POSSIBLE PRIMORDIAL OCEANS ON MARS: EVIDENCE FROM THE GLOBAL DISTRIBUTION OF ANCIENT DELTAS?

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Introduction: Marine deltas are among the most typical coastal landforms on Earth. They exhibit a large diversity of morphology as a result of the combination of several factors, including climate, geology, river characteristics, and basin bathymetry and waves regime. Nonetheless, they share the characteristic of being formed approximately at the same elevation all over the planet, the mean global sea level. Several possible deltas have been recently identified on Mars [1-7] and, in agreement with the terrestrial paradigm, they can provide a reliable approach to test the occurrence of the martian oceans and eventually to detect their past levels at a global scale. Here, we report preliminary results from such a test.

Data and Methods: We use the global distribution of ancient martian deltas [1-7] and valley networks [8] in combination with the global topography from Mars Orbiter Laser Altimeter (MOLA) and all the available imagery. In particular, by using MOLA shots topography, we extracted the elevation values of the apex (maximum water level), delta front (mean highstand), and of the basin floor (minimum water level) for each deltas (Fig. 1). These values were used as indicators of the maximum water level excursion (apex elev. - floor elev.) and of the main highstands during the formation

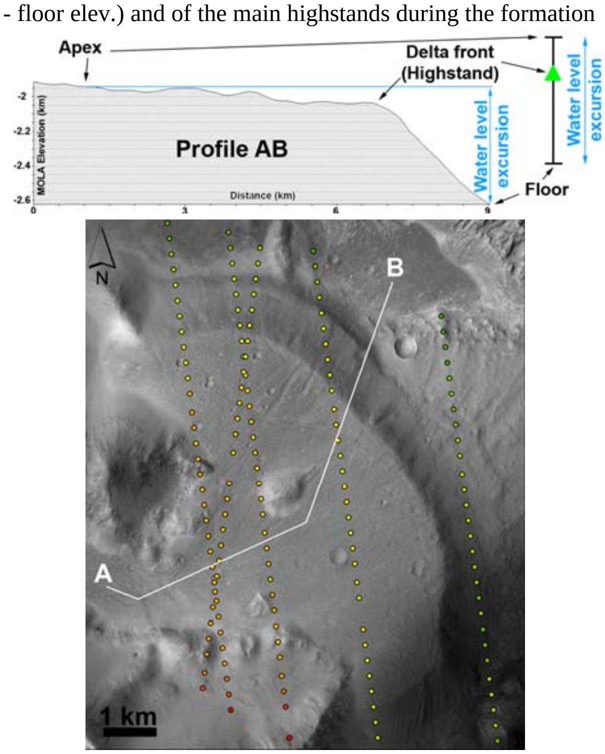

Figure 1. Example of method and data used to extract and plot the elevation values for the deltas.

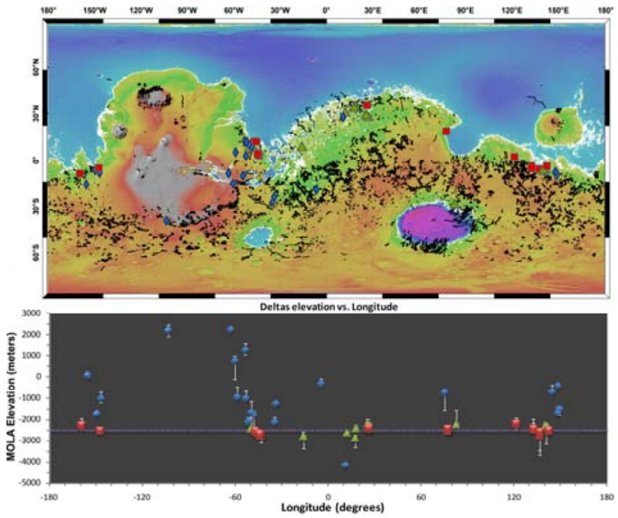

Figure 2. (top) Global distribution of valley networks (black lines) [8] and deltas [1-7]. The white contour and the light blue color mark the possible ocean's boundary; (bottom) plot of deltas' elevation in function of the longitude.

