A GLOBAL SURVEY OF CENTRAL MOUNDS IN LARGE MARTIAN CRATERS: IMPLICATIONS FOR PALEOLAKES K. A. Bennett[1] and J. F. Bell III[1], [1]School of Earth and Space Exploration, Arizona State University; Kristen.A.Bennett@asu.edu

Introduction: Craters that contain central mounds of sedimentary deposits occur across the Martian surface [1] but the specific processes responsible for their formation and subsequent modification are unknown. Since these interior deposits occur globally and their formation times are estimated to range from 10s-100s of Myr during the Noachian era [2,3], their method of formation could be representative of a global process that was active throughout an extended period of early Martian history.

Gale crater, the landing site for the Mars Science Laboratory (MSL) *Curiosity* rover, contains a central mound, Mt. Sharp, that is more than 5 km high and includes layered sediments that could preserve a record of the early Martian climate [3-5]. Some of the crater floor deposits have already been shown to represent an ancient lacustrine setting, and a recent MSL study yielded absolute ages for these deposits of 4.21 ±0.35 Ga with a surface exposure age of 78 ±30 Ma [6-8].

This work presents our global survey of central mounds in large craters, with the goal of testing various mound formation mechanisms while also characterizing the mounds so that discoveries made at Gale Crater with MSL can be placed into a global context. Our results have specific implications towards the feasibility of a lacustrine setting for mound formation.

Background: Central mounds are found in craters of varying sizes, are not always located in the center of their host crater, and at times rise higher than their crater walls. These deposits are postulated to be Noachian and created through either subaerial or subaqueous processes [1]. There have been two possible general formation mechanisms hypothesized for the creation of central mounds. In the first model, an empty crater is filled to the rim with sediments, which are then eroded into the mound shapes we observe today [1]. In the second model, sediments are deposited preferentially into mound shapes [9].

Methods: Previous surveys of central mounds have either been restricted to a limited area [2,10] or have been part of a broader general survey of sedimentary deposits on Mars [1]. This work focuses specifically on central mounds in large craters at a global scale.

To identify and characterize central mounds we used a combination of visible, thermal and topographic elevation datasets. To be classified as a central mound, an interior deposit must be rounded (as opposed to a typically sharp or jagged central peak) and the height of the mound must be greater than 20% of the height of the rim. Our search area was limited to within ±60° latitude and to craters above 25 km in diameter.

To identify potential mound features and ensure they met our criteria, we use Mars Global Surveyor Mars Orbiter Laser Altimeter (MOLA; [11]) topography maps, Mars Odyssey Thermal Emission Imaging System (THEMIS; [12]) daytime temperature maps, and images from the Mars Reconnaissance Orbiter Context Camera (CTX; [13]) and High Resolution Imaging Science Experiment (HiRISE; [14]).

Once they are identified, we find the height of each mound from MOLA elevation data. Since some craters exhibit large differences in elevation along their rims, we also measure the highest and lowest (excluding incised channels) elevation of each crater rim. By subtracting the elevation of the crater floor from these two values, we obtain the height of the highest and lowest points on the crater rim. Finally, we compare the height of each mound with the height of its host crater's rim to determine how many mounds rise above their host crater walls.

Results: *Global Survey:* Our survey identified a total of 50 mounds, 33 in the northern hemisphere and 17 in the southern hemisphere. Western Arabia Terra (from -10° to 30° N and -20° to 30° E) contains 32 mounds, which is more than 60% of the total population that we identified.

Rim vs. Mound Height: Figure 1 shows how each mound's height compares to its host crater's highest and lowest points. Points above the black line are mounds that rise above the crater rim. There are 32 mounds (out of 50) that rise above the crater's lowest rim height, but there are only two mounds that rise above the entire crater rim: Nicholson crater and an unnamed crater in Arabia Terra centered at 24.8° E and 3.6° N.

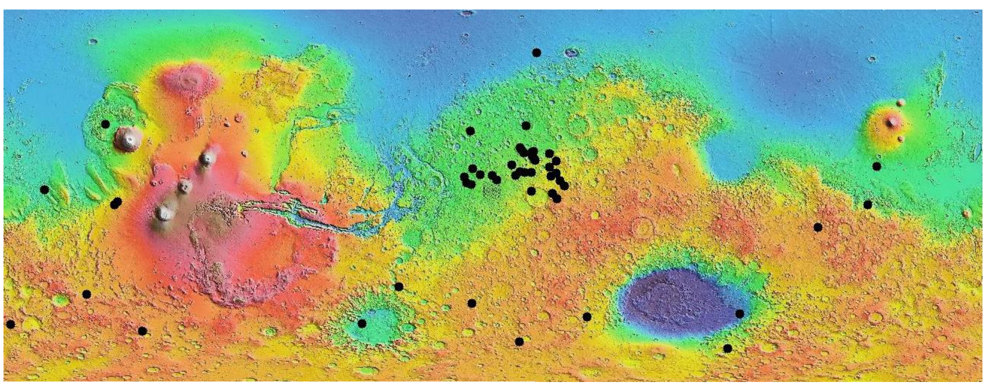
Interpretations: The highest point in Nicholson crater's mound is interpreted as a central peak around which the mound formed. There are other central peaks on Mars that are higher than their crater rims, such as in Burton crater. If we ignore the central peak, then this mound does not rise above its highest crater wall.

