THE GALE CRATER MOUND IN A REGIONAL GEOLOGIC SETTING: MAPPING AND PROBING SURROUNDING OUTCROPS FOR AREAS AKIN TO THE CENTRAL MOUND AT GALE. Lisa Korn[1] and Carlton Allen[2], [1]Department of Geosciences, University of Massachusetts Amherst, Amherst, MA 01003 (slbkm12@yahoo.com),[2]Astromaterials Research and Exploration Science, NASA-JSC (carlton.c.allen@nasa.gov).

Introduction: Is Mt. Sharp – the prominent mound in Gale Crater – an erosional remnant of regional sedimentary units or a singular occurrence unrelated to the surrounding geology?

There are several hypotheses on the origin of Gale Crater's central mound. These include ground water upwelling [1], aeolian, ice, volcanic [1-3], lacustrine [1-3], hydrothermal [1-3], and polar deposits [2].

The Mars Science Laboratory rover, Curiosity, landed in Gale Crater on August 6, 2012. It is currently analyzing samples along its traverse towards a channel and layered deposits that will provide insight into the sedimentary history of the crater [4].

Located at 5S, 138E, Gale is a 155km diameter, Late Noachian/Early Hesperian crater. It is situated along the southern highlands/northern lowlands dichotomy boundary and contains a central mound that rises approximately 5km from the crater floor [1]. The highest parts of Mt. Sharp are higher than the northern rim, but are roughly the same height as the southern rim. Mt. Sharp is divided into an upper mound and a lower mound, which are separated by an erosional unconformity [2]. The lower mound's sequences span the Late Noachian/Early Hesperian Epoch [1], while the upper mound's age is poorly constrained.

The lower mound's sequences feature parallel beds of varying thickness, albedo, texture, and dip angle that are eroded into channels and yardangs [2]. The upper mound has finer layers at higher angles [1] with yardangs, serrated erosional patterns, and lobate features [3]. The lower mound also exhibits an upward progression of phyllosilicate to sulfate rich sediments, contrasting the upper mound's lack of hydrated minerals [4].

Procedures: We employed orbital remote sensing data to determine if areas within 1,000km of Gale have features akin to Mt. Sharp. The data included day-time and night-time infrared (IR) images obtained by the Thermal Emission Imaging System (THEMIS) on the Mars Odyssey spacecraft, images from the Mars Orbital Camera (MOC) and altitude data from the Mars Orbiter Laser Altimeter (MOLA) on Mars Global Surveyor, and Context Camera (CTX) and High Resolution Imaging Science Experiment (HiRISE) images from the Mars Reconnaissance Orbiter.

Do sedimentary units resemble Mt. Sharp at a regional scale?

A base map of a 1,000km radius circle around Gale was constructed in ArcGIS using the THEMIS day-time IR mosaic [5]. A geographic information system layer was defined by Mt. Sharp's entire altitude range (-4,600m to 400m). A second layer was defined by mapped geologic units spanning the Late Noachian/Early Hesperian age range of the lower mound [6]. A third layer was defined by Mt. Sharp's brightness values from the THEMIS night-time IR mosaic (0 to 250). These values are correlated with near-surface thermal inertia [7]. The layers in ArcGIS were combined to define regions of interest matching Mt. Sharp in altitude, age, and night-time thermal IR brightness.

Do sedimentary units resemble Mt. Sharp at a local scale?

Comparisons were developed using geomorphic units mapped on Mt. Sharp [1; Table 1]. Images of the landforms in these units, from the CTX, HiRISE and MOC cameras, were compared to landforms at the same altitude and in the regions of interest outside of the crater (Fig. 1).

Could Gale have been filled with sediments?

Many large Martian craters contain layered sedimentary deposits, some of which have clearly been eroded. The degree of filling and erosion was documented for all Martian craters in the diameter range, 140 to 170km, using the THEMIS day-time IR mosaic [5].

Table 1: List of Geologic Units from Thompson et al. (2011)

UNIT	NAME	ELEVATION	BRIGHTNESS
LML	Lower Mound Eastern Layered Unit	-1500m to -3250m	50-175
UML1-2	Upper Mound Subdued Layers 1-2	300m to -1350m	0-175
UMP	Upper Mound Mountainous Unit	300m to -2100m	0-175
UMC	Upper Mound Chaotic Unit	-1800m to -2900m	100-200
UME3	Upper Mound Etched Unit 3	-1850m to -3200m	100-150

The above table shows the geologic units used in the specific study. Elevation is taken from MOLA Altimetry and brightness from THEMIS Nighttime Infrared. Units and names come from the Thompson et al. (2011) map [1].

Could the Lower Mound units have been formed in a lake?

Several large channels on Mt. Sharp and the inner walls of Gale widen significantly at altitudes of approximately -2,300m, suggesting that the channels entered into a body of water [8]. A map based on MOLA altimetry shows the correlation between the crater, Mt. Sharp, and the northern lowlands (Fig. 2).

Results: At a regional scale, lower mound analogues with an altitude range of -2,250 to -4,050m, and a brightness range of 50 to 250, were found in the late Noachian Npl2 unit to the southeast of Gale. Upper mound analogues with an altitude range of 400m to about -3,200m, and a brightness range of 0 to 150, were found to the northwest, in the Mid-Noachian to Mid/Early Hesperian HNu unit [6].

