LOCALIZED EROSION BY FLUID FLOW PRECEDED DEVELOPMENT OF CERBERUS FOSSAE FISSURES, MARS. M. W. Pendleton[1] and S. A. Kattenhorn[1], [1]Department of Geological Sciences, University of Idaho, 875 Perimeter Drive MS 3022, Moscow, Idaho 83844-3022. pend5955@vandals.uidaho.edu, simkat@uidaho.edu.

Introduction: The Cerberus Fossae, Mars, is a ~1200 km-long system of fissures that may be associated with a protracted history of volcanism, tectonism, and fluvial activity [1,2] (Fig. 1). The Cerberus Fossae formed in response to magmatic dike intrusions that likely propagated radially from the Elysium rise. Pre-MRO (Mars Reconaissance Orbiter) observations led to the hypothesis that heating by magmatic dikes melted an ice-rich layer and mobilized enough water to the Martian surface to produce a megaflood that carved Athabasca Valles (AV) [2]. More recent studies reveal that AV is draped by a thin veneer of mafic to ultramafic lava [3]. Additionally, rootless cones are identified on the AV channel floor that likely post-date lava flow emplacement and are indicative of lava emplacement over an ice-rich substrate [4].

The goal of this study is to characterize the variability in the erosional morphologies present along the Cerberus fissures. We assert that a descriptive analysis of such features will provide insight into geomorphic modification processes that result from magmatic dike intrusion and its influence on the near-surface cryosphere, and hence the sequence of events that ultimately result in fissure formation. In this study, we report on erosional fissure morphologies that may be related to the mobilization of water and/or lava to the surface during dike intrusion. We propose a timeline of lava and/or water extrusion in the context of structural activity along a subset of Cerberus Fossae fissures located between 159° to 162.5° E, and 6.75° to 9.25° N.

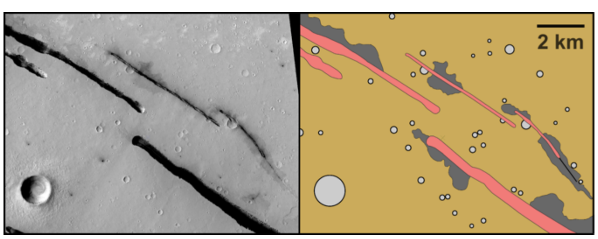

Figure 1. Cerberus Fossae fissures centered at 10.66° N, 156.43° E. (Left) CTX image B01_009847_1902_XN_10N203W. (Right) Geologic map of left image. Legend: Lt. Grey – Impact Craters; Lt. Brn – Elysium Plains unit; Pink – Cerberus Fissures; Dark Grey – Volcanic(?) Deposit.

Cerberus Fossae: The Cerberus Fossae region is located southeast of Elysium Mons volcano. The main part of the fossae consists of a cluster of four prominent, SE-trending, parallel fissures, up to 2 km wide and 1 km deep, the longest of which is ~1200 km long. The fissures are spaced 40-45 km apart and are distinctly segmented in a staggered, en echelon geometry.

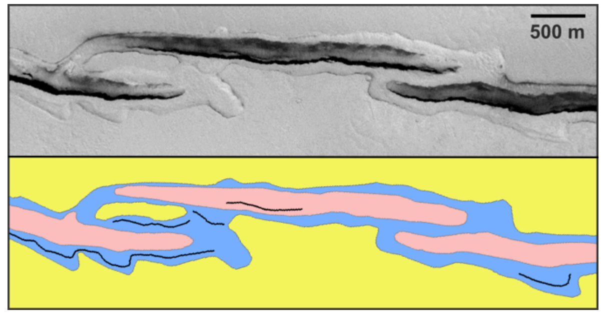

Figure 2. (Top) CTX image P12_005641_1889_XI_08N199W centered at 8.04° N, 161.16° E. (Bottom) Geologic map. Eroded Rim Depression (blue) borders en echelon segments of Cerberus Fossae (pink). Notice the symmetrical appearance of the erosional unit about the fissure. Pale yellow – Cerberus Plains Unit; Black Lines – Ridges.

Fissure Morphologies: Three end member erosional morphologies are identified across the entire Cerberus Fossae fissure system: (1) Eroded Rim Depression, (2) Fissure Sourced Smooth Unit, and (3) Eroded Channel. Each morphologic unit is located in close proximity to individual Cerberus fissures, and is topographically subdued relative to the surrounding lava plains crosscut by the associated fissure.

1. Eroded Rim Depression: A topographically subdued, erosional "ring" is present along the perimeter of several Cerberus fissures. The depression is distinguished on the basis of a smooth, continuous boundary that separates it from the surrounding plains. In some cases, the depression physically connects en echelon fissure segments (Fig. 2). The smooth surface texture of the depression is consistent along its length; however, the width of the erosional ring is variable along the length of individual segments. The Eroded Rim Depressions are crosscut by the associated fissures (Fig. 2).

