UPDATE ON THE CRATER CLUSTER MAPPING AND STATISTICS ON MARS. T. Neidhart[1], K. Miljković[1], I. J. Daubar[2], E. K. Sansom[1], A. Gao[2], D. Wexler[2], J. Eschenfelder[3], G. S. Collins[3], [1]School of Earth and Planetary Sciences, Curtin University, Perth, Australia (tanja.neidhart@postgrad.curtin.edu.au), [2]Brown University, Providence, RI, USA, [3]Imperial College, London, UK.

Introduction: An increasing number of new impact craters on Mars that formed in the last 15 years has been detected using before and after imaging by MOC (Mars Orbiter Camera) onboard of MGS (Mars Global Surveyor) and CTX (Context Camera) onboard MRO (Mars Reconnaissance Orbiter) [1-2]. These impact sites were first seen as dark spots in lower resolution images obtained from MOC [1]. The dark spots (or halos) form during the impact process where the bright surface material is removed. Later higher resolution images obtained by the narrow-angle camera of MOC and by HiRISE (High Resolution Imaging Science Experiment) revealed single craters or crater clusters within those halos [1-2]. Studying these new impact sites gives information about the impact flux on Mars [3], fragmentation in the atmosphere and even the excavation of ice in mid- and high-latitude regions [4-5]. Studies by [3] measured the diameters of 44 new craters and crater clusters to calculate the current impact rate on Mars. Furthermore, [2] studied the properties of 77 recently formed crater clusters: the number of craters in the clusters, size of cluster, dispersion (standard deviation of distances between each possible combination of pairs of craters) and impact angle. A weak correlation between the number of craters and dispersion and also a weak correlation between effective diameter and dispersion was found [2], where the mean value for effective diameters of clusters found in this study was 9.1 m [2].

Since the InSight (Interior Exploration using Seismic Investigations, Geodesy and Heat Transport) mission landed on Mars in 2018 [6], the search for newly formed impact craters became even more important, because identifying impacts in seismic signals could provide further constraints on the impact cratering process on Mars associated with atmospheric effects as well as help with placing further constraints on the properties of the uppermost crust on Mars [7-8].

Aims: This work contributes to the newly updated catalogue of crater clusters on Mars [9]. This builds on the previous study [2] in which a smaller number of crater clusters was first investigated in detail. Here we present similar measurements of a larger dataset of clusters of craters. We study properties of 460 crater clusters: the largest crater in the cluster, the number of craters within a cluster, dispersion and aspect ratio of the best-fit ellipse to get more information about fragmentation processes and the mechanisms of impacts on Mars. We also measured diameters of 400 single craters.

Methodology: We used images from HiRISE [10] having a pixel scale of 0.25 m/pixel. Craters were measured using ArcMap software with the CraterTools add-in [11]. Best-fit ellipses and their aspect ratio were calculated as described in [2]. The MOLA (Mars Orbiter Laser Altimeter) elevation map was used to determine the elevations of these newly mapped crater cluster sites. We measured the diameters of all craters associated with a new crater cluster down to 1 m in diameter. The criteria for a crater to be included as part of a new cluster was that it must be fresh and associated with the image-constrained blast zone.

Results and discussion: At present, 1156 recent impact sites have been identified and added to the cluster database. 58% of these impacts are clusters, comprising 2 to 465 craters (larger than 1 m in diameter); on average clusters consist of 18 individual craters (Fig. 1).

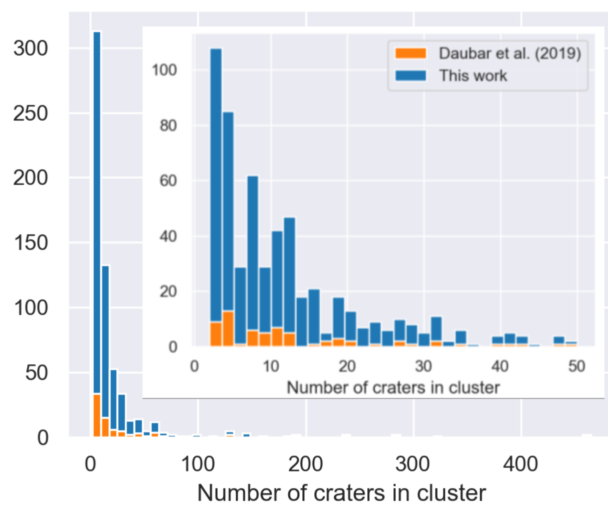

Figure 1: The histogram shows the number of craters within a cluster for recently formed crater clusters on Mars from this study and [2].

