Evolution of the Fluvial Systems in the Eastern Hellas Region, Mars: A Case Study of Dao Vallis

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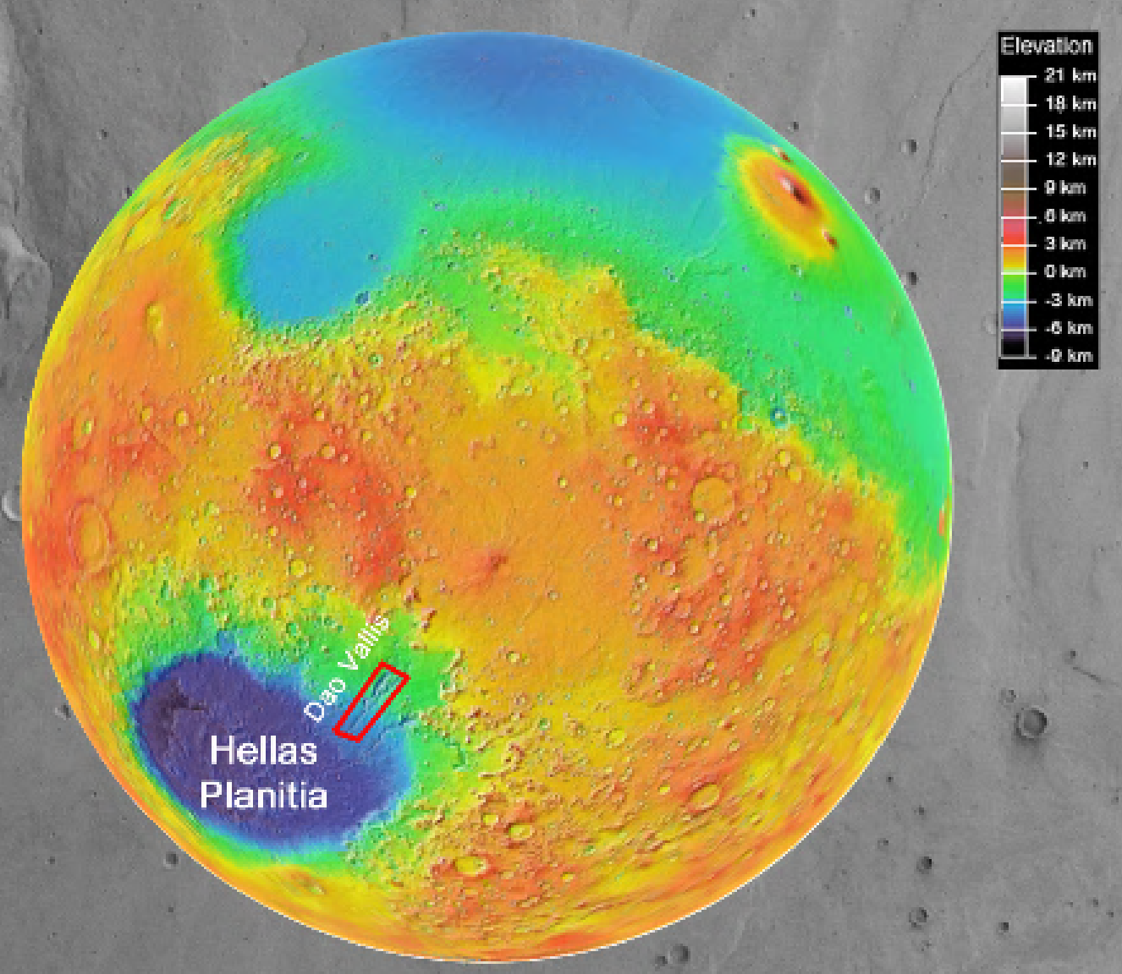
1. Introduction

In this work we apply the crater counting procedure and date the fluvial and glacial-like activity mapped on one of the large Martian channels, Dao Vallis. The dating was conducted at 6m/pixel using CTX (Mars Reconnaissance Orbiter's Contex Camera) mosaics (cf. central image) and at 0.25-0.5 m/pixel using HiRISE (High Resolution Imaging Science Experiment) data. Previous results of our dating and mapping are presented in Korteniemi et al. (2012).

Our aim is to identify how the units on the floor of Dao Vallis relate to each other and the canyon formation. The work is part of an ongoing project looking into the eastern Hellas fluvial systems, where the goal is to form a detailed picture of the drainage system evolution and to relate them to changes in the Martian climate.



