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Case study of climatic changes in Martian fluvial systems at Xanthe Terra

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ABSTRACT

An unnamed valley system was analyzed in Xanthe Terra south of Havel Vallis on Mars where three separate episodes of fluvial activity could be identified with different morphology, water source and erosional processes, inferring formation under different climatic conditions. The oldest scattered valleys (1. group) form interconnecting network and suggest areally distributed water source. Later two valley types formed from confined water source partly supported by possible subsurface water. The smaller upper reaches (2. group) with three separate segments and also a similar aged but areal washed terrain suggest contribution from shallow subsurface inflow. These valleys fed the main channel (3. group), which morphology (wide, theater shaped source, few tributaries, steep walls) is the most compatible with the subsurface sapping origin. While the first valley group formed in the Noachian, the other two, more confined groups are younger. Their crater density based age value is uncertain, and could be only 1200 million years. After these three fluvial episodes etch pitted, heavily eroded terrain formed possibly by ice sublimation driven collapse. More recently (60–200 million years ago) dunes covered the bottom of the valleys, and finally the youngest event took place when mass movements produced debris covered the valleys' slopes with sediments along their wall around 5–15 million years ago, suggesting wind activity finished earlier than the mass movements in the region. This small area represents the sequence of events probably appeared on global scale: the general cooling and drying environment of Mars.

Comparing the longitudinal profiles here to other valleys in Xanthe Terra, convex shaped valley profiles are usually connected to steep terrains. The location of erosional base might play an important role in their formation that can be produced convex shapes where the erosional base descended topographically (by deep impact crater or deep outflow channel formation) as time passed by. The analysis of such nearby systems that probably witnessed similar climatic forces in the past, provides ideal possibility to identify reasons and geomorphological context of longitudinal profile shape formation for fluvial valleys in general.

1. Introduction

Valleys, outflow channels and various fluvial sedimentary features provide important points to elucidate the past existence of liquid water on Mars. This work aims the comparative analysis of some valleys in Xanthe Terra, focusing on a previously unexamined system. The reason for this analysis is to give more insight into the possible differences in the formation of different valley sections, and understand the two morphological types in the region like those were identified in Tyras Vallis (Kereszturi, 2005) and several tributaries of Shalbatana Vallis (Kereszturi, 2011) previously. These two sections consist of an upper shallow, narrow, low slope angle, almost straight longitudinal profile part; and a lower, wider, deeper, steeper, occasionally convex shaped reach. These two sections were possibly formed under different periods and conditions, but the information from the analysis of these few valleys is not enough to elucidate the reasons for these differences. The valley system analyzed in this work might provide more information on this question, and the different valley sections could also give insight into the change of fluvial surface modification method around the Noachian/Hesperian boundary.

Valley networks on the Mars has been attributed dominantly to surface runoff (Craddock and Howard, 2002; Irwin and Howard, 2002), groundwater sapping (Carr, 1981; Carr and Malin, 2000; Goldspiel and Squyres, 2000; Grant, 2000) or a combination of runoff and sapping (first suggested by Milton (1973)). Despite the great sum of available information, their origin is still not clear.

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Sharp and Malin (1975) also suggested some channels with dendritic tributaries could be formed by runoff fed seepage and headward growth by sapping. High degree of branching for some channels on the plateau and canyons of the Valles Marineris favor the atmospheric precipitation origin, and their mature appearance suggest flow over long periods (Mangold et al., 2004). Fluvial structures like terraces suggest multiple periods of formation, and the complex network morphology, as well as the correlation with other fluviosedimentary features and chloride salts suggest extended activity periods (Hynek et al., 2010).

Despite this information, beside the origin, paleodischarge values (Irwin et al., 2005) and other characteristics, including the duration of their active period (Kereszturi, 2012) are poorly known. It is also uncertain in many cases, which structures are valleys (elongated depressions that were presumably carved over time by water, but were never full of water) and which are river channels (once filled with water). Most valley networks formed around the Noachian/Hesperian boundary (Hynek et al., 2010), but there was valley formation in later episodes even during Amazonian ages (Fasset and Head, 2008) occasionally, although there are indications that suggest that the style of post Noachian activity differs from the later type (Howard et al., 2005).

Based on earlier studies (Erkeling et al., 2012; Mangold et al., 2012) the detailed analysis of certain valleys and networks is important, as they help to reconstruct the changing role of fluvial erosion in the geological history of Mars (Moore et al., 2012; Parsons et al., 2012). The aim of this work is the survey of a valley system that has not been yet analyzed in details before, and to compare it to some channels nearby, as such research may help to reconstruct the change in the fluvial activity and erosional method.