The largest crater cluster has an effective diameter of ~34 m; on average crater clusters have an effective diameter of 8 m. Clusters are observed at altitudes from -6.72 to 17.91 km. Figure 2 shows the distribution of effective diameters of crater clusters from this study and [2]. (The effective diameter D_{eff} is defined as $D_{eff} = \sqrt[3]{\sum_i D_i^3}$ [3], where D_i is the individual crater diameters in a cluster).

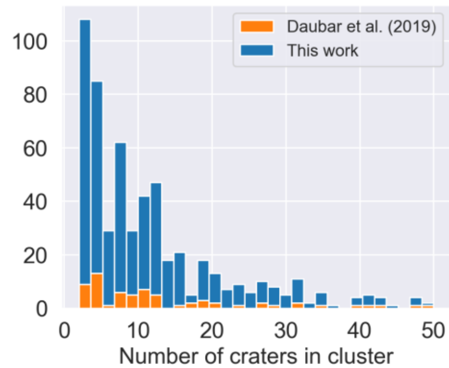

Figure 2: Histogram showing the effective diameters of recently formed crater clusters on Mars.

Figure 3 shows the effective diameter as a function of the largest crater within the cluster.

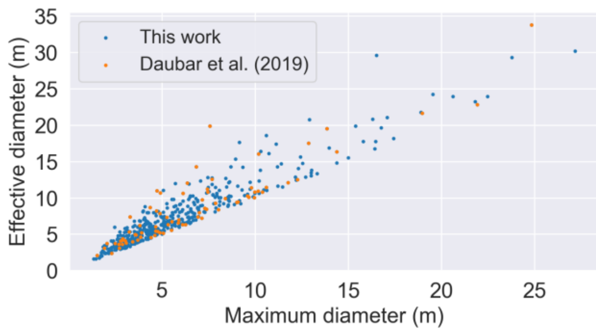

Figure 3: Diameter of the largest crater within the cluster as a function of the effective diameter.

Comparison with the previous study [2] shows that our results for effective diameters, dispersion and aspect ratio of the best-fit ellipse follow similar distributions, indicating that the conclusions drawn from the previous study [2] still hold when applied to a broader set of data.

We also calculate the aspect ratio of the best-fit ellipse of clustered craters (major over minor axis lengths). Figure 4 shows the relationship between this aspect ratio and the relative sizes of craters in a cluster from both our study and [2]. The $N>D_{max}/2$ notation refers to the number of craters in a cluster that have a diameter greater than half the D_{max} (D_{max} is the diameter of the largest crater in the cluster) (see also [12]). This notation is a way of showing the similarity in crater diameters in a cluster. Higher values correspond to craters with similar sizes, for lower values one crater primarily dominates. High aspect ratios correspond to highly elliptical clusters, which implies a shallow entry angle and therefore a longer flight path of the impactor through the atmosphere.

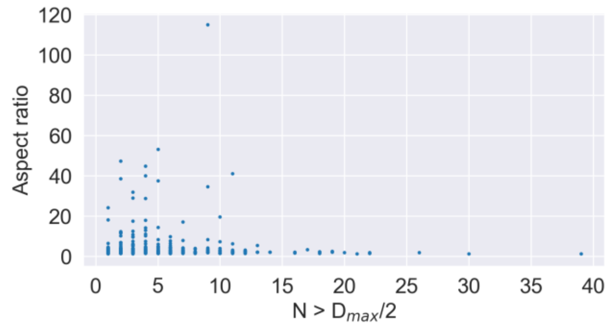

Figure 4: Observed $N>D_{max}/2$ shown on x-axis and aspect ratio of the best-fit ellipse of the cluster on y-axis. $N>D_{max}/2$ is the number of craters larger than half the diameter of the largest crater (D_{max}) in the cluster.

The relationship shown in Figure 4 implies that short trajectories (low aspect ratios) show a large variation of crater sizes, while longer trajectories result in few larger craters. This is indicative of the nature of impactor's fragmentation in the atmosphere and will be investigated further.

Conclusion: The mapped single craters in this study have diameters up to 48 m and the largest crater cluster has an effective diameter of ~34 m. The properties of the new investigated crater clusters in this study are similar to those of [2]. Having a catalogue that comprises properties of impact sites enables us to study crater clusters in a more detailed and statistically significant way by defining subgroups to investigate correlations between characteristics of the crater clusters, such as the number of craters within a cluster, crater sizes, and dispersion as a function of elevation. A further goal is to study differences in the properties between single craters and crater clusters.

Acknowledgments: TN and KM research is fully supported by the Australian Research Council (DP180100661, DE180100584).

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