MAJOR EPISODES OF THE HYDROLOGIC AND VOLCANIC HISTORY OF HESPERIA PLANUM, MARS. M.A. Ivanov[1,2], J. Korteniemi[2], V.-P. Kostama[2], M. Aittola[2], J. Raitala[2], G. Neukum[3], and the HRSC Co-Investigator Team; 1 - Vernadsky Institute, Moscow, Russia, 2 - University of Oulu, Oulu, Finland, 3 - FU, Berlin, Germany.

Introduction: Hesperia Planum (HP), which is a high-standing volcanic plateau of Hesperian age (1300x1700 km, area ~1.5 10^6 km^2), is in NE part of the Hellas basin rim. The region of HP and surrounding uplands hosts 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. Here we outline the most important features in the region of HP and try to correlate temporally 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. The flat surface of it has about the same elevation ~1.2 km above MPR, except for three areas: 1) Tyrrhena Patera, which is ~1.5 km above the surface of HP, 2) area in the SE part of HP that represents a basin between ~35-40°S and 225-240°W ("Morpheos basin"), which is ~750-800 m deeper than the rest of the surface of HP, 3) region in the SW corner of HP, which is a depression ~200 km wide ("SW trough") running toward the floor of 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 the surface of the uplands and the trough represents a "bottle neck" that breaches the uplands and connects HP with the Hellas basin. Dao, Niger, and Harmakhis outflow channels 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 of HP are wrinkle ridges that typically form polygonal networks of structures. The ridges are generally linear but in places they form unusual circular patterns. We interpret these circular ridges as structures formed by the deformation of lava plains against rims of impact craters. This interpretation is supported by the observation of the true flooded rims of craters predating emplacement of the lava plains in HP.

The initial height of the rim of the flooded craters is the measure of the thickness of the lava fill and the MOLA data allow precise determination of the shape of impact craters on Mars [5]. We have conducted a regional survey of the flooded craters in HP and found 43 such features (from 6.5 to 63 km). The mean rim height is estimated to be ~325±73 m (±1σ); the maximum value for the height is found to be ~ 495 m. These values give the total volume of the lava fill within HP in the range of ~0.4 to ~0.7 10^6 km^3.

The other very important aspect of the flooded craters is that they characterize the morphology of the floor of HP prior the lava filling. We have 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 volcanic provinces of the Hesperian age, Syrtis Major and Lunae Planum. We also have tested a hypothesis 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.

The Terra Tyrrhena curve shows the highest crater density and the Hesperian curves are practically identical and lie significantly lower. The curve for the exposed craters in HP corresponds well to the SFD of Syrtis Major and Lunae Planum. The SFD of the flooded craters in HP almost exactly mimics the distribution of the craters on the surface of both Hesperian regions meaning that the SFD of the flooded craters in HP 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 crater statistics strongly suggest that the Noachian population of impact craters in HP was erased before emplacement of the plains. The large-scale topographic depression of HP, thus, 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 range of the depths from ~750 to ~1000 m and, correspondingly, the maximum value of the total volume of material missed in the HP is from ~1.1 to 1.5 10^6 km^3.

If a depression in the area of 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 10^6 km^3.

Fluvial 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 Morpheos basin 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 Morpheos basin 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-size at the western edge of Morpheos basin and has no distinct source region. Formation of all these channels clearly postdate emplacement of the volcanic material in HP.

3) Viscous flows: The viscous flows are abundant in the southern portion of the region under study. The most spectacular flows are lobate debris aprons around massifs of the uplands in the northern part of Terra Promethei. The aprons are absent both around the upland massifs within HP and in the uplands north of about 38°S and east of about 250°W [9]. The viscous flows are common features in the Dao-Niger system and along the lower reaches of Reull Vallis. The position of the flow sources relative to the surface defines two types of them: sub-surface and on-surface flows. Both type 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. A range of features accompanying these flows (subsidence and breakup of the surface of the lava plains, pit chains, shallow trough and zones of graben marking their edges, arcuate concentric scarps concave toward the channels) indicates that the flows were originated from beneath of the composite layer of the HP 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 these flows are on the surface and there is no evidence for the subsurface sources.

Discussion: One of the 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 clearly 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 very attractive hypothesis of their formation is the base melting of thick ice sheets [10]. If this was the case, a large amount of ice accumulated around HP and possibly within it established the source for the later fluvial activity in the region of HP.

The SFD of flooded craters in HP strongly suggests that its surface has the Hesperian size-frequency distribution of craters before the lava fill. Thus, the area of HP probably should undergo an episode of massive removal of materials that erased the older crater record. The hypothesis of magmatic erosion of the volatile-saturated regolith at the initial stage of volcanism in HP [11] offers a good explanation for such an event. The total volume of material removed from HP before the main episode of the on-surface volcanism is estimated to be from ~0.45 to ~1.5 10^6 km^3. All these materials probably went into the neighbor Hellas basin where they may form a layer about 0.5-1.5 km thick.

The second episode of water release postdated emplacement of the lava plains and the centralized volcanoes such as Hadriaca Patera and led to formation of the outflow channels. For the Dao-Niger system, Harmakhis Vallis, and the unnamed channel in SE portion of HP there is the good evidence that the sources of the flows were beneath the layer of 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 Morpheos basin. The possible scenario of evolution of Reull Vallis and area around it is presented in the separate abstract [9].

At the apparently last stage of the fluvial activity, the viscous flows played the most important role. The flows are concentrated almost exclusively in the areas cut by the largest outflow channels (Dao-Niger, Harmakhis, and Reull Valles) and superposed on their floor and partly fill the channels but the total volume of the flows is small comparing with the amount of material eroded away from the channels. The most important feature of the flows is that they have distinctly different source regions. The flows that occur at the Dao-Niger system are originated from the subsurface (on-surface flows are absent) and the flows around Reull begin from the sources that were on the surface (subsurface flows are absent).

The different position of the flow source regions suggests the different explanation of their formation. The subsurface flows are most likely related to the remainders of volatiles in the reservoir that was almost emptied during the massive erosion in HP and formation of the outflow channels. The on-surface flows may have been formed due to formation of a transient water reservoir within the Morpheos basin 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 east part of the Hellas rim 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 of 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 probably is not related to volcanic activity and represents flows from the largely depleted initial reservoir of volatiles within HP.

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