Geophysical Research Abstracts
Vol. 16, EGU2014-9696, 2014
EGU General Assembly 2014

Mechanisms for pressurized groundwater outflow channels, implications for Mars

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Various valleys on Mars show evidence for extensive fluvial activity in the past. The largest valleys on Mars are several tens to hundreds of kilometers wide and are thought to have originated from outflow of pressurized groundwater. However, exact mechanisms of these processes are lacking, which hampers a quantitative interpretation of some of the most impressive morphological features on Mars.

Using flume experiments, we studied a range of possible pressurized groundwater outflow mechanisms including artesian seepage, enhanced seepage through fissures and the eruption of a pressurized groundwater reservoir. These experiments focused on the morphological development of such systems. We also analyze the scalability of the laboratory analogues to real-word systems and we study the outflow-channel areas in Lunae Planum and Xanthe Terra north of Valles Marineris.

In the experiments, we found that low water injection pressures led to the formation of surface lakes, intermediate pressures led to the formation of subsurface fissures, and high pressure led to the buildup of a pressurized subsurface lake that erupted to the surface. Each of these systems resulted in catastrophic release of water greater than the groundwater discharge, from accumulation in a lake, enhanced seepage through fissures or both. In all experiments, an outflow channel formed, but we observed other morphologies as well that are unique to the mechanism of release. Fissure seepage created small holes and in the case of a subsurface lake eruption, large depressions and fractures were formed. In all cases, the sudden release of water resulted in the deposition of sedimentary lobes due to infiltration of water flowing over downstream areas that were still dry. This mechanism is absent in in the case of slow groundwater outflow.

Our study of the surface of Mars reveals a range of morphological features that were not associated with pressurized groundwater outflow before. These features include sedimentary lobes, holes, depressions and cracks. We can now link these morphologies to different mechanisms of outflow. Our results contribute to the hypothesis of the formation of outflow channels by pressurized groundwater on Mars. The experimental insight enables us to quantify the amount of water required for the formation of these channels.