HIGH-RESOLUTION EXAMINATION OF THE GEOMORPHOLOGY OF PROPOSED OCEAN SHORELINES ON MARS. S. F. Sholes[1], D. C. Catling[1], R. Pretlow[1], and D. R. Montgomery[1]. [1]Dept. of Earth and Space Sciences, Box 351310, University of Washington, Seattle, WA 98195. email: sfsholes@uw.edu

Introduction: Mars is characterized by a striking topographic dichotomy between the southern highlands and the northern lowlands. Many outflow channels flow into the closed depression of the northern plains, which has led to hypotheses concerning episodic seas and possibly a large ocean during the Hesperian era of Mars, approximately 3.7-3.0 Ga [1-3]. There are also proposals of earlier oceans in the Noachian (4.1-3.7 Ga) northern plains fed by smaller fluvial features, dendritic river networks [4].

With imagery from the Viking orbiters, Parker [5,6] hand-traced two contacts called Deuteronilus and Arabia that were proposed to be paleoshorelines corresponding to smaller and larger oceans, respectively. These boundaries however, are not surfaces of equal gravitational potential as would be expected from a standing body of water, posing a problem to the viability of such shoreline features. Topographic warping of the contacts might be responsible for long wavelength changes on smoothed fits to elevation [7] but residuals in the unsmoothed data remain very large.

Previous work analyzing the nature of these contacts and putative ‘shoreline’ features have only used Viking, THEMIS (Thermal Emission Imaging System), and MOC (Mars Orbiter Camera) images with a maximum resolution of ~2-200 m/px. We utilize high-resolution data from HiRISE (High Resolution Imaging Science Experiment) at 0.25 m/px to reinterpret the features in an unprecedented way.

Methods: In the past literature, 34 images have been published that are identified as plausible shoreline contacts. Of these, 14 have HiRISE coverage, which allowed us to reclassify geormorphological features using the HiRISE data. We searched for characteristic features indicative of different genetic origin. Assessment of feature origin was divided amongst five broad categories: volcanic, glacial, impact, mass wasting, coastal, and “other” based on signature landforms and unique characterisitics. For example: pressure ridges and lobate flows for volcanic, hummocky terrain and moraines for glacial/periglacial, ejecta blankets and craters for impact, wave-cut terraces and sea cliffs for coastal contacts, and large mounds of colluvium for mass wasting events. These are all not mutually exclusive, but provide a basis for alternative formation processes. Slope angle can also be used to distinguish coastal features, which are expected to slope towards the body of water.

In addition to the high-resolution imagery, digital elevation models (DEMs) were created to examine the putative shoreline areas. MOLA (Mars Orbiter Laser Altimeter) data can be used to analyze terrain and elevations but while MOLA provides global coverage, its average lateral resolution of ~400 m/px is too coarse to detect small-scale and narrow features such as small wave-cut terraces and slopes of small areas.

Instead, we utilize the NASA Ames Stereo Pipeline (ASP), which can create a DEM with a resolution of ~1 m/px from HiRISE images from a stereo pair of images [8]. We used these DEMs in ArcGIS for topographic terrain analysis. Additionally, CTX (Context Camera) and Mars Express’s HRSC (High Resolution Stereo Camera) stereo pairs were used when HiRISE is unavailable which have resolution approximately four times the input images. Where no DEMs or stereo image pairs are available the individual MOLA tracks are

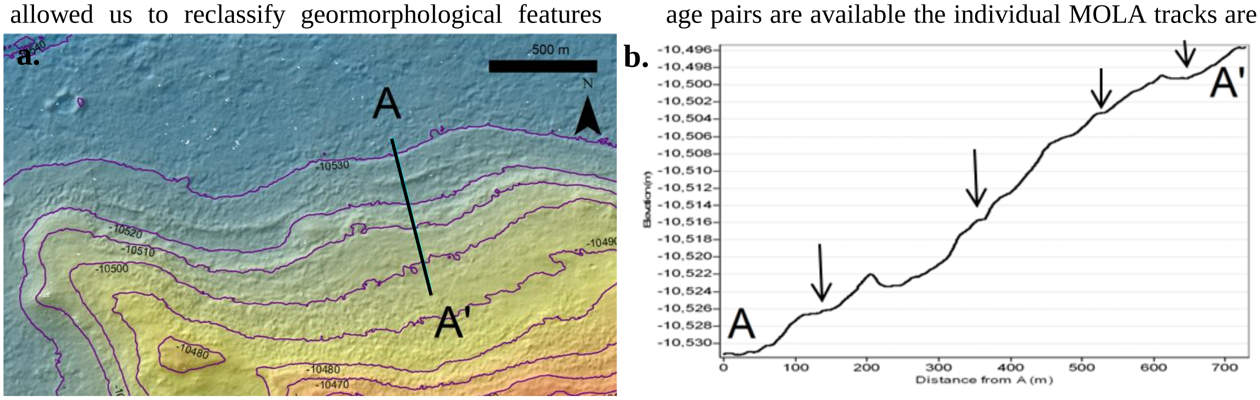

Figure 1: *a)* A DEM from stereo HiRISE images (PSP_001414_2165, PSP_001968_2165; 36.10°N, 351.15°E) with contours every 10 m; a topographic profile from A to A’ is shown. Possible ‘strandlines,’ indicated with arrows, tend to follow the contours, indicating an equipotential surface. *b)* A topographic profile from the DEM; black arrows show possible wave-cut terraces.

used as has been done in the past. These raw data points are spaced ~300m apart north/south and provide little data for such narrow features on the order of 10-50m terraces.

