LATE AMAZONIAN VOLCANISM, TECTONICS AND BOULDER AVALANCHES IN THE CENTRAL THARSIS REGION, MARS: IMPLICATIONS FOR GEODYNAMICS

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Introduction: Tharsis is the largest volcano-tectonic province on Mars and in the entire solar system[1]. Tharsis witnessed geological activity spanning from Pre Noachian to Amazonian and even ongoing geological processes are observed in the area[2]. The Central Tharsis region consist of Olympus Mons, Arsia Mons, Pavonis Mons, Ascraeus Mons numerous smaller volcanoes along with numerous large graben systems like Noctis Fossae Ulysses Fossae etc. The detailed lava flow, graben and pit mapping in the northern Tharsis region by Krishnan and Kumar, (2023)[3], revealed continual volcanism, long lived magma chamber and sub crustal magma under plating driven by a mantle plume beneath Alba Mons volcano. This magma chamber was subsequently migrated to Ceraunius Fossae region. Such large scale mapping of lava flows were not attempted in the Central Tharsis region before. Hence in this work, we started dating hundreds of lava flows supplied by main Tharsis Montes and the small vents and fissures found in the flanks of these volcanoes. This analysis will help us in understanding the periodicity of volcanism, timing of shifting from central eruption to fissure eruption and plume migration patterns in the Central Tharsis region during the late Amazonian time period.

Among the large graben systems in the Tharsis region, the precise age of Fortuna Fossae[4] is only known. Hence in this work, we mapped and dated all the 8 large graben systems found in the Tharsis region to understand the timing of formation of these grabens.

Various geological and InSight data[5] reveal the present day seismic activity in the northern[3] and eastern part[6] of Tharsis region. However, the seismicity of the Central Tharsis region is poorly known. Hence in this work, we mapped the spatial distribution of boulder falls from the Central Tharsis region. This data compiled with past published data will make the first boulder fall map for the entire Tharsis region.

Study Area: In this study, we focused on the Central Tharsis region that extends for ~ 2500 km in the N-S direction and ~2000 km in the E-W direction. According to geological map of Tanaka et al. (2014) [7], the vast plains of the central Tharsis were mapped as Amazonian Hesperian volcanic unit (AHv). Each of the individual Tharsis Montes were identified as Amazonian volcanic edifice unit (Ave). However the caldera of Arsia Mons and the young lava flow field in the eastern side of Tharsis Montes were mapped as Late Amazonian volcanic field unit (lAvf). The apron units found in the northwestern side of Tharsis Montes were mapped as Late Amazonian apron unit (lAa). According to Bouley et al, (2018)[1], grabens in the Central Tharsis region were found to be formed between Early Hesperian and Late Amazonian epoch.

Methodology: In this study, we used NASA's Mars Reconnaissance Orbiter's Context camera images (MRO CTX, ~5 m/pix), High-Resolution Imaging Science Experiment camera images (MRO HiRISE, 25-50 cm/pix), NASA's Mars Odyssey's Thermal Emission Imaging System daytime infrared mosaic (THEMIS, 100m/pix) and NASA's Mars Global Surveyor, Mars Orbiter Laser Altimeter (MOLA) digital terrain model (DTM) for mapping boulder trails, grabens and lava flow from the Central Tharsis region. For determining the absolute formation ages of the lava flows, we counted the primary impact craters that are superimposed on the individual lava flows. The crater courting was performed using the 'Cratertools' software. The statistical analysis including the cumulative size frequency distributions of the counted craters was performed using 'Craterstats' software. The production and chronology functions of Ivanov (2001)[8] and Hartmann and Neukum (2001)[9], respectively, were used for obtaining the absolute model formation ages. Secondary craters were excluded from the above analysis.

Results & Discussion: At this stage we have completed mapping and dating of more than 120 individual lava flows around Arsia Mons (Figure 1). The lava flow ages were found to range from 24 Ma to 1060 Ma. Numerous previously unmapped vents and fissures were found along the southern flank of Arsia Mons. The huge lava flow fan found in the NE and SW flanks of Arsia Mons were mapped and dated. Each lobes were divided into two units based on topographic data. Lava flow lobes in the NE flank have an age of 70 Ma and 78 Ma, while the age of lava flow fan in the SW have an age of 94 Ma and 83 Ma (Figure 1). The presence of circular lower crustal thickness anomaly beneath the SW flank region of Arsia Mons (Figure 1), suggest an underplated magma body beneath the crust and whether it is a source of late Amazonian volcanism is being studied.

