EVIDENCE OF SURFACE MODIFICATION BY WATER AND ICE ON THE HARMAKHIS VALLIS REGION, MARS. S. Kukkonen, V.-P. Kostama, A. I. Rauhala and J. Raitala, Department of Physics, P. O. Box 3000, FI-90014 University of Oulu, Finland (soile.kukkonen@oulu.fi).

Introduction: Harmakhis Vallis is one of the four large-scale outflow channel systems (Dao, Niger, Harmakhis and Reull Valles) which cut the eastern rim region of the Hellas impact basin on Mars. This >800 km long channel is located ~450 km south of Hadriaca Patera and ~1100 km southwest of Tyrrhena Patera, cutting the surrounding suites of sedimentary and volcanic material and thus being one of the youngest features on the area. Due to the close proximity to the volcanic features, Harmakhis Vallis is likely to have been formed by the mobilization and releasing of subsurface volatiles by volcanic heat in a similar way to the other close outflow channels [1–7]. Thus it is in a key role when we are timing the volatile-driven activity on the region.

Previous studies: Previously the Harmakhis Vallis region [Fig. 1a] has been mapped based on the Viking imagery [3, 8–9]. There are also several works which focus on either different geological events [e.g., 10–13] or only on some limited regions [i.e., 14] of the area. In our works [15–16] we have presented some results of ongoing detailed mapping and dating processes based on the CTX and HiRISE images.

It has been evidenced that after the formation of Harmakhis Vallis, the channel has been modified due to the later geological processes so that the original surface of the channel floor is not detectable anymore [15–16]. In this work we gather the CTX and HiRISE data based observations that indicate that the water and ice influence on the Harmakhis Vallis region has been more complex and extensive than it has been previously thought.

Water and ice on the Harmakhis Vallis region: Previously it has been presented [7] that Harmakhis Vallis formed when the subsurface ice-storage melted due to the heat of nearly activated volcanoes. The melted ice eroded the surface when it run towards the lower topography, the Hellas basin. Finally, the surface collapsed and the now visible valley formed. After its formation, the channel was modified due to the later resurfacing processes, which are now seen as a floor covering ice-related viscous-like flows.

By looking at the structure of Harmakhis Vallis, it is clear that its evolution has been complex. One of the most significant characteristics of Harmakhis Vallis is that it is not a continuous channel. Instead, its head depression and main valley are separated by the topographically higher "barrier surface" [Fig. 1b]. Because there is no evidence of a broad and full-sized channel connection on the barrier surface, it has been presented that the connection is mainly subsurface [i.e., 14]. This indicates complex evolution of the channel and that there have been differences in the hardness of bedrock.

Correspondingly, when we mapped the Harmakhis Vallis region, we found a lot of evidence that the existence of water and ice on the region has been more extensive than it has been suggested before.

Small channels. Most of the small channels on the Harmakhis Vallis region are easily seen even in Viking and HRSC images. However, the detailed study reveals that the number of channels is bigger and that the channels have been modified due to the later processes. On the northeastern part of the Harmakhis region, the small channels seem to originate from the chaos area and the vicinity of a northern plain unit, which are interpreted to be ice rich sedimentary materials [14]. On the southern side of Harmakhis, the small channels seem to originate from the area between Reull and Harmakhis Vallis. Most of the small channels seem to cut the Harmakhis channel, so they postdate its formation.

Debris aprons. In the eastern part of the Harmakhis Vallis region, there are several debris aprons. The formation of debris aprons is typically related to the existence of ice (comparable to terrestrial rock glaciers [17]). Cutting Harmakhis Vallis, the small channels and the surrounding plains, the debris aprons are one of the youngest features on the region.

Double layered crater ejecta deposits. Harmakhis Vallis cuts the smooth plain material which consists of Hesperian-Amazonian age volcanic and sedimentary materials [3]. Thus it is expected that the number of large impact craters (D > 5 km) on the region is quite small, as it is. However, some of the big impact craters have distinctive ejecta deposit boundaries rather than an ejecta deposit of gradational thickness. Usually this kind of double layered ejecta deposits have been interpreted to form when the impacts occur in a near-surface volatile reservoir [i.e., 18] or in a subsurface ice layer [19].

Terraces around the rounded hills. After ~25 km, Harmakhis Vallis cuts a large-scale unit, measured to be hummocky plain material [i.e., 3] which has been interpreted as possible bedrock material eroded by glacial processes [14] or alternatively volcanic processes [10]. The surface of this unit is highly irregular. In places, however, the topographic highlands, i.e. the rounded hills, show evidence of several terraces which

could have formed due to the water. This might support the theory of glacial origin of the unit.

