SYSTEMATIC DIFFERENCES IN TOPOGRAPHY OF MARTIAN AND TERRESTRIAL DRAINAGE BASINS. T. F. Stepinski, *Lunar and Planetary Institute, Houston TX 77058-1113, USA, (tom@lpi.usra.edu)*, S. Coradetti, *Dept. of Earth, Atmospheric and Planetary Science, MIT, 77 Massachusetts Ave., Cambridge, MA 02139, USA, (scorad@mit.edu)*.

Abstract. We have computationally extracted and quantitatively analyzed a significant number of terrestrial and Martian drainage basins. The analysis reveals systematic differences between topography of drainage basins on the two planets. This dichotomy provides a direct and quantitative argument for an immaturity of Martian drainage basins with respect to fluvial erosion. Our findings indicate that Noachian surfaces on Mars did not experience runoff erosion of intensity and duration required to produce terrestrial-style basins.

Introduction. The interest in Martian valley networks, predominantly located on ancient Noachian terrain, remains high because the issue of their origin remains unsolved despite extensive studies. On one hand, valley networks, as visible on images, bare a strong resemblance to terrestrial river networks which are eroded by surface runoff. On the other hand, closer examination of imagery data reveals that many morphometric features of the valley networks are similar to terrestrial streams eroded by groundwater sapping. The broader importance of establishing the origin of valley networks stems from climatic implications. Positive identification of valley networks as remains of ancient river beds would imply an existence of warmer and wetter epoch in Mars history.

Whereas previous studies (1,2,3,4), addressing the origin of Martian valley networks, have focused on morphology of the valleys themselves, we concentrate on topography of underlying drainage basins. Our analysis is based on the original idea to use integral-geometry morphological image analysis (IGMIA) methods in order to characterize quantitatively the 3-D structure of drainage basins underlying the visible valley networks. Using digital topography as an input we computationally extract basins and apply the IGMIA to obtain a set of functions describing the 3-D structures of these basins. As a result, a comparison of basins is reduced to an objective and quantitative comparison of numerical functions.

Methods. IGMIA (5) employs image functionals to assign numbers to the shape and connectivity of patterns formed by the pixels in the binary (black-and-white) image. The IGMIA aims to succinctly describe a complex pattern and facilitates quantitative comparison between patterns. For 2-D patterns there are only three independent image functionals called Minkowski functionals, $\mathcal{F}_i$, $i = 1, 2, 3$. They are the area $\mathcal{F}_1 = S$, the perimeter $\mathcal{F}_2 = U$, and the Euler characteristics $\mathcal{F}_3 = E$ that describes the topology of the pattern. E equals the number of regions of connected black pixels minus the number of completely enclosed regions of white pixels.

Our method "scans" the basin by a large number of horizontal planes located at progressively higher normalized elevations H. A given plane divides basin's pixels into two categories: those above the plane ("white"), and those below the plane ("black"). All black pixels form a shape $\Omega(H)$ that is studied using IGMIA. Note that this shape is an "*image*" in the name "IGMIA." The black shape is a single pixel at $H = 0$ and the entire basin at $H = 1$. At an intermediate value of H the black shape represents a region of the basin located at elevations $\leq H$. Thus in our method, H is a "shape parameter". We calculate $\mathcal{F}_i[\Omega(H)]$, $i = 1, 2, 3$ for all drainage basins. Using these functionals basins can be quantitatively characterized and compared. In particular, a combination of $\mathcal{F}_i$, a function $\alpha = 4\pi S/U^2$, which we call an elongation function, is a good indicator of the degree of fluvial erosion. Terrestrial and Martian drainage basins comes in different shapes due to varied regional geology. The elongation function, α, concentrates on an internal structure of the basin, and not on its overall shape. This function is invariant for a given shape under dilation or contraction. Its value ranges from 0 for a line (extreme elongation), to 1 for a circle (no elongation).

Results. We have used DEM's based on the MOLA data (Mars, 500 m resolution) and the SRTM data (Earth, originally 90 m resolution, degraded to 450 m resolution for compatibility with Mars data) to delineate 26 Martian basins (located at Noachian terrain) and 15 terrestrial basins, 12 located at various locations in the USA, and 3 located at northern Chile Atacama desert. The Atacama locations contain deeply incised, wide valley drainages (quebradas) that have been recently suggested to be formed by groundwater sapping (6). We have calculated elongation functions for all basins. There are systematic differences between the shape of $\alpha(H)$ for terrestrial and Martian basins. In general, all terrestrial basins yield $\alpha(H)$ having a characteristic S-like shape, whereas Martian basins yield $\alpha(H)$ that are irregular but flat on average. Fig. 1 shows typical examples. A basin of Gila River is a typical example of terrestrial river basin shaped by a runoff erosion. Visually, channel network follows the basin topography in a natural fashion. Quantitatively, the shape of an elongation function indicates that the lower regions of the basin are the most elongated – the river forms a broad valley in its lower section. Visually, the channel network at Warrego Valles appears to be superficial, disconnected from basin topography. Quantitatively, the shape of an elongation function is rather flat, reflecting lack of broad valley at the lower portion of the basin.

