin's terrain parameters, as well as between basin's morphologic class and the values of terrain parameters. The overall purpose of this study is to understand a fluvial environment responsible for formation of valley networks during the Noachian era in Martian history.

Mapping. The ISIS software was used to construct the mosaics of each site using 15-40 THEMIS images (band 1) covering a given site. The sites are: Locras Valles (6.0, 11.0, 45.0, 49.0), Pollack (-11.1, -6.7, 27.8, 34.8), Evros Vallis West (-15.8, -10.2, 10.8, 18.0), Evros Vallis North (-11.3, -5.3, 11.6, 18.6), Dawes East (-8.4, -3.2, 42.5, 47.9), Millochou West (-23.4, -16.9, 84.7, 91.7), Millochou South (-26.0, -20.0, 85.0, 91.0), and Naktong Vallis (1.0, 9.0, 28.0, 36.0). The number in brackets indicate site's location: latitude of the lower edge, latitude of the upper edge, east longitude of the left edge, and east longitude of the right edge, respectively. The valleys were mapped manually by drawing over an image in the ArcGIS software. Fig1A shows a mosaic of 18 images covering the area of Locras Valles site. The mosaic is colorized using MOLA data to show co-registered topographic elevations. Its dimensions are 2965 X 2371 pixels. Valley networks mapped from this mosaic are shown as red lines. Fig.1B shows a visual rendering of MOLA topography of Locras Valles site with exaggerated vertical dimension. The blue-to-red color gradient corresponds to low-to-high elevations. Drainage network extracted by a computer algorithm [2] based on directions of steepest descent ($A_{th} = 175$ pixels) is shown as black lines. Comparison of computer to manual mappings reveal that automatic mapping misses some visible channels, and put channels in places where there are not visible. This underscores limitations of the computer algorithm.

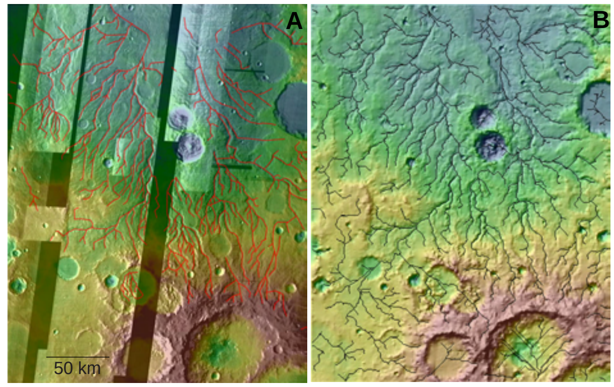

Figure 1: The Locras Valles site. (A) THEMIS mosaic colorized using MOLA data. Mapped networks are shown in red. (B) MOLA-derived topography, computer-extracted drainage network is shown black.

Fig.2A shows a small portion of the Naktong Vallis site as it appears in the MOC 256 m/pixel image mosaic. Black lines indicate location of valley networks as mapped in [1]. Fig.2B shows the same portion of the Naktong Vallis site as it appears in our 100 m/pixel THEMIS image mosaic. Black lines indicate location of valley networks as mapped by us. Despite the higher resolution of our mosaic we map less channels than [1]. This underscores limitations of manual mapping, which is an subjective and imperfect science! Because of differences in mapping channels, our value of drainage density calculated for the entire Naktong Vallis site is 0.045 km^{-1} compared to 0.065 km^{-1} reported in [1]. Values of drainage density calculated for other 7 sites are in the range of 0.055 to 0.105 km^{-1}.

