OUTFLOW CHANNEL FLOOR COLLAPSE AND THE FORMATION OF SIMUD AND TIU VALLES, MARS.

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1. Introduction: Catastrophic and non-catastrophic flooding related to the episodic release of highly pressurized groundwater confined within the Martian cryolithosphere in various types of aquifers [e.g. 1-3], resulted in the excavation of the eastern circum-Chryse outflow channels, which display the most striking dissectional signature on Mars. Other proposed mechanisms for the formation of outflow channels, include debris flows and glacial erosion [e.g., 4-5].

Chaotic terrains are commonly located at the source regions and along the margins of the outflow channels. These irregular depressions lined with chaotic blocks, are mostly attributed to the undermining and collapse of the of cratered highland [e.g., 6-8], basin [9], and outflow channel floor materials [3]. The morphogenetic association between the chaotic terrains and the outflow channels remains controversial. For example, chaotic terrain may form strictly by catastrophic discharges of water and debris and attendant surface collapse [e.g. 1, 7].. On the other hand, *Rodriguez et al*. [3] propose that much of the chaotic terrain formation post-dates outflow activity in the region and that chaos formation may not have involved significant groundwater emanations.

In this work, we investigate the geologic history of the Simud and Tiu Valles. Based on geologic mapping and geomorphic assessment using Viking-, Mars Global Surveyor-, and Mars Odyssey-based information we discuss significant surface collapse in the region.

2. Collapse in the Tiu and Simud Valles: The Simud and Tiu Valles are marked by extensive regions of surface dissection and collapse. Crater counting of the outflow channel floors indicates a Late Hesperian to perhaps Early Amazonian age [10-11], although some outflow activity may have started as early as the Late Noachian [12]. *Rotto and Tanaka*, [12] observed two main topographic levels of outflow channel floor materials: a higher floor level, which formed during the early to intermediate stages of catastrophic flooding, and lower floor level, which formed during the latest stages of outflow activity (Fig. 1).

The higher outflow channel floor in southern Tiu Vallis is characterized by deeply scoured surfaces marked by linear grooves and streamlined islands and is locally dissected by box-like flat-floored channels (Fig. 2). Also, within this floor level, enclosed depressions approximately 1 km deep and containing broken floor materials form patches of chaotic terrains. There is an absence of chaotic material on the higher channel floor, which is consistent with predominantly vertical collapse and the absence of significant lateral drag during collapse (as would be expected if collapse took place during the flood).

The lower outflow channel floor in northern Simud Vallis shows two distinct and vast regions, a smoother northern region, which extends approximately from 15° N to 30° N, and a rougher and topographically lower southern region, which extends approximately from 5° N to 15° N. The contact between these two terrains consists of a distinct break in slope (Fig. 1). The northern region preserves surface flow features produced by the latest catastrophic floods, including longitudinal grooves, streamlined islands, and distinct erosional margins. In this region there are numerous dissected highland remnants (Figs. 1, 2). In contrast, the southern region does not contain distinct flow features. Instead there are patches of chaotic terrain and systems of large irregular surface depressions, and contain no erosional contacts along the Vallis margins (Fig. 1). When compared with the northern region, the southern region has fewer dissected highland remnants, and these have irregular margins. This is in contrast with the fluvially-scoured margins of the highland remnants in the northern region (Fig. 1).

3. Discussion: These observations indicate that: (a) the formation of the lower floor level and widespread chaotic terrains resulted from widespread collapse of the higher floor level, and (b) that the formation of the Simud Vallis southern region resulted from collapse and degradation of pre-existing channels--which initially extended all the way from the Hydraotes Chaos--of which only the northern region remains.

3.1. Collapse of the higher channel floor: The maximum depth of collapse in the higher channel floor is ~1 km, whereas the maximum depth of collapse in the lower channel floor is ~100 m. We propose that the accentuated depth of collapse in the higher channel floor may have been related to intensive cryoturbation at about the end of the Noachian due to high infiltration rates of floodwater into porous highland materials and (or) to channel dissection into a shallower cryolithosphere/hydrosphere contact. If the initial groundwater emanations into the outflow channels contained relatively high concentrations of dissolved CO_2, infiltration and subsequent capping by a frozen cryolithospheric seal may have resulted in unstable channel floor regions.

3.2. Collapse of the lower channel floor: The distinct terrain contact with the northern and southern regions in the Simud Vallis indicates the existence of a channel floor stability boundary, which may be indicative of subsurface structural control. We propose that the formation of the southern region may have been related to either: (I) Regional basal warming of the cryolithosphere by shallow igneous intrusions, which may have resulted in formation of highly pressurized subsurface hydrothermal systems. Surface bulging and subsequent collapse of the ground could account for the formation of large depressions, and fracturing and break up of proximal highland plateau materials could account for the much of the chaotic terrains in the region. Volatiles depletion may have been related to the overall subsidence of the region. (II) Channel dissection intercepted the cryolithosphere/hydrosphere contact at a depth of ~1 km [e.g. 13] (The margin between the southern and the northern regions occurs in the region where Simud Vallis becomes shallower than 1 km). In the channel floor regions where the hydrosphere is exposed, volatile depletion by processes such as sublimation and groundwater emanations will result in subsidence and collapse. Depletion of the hydrosphere underlying the plateau margins and highland dissectional remnants may result in instability of these regions and their collapse into chaos.

