MAPPING AND DATING THE OUTFLOW CHANNELS ON THE NORTHEASTERN HELLAS RIM REGION OF MARS BY USING HIGH-RESOLUTION IMAGES: A CASE STUDY OF HARMAKHIS VALLIS.
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Introduction: The Hellas basin is one of the most significant impact structures on Mars. Its northeastern rim region is characterized by four distinct outflow channel systems which also represent the most prominent episodes of fluvial activity in the region. The channel systems cut the Late Noachian–Early Amazonian age volcanic, sedimentary and mixed material of the Hellas rim being thus one of the youngest features there [e.g. 1–3].

Harmakhis Vallis is one of the outflow channels on the northeastern Hellas rim region. It starts as a broad (38 x 90 km) and deep (in places > 1.6 km) depression. Due to the lack of the other fluvial features around the head depression, it is suggested that the source of the channel has been subsurface and the channel formed when this source, probably ice, melted due to the volcanic heat from the nearby volcanoes activation [e.g. 1–5]. When the released water ran towards the regional slope of the Hellas basin, the surrounding surface eroded until it finally collapsed, and the now visible valley formed.

Harmakhis Vallis has very varying structure which indicates that the evolution of the channel after its formation has been complex. For example, one prominent characteristic of Harmakhis is that it is not a continuous channel. Instead, its head and main channel are separated by the ~80 km long and ~0.4–1.8 km high “barrier surface” [6] (Fig. 1a) which probably represents the still existing subsurface part of the channel.

In this work we outline our results of mapping and dating the geologic activity on the Harmakhis Vallis floor (see also our previous studies [7–9]).

Data and methods: The used data consist of a full resolution CTX mosaic (~5 m/pixel) which cover the entire channel system. In addition, we use separate HiRISE images (~0.3 – 0.5 m/pixel) the availability of which is, however, limited, and most of which focus on the wall of the channel only. In mapping, images of Mars Express’ HRSC (~ 50 m/pixel) and Mars Odyssey’s THEMIS infrared (day and night) camera were also used. All image data have been imported onto a GIS environment, where the mapping and crater counts have been performed. In the case of crater counting [e.g. 10–12], the crater model ages were measured by using the Craterstats software.

Challenges of the study: In the case of Harmakhis Vallis, the region has experienced significant recent modification and degradation [e.g. 9], and thus the surface of its floor is relatively young and the craters superposed to it are relatively small. Thus the using of small craters (<500 m) in crater counting is arguable. On the other hand, usually when we are viewing at the small craters, the distribution of secondary craters is significant and thus the usability of small craters in age determination may be debatable. However, now we can assume that the units covering the channel mostly postdate the latest secondary forming impacts, so that most of the small craters are primaries. Thus only obvious secondary craters were excluded from the counts in order to minimize the error.

A second restrictive factor in this study is the carrying quality of the CTX images (this is significant because now we are counting craters, the diameter of which is relatively small compared to the image resolution) with the relatively small units and thus with the small counting areas. Small number of small craters on small counting areas naturally limits the reliability of the crater counting results.

Results and discussion: Mapping on Harmakhis Vallis shows that the channel is almost entirely (also a part of the barrier surface) covered by the flows the varying texture of which indicates that they are ice-facilitated. Crater count results (Figure 1b) evidence that the flow units are relatively young. The oldest cratering model ages were found on the flow of the head depression and near the end of the main channel, and also these ages are only ~1 Ga. Otherwise, the oldest founded ages are mainly between ~100Ma and 350Ma (except for a oldest age of ~70 Ma at the beginning of the main channel and an age of ~15 Ma near the end of the channel). However, all of the units also show evidence of ~1–3 resurfacing events, the ages of which correlate with each other on different units. This might indicate that several channel-scale resurfacing processes have occurred on the channel, varying only locally in intensity and duration. The results of HiRISE data support this assumption (Figure 2).

It is still unclear why the ‘oldest age’ of ~0.1–1Ga is disappearing from some flow units. Because the resurfacing ages of the flows seem to correlate throughout the channel and there is no evidence of significant deposition on the flow units, it is implausible that the oldest ages (~100 Ma) would be the formation ages of these units, even though the measured crater size-frequency distributions do not show evidence of any older ages. One reason for the lack of older ages could...
be the possible ice-facilitated nature of the flows and thus the crater erosion caused by ice sublimation. If the erosion rate has varied on different parts of the channel, it may be seen in the crater size-frequency distributions as a lacking of some crater populations.

**Conclusion:** The original floor of the Harmakhis Vallis channel is completely modified by later processes which are now seen mainly as the possibly ice-facilitated flows the oldest measurable cratering model age of which varies from ~ 0.1–1 Ga. Due to the possible ice-facilitated nature of the flows, this may be only the youngest limits for the formation age. All of the flows also have several resurfacing ages which can be roughly divided in three phases. The results of HiRISE data indicate that although on the channel, there have occurred several channel-scale resurfacing processes, the intensity and duration of them have varied locally.


**Figure 1:** A) A CTX mosaic of Harmakhis Vallis and B) an overview of the crater counting results for the flow units on different parts of the channel floor. The dashed lines indicate the location of the barrier surface and the different colors show the location of measured ages (see the labels; the lined units correspond the ages based on the ≤4 craters only). The crater counting results indicate that the flow units have suffered at least three separate resurfacing events after their formation.

**Figure 2:** An example of the crater count results from Harmakhis Vallis based on the CTX (area A, outlined by white) and HiRISE images (area B and C, outlined by red). Differences in the HiRISE results are probably caused by the local differences of resurfacing processes.

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