CRATER COUNTS BY USING THE CTX AND HIRISE IMAGES: A CASE STUDY OF THE HARMAKHIS VALLIS CHANNEL, MARS. S. Kukkonen and V.-P. Kostama, Astronomy and Space Physics, P. O. Box 3000, FI-90014 University of Oulu, Finland (soile.kukkonen@oulu.fi, petri.kostama@oulu.fi).

Introduction: The usability of small (diameter < 500 m) impact craters in crater counting has been the subject of ongoing debate for a long time [1–5]. Originally, small impact craters were not used in crater counts because of the uncertainty of their origin (primary or secondary crater). Nowadays, owing to the very high-resolution data, the established practice is that small craters can be used in age determination, if obvious secondary craters and clusters are excluded and the areas showing signs of recent large impact craters are avoided (e.g. [1]).

Small impact craters offer valuable information about surface history, especially recent, short-time or small-scale geologic processes, which are not necessarily available for detection by using only large impact craters for age determination. Additionally, in some cases small impact craters are even the only way to measure the age of the surface, for example on young surfaces or small surface units. Thus, it is very important to study their role in the age determination.

The availability of the new high-resolution images obtained by the CTX and HiRISE cameras onboard MRO makes it possible to extend the crater size-frequency distributions to smaller craters providing new insights about the later evolution of the surfaces. In this work we present some results of our crater counts on Harmakhis Vallis (see also our previous works [6–8]], one of the northeastern Hellas outflow channels, based on the CTX and HiRISE datasets. In addition to the evolution studies of Harmakhis Vallis, we compare the results of the different data and thus reveal information on the benefits and limitations of very high-resolution imagery used in age determination studies.

Data and methods: The Hellas basin is one of the largest known impact structures on Mars. Its northeastern rim region is characterized by several channel features, the most prominent of which are the large outflow systems of Dao, Niger, Harmakhis and Reull Valles [8–9]. The outflow channels cut the eastern Hellas sedimentary and volcanic deposit suites mostly postdating their emplacement (e.g. [5]). However, the channels also show evidence of later evolution as their surfaces are covered by large-scale viscous-like flows.

Now we estimate the cratering model ages for the Harmakhis Vallis floor units using established crater count methods (e.g. [10–13]). The age determinations were conducted using the Mars Reconnaissance Orbiter's CTX and HiRISE datasets. Although the HiRISE imagery has a better spatial resolution, ~ 0.3 – 0.5 m/pixel, which is an important factor on this kind of young and modified surfaces with only few craters having a diameter of > 1 km, the availability of the HiRISE images is limited. Additionally, on Harmakhis Vallis many of them focus on the wall of the channels only. On the other hand, the CTX images cover the entire channel system with a resolution of ~ 5 m/pixel.

All the image data were imported onto a GIS environment, where the floor units of the Harmakhis channel were mapped and dated. The crater model ages were measured using the Craterstats software.

Results and discussion: Mapping on Harmakhis Vallis shows that the channel is almost entirely covered by the flows, the varying texture of which indicates that they are ice-facilitated (see [8]). Because the craters superposed to the flows are relatively small, we can assume that their relative age is young, and for successful dating the using of very high-resolution images is necessary. In addition, the areas of the flow units are relatively small, which also limits the number of occurring large craters. On the other hand, the use of very high-resolution images and their small craters for dating is acceptable because we can assume that most of the small craters on the Harmakhis Vallis floor are primaries. Usually, in the small crater populations the distribution of secondary craters is significant and thus the usability of small craters in age determination may be debatable. In the case of Harmakhis Vallis, however, the flow units are relatively young, and thus their formation and modification probably mainly postdate the latest secondary-forming impacts, so the superposed craters are mainly primaries.

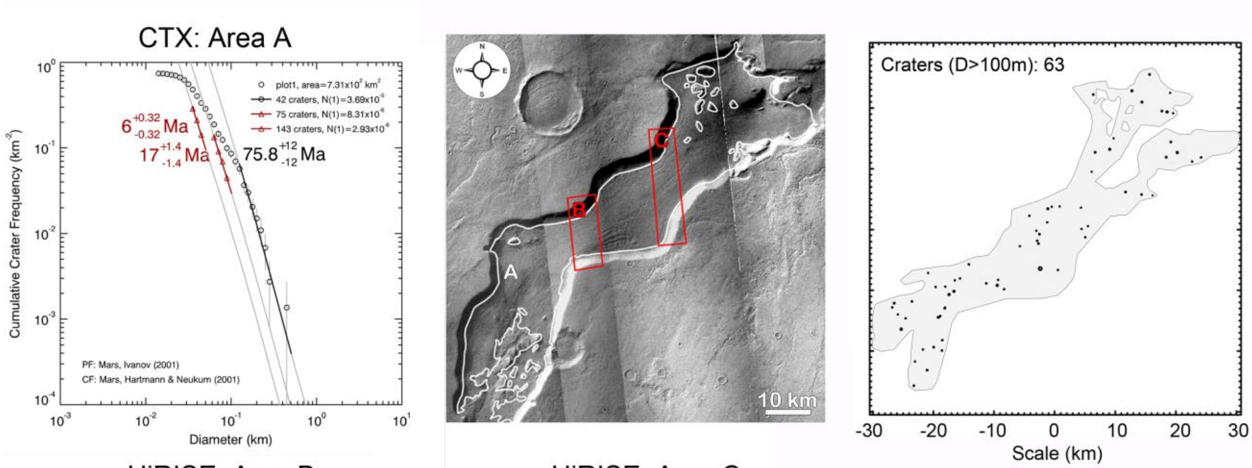
The crater count results according to the CTX data on the Harmakhis Vallis floor units show that the oldest measurable cratering model age of the flow units varies from ~ 0.1–1 Ga. Due to the possible ice-facilitated nature of the flows, these may however be only the youngest limits for the oldest possible age. All the flows also have several resurfacing ages. On the other hand, the results of HiRISE data indicate that although several channel-scale resurfacing processes may have occurred on the channel, their intensity and duration may have varied locally. Figure 1 shows an example of the crater count results from a flow unit at the beginning of the Harmakhis Vallis main channel. A CTX mosaic (Area A in Fig. 1) gives three ages for the unit, a formation age of 75.8 Ma and resurfacing ages of 17 Ma and 6 Ma. Additionally, there are two HiRISE images which cover parts of the unit. The first

