

## SURFACE MONITORING OF DUNE CHANGES FROM MSL: CURRENT RESULTS AND UPCOMING CAMPAIGNS

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### Introduction

Of the seven locations so far visited by landed spacecraft, Gale Crater is probably the best for understanding wind effects on Mars. With active sand dunes [1], a central mound whose formation, erosion, and likely exhumation has been heavily driven by aeolian processes [1-6], and evidence for abrasion reflected in measured exposure ages of rocks [7], wind has been and remains a major geologic agent. The active dunes in Gale provide a unique opportunity to study active Martian sand dunes at a range of scales ranging from HiRISE orbital images to small bedforms and even sand grains. With Curiosity's payload of high resolution imagers [8-10] and the REMS meteorological package [11], the potential exists to correlate dune and ripple migration with current conditions.

On Curiosity, Mastcam provides stereo color imaging with two cameras, M34 (34 mm focal length) (left eye) and M100 (right eye), with pixel scales of 220 and 74  $\mu$ rad, respectively [10]. RMI, at 19.6  $\mu$ rad/pixel [8,9], is the highest resolution remote imager ever put on a planetary surface in terms of pixel sampling, exceeded only in spatial scale by microscopic imagers placed close to rocks and soils. With these pixel scales, RMI and M100 exceed the resolution of HiRISE (27 cm pixel scale from 270 km) at distances of ~14 and 3.6 km, respectively. Curiosity's landing point at Bradbury was about 2.5 km from the "Bagnold" dune field to the south, with the rover getting closer to the dunes since leaving Yellowknife Bay. Therefore, already the resolution exceeds that from HiRISE. This abstract reports on initial observations of sand dunes with combined M100 and RMI images. Although the timespan and colocation of MSL images is thus far insufficient to document changes, we show that ripple patterns at scales finer than that seen from orbit offer the promise of monitoring future dune dynamics

### Methods

During MSL surface operations, RMI and M100 were specifically targeted on the "Bagnold" dune field surrounding Mt. Sharp (Table 1). Images were processed by the MSL Team using standard pipelines and procedures (e.g., 9) and mosaics made where there were two or more frames.

Table 1: High Resolution MSL Images of Bagnold Dune Field

Sol	Informal Name	ChemCam	M100 Sequences
		RMI	
		Sequences	
327	Ameto	ccam05326 (5x2)	mcam01327 (1x1 R0)
404	Dune Fields	ccam02404 (z-stack)	mcam01679 (1x1 R0)
408	Mt. Sharp	ccam08407 (2x11)	mcam1692 (1x2R0)
432	Mt. Sharp	ccam02432 (2x10)	mcam01759 (1x2 R0)
432	Mt. Sharp (N43111)	ccam03432 (1x10)	NA
434	West Falls	ccam02434 (2x10)	mcam01773 (1x2 R0)
466	Hematite Ridge	ccam02466 (1x10)	mcam01863 (27 x 3), mcam01864 (1x1 Rall)
466	Hematite Ridge	ccam03466 (1x10)	mcam01863 (27 x 3), mcam01864 (1x1 Rall)
475	Hematite Ridge	ccam01475 (1x10)	mcam01888 (1x1 Rall)
475	Hematite Ridge	ccam02475 (1x10)	mcam01887 (1x1 R0)

*values in parentheses are the number of columns and rows, respectively, of images*

### Results

There have been 10 long distance RMI images of the dunes since leaving Yellowknife Bay, all but one having with supporting M100 coverage (Fig. 1, Table 1). This compares with 12 HiRISE images each acquired before (4/22/07-8/1/12) and after (8/6/12-9/30/13) landing. The MSL images show clear ripple sets that, as seen in HiRISE, are located on sand patches (Fig. 2-3). Future work will register the features seen in the two datasets. No barchans dune slip faces are yet seen from the surface because they are occluded by foreground topography.

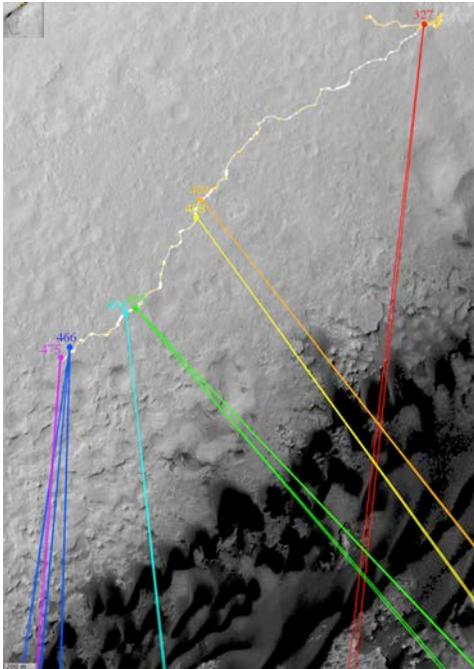


Figure 1: HiRISE orthoimage mosaic overlaid with rover path, shown in white. The colored numbers designate sol position from which RMI and M100 images of dunes were acquired. The colored lines show the azimuthal field of view of the RMI images or mosaics.

