CLIMATE CHANGE AND TOPOGRAPHY FOCUSED AEOLIAN EROSION IN GALE CRATER, MARS –TEN-YEARS OF MSL OBSERVATIONS. H. E. Newsom[1,2], M. E. Hoffman[1,2], Z. E. Gallegos[1,2], J. M. Williams[1,2], S. A. Los[1,2], F. D. Dimitracopoulos[1,2], M. A. Nellessen[1,2], D. Mason[1,2], L. A. Scuderi[2], L. J. Crossey[2], P. J. Gasda[3], N. Lanza[3], O. Gasnault[4], E. S. Kite[5], W. E. Dietrich[6]. [1]Inst. of Meteoritics, [1]Univ. of New Mexico, Albuquerque, NM 87131, USA (newsom@unm.edu), [2]Dept. of Earth & Planetary Sci. UNM, [3]Los Alamos National Lab, USA. [4]IRAP, FR, [5]Univ. of Chicago, USA, [6]Univ. of .Calif. Berkeley, USA.

Introduction: The topography traversed by the Mars Science Laboratory (MSL) Curiosity rover for ten years ranges from the swales and troughs of the Bradbury Formation (**Fig. 1**), up through the spectacular valleys and hills of the Marker Band valley on the lower slopes of Mt. Sharp (**Fig. 2**). The terrain along the traverse consists of fluvial, lacustrine, and aeolian sedimentary rocks. The nature of this terrain is very different from our tantalizing views of the Gale crater rim across the crater floor, presumed to consist of igneous crustal rocks. The observations from Curiosity lead to the question of the primary erosion mechanism and rates of erosion in different areas along the Curiosity traverse [1, 2]. Multiple lines of evidence support the role of topographic focusing of sand, and thus aeolian erosion by saltation abrasion along swales and valley floors. This process was postulated by the late Nathan Bridges [3] during the early stages of Curiosity's journey, and there is now more evidence for this hypothesis. Also, aeolian erosion is likely more effective during periods with a denser atmosphere due to obliquity variations as recently as 0.5 - 5 Ma [4-6].

Fig. 1 Sol 431 pyramidal ventifacts (aka wheel destroyers) on Bradbury Fm. Mastcam sol 431 ML_001752.

Topographic focusing of erosion by sand:

Swales and valleys along the traverse are eroded along orientations consistent with the wind directions, rather than changes in sedimentary composition. Valleys on the crater floor are formed roughly NE to SW along a trend parallel to the linear Bagnold dunes. On the steeper slopes of lower Mt. Sharp above Vera Rubin ridge, the valleys are oriented parallel to the slope of the mountain, which is the direction for gravity driven mass movement and katabatic drainage winds from Mt. Sharp [7, 8].

Many swales and valleys have abundant float blocks on steep adjacent walls, with few blocks on the valley floors (**Fig. 2**). This observation is especially relevant where the slope erosion produces float that can roll downhill. The low population of blocks on the floors suggests a more rapid removal of valley floor blocks. The tops of most of the elevated buttes also tend to have accumulations of dust, in contrast to the floors of the adjacent valleys (e.g. Murray Buttes and Buttes on Mt. Sharp adjacent to the traverse).

Fig. 2. Marker Band Valley looking south, Mastcam: sol03563 ML_102556 illustrating drifts, uneroded float blocks, and the scoured valley floor.

Grooved sand blasted surfaces parallel to the valleys are present on valley walls and high up onto the buttes in and around the Marker Band valley (**Fig. 3**). These surfaces also exhibit faceting on a large scale, first seen at the buttes adjacent to the Greenheugh pediment.

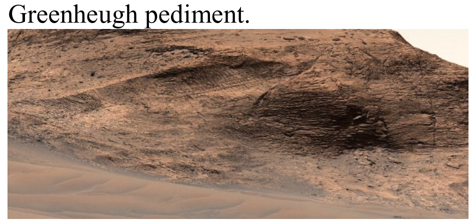

Fig. 3 Facets and grooves likely due to sand blasting on the wall of Bolivar hill leading into Marker Band Valley. MastCam sol03576 ML_102660.

