A COMPREHENSIVE STUDY OF MARTIAN CENTRAL PIT CRATERS TO CONSTRAIN FORMATION MECHANISMS.

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Introduction: Central pit craters are a type of complex crater with a pit either on the crater floor or atop a central peak. They occur in significant numbers on only a few bodies in our solar system: Mars, Ganymede and Callisto. They also have been identified on the volatile-poorer bodies of Mercury and the Moon, although in smaller quantities [1, 2].

The focus of this research is on the detailed geologic mapping of representative central pits. The goal of the project is to place constraints on the mechanism(s) of central pit crater formation based on detailed analysis of central pit morphology and morphometry, but also spectroscopy and thermophysical characteristics where applicable. This project utilizes data and images from the Mars Reconnaissance Orbiter, Mars Global Surveyor, Mars Odyssey and Mars Express to create 6 to 8 geologic maps of the three types of central floor pits using ArcGIS.

This project focuses on these craters found on Mars because of the wealth of data sets available to study Martian central pit craters. Nevertheless, these craters are fairly rare, making up only about 5% of the total crater population on Mars. They are found almost everywhere on the planet, regardless of latitude, longitude, or surface lithology [3]. The issue is that these craters present conflicting attributes that make them a challenge to explain. For example, they sometimes appear adjacent to craters of a similar age and size that do not have a central pit or which have a central pit of a different type.

Background: Central pit craters are divided into two general classes: summit pit and floor pit craters [4]. Summit pits appear within a central peak but the floor of the pit remains above the floor of the crater. Floor pit craters are centralized pits that occur within the floor of the crater—the elevation of the pit floor lies below the elevation of the crater floor. Additionally, floor pits are categorized into three types: rimmed, partially rimmed and non-rimmed.

There are four models from the late 1970s and 1980s to explain the floor pits' existence. The models are: the melt drainage model [5], the layered target model [6], the central peak collapse model [7, 8], and the volatile vapor release model [9]. The key to all of the models is a necessity of a high volatile content in the target surface. These theories however were compiled before we knew of the existence of several dozen central pit craters on Mercury and the Moon. This means that these models need to be modified to include cases with lower percentage of volatiles, new models need to be theorized altogether, or the craters' presence indicates that the surface volatile content has changed over time.

The melt drainage model is a leading model currently because it explains the formation of both summit and floor pit central pit craters. According to this model, volatile-rich material underlying the center of the transient crater undergoes shock melting and eventually drains away into subsurface fractures, leaving a pit.

The layered target model [6] asserts that the creation of a pit is from impacts that occur in a target with layers of different lithologies and thus different strengths. This model however does not explain why the pits would have a partial or complete rim.

The central peak collapse model [e.g., 10] argues that the central pit starts off as a central peak and the volatile-rich crustal material within the crater interior either melts through the brecciated material underneath, sublimates away or the rocky melt from the impact falls through the fractured material.

Wood et al. [9] explain in the volatile vapor release model that the central pits are purely due to the escape of volatiles during the impact. The source of the volatiles could be from the surface or it could be from the impact by a comet instead of a rockier body.

Williams et al. [11] has proposed a new model in which the pit is brought about by an explosion of the volatile material in response to the release of pressure during the modification stage of the formation of the crater. Many pits do not show evidence to support this model because there is no ejecta material around the pits in CTX or HiRISE.

Current Study: We have completed a survey of three databases which included Barlow's central pit crater database with 1080 craters, 46 central pit craters containing pitted materials interpreted as volatile-rich impact melt-bearing deposits (a criterion for crater preservation) [12] and a database of 24 central pit craters with exposed bedrock [13]. In addition, central pit craters to be mapped were carefully chosen based on data and image coverage, dust coverage, and how well the specific pit represented a typical central pit of that type. We wanted at least two of each category of central pits (rimmed, partial rimmed and rimless). The results of our survey identified the rimmed and partially rimmed floor pit craters in Table 1. Geologic mapping has commenced for crater 1.

Crater	Type of Pit	Latitude	Longitude	Diameter (km)
1	Rimmed (in pitted material)	8.95°N	313.40°E	16.3
2	Rimmed	17.63°S	296.38°E	50.6
3	Rimmed	20.18°N	69.39°E	50.9
4	Partially Rimmed	27.55°S	290.32°E	53.0
5	Partially Rimmed	15.84°S	296.33°E	55.3

Table 1: Floor pit craters selected for this study.

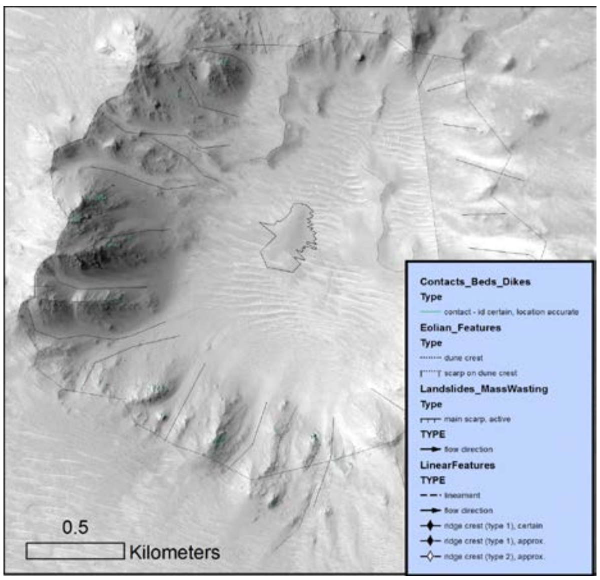

Figure 1. Initial iteration of the pit from crater 1.

We are using Mars Orbiter Laser Altimeter (MOLA), Thermal Emission Imaging System (THEMIS), Context Camera (CTX), Compact Reconnaissance Imaging Spectrometer for Mars (CRISM), and High Resolution Imaging Science Experiment (HiRISE). As seen in Table 1, we have one smaller crater (crater 1, Figure 1) and four of similar size. Comparison of the smaller and larger crater morphologies will provide insights into how changes in diameter (and impact energy) affect central pit formation; whereas the comparison of the four similarly-sized central pit craters will allow us to take out diameter as a factor in any observed morphologic differences and thus focus on more environmental factors.

The first map has revealed a few morphological and structural features of note. There are layered sections of bedrock exposed on the west side of the pit within the ridges that form the pit rim. The layers poorly match up across the rims and look very brecciated. The THEMIS data shows that these ridges are composed of course grained material, unlike the rest of the rim and the pit floor. This is unsurprising for the floor since it is covered in dunes and potentially ancient pitted material that has undergone considerable erosion. Mass wasting appears to have occurred to much of the rim, for gullies are present, but mainly on the west side of the rim.

Future Work: Over the next two years, we will finish mapping the rest of the craters on the table and select at least two of the non-rimmed craters. After completion of the geologic mapping, we will do a comparison of the statistics on location of each type of crater and analyze pit depth to pit diameter ratios to the respective craters' diameter to depth ratios. In addition, we will compare the composition of the surface with pit diameters, volatile content in the surface with pit diameters and pit depths with the thickness of subsurface layers.

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