AN INSIGHT INTO THE FORMATIONAL PROCESSES OF THE EROSIONAL VALLEY NETWORKS IN THE THAUMASIA HIGHLAND REGION, MARS. D. Ghosh[1], M. Aranha[1], A. Porwal[1] and G. Thangjam[2], [1]Centre of Studies in Resources Engineering, Indian Institute of Technology, Bombay, India, [2]School of Earth and Planetary Science, NISER, HBNI, Bhubaneswar-752050, India (ghosh.dibyendu@iitb.ac.in)

Introduction: Extensive erosional valley-like features on the Martian surface formed during the early Noachian to late Amazonian time [1-3] affirm that the past climatic conditions favoured flowing water [4-5]. However, climate models predict a cold and dry Mars under a faint young sun [6-7]. Therefore, the formational process of the Martian valley networks has been a subject of debate for a long time. Various theories have been proposed to explain the processes that led to the formation of Martian valley networks, including Fluvial erosional processes such as surface runoff, sapping or their combination [8-10] or glacial/subglacial erosional process [11]. In a recent study of global samples of Martian valleys networks, Galofre and others infer that valley formation includes diverse erosional processes such as groundwater sapping, fluvial and glacial/subglacial; a combination of the last two processes were the predominant erosional mechanisms [12]. They infer a predominantly fluvial erosion for the valley networks of the Thaumasia Region, but their results are marked by high uncertainty. In the present study, we report critical qualitative and quantitative drainage and basin morphometric features to gain insights into the agents of erosion that carved the valleys in the Thaumasia Region (Fig. 1) and investigate any changes temporally.

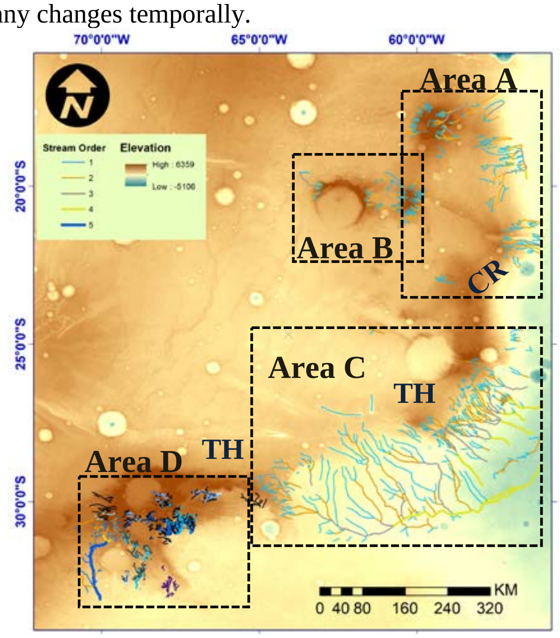

Figure 1: Map of the Thaumasia region delineating the study areas (Area A to D). TH – Thaumasia Highland area, CR – Coprates Rise area.

Study Area: This study is focused on the Thaumasia Highland region and nearby Coprates Rise area between 15S-35°S and 55W-70°W (Fig. 1) to determine the possible modes of erosion of the extensively diverse drainage systems covering equatorial to mid-latitude regions on the surface dated back to Noachian to Hesperian time [13]. Therefore, this study can be useful to get some insight into the past Martian climate. Based on the distribution of the valley networks and basinal extent, four areas, namely, A, B, C and D, were selected for the detailed study (Fig. 1).

Datasets and Methodology: Table 1 summarises the geomorphic, valley and basin morphometric parameters estimated for Areas A, B, C and D; and the datasets used. Published geological maps [13] are used to delineate areas of different ages.

Table 1: Geomorphic and morphometric parameters estimated and the datasets used.

Type	Parameter	Data used (resolution)
Geomorphic	Ice Features	Context Camera (CTX) (6m) [14]
	Theatre Head/ Alcove Head	
	Alluvial fan	
	Anastomosing pattern	
Drainage Morphometry	Age of the valley segment	High Resolution Stereo Camera (HRSC) DTM (50-75m) [15] and CTX [14]
	Stream order [16]	
	Stream length [17]	
	Sinuosity	
	Junction angle	
Basin Morphometry	Bifurcation ratio [18]	HRSC DTM [15] and CTX [14]
	Drainage Density [17]	

