AMAZONIAN FLUVIAL OUTFLOW CHANNELS NEAR JOVIS THOLUS REGION, MARS. S. Vijayan[1] and Rishitosh K Sinha[1], [1] Physical Research Laboratory, Ahmedabad, India. vijayan@prl.res.in

Introduction: Outflow channels on Mars are one of the prominent geomorphic evidence for the fluvial activities [1-2]. Wide presence of such fluvial valles/channels on the Noachian landform declined significantly over the Hesperian surface and only sporadic evidence are present over the Amazonian landforms [1-2]. However, during Amazonian several valles like Mangala Valles, Athabasca Valles, Grjota Valles [3-5] outflow channels were formed with the catastrophic release of water. Such channels on Amazonian landforms arises the question for their source, triggering process and period of flow. Apart from these channels, Olympica Fossae region and western part of Tharsis host several outflow channels [6]. In this study, we present new evidence for an outflow channel near Jovis Tholus region that further substantiates the role of fluvial activities.

Study region, data and methods: To the north of Jovis Tholus, an unnamed crater with layered ejecta and with floor fractured knobs was present. To the northwest of the crater and superposing its ejecta, there lies a graben oriented towards SW-NE direction. From this graben, two out breaches occurred which lead to forms outflow channels (Fig. 1). The channels are oriented towards the NW side with respect to crater. We used the MRO-CTX and -HiRISE images for morphological analysis and MOLA PEDR data for topographic analysis. Crater size frequency distribution was carried out to decipher the period of fluvial activity.

Geomorphology:

Channels. Two main channels (1 and 2) emanated from the graben at distinct locations which are ~18 km apart (Fig. 1a). The currently visible extent of these channels are ~31 km and ~28 km. Though they are spatially distinct, their flow orientation is towards NW of graben. Channel 3 likely branched from channel 1. The channel floors are irregular, hummocky, and dust covered. Several interconnected channel networks exist over the southerside side of channel1.

Streamlined islands. They are one of the most reliable class of flood evidence due to their planform geometric shapes and an indication of fluvial flow direction [4,7,8]. Narrow ends of streamlined island indicate the downstream direction (Fig. 1a). Some islands are within the channel, oriented parallel to the channel slope and predominantly caused due by depositional or erosional of bedrock material.

Terraces. They are visible around some of the streamlined islands and at the channel edges (Fig. 1a) with multiple layers. The variable height of the terraces is possible indicators of flood height [4,9] or erosional exposure during flood event. However, they can be either depositional or erosional remnant of stratigraphy layers present in the region. Terraces at the termini of channels are elevated from their surrounding suggesting possible erosional evidence for their formation.

Divide crossing. It has typical geometrical characteristics like the near parallel bars, reconnects towards the downstream direction (Fig. 1a) and high angle to the dominant flow direction [10]. The crossover channels are present towards the downstream end of the island with an oblique angle to the flow directed, but with reconnected networks.

Braided-like networks. They are likely present over the downstream end of the channel 1 banks (Fig. 1a, marked B). Over this region, multiple channels divide around islands or bars, which confluences further without change of flow direction. Braided like formation occurred over the place where steeper gradient and with high bedload. No braided-like networks are visible within the channel floors (Fig. 1a).

Unnamed crater. The diameter and depth are ~32 km and ~1.3 km. Crater is characterized by floor fractured knobs, layered ejecta with ramparts at termini (Fig. 1b) and resurfacing on the floor and over the ejecta.

Crater floor fracture. The knobs are several km in length and width with the presence of lateral fractures over it (Fig. 1b). Some of the floor knobs are tilted towards the central part with slope <1° and have an elevation difference of ~100 m. Crater center shows evidence for floor subsidence and with few submerged knobs possibly suggesting resurfacing activity after the floor fracture (Fig. 1b).

Crater ejecta. It shows a multi layered ejecta deposits with ramparts at its termini [Fig. 1b]. The NW part of the ejecta have been incised by channels and eroded significantly. However, some of the ramparts remnants persist in between the channels due to their thick deposits and relatively elevated from the floor. The superposition of channels over the ejecta suggests that the fluvial activity is possibly younger than the crater.

*Graben. F*rom which outflow channels originated (Fig. 1a) extend up to ~115 km and to its length the outflow channels are not observed elsewhere. The graben channelized the flood through the weak zone where it ruptured. Linear mafic dikes, underneath many of the Tharsis region graben, could produce significant heat that melts subsurface ice and release water to the surface [11,12].

