USING OUTCROP EXPOSURES ON THE ROAD TO YELLOWKNIFE BAY TO BUILD A STRATIGRAPHIC COLUMN, GALE CRATER, MARS. K. M. Stack[1], J. P. Grotzinger[1], D. Y. Sumner[2], B. L. Ehlmann[1], R. E. Milliken[3], J. L. Eigenbrode[4], S. Gupta[5], R. M. E. Williams[6], L. C. Kah[7], K. W. Lewis[8], and the MSL Science Team. [1]California Institute of Technology, Pasadena, CA 91125 (kstack@caltech.edu), [2]UC Davis, Davis, CA 95616, [3]Brown University, Providence, RI 02912, [4]NASA Goddard Space Flight Center, Greenbelt, MD 20771, [5]Imperial College, London, UK, [6]Planetary Science Institute, 1700 E. Fort Lowell, Tucson, AZ 85719, [7]University of Tennessee, Knoxville, TN 37996 [8]Princeton University, Princeton, NJ 08540.

Introduction: Since landing in Gale Crater on August 5, 2012, the Curiosity rover has driven 450 m east, descending ~15 m in elevation from the Bradbury landing site to Yellowknife Bay. Outcrop exposure along this drive has been discontinuous, but isolated outcrops may represent windows into underlying in-place stratigraphy. This study presents an inventory of outcrops targeted by Curiosity (Figs. 1-2), grouped by lithological properties observed in Mastcam and Navcam imagery. Outcrop locations are placed in a stratigraphic context using orbital imagery and first principles of stratigraphy. The stratigraphic models presented here represent an essential first step in understanding the relative age relationships of lithological units encountered at the Curiosity landing site. Such observations will provide crucial context for assessing habitability potential of ancient Gale crater environments and organic matter preservation.

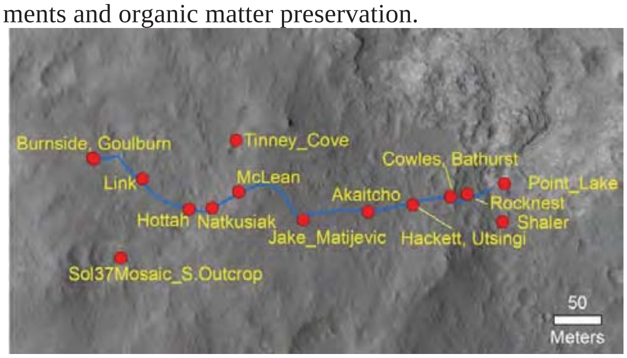

Figure 1. Outcrop locations and Curiosity rover traverse (sols 0-102) plotted on a HiRISE image.

Methods: Potential outcrop locations were identified in color Mastcam and Navcam images using parameters such as thickness, orientation, and similarity to nearby rock fragments to distinguish in-place outcrop from float. Outcrop locations were then localized in HiRISE orbital imagery relative to the rover traverse (Fig. 1). Geoid elevations for each outcrop location were derived from a HiRISE DTM created for the MSL Project [1, 2]. Using these extracted elevations, outcrop locations were plotted along a 2-D cross-section of the rover traverse (Fig. 2). Tone and color, presence of bedding, grain-size, and weathering style were used to characterize and classify seven outcrop types (Fig. 3), and three potential stratigraphic models were constructed using the elevation values and lithologic properties (Fig. 4).

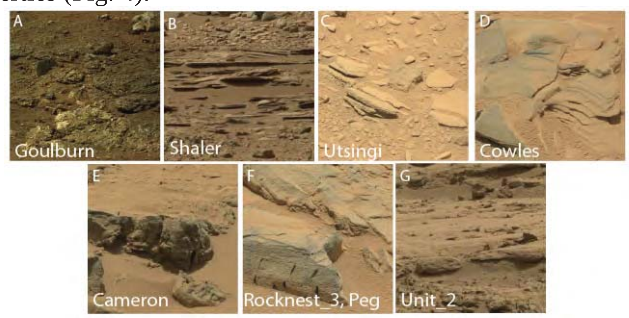

Figure 3. Mastcam M100 images showing type examples of lithologic units. A) conglomerate, B) fine-grained, platy, cross-bedded, C) fine-grained stratified, D) very fine-grained, finely laminated, E) massive, vuggy, ropey, F) layered vuggy, G) thickly-bedded, fractured.

