THE AGES OF CRATERS WITH CENTRAL MOUNDS G. J. Carrillo[1,2], K. A. Bennett[1], and C. S. Edwards[2] [1]United States Geological Survey, Astrogeology Science Center, Flagstaff, Arizona, [2]Dept. Physics and Astronomy, Northern Arizona University, Flagstaff, AZ 86011-6010; (contact: gjc59@nau.edu)

Introduction: The martian surface has been shaped by impact craters throughout the planet's history; these craters allow for many observations to be made about the surface's geologic history. Sedimentary central mounds occur within impact craters across the martian surface. Mt. Sharp, within Gale Crater, where the Mars Science Laboratory (MSL) rover is located, is a prime example of such a sedimentary mound. Craters hosting sedimentary mounds offer an opportunity to analyze the transition from wet to dry conditions on Mars near the Noachian/Hesperian boundary and constrain the ages of certain martian surfaces.

Crater sedimentary central mounds are unlike central peaks because the central mounds were formed post-impact by sediment accumulating in the crater via a variety of processes. The central mounds come in all shapes and sizes, and are sometimes offset from the center of their host craters [1].

Sedimentary central mounds exist in abundance across the martian surface, yet their origins are still unexplained. Currently, the best estimate as to the formation time of these mounds is thought to be on the order of 10-100s Myr [2]. There are many hypotheses as to how the central mounds formed, but the most prominent hypothesis is that sediment filled the craters and was then eroded over time, resulting in the mound morphology that is currently observed [1,2]. The mound sediment may have been deposited as the result of a variety of processes, such as: explosive volcanic, ice related, aeolian, impact, groundwater upwelling, lacustrine, deltaic, alluvial, or submarine processes [1,2].

The reason that these mounds may aid in understanding of the transition from a wet to a dry climate on Mars comes from theory as well as experiment. For example, the central mound in Gale crater (location of the Curiosity rover) exhibits clay minerals at the base of the mound and sulfates higher up the mound [3]. Curiosity has shown that the lowest layers of the mound were deposited in a lake [4]. This likely represents a transition from a wet environment to a drier environment on ancient Mars.

Using crater statistics to calculate ages of surfaces, specifically within the Medusae Fossae Formation (MFF) and Arabia Terra which contain the majority of the mounds, allows us to compare the age of the mounds to observations to be made related to the morphology, composition, and crater populations of these mounds. This data then allows us to constrain the types of geologic processes that formed and modified these central mounds.

Methods: We hypothesize that the age of the crater and the age of the crater floor (revealed after the mound has been eroded) can be used to estimate the age of the central mound. We use the age of the crater ejecta as the maximum age of the mound and we use the age of the crater floor as the minimum age of the mound.

In order to get the necessary age dates, JMARS [5] was used to collect crater statistics, and CraterStats2 [6] was used to determine a model age based on crater size and frequency. We created shapefiles of known sedimentary central mounds, as well as the mounds' accompanying crater ejecta and crater floor shapefiles. The crater floor shapefiles were made to avoid terrain that cannot be dated such as sand dunes or locations of substantial modification. The crater ejecta shapefile, which outlines the ejecta blanket of each crater, estimated the ejecta blankets using the $R_{ce} = (2.348)\ R^{1.006}$ formula, with R_{ce} being the radius of the ejecta and R being the radius of the crater [7]. This formula was necessary for creating the crater ejecta shapefile because, unlike the crater mounds and floors, the ejecta cannot always be outlined perfectly without an empirical method. This formula was created using empirical data of lunar craters but has been proven to be accurate for martian crater ejecta blankets as well [8]. The Mars Reconnaissance Orbiter's (MRO) Context Camera (CTX) images were used to identify craters, and the internal JMARS crater counting tool was then employed to mark each crater by fitting a circle to its diameter. Craters 100 m in diameter and greater were measured. The resulting crater diameters were then imported into CraterStats2, where the Hartmann & Neukum (2001) chronology function and Ivanov (2001) production function, along with a resurfacing correction when needed, was employed to estimate surface exposure age of the different regions [9,10]. The largest craters were primarily used to estimate the ages of the surfaces due to the fact that smaller craters are more susceptible to preferential modification.

Results: We have completed the analysis of several crater floors, mounds and ejecta blankets on Mars. To first order, we observe that the ejecta is significantly older than the mound and crater floors. As can be seen in Figure 1, the numbers of craters in each size frequency bin can be quite small, especially for the mound and crater floor. It is important to assess the differences in area counted when examining crater size frequency distributions, especially when considering the cross-comparisons we aim to conduct. Resurfacing corrections also result in large age differences, though in many cases it is clear that significant resurfacing, which would preferentially destroy smaller craters has been at work.

Future Work: Further analysis is required before robust conclusions can be made across the suite of crater mounds. We anticipate completing the analysis of >20 craters to obtain a robust regional/global understanding of the ages of craters containing mounds and their associated features. This will be done by obtaining more crater statistics using JMARS and interpreting the data into age dates of certain surfaces using CraterStats2, as previously outlined. A detailed assessment of areal size counted vs age will also be conducted to ensure we are not mis-representing the age dates. Once these age dates are complete we aim to relate the different mound morphologies and characteristics to age distributions in order to help constrain the origins, degradation histories and evolution of these enigmatic martian features.

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Figure 1 (below): The results of crater counting at an unnamed crater (11.8 E, 6.7 N). This shows the estimated age (from left to right) of the crater ejecta (3.7 Ga +/- 0.02 Ga), the crater floor (120 Ma +/- 70 Ma), and the central mound (230 Ma +/- 70 Ma). While the surrounding ejecta has sufficient crater density to obtain reliable statistics, the crater floor and mound may not.