ASSESSING CONTROLS ON THE TERMINATION OF OVERFLOW FLOODS FOR PALEOLAKES ON MARS. T. A. Goudge[1], C. I. Fassett[2], and M. Coholich[1,3], [1]Jackson School of Geosciences, The University of Texas at Austin, Austin, TX, [2]NASA Marshall Space Flight Center, Huntsville, AL, [3]Department of Geological Sciences, Stanford University, Stanford, CA. (Contact: tgoudge@jsg.utexas.edu)

Introduction: Mars' paleolake record includes more than two hundred open basins drained by an outlet canyon [*1,2*]. Rapid incision of these outlet canyons occurred as the lakes catastrophically overflowed their confining topography [*2,3*]. Outlet canyon size scales with the volume of water drained from the basin, indicating more erosion for larger paleolakes [*3*].

While this is the case, all of the identified open-basin lakes remain as topographic lows on the martian landscape [*2*]. This means these paleolakes did not completely drain of water, and the process of catastrophic overflow flooding and outlet canyon incision must have self-arrested. An important point to note is that this does not mean there were no martian paleolakes that completely drained. Rather, this is an observational bias; fully drained paleolakes have not previously been searched for, as they cannot be identified using criteria of a perched valley draining an otherwise closed contour [*2*].

For the identified, partially drained paleolakes, how completely a given basin drained can be quantified using the drained fraction, i.e., the ratio of the drained volume to the initial lake volume. For the 24 basins studied by [*3*], the drained fraction ranges from ~0.13–0.98, with a median value of 0.62. The major boundary conditions that control this drained fraction, and thus after how long (in a relative sense) the catastrophic overflow flooding and outlet incision process self-arrested, remain unconstrained. Here we present results to address this unknown through numerical modeling and observational analysis.

Methods: We aim to test the influence of four primary boundary conditions on the drained fraction of martian open-basin lakes: (1) basin size; (2) the regional slope; (3) the height of the crater rim that acts as the initial dam behind which water ponds; and (4) the erodibility of the substrate. Here we take a two-pronged approach, comparing numerical modeling experimental results with observations from Mars paleolake basins.

Mars Paleolake Observations: We measure the drained fraction, exterior slope, rim height, and basin size for the catalog of 24 open-basin lakes studied by [*3*]. These measurements make use of stereo-derived DEMs from HRSC [*4,5*] and CTX [*6*] images, the latter produced using the NASA Ames Stereo Pipeline [*7,8*], as well as the global gridded MOLA topography [*9*].

Numerical Model: Our morphodynamic model of the catastrophic lake overflow flooding process, developed initially by [*10*], is built upon the ANUGA open-source finite volume solver for the shallow water equations [*11,12*]. Coupled to this hydrodynamic model we include three morphodynamic operators that deal with: (1) bedload sediment transport [*13*]; (2) advection of sediment in the water column, i.e., suspended sediment transport [*14,15*]; and (3) relaxation of steep slopes that exceed the angle of repose (35°). Our numerical experiments are run using Mars gravity, and the sediment transport operators employ a dynamic bed friction recalculation using the Darcy-Weisbach friction factor, as adapted to Mars [*16*].

Our model domain includes a circular 'impact crater' basin with a topographically high rim and a sloping corridor on which the outlet is dynamically incised. For our experiments we vary the size (radius) of the lake, the height of the crater rim, the slope of the background terrain, and the grain size of the sediment (used as a proxy for substrate erodibility). The geometric/topographic values for our parameter sweep were selected to encompass the range of observed values for the studied open-basin lakes on Mars.

Results: Our morphodynamic model is able to reproduce both the general morphology of lake outlet canyons and the geometric scaling observed for Mars open-basin lakes (**Fig. 1**) [*3*]. This suggests that, broadly, our implementation of the model physics sufficiently captures the lake overflow flooding process to enable robust comparative analysis. However, we stress that our model is vastly over-simplified in terms of domain setup, and we are in no way attempting to exactly reproduce the conditions of erosion for any one lake overflow event on Mars. Rather, we are using the numerical modeling experiments as a guide to assess controlling parameters on observed erosion and drained fraction, and where the Mars data differ from predicted trends (**Fig. 2**).

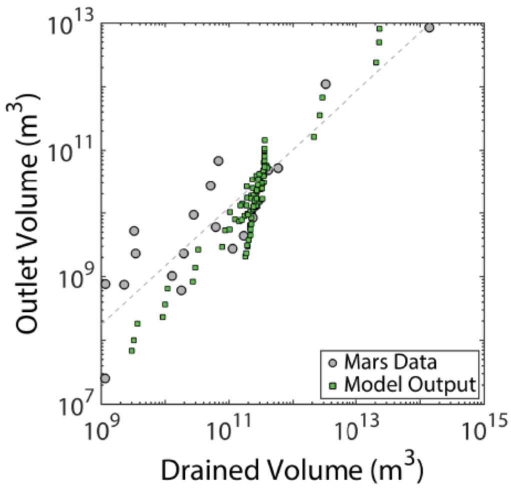

Fig. 1. *Eroded outlet volume vs. drained lake volume for the numerical modeling experiments (green squares) and Mars observational results (grey circles [3]). Best-fit power law to Mars observational results shown in dashed grey line. Note the broadly similar geometric scaling.*

In our model rim height, slope, and basin size are all strong controls on drained fraction, where higher rims, steeper slopes, and larger basins result in more completely drained lakes (**Fig. 2a–c**). Grain size, as a proxy for substrate erodibility, also appears important, with more erodible substrates (i.e., smaller grain sizes) yielding larger drained fractions. For the Mars data rim height and, to a lesser extent, slope appear to follow qualitatively similar trends to the numerical modeling results (**Fig. 2d,e**). In contrast, lake size has no clear correlation with drained fraction for the Mars data, a marked distinction from the numerical modeling results (**Fig. 2c,f**).