2. Hellas Planitia and Dao Vallis

Hellas Planitia is one of the largest known impact structures in the Solar System. The northeastern rim region of the basin is characterized by several channel features, which represent the most prominent episodes of fluvial activity in the area. The northernmost channel is known as Dao Vallis. The channel system of Dao Vallis extends for about 1200 km from the southern margin of the Hadriaca Patera volcano. The channel apparently starts from a head depression with a volume of 11.4×10^3 km^3 (Kostama et al., 2010). It continues in a well-delineated, 40 km wide canyon and extends down into the floor of Hellas where it terminates. The canyon can be divided into three segments which differ in their topography. The upper and middle parts of Dao Vallis are anomalously wide and deep. The steep sided lower part of Dao Vallis runs toward the floor of the Hellas basin where it disappears, leaving little evidence for deposits at its mouth. Crown and Bleamaster (2004) presented the following evolutionary sequence for the formation of Dao Vallis:

1) withdrawal of underlying support and potential removal of subsurface volatiles,
2) vertical collapse and surface fracturing,
3) sapping and surface runoff facilitated by collapse-induced topography,
4) wall collapse and erosion,
5) resurfacing of the channel floors.

2.1 The morphology of Dao Vallis

The floor of upper Dao Vallis consists of varying surface units. The beginning of the channel is characterized by smooth floor material (viscous-flow patterns (*vf*) and smooth central valley unit (*Sd*)), which ends at the plateau remnant and continues after that as chaotic floor material. The chaotic material consists of numerous rounded hills (remnant massifs, *rm*) and mass movement deposits that are partially covered by material with viscous-flow patterns. The rounded hills are plausibly consistent with eroded down-dropped plateau remnants and mass movement deposits. Viscous-flow materials continue at middle and lower Dao Vallis and they are a prevalent surface feature of the channel's floor. The floor of lower Dao Vallis shows a distinct regional slope along its length. On the base of the lower channel, there is no evidence of the rounded hills that were present in the upper part of the channel.

