MAJOR EPISODES OF THE HYDROLOGIC HISTORY OF HESPERIA PLANUM, MARS.

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Introduction: High standing volcanic plateau of Hesperia Planum (HP), (1300x1700km, area ~1.5×10^6km^2), is in the NE part of the Hellas basin rim. The HP and surrounding uplands host a rich array of volcanic and fluvial landforms suggesting that the interaction of volcanic and fluvial processes is the main theme of both the evolution of HP and probably the history of deposition in the Hellas basin. We outline the most important features in the region of HP and correlate temporally the processes that have led to their formation using the whole set of imagery and topographic data available to date (Viking, MOC, THEMIS, HRSC, and MOLA-1/64 -gridded topography).

Topography of Hesperia Planum: The surface of HP forms a broad and shallow depression. Its flat surface has about the same elevation ~1.2 km above MPR, except for three areas: 1) Tyrrhena Patera, ~1.5 km above the surface of HP, 2) area in the SE part of HP that represents a basin in ~35-40^{o}S & 225-240^{o}W ("Morpheos basin"; “MB”), which is ~700-800 m deeper than the rest of the HP, 3) region in the SW corner of HP, which is a depression ~200 km wide ("SW trough") running towards Hellas. The mean of the measured differences in elevation between the surface of HP and the adjacent uplands is ~450 m for the major portion of the HP boundary. Within the SW trough, however, the surface of HP is up to ~3 km lower than that of the uplands. The trough is a "bottle neck" that breaches the uplands and connects HP with Hellas basin. Dao, Niger, and Harmakhis Vallis are concentrated in the trough.

Volcanic plains, impact craters, and volume of HP: The vast Hesperian plains make up the surface of HP [1-4]. The characteristic features of the surface are wrinkle ridges that typically form polygonal networks. The ridges are generally linear but in places they form circular patterns. We interpret these circular ridges as structures formed by the deformation of plains over rims of impact craters. The observations of the true flooded rims of craters in HP predating emplacement of the plains support this. The initial height of the rim is the measure of the thickness of the lava fill. The MOLA data allow precise determination of the shape of impact craters on Mars [5]. We made a survey of the flooded craters in HP and found 43 features (from 6.5 to 63 km). The mean rim height is estimated to be ~325±73m (±1σ); the maximum height is ~495 m. These values give the total volume of the lava fill within HP (~0.4 to ~0.7×10^6km^3). The flooded craters also characterize the morphology of the floor of HP prior the lava filling. We compared the size frequency distribution (SFD) of the flooded craters in HP with SFD of craters in a typical Noachian terrain (Terra Tyrrhena) and in classical Hesperian volcanic provinces Syrtis Major and Lunae Planum. We also tested if the combined population of the flooded and the exposed craters in HP would make the SFD to be more similar to that of the cratered uplands.

Terra Tyrrhena curve shows the highest crater density while the Hesperian curves are practically identical and lie significantly lower. The curve for the exposed craters in HP corresponds well to the Syrtis Major and Lunae Planum SFD. The SFD of the HP flooded craters mimics also that distribution. The SFD (HP) clearly belongs to the family of the Hesperian distributions. When the exposed and flooded craters in HP are combined, it provides a negligible shift toward the higher crater density, which is not significantly different (±1σ) from the SFD of the other Hesperian units. The statistics strongly suggest that the Noachian population of impact craters in HP was erased before plains emplacement. Thus, the large-scale depression of HP may have partly to wholly been formed in the post-Noachian time. If by that time the region of HP was not a depression, the maximum depth of the topographic basin that later had been formed in this area can be estimated as the sum of the mean topographic difference between the surface of HP and surrounding uplands (~500 m) and the thickness of the plains (~250 to ~500 m). This gives the depth range from ~0.75-1 km and the maximum value of the total volume of material missed in the HP from ~1.1-1.5×10^6km^3.

If a depression in HP existed during Noachian then the minimum value of the thickness of material removed from this area can be estimated by the rim height of the larger impact craters characterizing the surface of the Noachian terrain. This height is ~300 m for the craters in wide range of diameters from 100 up to 1000 km [5]. For this value, the total volume of the materials removed from the floor of Hesperia Planum is ~0.45×10^6km^3.

Flow features in HP: 1) Small valley networks: The Noachian units around HP are among terrains that are most dissected by small valleys [6,7]. The local to regional topographic gradients govern the orientation of the small valleys and the area of HP appears to be the principal sink for the valley effluents. The valleys are abruptly terminated by the contact between the uplands and HP. The absence of the deltas, fan-shaped deposits, and the channels cutting the plains means that the formation of the valleys took place before emplacement of the lava plains.

2) Large outflow channels: Three large outflow channels, Dao, Niger, and Harmakhis Valles, cut the surface of HP in the SW trough. The fourth channel, Reull Vallis, runs from “MB” across the northern edge of Promethei Terra. The fifth, unnamed, channel is in the SE part of HP. This relatively short channel appears at ~32°S 246.5°W, and runs southward disappearing at the northern edge of “MB” at ~35°S 246°W. Dao and Harmakhis start in distinct closed depressions. The source regions of Niger Vallis and the unnamed channel are less distinct and marked by circular and elongated depressions suggesting both the subsidence of the surface and subsurface flows [8]. Reull Vallis begins full-sized at the western edge of “MB” and has no distinct source region. Formation of all these channels postdate emplacement of the volcanic material in HP.