Outcrop Lithologies:

Conglomerate. Curiosity observed pebbly conglomerate outcrops at the Bradbury landing site and intermittently during the first 200 m of the rover traverse [3]. Goulburn, Burnside, Link, Hottah, Natkusiak, and McLean targets are examples of this facies (Figs. 2, 3A).

Fine-grained platy, possibly cross-stratified. Mastcam color mosaics targeted at the area surrounding the Bradbury landing site revealed bright, thinly-bedded rocks containing possible cross-stratification. From a distance these outcrops appear to be finer-grained than

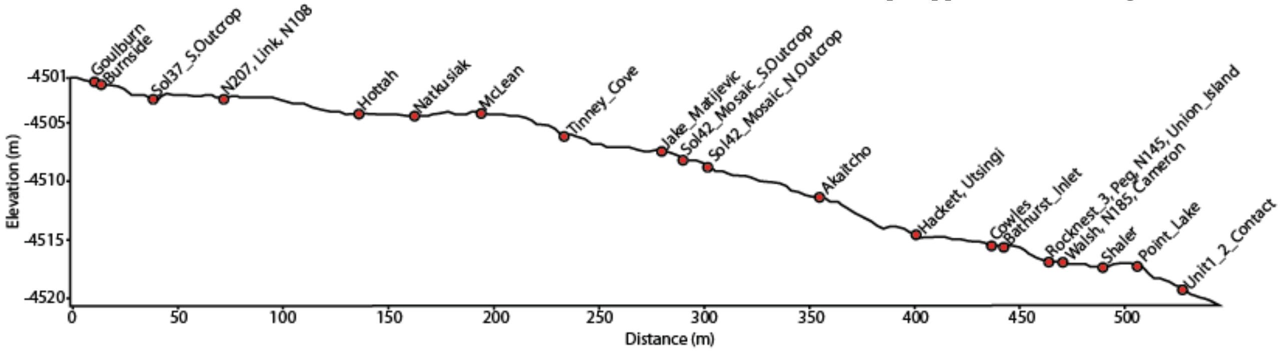

Figure 2. Outcrop target locations plotted on a topographic cross-section of the Curiosity rover traverse (sols 0-102). Note that Tinney_Cove is plotted according to its elevation rather than horizontal position along rover traverse. V.E. = 5.6

the conglomerate facies. Tinney_Cove, Shaler (Fig. 3B), N145, and an unnamed outcrop located south of the rover's landing site represent this unit.

Fine-grained, stratified. A third outcrop type is exposed intermittently between the Jake_Matijevic target and the Cowles area. This outcrop type exhibits tabular beds when visible, and appears to be fine-grained. Cross-stratification has not been observed. Targets Hackett, Utsingi, and outcrops exposed near Jake_Matijevic represent this unit (Fig. 3C).

Very fine-grained, finely laminated. The Cowles and Bathurst_Inlet rocks represent an outcrop type that is very fine-grained (silt-size or smaller), well indurated, dark gray in color on dust-free surfaces, and characterized by thin (< 1 cm) laminations (Fig. 3D).

Massive vuggy, ropey. This unit is represented by an assortment of outcrops observed at and around the Rocknest scoop location, as well as outcrop located in the Point Lake vicinity. Walsh, Cameron, and rocks of the Rocknest crest and Point Lake are dark gray in color, massive, contain abundant vugs, and sometimes exhibit a ropey weathering style (Fig. 3E).

Layered, vuggy. This group is represented by outcrops observed at and around the Rocknest scoop location (Fig. 3F). Targets Rocknest_3, Peg, and Union Island are dark gray in color and characterized by thin layers or laminations, spindle-shape voids, filled fractures, and small vugs.

Thickly-bedded, fractured. Outcrop exposed below Point Lake in Yellowknife Bay is composed of fractured bedrock of unknown grain-size exhibiting decimeter-scale bedding (Fig. 3G). This outcrop type has been divided into two units (Units 1 and 2) based on the presence of a very distinct stratigraphic boundary visible in Mastcam mosaics and HiRISE imagery [4].