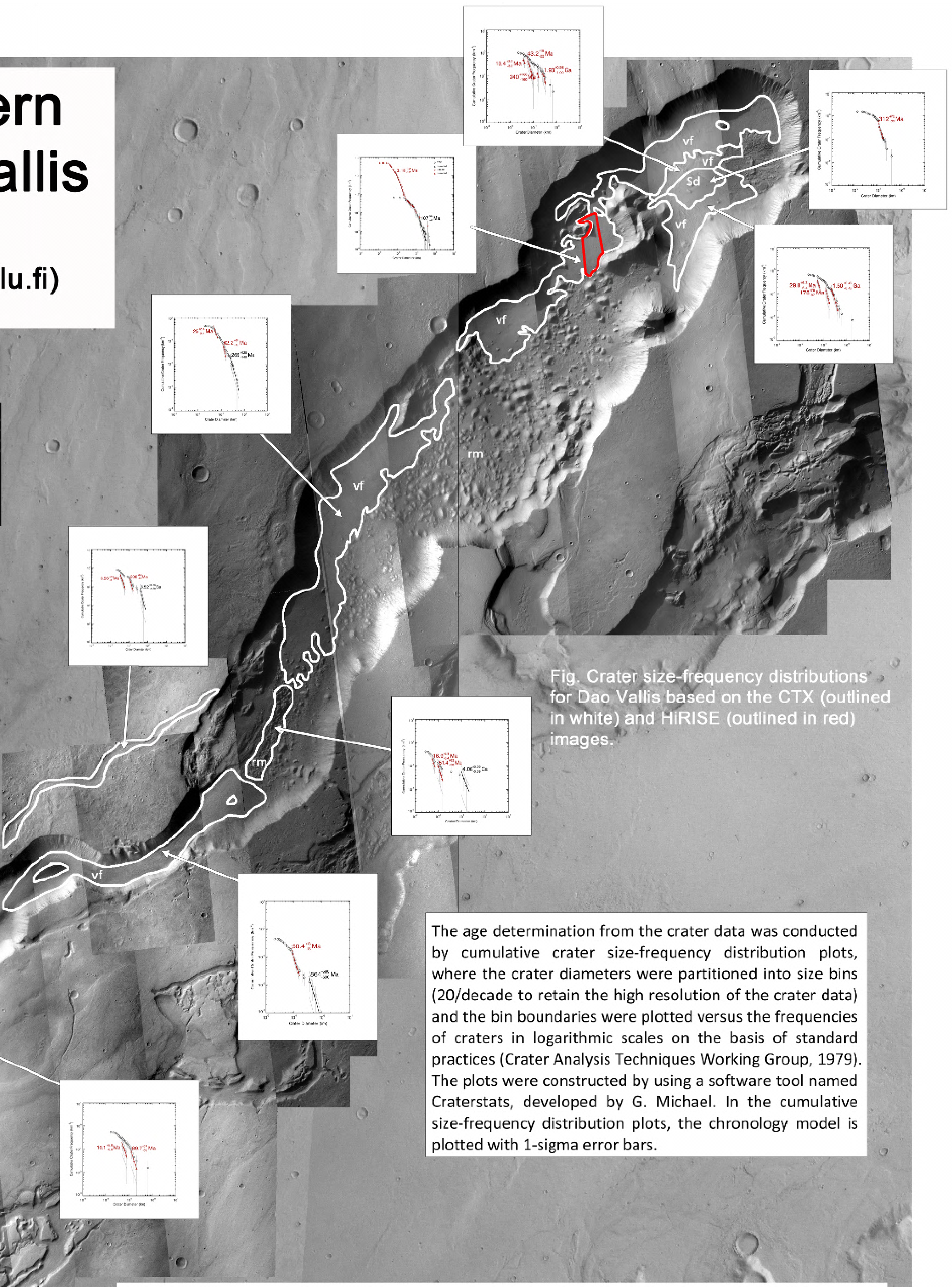
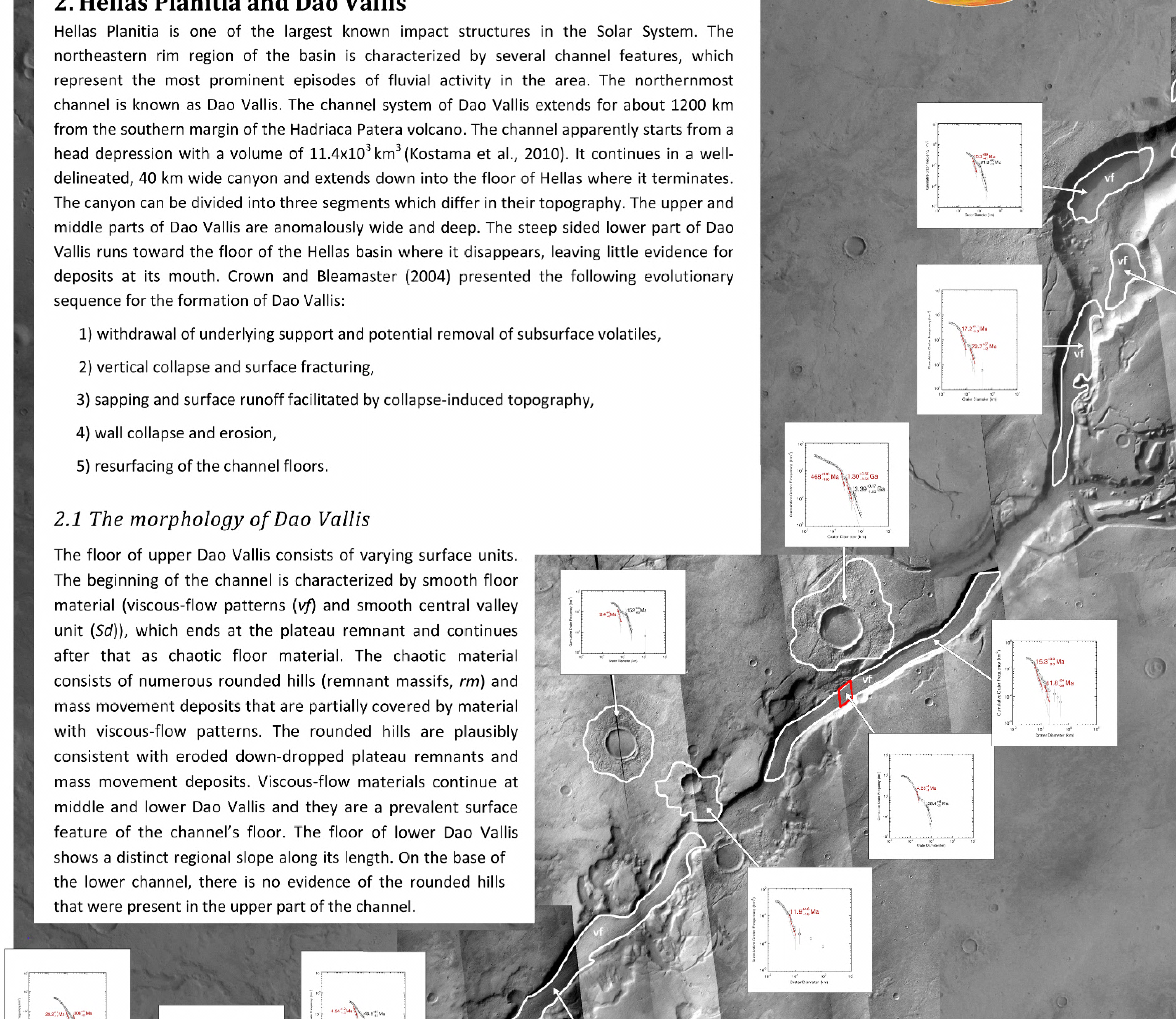