Discussion and Implications: The broad agreement between numerical modeling results and Mars observational data for rim height and exterior slope suggest that both of these boundary conditions acted as important controls on the degree of draining for martian open-basin lakes. These results are largely intuitive – a larger rim (dam) and/or a steeper slope are both likely to promote outlet canyon erosion, thus allowing the overflow flood to more completely progress.

In contrast, the disagreement between model and observational results for lake size are perhaps more interesting. In general, the more complete draining of larger paleolakes makes sense – weir discharge, such as at a lake outlet, scales with stage height [*17*], meaning larger lake areas require more discharge to drop the lake level a given amount. However, we note that our model incorrectly assumes a homogenous martian crust. Instead, it has been suggested that the martian crust becomes more competent (less erodible) with depth due to overburden pressure and the lessening effects of impact-induced fracturing [e.g., *18*]. Therefore, we hypothesize that large martian paleolake basins may have been forced to erode increasingly more competent crust with depth, potentially offsetting the (independent) size-control on drained fraction. This hypothesis implies that open-basin lake drained fraction may be used as a novel proxy for spatial variations in crustal erodibility on Mars.

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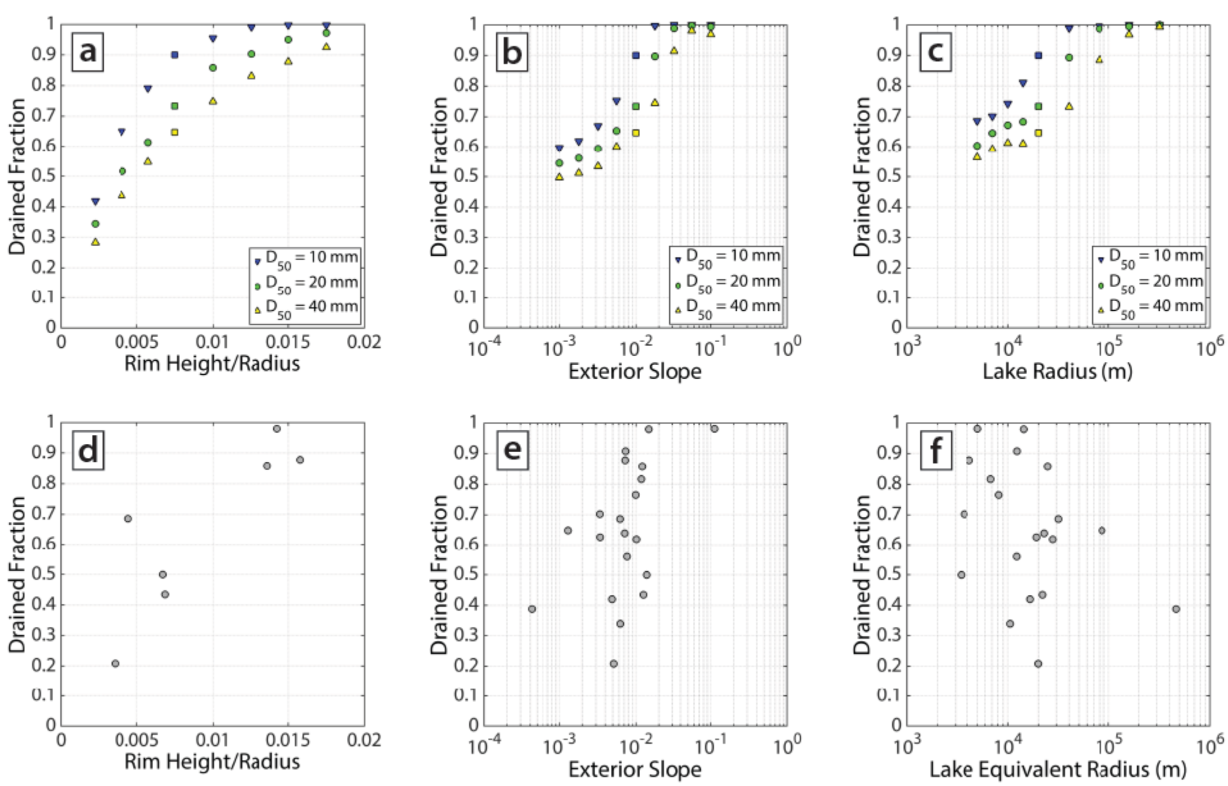

Fig. 2. *Drained fraction vs. rim height (normalized to basin size)* ***(a,d)****, exterior slope* ***(b,e)****, and lake size* ***(c,f)*** *for numerical modeling experiments* ***(a–c)*** *and Mars observational data* ***(d–f)****.*