Enhanced erosion during high atmospheric pressure excursions: Currently, accumulations of dust and ripples, are present on deflated surfaces in Marker Band valley. Drifts and float on the slope below the marker band shield bedrock, suggesting that limited erosion of the slopes is occurring at the present day e.g. [9]. Furthermore, most of the float blocks on the scoured surface along the traverse, especially on Mt. Sharp, are relatively pristine and unmodified and have not been subjected to the process that created that surface.

The scoured surfaces of the valleys on Mt. Sharp are dramatic. Additional evidence of older surfaces that experienced substantial erosion include blocks with ventification features (flutes, pits, grooves) on old undulating terrains on Bradbury Fm, in the swales where Curiosity took extensive wheel damage. Some ventifacts are also seen in blocks embedded in higher slopes visited during excursions by Curiosity up spur valleys from the main traverse in the Gediz Vallis region (**Fig. 4**). However, there is not a continuum of fresh uneroded blocks grading into increasingly more eroded and ventifacted blocks, suggesting an earlier more intense erosional epoch was followed by the current less effective erosional climate.

Fig. 4. Ventifacts along the edge of a spur valley from Gediz Vallis, Mastcam sol 3449 ML_101872.

The distribution of small craters along the traverse provides additional constraints. Consistent with orbiter data [10], Small craters (< 5 m diameter) are relatively common on the plains, but mostly absent on the slopes of Mt. Sharp [11], consistent with higher erosion rates above the Murray Buttes. Additional evidence for recent higher atmospheric pressures come from the statistics for small (> 5 m) craters on the plains along the traverse, as the crater abundances are lower than predicted for the present atmospheric pressure [12]. Thus, it is likely that during the most recent period of high pressure, fewer small crater forming objects hit the surface overall and they were rapidly erased in areas where focused erosion was most intense.

Discussion: Fluvial and glacial erosion can produce exaggerated topography; however, along the traverse, there is no evidence that fluvial or water-related erosion has produced the current topography along the traverse. Evidence for earlier geomorphic processes that include glacial and fluvial erosion may be preserved on the crater rim where the igneous basement rocks are more resistant to erosion, and possibly high on Mt. Sharp [13]. The most likely explanation for the topography, as suggested by Bridges et al. [3], is aeolian erosion by sand grains that are preferentially concentrated along the floors of swales and valley floors. An example encountered early in the mission was the observation of the blocks in the valley past Dingo Gap after sol 530 [2].

Recent changes in atmospheric pressure driven by obliquity changes, such as those recorded in layered polar deposits [5, 6], are another important part of the story of aeolian erosion in Gale crater. The exact changes in atmospheric pressure due to obliquity changes are highly model dependent, but work by Buhler et al. [6] suggests that even recent changes could result in higher pressures by a factor of 2-4 within the last 5 to 20 Ma for the most recent high obliquity interval. There could be many of these intervals throughout the Amazonian. The winds during these higher-pressure episodes will cause a larger flux of sand, substantially increasing erosion. Therefore, the current erosion rate may be much less than the erosion rates during periods of higher pressure. The changes in atmospheric pressure and erosion rate have likely affected the very small crater record as well. A thicker atmosphere than today and accompanying higher erosion rates has lowered the numbers of small craters below the numbers predicted based on the current flux and pressure [11]. The higher erosion rates due to focused sand blasting in the steep valleys on Mt. Sharp and between the Murray Buttes is also a likely explanation for the near complete absence of small craters in those areas.

Conclusions: The evidence produced by Curiosity's observations over ten years along the traverse suggests that the topography of the sedimentary packages becomes exaggerated by topographic focusing of sand (and therefore sand blasting along the floors of swales and valleys [3]. While this process has probably been occurring for billions of years, the more recent history of erosion has been complicated by the variations of atmospheric pressure due to obliquity changes. We see evidence (based on the small crater occurrences and other climate models and layered polar deposits) for an episode with a denser atmosphere and more intense erosion that produced the scoured slopes on Mt. Sharp and formed ventifacts in some areas. The principal wind direction that affected the crater floor during the denser atmosphere excursions could have been different [14]. The current climate with lower atmospheric pressure leads to deposition of dust on previously eroded surfaces, and relatively little erosion of more recently liberated float blocks now sitting on the scoured surfaces. Thus, the majority of the erosion of the sediments in Gale crater is likely to occur during periods when the atmosphere is denser and sand grains are more easily mobilized by saltation processes [3].

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