OCEANS ON MARS: A SEARCH FOR COASTAL CONSTRUCTIONAL LANDFORMS USING THEMIS, MOC AND MOLA DATA. G. J. Ghatan, J. R. Zimbelman and R. P. Irwin, Center for Earth and Planetary Studies, National Air & Space Museum, Smithsonian Institution, Washington, D.C. 20013-7012, ghatang@si.edu.

Introduction: The case for an ocean having once occupied the northern lowlands of Mars has largely been based indirectly on the debouching of the outflow channels into the lowlands, and directly on erosional features along the margins of the lowlands interpreted to be the result of wave action. Two global shorelines, originally mapped by Parker et al. [1, 2] and more recently revised based on MGS data by Clifford and Parker [3], delineate hypothesized still-stands of a past Martian ocean or oceans. The southern, higher-standing shoreline is the Arabia shoreline, and the northern, lower-standing one is the Deuteronilus shoreline. With the exception of a handful of curvilinear ridges in Cydonia Mensae (between Arabia Terra and Acidalia Planitia) and northwestern Isidis Planitia, absent from the ocean discussion is the presence, or lack thereof, of features near the mapped "shorelines" that could reasonably be interpreted as coastal constructional landforms similar to barriers and spits formed in association with coastal erosional features on Earth [4].

As part of an ongoing study, we report here the results of a detailed survey of all available THEMIS visible (VIS) and MOC narrow angle (NA) images that cross or are located near either of the two "shorelines," within the Chryse Planitia/Arabia Terra region and the Isidis Planitia region, in search of any features resembling coastal constructional landforms. We also reexamine those ridges previously interpreted as barriers or spits [2].

Several authors have noted that the absence of vegetation on Mars [e.g. 5, 6] may hinder identification of shoreline features in satellite photos. Therefore, in addition to our photo survey, we use raw MOLA profiles across the mapped "shorelines" to identify potential coastal landforms. Differential Global Positing System (DGPS) profiles, gathered during ongoing field studies from glacial paleolakes in Nevada [7], reveal distinctive attributes that are laterally continuous across multiple, parallel profiles. We use these terrestrial profiles as a basis by which to examine MOLA profiles for evidence of coastal ridges on Mars.

THEMIS and MOC Analysis: A wide variety of constructional landforms occur along the coasts of standing bodies of water on Earth, and vary in scale, shape, orientation and composition due to multiple local factors such as sediment availability, wave behavior and fetch, storm activity, and offshore slope [4]. This study focuses on identifying spits and barriers, which can occur as individual ridges, such as off the U.S. east coast, or as clusters of stacked ridges, as observed in Long Valley, Nevada (Fig. 1).

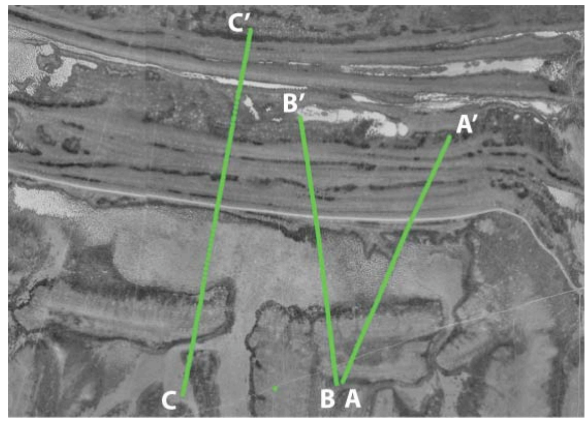

Figure 1: Portion of Landsat TM image of the south end of Long Valley, Nevada. Scene is 2.3 km across. Shorelines are seen as grey arcs. Survey lines indicate location of transects in Fig. 2.

We examined 224 THEMIS VIS and 502 MOC NA images of the Chryse/Arabia region and 223 THEMIS VIS and 223 MOC NA images of the Isidis region. With the exception of two ridges in Chryse/Arabia, and one in Isidis, previously identified by [2], we find no ridges that bear sufficient morphological resemblance to terrestrial coastal ridges to warrant further consideration as Martian coastal landforms. Based on our THEMIS & MOC observations, the remainder of the Parker et al. [2] ridges, as well as other ridges located near the "shorelines," are more readily interpreted as remnants of crater rims, scarps, aligned pitted domes, raised margins of debris/lava flows, wrinkle ridges or aeolian constructs.

The three ridges we do not dismiss are morphologically similar to terrestrial coastal ridges and may therefore be their Martian equivalent, but their meager number raises some doubt about this scenario.

MOLA Analysis: Three, ~ 1 km long, roughly parallel DGPS profiles were obtained across a series of stacked barrier ridges in Long Valley, Nevada (see Fig. 1 for locations) [7]. With ~ 20 m along track spacing between data points, these profiles exhibit distinctive bumps, broader swells, and tie points that correspond to distinct ridges that are identified across multiple profiles (Fig. 2).

