THERMAL MODELING OF PERMAFROST MELT BY OVERLYING LAVA FLOWS WITH APPLICATIONS TO FLOW-ASSOCIATED OUTFLOW CHANNEL VOLUMES IN THE CERBERUS PLAINS, MARS.

Z. A. J. Chase[1] S. E. H. Sakimoto[2], [1]Morehouse College, Atlanta, Georgia 30314, zen1083@aol.com, [2]GEST at the Geodynamics Branch, NASA/Goddard, Greenbelt MD 20771, sakimoto@geodynamics.gsfc.nasa.gov.

Introduction: The Cerberus region of Mars has numerous geologically recent fluvial and volcanic features superimposed spatially, with some of them using the same flow channels and apparent vent structures [1, 2]. Lava-water interaction landforms such as psuedocraters suggest some interaction of emplacing lava flows with underlying ground ice or water (e.g. [1, 3]). This study investigates a related interaction type a region where the emplaced lava might have melted underlying ice in the regolith, as there are small outflow channel networks emerging from the flank flows of a lava shield over a portion of the Eastern Cerberus Rupes. Specifically, we use high-resolution Mars Orbiter Laser Altimeter (MOLA) topography to constrain channel and flow dimensions, and thus estimate the thermal pulse from the emplaced lava into the substrate and the resulting melting durations and refreezing intervals. These preliminary thermal models indicate that the observed flows could easily create thermal pulse(s) sufficient to melt enough ground ice to fill the observed fluvial small outflow channels. Depending on flow eruption timing and hydraulic recharge times, this system could easily have produced multiple thermal pulses and fluvial releases. This specific case suggests that regional small water releases from similar cases may be more common than suspected, and that there is a possibility for future fluvial releases if ground ices are currently present and future volcanic eruptions in this young region are possible.

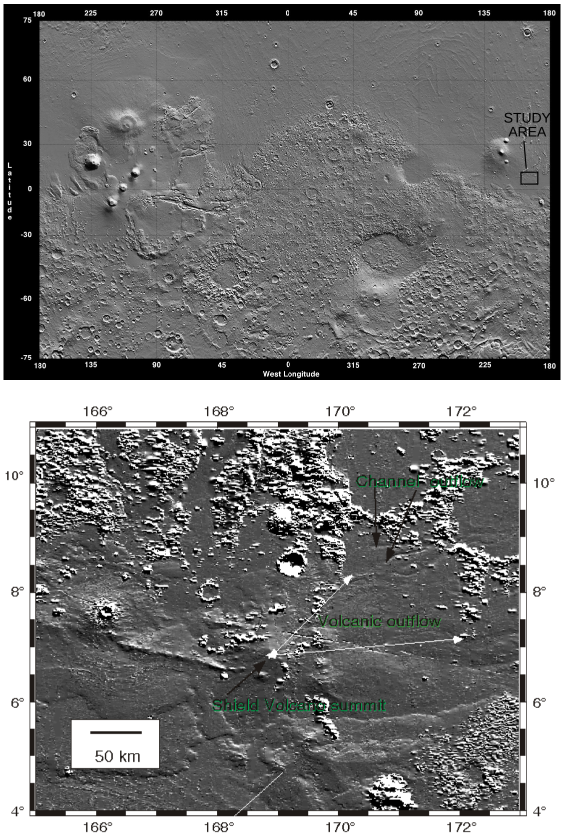

Fig. 1a (top) shows a MOLA shaded relief map of Mars with the Cerberus region shown as a black box. Fig. 1b (bottom) shows a shaded relief MOLA grid at 460 meters per pixel of a portion of the E Cerberus vent system, with the shield summit and associated lava flows indicated, and the fluvial channels labeled.

Data: We use both MOLA profiles for detailed measurements, as also regridded the MOLA data to construct a local crossover-corrected topography grid at 128 pixels/deg. longitude by 256 pixels/deg. latitude using the approach of Neumann et al. [4]. We use a suite of tools within the IDL-based *Gridview* program [5] to measure parameters such as channel depths and volumes and flow heights and volumes, which are input as constraints into the thermal models.

Channel volumes. The channel volumes are measured with profile and gridded data. Since they are locally V-shaped, multiple cross-sectional areas are sequentially integrated from cross-section to cross-section to obtain a total volume. For the small channel system emerging from under the flows we estimate a total volume of 7.9×10^8 m^3 ± 62%

Lava volumes. The lava volume is integrated from multiple profiles with the assumption of a planar surface (best-fit to the shield margin locations) prior to emplacement of the shield, with the embayed (older) high standing terrains removed from the shield volume calculation. . We estimate a lava volume of 7.66×10^8 m^3 ± 25% for the shield segment directly over and upslope of the channel network.

Modeling Approach and Results To estimate the depth and intensity of the thermal pulse(s) over time due to the lava flow emplacement, we use a well-known solution to the unsteady heat conduction equation [6]. which assumes that the lava is far enough from its source (here assumed to be the volcano summit) that it is not actively flowing. The thermal pulse as a function of depth *T(z)* is then described by

$$T(z) = T_0 + \frac{Q}{2\rho C\sqrt{\pi\kappa t}} \exp\left(\left(-z^2\right)\Big/\left(4\kappa t\right)\right) \qquad (1)$$

where κ is the thermal diffusivity, C is heat capacity, ρ is the rock density, t is time, T_0 is the initial substrate temperature, and Q is the heat flux transmitted in to the rock. Table one shows assumed parameter values.

