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Eruption history of the Elysium Volcanic Centre, Mars

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The surface of Mars has been extensively reshaped by volcanic processes. Large volcanic edifices and vast lava plains dominate the planet. Although it is generally known that volcanic activity at various volcanic centres on Mars peaked in the Late Noachian/Early Hesperian, little knowledge exists about the complete eruption history at individual volcanic centres. Estimates of the eruption frequency, associated volume of erupted material, and volatile release to the atmosphere at each volcanic centre on Mars would propel our understanding of global climate changes and atmospheric evolution, sustained heat production, melt generation, and magma ascent. In our ongoing efforts to quantify the global volatile escape during volcanic eruptions on Mars we first focused on the Elysium Volcanic Centre. We estimated the total minimum volume of erupted material at the Elysium Volcanic Centre to be $>3.5\times10^6$ km^3. However, to evaluate the volatile release in time, we also need to identify the duration of volcanic activity and its main periods along with associated volumes of erupted material. Light has now been brought into the eruption frequency of the Elysium Volcanic Centre. Here we report on the first comprehensive eruption frequency record of a single volcanic region.

The Elysium Volcanic Centre consists of three edifices: Elysium Mons, Hecates Tholus, and Albor Tholus. Elysium Mons is the largest volcano and is located on a c.1000 km$\times$1500 km rise. The summit of Elysium Mons rises c.17,700 m above the surrounding plain to the west. Hecates and Albor Tholi are located to the NNE and SSE, respectively, of Elysium Mons at the periphery of the Elysium rise. Volcanic material erupted from Late Hesperian to Early Amazonian from the Elysium Volcanic Centre and was mapped by Tanaka et al. as unit AHEe. It spreads over 110° E-W (>3600 km) and 35° N-S (>1600 km) and covers an area of approx. 3.4×10^6 km^2. In order to obtain a representative set of crater model ages from lava flows, mapping efforts concentrated on proximal, medial, and distal reaches of the volcanic region. This approach was only biased by the availability of suitable imagery and varying degrees of obliteration across the region. In addition, the formation ages of selected calderas were also determined. Lava flow mapping was performed in a GIS environment using HRSC and THEMIS IR day imagery. Crater-size frequency determinations were primarily carried out on CTX and HRSC images and subordinately on THEMIS VIS data. Crater measurements and analysis was done using cratertools and craterstats, respectively. Crater modelling ages were compiled in frequency plots and cumulative probability density plots.

A total of 141 lava flows and 6 calderas were mapped and their formation ages determined using impact craters. Model ages range between 3.4 Ga and 60 Ma. The majority of lava flow effusion occurred between 1-1.1 Ga. Since then activity rapidly waned with minor broad peaks at 250 Ma and 100 Ma. The oldest age of a buried surface underlying a lava flow is 3.8 Ga. Currently, there is no obvious time-space correlation apparent. However, it is observed that 9 of 10 lava flows younger than 500 Ma are located at the lower flanks of the Elysium rise or at more distal reaches. The youngest caldera-forming events occurred at Hecates Tholus. This study shows that the Elysium Volcanic Centre was active much longer than previously thought. Although only a small number of exposed lava flows were studied, it is evident that Elysium was active for more than 3.8 Ga. If it is inferred that the Elysium Volcanic Centre developed following the Utopia impact at c. 4.1 Ga, then most of the Elysium rise and edifices were formed in less than 300 Myrs. Further, we anticipate a genetic link between Elysium Volcanic Centre and Elysium Planitia, where some of the youngest known lava flows and low shield volcanoes on Mars exist. Those exposed volcanic products are related to the Cerberus Fossae system which extends well into the Elysium Volcanic Centre. There, the fossae were activated at least twice enabling the ascent of magma to the surface. Therefore, we suggest that both volcanic regions share a common magma source at depth. If true, volcanic activity preferentially migrated along the Cerberus Fossae system to lower altitudes within Elysium Planitia. Vaucher et al. (2009) determined surface ages of lava flows and low shield volcanoes. We have reprocessed their data using the Hartmann and Neukum chronology. As a result, two peaks in activity occur at about 10 Ma and 60 Ma with the youngest material erupted at 1.4 Ma. If we take the Elysium Planitia ages into consideration it appears probable that Mars is still volcanically active in the broader Elysium region.