Fig. 2 shows a comparison of all 41 elongation functions. Each function was reduced to just 2 numbers, its value at $H = 1$ (an elongation of the entire basin), and the difference between the elongation of the entire basin and the minimum value of an elongation function. Terrestrial basins tend to group around a diagonal because minimum value of elongation function is much smaller than the elongation of the entire basin (S-like shape). Martian basins are grouped below diagonal because their elongation functions are more flat. Chilean quebradas, that are shaped predominantly by groundwater sapping and not by runoff, are distributed more like Martian basins. The mean distance to diagonal for terrestrial basins is 0.017 with standard deviation of 0.009. The mean distance to diagonal for

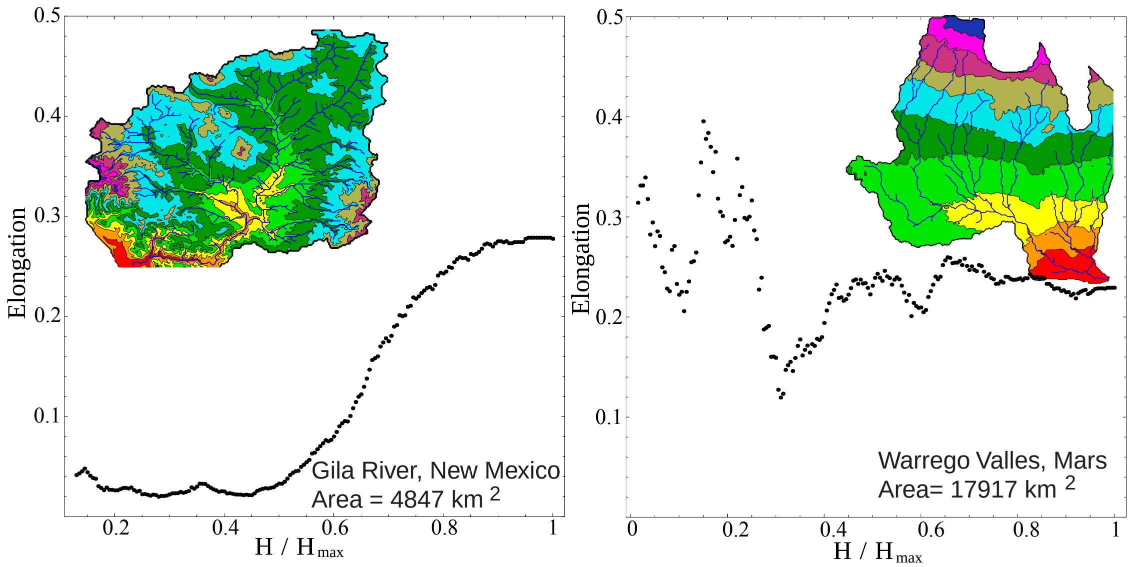

Figure 1: Elongation functions and the 3-D structure of typical terrestrial and Martian drainage basins. Elongation functions are constructed from 200 horizontal cross-sections. The inserts show basin topography, with different colors indicating different elevations. The channels, computationally extracted, are shown for reference.

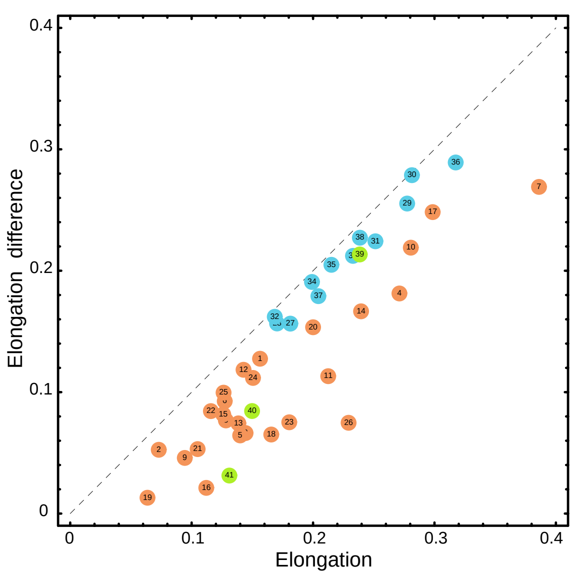

Figure 2: Comparing elongation functions of Martian and terrestrial drainage basins. Orange dots indicate Martian basins, blue dots indicate terrestrial basins in USA, green dots are basins from Atacama desert.

Martian basins is 0.064 with standard deviation of 0.03. For Chilean quebradas the mean is 0.063 and standard deviation is 0.04.

Conclusions. Even a simple superposition of basin topography with network topology reveals difference between terrestrial and Martian basins. In terrestrial basins network topology follows the landscape topography, in Martian basins network topology seems disconnected from landscape topography. The IGMIA method offers a quantitative approach to study this difference thorough elongation functions. There is a clear dichotomy in a character of elongation functions which follows the terrestrial/Martian label. This dichotomy points to the fundamental difference in the 3-D structure of terrestrial and Martian basins, which may be the result of a different erosional mechanism, or simply a lower degree of runoff erosion on Mars. In any case, our results indicate, in quantitative fashion, that Noachian surfaces did not experience terrestrial-style runoff erosion.

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