EPISODIC VOLCANISM AND FLUVIAL ACTIVITIES IN A FLOOR-FRACTURED CRATER AT THE FLANKS OF ARSIA MONS. Nandita Kumari¹, P. L. Whelley², J. C. Cowart¹, and T. D. Glotch¹ (Nandita.kumari@stonybrook.edu) ¹Department of Geosciences, Stony Brook University, Stony Brook, NY, ²Planetary Geology, Geophysics and Geochemistry, NASA Goddard Space Flight Centre, Greenbelt, MD, ³Department of Astronomy, University of Maryland, MD, USA.

Introduction: The Tharsis region forms the largest volcanic province on Mars. The lava flows [1], dikes [2] and fractures/grabens that formed due to tectonic [3,4] and volcanic activity [5] has been studied in detail in Tharsis to understand and constrain the geologic history of the region. In this study, we have used an unnamed crater (220° E, -23° S) of 23km-dia on the southwestern flanks of Arsia Mons which has undergone extensive intrusive and extrusive volcanism as a proxy to understand the magmatic process in the region and its consequence for other erosional processes. (Fig. 1a, b). The crater displays presence of several flow fronts of lava with different textures, concentric fractures, V-moat at the periphery and two channels entering in through the wall with and without deposits respectively. These indicate that the region has seen multiple episodes of lava flow with evolving magma and erosion both by lava and fluvial processes.

![Fig 1a. MOLA-HRSC elevation map displaying Arsia Mons and the location of crater (in black square) on its southwestern flank. b. CTX image of the crater with close-up view of different units in Fig 4.](image)

Topographic Analysis: We carried out a detailed topographic analysis of the crater by creating a pair of CTX DEMs overlaying the crater. The topographic analysis reveals that the crater has an undulating floor with an elevated dome-like central region (Fig. 2a) surrounded by a subsided region which further elevates near the periphery of the crater (Fig. 2a). A ~50 m deep V-shaped moat occurs close to the channels cut into the northern crater rim. The central peak of the crater is higher than the surrounding collapsed material.

Morphological Analysis: A detailed morphological analysis was carried out using CTX and HiRISE images. We mapped 11 units within the crater and 3 units in the nearby region (Fig. 2b). The two peaks (CP) in the center of the crater cover an area of 0.136 km² and 0.238 km² respectively, surrounded by a region of collapse covering an area of 1.54 km² (Fig. 3a). The collapsed region (CR) displays presence of terraces carved in the pre-existing terrain with flow features. This unit is surrounded by ridged plains (U1) (Fig. 3a) and a series of concentric and radial fractures.

![Fig 2a. CTX DEM overlain on CTX image of the crater displaying the undulating floor of the crater b. Morphological map of the crater prepared using CTX images displaying different units](image)

This terrain has relatively light toned deposits, lies in the central part of the crater, and mostly covers the uplifted portion of the dome (Fig. 2a).

![Fig 3a. Peak within the collapsed region surrounded by U1. b. Smooth Plains (U2) with fractures filled with light-toned lava. c. Lobate plains and wrinkle ridge. d. Channel in the NE with deposits and V-moat on the floor. e. Channel in the NW without deposits and V-moat on the floor. f. Young lava flows on U1 flowing into V-moat.](image)

We also notice local pitted surfaces in the region. This unit is encircled by smooth plains (U2) with low albedo (Fig 1b, 3b), a network of fractures with light-toned material within them, and exhibits topographic collapse bound by two large fractures on the north and south and a topographic high in the middle. Adjacent to these plains is a type-I broad asymmetric wrinkle ridge (WR)
with a broad arch [6] (Fig. 2b, 3c). The collapsed smooth plains are further enclosed by another set of ridged plains (U3) (Fig. 2b). These plains on the periphery of the crater wall share their boundary with a V-shaped moat further carved out by two channels (Fig 3d-e). These channels enter the crater from northeast and northwest. (Fig. 1b). While the channel in the northeast has deposits at its entrance in the crater, the one in the northwest lacks any deposits (Fig. 2b, 3e). The originating region of channel without deposits in the far north-west displays possible presence of lava tubes. The crater has impacted into southern highlands (SH) material. To the north, crater ejecta appears to have been buried by ridged plains (RP) lava flows sourced from Arsia Mons. To its south, ejecta material has been modified by a fracture system.

Discussion: This crater is a unique example of floor fractured craters that have undergone magmatic and fluvial processes in Amazonian era. The two peaks being higher than the surrounding collapse (Fig. 3a) and lack of any visible layers suggest that they are the central peak of the crater. Stratigraphically, unit U1 appears to be youngest, with the lobate plains unit, unit U2, and U3 following in order of increasing age. (Fig. 2b). The presence of the wrinkle ridges indicate that there have been multiple episodes of lava flow within the crater floor [5] and the variation in texture and several flow-fronts indicate that it has undergone episodic volcanism with lavas of different rheologies. The channels seem to have cut through the crater rim very late, after the emplacement of different units with occasional small lava flows in the southern part of the floor. The absence of deposits [7] and presence of lava tubes at the source of the northwest channel suggests it was carved by lava. Alternatively, the channel deposits got buried under the lava flow and were further eroded given, the channel predates the flow. The other channel is a juxtaposition of two channels that merge at the crater rim and displays deposits on the crater wall sloping towards the floor, suggesting that it is an alluvial fan of fluvial origin [8]. This deposit seems to be further carved again indicating that the one of two channels that merge at the rim was younger and flowed after the deposition by the previous channel. The domical shape of the floor, presence of the V-shaped moat on the periphery, and concentric and radial fractures in the central region indicate that the crater underwent magmatic intrusion leading to floor uplift and fracture formation [9,10]. This uplift was followed by release of trapped volatiles through the fractures leading to subsidence as we see in U2 [10]. Another magmatic intrusion may have further made its way through the fractures to erupt, and with evolving composition, display different rheologies [11] as we observe in U1 and U3. An important observation is the height of the central peak of the crater. Two contradicting models [10, 12] describe the fate of central peaks in terms of uplift. While the model by [9,10] predict that the central peak gets uplifted during an intrusion beneath the floor. The magma rises through these fractures with excess pressure resulting in the uplift. A geophysical model[12] on the other hand, states that central peak induces an increased lithostatic pressure on the floor and even in the lower end (where peak is only 1/3rd of crater depth and only 1/4th in area) this pressure is enough to prevent the thickening of intrusion in the center and form a moat surrounding it. Here we do not observe any uplift in the central peak, supporting the modeling results from [12]. This aids that though the intrusion flow is primarily controlled by the overlying layer thickness and crater diameters, the central peak doesn’t get uplifted during the process. The flow of the channels being restricted primarily to the V-shaped moat demonstrates the influence of such intrusions on fluvial erosion. Such intrusion through the fractures and moats can restrict such flows, thus limiting the area undergoing fluvial erosion.

Summary: The flanks of Arsia Mons have undergone multiple episodes of volcanic and fluvial activity as indicated by our observations. The crater has also helped us test the various models regarding magmatic intrusion within crater floor and its effect on the fluvial erosion.

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