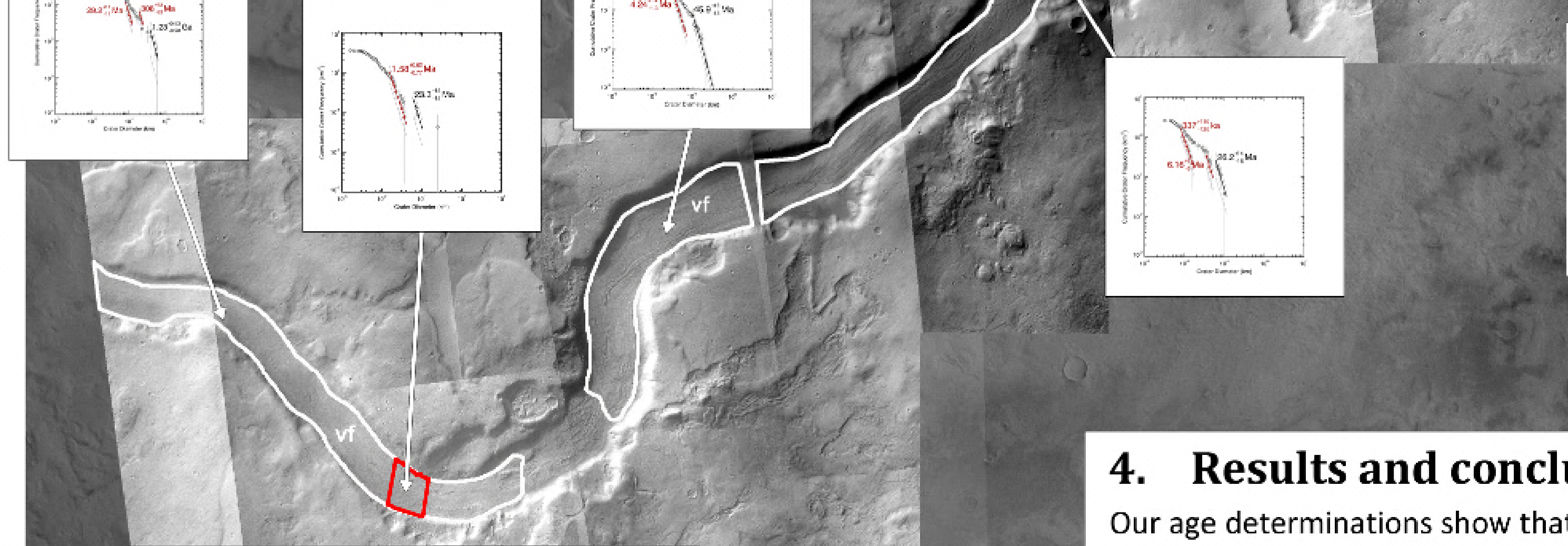


