THE VOLUME OF POSSIBLE ANCIENT OCEANIC BASINS IN THE NORTHERN PLAINS OF MARS.
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Introduction: Based on geologic, geomorphologic, and topographic evidence, the past occurrence of great water bodies on the northern plains of Mars has been proposed [e.g., 1,2] and their peloshorelines mapped [1,2,4,5], including water bodies that range in extent from oceans to paleolakes [for reviews see 3,4,6]. Topography in regions lower than the mean elevation of the main proposed paleoshorelines has been previously used to propose preliminary estimations of water volume in these putative oceanic basins [7,8].

Tests of paleoshoreline hypothesis have been performed using both MOC imagery and MOLA data, but the results are not definitive. High-resolution MOC images indicate that there is not sufficient evidence to support the paleoshoreline hypothesis [9], although other workers present arguments that dispute these findings [4,5]. From high-resolution MOLA topography it has been stated that the Deuteronilus shoreline is the only putative paleoshoreline which roughly correlates to an equipotential surface [7,8]. However, by taking into account lithosphere rebound due to water unloading associated with the disappearance of an ocean [10] or different thermal isostasy histories among regions [11], especially relevant for the Tharsis and Elysium region, it has been argued that it is not necessarily true that a paleoequipotential surface must match a present-day equipotential surface.

So, while we recognize that evidence for martian paleoshorelines is controversial, here we assume the early existence of oceans enclosed by the proposed paleoshorelines and calculate their water area and volume using high-resolution MOLA data. Previous estimations have been useful for preliminary discussion, but they were approximated. For example, values derived from MOLA data averaged in one-degree boxes are presented in [8]. Here, we present more precise calculations by using 32 pixel/degree maps.

Estimations based on present-day topography can only provide lower basin volume limits. Indeed, if an ocean occupied the lowlands, the weight of the water column would result in a significant load on the lithosphere in the regions inundated by water [10,12-14], creating a sag in the sea floor, and thus increasing the total volume of the water body. Here we assume Airy isostasy to estimate a preliminary upper limit on the effect of the water load on basin volume calculations.

Calculations: We have calculated areas and volumes below mean altitudes of the proposed Meridiani, Arabia, and Deuteronilus shorelines, by using 32 pixel/degree maps produced from MOLA data. The volume of the north polar region, which includes the ice cap and layered deposits [15], is taken into account, since these features contribute to the MOLA topography [16]. Lithospheric flexure due to north polar cap loading is not considered here, since that not flexure represents the lower limit for north polar contribution to the basins volumes, and upper limits are calculate assuming Airycompensation.

To assume Airy compensation achieved in the mantle implies that elevation variations in the sea floor due to changes in the height of the overlying water column is $y = h_w\rho_w/\rho_m$, where h_w is the height of the water column (i.e., the ocean depth), and ρ_w and ρ_m are the ocean and mantle densities, respectively. If h_w is taken as the depth of an ancient ocean, and h is the altitude difference between the dry ocean basin floor and the mean paleoshoreline level, obviously $y = h_w - h$, and the isostasy principle requires $h_w/h = \rho_m/(\rho_m - \rho_w)$. So, if h is taken as the present-day value, then this implies that estimations for the water volume enclosed in the martian oceans should be increased by a factor h_w/h (with higher ocean density and lower mantle density increasing this factor). If we assume ρ_w = 1-1.1 g m^{-3} and ρ_m = 3.3-3.5 g m^{-3}, then h_w/h = 1.4-1.5; in this work we assume h_w/h = 1.45.

It is important to note that, although water load of putative ancient oceans would result in a substantial increase in the basin volume with respect to calculations based on present-day topography, the assumption of Airy isostasy would imply that the lithosphere has not rigidity, and therefore the increasing factor h_w/h is an upper limit. As such, volumes presented in Table 2 are given as intervals between estimated results for present-day topography and results for water load compensated by Airy isostasy. Also, Table 2 shows mean depth of the basins, and the Global Equivalent Layer (GEL) if the water contained within the ocean basin is homogeneously distributed on the surface of Mars.

Discussion: Our results for Arabia and Deuteronilus shoreline present-day topography are somewhat lower than those obtained previously [7,8]. For the Meridiani shoreline our result is clearly lower than that in [8], fundamentally due to the fact that these authors use an excessively high value of 0 (with respect to the global datum) for the mean paleoshoreline elevation, whereas we use a mean elevation of −1.5 km [17].

Elevational range and geologic relations along Arabia shoreline, especially with respect to the Tharsis region, suggests that this is not a true paleoshoreline [7,8]. This implies that volumes obtained for the Arabia shoreline are likely not representative of any ancient martian ocean. Otherwise, elevations in the putative Meridiani shoreline are roughly similar to those of the Arabia shoreline in northeast Arabia, Utopia (not taken into account the Isidis basin), Elysium, and Amazonis regions. A paleoshoreline through these Arabia shoreline portions and the Meridiani shoreline would be a better candidate to represent a true ancient oceanic limit [5,18]: areas, volumes, mean depths and GELs obtained here for the Meridiani shoreline would be roughly valid for this possible paleoshoreline.

We emphasized here that further refinements in volume estimates for putative ocean bodies on Mars should take into account: (1) the effect of the rigidity of the lithosphere on flexure due to water load in the oceanic basins [10,19], (2) local and/or temporal changes in the effective elastic thickness of the martian lithosphere [20], (3) possible local variations of the thermal structure of the lithosphere producing differential thermal isostasy [11,21], (4) the deposition of sediment [22] and/or emplacement of lava flows [14] in the putative northern ocean basin region, such as recorded for the late Hesperian and the early Hesperian, respectively, (5) water transfer between different regions [10], and (6) degradation of basins boundaries related to endogenic or exogenic activity [4,5]. So, with the current knowledge, a complete reconstruction of the basins paleotopography seems to be very difficult.

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Table 1. Basins area and volume for present-day topography

Shoreline enclosing basin	Mean elevation (m)	Basin area at mean eleva-tion level (10^7 km^2) [c]	Basin volume (10^7 km^3)	
			North Polar Cap no included	North Polar Cap Included
Meridiani shoreline	−1500 [a]	5.35	10.54	10.66
Arabia shoreline	−2090 [b]	4.67	7.56	7.67
Deuteronilus shoreline	−3792 [b]	2.47	1.31	1.38

[a] Ref. [20], [b] Ref. [8], [c] North polar cap contribution included.

Table 2. Lower (present-day topography) and upper (water load compensated by Airy isostasy) limits for basins volume, mean depth and GEL

Shoreline enclosing basin	Volume (10^7 km^3)	Mean depth (km)	GEL (km)
Meridiani shoreline	10.66-15.46	1.99-2.89	0.74-1.07
Arabia shoreline	7.67-11.12	1.64-2.38	0.53-0.77
Deuteronilus shoreline	1.38-2.00	0.56-0.81	0.10-0.14