Observations and Results: Most valley networks in the study area exhibit dendritic and sub-parallel drainage patterns, although single valley segments are also present. Valleys generally follow the regional slope, except for a few in Areas A and C, where a structural control is observed. Average stream length increases with increasing stream order from all four areas (Fig. 2), and a greater number of the lower-order streams contribute to the total stream length (Fig. 2). The overall sinuosity value of the region is around 1.0 and slightly rises with increasing stream order; however, it decreases slightly at the highest order. Fan deposits are present at a few locations in Areas A and B. Areas A, B, and C also display anastomosing patterns. The average junction angle value of the whole region ranges between 50-60˚, and except for a few channels, it never approaches 90˚. Alcove head is a common feature in Area D. The Mean Bifurcation ratio minorly increases from Area A to D (3.1 to 3.9). The drainage density value is very low (ranging between 0.11 to 0.24) compared to terrestrial values. Across all four areas, an increase in the intensity of erosional activity is observed from Noachian to Noachian-Hesperian time as we move from lower latitude towards the higher latitude region, evidenced by an increasing number of channel segments from Areas C and D (Fig. 3a). Accordingly, ice-related features such as alcove head, moraine-like features and concentric crater-fill materials also increase in and around the comparatively younger valleys in Areas C and D (Fig. 3b).

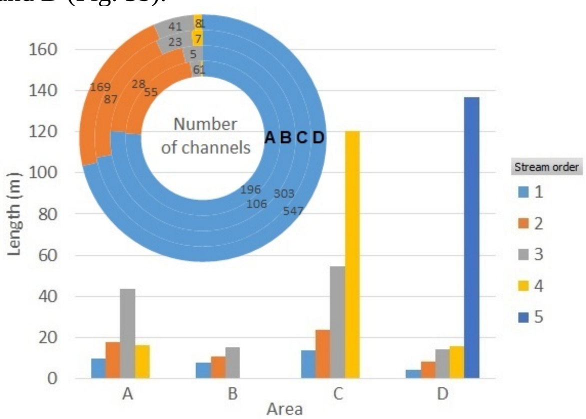

Figure 2: Average stream length with respect to stream order; the inset shows number of streams in each order.

Discussion: The branching nature of valley networks throughout the study area indicates a prolonged erosional process, though the sinuosity is low. The regional slope was the dominant factor for the water flow over the surface; however, a few cases display a structural influence. Because of the variation in lower and higher slopes, dendritic to sub-parallel drainage patterns are observed throughout the area. An increase in average stream length with stream order is (Fig. 2) characteristic of a fluvial regime, where lower-order tributaries pour water to the mainstream. The higher number of lower-order streams (Fig. 2) also supports this interpretation. Fan deposits and anastomosing patterns in Areas A, B and C indicate a fluvial erosional process. However, the increasing presence of ice-related features in and around the valleys in Areas C and D (Fig. 3b) indicate glacial erosion's increasing role in carving these valleys. These observations suggest that water and ice played an equally important role in valley formation, particularly in Area D. Features such as alcove heads attest to glacial erosion. The higher latitudinal Areas C and D also contain a greater proportion of younger channels belonging to the Noachian-Hesperian transitional period, whereas valley networks from Areas A and B generally belong to the Noachian age (Fig. 3a).

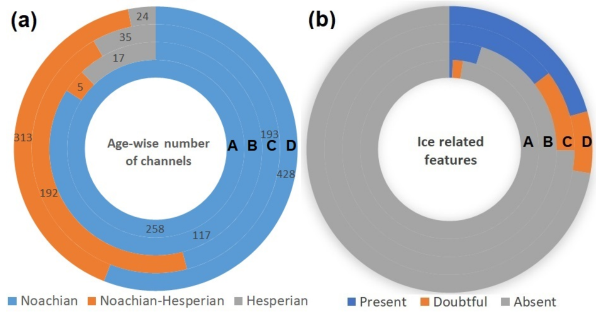

Figure 3: (a) Age distribution of valleys in the study areas (b) Proportion of ice features observed in the study areas.

The mean bifurcation ratio throughout the region resembles that of the terrestrial bifurcation value of 3.0 to 5.0 [16], indicating a homogeneous nature of the underlying materials [16].

Conclusion: Our analyses conclude that fluvial erosional processes were responsible for valley formation in the lower latitude areas (Areas A and B) during the Noachian time. Towards the higher latitudes (Areas C and D), valleys formed by a combination of glacial and fluvial processes during the Noachian-Hesperian transition period. These interpretations indicate that there could be a transition in the climate regime from warm and wet during Noachian to colder and drier during the Noachian-Hesperian transition period. Also, the climate potentially became colder towards the higher latitudes.

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