Discussion: Crater counting over the ejecta blanket revealed the crater age as ~3.37 Ga and some of the lava flow superimposing ejecta occurred at ~35 Ma [13, 14] (Fig. 1c). Crater count over the crater floor fractured knobs lead to an upper model age of ~2 Ga. On examining the channel floor, it has undergone partial resurfacing either by volcanic or aeolian activity. The model ages for the three channels tends to ~0.2 - 0.5 Ga [13, 14] (Fig. 1c). Through chronological estimation, we interpret that the fluvial activity might have occurred after the crater formation, but before the channel floor resurfacing, which is during Middle-to-Early Amazonian. We envisage that the fluvial activity during the Amazonian epoch on a highly volcanic region like Jovis Tholus need to have sufficed source and cryosphere cracking/melting to form channels. Activities like dike intrusion and graben formation lead to cracking of cryosphere and melting of ground ice/water, to form the km wide outflow channels [4,11,12]. Graben acted as a notch conduit through which the water could flown for the formation of fluvial related geomorphic features, which are only present on the western side of graben. The current channel termini are covered by lava flows suggesting that the real extent of the channel could be much further than its current extent.

Summary: Our analysis shows that the geomorphological characteristics of Jovis Tholus region channel system can be of water release event. The channels are interconnected, possibly coeval in nature. Chronologically, the source persists before crater formation (~3.37 Ga) and discharge occurred during the Amazonian. This reveals that amenable conditions prevailed sporadically on Mars during the Amazonian period over this region for the fluvial activity.

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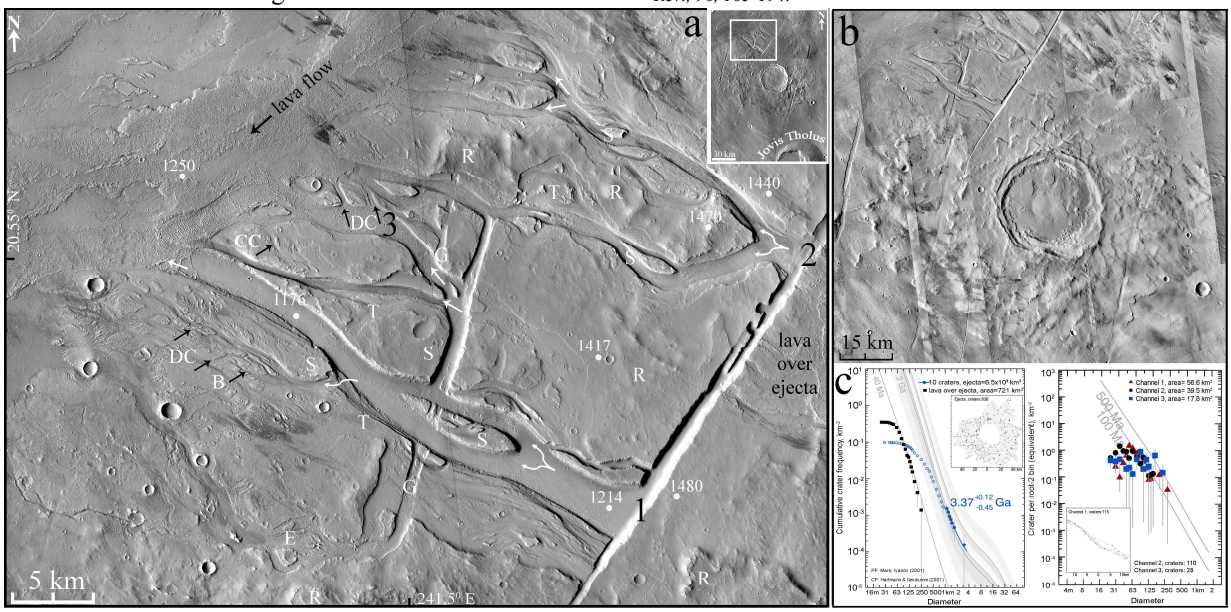

Figure 1. The Jovis Tholus volcano, unnamed crater and graben associated channels are shown in the inset image. a) The two prominent channels (1,2) breached from the graben lead to form streamlined island-S, terraces-T, divide crossing-DC, crossover channels-CC, braided like networks-B and eroded craters-E. The rampart ejecta (R) are incised by channels reveals their post formation after the crater. Along with the main graben where outburst occurred, there are several graben (G) got exposed due to the outflow event. Streamlined island possibly reveals the erosional bedform, elongated bar along the axis of flow, and terraces. b) Unnamed crater with layered ejecta, ramparts at ejecta termini and with floor fractured knobs. To the NW of crater, the graben and outflow channels have incised the ejecta layers. c) Crater size frequency distribution over the ejecta blanket reveals crater formation age as ~3.37 Ga, some of the lava flow on N-NE part of crater ejecta formed during ~35 Ma. Crater counting on three channel floor revealed the tentative model age as ~0.2-0.5 Ga. Chronologically, this implies that fluvial activity occurred after crater formation i.e., during middle-to-early Amazonian epoch. The major implication is that the source for outflow channel persists over this region from pre-Amazonian epoch (white arrow-direction of fluvial flow; white dot- MOLA elevation in m).