A HYDRODYNAMIC CONTROL OF CHANNEL MORPHOLOGY IN UNSATURATED REGOLITHS ON EARTH AND MARS: Paul A. Washington and René A. De Hon, Department of Geosciences, Northeast Louisiana University, Monroe, LA 71209.

Summary

Channels cut by short-lived, episodic discharge in unconsolidated, unsaturated materials are characterized by steep-walled, flat-floored channel morphology. Martian outflow channel and terrestrial arroyo morphologies are attributed to the interaction of capillary forces and the Bernoulli effect for water flow across an unsaturated regolith.

Introduction

Martian channels are grouped into four morphologic classes--outflow channels, fretted channels, sinuous channels, and valley networks [1]. Outflow channels exhibit relatively short histories of flood surges, especially in their upper reaches. Many of these channels exhibit only minor erosional effects in the headward regions, or they tend toward a steep-walled, flat-floored morphology similar to that of arroyos of terrestrial arid terrains. On earth, arroyo channel morphology is attributed to the nature of the channel bed and the degree of consolidation, and on Mars, steep-sided channel morphology is often attributed to resistant, coherent material, usually basalt. As flash floods primarily shape terrestrial arroyos, so also are martian outflow channels cut by short duration flood surges. Recent work on the mechanics of interaction between flowing surface water and groundwater [2, 3, 4] suggests that erosion in unconsolidated material is controlled by the interaction between pore pressures within the stream bed and Bernoulli effects of the flowing water. The magnitude of capillary forces within unsaturated materials creates a unique erosional mechanism that controls channel morphology.

Mechanism of erosion

The initial flow across an unsaturated, porous surface begins by wetting the surface over which it is flowing. The matric potential (capillary force) of the undersaturated channel floor draws water from the surface water into bed materials. Until the subchannel material reaches saturation and approaches equilibrium with the adjoining fluid, capillary forces hold the unconsolidated grains in place. In short-lived flow events, this matric suction continues for the duration of the flow, producing low pore pressure in the bounding regolith. Once pore space is filled, Bernoulli effects along the floor of the channel create unbalanced forces that draw water from the subchannel material promoting erosion by ejecting grains from the sediment surface. In saturated materials with continuous channel flow, the pore pressure in the subjacent regolith is in equilibrium with channel flow, so erosion begins whenever flow increases.

The delay between the beginning of flash flood and the beginning of bed erosion in undersaturated, unconsolidated materials allows the flow to spread across the surface as a sheet. Low pore pressure during infiltration impedes localized scouring because capillary forces in the regolith exert increasing resistance to erosion with depth beneath the channel. This forces erosion to proceed downward along a nearly planar front, producing the characteristic flat-bed profile of arroyos and wadis. Only when prolonged flow allows pore pressures within the bed to reach equilibrium with the channel flow does a localized scour channel form within the flat channel floor.

During brief-flow episodes, common in ephemeral channel systems such as outflow channels on Mars and arroyos of arid climates on Earth, the banks remain undersaturated. The undersaturated nature of the bank, coupled with reduced Bernoulli effects, inhibits erosion of the channel walls. Thus, the flood surge is able to erode the channel floor more rapidly than the channel walls, producing a steep-bank channel morphology. Significant channel wall occurs only where the wall material is much less consolidated than the bed material, such as in a channel with regolith walls and a bedrock floor.

Significance

Steep-bank, flat-floored channel morphology common to terrestrial arroyos or wadis is characteristic of an erosional mechanism unique to unconsolidated, unsaturated regolith. Typical terrestrial arroyos in the southwest United States, which are created by large flash floods [5], exhibit width to depth ratios ranging from 4 to 10 [6]. Larger ratios are common where bed erosion is limited by highly resistant bedrock, and smaller ratios are characteristic of flow across saturated materials.

Broad, ill-defined channels, such as found at the head of Maja Valles, Kasei Vallis, or Mangala Valles, are formed by short-term, catastrophic flood surges on either resistant bedrock or unconsolidated, unsaturated regolith. Channeling within the head region begins after material becomes saturated. Similarly, arroyo-like channels, as found within the lower Mangala Valles basins [7] or the Maja Valles fan in Chryse Planitia [8], are indications of sufficient duration of discharge to fully saturate regolith materials and initiate down cutting. River-like channels are established only with prolonged flow.

References

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