EVALUATING THE ROLE OF LARGE-SCALE LAVA-ICE INTERACTIONS DURING ELYSIUM PLANITIA VOLCANISM AND THE FORMATION OF ATHABASCA VALLES. J. P. Cassanelli[1] and J. W. Head[1], [1]Dept. Earth, Environ., and Planetary Sciences, Brown University, Providence, RI 02912 USA (James_Cassanelli@Brown.edu)

Introduction: The Central Elysium Planitia region of Mars [*e.g.* 1,2] contains evidence for the youngest volcanic and fluvial activity on the martian surface [*e.g.* 1,3,4]. The region is characterized by geologically recent lava plains which are interpreted to have formed in a flood basalt mode, involving voluminous eruptions of low viscosity magma at high effusion rates with eruptive activity sustained over significant timescales [*e.g.* 5]. The flood basalt plains of Central Elysium Planitia are modified by Athabasca Valles, a large fluvial system thought to have been active within the last ~20 Myr [6] (although the channel could be much older; [7]), representing the most recent large-scale fluvial activity on Mars. Both the flood basalt plains as well as the water thought to have carved Athabasca Valles appear to emanate from Cerberus Fossae [8,9], a series of extensional fissures extending over a total length of ~1,235 km within the region.

The Athabasca Valles outflow channel is canonically interpreted to have formed through the effusion of pressurized groundwater released from aquifers confined beneath the martian cryosphere by magmatic dike emplacement [8]. However, some investigators [10] have questioned the importance of water in the formation of the channel, suggesting a range in possible origins from purely fluvial to purely volcanic, or through a combination of both. Assuming that the Athabasca Valles system was carved exclusively by water, the geologically young age of the system results in several demanding requirements for the canonical formation mechanism. (1) A liquid groundwater system must have been preserved at great depth beneath a very thick cryosphere to near the present day (against the relatively efficient action of vapor diffusive loss to the cryosphere; [11]), and must have been supplied by a source of active groundwater recharge (most plausibly Elysium Mons, still an unlikely source of recharge late in the Amazonian period; [12,13]). (2) The groundwater system must have been saturated to the base of the cryosphere to allow confinement and pressurization, requiring significant volumes of liquid water [14]. (3) Dike emplacement or tectonic extension must have produced and maintained an open conduit across the entire ~5-10 km thick cryosphere [15] to allow water outflow to the surface. (4) The permeability of the aquifer from which the floods emanated must have been unreasonably large, far exceeding those common of terrestrial aquifers at similar depths and scales [8].

Could any other mechanisms have been involved in the formation of Athabasca Valles that could relax these stringent requirements? Here we perform a first-order assessment of the potential for large-scale lava-ice interactions [16] to have generated melting of surface snow and ice during Central Elysium Planitia volcanism and to have contributed to outflow channel formation. Large-scale lava-ice interactions can operate independent of the difficulties that challenge the groundwater formation model and are plausible in the Central Elysium Planitia region given the significant volumes of lava spread across the region, the predicted presence of surface snow and ice, and the preserved evidence for past lava-ice interactions [17]. We begin by reviewing the volcanic characteristics of the region and the evidence for past surface snow and ice.

Regional Volcanism: The volcanic nature of Central Elysium Planitia is thoroughly established [*e.g.* 1]. The region contains extensive flood basalt plains covering a total area of ~1-10x10^6 km^2 with a volume of ~0.1-0.15x10^6 km^3 [*e.g.* 18]. Within the region, typical individual lava flow units exhibit thicknesses of ~1-40 m, areas of ~10^4 km^2, and volumes of ~10^3 km^3. Crater count age dating [1] suggests volcanic activity within the Central Elysium Planitia region continued to as recently as ~2 Ma and extended to at least 250 Ma. Individual periods of activity in the Central Elysium Planitia region are estimated to be on the order of 1 Myr, with some investigations [18] suggesting emplacement of large portions of the province (specifically the ~2.5x10^5 km^2 Athabasca Valles flood lava) over time periods as little as weeks to months.

Regional Snow and Ice: Several lines of evidence have been documented indicating that regional snow and ice are likely to have been common within the latitude range of Central Elysium Planitia during the Amazonian period. (1) The deposition and formation of tropical mountain glaciers on the Tharsis Montes and the ice-bearing latitude-dependent mantle resulting from redistribution of polar volatiles toward the equator during periods of increased obliquity [19, 20]. (2) The preservation of pedestal craters which exhibit heights of several tens to in excess of one hundred meters [21]. (3) The presence of lineated valley fill, lobate debris aprons, and concentric crater fill [22]. (5) Global climate model simulations predicting the accumulation of ice at similar latitudes and within the northern portions of Central Elysium Planitia [23]. Together, these observations and predictions suggest that the presence of regional surface snow and ice deposits in excess of tens of meters thick was likely within Central Elysium Planitia during the Amazonian period.

