MORPHOMETRIC CHARACTERISTICS OF MARTIAN CENTRAL PIT CRATERS AND COMPARISON WITH CENTRAL PIT CRATERS ON GANYMEDE, MERCURY, AND THE MOON. N. G. Barlow, Dept. Physics and Astronomy, Northern Arizona University, Flagstaff, AZ 86011-6010 Nadine.Barlow@nau.edu.

Introduction: Central pit craters are characterized by a central depression either directly on the floor of the crater ("floor pit") or atop a central rise/peak ("summit pit") (Fig. 1). Central pit craters are seen in abundance on Mars, Ganymede, and Callisto, which has led to the proposal that subsurface volatiles are necessary for the formation of these features [1-4]. However, a small number of central pit craters have been identified on the volatile-poorer bodies of Mercury and the Moon [5-8], leading to a re-evaluation of the importance of target volatiles in the formation of central pit structures. We are undertaking a solar system-wide study of central pit craters to gain a better understanding of their similarities and differences in order to better constrain potential pit formation mechanisms. The detailed image, composition, and topographic datasets available for Mars, combined with the fact that Mars is intermediate between the volatile-richer icy moons of the outer solar system and volatile-poorer bodies of the inner solar system makes it an excellent test case against which central pit craters elsewhere can be compared when considering the roles of volatiles versus other factors in central pit formation.

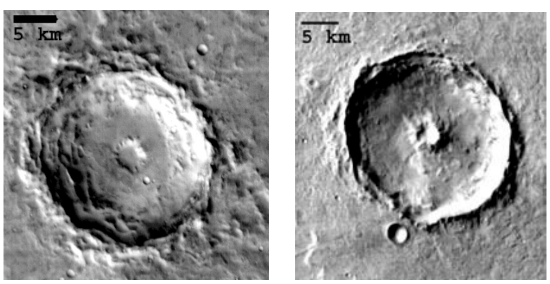

Figure 1: Examples of a Martian floor pit crater (left) and summit pit crater (right). Floor pit crater is 20.7 km in diameter and located at 22.46°N 340.41°E (THEMIS I01199005). Summit pit crater is 22.2 km in diameter and centered at 5.73°N 304.64°E (THEMIS I03218002).

Several models for central pit formation have been proposed, including release of vapor produced as target volatiles are heated during crater formation [1], melting of target volatiles and subsequent drainage through subsurface fractures [2, 3], collapse of a central peak [3, 4], and collapse of weaker subsurface layers [9]. Numerical simulations of impacts into icy targets [2, 3] reveal that the melt-drainage and central peak collapse mechanisms are viable, although neither work well for impacts into volatile-poor targets [10]. The question we will address through this study is whether a single formation mechanism can explain central pit craters throughout the solar system or if different mechanisms are required for central pits on volatile-richer versus volatile-poorer bodies.

Martian Central Pit Craters: Our survey of central pit craters on Mars currently contains 1692 craters, of which 65% (1107) contain floor pits (defined by the elevation of the pit floor lying below the elevation of the crater floor) and 35% (585) are summit pits (pit floor elevation above crater floor). Central pit craters comprise about 8% of all the craters thus far included in our revision of the global database of craters ≥5-km-diameter on Mars [11]. Central pit craters show no strong correlation with specific geologic units or terrains of particular ages. Central pit craters display a range of preservational states from highly degraded to pristine, with most being fairly fresh (1.0-7.0 with median of 5.0 on the 8-point preservation scale of [12]).

Floor pit craters range in diameter from 5.0 km to 114.0 km with a median diameter of 14.0 km. Pit diameters range from 0.3 km to 17.8 km with a median of 2.4 km, resulting in a pit-to-crater diameter ratio (D_p/D_c) ranging from 0.02 to 0.48 with a median of 0.16. No updoming of the crater floor is seen for Martian floor pit craters [13], indicating that rebound from very high concentrations of subsurface ice has not occurred, unlike the situation observed for central pit craters on Ganymede. Floor pits can be rimmed, partially rimmed, or non-rimmed and a preliminary analysis suggests that the presence/absence of a rim is dependent on terrain and crater diameter [14]. We are conducting detailed geologic mapping of fresh examples of each floor pit type to gain improved insights into their characteristics and implications for formation models [15].

