Geometric and Geomorphic Properties of Pit Craters in the Region of Noachis Terra, Mars. K. Cairns, H. Hiesinger, and W. Iqbal, Institut für Planetologie, Westfälische Wilhelms-Universität, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany (k.cairns@uni-muenster.de).

Introduction: Within the Noachis Terra region, there are several impact craters that contain pits on their floors, where some of these pit craters are adjacent to large, dark dune fields. To understand the formation of these pit craters, we geologically mapped [1][2] and geometrically analyzed seven of the 17 pit craters in the region, and compared the geometric characteristics, such as crater size and pit size to gain an overall perspective on their formation.

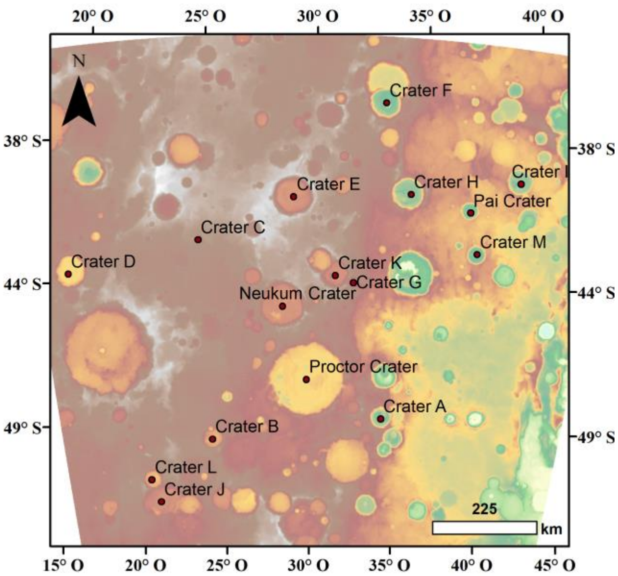

Figure 1: MOLA DTM images showing an overview of all pit craters found in Noachis Terra.

Methods: CTX images (6 m per pixel), THEMIS-IR, and MOLA DTM images were selected from the MUTED (Multi-Temporal Database) [3] and imported into ArcGIS. In total, four comprehensive geologic maps covering seven craters were compiled, which include Rabe crater, Proctor crater, and five unnamed craters within the Noachis Terra region [1][2]. For the geometry of the mapped craters, the crater properties were measured in ArcGIS (Figure 3), and the mapped units data were used to calculate the crater floor- and pit size for comparison of the mapped craters.

Geologic Setting: The pit craters are located in the Noachis Terra region, which is part of the southern highlands of Mars. Geologic units of the area include heavily degraded Middle to Late Noachian highland units, with some Hesperian and Amazonian impact units [4]. This region exhibits distinct pits and large, dark dune fields within several craters [1][2]. Exposed within the craters are volcanic, fluvial, and basin materials [5], with the large, dark dune fields consisting of mafic materials [6].

Pit Craters: Pits found in the craters are near-circular to elongated local depressions on the crater floors. They are widely distributed within the Noachis Terra region. Each pit shape is unique, with some situated adjacent to large dark dune fields on crater floors (Figure 2). Some of the pits analyzed extend almost across the entire crater floor, whereas other pits are proportionally smaller and take up a smaller area of the floor. Pits may provide a window into the geologic past of the crater, as they locally exhibit layers of infill on crater floors that have been re-exposed by the pit forming process. They also aid in the investigations on the regional geology of Noachis Terra, as the pit craters are spread across the Noachis Tera region.

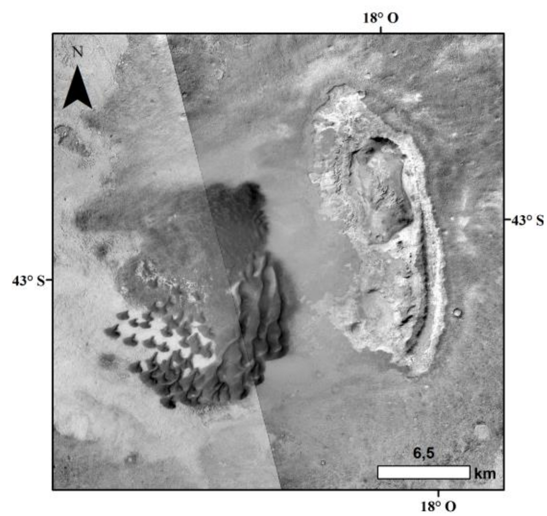

Figure 2: CTX images of a large dark dune field adjacent to a pit on the crater floor of crater D.

Geometry and Geomorphology of Mapped Craters: To gain an understanding of pit formation, it is essential to be familiar with the geomorphology and geometry of the craters. By measuring (Figure 3) the pit sizes and host crater floor sizes in ArcGIS, we can provide a depth-diameter relationship by using already existing empirical models [7] and [8]. This allows for an analysis of the initial crater morphology which is then compared with the crater dimensions measured in ArcGIS. Thus, we can calculate the initial crater depth of the fresh crater impact (d_f) by using the measured crater diameter (D) data. According to Garvin et al.