Eight major graben system (Fossae) in the Tharsis region were mapped and dated (Figure 2). These

grabens are Noctis Fossae, Fortuna Fossae, Claritas Fossae, Ceraunius Fossae, Tractus Fossae, Tantalus Fossae, Alba Fossae and southern lobe (SL) of Alba Mons volcano. All these graben systems were found to be formed during the Hesperian period between 3.57 Ga and 3.22 Ga (Figure 2) such that Noctis Fossae was the oldest and Tantalus Fossae was found to be the youngest. The ages of graben systems (Fossae) indicates that, all of them were simultaneously developed in the Hesperian period. However it should be noted that these ages only represent average age of all grabens present in the graben system. We plan to determine the minimum and maximum ages of individual grabens having stratigraphic contact with the surrounding lava flows. In this way we determined maximum ages of 16 grabens from Arsia Mons volcano and their ages were found to vary from 51 Ma to 335 Ma (Figure 1). The ages of these grabens indicate their late Amazonian origin.

We used 617 HiRISE used for mapping boulder falls and only 140 images contain a total of 2739 boulder trails (Figure 2). These trails are distributed across craters (N=266), pits (N=1924), grabens (N=462) and caldera walls (N=34). Larger number of boulder trails were found along collapsed terrain (vents) of Tharsis Montes (Figure 1) region and this could be an indication of ongoing dike processes underneath these volcanoes. The least number of trails were discovered from Olympus Mons. Considering the boulder trails mapped by past workers [3,6] and present study, a complete boulder fall map can be obtained for Tharsis region.

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References: [1] Bouley et al. (2018), *EPSL*, *488*, 126–133. [2] Carr & Head (2010), *EPSL*, *294*(3–4), 185–203. [3] Krishnan & Kumar, (2023), *J.Geophys.Res. Planets*, *128*, e2022JE007511. [4] Kneissl et al. (2015), *Icarus*, *250*, 384–394. [5] Horleston et al. (2022), *TSR*, *2*, 88-99. [6] Kumar et al. (2019), *ESPL*, *505*, 51-64. [7] Tanaka et al. (2014), *USGS*. [8] Ivanov (2001), *Spa Sc Rev 96* 87-104. [9] Hartmann & Neukum (2001), *Spa Sc Rev 96* 165-194.

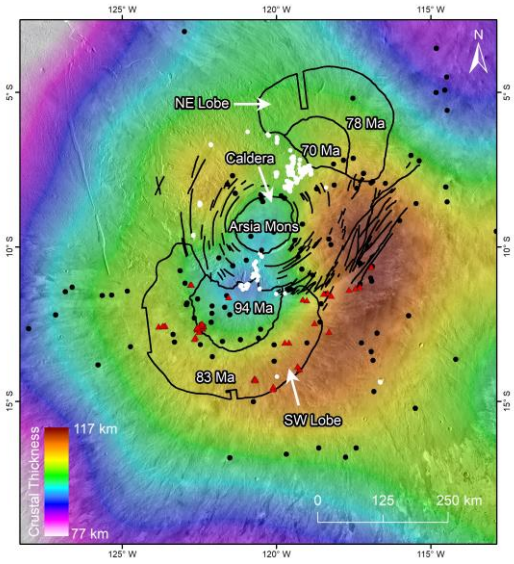

Figure 1. THEMIS day time imagery overlain on crustal thickness data representing the lava flows dated from Arsia Mons volcano (black dots). The lava flow fan and the corresponding ages are also given (black polygon). The grabens surrounding the Arsia Mons is given in black lines. The newly detected small vents are given as red triangles and the boulder trails are given as white dots.

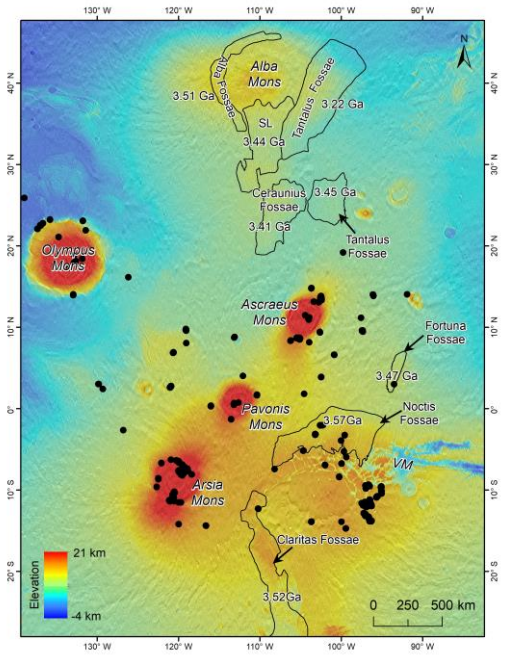

Figure 2. THEMIS day time imagery overlain on MOLA topography representing the distribution of boulder trails from the Central Tharsis region (black dots). The mapped fossae systems are also represented (black polygons) and their corresponding ages are given.