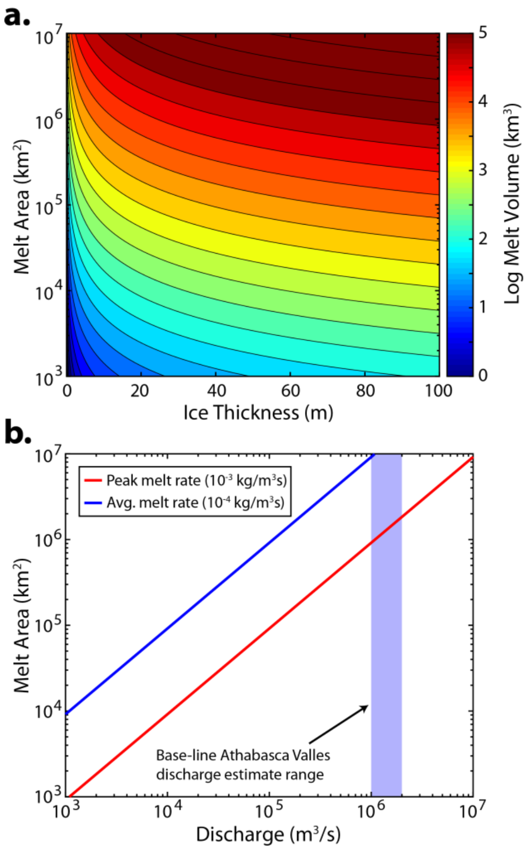

Figure 1. (**a.**) Contours of melt volume produced by lava-ice interactions as a function of the thickness of present regional surface snow and ice and the area of melting (**b.**) Total discharge produced by lava-ice interactions as a function of melting area, with a nominal range of discharge estimates [6] for the Athabasca Valles shown for comparison.

Regional-scale Lava-Ice Interactions: Given these characteristics we assess large-scale lava-ice interactions in Central Elysium Planitia by assuming a total lava-ice interaction area of up to 10^7 km^2 (the maximum extent of the lava, also assuming equally extensive surface ice deposits), individual lava flow thicknesses of 20 m and areas of 10^4 km^2, and surface ice deposits up to 100 m in thickness. The effects of lava flow emplacement timescale are neglected as it does not significantly influence the total amount of ice melted [16]. Utilizing these parameters and previously developed melting rate predictions (Figure 1b; [16]) we evaluate the volume and rate of meltwater production that could be produced by large-scale lava-ice interactions generating top-down melting of surface snow and ice deposits (Figure 1). We find that individual lava flows could generate meltwater volumes and production rates of ~10^1-10^3 km^3 and ~10^3-10^4 m^3/s, respectively, while volcanism across the entire area simultaneously (unlikely) could generate up to ~10^5 km^3 of water at a discharge rate of ~10^6-10^7 m^3/s.

Conclusions: Central Elysium Planitia is a region with a well-documented history of extensive volcanic activity and an area which is likely to have had extensive regional surface snow and ice deposits during the Amazonian period. The occurrence of large-scale lava-ice interactions is very plausible, particularly given the preserved evidence of past lava-ice interactions. The emplacement of extensive volcanic plains within the region during times of surface snow and ice cover is an optimum mechanism for generating substantial volumes of meltwater through lava-ice interactions. We find meltwater volume and production rate ranges for individual lava flows of ~10^1-10^3 km^3 and ~10^3-10^4 m^3/s, respectively, while volcanism across the entire area could generate up to ~10^5 km^3 of water. Given that the discharges produced by lava-ice interaction fall short of those estimated for the Athabasca Valles outflow channel (Figure 1), we find that the formation of Athabasca Valles itself is not plausibly accomplished through meltwater production from the interaction of lava and ice alone. On the basis of these difficulties, and the challenges faced by the canonical groundwater eruption mechanism, we suggest that the Athabasca Valles channel may be due to a combination of lava construction and thermal erosion. However, the interaction of lava and ice is able to produce relatively substantial volumes and fluxes of meltwater which could have played an important role in shaping the geomorphology of Central Elysium Planitia and may have contributed to the formation of the region's outflow channels (Athabasca, Grjota´, and Marte Valles) and other features (such as the platy-ridged surface texture exhibited across portions of the volcanic plains).

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