LANDFORM EVOLUTION MODELING OF FINE-GRAINED ALLUVIAL FAN SEDIMENTATION ON MARS UTILIZING AN ATACAMA DESERT ANALOG.

A. M. Morgan[1,2], A. D. Howard[1], J. M. Moore[3], R. A. Craddock[2], [1]Department of Environmental Sciences, University of Virginia, 291 McCormick Rd, Charlottesville, VA 22903 (amm5sy@virginia.edu), [2]Center for Earth and Planetary Studies, Smithsonian Institution National Air and Space Museum, Washington, DC, [3]NASA Ames Research Center, Moffett Field, CA 94035

Introduction: Hesperian to Amazonian-aged [1] alluvial fans may be representative of the last eras of widespread fluvial modification to the martian surface, and understanding the climatic conditions present during their formation may provide insights into the planet's habitability as it transitioned from a potentially wet and warm early world to the cold and dry Mars we observe today. Martian alluvial fans are found within large impact craters [2,3] and are primarily composed of fine-grained (wind transportable) sediment (Figure 1) [4]. As a sedimentary depositional feature within an a crater basin, these fans are an inherently closed system between the ability to erode and transport sediments from the interior crater rim and the general lack of lake deposits present on the crater floor.

This work combines landform evolution modeling with data obtained from field work in the Atacama Desert and remote sensing observations of martian alluvial fans to address two related questions: (1) what were the characteristics of water discharge (e.g. flow magnitude and duration) during the era of fan formation? and (2) what are the associated implications for the responsible climatic environment (e.g. amount and frequency of precipitation)?.

Methods: *Boundary Conditions.* We use the alluvial fans of the hyperarid northern Atacama Desert to calibrate and fine-tune the model before applying it to Mars. The large size (often tens of km), gentle gradient (average ~2°), and dominantly fine-grained composition of martian fans contrasts with the small, steep, coarse-grained fans typical in arid regions on Earth (e.g. the Great Basin). However, alluvial fans along the eastern edge of the Pampa del Tamarugal in northern Chile meet all of these requirements (Figure 2). In addition, the Atacama Desert fans feature low branching densities, a low degree of lateral channel migration (e.g. scroll bars), and a high proportion of overbank-deposited sediment, all properties that have been identified on martian fan deposits [4]. Exposed stratigraphy contains cobble-sized alluvium interbedded with fine-grained mudflows. Recently-deposited mudflows are sheetflow-like deposits extending outward from the main channel for 100s of meters (Figure 2).

Model Architecture. Fan formation is simulated as an avulsing distributary channel network. Sediment-laden water flow is introduced through a single incoming channel and is routed through a network of leveed distributaries. Numerous channels can be active at a given time, and channels may branch and recombine. At branches, flow is distributed based on relative channel gradients, which are re-calculated each iteration. Distributaries become inactive if the discharge drops below a specified fraction of the total flow through the system, but channels can be reactivated if flow is reintroduced.

Sediment transport is modeled as a two end-member system: bedload, which is transported and deposited as a function of channel depth and gradient, and fine-grained sheetflow-like overbank flows, modeled after those observed in the Atacama Desert (Figure 2). Bedload transport may aggrade or erode the channel bed while overbank deposition constructs levees. The fan stratigraphy is recorded throughout a simulation run. Avulsions occur when sediment deposition superelevates the channel bed above the surrounding terrain. This typically results in extensive overbank deposition (Figure 3), followed by incision into a new or formerly occupied channel as the network stabilizes.

Results: The model successfully recreate the overbank deposits observed on fans in both the Atacama Desert and on Mars (Figure 3). We are currently in the process of applying the model to simulating martian fan formation. Preliminary results indicate that that the martian fans formed from many thousands of flow events, with snowmelt a likely candidate for water source. This is in general agreement with other work suggesting that large fans formed over time periods ranging from 10 Kyrs to Myrs [4,5].

We use a number of measures, including channel widths, cumulative volume of bedload versus overbank deposited sediment, and channel branching frequency to compare model results with deposits observed in martian fans, particularly those in the well-exposed Saheki crater fans. By adjusting model boundary conditions and comparing output to features observed on the martian fans, we can assess the range of climatic conditions present during fan formation. We are continuing to refine the model to test for the influence of initial sediment size distribution and duricrusts, as well as comparing climatic environments inferred from model results with the global distribution of alluvial fans on Mars [2].

References: [1] Grant J. A, Wilson S. A. (2011) *GRL*, 38, 8. [2] Wilson S. A. et al. (2013) *LPSC 44*, Abstract #2710. [3] Moore J. M., Howard A. D. (2005) *JGR*, 110, E4. [4] Morgan A. M., et al. (2014) *Icarus*, 229, 131–156. [5] Armitage J. J. et al. (2011) *GRL*, 38, 17.

