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Experimental formation of stepped fan deposits on Mars

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Fans on the surface of Mars imply persistent, flowing surface water; furthermore, deltaic fans indicate standing bodies of stable surface water. Understanding the type of flow (catastrophic versus sustained) and number of events (single versus multiple) required to form Martian fans is vital to understanding the hydrologic system responsible for their formation. One population of fans, the stepped fans, stands out as particularly unique. These fans (approximately a dozen reported in the literature thus far) have distinctive "stair step" breaks in their topography. The formation mechanism of these steps is debated and hypotheses range from volcanic flows to erosive wave action to subsequent alluvial deposition. Each hypothesis has important implications for the hydrologic cycle and climate present during fan formation.

We conducted a series of flume experiments designed to investigate the formation mechanisms for the stepped fan deposits on Mars. Previous experimental work indicates that topographic breaks can be associated with fan deposition in a filling basin (Muto and Steel, 2001 and Van Heijst et al. 2001). Our experiments, run at the Eurotank at Utrecht University, focused on recreating the unique morphology observed in remotely sensed data (Mars Orbiter Camera (MOC), High Resolution Stereo Camera (HRSC), Mars Orbiter Laser Altimeter (MOLA), Thermal Emissions Imaging Systems (THEMIS)).

We built two experimental set-ups. One focused on reproducing the formation of subtle, concentric steps using controlled, rising sea level with constant water and sediment discharge. These results prove that concentric steps easily form in deltas as they deposit under rising water level conditions, even in the absence of autogenic processes such as avulsion or lobe formation. The general morphology of these steps compares well with some of the stepped terrace deposits on Mars. The second exper-

iment formed a fan in a filling ‘crater.’ These fans experienced variable water level rise due to ground water infiltration and variable sediment discharge due to channel migration and bank erosion. These fans transitioned from alluvial, sub areal deposition to deltaic, sub aqueous deposition as the basin filled. Because of the higher and more variable sediment discharge rates, these deltas experienced frequent avulsions and formed steps as lobes were deposited at different levels while the basin filled.

Our results show that stepped fan deposits are easily formed when fans deposit into filling basins. The morphology of these deposits, such as concentric or lobed, can be used to infer the relative rate of sediment and water discharge and water level rise. We conclude that stepped fans were likely formed during a single fluvial event. The preservation of the fan steps indicates that there was not long-term deposition at a stable water level and no reactivation of the fluvial system post fan formation.

References

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