PLUVIAL SHORE LANDFORMS IN THE GREAT BASIN, USA: ANALOGS TO MARTIAN PALEOLAKE BASINS.

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Introduction: The Martian highlands are a multi-basin landscape that was favorable for ponding during wetter intervals of the Noachian and Hesperian Periods [1]. The most compelling evidence for highland paleolakes includes overflowed basins, which have both a contributing valley network and an outlet valley [2], and putative steep-fronted deltas located at the mouths of contributing valleys [3,4]. These highland features are rarely associated with compelling shore landforms. Mapped shorelines in the northern lowlands have been controversial, and alternative interpretations of putative shore landforms have been promoted in the literature [5–6].

Evidence for paleolakes has motivated theoretical investigations of wave action on Mars. Kraal et al. [7] adapted the Trenhaile [8] model for wave erosion of shore platforms to Mars, finding that dissipation of wave energy limited shore platform width to tens to hundreds of meters. Platform width depended on wind speed, bedrock erodibility, platform roughness, and slope. Lower atmospheric pressure or persistent ice covers could have reduced or inhibited wave erosion on Mars [7].

Order-of-magnitude uncertainties in model parameters for wave erosion make a terrestrial analog investigation valuable. This study uses Late Pleistocene shore landforms in the Great Basin region of Oregon and Nevada as analogs for similarly sized basins on Mars. These terrestrial paleolakes had volcanic bedrock [9], variable water levels [10–12], and a paleoclimate that was broadly similar to peak environmental conditions in the Martian highlands [1]. We compare these shore landforms to the scale of features that have survived from multiple epochs in early Martian history, in order to constrain expectations of what landforms should be preserved from early pluvial conditions.

Study Areas: Five enclosed basins in Nevada and Oregon were selected based on the occurrence of well-developed erosional shore platforms (Figure 1) and depositonal beach ridges. These basins are Christmas Valley and the Summer Lake basin (pluvial lakes Fort Rock and Chewaucan, respectively) in Oregon; and Surprise Valley, Long Valley, and Spring Valley in Nevada (pluvial lakes Surprise, Hubbs, and Spring, respectively). Prior studies have used the shorelines and stratigraphy with well-constrained ages to interpret the pluvial climate of the region [e.g., 10–14].

Methods: We measured landform dimensions along 54 field profiles using a Trimble R8 differential Global Positioning System (DGPS) instrument, which is precise to centimeters in both horizontal and vertical dimensions, relative to benchmark and intersection elevations from the U.S. Geological Survey. We determined paleolake high stands and areas using Digital Orthophoto Quad imaging [15,16] and National Elevation Dataset topography [17]. Watershed areas came from the Nevada State Engineer Basin Boundaries dataset [18] and the Pacific Northwest Hydrography Framework's Watershed Boundary Dataset [19].

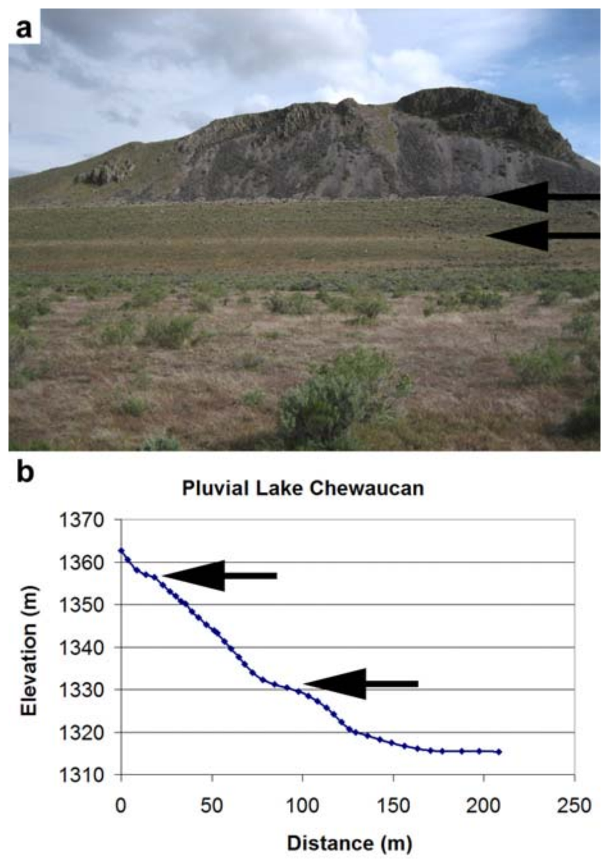

Figure 1. Erosional shore platforms in the Summer Lake basin, Oregon. (a) Tucker Hill site. (b) Survey profile, which runs approximately through the center of the photograph in (a). Shore platforms (arrows) may be prominent in imaging but are topographically subtle.

Results: Our paleolake high stands were similar to those in prior literature for the Spring, Christmas, and Summer valleys [10–12], but 22 and 10 m lower than were previously reported in the Surprise and Long Valleys, respectively [10]. Ratios of drainage basin area (including the paleolake) to lake area ranged from 2.7 to 5.4 in the study areas.

Shore platforms ranged from 2 to 25 m wide (e.g., Figure 1). Beach ridges commonly had low relief of <1–2 m, widths of <100 m, and lengths up to kilometers. Shore landforms were discontinuous around the basins, and still stands that were prominently expressed at some locations were not evident at others. Variable fetch and bedrock properties may be responsible for these inconsistencies.

Implications for Martian Paleolakes: Impact crater populations show that few craters of 4–8 km in diameter are preserved from the Noachian Period on Mars [20]. Since the mid-Hesperian, crater saturation at diameters <~200 m has led to impact gardening of 10–20 m [20,21], as confirmed by Spirit rover observations of Early Hesperian basalts in Gusev crater [22]. For these reasons, there is little potential to preserve shore landforms from Noachian paleolakes. Shore platforms related to possible lacustrine activity in the mid-Hesperian would also be missing or strongly degraded, unless they were unusually large.

Depositional beach ridges are commonly smaller and more susceptible to degradation. These landforms should not be preserved from either the Noachian Period or the Early Hesperian Epoch. If lakes covered only ~20–40% of the area within enclosed basins, as in our pluvial Great Basin analogs, then most Noachian craters would not have flooded deeply enough for wave action to modify the steep crater walls. Restriction of wave action to the floors of most craters would more likely have led to beach ridge development, as beach ridges are restricted to lower slopes of 1–2° in our study. Kraal et al. [7] showed that dissipation of wave energy should inhibit the development of wave-eroded shore platforms on such shallow slopes.

Investigations of Martian paleolakes dating to the Late Noachian or Early Hesperian Epochs should not use a lack of shore landforms as a means to falsify the paleolake hypothesis, as these landforms should not be preserved in most cases. If shore landforms are locally preserved, then their commonly discontinuous occurrence and susceptibility to post-pluvial erosion complicate interpretation of pluvial shorelines based on plan-view imaging alone. Erosional platforms or depositional ridges may represent multiple water levels, so a lack of topographic consistency does not rule out a possible relationship to paleolakes.

Given the scale of the Great Basin shore landforms, they should not be detectable in orbital imaging of >10 m/pixel resolution. Targeted searches for younger shore landforms on Mars should utilize high-resolution imaging and stereo digital elevation models from the High Resolution Imaging Science Experiment or possibly the Mars Orbiter Camera.

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