Drainage Basins. Because of the existence of numerous craters and other pits, the Martian terrain is not naturally drainable and its division into sensible drainage basins is not straightforward. Objective delineation of basin boundaries

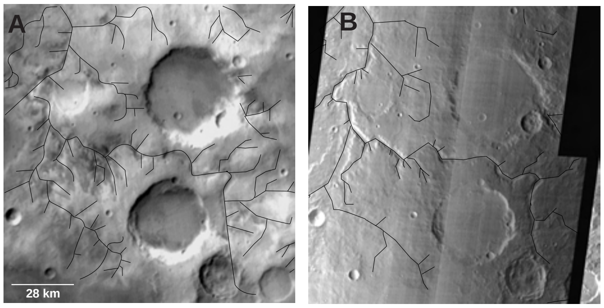

Figure 2: Fragment of the Naktong Vallis site. (A) MOC mosaic, black lines indicate channels as mapped in [1] (B) THEMIS mosaic, black lines indicate our mapping of channels.

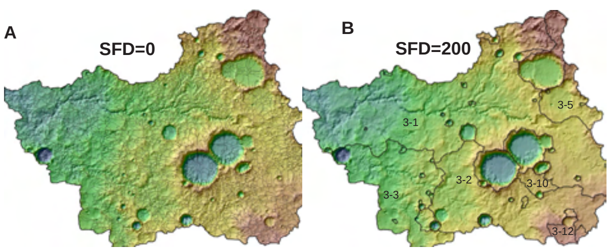

Figure 3: Division of large portion of the Evros Vallis West site into drainage basins. (A) No surface modification, SFD=0 m. (B) Surface modification with SFD=200 m.

from a DEM is achieved through a computer algorithm. Application of such an algorithm to the Evros Vallis West site divides it into hundreds of small basins (Fig.3A) which are of no scientific interest. A division into larger, more interesting basins can only be achieved after the original Martian surface is modified by the pits-filling algorithm. The degree of the modification is measured by the parameter SFD (sink-fill depth), larger value of SFD yields larger basins. There is no objective procedure to determine an optimal value of SFD, we used SFD=200-600 m to delineate basins in our eight sites. Fig.3B shows the large portion of the Evros Vallis West site divided into several large basins after its DEM was modified using SFD=200 m. The 83 basins that are larger than 10^3 km^2 and are not dominated by a crater are selected for further analysis. For these basins we have calculated drainage area, drainage density, average elevation, relief, and slope. Drainage densities calculated for individual basins have values of 0 to 0.29 km^{-1}. There is very little correlation between different terrain parameters in drainage basins, the biggest correlation (r=0.5) is between relief and drainage density.

Modifying Martian surface using a progressively larger values of the SFD integrates small drainage basins into larger watersheds. Frequently, the points of integration are craters that disrupt drainage continuity. Filling those craters restores flow continuity and results in large, integrated watersheds. This suggests that an ancient drainage was more continuous, but this continuity was later disrupted by subsequent cratering.

Morphologic classes. We compare quantitatively morphologies of all 83 drainage basins using circularity functions [3] as their formal representations. Using a hierarchical clustering algorithm [4] we construct a dendrogram of drainage basins that reveals an existence of 5 morphologic classes. Basins grouped in each class have similar morphologies, however morphologic differences between different classes are small. We have found no correlation between values of terrain parameters and the morphologic class of a basin.

Discussion. Mapping of valley networks based on higher resolution images (100 m/pixel) do not reveal an existence of smaller scale valleys. The drainage density of Martian highlands is likely to be fixed at about 0.1 km^{-1}, although localized networks of higher density exists. Comparison of present to previous channels mapping shows discrepancies due to differences in interpretation. This points to an intrinsic problem with manual mapping. Comparison to automatic mapping shows shortcomings of presently used algorithm for identification of channels, a better algorithm must be developed. Although we have identified morphologic classes of drainage basins in Martian highlands, there is no clear-cut division of these basins into truly distinct morphologies. This is in contrast to terrestrial basins that divides into distinct morphologies [5]. Martian highland terrain does not appear to be controlled by fluvial erosion. Whatever fluvial process was responsible for formation of valley networks, was not strong enough to imprint a characteristic morphology of fluvial basins.

References

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