INVESTIGATING THE HYDROLOGY OF THE ALLEGED HELLAS PLANITIA LAKE IN SOUTHERN MARS.

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Introduction: The search for water and the unsolved location of water reservoirs and sinks on Mars has stimulated numerous studies on the water geomorphology and sedimentology of Mars, and the hydrologic cycle especially in the Noachian and Hesperian [1]. Fluid water was once abundant to the point that the Northern Lowlands might have held an ocean [2]; perhaps also large areas like Valles Marineris were filled with water to form giant lakes [3].

The ellipsoidal impact basin of Hellas Planitia (HP) stretches between latitudes 30^0 S and 55^0 S, with axes lengths $D = 1{,}800\text{-}2{,}200\text{-}km$ (Fig. 1). It has been suggested that a lake filled ancient HP; water depths were uncertain, most likely between 6900 m [4] and 600 m [5], corresponding to a maximum water volume of $2\text{x}10^7$ Km^3. Sedimentary morphologies suggesting a submerged deposition include channel erosion, fan deposits and overbank deposition especially from the east, and peculiar morphologies such as honeycomb textures [5]. However, many features are ambiguously interpretable as subaqueous and others, like volcanic overflow from Malea and Hesperia Plani and periglacial textures, are obviously subaerial. The assessment of HP lake is important not only for the general issue of water on Mars, but also because a lake of this size would have affected the planet's hydrologic regime. Here it is argued that in addition to the sedimentologic indications for a HP lake, other dynamic constraints could be worth studying to assess its possible presence on ancient Mars.

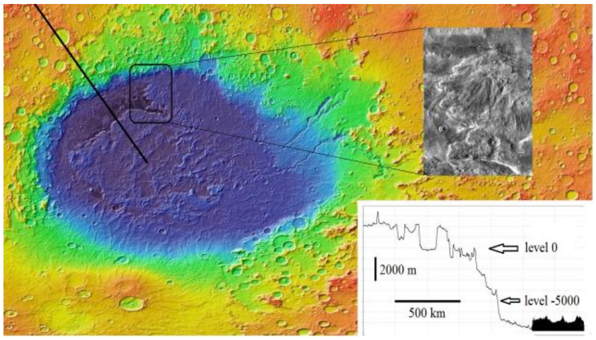

Figure 1. The HP basin (colored MOLA) and NW-SE topographic section along the black line. Cylindrical projection. In the section, the central unit is shown in black.

Issue 1: the central depositional unit: A puzzling feature of HP is the central depositional unit of Alpheus Colles (Fig. 1). This formation appears as a relatively abrupt step standing 400 km from the rim with maximum height < 600-800 m. The deposit volume can be estimated at $4\text{x}10^5$ km^3. Stacked sequences of centripetal subaqueous landslide deposits from the crater flanks, if attractive as a possible explanation of the central deposit [6], might be problematic considering that the slope of the flanks is only 1.5°-5° (estimated on a 100-km baseline). The wedge model indicates that the slope is gravitationally stable if $H<H_C$ where $H_C = (4C/\rho g)\left[\sin\beta_0 \cos\varphi / \left(1-\cos\left(\beta_0-\varphi\right)\right)\right]$ is the critical height, C is the cohesion, φ is the friction angle, $\beta = (\beta_0+\phi)/2$ is the present long-scale slope angle (1.7^0), β_0 is the pre-failure sloping angle and H is the height of HP borders. In failure has taken place, the slope and friction angles $\beta_0 \approx 2.21^0$, $\varphi \approx 1.19^0$ can be estimated based on the volume of the failed mass, from which $H_C(m) \approx 97\ C(kPa)$ which for $C=1\ MPa$ [7] would indicate $H<<H_C$, i.e., stability of the HP wallslope. In addition, the resulting ratio between fall height and run-out $H/R \approx 0.01\text{-}0.02$ would be more consistent with mudflows rather than subaqueous sector collapses of rock, for which H/R is usually 5-10 times greater [8]. Perhaps a series of subaqueous mudflows could better explain this unit; in this view, the northern step highlighted in Fig. 1, regarded as a fan deposit [4], could be interpreted as the front of a subaqueous debris flow from the east. As an alternate view, the central deposit might be derive from turbidity currents (TCs) from the rims of the crater. Some leveed channels like Dao Vallis [9] descend from the eastern crater rims with levees widths $W=12\text{-}15$ km and thickness $D=300$ m and may be Mars analogs of submarine channels on Earth transporting TCs. Some hundreds of TCs descending from the rim would have been sufficient to fill up the HP basin forming the central deposit. Because a TC damps the coarser sediment at the slope break, the annular lack of sedimentation especially to the west remains, however unexplained.

