NUMERICAL SIMULATIONS OF LAKE BONNEVILLE SHORELINE EROSION AT MARS-LIKE RATES AND DURATIONS.

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Introduction: Preserved Ocean shorelines along the highland-lowland divide of Mars are contentious. On Earth, ancient shorelines are recognized by relatively subtle topographic breaks in slope along equipotential lines as well as coastal sedimentary deposits, such as are preserved from the Pleistocene Lake Bonneville in modern-day Utah, USA [1, 2]. The proposed shorelines on the Martian surface were, however, originally based on textural differences in remote sensing images [3, 4]. Closer scrutiny with higher resolution images, topographic data, and planet-scale structural modeling has both supported and challenged the shoreline hypothesis, leaving little consensus [5, 6, 7].

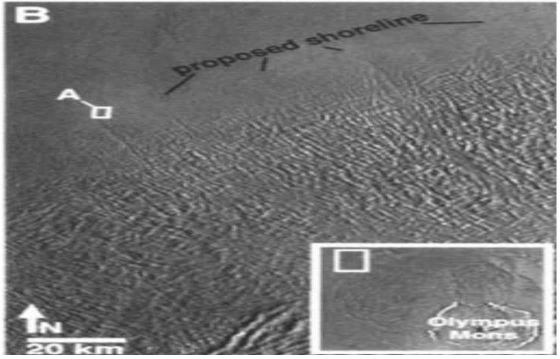

Figure 1. A proposed Martian shoreline defined at a textural difference between areas [5].

Erosional processes that have acted on shorelines have likely played a role in modifying or removing the topographic signatures of shorelines [8, 9]. Though erosion on Mars is currently driven by wind and is much slower than on Earth, erosion has played a major role in reshaping parts of the surface since the Noachian/Hesperian transition when the hydrologic cycle was most active [10, 11, 12]. Here, we performed numerical experiments to test the resilience of Earth-analog paleoshoreline topography to Mars-like erosion rates and durations. The analog chosen was Lake Bonneville, which has three well preserved shorelines from throughout its course of existence several thousand years ago. These shorelines can be noted by subtle breaks in slope in the topography.

Methods: 1 meter resolution LiDAR Digital Elevation Models (DEMs) of Lake Bonneville were obtained from the Utah Geospatial Resource Center (UGRC). The Python module, Landlab [13], was used to create a linear topographic diffusion model to run on the topographic data. This model promotes erosion at high-curvature locations, and deposition and low-curvature locations. Several experiments were run using the model, varying diffusivity between 10^{-5} and 10^{-9} m^2/yr [14, 15] and varying the scale of the landscape from 1x to 10x (with cell size and elevation multiplied by 10, preserving slopes). The topography was diffused over 350 timesteps of 10 myr each, equating to 3.50 billion years of simulated erosion.

Here, we present results on two experiments. Both used a diffusivity of 10^{-7} m^2/yr. Experiment 1 used a 1x landscape, and experiment 2 used a 10x landscape. To observe changes in the topography at the end of each experiment, we used before-and-after topographic maps (Fig. 2) and shoreline-perpendicular topographic transects (Fig. 3) Transects intersecting the three shorelines are shown in Fig. 2. Each shoreline is associated with a relatively subtle slope break. A drainage channel, which we are not specifically investigating in this research, can also be seen in the topographic maps and profiles.

Results: In experiment 1, the landscape's area was 2,700 km^2, and in experiment 2 the landscape's area was 27,000 km^2. Total volumetric change was 68.0 km^3 for experiment 1 and 899 km^3 for experiment 2. The average elevation change per cell was 0.02 m for experiment 1 and 0.03 m for experiment 2. The minimum and maximum elevation changes for experiment 1 were -26.195 m (erosion) and 23.07 m (deposition). The minimum and maximum elevation changes for experiment 2 were -107.49 m (erosion) and 130.58 m (deposition). The first experiment had a 49.2 m range of topographic change and experiment 2 had a 238 m range of topographic change. The standard deviation of topographic change for experiment 1 was 4.30 m and for the second experiment, 3.14 m.