Summit pit craters display a similar distribution in crater diameter to floor pit craters, ranging from 5.1 to 125.4 km in diameter with a median value of 14.4 km. Pit diameters tend to be smaller than for floor pits, ranging in diameter from 0.1 to 13.9 km with a median of 1.7 km. D_p/D_c for summit pits ranges from 0.02 to 0.29 with a median of 0.12. This shows that summit pits tend to be smaller relative to their parent crater than floor pits.

In summary, Martian central pit craters have formed on all geologic units over an extended period of time and do not require particularly high concentrations of target volatiles. Craters containing floor pits are similar in size to craters containing summit pits, although the floor pits tend to be larger relative to their parent crater than summit pits. Rims are sometimes seen around the floor pits but other times are absent—our current research is focused on understanding the conditions under which these different floor pit morphologies form.

Other Central Pit Craters: Table 1 shows a comparison of morphometric characteristics for floor and summit pit craters on Mars (this work), Ganymede [16], Mercury [7], and the Moon [8]. Ganymede data were obtained from Voyager and Galileo datasets, Mercury data are from MESSENGER imagery, and the lunar data are from Lunar Reconnaissance Orbiter Camera images. These datasets have a range of resolutions and thus comparisons at smaller crater diameters may be suspect, especially for Ganymede and Mercury. In addition, no summit pit craters were identified in the Ganymede analysis [16] and no floor pit craters were found in the Mercury analysis [7]. Nevertheless, some interesting trends begin to appear:

- Many fewer central pit craters occur on Mercury (27) and the Moon (47) compared to Ganymede (471) and Mars (1692 to date).
- Central pit craters occur over the narrowest diameter range for Mercury and over the largest diameter range for Ganymede.
- Median D_p/D_c values for floor pit craters are largest for volatile-rich Ganymede and smallest for the volatile-poor Moon.
- Median D_p/D_c values for summit pit craters are identical for Mars and Mercury and smallest for the Moon.
- The median D_p/D_c value for the Moon's floor pit craters is the same as for the summit pit craters on Mercury and Mars.

Conclusions: Central pit craters are now known to exist on both volatile-rich and volatile-poor bodies in the solar system. While the trends are generally in the direction of more central pit craters, larger craters, and larger pit-to-crater diameter ratios on volatile-richer bodies, the current data show enough variability that volatile content of the target material is not the sole contributor to central pit formation. The detailed comparison study that we are conducting will provide better insight into the conditions required for central pit formation.

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Table 1: Comparison of central pit morphometric characteristics

	Mars[1]	Ganymede[2]	Mercury[3]	Moon[4]
Number floor	1107	471	0	19
Number summit	585	0	27	28
D_c range (km) floor	5.0-114.0	12.0-143.8	NA	8.9-57.9
D_c range (km) summit	5.1-125.4	NA	16.0-33.0	19.3-95.3
Median D_c (km) floor	14.0	38.1	NA	22.3
Median D_c (km) summit	14.4	NA	20.5	32.8
D_p/D_c range floor	0.02-0.48	0.06-0.43	NA	0.05-0.29
D_p/D_c range summit	0.02-0.29	NA	0.09-0.20	0.03-0.16
Median D_p/D_c floor	0.16	0.20	NA	0.12
Median D_p/D_c summit	0.12	NA	0.12	0.08

[1]This study
[2]From Alzate and Barlow [16]
[3]From Xiao and Komatsu [7]
[4]From Xiao et al. [8]. Only "confirmed" central pit craters specifically designated as floor pit or summit pit are included.
NA = Not Applicable