Fig. Crater size-frequency distributions for Dao Vallis based on the CTX (outlined in white) and HiRISE (outlined in red) images.

The age determination from the crater data was conducted by cumulative crater size-frequency distribution plots, where the crater diameters were partitioned into size bins (20/decade to retain the high resolution of the crater data) and the bin boundaries were plotted versus the frequencies of craters in logarithmic scales on the basis of standard practices (Crater Analysis Techniques Working Group, 1979). The plots were constructed by using a software tool named Craterstats, developed by G. Michael. In the cumulative size-frequency distribution plots, the chronology model is plotted with 1-sigma error bars.





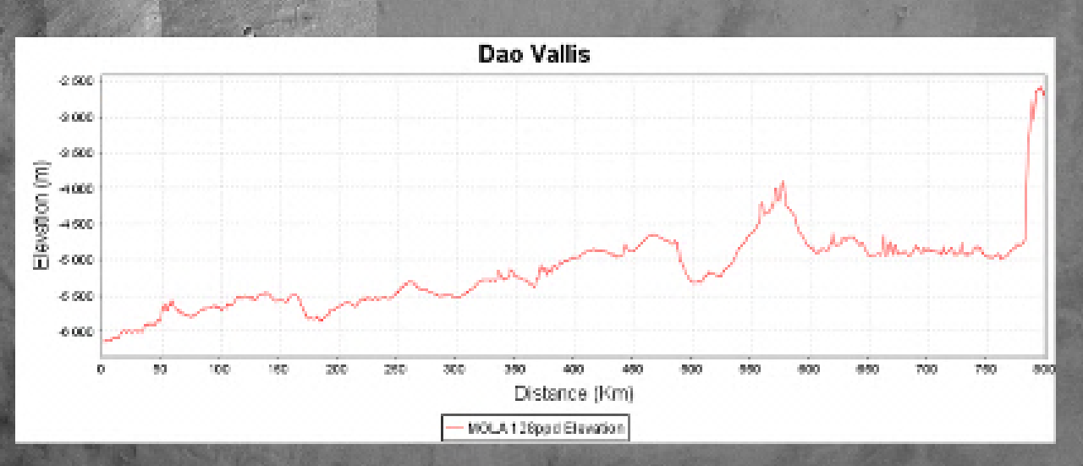


Fig. The topographic profile along thalwegs of Dao Vallis.

3. Crater counting methods and age determination

The dating of planetary surfaces is one of the latest applications of crater statistics. Because impact crater forming is a highly time dependent process and craters form at random locations on planetary surfaces, it is possible to measure the relative ages for the surfaces by comparing the crater density of the surfaces. Absolute ages are possible to obtain from relative ages, when the correlation between the crater density of the surface units and a radiometrically determined formation age of those units is known.

So far, the Moon has been the only body, from where there have been returned samples, thanks to the Apollo and Luna flights. Thus, Ivanov (2001) derived the cratering rate of Mars relative to the Moon by comparing the numbers of Mars-crossing and Earth-crossing asteroids. According to his determination, the rate of impacts per unit area on Mars is 2.04 times the rate for the Moon for the same-size projectiles. Hartmann and Neukum (2001) created a polynomial crater chronology function for Mars using the same scaling laws as for the Moon. The ages are determined from the following expression, which relates the cumulative number of craters larger than 1 km in diameter N(1) to time T in Ga:

$N(1) = 3{,}22 * 10^{-14} (e^{6{,}93T} + 1) + 4{,}875 * 10^{-4} T$

3.4 Resurfacing correction

Different geologic processes (e.g. eolian erosion, volcanism, and tectonic disruption) typically change the crater population by removing members from the low-diameter end of the distribution. On a cumulative crater frequency plot, the effect of the resurfacing is seen as a step between two segments. If there is no correction for the resurfaced surface, the age is overestimated due to the large craters which were formed before the resurfacing event ended.

In this work we used the resurfacing correction, which was developed by Michael and Neukum (2010). The correction estimates the expected larger population from the younger segment of the distribution by iterative fitting of the production function.

4. Results and conclusions

Our age determinations show that the oldest units on Dao Vallis are located in the head of the channel, from where we found ~1.50 Ga and ~1.92 Ga old viscous flows and 4.06 Ga old rounded hills. The oldest viscous flows surround the central valley unit *Sd*, which is clearly younger, ~312 Ma old, and plausibly consists of sediments. The other viscous flows are younger: the age of the base units varies between 107 Ma and 864 Ma, if the error bars are taken account, with the resurfacing events occurring at 41.8 - 89.7 Ma and 10.3 – 25 Ma.

The bottom of Dao Vallis is completely covered by periglacial deposits. Even most of the large impact craters are covered or eroded. Thus, the original formation age of the channel cannot be measured directly. However, there are three large impact craters whose ejecta blankets were cut by the channel. By analyzing them, we get at least an upper boundary for the formation age of Dao Vallis. Our results show that the formation ages of the ejecta blankets are 3.39 Ga, 11.9 Ma and 152 Ma.

Comprehensive dating on high resolution and high quality CTX and HiRISE images proved to be a very powerful tool in understanding the local and regional processes. We will continue to investigate the various aspects of the regional fluvial history of Dao Vallis.

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