Results: Of the putative shoreline features that were reanalyzed, many had characteristic landforms that did not resemble coastal morphologies. A majority were more indicative of volcanic processes, such as lobate lava flows and pressure ridges which echoes the concerns of Carr and Head (2003) [9]. Others showed signs of possibly being influenced by glacial or peri-glacial processes, mass-wasting events such as slumping, or impact events. At the contacts, it is found that many features that seemed to represent distinct boundaries at very coarse-resolution scales, are actually diffuse albedo differences across different geological units. This phenomena has been noted previously on the Deuteronilus contact using MOC images [10].

Of these 14 images that were reinvestigated, only one was labeled as being a possible coastal contact. This feature, originally described in Clifford and Parker (2001, Fig. 4) [1] as part of the Arabia shoreline is a small section of the southern rim of a large impact crater system just east of the Cydonia Mensae region, which is open to the northern plains on the northeast wall. The DEM of this area is shown in Fig. 1a. The elevation model shows that the features are consistent with possible strandline features follow local equipotential surfaces, and a cross section shows possible terrace structures. Furthermore, context imagery allows us to trace these strandline features for ~60 km into the adjacent crater.

In order to determine whether these resemble terrestrial strandlines, Earth analogs at Lake Bonneville, UT and Lake Missoula, MT were examined in a similar manner using the USGS elevation dataset. Fig. 2a shows a transect across Antelope Island, Utah. Fig. 2b shows lidar-based topography of the paleostrandlines from Lake Bonneville. These known strandlines and their terraces resemble, both in scale and shape, the putative strandlines that are found on Mars in Fig. 1. In order to distinguish between paleoshorelines and differential weathering, further work is being done to compare with other Earth analogs.

Discussion: While results show that many of the claimed shoreline features are more characteristic of other morphological origins, the lack of shoreline features does not discount the possibility of a martian ocean existing in the past. Future work will rigorously analyze Earth-analog features (e.g. Lake Bonneville, Lake Missoula, Antarctica Dry Valley strandlines, etc.) to test the validity of these features being wave cut terraces versus exposed strata layers or of other origin.

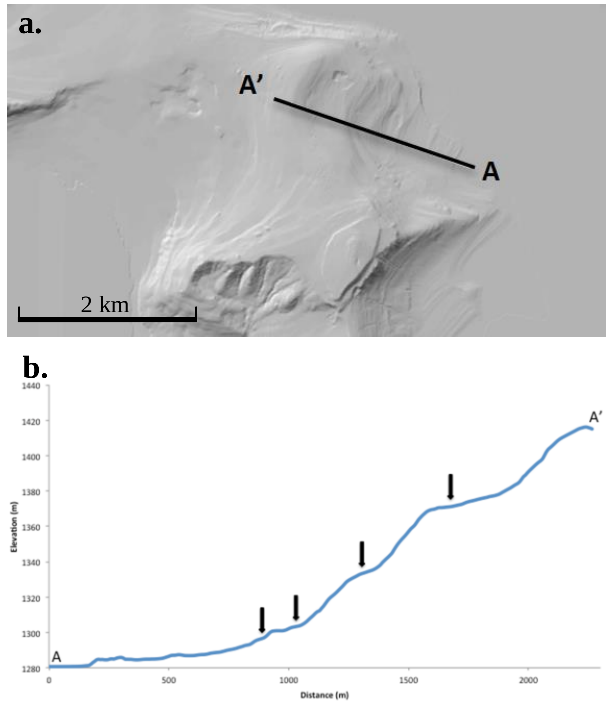

Figure 2: *a)* USGS lidar DEM of Antelope Island, Lake Bonneville, UT showing various strandline levels. *b)* Cross section from A to A' in *a* showing the terraces located at different strandlines.

The proposed shoreline features do not seem to compose a unified continuum around the northern plains, but are scattered and disjointed. Additionally, little evidence for coastal morphologies other than strandlines and marine terrace-like features were observed. Given the great age of such features, the potential for erosional (aeolian) reworking must also be considered.

Currently, we are further analyzing THEMIS and CRISM (Compact Reconnaissance Imaging Spectrometer for Mars) data to look at the thermal inertia which may provide a greater understanding to the degree of sediment sorting along these boundaries, as beaches should show an appropriate gradation.

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