At the local scale, landforms at Mt. Sharp and outside of the crater are analogous in layer thickness and erosion style. Lower mound analogues are about 200km northeast and southeast of Gale. Areas 5 and 6, with altitude ranges of -2,850 to -3,050m and -2,000 to -2,650m, respectively, and brightness ranges of 125 to 200 and 75 to 200, respectively, match the parameters of the LML unit (Table 1) and its geomorphology (Fig. 1).

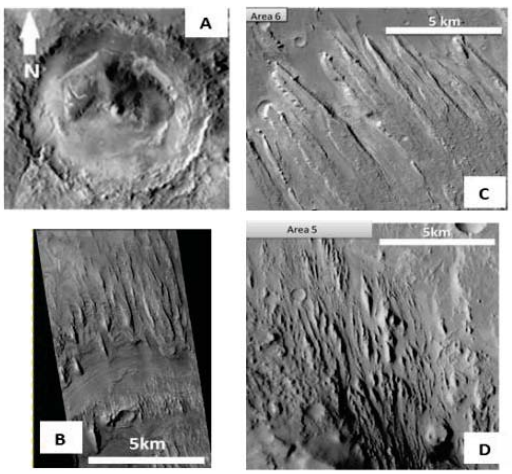

Figure 1: *Image A*: Gale Crater in THEMIS Daytime Infrared. *Image B:* The Eastern Lower Mound at Gale (HiRISE:ESP_01965_1745). *Image C:* Area 6 (CTX: B21_017799_1765). *Image D*: Area 5 (CTX: P05_002899_1759). *Images C* and *D* are analogues to *Image B,* in terms of altimetry, age, brightness (a proxy for thermal inertia) and geology. All images except *Image A* are at the same scale.

Upper mound analogues have altitude and brightness ranges of -200m to -2,350m and 50 to 200 for unit UML1, -2,250m to -2,150m and 75 to 175 for unit UMP, -1,400m to -2,550m and 50 to 200 for unit UMC, and -2,400m to -2,500m and 100 to 225 for unit UME3 (Table 1). Upper mound analogues are 260 to 900km northwest and 440km southeast of Gale.

All craters in the same size range as Gale are partially or completely filled. The fill is predominantly flat-lying and in some cases layered. The volume of fill in Gale is approximately 10% of the total crater volume, a smaller ratio than for any other crater of similar size

Most of the lower mound units, and the majority of Gale's floor, lie below an altitude of -2,300m [8; Fig. 2]. A surface at this altitude would connect to the northern lowlands by a gap in the crater's rim [9]. This gap contains a 500m-wide channel that slopes into Gale.

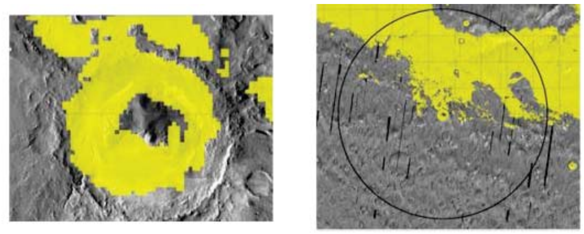

Figure 2: The above images show THEMIS Daytime Infrared overlain by MOLA Altimetry. Gale Crater with a 155km diameter is on the *LEFT.* The 1000km radius circle surrounding Gale is on the *RIGHT*. Both Images show areas below an altitude of -2300m.

Discussion: Within a 1,000km radius of Gale, two large units along the dichotomy boundary exhibit the same ranges of age, altitude and thermal inertia as Mt. Sharp. Within these units, some areas match the layering and erosion of the mound at similar altitudes.

All large craters on Mars are partially or completely filled, likely by sediments. The layering and mineralogy of Mt. Sharp indicate that much of the mound is likewise sedimentary. The size of the mound relative to the crater, as well as the numerous yardangs, indicate that portions may have been eroded by the wind.

Multiple channels in Gale that open at the same altitude suggest that the crater once hosted a lake with a surface at -2,300m. If so, the lower units of Mt. Sharp could have been formed or altered under water. If a lake stood at -2,300m and the crater rim was in its present configuration, the lake would have been in contact with a much larger body of water in the northern lowlands.

Conclusions: These observations are consistent with the hypothesis that the sedimentary units in both the upper and lower sections of Mt. Sharp are related to nearby regional units. This relationship supports a geologic history that includes episodes of widespread sedimentary deposition and erosion. In this model, Mt. Sharp is the remnant of these regional sedimentary deposits that partially or completely filled the crater and were later deeply eroded. The history of Gale Crater and its mound may also include a sizable lake that could have been connected to a much larger body of water. The *in situ* investigations by Curiosity over the next several years will directly address the origin and history of Mt. Sharp and its surroundings.

References: [1] Thomson et al. (2011) *Icarus,* 214, 413-432. [2] Milliken et al. (2010) *GRL,* 37, L040201. [3] Anderson, Bell (2010) *Mars,* 5, 76-128. [4] Andrews-Hanna et al. (2012) 3rd Conf. on Early Mars, Abs 7038. [5] THEMIS Daytime IR mosaic http://www.mars.asu.edu/data/thm_dir/. [6] Greeley and Guest (1987) *USGS*, I-1802-B.[7] Jakosky et al. (2000) *JGR* 105, 9643-9652.[8] Sumner et al (2011) 5th MSL Landing Site Workshop. [9] Parker (2010) 5th MSL Landing Site Workshop.