3) Viscous flows: The viscous flows are abundant in the southern parts of the studied region. The most spectacular flows are lobate debris aprons around upland massifs in Terra Promethei. The aprons are absent both around the upland massifs within HP and in the uplands north of ~38°S and east ~250°W [9]. The viscous flows are common in the Dao-Niger system and along the lower reaches of Reull Vallis. They postdate formation of the channels.

The subsurface flows occur on the walls and at the heads of the large outflow channels within the SW trough. The features accompanying the flows (subsidence & break-up of the surface, pit chains, shallow trough and zones of graben marking their edges, arcuate concentric scarps concave towards the channels) indicate that the flows originated from beneath the composite layer of the lava fill. The viscous flows of the other type occur almost exclusively within the northern portion of Promethei Terra near middle and low stretches of Reull Vallis. The flows are superposed on the surface of surrounding plains and partly fill channel of Reull. The sources of the flows are on the surface and there is no evidence for subsurface sources.

Discussion: First recognizable episodes in the history of the HP area is the formation of small valley networks that dissect the surrounding uplands. The lava plains of HP embay the valleys implying that they most likely continued to the original floor of HP and stored there their effluents. Although the source of the valleys is unknown, the hypothesis of their formation is base melting of thick ice sheets [10]. If this was the case, a large amount of ice accumulated around HP and possibly established the source for the later fluvial activity in the region of HP.

The SFD of flooded craters in HP suggests that its surface has the Hesperian SFD of craters before the lava fill. Thus, the area of HP probably went thorough an episode of massive erosion that erased the older crater record. For this, the hypothesis of magmatic erosion of the volatile-saturated regolith at the initial stage of volcanism in HP [11] offers a good explanation. The total volume of material removed from HP before the main episode of the on-surface volcanism is estimated to be ~$0.45\text{-}1.5\times10^6$ km^3. Hellas basin was the probable destination where the material may have formed a 0.5-1.5 km thick layer.

The second episode of water release post-dated the lava plains and the centralized volcanoes (e.g. Hadriaca Patera) and led to formation of the outflow channels. For the Dao-Niger system, Harmakhis Vallis, and the unnamed channel in SE HP the sources of the flows were beneath the lava plains. The volume of material removed from these channels is ~0.02×10^6 km^3 [12] or only ~1.5-5.5% of the total volume of material possibly eroded from HP. Reull Vallis is different from other channels because its source apparently was on the surface of the plains within the depression of the “MB” [9]. The volume of this “Morpheos basin” paleolake may have been very considerable.

At the last stage of the fluvial activity, the viscous flows played the most important role. They are concentrated almost exclusively in the areas cut by the large outflow channels partly filling the channels. Their total volume is small comparing to the amount of material eroded from the channels. The flows have distinctly different source regions. Dao-Niger system flows originate from subsurface (on-surface flows absent) and the flows around Reull begin on the surface (subsurface flows absent). The different positions of the flow source regions suggest different explanations of formation. The subsurface flows are likely related to the left over volatiles in the reservoir that was almost emptied during the erosion in HP and formation of the outflow channels. The on-surface flows may have been formed due to the transient water reservoir within the “MB” that was filled from the subsurface source by the unnamed channel. Reull Vallis then drained the basin and its effluents were re-accumulated in the eastern Hellas rim area where the on-surface flows now prevail [9].

Conclusions: The hydrologic history of HP appears to begin with the accumulation of volatiles around and in the HP basin and formation of a large reservoir there in the late Noachian. The reservoir was then emptied in three different modes that reflect diminishing in the amount of the stored volatiles: 1) the massive areal erosion, 2) the outflows concentrated in a few places, and 3) dispersed viscous flows. Volcanism within HP probably played the major role in mobilization and release of the volatiles. It is appears to be likely that the volcanic activity had induced the main episode of erosion in HP [11] and it is also possibly that later magmatism was triggering the outflow channels [8,13]. Formation of the viscous flows is not probably related to volcanic activity and represents flows from the largely depleted initial reservoir of volatiles within HP.

References: [1] Greeley & Guest, 1987, *Map I-1802-B*; [2] Greeley & Spudis, 1981, *RGSP*, 19; [3] Tanaka, 1986, *JGR Suppl. 91;* [4] Tanaka et al, 1992, *in: Mars, H. H. Kiefer, et al. eds., UA*, 345, [5] Garvin et al., 2000, *LPSC31*, #1619, [6] Carr 1995, *JGR*, 100; [7] Carr & Chuang, 1997, *JGR*, 102; [8] Squyres et al., 1987, *Icarus, 70*; [9] Kostama et al., 2004 *V-B 40*, #47, [10] Carr & Head, 2003, *GRL*, 30; [11] Tanaka et al., 2002, *GRL*, 29; [12] Rogeiro et al., 2003, *V-B 38*, #65, [13] Crown & Greeley, 1993, *JGR*, 98.