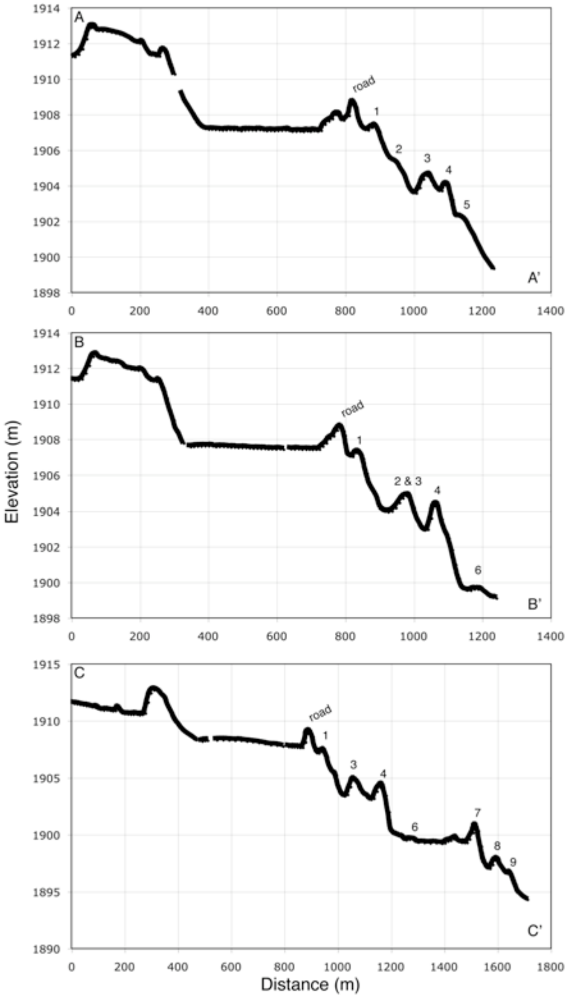

Figure 2: DGPS transects across barrier ridges in Long Valley, Nevada (see Fig. 1). Ridges show up as bumps in the profiles. Tie points linking the same ridge between multiple profiles are numbered.

These observations and techniques provide a basis by which raw MOLA profiles crossing the mapped "shorelines" can be used to search for possible coastal constructional landforms. Clearly the ~300 m along track spacing of MOLA is of insufficient resolution to distinguish landforms similar to the smaller-scale features observed in the terrestrial profiles, but may be sufficient to distinguish the broader swells.

We collected raw MOLA profiles at regularly spaced intervals along both "shorelines" in the Chryse/Arabia and Isidis regions. For each profile we examined a stretch extending 7.5 km upslope and 10 km down slope. For any profile that displayed features-of-interest (i.e. features resembling the ridges and valleys observed in the terrestrial profiles) we collected adjacent profiles and examined the lateral continuity of these features to distinguish isolated knobs from ridges.

Our survey returned no convincing examples of laterally continuous ridges observed in MOLA data along the entire lengths of both the Arabia and Deuteronilus "shorelines" within the Chryse/Arabia and Isidis regions.

Summary and Conclusions: Our detailed THEMIS VIS and MOC NA survey of the Arabia and Deuteronilus "shorelines" in the Chryse Planitia/Arabia Terra and Isidis Planitia regions reveals a paucity of candidate coastal constructional landforms (3 possible ridges). Our MOLA survey reveals no laterally continuous features similar to those observed in DGPS profiles across paleo-shorelines on Earth.

These results can be interpreted in several ways, placing important constraints on the ocean hypothesis:

1) No ocean existed within the northern lowlands up to the level of the mapped shorelines.

2) An ocean existed, however wave action, the primary agent responsible for construction of coastal landforms, was minimal to non-existent. Recent work by Kraal et al. [8] suggests that energy associated with waves generated in a Martian ocean would have been largely of insufficient energy to generate recognizable coastal landforms from orbital data sets.

3) An ocean existed, but sediment input was not significant enough to form coastal deposits. If sediment input to an ocean was minimal, either from offshore delivered via rivers, or supplied via coastal erosion, there may have been insufficient material necessary to construct coastal landforms.

4) An ocean existed, but readily froze, and over time sublimated [9]. This scenario is similar to number 2, but rather than having weak wave action, a frozen ocean would have no wave action available to generate coastal landforms.

5) An ocean existed and coastal landforms were constructed, but in the intervening time since their formation they have nearly all been eroded away.

References: [1] Parker T. J. et al. (1989) *Icarus, 82*, 111-145. [2] Parker T. J. et al. (1993) *JGR, 98*, 11061-11078. [3] Clifford S. M. and Parker T. J. (2001) *Icarus, 154*, 40-79. [4] King C. A. M. (1972), Beaches and Coasts, 2nd 570 p. [5] Malin M. C. and Edgett K. S. (1999) *GRL, 26*, 3049-3052. [6] Webb V. E. (2004) *JGR, 109*, E09010, doi:10.1029/2003JE002205. [7] Zimbelman J. R. and Irwin R. P. (2005) *GSA Abs. Prog, 37*(7), 513. [8] Kraal E. R. et al. (2006), *JGR, in press.* [9] Lucchitta B. K. et al. (1986) *Proc. Lunar Planet. Sci. Conf. 17th, JGR, 91*, suppl., E166-E174.

This work was supported by NASA Mars Fundamental Research Program grant NAG5-12746.