MODELING THE GEOLOGIC HISTORY OF MT. SHARP. A. Pascuzzo[1] and C. Allen[2], [1]Department of Geosciences, Smith College, Northampton, MA 01063 (apascuzz@smith.edu), [2]Astromaterials Research and Exploration Science, NASA-JSC (carlton.c.allen@nasa.gov).

Introduction: Gale is a ~155 km diameter crater located on the martian dichotomy boundary (5°S 138°E). Gale is estimated to have formed 3.8 – 3.5 Gya, in the late Noachian or early Hesperian [1,2,3]. Mt. Sharp, at the center of Gale Crater, is a crescent shaped sedimentary mound that rises 5.2 km above the crater floor (Fig. 1). Gale is one of the few craters that has a peak reaching higher than the rim of the crater wall [1,2,4]. The Curiosity rover is currently fighting to find its way across a dune field at the northwest base of the mound searching for evidence of habitability.

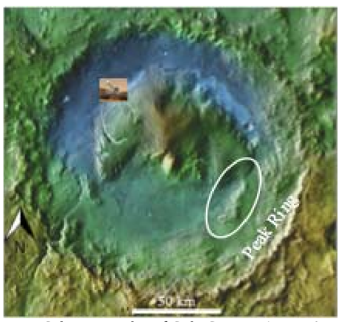

Fig 1. *MOLA & THEMIS day IR overlay of Gale Crater using JMARs showing the location of the Curiosity rover and proposed peak ring*

This study used orbital images and topographic data to refine models for the geologic history of Mt. Sharp by analyzing its morphological features. In addition, it assessed the possibility of a peak ring in Gale. The presence of a peak ring can offer important information to how Mt. Sharp was formed and eroded early in Gale's history.

Methodology: *Craters with sedimentary mounds.* Craters located between 60°N - 60°S and 100-200 km in diameter with interior deposits were searched for using the Mars Crater Database (http://crater.sjrdesign.net/) [5]. The latitude limits were chosen to avoid ice processes that may affect mound formation, erosion and exposure. This search yielded 255 craters, of which 6 were selected (Fig 2, Table 1) to observe closely using orbital Context Camera (CTX), High Resolution Imaging Science Experiment (HiRISE), and Thermal Emission Imaging System (THEMIS) images. These images were used to identify similarities and differences in mound morphology with Mt. Sharp.

The six craters were chosen based on their unique mound morphology as well as their similarity to Mt. Sharp. Topographic profiles for each crater were constructed using ArcMap10.1 software and Mars Orbital Laser Altimeter (MOLA) derived digital elevation models.

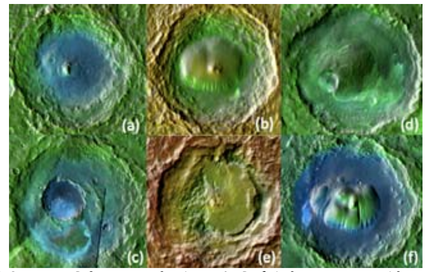

Fig 2. *MOLA & THEMIS day IR overlay in JMARS of six large craters with central mounds. (a) Cerulli crater, (32°N 22°E). (b) Unnamed 70 km crater located in Arabia Terra (9°N 21°E). (c) Becquerel crater, (22°N, 8°W). (d) Firsoff crater, (3°N 9°W). (e) Maunder crater (50°S 1°W). (f) Nicholson crater (0° 165°E)*

Craters with peak rings. Craters between 60°N - 60°S and 100 km-230 km in diameter with peak rings were cataloged using the same Mars Crater Database [9] as well as examining MOLA data and GoogleMars. Four craters were selected for close analyses of morphologic features and textural characteristics (Table 2).

Results and Discussion: *Craters with mounds.* Craters with strong evidence of fluvial processes, for example Firsoff (Fig 2d), have dried up river channels and layered sediment along the walls. This suggests that the crater was once partially or completely filled followed by erosion to form a circular mound in the center of the crater. Prominent yardangs show recent prevailing wind directions.

Cerulli (Fig 2a) and Becquerel (Fig 2c) have sedimentary mound deposits showing little correlation to the other four craters or to Gale. There isolated mounds show evidence for glaciation and periodic depostition in addition [6].

Nicholson as Gale analog. Out of the six craters analyzed, Nicholson (Fig 2f) is the closest analog to Gale in terms of mound morphology. Both Gale and Nicholson essentially lie on the dichotomy boundary [3]. Both craters are younger than the Hesperian Noachian transition unit and are located at the equator. Therefore they may have been exposed to similar climate evolution when Mars transitioned from a wet to arid climate [3]. Nicholson has a large central peak and a surrounding sedimentary mound similar to Gale. The cross section (Fig 3) of the Nicholson mound shows the rim and crater floor slope down towards the north-northwest [4]. The peak of the Nicholson mound rises higher than the surrounding rim, similar to Gale.

Both craters show evidence of deposition of wind-transported sediments on the mound and central peak.

