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Dike-Related Fissures and Resultant Jökulhlaups at Cerberus Fossae, Mars

Simon Kattenhorn and Jonathan Meyer
Dept. of Geological Sciences, University of Idaho, PO Box 443022, Moscow, ID 83844-3022, USA (simkat@uidaho.edu)

Cerberus Fossae is located southeast of the volcano Elysium Mons, Mars, between 154-174°E and 6-12°N. It consists of a cluster of four sets of SE-trending parallel fractures (manifested as 50-150 m deep fissures), the longest of which extends a distance of 1200 km. The fracture sets are spaced 40-45 km apart and are approximately radial to Elysium Mons, reflecting dikes that propagated away from the central volcanic complex driven by magma pressures, as is typical of dikes on Earth. The dike system curves towards the east with increasing distance from Elysium, implying intrusion into a regional stress field where the maximum compression was oriented E-W. Effusive products along the fractures indicate they were eruptive fissures, highlighted by prominent SW-directed wind streaks from the fracture margins. The detailed fracture geometry reveals a highly segmented system, also typical of terrestrial dike systems. This segmentation occurs over a range of scales, reflecting dike development through the mechanical interaction and linkage of smaller segments to form longer segments. Segments occur in the length ranges 3-10 km, 20-50 km, and 90-120 km. Dikes are well approximated as dilating cracks within an elastic body. As such, they should show an approximately elliptical distribution of dike opening from tip to tip along the dike length. Accordingly, the width (dilation) of the longest fissures varies from zero at the tips to around 1 km near the centers. Rounded ends and scalloped margins cause significant noise in the width distribution and is the result of geomorphic modification through collapse of the fissure walls. Detailed views of the fissure margins in HiRISE images reveal multiple, parallel, vertical cracks. Hence, the fissures do not represent a single dilated dike, but rather a discrete zone of deformation. This geometry is not inconsistent with dike intrusion as dikes commonly propagate through a tight cluster of cracks that formed in the process zone ahead of the propagating dike. However, portions of the fractures are also distinctly graben-like, implying that steep, dilational normal faults formed above upwardly propagating dikes, as is common in the rift zones of Iceland and elsewhere on Mars. The Cerberus Fossae fractures appear to have acted as a source for Late Amazonian megafloods that flowed southward from the western end of Cerberus. Melting of a subsurface layer of ice, such as a frozen groundwater system, by magma as dikes propagated upward through the martian crust resulted in giant jökulhlaups that moved down the regional slope towards the south, creating the prominent erosional channel Athabasca Valles. Such floods create a strong case for the presence of a subsurface cryosphere that may hold vast quantities of water. Our analysis of MOLA surface topography along the Cerberus Fossae cracks suggests that Athabasca Valles may have formed through numerous superposed jökulhlaup events, each related to a dike intrusion event at Cerberus. The main erosional channel (120 m deep) is associated with the longest, central fracture; however, a 60 m deep channel upslope of this fracture may result from earlier jökulhlaup events related to dikes further north. Hence, Athabasca Valles may represent the cumulative result of a protracted period of megafloods during the progressive development of the dike system from Elysium.