of the sedimentary deposits. Afterwards, by assuming that the present topography is similar to that at the time of the occurrence of the putative ocean, and that all the deltas formed during the same epoch, we plotted all the values in function of the longitude (Fig. 2) to detect possible equipotential surfaces indicative of ancient oceans' coastlines. Additionally, we extracted the termini elevations of all the martian valleys in order to compare them with the distribution of deltas. In fact, a planetwide standing body of water should have determined abrupt channels' terminations all over the planet approximately at the same elevation indicated by the analysis of the contemporary deltas. Our test does not take into account possible isosastic, tectonic, and subsidence movements that may have occurred after the disappearance of the putative oceans. The latter assumptions, however, were implicit in all the previous tests for the martian oceans [e.g. 9, 10, 11, 12].

Results: The database of sedimentary deposits considered here consists of 47 deltas [1-7]. At a global scale the deposits appear preferentially located a short distance upslope from the crustal dichotomy of the planet and show a regional correlation with the distribution of valley networks [8] (Fig. 2). Surprisingly, the fronts (mean water level) of all the 15 (~32% of total) deltas formed in open basins and/or topographically connected to the northern lowlands (the site putatively occupied by the ocean) define a possible equipotential surface at the mean elevation of -2533 m with a rela-

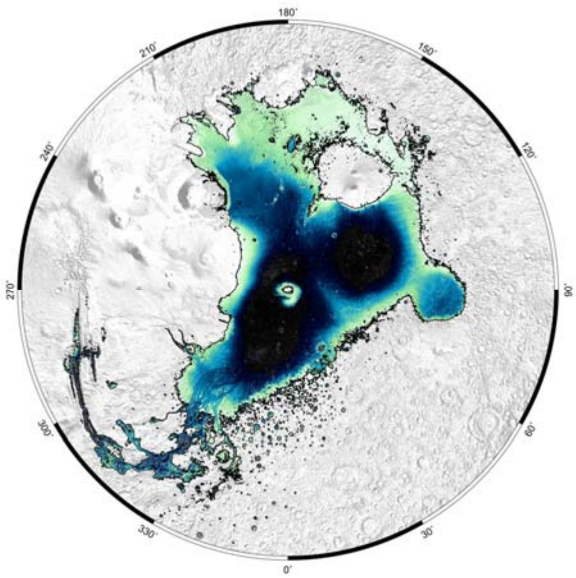

Figure 3. Polar stereographic projection of the ocean's extension as inferred from the analysis of the deltas.

tively low planetwide standard deviation of 158 m (red squares in Fig. 2). A contour at this elevation traces a complete closure within and along the margins of the northern lowlands (Fig. 2 and 3), encompassing the boundary of a single global basin within which the deposits could have been formed. The level of the inferred equipotential surface follows a large portion of the "Arabia shoreline" previously identified from geomorphologic and topographic analyses [9, 10, 11] and is consistent with the elevation value that would minimize the deviation of the "Arabia shoreline" from its predicted location after the deformation caused by true polar wander [12]. Moreover, the value inferred from the analysis of the deltas is remarkably close to the -2550 m suggested by theorethical calculations of the global distribution of water during the Noachian [9]. The latter is based on the thermophysical properties of Mars and implies that water was saturating the crust and ponding in hydrostatic equilibrium at this level on the surface of the planet, determining the occurence of several standing bodies of water, including also those in the Hellas and Argyre basins [9]. With this assumption, and hence considering also the deltas in closed-basin settings (green triangles in Fig. 2), the fronts of 25 (~53% of total) deltas would define an equipotential surface at about -2500 m with a standard deviation of 193 m. Finally, the equipotential surface inferred from the delta analysis is also consistent with the global distribution of the martian valley networks and their terminations at a global scale [8]. In fact, the majority of the Martian valleys terminate at higher elevation with respect to the inferred level (Fig. 4). Only Hesperian and Amazonian valleys and ravines in Valles Marineris and Hellas basin show terminations below the -2533 m $\pm$ 158 level. This, in addition to the above observations, suggests that the inferred equipotential surface could eventually mark the boundary of a possible Noachian ocean of Mars.

