GEOMORPHOLOGICAL ANALYSES OF THE HELLAS BASIN FLOOR, MARS: NEW IMPLICATIONS FOR ITS GEOLOGIC HISTORY

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Introduction: Based on our new comprehensive photogeological map of the Hellas basin floor and its immediate surroundings (scale 1:2,000,000. see companion LPSC'15 abstract #1335), we conducted an in-depth analysis of this region's geologic history. As a major depositional sink located between two volcanic provinces [e.g., 1-4], the geomorphologic record preserved in the Hellas basin can help to assess the evolution of climatic conditions on Mars and how they might have been influenced by volcanic activities [5]. The basin floor also hosts a suite of unique, enigmatic landforms, e.g., the "honeycomb" [e.g., 6], "banded" [7], and "reticulate" [e.g., 8] terrains, whose origins can be better constrained by an improved understanding of the entire region's general geology.

Selected observations and discussion: We identified 34 geomorphological units using all state-of-the-art datasets (period extents based on [9]; see companion abstract #1335) and derived absolute model ages (AMA) from crater-size-frequency measurements for nine of these. Following is a selection of key observations we made (from oldest to youngest):

1) Layered rim sequence (Nld, Nli, Nll): Among the oldest deposits in the Hellas basin is a sequence of materials dominating the northern and eastern parts of the rim. Spectral [10-12], stratigraphic, and morphological characteristics (e.g., horizontal layers and partially inverted, meandering channels) suggest their formation by fluvial processes before the emplacement of the lower wrinkle-ridged plains (AMA 3.78-3.82 Ga; basin formation ~3.99 Ga ago [13]).

2) Lower wrinkle ridged plains ($Npwr_1$): The layered rim sequence is embayed by wrinkle-ridged plains, whose lower member shows an AMA of 3.78-3.82 Ga. Elongated buttes and pedestal craters of Hih (described below), yardangs, and a general absence of dunes, all indicate aeolian erosion has exhumed the $Npwr_1$ unit. The orientation of older buttes and yardangs, as well as of more recent wind-streaks and dust devil-tracks, is in agreement with previously modeled prevalent winds moving in a cyclone-like pattern, i.e., parallel to the basin rim in a clock-wise direction [14]. Based on previous models for wind abrasion and deflation rates on Mars [15-19], we estimate that within 50 to a few 100 Ma ~1 km of Hih might have been removed, thereby exhuming the $Npwr_1$.

3) Arcuate, layered member (HNila): Close to the basin center, up to ~300 m high buttes of arcuate, layered deposits superpose the wrinkle-ridged plains and are partially covered by Hih. Their morphological and thermophysical characteristics are comparable to the Nld/Nli units and very similar to other deposits on Mars commonly interpreted as phyllosilicate and sulfate-rich sediments formed in aqueous environments [e.g., 20,21]. Although the HNila unit might represent the remnants of a pre-existing basin-wide deposit, possibly of lacustrine origin, its occurrence near the deepest areas of the Hellas basin (before winds carved out the northwestern trough; see $Npwr_1$) might indicate that it was formed by localized processes. Thus, HNila might have been laid down between the emplacements of $Npwr_{1/r}$ and Hih (i.e., 3.82-3.67 Ga ago) in relatively small sub- or englacial lakes [22,23]. Other landforms indicating a past glaciation of the Hellas basin, e.g. drumlins, eskers, or moraines, seem to be absent, however.

4) Upper wrinkle-ridged plains ($Hpwr_2$): The upper member of the wrinkle-ridged plains has an AMA of 3.63-3.74 Ga and correlates well with a low-K (~0.3 wt%) area in Gamma Ray Spectrometer data [24]. Both characteristics are shared by the shield volcano-like Hadriaca and Tyrrhena Paterae [4] and indicate more evolved basalts than those of the $Npwr_1$ [25]. Extrapolations based on stratigraphic constrains (Fig. 1 in companion abstract #1335) as well as structural models of the wrinkle ridges indicate a total volume of the $Npwr_1$ and $Hpwr_2$ units of ~1.7 x 10^6 km³ (~4 x Deccan traps, Earth) [26].