For the solution in equation one and the assumed parameters in table one, A locally typical ten meter thick flow would take approximately 169 days to solidify after emplacement, and during the first several years, it would pump enough heat into the substrate to melt off the top several to a few tens of meters of ground ice (See Fig. 2a). The maximum ice melting depth would be about 360 meters, which would be reached in 2000 years, and the entire underlying substrate would be expected to refreeze within 5000-7000 years. For end-member examples of thinner and thicker lava flows, we also modeled 1 meter and 100 meter thick flows. The one meter lava flow solidified in 2 days, its thermal pulse reached its deepest extent of approximately of 38 m in about 20 years, and had a total refreeze time of about 50 years. The 100 meter lava flow solidified in 24 years, its thermal pulse reached its deepest extent of approximately of 3510 m in about 200,000 years, and had a total refreeze time of about 500,000 years.

Discussion and Conclusions: This basic model, while somewhat simplistic in some of the assumptions such as flow thickness, shows that the lavas observed in the small shield example considered here are more than sufficient to melt enough water to fill the observed small channel network. The potential maximum water released from the modeled study region would be 9.51 x10^{11} m^3 for a 35% permeability (after [7]), and exceeds the estimated channel network capacity by a few orders of magnitude, suggesting that multiple water releases from multiple thermal lava flow events are not only volcanically more reasonable, given the observed radial flow textures locally, they are probably thermally required. While this work has no available constraints on either lava flow emplacement times or hydraulic recharge times for the underlying substrate, we suggest that the scenario suggested by the model results here of repeated flow emplacement, thermal pulses, and water release, is consistent with observed local fluvial and volcanic morphologies, and perhaps applicable to multiple areas in the Cerberus plains region where geologically recent examples of both fluvial and volcanic features are observed.

Acknowledgements: This work is supported by NASA MDAP grants NAG5-11150 and NAG5-12287, Project SPACE at Morehouse College, and funds from the MOLA Science Team. We thank D. E. Mitchell, T. Sabaka, J. Roark, D. Burr, and S. Cohen for discussions and assistance.

References: [1] Burr, D.M. et al., (2002) *GRL,* 29, 10.1029/2001GL013345. [2] Sakimoto S.E.H. et al. (2001) *GSA Ann. Mtng. Abstr* Paper #178-0. [3] Hartmann, W.K., and D.C. Berman, (2000) *JGR*, *105*, 15011-15026. [4] Neumann, G.A. et al. (2001) *JGR*,106 (E10), 23573-23768. [5] Roark, J., et al. (2000) *LPSC XXI*, CDROM, Abstract #2026. [6] Turcotte, D.L. and Schubert, G., (1982) *Geodynamics,* J. Wiley. [7] Boynton, W.V., et al. (2002), *Science*, 297, 81-85. [8] E.B. Grosfils and S.E.H. Sakimoto (2001) *LPSC XXXII*, Abstract #1111. [9] Kieffer, H.H., et al. (1992) *Mars*, Univ. Arizona Press.

Table 1. Thermal model parameter values

Parameter	Value	units
Density^1	2900	kg m^{-3}
Thermal Diffusivity	7.134x 10^{-7}	m^2 s^{-1}
Lava melting temperature	1200	¡C
Underlying rock temperature	-10	¡C
Heat capacity^2	1450	J $kg^{-1}K^{-1}$
Permeability^3	35% ± 15%	

^{1}[9], ^{2}[8], ^{3}[7].

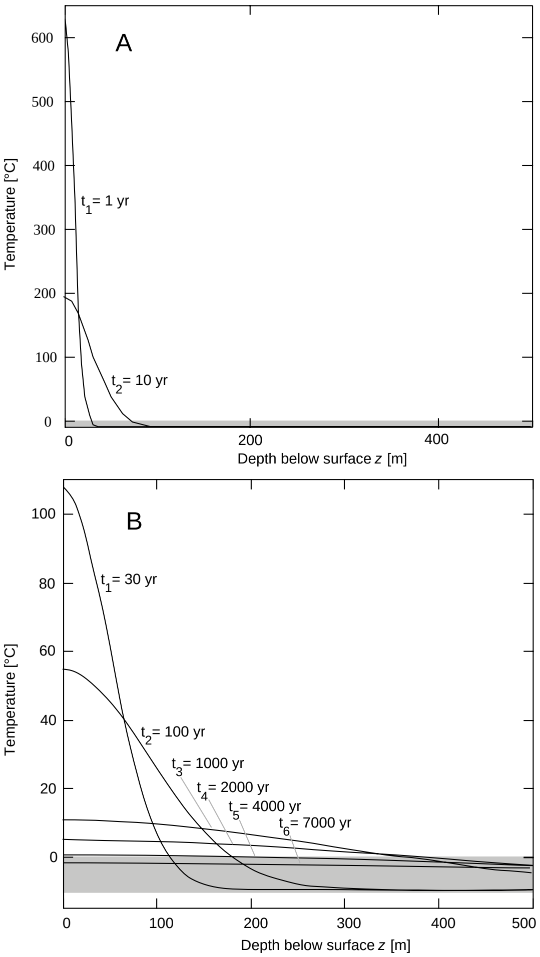

Figure 2. Results for the thermal modeling for a locally typical 10 m thick lava flow. Figure 2a shows the sub-lava thermal pulse into the substrate as a function of depth for a 10 m thick lava at one and ten years, while Figure 2b shows the same thermal pulse for longer time periods. Gray boxes are temperatures of 0 to —10C.