Stratigraphic Models: Creating stratigraphic columns from a 2-D rover traverse cross-section requires several assumptions: (1) identified outcrops represent in-place stratigraphy, (2) units were deposited horizontally and are still horizontal so that outcrop elevations are a proxy for stratigraphic position, and (3) units follow the Law of Superposition. Using these assumptions, the following three stratigraphic models are proposed (Fig. 4).

Model 1 strictly follows horizontality and superposition such that fine-grained, platy, potentially cross-stratified units are inter-bedded with the Bradbury gravels, as dictated by the variable elevation of the conglomerates and Tinney_Cove-like outcrops. In this model, Shaler and other platy rocks near Rocknest are interbedded within the Glenelg stratigraphy.

In Model 2, the platy rocks of Tinney_Cove and Shaler represent the youngest units of the entire succession, deposited unconformably on the Bradbury gravels and exposed Glenelg/Yellowknife Bay stratigraphy.

Alternately, Model 3 considers the Bradbury conglomerates to be the youngest unit in the sequence, deposited unconformably on fine-grained rocks of Tinney_Cove, Hackett, and Utsingi.

Geochemical and image observations [5] indicate that the units exposed on the Bradbury rise may be distinct from those exposed in the Glenelg succession. Therefore it is possible that the stratigraphic relationship between these two parts of the sequence is more complex than indicated by the simple models presented here.

Discussion: All three stratigraphic models presented here are plausible given the existing inventory of targeted outcrop observations. However, each model has unique implications for the timing and extent of aqueous deposition in Gale Crater, particularly concerning the conglomerate facies interpreted by [3] to represent fluvial deposition. Whereas it may not be possible to distinguish between the three stratigraphic models at this point in the mission, stratigraphic frameworks such as those presented here can aid in the development of testable hypotheses that guide the selection of targets for continued camera observations, drilling, and detailed geochemical analysis. This type of coordinated campaign, combining in-situ stratigraphic analysis, geochemical analysis, and continued orbital mapping campaign will be necessary to refine the age relationships and depositional interpretations of the Bradbury, Glenelg, and Yellowknife Bay units.

References: [1] Kirk, et al. (2008) *JGR, 113*. [2] Calef, et al. (2013) *LPS XLIV* this volume. [3] Williams, et al. (2013) *LPS XLIV* this volume. [4] Sumner, et al. (2013) *LPS XLIV* this volume. [5] Weins, et al. (2013) *LPS XLIV* this volume.

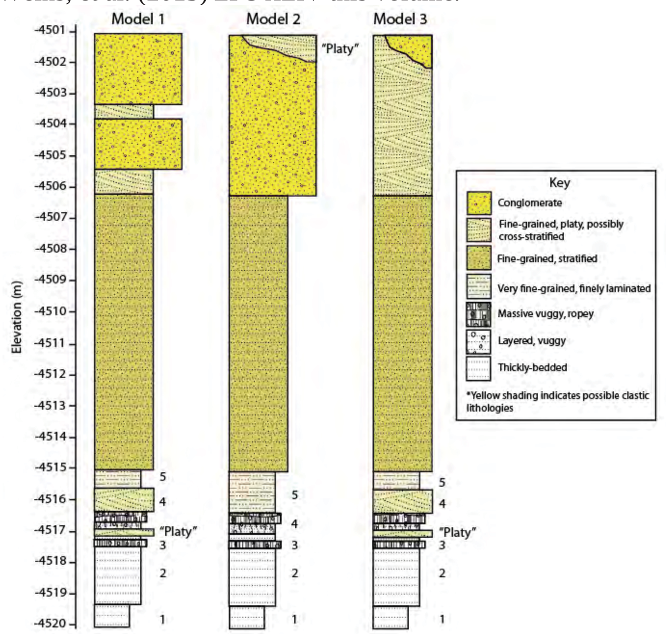

Figure 4. Three possible stratigraphic models consistent with Curiosity outcrop observations. Horizontal scale indicates relative changes in grain-size and resistivity since grain-size is not known for all outcrops. Numbers 1-5 correspond to orbital geomorphic units identified by [4].