CROSS-BEDDED FACIES AND INFERRED PALEOCURRENTS OBSERVED BY THE CURIOSITY ROVER ALONG THE TRAVERSE TO MT. SHARP, GALE CRATER, MARS.

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Introduction: Since landing in Gale crater, the Mars Science Laboratory (MSL) rover Curiosity has investigated a number of sedimentary outcrops. Many of these outcrops show evidence for decimeter-scale cross-bedding, inferred to have formed by the migration of subaqueous and subaerial bedforms [1-3]. Here we present a comprehensive survey of the distribution of cross-stratified deposits along Curiosity's traverse from Yellowknife Bay to The Kimberley, and use cross-bedding geometries to infer regional trends in paleocurrent direction.

Geologic Context: During the first year of the mission, Curiosity explored Bradbury Landing and Yellowknife Bay, interpreted to represent a habitable fluvial-lacustrine environment [1]. These outcrops lie at the distal extent of a large alluvial fan that extends from the northern crater rim [4]. While a number of large-scale fluvial landforms have been identified at Gale crater based on orbital imaging [4-6], these outcrops explored by Curiosity represent the first opportunity for detailed in-situ investigations of facies variations and sedimentary structures.

Since leaving Yellowknife Bay, Curiosity has driven more than 3.6 km to the southeast along the traverse to Mt. Sharp, from sol 326 to sol 606. Along the way, Curiosity has gained ~ 40 m in elevation. Data from the Mast Cameras (Mastcam), the Mars Hand Lens Imager (MAHLI) and the ChemCam Remote Micro-Imager (RMI) provide insight into the distribution of cross-stratified facies along the traverse, and the depositional processes and paleoenvironments that they record.

Methods: The outcrops discussed here were first identified in Mastcam images. Mastcam is a multispectral imaging system that consists of two digital cameras located on the rover's mast, 1.97 m above the ground. The left and right cameras have 34 mm (M-34) and 100 mm (M-100) focal lengths, yielding pixel scales of 0.22 and 0.074 mrad/pixel, respectively. Mastcam is capable of full color panoramic and stereoscopic measurements. Mastcam images were used to identify cross-bedded facies and determine dip directions of bedding for paleocurrent analyses.

Where possible, data from the MAHLI and ChemCam RMI provide additional information about stratification and grain size. MAHLI is a high-resolution camera mounted on the rover's arm, capable of both color and stereoscopic imaging. MAHLI operates at working distances between 2.1 cm to infinity, with a maximum resolution of ~14 um/pixel [7]. MAHLI images enable the identification of small-scale sedimentary structures and grain sizes. The ChemCam RMI can also be used to analyze grain sizes and sedimentary structures in more distant targets. The RMI is located on the rover's mast, and has a field of view of 20 mrad and a pixel scale of 19.6 μm per pixel [8].

Preliminary Results: Cross-stratified deposits can be divided into three distinct facies based on grain size and sedimentary structures.

Facies 1: Fine-grained evenly laminated sandstone facies. This facies is interpreted to represent aeolian wind-ripple stratification.

Facies 2: Fine-to-coarse-grained cross-stratified sandstone facies. Cross-bedding is centimeter to decimeter in scale and exhibits sub-critical angles of climb. This facies is interpreted to represent the migration of subaqueous bedforms.

Facies 3: Cross-stratified pebbly sandstones and conglomerates. Cross-bedding is typically decimeter in scale and exhibits sub-critical angles of climb. This facies is interpreted to represent the migration of subaqueous bedforms.

Distribution: Cross-stratified deposits were identified across the entire traverse, covering a distance of more than 3.6 km and spanning ~ 40 m in elevation (Fig 1). However, individual cross-stratified deposits cannot be traced laterally for more than several tens of meters. Many of these cross-stratified outcrops appear to be preserved only in topographic lows.

Paleocurrents: Cross-bedding dip directions were used as a proxy for paleo transport direction. While there is great variability in bedform migration direction (small-scale bedforms appear to have migrated in nearly every direction), preliminary results based on large-scale bounding surfaces suggest that many outcrops record a net transport direction towards the southeast (Fig 2).

Conclusions: Many of the outcrops encountered along the traverse show evidence for fluvial deposition with some aeolian reworking. The widespread distribution across the entire traverse suggests that fluvial deposition was a common mode of deposition for many of the sedimentary rocks encountered by Curiosity. However, fluvial activity was not continuous, as evidenced by aeolian reworking. Paleocurrent analyses suggest that sediment was primarily transported to the southeast, which is consistent with an inferred source coming from the northern crater rim. Many of these outcrops are too small to be detected in orbital images, and were not originally identified in mapping efforts, which highlights the need for in-situ investigations by the rover. Insight gained from this survey and ongoing analyses at the Kimberley outcrop will help to constrain the duration and distribution of aqueous and atmospheric activity along the traverse to Mt. Sharp.