(2003), the initial crater depth with a mean diameter between 7-110 km is given by the following equation: $d_f=0.36*D^{0.49}$, and from Howenstine (2006), the depth-diameter relationship for fresh impact craters is given by: $d_f=0.610D^{0.327}$. The results can be subsequently compared to the measured crater depths to get an estimate of the thickness of the crater infill material and pit penetration depth. These results of course, should be considered with caution, as many other parameters (e.g., crater size, inclination of crater walls, sediment supply, geologic properties, etc.) play an important role in degradation processes. However, our calculations give first-order information about the state of the craters.

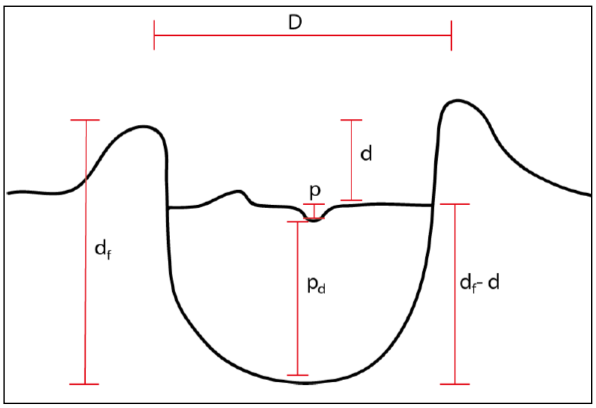

Figure 3: Geometric properties of a crater, where D *is crater diameter;* d_f *maximum depth of fresh impact crater;* p_d *height from the maximum depth of the pit to the bottom of the crater;* d *height from the observed infill to the average top of the crater rim;* d_f-d *depth of the crater infill; and* p *maximum pit depth*.

Results of Calculations: Five of the eight measured pits of the calculations using the Garvin et al. (2003) equation (Table 1), penetrate into the crater infill material to a depth corresponding to only ~10% of the total infill thickness. The pit in Rabe crater by contrast, penetrates 33% into the infill material and therefore shows by far the largest relative penetration depth of all the measured craters. The results based on the calculations from Howenstine (2006) equation (Table 2) show slightly different results. The pit in Rabe crater penetrates through around half of the infill material. The pit in crater D has the second largest relative pit penetration depth of 25%, while the other results vary between 10% to about 19%. Calculations based on Garvin et al. (2003) are slightly larger with a mean d_f of 2.85 km compared to those of Howenstine (2006) with a mean d_f of 2.47 km.

Conclusions: The mapped craters with pit craters [1][2] in Noachis Terra provide information on the geology and evolution of the craters in this region to help analyze the pit formation processes occurring on the crater floors. Additional maps of other pit craters in the area will provide an extended framework for gaining more information on the geology, geomorphology, and geometry of the pit craters for the investigations into the geologic past of the region.

Table 1: Results based on equation from Garvin et al. (2003).

	Results - Garvin et al. (2003)				
Crater	Diameter D [km]	Total Crater Depth d_f [km]	Depth infill d_f – d [km]	Depth under Pit (df – d) – p [km]	% of Pit in Infill
Rabe	105	3.5	2.1	1.4	33.3%
C	18	1.5	0.9	0.8	11.1%
D	72	2.9	1.4	1.15	17.8%
E	102	3.5	1.5	1.35	10%
A	56	2.6	0.9	0.8	11.1%
B	51	2.5	1.5	1.35	10%
Proctor*	150	4.2	2.7	2.4	11.1%
				2.6	3.7%

**Proctor has two pits on the crater floor. One in the northern part of the crater floor (top data) and one on the western part of the crater floor (bottom data). Proctor also has a larger crater diameter than the diameter range given by Garvin et al. (2003).*

Table 2: Results based on the equation from Howenstine (2006).

	Results - Howenstine (2006)				
Crater	Diameter D [km]	Total Crater Depth d_f [km]	Depth infill d_f – d [km]	Depth under Pit (df – d) – p [km]	% of Pit in Infill
Rabe	105	2.8	1.4	0.7	50%
C	18	1.6	1.0	0.9	10%
D	72	2.5	1.0	0.75	25%
E	102	2.8	0.8	0.65	18.75%
A	56	2.3	0.6	0.5	16.6%
B	51	2.2	1.2	0.5	12.5%
Proctor*	150	3.1	1.6	1.3	18.75%
				1.5	6.25%

**Proctor has two pits on the crater floor. Northern pit on the crater floor (top data) and one on the western area of the crater floor (bottom data).*

References: [1] Cairns et al. (2021) LPSC 52 2077; [2] Cairns et al. (2020) LPSC 51 1929; [3] Heyer et al. (2018) PSS 159; [4] Tanaka et al. (2014) USGS IMAP 3292; [5] Fenton (2005) JGR 110, 1–27; [6] Fenton et al. (2003) JGR 108 (E12); [7] [1] Garvin et al., 2003, 6th Inter. Conf. on Mars, # 3277 [8] Howenstine (2006) Analysis of the Depth-Diameter Relationship of Martian Craters Thesis