Experiment 1 showed significant change to shoreline topography. The breaks in slope associated with the different shorelines were almost completely erased and smoothed out (Fig. 3). Experiment 2 showed the opposite. The breaks in slope for the three shorelines persisted and were preserved after the simulated 3.5 billion years (Fig. 3).

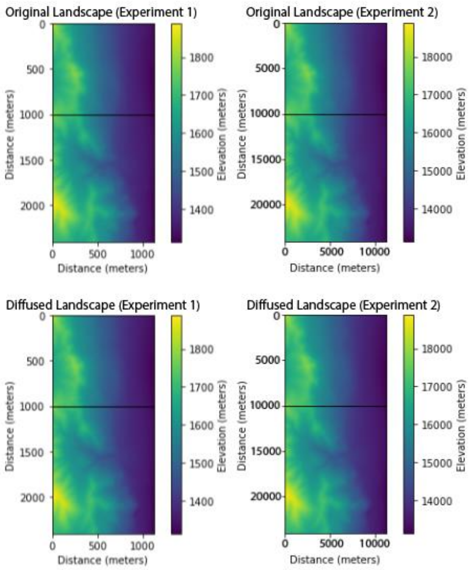

Figure 2 – Initial (top) and final (bottom) landscapes for experiment 1 (left) and experiment 2 (right). Black lines show transect locations (Fig. 2).

Discussion: The difference in shoreline preservation between the two experiments (Fig. 3) demonstrates the sensitivity of the results to our range of landscapes scales at this diffusivity, which is between some common values used for Mars [14, 15]. Though the landscape in experiment 2 was an order of magnitude larger, the average topographic change per cell increased by less than an order of magnitude, suggesting there was less overall modification of the larger landscape.

The results suggest the potential for shoreline preservation if Mars ocean shorelines are at least 10 times larger than the Lake Bonneville shorelines. However, it is still unclear how time-varying erosion rates and non-diffusive erosional processes might affect the results. It has also been suggested that most erosional processes on Mars may in fact be non-diffusive [16], suggesting that our results may favor shoreline preservation when compared to reality because diffusion alone does not represent all erosional processes active on Mars.

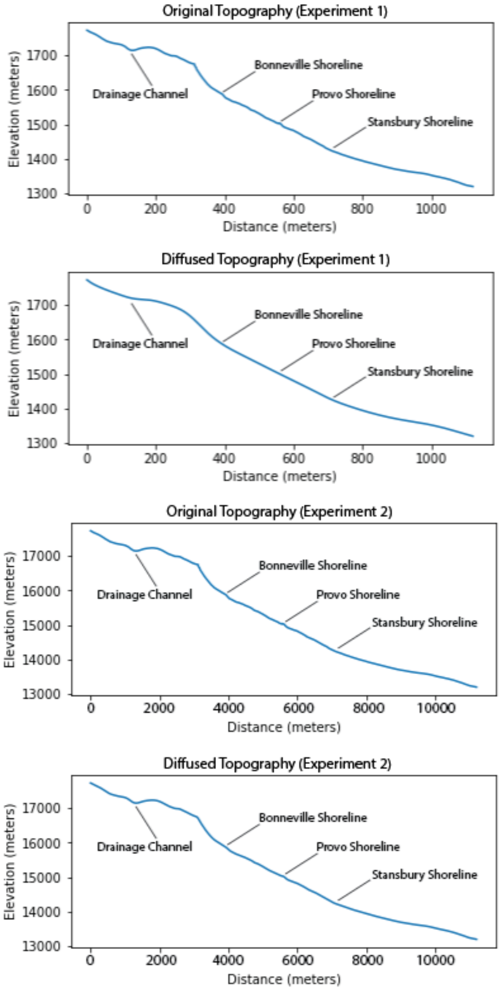

Figure 3 – Topographic transects for landscapes shown in Fig. 3.

We are currently performing more experiments expanding the range of diffusivities and landscape scales presented here. However, given our likely conservative treatment of erosional processes on Mars, we suggest stratigraphic evidence for or against an ancient ocean may be more reliable than geomorphic.

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