Sand paper like morphology of the basins. On the Harmakhis Vallis region, there are several small units whose morphology resembles sand paper like features. Because most of these units appear in the floor of the small channels, the outer layers in crater ejecta deposits and the basins of hummocky plain material, we present that the formation of this unit is related to water and/or ice.

Conclusion: The Harmakhis Vallis channel is suggested to have been formed when the subsurface ice melted and eroded the bedrock material. However, on the region around Harmakhis Vallis, there are several features whose morphologies and structures also require the presence of water and/or ice, and which thus indicate that after the channel formation, the water and ice have widely affected the Harmakhis Vallis region, not only the channel itself.

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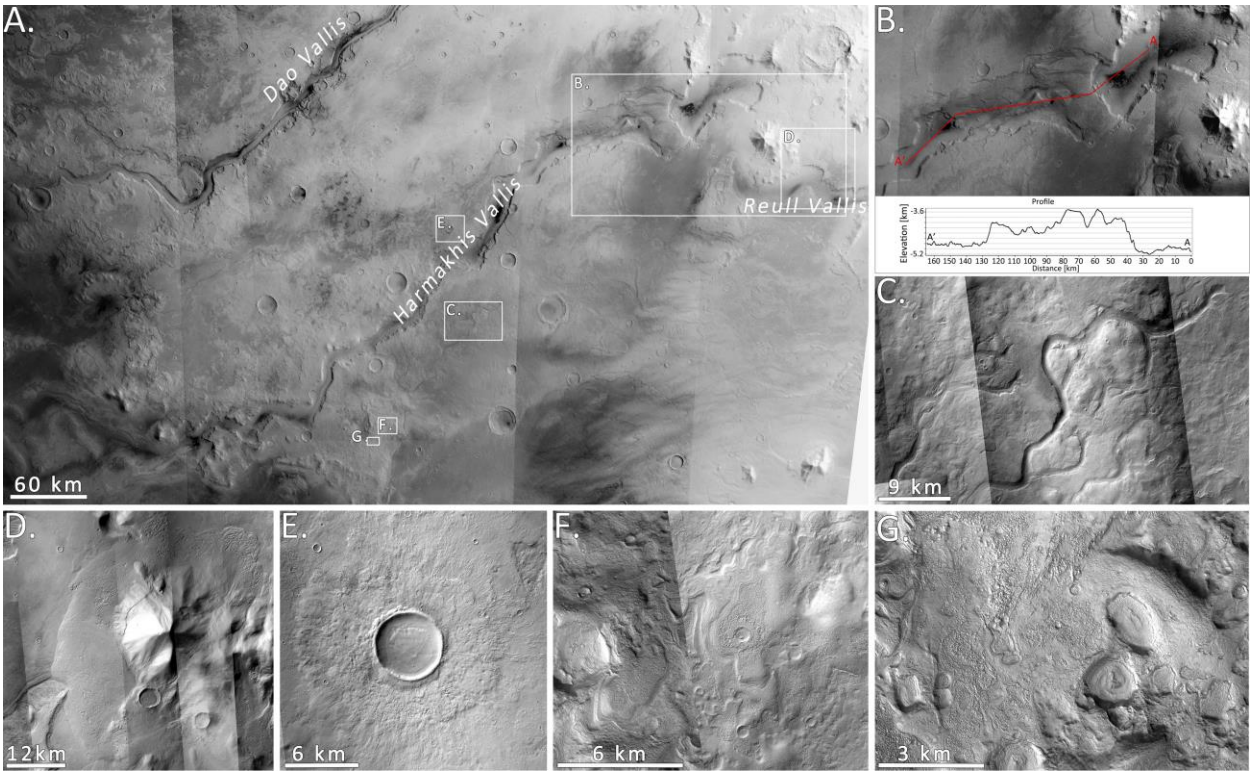

Figure 1. A) A HRSC mosaic from the Harmakhis Vallis region. The white rectangles show the locations of the CTX detail images B-G. The center of the image is at ~40.7°S, 90.3°E. B) The Harmakhis head depression is separated from the main channel by the barrier surface, the topographically higher part of the channel. C) The Harmakhis Vallis channel is surrounded by the smaller channels, which mostly postdate the formation of Harmakhis. D) Debris aprons indicate the existence and evolution of later ice-related processes such as the E) double layered ejecta deposits of impact craters. F) The terraces around the rounded hills and G) sand paper like features in the basins possibly indicate the existence of water.