References: [1] Grotzinger J. P. et al. (2013) *Science*, 343. [2] Edgar L. A. et al. (2014) *LPSC* Abstract #1648. [3] Gupta S. et al (2013) *AGU* Abstract #P14B-01. [4] Palucis M. C. et al. (2014) *JGR*, 119. [5] Anderson R. A. et al (2010), *Mars*, 5, 76-128. [6] Thomson B. J. et al. (2011), *Icarus*, 214, 413-432. [7] Edgett K. et al. (2012) *Space Sci Rev*, 170, 259-317. [8] Le Mouelic, S. et al. (2014), *Icarus*.

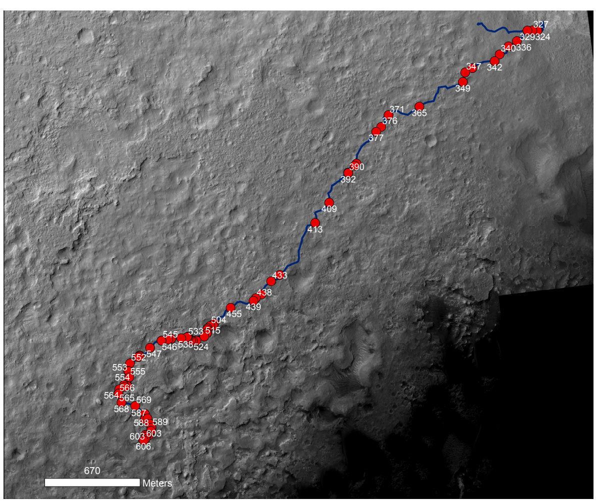

Figure 1: Curiosity traverse map as of Sol 606. Locations at which cross-bedded facies have been identified are shown in red, spanning the length of the entire traverse.

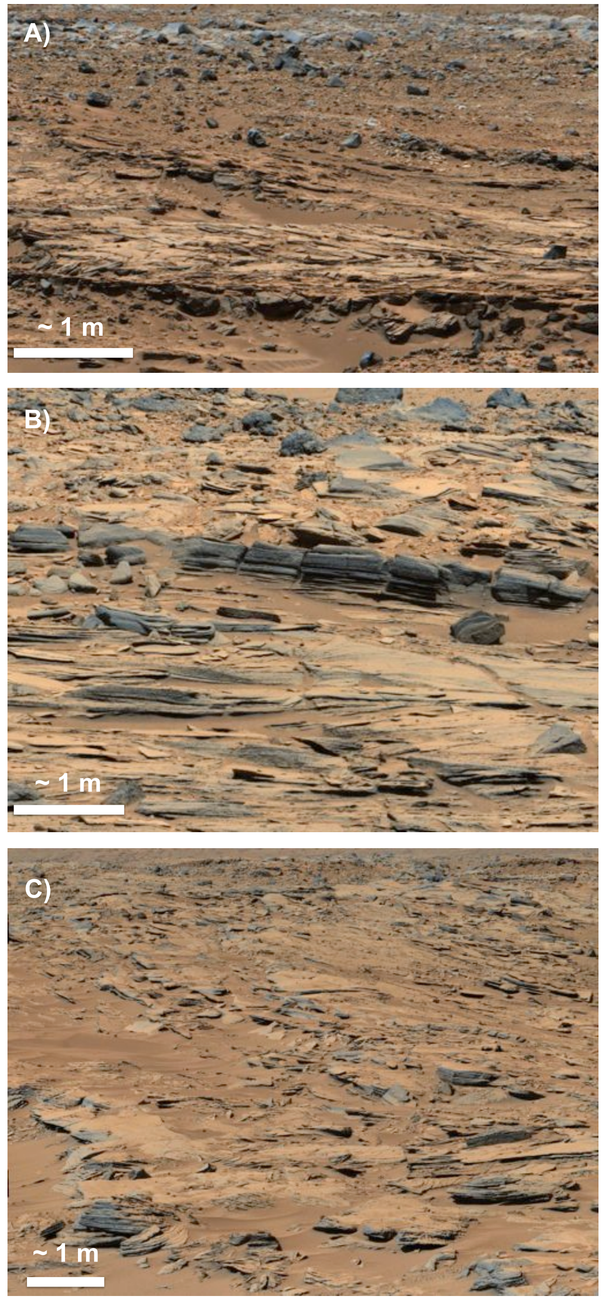

Figure 2: Examples of cross-stratified deposits encountered along the traverse. A) Prospect Mesa, acquired with the M100 camera on Sol 376, mcam01545. Mosaic is centered on azimuth 105, showing cross-beds dipping to the south-southeast (to the right). B) Target Inwood, acquired with the M100 camera on Sol 439, mcam01790. Mosaic is centered on azimuth 157. Cross-beds exhibit a variety of dip directions, while large-scale surfaces dip to the south (into the page and to the right). C) Drive direction mosaic acquired by the M100 camera on Sol 548, mcam02210. Mosaic is centered on azimuth 82; beds mainly dip to the southeast (to the right in the image).