3.3. Degrees of scouring in higher and lower channel floors: The higher outflow channel floors are significantly more scoured than the lower floors. This may be related to either more turbulent flooding during the excavation of the higher floors and (or) to enhanced deposition during the formation of the lower floors. Large amounts of dissolved CO_2 in the earliest groundwater emanations could have resulted in very turbulent floodwaters.

3.4. Hydrologic implications: The present bulk volume of Simud and Tiu Valles is morphogenetically the cumulative result of surface dissection and fluvial deposition, and multiple episodes of channel floor collapse, break-up, and degradation. We propose that a significant volume of the Simud and Tiu Valles was related to collapse.

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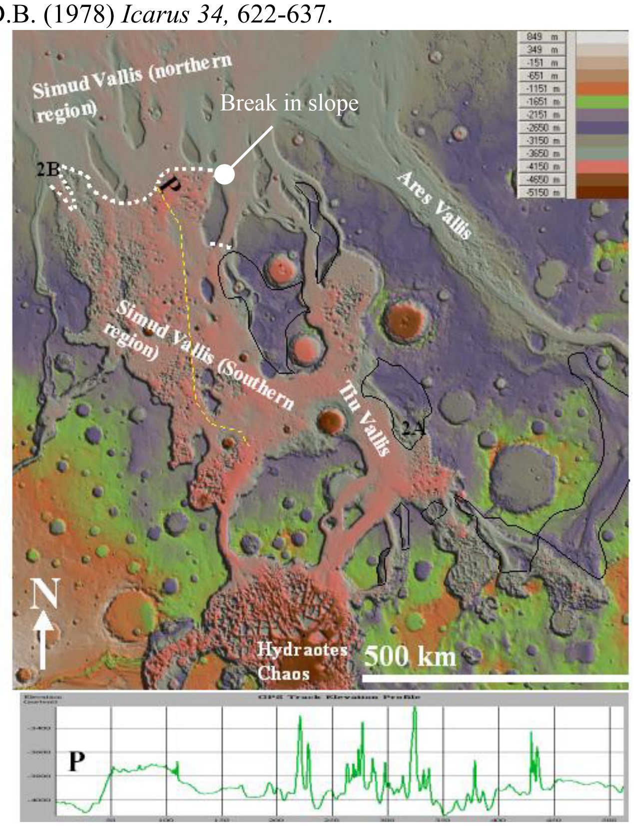

Figure 1: Above: MOLA DEM of eastern circum Chryse outflow channel system. Higher outflow channel floor regions are demarked by a black line.The white dotted line is the terrain contact between the northern and southern Simud Vallis regions. Dashed yellow line corresponds to the elevation profile shown below. Below: MOLA derived digital elevation data shows reveals two distinct terrain roughness wavelength populations. A shorter wavelength population, which corresponds to knobby materials, and a longer wavelength population, which corresponds to large depression systems.

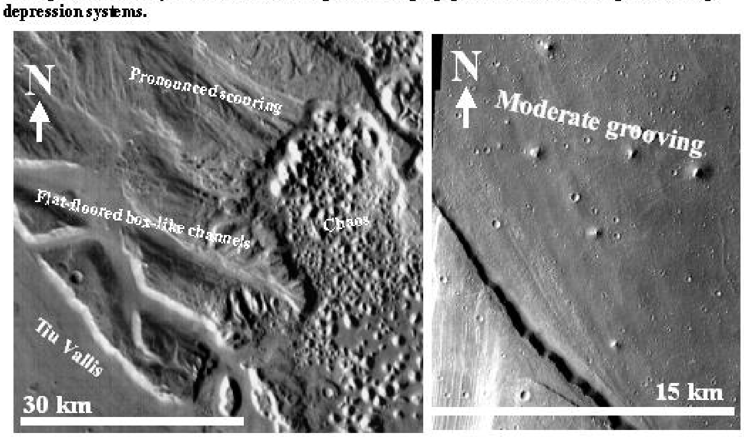

Figure 2A. Center of latitude 7.164°N, center of longitude 329.591 °E. THEMIS DIR composite of a region in the southern extents of the Tiu Vallis showing the morphology of the higher floor level and associated chaos. 2B. THEMIS VIS composite of a region in the northern extents of the Simud Vallis showing the morphology of the lower floor level.