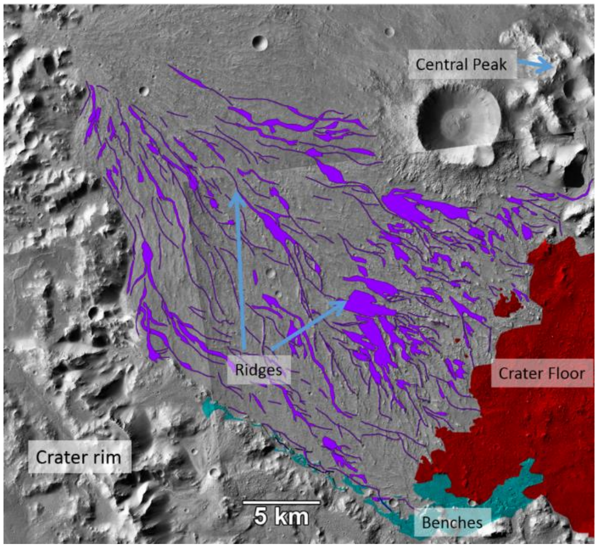

Figure 1. Map of surficial features on an alluvial fan in Saheki crater, Mars. CTX image centered on 21.89°S, 72.80°E, north is up. Fans are sourced entirely from alcoves carved into the crater rim. Similar to other martian fans, the surface is covered by downward trending ridges, inferred to be inverted channels. Splay deposits, layering on the sides of ridges, and fine layering exposed from subsequent impact cratering reveals that the bulk of than fan consists of fine-grained, sheetflow-like overbank deposits.

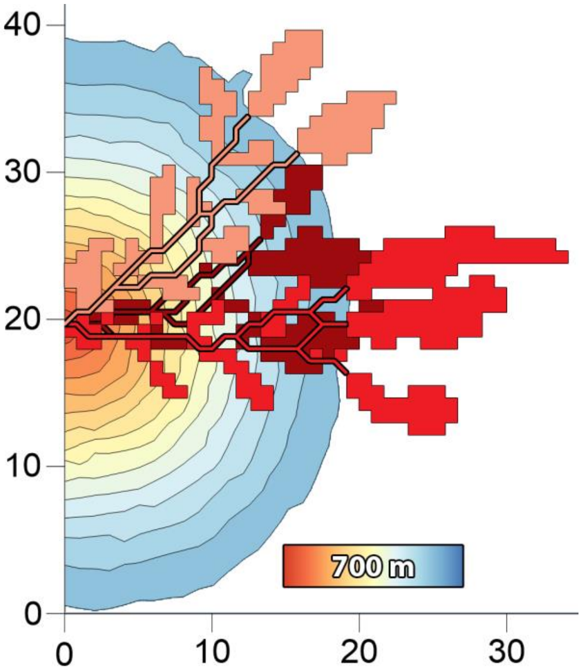

Figure 3. Example of model output. This simulated alluvial fan has a slope of 2.2° and was deposited into an empty domain. Horizontal scales in km. Colors indicate channel network (outlined in black) and flood deposits at three iterations near the end of a simulation run, with dark red being the oldest and pink the youngest. Note similarities with both Saheki and Atacama deposits. While overbank flows deposit sediment further downstream than the channel network, their apparent deposition beyond the fan toe is due to their thinness relative to the 50m contour spacing.

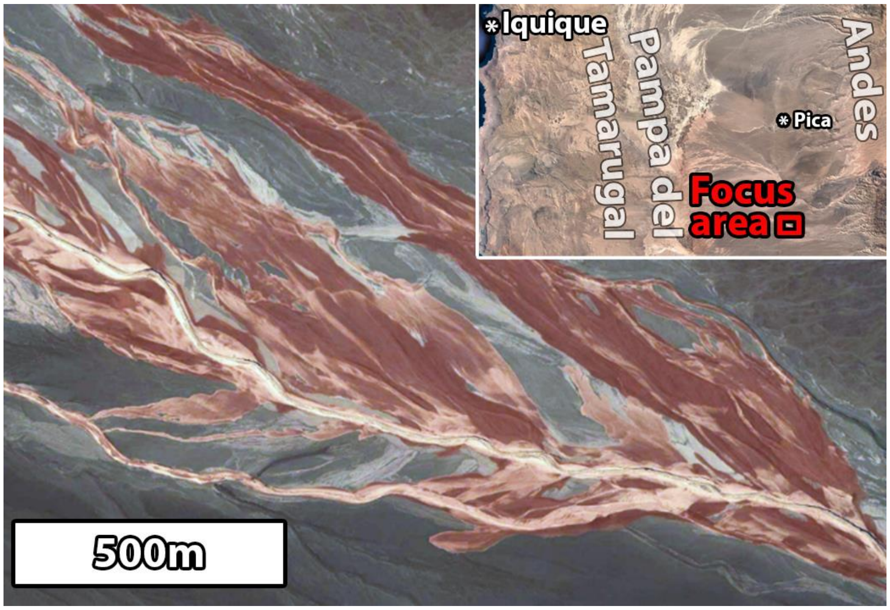

Figure 2. Atacama fan flood deposits. Red-toned material deposited by an early 2012 flood sourced from the Andes foothills to the east. Broad sheet deposits source from overflow of main distributary channels. Earliest deposits are darkest red, with later overflows and channelized flow being lighter pink. Main distributary averages about 12m wide. Flooding and sediment deposition continued for 25 km downstream, spanning the length of the alluvial fan. IKONOS-2 0.8 m/pixel image, taken 12/27/2012.