MODIFICATION HISTORY OF THE HARMAKHIS VALLIS OUTFLOW CHANNEL, MARS.

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Introduction: Harmakhis Vallis is one of the four major outflow channel systems (Dao, Niger, Harmakhis and Reull Valles) which cut the eastern rim region of the Hellas basin, the largest well-preserved impact structure of Mars. The structure of Harmakhis Vallis, the volume of its head depression and the earlier dating studies of the region suggest that the channel formed in the Late Hesperian period by collapsing when a large amount of subsurface fluids was released (e.g. [1–5]). Thus, Harmakhis Vallis, as well as the other nearby outflow channels, represents a significant stage of the fluvial activity in the regional history. On the other hand, the channel lies on the Martian mid-latitude zone, where there are several geomorphologic indicators of past and possibly also contemporary ground ice (e.g. [2]). The floor of Harmakhis also displays evidence of a later-stage ice-related activity as the channel is covered by lineated valley fill deposits and debris apron material.

The purpose of this work is to use mapping and dating to find out how the floor of Harmakhis Vallis has been modified after its formation, what kind of geological processes have modified the channel and when, and by doing so, provide further understanding of the channel evolution (see also our previous works [6–7]).

Data and methods: The mapping and dating are based on MRO's full resolution CTX data (~5 m/pixel). To support the mapping, the images of Mars Express' HRSC (~50 m/pixel) and Mars Odyssey's THEMIS infrared (day and night, 12.5–50 m/pixel) cameras were also used.

The age determinations were conducted by following the established crater count methods [8–10], and the crater model ages were measured from the cumulative crater size-frequency distribution plots obtained by the Craterstats software [11].

Results: The mapping results of the Harmakhis Vallis floor show that due to the strong resurfacing, the remnants of the original, uncovered Harmakhis Vallis floor may be observable only on small regions on Harmakhis' main channel and "barrier surface" (~80 km long, topographically significantly higher segment, which represents the still existing subsurface part of the channel and which separates the Harmakhis head depression from the main channel [12]). On the barrier surface, the uncovered surface unit has a terrace structure indicating that at least on this part of the channel the on-surface activity included several flow pulses (Fig. 1).

Our mapping results also support the earlier findings according to which Harmakhis has been modified after its formation by the lineated valley fills and other flow-like deposits [2–5] which now cover the channel almost entirely. Based on the stratigraphic analysis and crater counts, the formation of these flow-like units ended no later than 400 Ma ago. In addition, we dated 2-3 resurfacing events for the ice-related units.

The nature of the resurfacing processes, however, is still partly unknown. Due to the possible ice content, the units can be assumed to have suffered sublimation as Martian ice-content features usually do (e.g. [13]). Correspondingly, as the existence of the compressed lineations in the units evidences, the units have been in motion, which has also modified and destroyed the recorded crater populations. The crater morphology analyses support these assumptions, as many of the largest craters on the units display a similar morphology as flat "oyster-shell", ring-mold or heavily subdued ghost craters, i.e. the typical craters on the ice-rich substrate covered by an ice-poor debris till and modified both due to the ice sublimation and flowing of the unit, (e.g. [14–16]). In addition, the Harmakhis Vallis floor has clearly suffered quite recent wind erosion, as the channel is covered by several fresh dune-like transverse ridge fields and other eolian deposits. These eolian features are observable especially on lower Harmakhis (Fig. 2), which means that at the time of the eolian activity, the ice content on lower Harmakhis units must have been lower than on upper Harmakhis, as there must have been more uncemented dust susceptible to being carried away by the wind to form the ridges which are observable now. Even though on upper Harmakhis Vallis there is also some evidence of eolian activity, the number of these features is clearly lower (Fig. 2).

The appearance of the flow-like units also varies in different parts of the channel, supporting the assumption of the varying (ice)content and/or the modification history of the units. The number and size of the features (e.g. pits and buttes) which are usually considered to characterize ice-content material is smaller, the texture of these features is finer, and the compressed ridges and lineations formed by the flowing of the units seem to be significantly smaller and have a sparser distribution on lower Harmakhis compared to the upper Harmakhis channel.

