Introduction: Elysium Planitia includes several of the youngest lava flow fields on Mars [e.g., 1–5] and thus represents a crucial location for constraining the late volcanic history of the planet. The low-lying volcanic plain, designated as the Cerberus Fossae 3 unit (AEc3 [1, 2]), is bounded in the north by the Elysium Rise unit (AEc3 [1, 2]) and in the south by the equatorial Medusa Fossae Formation. Flows within AEc3 include: the 5–20 Ma Athabasca Valles lava (Aav [3]); and a succession of older lava, but still young (<50 Ma) flows that occupy the central part of the Cerberus Basin [4] (Figure 1). Determining the similarities and differences between these two groups is critical for determining how eruption styles have evolved on Mars during the geologically recent past. For instance, are all major eruptions in this region characterized by high effusion rate, short duration eruptions, like the Aav flood basalt, or do there exist a wider range of eruption styles that reflect different magmatic storage regions throughout Elysium Planitia? If so, have magmatic source depths, eruption styles, and emplacement durations changed in a systematic way through time? This study addresses these issues.

Background: The Aav flood basalt may have been emplaced as recently as 5–20 Ma [6, 7], making it the youngest and best preserved major lava flows on Mars. Aav occupies the western part of Elysium Planitia and includes two main branches. The larger of the two branches infilled Cerberus Palus, overtopped its confinement to the south, and continued to flow northwest through a trough formed by the erosional retreat of the Medusa Fossae Formation from the AEc3 unit. However, Aav also includes an eastern branch that overlies older AEc3 lava within the central part of the Cerberus Basin.

The Aav flood basalt is interpreted to have been emplaced turbulently at high effusion rates of 5–20 × 10^6 m^3/s over a relatively short amount of time. For instance Jaeger et al., (2010) [3] suggest that the bulk of the erupted volume may have been emplaced over a period of only several weeks.

In contrast to the Aav flood basalt, other flows within the AEc3 may have been emplaced more gradually. While the total number of flows within the Cerberus Basin remains poorly constrained, some of the youngest major flow units debouched through Marte Vallis and onto the Amazonis Planitia (Figure 1). Effusion rates associated with this event were high (10^3–4 m^3/s [8]), but still too to three orders of magnitude lower than for the Aav eruption—even through the eruption volumes may be comparable [9]. Additionally, lava flow morphologies in the distal end of the Marte Vallis flows resemble terrestrial sheet-like lava lobes produced through a process of lava flow inflation, and suggesting an emplacement duration of years to decades [9].

We conjecture that high effusion rate eruptions, like the one that formed the Aav flood basalt, erupt more volatile rich magma over a short period of time from deeply-sourced reservoirs, whereas the other lava flows within central Elysium Planitia may be fed by more volatile-depleted magmas erupted over longer periods of time from shallower crustal reservoirs.

To develop improved models for how magmatic source regions are related to effusive eruption styles within Elysium Planitia, we are developing a new inventory of eruptions within this region by systematically mapping the area of major flow units and using thickness estimates, based of stereo-derived topography and radar sounding data, to infer flow volume. Combining this information with detailed descriptions of flow morphology this information will be used to run and validate eruption scenarios for magma batches erupted at different depths within Mars. Predictions of inferred magmatic source region can also be compared to measurements by the Heat Flow and Physical Properties Package (HP3) and Seismic Experiment for Interior Structure (SEIS) instruments onboard InSight (Interior Exploration using Seismic Investigations, Geodesy and Heat transport) lander [10, 11]. For the first time, this will provide the opportunity to evaluate predicted magma sources based on geomorphological observations and compare them with heat flow data and seismic signals on Mars.

Data and Methods: This study utilizes orthoimages from the Context (CTX; 6 m/pixel [12]) camera and High Resolution Imaging Science Experiment (HiRISE; 0.3 m/pixel [13]) camera onboard the Mars Reconnaissance Orbiter (MRO) as well as High Resolution Stereo Camera (HRSC; 12.5 m/pixel [14]) onboard Mars Express. Topo-
graphical analyzes are based on the Mars Orbiter Laser Altimeter (MOLA) on the Mars Global Surveyor (MGS) spacecraft [15]. Combining orthoimages and subsurface radar reflectors obtained from the MRO SHAllow RADar (SHARAD) allow to infer the thickness of the lava flows [16].

To measure the spatial area and thus infer the volume of the emplaced lava flows the Environmental Systems Research Institute (ESRI) software ArcGIS 10.5.1 is used to digitize the lava flow margins. The discharge rate defines the ratio of lava volume per time which can be determined by calculating the average flow velocity for a laminar Newtonian flow or turbulent flow, as summarized by Jaeger et al., (2010) [3].

**Conclusion:** This study investigates the critical question whether eruption styles have changed over the late history in Elysium Planitia on Mars. Systematically comparing two groups of lava flow fields (see Figure 1) according to their morphological characteristics, volumes, and effusion rates provides insight into the evolution of magma reservoirs within the geological recent past.

Comparing these results with seismic signals and surface heat flow measurements from the InSight mission allows for better constraining the thermal evolution of the planet.


**Figure 1.** This figure shows an overview of Elysium Planitia, with the Cerberus Fossae 3 unit denoted in translucent white. It inundates the central Cerberus Basin and debouches through Marte Vallis and onto Amazonis Planitia in the Northeast. The unit shown in solid white represents the Athabasca Valles lava with the black star indicating its source. The black lines mark the Cerberus Fossae graben.