POTENTIAL FOR LAVA EROSION ON MERCURY: MODELING THE FORMATION OF BOTH SMALL AND LARGE LAVA CHANNELS. Debra M. Hurwitz[1], James W. Head[1], Paul K. Byrne[2], Zhiyong Xiao[3]. [1]Dept. of Geological Sciences, Brown University, Providence, RI 02912, debra_hurwitz@brown.edu; [2]Dept. of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, DC 20115; [3]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721.

Introduction: Broad regions of smooth volcanic plains have been observed in the north-polar region of Mercury in images collected by MESSENGER Mercury Dual Imaging System (MDIS) [1,2]. These volcanic plains have morphologies similar to some mare basaltic plains that flood large impact basins on the Moon, including broad expanses of relatively flat terrain that show no evidence for specific vents that fed the observed flows. The dearth of vents observed within the flood plains is consistent with high-effusion emplacement of low-viscosity lava that flooded and covered associated vents. Evidence for channelized lava flows has also been observed on Mercury, but the channels on Mercury are rare and their dimensions are typically much smaller than typical lunar sinuous rilles.

This study uses recently acquired MDIS narrow-angle camera images to locate and describe features that potentially formed as the result of vertical incision into the substrate by lava erosion. Observations of channel morphology, specifically channel width, depth, and slope, are used as inputs into analytical models that simulate the formation of the channel by mechanical or thermal erosion. Model results 1) indicate the type of erosion that dominated during the formation of the channel and 2) provide estimates of the erosion rate and eruption duration required to form the observed features. Results are then put into the context of the volcanic history of Mercury.

Description of Channels: Several features have been identified on Mercury that represent potential lava erosion features. A cluster of large valleys observed along the margin of the northern volcanic plains exhibit textures consistent with surface erosion by lava [1-4], though these valleys may have formed initially due to sculpting related to the formation of the Caloris basin [5] before being

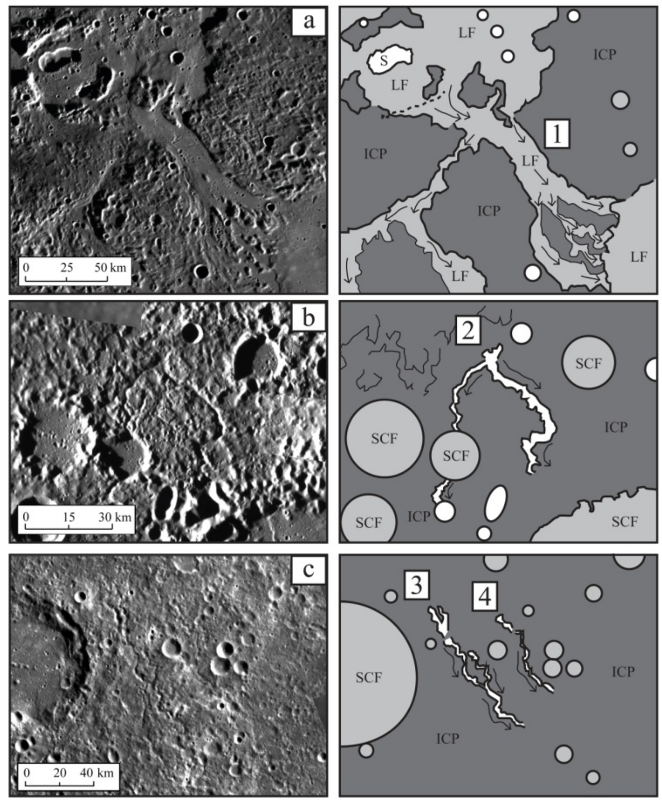

Figure 1: Channels observed on the surface of Mercury, with MDIS imagery on the left and a sketch on the right (S, source; LF, lava flow; ICP, inter-crater plains; SCF, smooth crater fill). a) Large lava-filled valley at 59°N, 110°E; potentially formed by lava erosion. b) Smaller, highly degraded channel located at 32°S, 25°W; impact crater may have formed during or after flow. c) Two small channels with potential elongate sources located near 56°S, 33°W.

Table 1: Observations and model results for potential lava channels on Mercury

channel	section	lon	lat	length km	width km	depth m	slope degrees	source area km²
1	total	59	110	180	18	500	0.3	242
2	western	-32	-25.2	58	2.3	450	0.1	20
2	eastern	-32	-25.2	60	2.8	415	0.1	20
3	western	-56.4	-32.8	84	2.7	860	0.1	95
4	total	-55.4	-32.9	43	1.5	480	0.1	44

channel	section	lava flow depth m	flow velocity m/s	effusion rate m³/s	mechanical erosion rate m/day	time for mech. eros. days	thermal erosion rate m/day	time for therm. eros. days
1	total	6.4	2.7	3.14×10^5	0.39	349	1.4	500
2	western	1.1	1.7	4200	0.01	32200	1.5	290
2	eastern	1.1	1.7	5100	0.01	30000	1.5	270
3	western	1.1	1.7	4900	0.01	61700	1.5	560
4	total	1.1	1.7	2700	0.01	34400	1.5	315

