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Mapping and formation timescales of Martian valley networks

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Abstract

To understand the formation mechanisms of Martian fluvial systems we have mapped all the valleys longer than 20 km and for a sample extracted among them, containing the widest and more developed systems, we have also determined the formation time finding values typically in the range 10^5-10^8 years.

1. Introduction

Since the first observation of valley networks on Mars, these systems have aroused great interest [1] because their presence suggests that in the past the planet contained a significant amount of water at the liquid state, that today is totally absent. These valleys show features resulting from the formation due to water surface flow likely supported from rain or snow melting, phenomena now also absent on Mars. This suggests that early Mars could have been warmer and wetter than today with atmospheric pressure and surface temperature different from the present ones [2]. However, detailed geomorphic analysis of individual valley networks did not lead to a general consensus regarding their formation timescales. Therefore from a paleoclimatic point of view is interesting to map Martian valley networks and to determine their formation timescales.

2. Data and methods

In this work we have used QuantumGIS (QGIS), a Geographic Information Software as a tool to create a map of martian valleys and to calculate their area and volume, based on MOLA and THEMIS data. The THEMIS daytime IR imagery, with a resolution of 100 m/pixel, is the highest resolution global dataset for MARS. The MOLA data have a resolution of 463 m/pixel. In some cases we have also used CTX data with a resolution up to about 6 m/pixel.

2.1. Mapping

The valleys have been mapped manually using same criteria as those of Carr (1995) [3] and Hynek et al. (2010) [4]. We searched for sublinear, erosional channels that form branching networks, slightly increasing in size downstream and dividing into smaller branches upslope. The mapped valleys have also been divided into different groups: valley networks (systems highly developed with many tributaries); single valleys (systems with no tributaries or at most with one or two tributaries); longitudinal valleys (structures characterized by a long main branch and few tributaries); valleys on vulcanoes (valley networks and single valleys which are located on vulcanoes). Central coordinates and valleys' total length were included for each valley. The process of manual mapping is subjective and it can be influenced by albedo variations and image quality. Due to geological resurfacing events subsequent to the formation of valley networks, the observed geographic distribution is likely an underestimation of the original distribution and partly represents the overprinting effects of later geological history. For example, it is increasingly difficult to recognize valley networks drainage patterns at the higher latitudes of the southern hemisphere (south of 30°S) due to the effects of recent mantling and terrain softening [5], [6], [7].

2.2. Formation timescales

To understand the formation mechanisms of these fluvial systems and consequently make assumptions on the ancient climatic conditions of the planet, we have determined the formation time of a sample of Martian valleys, among them: Ma'adim Vallis, Warrego Valles and other important valley networks located in Arabia Terra, Meridiani Planum and Terra Sabea. To estimate the duration of water flow in these valleys we have used a method never used before for Martian valleys and based on the evaluation of erosion rate of the terrain. The latter is a key parameter for calculating the timescale of valleys formation and depends on a large

number of factors such as the size of the river, the nature of the load, the speed of the current, the gradient of the fluvial valley and finally the climatic and environmental conditions. In the present work the erosion rate has been evaluated using data obtained on Earth and extrapolated to the Martian case assuming different possible situations.

3. Results and discussion

More than 50% of Martian surface have been mapped. Thus far, the use of 100 m/pixel global mosaic allowed us to identify more developed valley systems with respect to previous studies based on the 200 m/pixel mosaic. Moreover, the obtained results for the formation timescales range from 10^5 to 10^8 years (depending on erosion rate) and are in good agreement with those reported in literature and obtained through more detailed models of sediment transport [8]. These results imply that Mars experienced at least short periods of clement conditions toward the end of the Noachian Era that supported a hydrologic cycle and potentially a biosphere.

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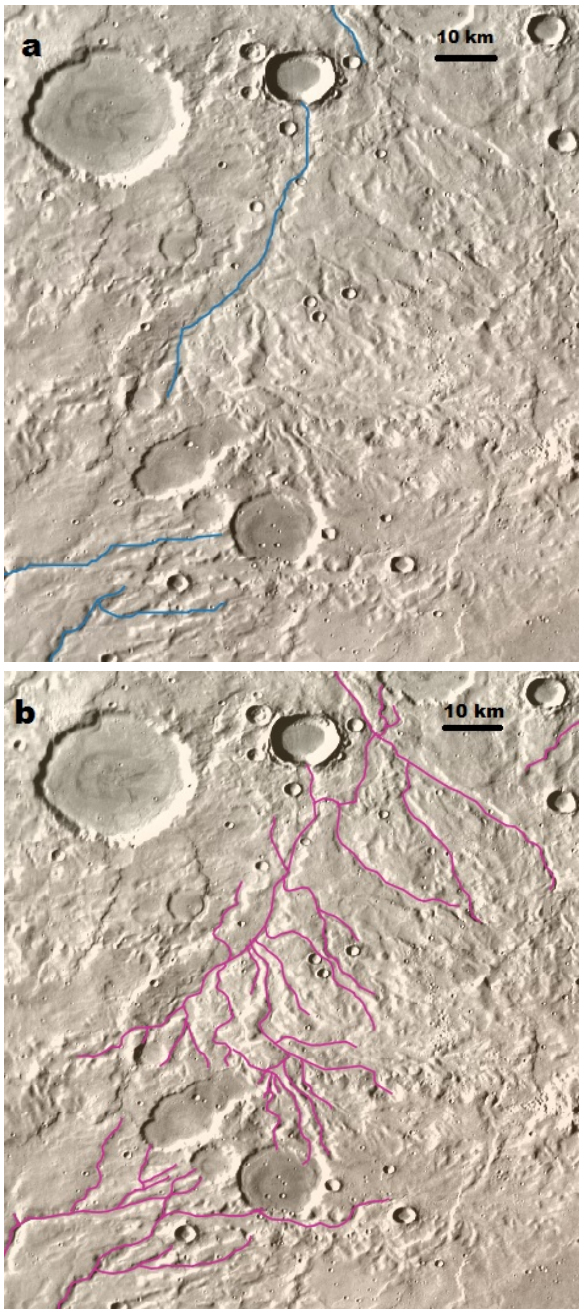

Figure 1: Comparison between valleys mapped by Hynek et al.(2010) [4] from THEMIS data with a resolution of 200 m/pixel (a) and those identifiable from THEMIS data at 100 m/pixel (b). The area is centered around 32 °S, 162°E.