HiRISE image (Area B, Fig. 1) gives three ages for the unit which correlate well with the CTX results (oldest age of 86.9 Ma and resurfacing ages of 10.6 Ma and 5.82 Ma). However, the second HiRISE image (Area C, Fig. 1) shows only two ages: 16.3 Ma and 6.57 Ma. In this case, we found three possible alternative reasons for this. 1) The flow unit, which seems to be homogenous in the CTX scale, may actually consist of several units which can be detected in the HiRISE scale only. 2) In some parts of the channel, the flow unit may be so thin that large craters on older underlying units can be detected. 3) It could also be possible that there have been local differences in resurfacing intensities or scales, which have caused the large crater population (D > ~ 100 m) to be erased in places (in this case on Area C, but not on Area A or B). A detailed HiRISE mapping, the morphology of the large craters and crater distribution studies, however, reveal that in this case the main reason may be the differences in resurfacing events.

Conclusion: Small (< 500 m) impact craters are very useful and sometimes even the only way to get information about short-time, small-scale or young geologic processes of surfaces. Although the crater count data of HiRISE images in many cases correlate quite well with the data of lower resolution CTX images, it is good to be careful when only single HiRISE images are used for age determination on larger units. All the results obtained from a specific counting area always primarily represent the results of that area – not the whole unit. On the other hand, together with CTX images, HiRISE images are a very valuable tool for getting additional information about the local processes of the surface units.

References: [1] McEwen A. S. et al. (2005) *Icarus, 176, 351–381.* [2] Hartmann W. K. (2005) *Icarus 174, 294–320.* [3] Hartmann W.K. *(2007) Icarus, 189, 274–278*. [4] Werner S. C. et al. (2009) *Icarus, 200, pp. 406–41*7. [5] Hartmann W. K. and Werner S. C. (2010) *Earth and Planetary Science Letters, 294, 230-237.* [6] Kukkonen S. et al. (2013) *LPS XLIV,* abstract #2140. [7] Kukkonen S. et al. (2013), *EPSC2013*, #743. [8] Kukkonen S. et al. (2014) *LPI Contribution 1791,* abstract #1218. [8] Greeley R. and Guest J. (1987) *USGS Map I-1802-B.* [9] Leonard G. and Tanaka K. (1998) *USGS Map I-2557.* [10] CATWG (1979) *Icarus, 37,* 467-474. [11] Ivanov B. (2001) *Space Sci. Rev. 96,* 87-104. [12] Hartmann W. K. and Neukum G. (2001) *Space Sci. Rev. 96,* 165-194. [13] Michael G. and Neukum G. (2010) *EPSL, 294, p. 223-229.*

Additional Information: S.K. is sincerely grateful to Jenny and Antti Wihuri Foundation for funding this study.



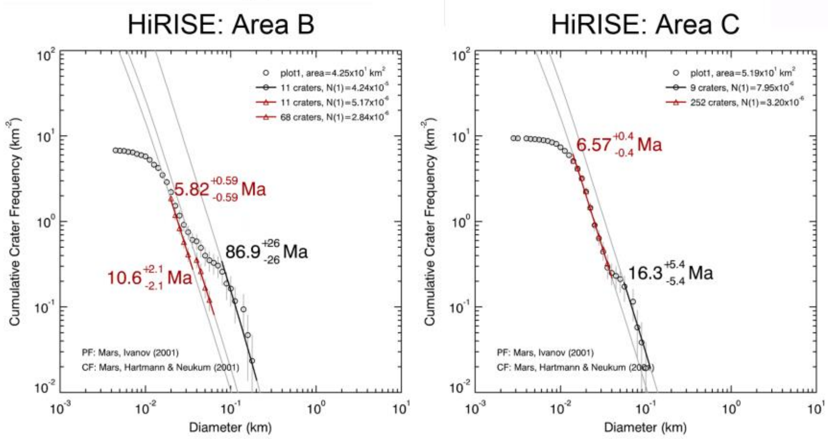


Figure 1: An example of the crater count results on the flow unit from Harmakhis Vallis based on the CTX (area A, outlined by white) and HiRISE images (areas B and C, outlined by red). Areas A and B shows that the unit has resurfaced twice after the formation. On Area C, however, only these resurfacing ages can be seen, possibly due to the local differences between resurfacing processes. The upper-right image shows the distribution of the crater population (D>100m) which forms the oldest age.