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Pressurized groundwater systems in Lunae and Ophir Plana (Mars): insights from small-scale morphology and experiments

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Large outflow channels on Mars reveal the past presence of water on the surface, possibly released from pressurized groundwater reservoirs. Due to a lack of understanding of the underlying processes, the hydrological and corresponding climate conditions remain a subject of debate.

We investigate the detailed morphology of possible pressurized groundwater outflow systems in comparison to landscape evolution experiments. These experiments show that incised valleys like the classic outflow channels are a last erosional stage in morphological development. This is preceded by the formation of sedimentary lobes due to rapid water loss by infiltration.

On Mars, we observed similar features related to different stages of groundwater outflow in Lunae and Ophir Plana, which form parts of the high standing plateaus adjacent to the huge depressions of the Valles Marineris. In both the experiment and the Martian cases, we observed lobate depositions that emerge from collapsed pits and pit chains. These lobes have channelized surfaces related to fluvial flow. In the experiments, pits formed adjacent to the valley heads due to the outflow. The pits in the source regions of Mars strongly relate to the regional tectonic structure and likely result from subsidence by extension and not by groundwater alone. Faulting, subsidence and collapse likely triggered outflow from a pressurized aquifer and could have aided in aquifer pressurization.

This scenario is consistent with the presence of one or several cryosphere-confined aquifers from the Early Hesperian to at least the middle Amazonian. A pronounced spatial trend of larger and further developed outflow systems at lower elevations suggests that features ranging from small lobes to large outflow channels were sourced from a common aquifer or from aquifers with similar pressures. The required cryosphere indicates a cold climate and enables groundwater outflow even under atmospheric conditions unfavorable for sustained presence of liquid water.