SINUOUS CHANNELS EAST OF OLYMPUS MONS, MARS: IMPLICATIONS FOR VOLCANIC AND FLUVIAL PROCESSES.
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Introduction: The debate regarding the fluvial versus volcanic origin of Amazonian-aged channels on Mars has primarily focused on major outflow channels such as Athabasca Valles, Grjótá Valles, and Mangala Valles [1–7]. However, similar considerations also apply to smaller channels located in many regions of the Tharsis volcanic province.

Geologic Setting: This study focuses on Late Amazonian channels located near the eastern flank of the Olympus Mons, where crater size-frequency relationships suggest channel ages ranging from 30 Ma to 145 Ma [8]. The channels in this region are typically 8–40 m-deep [9] and exhibit diverse morphologies, dividing into three types (see Fig. 1): (1) narrow (50–400 m-wide) single-stemmed sinuous channels; (2) intermediate-width channels exhibiting ragged banks and complex anabranching networks; and (3) broad (up to 4 km-wide) streamlined channels located adjacent to linear fractures and fracture networks. These channels have been variously attributed to flows of water, lava, or a combination of water and lava [8–10].

Methodology: To constrain the origin of channels near the eastern flank of Olympus Mons, we have mapped the regional distribution of channels and fractures, examined channel morphologies in detail using digital terrain models (DTMs) generated from Mars Reconnaissance Orbiter (MRO) Context Camera (CTX) and High Resolution Imaging Science Experiment (HiRISE) stereo-image pairs, and compared observed channel morphologies to terrestrial analogs such as the Laki lava in Iceland and Channeled Scablands in the Pacific Northwest of the United States.

Results: *Channel Type 1.* These narrow sinuous channels are typically tens of meters-deep, up to 0.5 km-wide, and tens to hundreds of kilometers long. The channels originate from linear fissures and near their source they commonly exhibit a nested relationship within broader (Type 2) channels that are up to several km-wide. Type 1 channels tend to be located along the axis of a ridge-shaped structure with lobate exterior margins. Channel floor elevations are generally equal to the surface elevation directly outside the lobate ridge, which implies an absence of substrate erosion along the channel axis. The channels follow the regional slope and broaden near their terminations, where they transition into lobate to plateau-shaped structures. In planform, Type 1 channels are generally single-stemmed in the medial to distal regions, but they include anabranching segments with quasi-streamlined islands closer to their source. However, HiRISE images reveal that the "streamlined" islands and channel banks appear irregular to jagged at scales of 1:10,000 (or higher). The channels also exhibit raised levées that extend tens to hundreds of meters from the edge of the channels and terminate in meter-thick lobes. Channel beds are generally flat-floored with blocky rubble located near the walls.

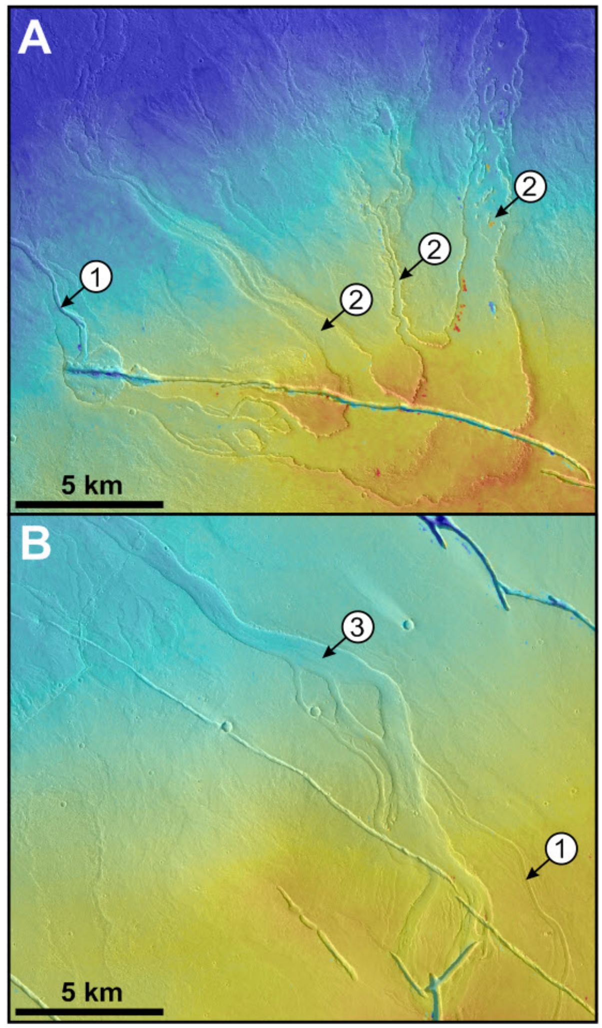

Figure 1. Stereo-derived DTMs showing channels near the eastern flank of Olympus Mons. **A:** DTM generated from CTX D06_029716_1979 and D06_029426_1980, centered on 17°53'N, 127°53'W. **B:** DTM created from CTX G05_020169_1976 and G05_020024_1976, centered on 17°26'N, 126°45'W. In both panels, warmer colors represent higher elevations and numerals identify examples of Channel Types 1, 2, and 3.

