VERTICAL ANALYSIS OF MARTIAN DRAINAGE BASINS. T. F. Stepinski, *Lunar and Planetary Institute, Houston TX 77058-1113, USA, (tom@lpi.usra.edu)*, W. J. O'Hara IV, *NASA, JSC, Houston TX 77062, USA, (william.j.ohara1@jsc.nasa.gov)*.

Abstract. We have performed a vertical analysis of drainage basins on Mars that were computationally extracted from DEMs based on the MOLA data. Longitudinal profiles of main streams are calculated and the slope-area relation is established for 20 basins coming from assorted martian locations. An identical analysis is done for 19 terrestrial river basins. Our results show that, in comparison to terrestrial basins, martian basins have more linear longitudinal profiles, more frequent existence of knickpoints, predominance of asymmetric location of the main stream in the basin, and smaller values of concavity exponent. This suggests a limited role for surface runoff on the global scale. However, two basins extracted from the slopes of martian volcanoes show a strong similarity to terrestrial basins, indicating a possible local role for the process of surface runoff.

Introduction. It is widely accepted that valley networks on Mars formed by erosion, probably due to the flow of water, either by surface runoff or groundwater sapping. The relative contributions of these two processes to the origin of observed valley networks, and the observed topography in general, are of great interest inasmuch as they pertain to the climatic conditions in the Mars past. Dominance of surface runoff would indicate an existence of a warmer epoch, substantially different from the present climatic conditions.

Analysing topography of drainage basins permits a quantitative study of martian valley networks and may be used to constrain their origin. In this study we concentrate on comparing martian and terrestrial drainage networks on the basis of vertical analysis of the underlaying terrain. (A comparison based on the planar properties of networks is given in (1).) Two different indicators of an erosion process are considered, longitudinal profiles of main streams and the relationship between local slope S and contributing area A in the entire drainage basin. A longitudinal profile, $h(l)$, gives an elevation h as a function of path length l in the main stream of the network, starting at the basin boundary ($l_t = 0$) and ending at the outlet (l_b). Surface runoff is indicated if $h(l)$ is smooth and concave upwards, whereas sapping is indicated if $h(l)$ is linear (or convex) and/or possibly broken by knickpoints. Observations of terrestrial basins, eroded by surface runoff, indicate that the mean of a local slope $\langle S \rangle$ scales with a contributing area A (A is the total area that drains through a given location, it is also a measure of the flow rate through this location), $\langle S \rangle \sim A^{-\theta}$. The concavity exponent θ is typically in the range of 0.3-0.7 for terrestrial basins (2). It is expected that for basins that are not eroded by surface runoff θ should be small, moreover, for such terrains the relation between $\langle S \rangle$ and A may not be a simple power-law at all. We have calculated and analyzed longitudinal profiles and slope-area relations for 20 drainage basins on Mars and for 19 terrestrial basins.

Data and Methods To study martian drainage networks we have constructed digital elevation models (DEMs) (500m resolution) of 12 areas on the surface of Mars (Sinus Sabaeus (13S, 24E), Tyrrhena (22S, 101E), Hecates Tholus (33N, 150E), Ma'adim Valles (13S, 175E), Tader Valles (49S, 209E), Alba Patera (46N, 248E), Warrengo Valles (43S, 267E), Bosphorus Planum (34S, 288E), Melas Fossae (25S, 289E), Nanedi Vallis (5N, 312E), Nirgal Vallis (27S, 316E), Margaritifer Valles (30S, 337E)) using topography data from Mars Orbiter Laser Altimeter (MOLA) (3). From these DEMs 20 drainage basins were computationally extracted using an algorithm developed for studies of terrestrial river basins (4). Terrastrial basins were extracted from US Geological Survey DEMs for the following rivers:Republican, KS; Marias, MT; Yellowstone, MT; Platte, NE; Blacks Fork, UT; Green, UT; Grands, SD; St. Miguel, CO; Big Blue, NE; Gila, NM; Clarks Fork, WY; Flathead, MT; Mimbres, NM; St. Joe, ID; Alamosa, NM; Racoon, PA, Brushy, AL, Big Creek, ID.