5) Interior formation (Hih, Hik): The Hellas basin center is covered by ~340,000 km³ of highly degraded, hummocky material superposing the wrinkle ridged plains and the HNila unit amongst others. Two observations imply a relatively short-lived Hih-coverage of the entire basin floor around 3.7 Ga ago: a) Buttes, pedestal craters, and crater-fill remnants likely to be Hih-zeugenbergs, b) An AMA of 3.67-3.74 Ga, which is similar to that of the underlying $Hpwr_2$ unit. Such a

complete coverage would imply an initial Hih-volume of ~1.1 x 10^6 km³. The volume of material removed by fluvial, glacial, and possibly aeolian processes from Hesperia Planum and the area between it and Hellas Planitia has been suggested to be on the order of 0.5-1.5 x 10^6 km³ [27], thus being a plausible main source for Hih. Additional, minor contributions likely were the materials eroded by the formation of Dao/Niger and Harmakhis Valles (~4 x 10^4 km³ [28]), and those eroded from northern Promethei Terra (5-6 x 10^4 km³ [28]). The OMEGA-based detection of (aqueously altered) mafic rock, namely vermiculite/smectite and low-Ca pyroxene [3,11,12] is in agreement with an interpretation of Hih being material transported from the adjacent volcanic provinces into the Hellas basin, possibly by liquid water. Although stagnant bodies of liquid water and/or ice within the Hellas basin have repeatedly been suggested [e.g., 6,8,30], clear morphologic evidence remains elusive. However, a generally low thermal inertia, scarcity of visible layering, and extensive slumping, all indicate the top few 100s of meters of the Hih to consist of poorly cemented material, possibly re-deposited airfall deposits.

6) Dao/Niger and Harmakhis Valles ($AHv_{D/H}$, $Hils_1$/$AHils_2$, AHf/AHdf): Two major outflow channels originating on the southern flanks of Hadriacus Mons enter the Hellas basin floor from the east. At its transition to the basin floor, the floor of Harmakhis Vallis shows an AMA of 3.55-3.71 Ga. Within the basin, furrowed (AHf) and dissected (AHdf) materials occupy the topographic extensions of the channels toward the basin center. Here, two smooth, lobate deposits ($Hils_1$ and $AHils_2$) cover ~1.5 x 10^4 km^2 and show AMAs of 3.68-3.83 Ga and 3.11-3.48 Ga, respectively. As Hadriaca Patera shows an AMA of 3.5-3.7 Ga [4], episodic late-stage fluvial activity might have been triggered by volcanic activity [27].

Based on our results, a possible sequence of major geologic events on the Hellas basin floor is as follows (ages rounded to one digit):

4.0-3.8 Ga: Early, post-impact fluvial activity depositing vast sequences of layered material along the basin rim. Malea, Peneus and Tyrrhena Paterae active as early as 3.9 Ga ago [2-4].

3.8 Ga: Emplacement of lower wrinkle-ridged plains, potentially by basalts from Tyrrhena Patera.

3.8-3.6 Ga: Deposition of layered material close to basin center, possibly by glacio-fluvial or lacustrine processes.

3.7 Ga: Emplacement of upper wrinkle-ridged plains, most likely by already more evolved basalts from Hadriaca and Amphitrites Paterae. Compressive stress field causes formation of wrinkle ridges soon after plains emplacement [26].

3.6 Ga: Emplacement of Hih/Hik on the entire basin floor, possibly by large-scale erosion on, as well as southeast of, Hesperia Planum and subsequent glacio-fluvial transport into the Hellas basin.

3.6-3.1 Ga: Episodic fluvial activity of Dao/Niger and Harmakhis Valles forms deposits in basin center.

Since 3.1 Ga: Intense aeolian activity exhumes $Npwr_{1/r}$ and $Hpwr_2$ by removing Hih from the outer annulus of the basin floor and re-depositing it as loose sediments in the interior.

Conclusions: Although the early history of the basin experienced extended periods of fluvial activity, the majority of the Hellas basin infill (~1.7 x 10^6 km³) appears to consist of volcanic material (units $Npwr_1$ and $Hpwr_2$). Intermittent and younger non-volcanic units HNila and Hih/Hik suggest huge volumes of material were deposited simultaneously and/or shortly after volcanic episodes. Melting of large ice masses and/or relatively short-lived atmospheric warming due to outgassing are candidate processes, making Hellas Planitia and its surroundings a prime target for investigating the influence of punctuated volcanic activity on the early Martian climate and habitability.

Aside from this, our observations are in good agreement with a previous wind circulation model [14]. Persistent, katabatic winds capable of saltation and, thus, abrasion, likely carved out the northwestern Hellas Planitia trough (containing the deepest point on Mars) within few 100s of Ma. The material was probably re-deposited closer to the center, where the model predicts lower wind speeds. Coverage by 100s of meters of such airfall deposits might also explain the apparent absence of landforms formed by a past basin-wide glaciation and/or sea, which were repeatedly proposed in previous investigations [e.g., 6,8,30].

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