The correlating resurfacing ages of the nearby units evidence that the later modification processes have occurred at least on a local scale on the Harmakhis Vallis region, not only on separate units. This in turn may indicate that the processes were results of some larger-scale change, for example in the Martian climate. On the other hand, due to the significant modification, the now measured oldest cratering model ages of the flow units do not straightforwardly represent the absolute formation ages of the units. In many cases, the crater count results are not consistent with the stratigraphical studies, which means that at least some of the oldest modification processes (for example sublimation or motion of the flow-like units) must have been so intensive that the earlier superposed crater populations have been destroyed completely or almost completely.

Conclusion: The mapping and dating results from the Harmakhis Vallis floor support the earlier studies according to which Harmakhis has been modified after its formation by several processes, the most significant of which is the formation of the lineated valley fill units, which ended no later than 400 Ma ago. The deposits now cover the channel almost entirely. The modification of the lineated valley fills has been a complex and multi-stage process and the fills have resurfaced several times, usually 2 or 3, after their formation due to sublimation, ice flow and eolian activity (and possible other processes).

The appearance of the flow-like units clearly varies in different parts of the channel, indicating the different (ice-)content and/or the modification history of the units. This is supported by the finding that the features formed by eolian activity are more abundant on lower Harmakhis Vallis than upper Harmakhis.

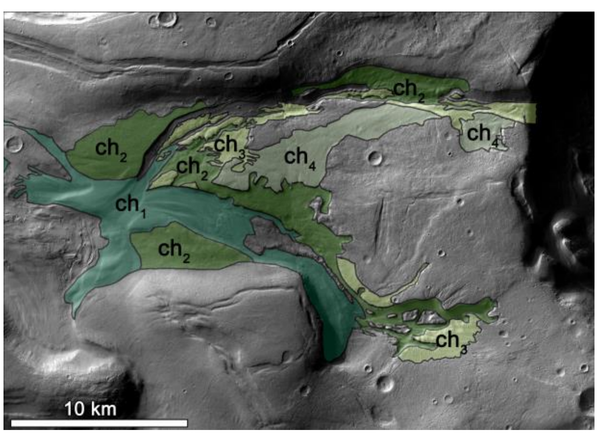

Figure 1: CTX detail of the terrace structures (ch_1-ch_4) on the valleys on the western barrier surface. The valleys were probably formed due to the on-surface activity of the barrier surface. The number of terraces indicates that the valleys were carved by at least four flow events.

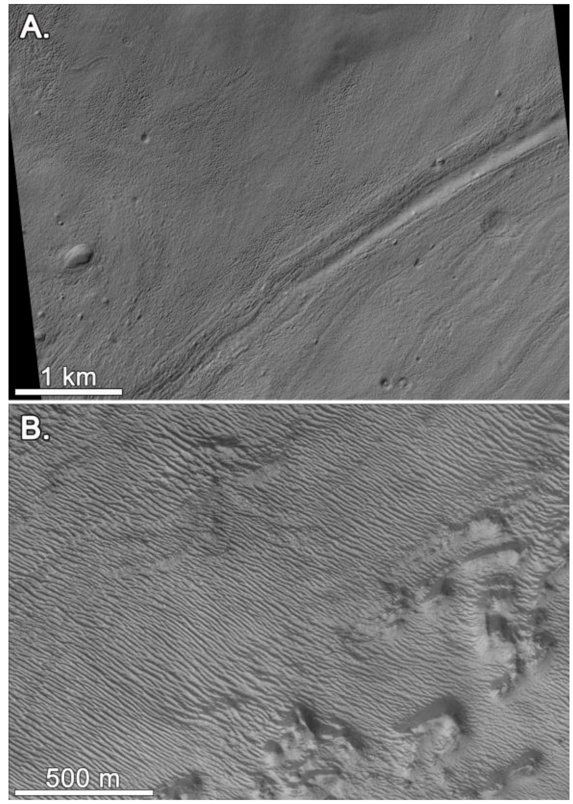

Figure 2: HiRISE detail of the texture of the flow-like units on A) the upper Harmakhis and B) the lower Harmakhis main channel. The different appearance of the units and the number of features formed by the eolian activity are indicators of the different (ice-)content and/or the modification history of the units.

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