Name and Diameter	Age	Primary Deposition	Primary Erosion	Thickness of Mound (km)
(9°N21°E) 70 km	Early-Mid Noachian	Fluvial or Aeolian	Aeolian	2.6
Firsoff 85 km	Mid. Noachian	Fluvial	Fluvial then Aeolian	1.8
Cerulli 115 km	Mid. Noachian	Fluvial or Glacial	n/a	0.9
Maunder 100 km	Mid. to Late Noachian	n/a	Fluvial	0.8
Becquerel 165 km	Late Noachian	Fluvial or Glacial	Fluvial then Aeolian	1.0
Nicholson 110 km	Late Noachian to Early Amazonian	Fluvial and Aeolian	Fluvial then Aeolian	3.6

Table 1. *List of six comparison mounds and their interpreted geologic history determined from morphologic analyses. Geologic units/ages based on Geologic Map of Mars by K. L. Tanaka et. al (2014). Craters in table are in chronological order from oldest to youngest. Table shows thickness of each mound from apparent crater floor to highest peak and the primary deposition and erosion of the mounds interpreted by their morphological features.*

On Gale, there is a thin young layer of wind transported possibly an outer layer of the Medusae Fossae formation (MFF) [4, 7]. On the east and west lobes of the Nicholson mound the surfaces exhibit crescentic scour features, similar to features found in the MFF, indicating a young layer of MFF may also present on the Nicholson mound [8].

Another distinguishing feature on Nicholson's mound is the large deep channel, ~18 km long, running from the center to the near southeast base of the mound. A similar large canyon incises the western lobe of the LM of Mt. Sharp. Such canyons suggest large quantities of water were once present.

The major morphological feature that makes Gale unique is the crescent shape of Mt. Sharp. The comparison mounds are relatively concentric with their crater rims, but Gale is a half-circle mound with the central peak exposed along the southern face. This unique erosion of Mt. Sharp may suggest the presence of a partial peak ring that allowed protection of the sediment [9].

Peak ring morphology. A peak ring typically has a diameter that is half of its craters diameter. Peak rings are composed of deep-seated materialthe look fundamentally diffent than bedded sedimentary moudns. The maximum depth of excavation for the peak ring in Gale is ~17 km [10].

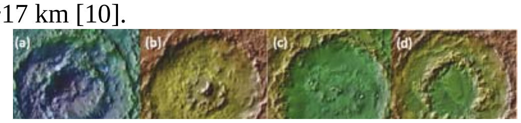

Fig 4. *MOLA & THEMIS day IR overlay of (a) Lyot, (b) Liu Hsin, (c) Holden, (d) Lowell*

After analyzing the four peak rings (Fig 4) it became apparent that not all peak rings have the same rock texture, which depends on the underlying substrate. What the peak rings do have in common is their style of erosion into massive unlayered conical hills, of which some areas erode into boulders only seen in peak rings. Lowell (Fig 4d/Fig 5b) is the ideal representation of a well formed peak ring crater. A thin mass of sediment is corralled inside the northeast quadrant of the peak ring. This may be analogous to the much thicker mass of sediments that forms the LM of Mt. Sharp.

An arc of low hills southeast of Mt. Sharp may be the eroded remains of a peak ring in Gale crater (Fig 5c). Holden Crater has conical hills (Fig 5d) analgous to Gale's peak ring hills.

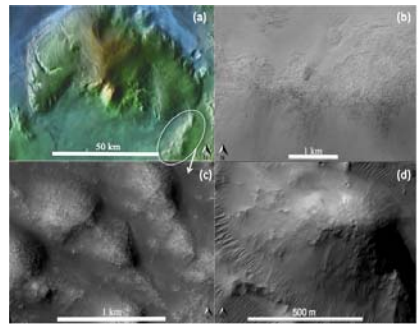

Fig 5. *(a) MOLA & THEMIS day IR overlay of Gale. (b)* HiRISE image *ESP_023662_1280 of Lowell Peak ring [Fig 4d.]. (c) Gale Crater peak ring conical hills; HiRISE image ESP_018643_1745. (d) Conical mound in Holden Crater peak ring [Fig 4c.]; HiRISE image ESP_026693_1530.*

Conclusions: The present findings support the conclusions of previous studies that fluvial deposition and erosion, followed by aeolian deposition characterize the history of Mt. Sharp [1,2,4].

Nicholson is morphologically the closest analog to Gale. Studies focusing on morphology and mineral composition should be done to further compare Nicholson with Gale.

The presence of a peak ring within Gale is plausible based on the analyses of peak rings in other craters. Peak rings erode to very distinct, unlayered conical hills, especially in craters smaller than 200 km in diameter. Peak rings may allow protection for sediments within the ring, resulting in the formation of a mound high in topography in relation to the eroded crater floor [4].

References: [1] Thomson et al. (2011) *Icarus*, 214, 413-432. [2] Milliken et al. (2010) *GRL*, 37, L040201. [3] K. L. Tanaka et al (2014) *USGS: Geologic map of Mars*, Scientific Investigations Map 3292. [4] C. Allen and A. Dapremont (2014) *8th International Conf. on Mars*, Abs. #1119. [5] S. J. Robbins and B. M Hynek (2012) *J. Geophys. Res.*, 117, E05004. [6] J. C. Bridges et al (2008) *LPS*, Abs. #1913. [7] S.W. Hobbs et al (2010) *Icarus*, 210, 102-115. [8] Bradley B. A. and Sakimoto S.E.H (2001) *LPS XXXIII*, Abs. #1335. [9] Spray J. et al (2013) LPS XLIV, Abs. #2959. [10] S.P. Schwenzer et al (2012) *Planet. Space Sci.*, 70, 84-95.