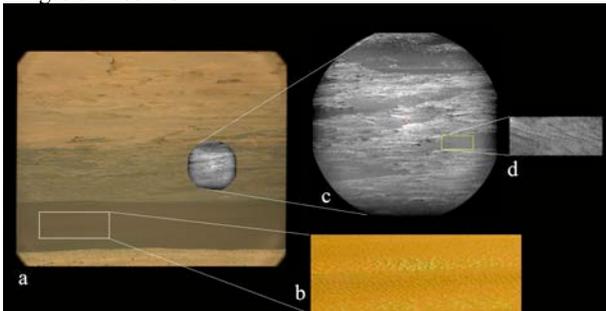


Figure 2: M100 and RMI images of "Dune Fields" region at base of Mt. Sharp (Sol 404). a) M100 mcam01679 show collocated RMI image and box highlighted in b. b) Enhanced view of ripple textures, c) RMI image 02404, d) Enlargement of portion of RMI image showing ripple texture.

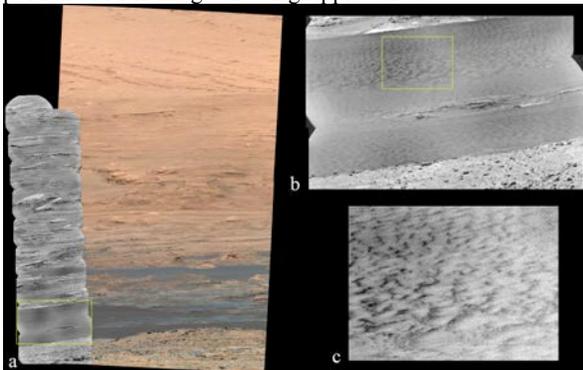


Figure 3: M100 and RMI images of Mt. Sharp (Sol 408). a) M100 mcam01759 show collocated RMI image mosaic 02432 and box highlighted in b. b) Enhanced view of ripple textures, c) Enlargement of ripple textures.

**Discussion**

Although the dunes in the vicinity of MSL have not yet been analyzed for changes in HiRISE images, those to the southwest with similar morphologies have migration rates of ~ 0.4 m per Earth year [1]. With proper registration and assuming that changes over three pixels can be discerned, RMI and MCAM at 2.5 km distance should see such changes in just ~130 and 500 days, respectively (Fig. 4). Presently, topographic obscuration and temporal coverage have not yet allowed detection of movement. However, as Curiosity gets closer to the dunes, such changes should be easier to see both because of the higher spatial resolution and lower required temporal baseline. Primary and secondary ripples, which should have migration rates faster than larger dunes, will be seen at correspondingly smaller time scales. Through such studies, migration rates and sand fluxes from ripples and dunes [12] can be determined.

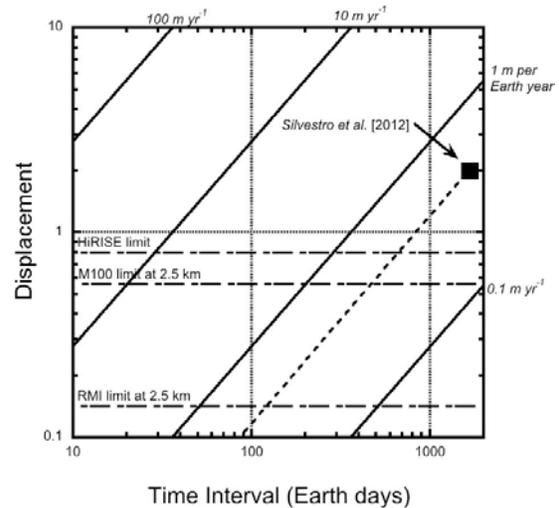


Figure 3: Schematic diagram of bedform displacement vs. elapsed time. Horizontal lines delineate 3 pixel displacements that can be discerned by HiRISE from a 270 km slant distance and M100 and RMI from 2.5 km. The diagonal dashed line is Gale dune migration rate of 0.4 m yr<sup>-1</sup> as determined by [1].

**References** [1] Silvestro, S. et al. (2013), *Geology*, 41, 483-486 [2] Malin, M. C., and K. S. Edgett (2000), *Science*, 290, 1927-1937. [3] Anderson, R.B. and J.F. Bell (2010), *Mars*, 5, 76-128. [4] Milliken, R.E., et al. (2010), *Geophys. Res. Lett.*, 37, doi:10.1029/2009GL041870. [5] Thomson, B. et al. (2011), *Icarus*, 214, 413-432. [6] Kite, E.S. et al. (2013), *Geology*, 41, 543-546. [7] Farley, K.A. et al. (2013), *Science*, doi: 10.1126/science.1247166. [8] Maurice, S. et al. (2012), *Space Sci. Rev.*, doi: 10.1007/s11214-012-9912-2. [9] Le Mouélic, S. et al. (2013), *Lun. Planet. Sci. XLIV*, 1213. [10] Malin, M.C. et al. (2010), *Lun. Planet. Sci. XLI*, 1123. [11] Gomez-Elvira, J. et al. (2011), *4<sup>th</sup> International Workshop on the Mars atmosphere: Modeling and observations*. [12] Bridges, N.T. et al. (2012), *Nature*, doi.10.1038/nature11022.