Issue 2: inferences on the hydrodynamics of the Hellas Planitia lake: In analogy with large lakes on Earth, water in HP lake must have been affected by the rotation of Mars with an acceleration of the order $f\,v$ where the Coriolis parameter is $f = 2\Omega \sin\phi$, ϕ is the latitude, and $\Omega = 7.09 \text{ x } 10^{-5}\ s^{-1}$. The HP basin stretches between latitudes 30^0 S and 55^0 S , corresponding to a Coriolis parameter $7.09 \text{ x } 10^{-5}\ s^{-1} < f < 1.16 \text{ x } 10^{-4}\ s^{-1}$ with an average $f = 0.934\ 10^{-4}\ s^{-1}$. Water depths suggested for Hellas range from -6900 m barely wetting the lowermost depths of the crater [4] to a height well above the conventional "0" level [5]. The importance of Coriolis effects in the water lake dynamics is quantified by the dimensionless ratio $n = D f / C_I$ between the lake diameter D and the internal Rossby radius C_I / f where $C_I = \sqrt{gT}$ is the phase velocity and T is the water depth. Values higher than unity indicate a significant role of circular currents in HP induced by Martian rotation. Consider as an example that for the Russian Lake Baikal, large on terrestrial standards (80 km x 640 km) but by no means comparable to Hellas Planitia, n is about *0.33*. In this lake, the rotary spectra of deep currents exhibit a high component at a clockwise frequency compatible to currents induced by the Earth's rotation [10]. Similar currents have been documented in other lakes [11]. As a consequence of the large size of the Hellas Planitia basin, the Coriolis acceleration might have appreciably influenced the hydrological dynamics of the lake. The geometry of the basin suggests values of n of the order of 2.04 and 1.48 for water levels at -6000 m (water depth 1000 m) and -1000 (water depth 6000 m) respectively. Clockwise currents in the form of Kelvin waves (e.g., [12]) involving vertical movement of water travelling parallel to the rim at a speed C_I (with 61 m/s < C_I <149 m/s), would have been consequence of water perturbations in the basin, also in an ice-covered lake [13]. Wave height and speed decayed from the lake rim toward the center of the basin with a length scale $R \approx C_I / f \approx 500 - 1{,}000\ km$ and were thus greater toward the border than at the center. Perhaps the peripheral currents in the lake hampered the settling of clay-sized material, so creating the morphological gap between the eroded annulus and the central depositional unit in the lake.

Issue 3: the scarcity of impact craters in Hellas Planitia: The small number of craters observed in the HP basin compared to the surrounding Noachian terrain is likely consequence of i) initial erasure of pre-Hellas craters by the impact, followed by ii) obliteration due to sedimentation in Hellas, and/or iii) shielding of impacts by the presence of water and/or ice. The effect iii) is preliminarily investigated considering the drag against a meteoroid traveling in water, and neglecting meteoroid break-up [14]. Upon travelling through a water/ice layer of thickness D_W, the impact velocity at the bottom of HP is found integrating a simple differential equation which yields [14]

$$V_{SEAFLOOR} \approx V_{SURFACE} \exp\left[-\frac{3}{2} \frac{\rho_W}{\rho} \frac{C_D D_W}{L \sin \vartheta} \right] \quad (1)$$

where $C_D \approx 0.877$ is the drag coefficient for the meteoroid in water/ice travelling with angle ϑ with respect to the horizontal, L the meteoroid diameter. For the density of a stony body $\rho = 2{,}500\ \mathrm{kg\ m^{-3}}$, and using the relationship between crater diameter D and L [14],

$$D \approx 1.161 \left(\frac{\rho}{\rho_{SURF}} \right)^{1/3} L^{0.78} V^{0.44} g^{-0.22} (\sin \vartheta)^{1/3} \quad (2)$$

the crater distribution modified by the presence of shielding water can be estimated for a 3.5 Ga old surface (Fig. 2). Note the strong decrease of frequency for craters of diameter less than 10 km (this result, however, neglects the post-water small craters population).
A better characterization of the issues presented here is under study.

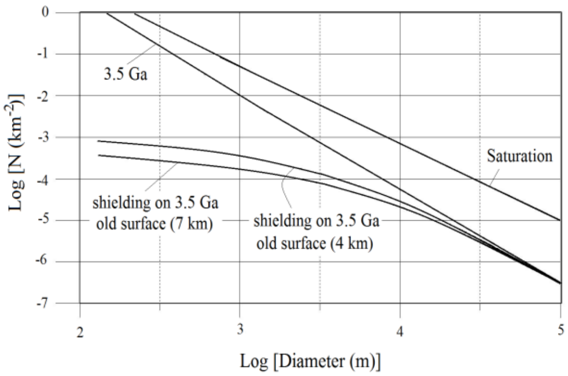

Figure 2. A first approximation to account for the shielding effect of water on the frequency distribution of craters on Mars' surface. Each curve shows the total number of craters equal or greater than the given diameter. Without water, a "3.5 Ga" Hartmann integral distribution would result for a surface this old (likely age of HP); 7 and 4 km of water modify the distribution to produce the curves shown (head-on impacts). "Saturation" is the ideal power-law distribution for a surface of age > 4.5 Ga. Meteoroid breakup is neglected in this first approximation.

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