2. Fissure Sourced Smooth Unit: In contrast to an Eroded Rim Depression, which has continuous boundaries around the perimeter of the fissures, the Fissure Sourced Smooth Unit has an irregular periphery, with resistant mounds preserved as islands protruding above a smooth unit that embays the eroded terrain adjacent to the fissure (Fig. 3). An almost skeletal, positive topographic ridge occasionally acts as the boundary of the Fissure Sourced Smooth Unit. The unit is asymmetric about the perimeter of the fossae, and is less densely cratered than the surrounding Cerberus Plains Unit, implying the Cerberus Plains are relatively older.

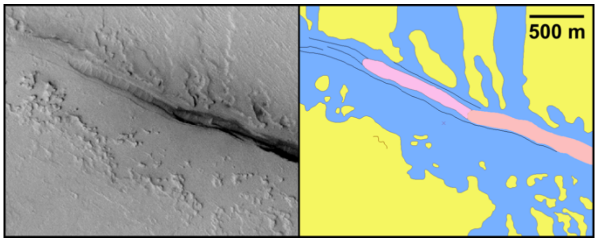

Figure 3. Fissure Sourced Smooth Unit showing an embayed morphology along its southern periphery. The image is centered at 8.46° N, 160.18° E. (Left) CTX image P06_003373_1885_XN_08N199W. (Right) Geologic map of left image. Color scheme same as Fig. 2.

3. Eroded Channel: A topographically subdued unit with a channel-like planform emanates from several Cerberus fissures (Fig. 4). The boundaries are irregular to lobate, and fairly continuous. The channel increases in cross sectional width with increasing distance from the fissure. While the example in Fig. 4 has distinguishable boundaries on all sides, other Channel Units have a scalloped appearance along the unit boundary that is less pronounced farthest from the fissure.

In contrast to the Eroded Rim Depression, which is present on both sides of the fissures with a smooth continuous boundary, Eroded Channels are not restricted to the region immediately around the associated fissure. Instead, erosional channels may either develop perpendicular to the fissure segment, or may propagate along-strike to the fissure (based on local topography).

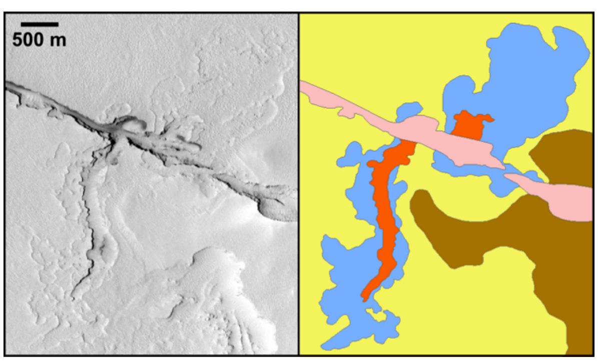

Figure 4. Channel Unit, centered at 8.42° N, 159.25° E. (Left) CTX image P15_006775_1897_XN_09N200W. (Right) Geologic map of left image. The red unit is a younger, deeper Channel Unit that incises the broader Channel Unit (blue). The brown unit indicates a knobby Noachian mound.

Discussion: The close association of the erosional morphologies with Cerberus Fossae fissures indicates a causal, possibly coeval, formation process. Each morphology discussed is comprised of a topographically subdued unit, and implies that older surface units were eroded away. The Eroded Rim Depression and Fissure Sourced Smooth Unit both have texturally smooth surfaces and do not appear as heavily cratered as the surrounding plains. A resurfacing process such as lava emplacement may have occurred to produce these morphologies. The units were then each crosscut by their associated fissures. A similar sequence of events may have developed prior to the formation of the fissures at the Athabasca Valles source.

Erosion by lava is feasible for all morphological units reported here, with subsequent production of smooth units with low cratering densities by lava emplacement within topographic depressions above developing fissures. Another possibility is that geothermal heat produced by intruding magmatic dikes melted an ice-rich layer, and resulted in the mobilization of water to the surface. Fluid flow must have been very turbulent to erode into the primarily basaltic plains through which the fossae crosscut. If a sufficiently thick (10s of meters) dust layer was present, the production of these morphologies may have required less powerful fluid flow and perhaps lahar-like deposits.

Our interpretation that the diverse fissure related morphologies developed as a consequence of the extrusion of lava, or magmatic heating of an ice-rich layer, implies that each fissure is related to an underlying dike. The near vertical fissure walls that crosscut the erosional morphology are not draped in lava, indicating the fissure opening postdated the eruption of lavas into surface depressions. We infer that tectonic activity at the surface postdated the creation of erosional depressions by fluids, mobilized by dike intrusion in the subsurface and that the fissures ultimately widened in response to ongoing dike intrusion (via increased magma supply) that created extensional stresses at the surface above the dikes. Some of the surface breaks involved fissure eruptions and the production of lava flows that postdate the smooth morphologic units described here (including in AV). Our observations are consistent with previous assertions that tectonism is the most recent active process at Cerberus Fossae [1,2].

References: [1] Berman D.C. & Hartmann W.K. (2002) *Icarus,* 159, 1-17. [2] Burr et al. (2002) *Icarus,* 159, 53-73. [3] Jaeger et al. (2010) *Icarus,* 205, 230-243. [4] Jaeger et al. (2007) *Science,* 317, 1709-1711.
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