For each basin the main stream was identified and its longitudinal profile was constructed. The following quantities were entered into the database: l_b - length of the main stream, $\Delta h = h(l = 0) - h(l_b)$ - vertical drop of the main stream, $k = \Delta h / l_b$ - a measure of basin's slope, and $\chi = \int h(l) dl / l_b (h_t - h_b)$. The parameter χ is a global measure of concavity, $\chi = 0.5$ indicates a linear profile, progressively smaller values of χ corresponds to increasingly more concave profiles. In addition, we have marked the existence or absence of knickpoints in the profile and the symmetric or asymmetric location of the main stream within a basin. For each basin we have constructed a $\log \langle S \rangle$ – $\log A$ diagram. In all cases a linear fit was possible indicating a validity of the power-law relation. In cases where a broken power-law was indicated by the $\log \langle S \rangle$ – $\log A$ diagram, only the part corresponding to large values of A was used for estimating the value of θ. The values of θ and their standard deviations were entered into our database.

Results. For terrestrial basins we have found that the concavity indicator, χ changes from $\chi^{terr}_{min} = 0.19$ to $\chi^{terr}_{max} = 0.44$. The average value is $\langle \chi \rangle_{terr} = 0.32 \pm 0.07$. Concavity parameter θ changes from $\theta^{terr}_{min} = 0.375$ to $\theta^{terr}_{max} = 0.64$, with an average $\langle \theta \rangle_{terr} = 0.42 \pm 0.13$. There is a high correlation ($r = -0.66$, where r is the correlation coefficient) between values of χ and θ for terrestrial basins. This is expected inasmuch as both parameters measure the degree to which the surface runoff evolved a landscape. There is a modest correlation between χ and k ($r = -0.5$) and θ and k ($r = 0.32$). We have founded that 6 out of 19 (32%) terrestrial stream profiles features knickpoints and that 8 out of 19 (42%) terrestrial main streams are located asymmetrically within their basins.

For martian basins we have found that concavity indicator, χ changes from $\chi^{mars}_{min} = 0.16$ to $\chi^{mars}_{max} = 0.55$. The average value is $\langle \chi \rangle_{mars} = 0.38 \pm 0.11$. Concavity parameter θ changes from $\theta^{mars}_{min} = 0.034$ to $\theta^{mars}_{max} = 0.61$, with an average $\langle \theta \rangle_{terr} = 0.28 \pm 0.13$. There is a low correlation ($r = -0.15$) between values of χ and θ for martian basins. This is probably because existence of many knickpoints in

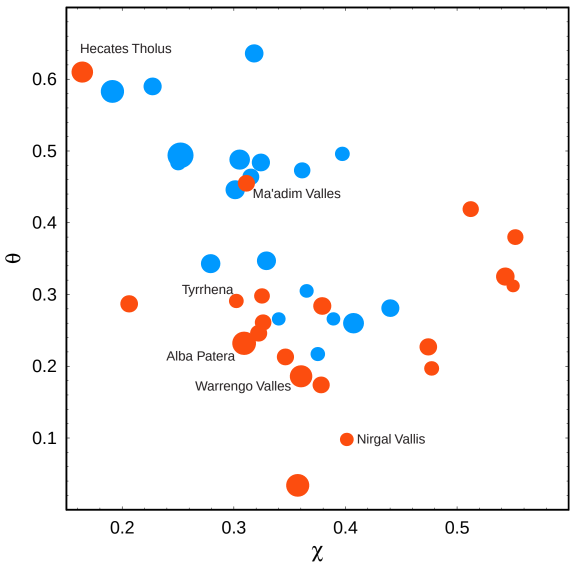

Figure 1: $\chi - \theta$ diagram for martian (red) and terrestrial (blue) drainage basins. The size of each point is proportional to k, the overall slope of the basin. Some martian basins are labeled by the names of locations from which their were extracted.