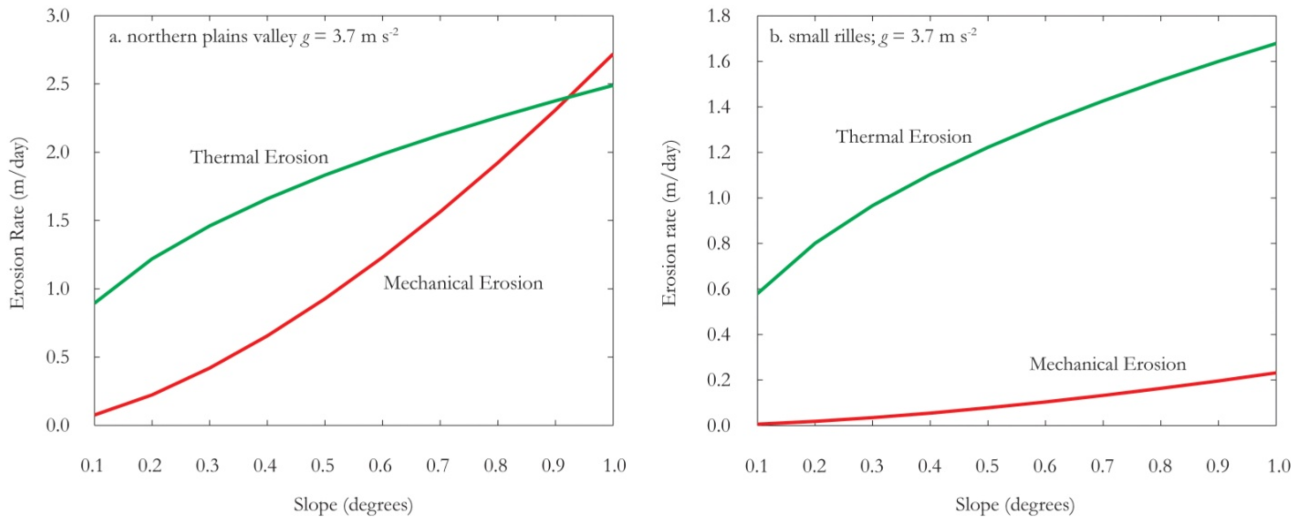

Figure 2: Model results for erosion rates of the large valley (a) and smaller channels (b) as a function of slope. The observed slope of the large valley (0.3°) suggests a thermal erosion rate of 1.4 m/day may have occurred during valley formation, and the assumed slopes of the smaller channels (0.1°) suggests that a thermal erosion rate of 0.6 m/day may have occurred during channel formation. The small channels are all similar in size so they have similar model results.

flooded and partially modified by lava erosion. Figure 1a shows one such valley (59°N, 110°E), where relatively smooth lava potentially flowed from a source pit or fissure to the northwest (S, dashed line in Fig. 1a), and may have carved the observed valley before depositing ~15 × 10^3 km^3 of lava into a basin to the southeast.

Three other, smaller channels have also been identified (Fig. 1b: 32°S, 25°W, Fig 1c: 56°S, 33°W). These channels have been degraded by subsequent impacts. The first small channel appears to have formed in the ejecta of a larger impact crater northwest of the image in Fig. 1b. The channel branched to form two segments, and the eastern segment is superposed by an impact crater. The other two small channels (Fig. 1c) are similarly narrow and degraded, and none of the small channels appear to have deposits at the channel termini, though this may be due to subsequent degradation of the channel or deposits.

Models: Two types of erosion, mechanical and thermal erosion, are considered to determine the eruption flux, flow velocity, and duration required to form the observed channels. Mechanical erosion occurs as the result of collisions between particles entrained in the flowing fluid and the substrate, and the erosion rate as the result of mechanical erosion [6] is given by:

$$\left(\frac{\mathrm{d}(d_{\mathrm{chan}})}{\mathrm{d}t}\right)_{\mathrm{mech}} = K\,\rho\,g\,Q\sin\alpha, \qquad \text{Eq. 1}$$

where Q is the eruption flux (m^3 s^{-1}), ρ is the lava density (kg m^{-3}), g is gravity (3.7 m s^{-2}), α is the surface slope, and K is a factor that represents the erodibility of the surface (Pa^{-1}), where a higher value represents a less consolidated, more easily eroded surface [6,7.

Alternatively, thermal erosion occurs when a hot flowing fluid melts into the substrate, and the erosion rate as the result of thermal erosion [8] is given by:

$$\left(\frac{\mathrm{d}(d_{\mathrm{chan}})}{\mathrm{d}t}\right)_{\mathrm{therm}} = \frac{h_{\mathrm{T}}(T-T_{\mathrm{mg}})}{E_{\mathrm{mg}}}, \qquad \text{Eq. 2}$$

where T and T_{mg} represent the temperature of the erupted lava and the melting temperature of the substrate, respectively, h_{T} is the heat transfer coefficient, and E_{mg} is the energy required to melt the substrate and is given by

$$E_{\mathrm{mg}} = \rho_{\mathrm{g}}\left[c_{\mathrm{g}}\left(T_{\mathrm{mg}} - T_{\mathrm{g}}\right) + f_{\mathrm{mg}}L_{\mathrm{g}}\right] \qquad \text{Eq. 3}$$

where T_{g} is the initial temperature of the substrate, c_{g} is the specific heat of the substrate, L_{g} is the latent heat of fusion of the substrate, and f_{mg} is the fraction the substrate must be melted before being carried away by the flowing fluid [8]. These models are solved by using observed slopes and an assumed initial lava flow depth to solve for velocity [9] and volume flux. The lava flow depth is adjusted until the modeled volume flux matches an analytically derived flux [10], and then erosion rates are calculated using Eq. 1-3. Similar approaches have been used in analyses of martian [7] and lunar [11] channels.

Results: Modeled volume fluxes and erosion rates for both the large and the small channels observed are shown in Table 1 and Fig. 2. In both cases, thermal erosion is expected to dominate channel formation at the slopes observed or estimated for each channel. If the large valley formed completely by lava erosion, erosion would have occurred at a rate of 1.4 m/day for 500 Earth days to form the observed feature. Smaller channels would have eroded at a rate of 1.5 m/day over 300 – 500 Earth days. Further analysis will determine how these channels formed in the context of volcanism on Mercury.

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