Channel Type 2. These channels are widest near their source, but narrow down-slope to terminate in distributed lobes and plateaus that exhibit numerous circular to elliptical depressions. Type 2 channels generally extend only a few kilometers and have broad flat floors that are tens of meters deep. However, in some cases, the channels may exhibit interior terracing and host Type 1 channels. Type 2 channels are located within ridge-shaped structures and do not appear to have eroded into the substrate. However, the inner banks of the Type 2 channels are more irregular than the Type 1 channels and more commonly include raised-rim islands, blocky rubble near steep-sided channel walls, nested levées with lobate margins, crevasse splays, and abandoned side-channels.

Channel Type 3. These channels are commonly several kilometers wide near their source and then focus into a main kilometer-wide sinuous channel that extends for tens of kilometers. However, the distal margins of these channels are rarely preserved because they are in-filled by younger lobate flows. The channel sources tend to be complex fracture networks that feed numerous anabranching segments confined within a broader alcove-shaped region. Type 3 channels axes are strongly influenced by the surrounding topography and channel floors are deeper than their surroundings. Channel banks and islands tend to be terraced and exhibit significant streamlining even at scales of 1:10,000 (or higher). The channel banks also appear to have incised laterally into older units. Levées (where present) are much broader and shallower than for the other channel types. Hanging side-channels and crevasse splays are also common and channel floors commonly exhibit longitudinal striations and bars.

Interpretation: Channel Type 1 is interpreted to be volcanic. The location of Type 1 channels along the axis of ridge-shaped landforms with lobate margins is inconsistent with the expected setting of a fluvial stream channel, which would occupy topographic lows. Type 1 channels show no evidence of erosion into the substrate or their lateral banks, which is consistent with a volcanic origin in which an initial period of levée construction is followed by partial drainage of the preferred lava pathway. Nested channel structures may indicate overall waning effusion rates at the vent, with episodic increases in local discharge rate leading to overbank flow and the formation of steep-sided levées that are similar to those observed within channelized sections of the Laki lava flow.

Channel Type 2 is also interpreted to be of volcanic origin. In this case, the opening phase of a fissure eruption may have fed lava through series of channels at high-discharge rates, thereby promoting lava surface disruption, enhanced cooling, and shorter overall flow lengths relative to Type 1 channels. As the effusion rate decreased, partial drainage produced channels with ragged edges that are confined within larger lobate structures. In some cases, preferred lava pathways may have developed into nested Type 1 channels that were supplied with lava for longer periods of time.

Channel Type 3 is fundamentally different from the other channel types in that these channels appear to have eroded into both their floors and banks to produce highly streamlined channel margins and islands with abundant evidence of terracing, scour marks, and other erosional bed forms. The lack of lobate margins and constructional levées is inconsistent with a volcanic origin and therefore these channels are interpreted to be the products of stream flow erosion associated with flood water in either a normal or hyperconcetrated flow regime. Type 3 channels are analogous to eroded bedrock landforms in the Channeled Scablands that were carved by the catastrophic aqueous floods.

Discussion and Conclusions: The co-occurrence of volcanic and aqueously carved channels near the eastern flank of Olympus Mons implies a complex geologic history in which aqueous flooding events occurred intermittently during an extended period of Amazonian-age volcanism. In some instances, aqueous flood paths appear to have been highly influenced by older lava flows, either being deflected by high-standing flow margins, or exploiting existing lava channels. In other cases, lava appears to have occupied older aqueously carved channels. The interaction between these landforms and processes resulted in complex channel morphologies that require detailed examination on a case-by-case basis to determine their origins. The isolated occurrences of Type 3 channels also raise intriguing questions regarding the origin of the flood water. One explanation may involve the interaction between ascending magma under different climate conditions, with higher-obliquity favoring lower-latitude accumulations of ground-ice, and therefore flooding events when magma approached the surface and melted these ice deposits. However, most fissures appear to have produced "dry" volcanic channels, implying that near-surface ice accumulations in this region were relatively rare during the Late Amazonian.

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