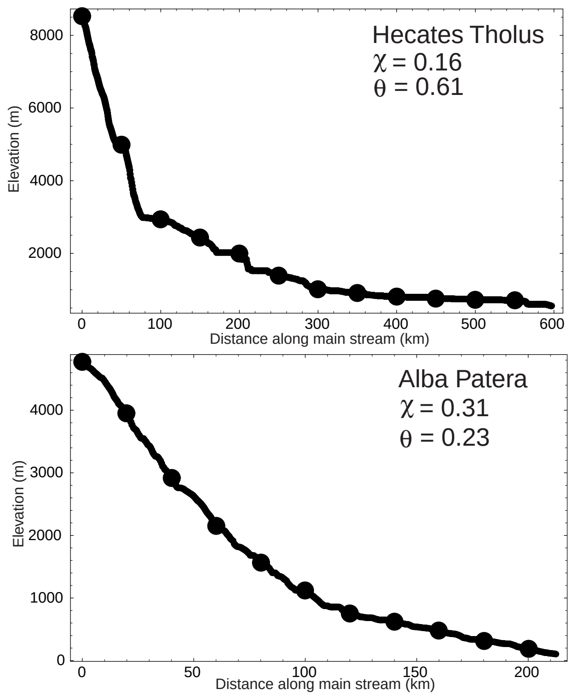

Figure 2: Longitudinal profiles of main streams in drainage basins extracted from the slopes of Hecates Tholus (top) and Alba Patera (bottom). 50-km intervals along the stream are indicated by points for Hecates Tholus, for Alba Patera intervals are 20-km.

martian profiles makes χ a less reliable indicator of an erosion process. There is no significant correlation between neither χ nor θ and k, but there is a modest correlation ($r = -0.49$ and $r = 0.44$, respectively) between χ, θ and Δh. Majority of martian main streams, 17 out of 20 (85%) have knickpoints in their longitudinal profiles. Also, 14 out of 20 (70%) of martian main streams are located asymetrically within their basins.

Figure 1., a $\chi - \theta$ diagram, summarize our results. It's clear that martian basins are characterized, overall, by larger values of χ and smaller values of θ than the terrestrial drainage basins. That means that overall, martian drainage systems have main streams that have less concave profiles and that slopes in martians basins correlates weakly with the rate of flow (contributing area). This result is consistent with the previous studies (5) of drainage basins in two martian locations: Ma'adim Vallis and Al-Qahira Vallis.

Longitudinal profiles of the great majority of martian main streams have knickpoints. Most, but not all of these knickpoints can be attributed to existence of craters, that are filled in order to make the martian surface drainable. Indeed, the only martian stream profiles without knickpoints are from basins on the slopes of the volcanoes, Hecates Tholus and Alba Patera (see Fig. 2). Also, a great majority of martian main stream are located asymmetrically in their basin. All these results point to the conclusion that surface runoff was probably not a major contributor in landscape evolution in majority of martian locations. Thus, our finding are inconsistent with the notion of sustained rainfall in the Mars past.

From the point of view of the vertical analysis of drainage basins, the drainage systems on Mars that most resemble terrestrial basins are the two basins extracted from the slopes of the martian volcanoes, Hecates Tholus and Alba Patera (see Fig. 2). In both cases the main streams have smooth concave profiles. However, the slope-area analysis reveals differences between the two terrains. Whereas, $\theta = 0.61$ for the basin on the slopes of Hecates Tholus, $\theta = 0.23$ for the basin extracted from the slopes of Alba Patera. The small value of θ for the Alba Patera basin is nevertheless comparable to the values in some terrestrial basins (see Fig. 1).

References

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