The highest point in the unnamed Arabia Terra crater is interpreted as part of an ejecta blanket from a nearby crater. The impact ejecta does not make up the entire mound. At its thickest point in a location away from the mound, the ejecta blanket is 320 m above the surrounding area. The mound's vertical relief is roughly 1140 m, so there must have been at least 800 m of material in the crater before the ejecta blanket covered it. Based on these two cases, we can conclude that no mound on Mars rises above its entire crater rim, helping to constrain their potential formation process.

A lacustrine settling origin for mounds that rise above part of their crater rims would be feasible if the rims have been eroded relative to their original height. Indeed, significant evidence for incision and erosion/sediment transport exists within the walls and floor of Gale crater [5, 6]. Alternately, non-paleolake depositional processes that preferentially occurred near the centers of these basins (perhaps related to groundwater transport, or to aeolian interactions with pre-existing central peak topography) need not impose any specific constraints on the relationship between mound height and crater rim height.

According to these results and other recent studies [6,7], part of Mt. Sharp's Lower formation could consist of lake sediments that once spanned the entire crater floor. To remain consistant with the observed mound morphology, the sediments must have then been eroded (possibly by wind; [15]) around the edges of the crater. Yellowknife Bay crater floor material has been interpreted to be lacustrine in origin [7]. Either a lake existed on the crater floor after the central mound was eroded, or Yellowknife Bay could be an extended part of Gale's central mound. Farley *et al.* [8] found a crater floor surface exposure age of only 80 Ma, meaning erosion of the crater floor is still occuring today. If Yellowknife Bay is a part of the mound, this would imply that mound erosion is still occurring.

References: [1] Malin M.C. and Edgett K.S. (2000) *Science*, 290, 1927-1937. [2] Andrews-Hanna J.C. et al. (2010) *JGR*, 115, E06002. [3] Thomson, B. J. et al. (2011) *Icarus*, *214*(2), 413–432. [4] Milliken R.E. et al. (2010) *GRL*, 37, L04201. [5] Anderson, R. B. and Bell J. F. III (2010). *The Mars Journal*, *5*, 76–128. [6] Williams, R. et al. (2013) *Science*, *340*(6136), 1068–1072. [7] Grotzinger, J. P. et al. (2013). *Science*. [8] Farley, K. A. et al. (2013) *Science*. [9] Kite, E. S. et al. (2013). *Geology*, *41*(5), 543–546. [10] Fergason R.L. and Christensen P.R. (2008) *JGR*, 113, E12001. [11] Zuber, M. T. et al. (1992). *JGR*, *97*(E5), 7781. [12] Christensen, P. R. et al. (2004). *Space Science Reviews*, *110*, 85–130. [13] Malin M.C. et al. (2007) *JGR*, 112, E05S04. [14] McEwen, A. S. et al. (2007). *JGR: Planets (1991–2012)*, *112*(E5). [15] Bennett, K. A., & Bell, J. F. (2013). *LPSC*, *1719*, 2652.



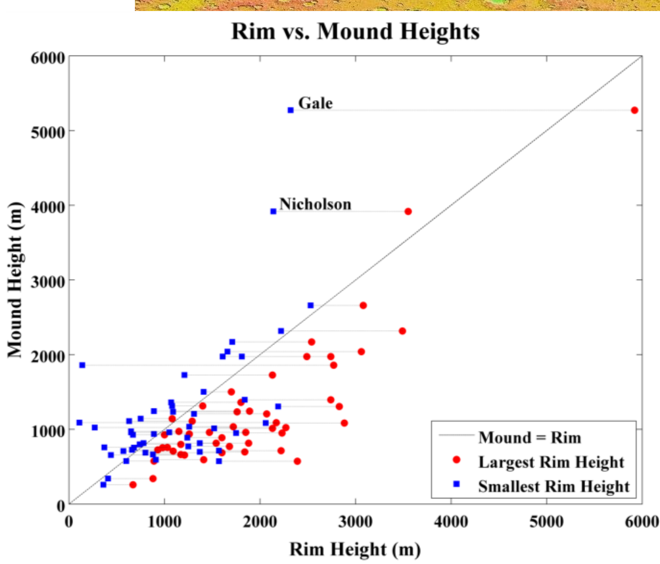


Figure 1: (Above) Global survey of craters containing central mounds. Background is colorized MOLA elevation map centered on 0° latitude, 0° longitude.

Figure 2: (Left) Plot comparing each mound's height to the largest (red) and smallest (blue) height of its host crater rim. The points for each crater's highest and lowest rim height are connected by the dotted lines. These dotted lines indicate the difference in height between the highest and lowest parts of each crater rim. The black line shows where a mound and its crater rim would be equal heights. Points above this line, like Gale, represent mounds that are taller than their crater rim.