The analyzed valleys are located at 301.3E–0.4S, at the southwestern part of Xanthe Terra, east of Maja outflow channel (Fig. 1). The area is covered with ancient undulating Noachian aged surface units and early Hesperian aged lava flows (Crumpler, 1997) with many craters (Rotto and Tanaka, 1995). The region is eroded by fluvial erosional structures of various age, including smaller and older valleys formed 4.0–3.8 billion years ago, and large outflow valleys formed mostly during the Hesperian (Nelson and Greeley, 1999). Using Viking orbiter images Scott and Tanaka (1986) defined two main surface units: plateau cratered unit (Npl1) and subdued unit (Npl2) in the region. Various sedimentary units (Hauber et al., 2008a, 2008b) point to that fluvial sedimentary transport played important role in the formation of the terrain. In Xanthe Terra other fluvial systems were also analyzed with focus on the sedimentation processes (Hauber et al., 2008a, 2008b) and their activity happened around 4.0–3.8 billion years ago. The fluvial system analyzed in this work is found around 80 km southeast from the starting point of Havel Vallis (Rotto and Tanaka, 1995) a 450 km long channel originate from Juventae and Baetis Chaos systems (Voelker et al., 2012). There is no direct contact between the valleys analyzed here and the relatively close Havel Vallis, although the system analyzed in this work poured its water near to the area of Baethis Chaos. As being a terrain of diverse age, this region provides an ideal area to survey the ancient fluvial erosion and its change on Mars.

2. Methods

To analyze the formation of the valleys the author carried out (1) morphological survey of the area, (2) topographic analysis

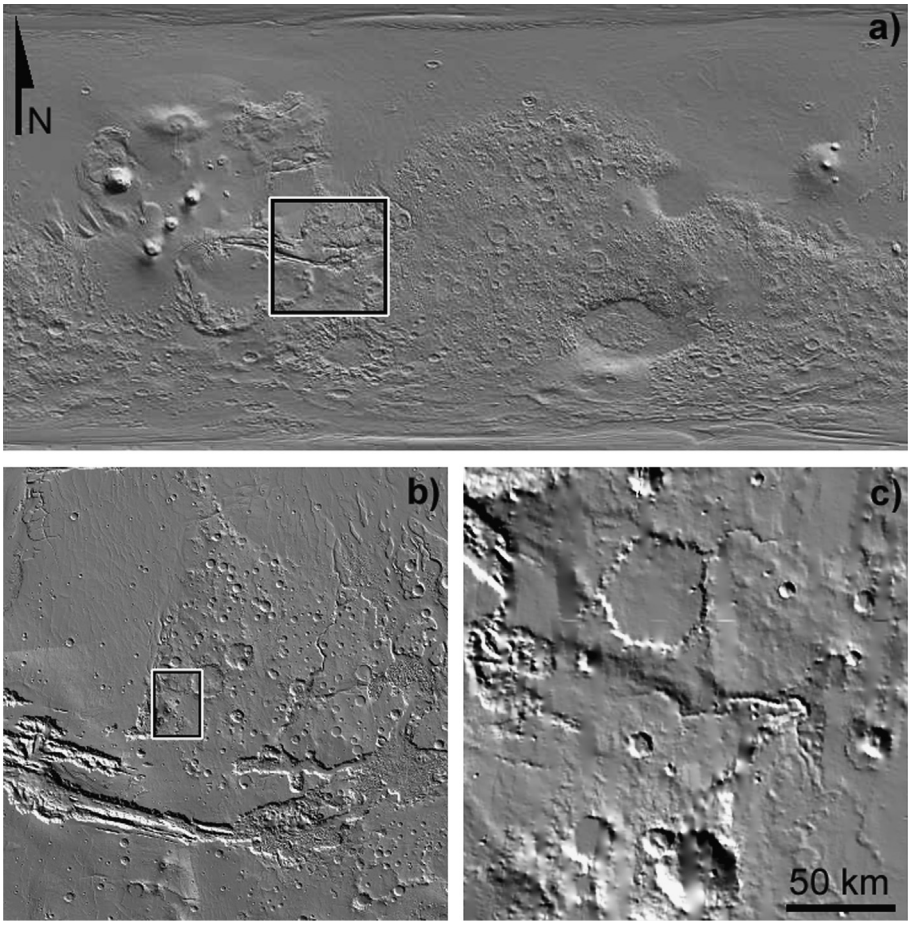

Fig. 1. Location of the analyzed valleys to the north of Valles Marineris. North is upward on every images.