Outlook: The global distribution of martian deltas supports the theory that the northern lowlands of the planet could have been once occupied by a large standing body of water. The inferred level is consistent with the global distribution and age of valley networks and in places with the "Arabia shoreline" previously suggested from geomorphologic and topographic observations. However, only detailed planetwide analysis along the possible boundary and identification of typical coastal landforms can confirm this hypothesis.

References: [1] De Hon (1992), *Earth, Moon and Planets*, *56*; [2] Cabrol and Grinn. (1999), *Icarus*., *125*; [3] Ori et al. (2000), *JGR*, *105*; [4] Malin and Edgett (2003), *Science*, *302*; [5] Irwin et al. (2005), *JGR*, *110*; [6] Di Achille et al., (2007), *JGR*, *112*; [7] Hauber et al, *Planet. Sp. Sci*., *in press.*; [8] Hynek (2008), *Eos Trans. AGU*, *89(53)*, *Fall Meet. Suppl*., *p44c-05*; [9] Clifford and Parker (2001), *Icarus*, 154 ; [10] Carr and Head (2003), *JGR*, *108*; [11] Webb (2004), *JGR*, *109*; [12] Perron et al. (2007), *Science*, *447*.

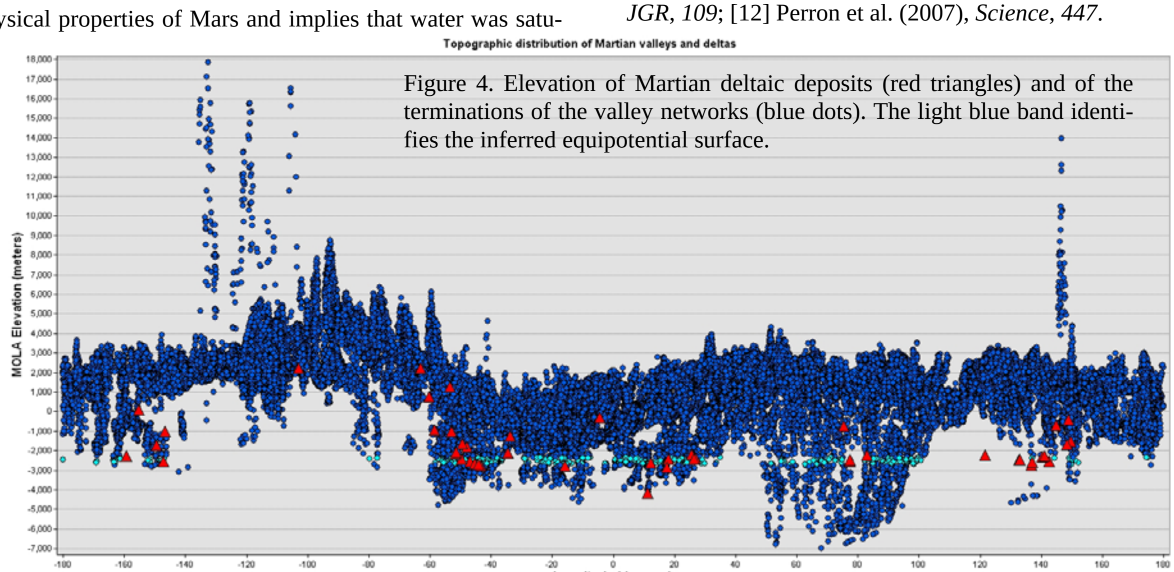

Figure 4. Elevation of Martian deltaic deposits (red triangles) and of the terminations of the valley networks (blue dots). The light blue band identifies the inferred equipotential surface.