SEDIMENTARY FACIES AND BEDFORM ANALYSIS OBSERVED FROM THE ROCKNEST OUTCROP (SOLS 59-100), GALE CRATER, MARS.

L. A. Edgar[1], D. M. Rubin[2], J. P. Grotzinger[3], J. F. Bell III[1], F. J. Calef III[4], G. Dromart[5], S. Gupta[6], L. C. Kah[7], K. W. Lewis[8], N. Mangold[9], J. Schieber[10], K. M. Stack[3], D. Y. Sumner[11], and the MSL Science Team. [1]Arizona State University, Tempe, AZ, 85287, ledgar1@asu.edu, [2]USGS, Santa Cruz, CA, [3]California Institute of Technology, Pasadena, CA, [4]Jet Propulsion Laboratory, Pasadena, CA, [5]Universite de Lyon, France; [6]Imperial College London, London, UK, [7]University of Tennessee, Knoxville, TN, [8]Princeton University, Princeton, NJ, [9]Laboratoire de Planétologie et Géodynamique de Nantes, France, [10]Indiana University, Bloomington, IN, [11]UC Davis, Davis, CA.

Introduction: Since landing in Gale Crater, the Mars Science Laboratory Curiosity rover has investigated a number of rock outcrops. Sedimentary outcrops are of particular interst, because they record past aqueous and atmospheric processes. From the Rocknest location, during sols 59 to 100, Curiosity observed a range of cross-bedded deposits spanning more than 60 m in lateral extent. Cross-bedding is best exposed in an ~80-cm-thick outcrop known as Shaler, located approximately 40 m to the SE of Rocknest (Fig 1). Observations of cross-bedding both at Shaler and in the blocks and outcrops near Rocknest enabled the recognition of several distinct cross-bedded facies. Analysis of cross-bedding geometries provides insight into the depositional environment.

Methods: Sedimentary outcrops were observed by the Mast Cameras (Mastcam). Mastcam is a multispectral imaging system which consists of two digital cameras mounted 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 lenghs, 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 delineate facies and determine dip directions of bedding.

Facies: Several distinct facies can be recognized on the basis of inferred grain size, erosional resistance, color, and sedimentary structures.

Resistant cross-stratified facies – This facies is expressed as cm-thick, well cemented beds commonly but not always separated by recessive gaps. This facies is light-toned in comparison to surrounding facies, and some beds show a characteristic roughness inferred to represent grain sizes of up to coarse sand to pebble. In addition to its erosional resistance, this facies is defined by simple cross-stratification (Fig 2a).

Smooth, fine-grained cross-stratified facies – This facies is characterized by a lighter tone, blue-gray color, and smoother appearance than the surrounding deposits. This facies may appear massive, but simple cross-beds are observed in favorable lighting conditions. The smooth appearance likely reflects finer average grain sizes than the resistant cross-stratified facies (Fig 2b).

Dark gray, pitted facies – This facies has a darker appearance than surrounding facies, and a distinctive pitted weathering texture. If pitted textures result from preferential weathering of sedimentary clasts, the pits suggest the presence of granule to pebble-sized clasts (Fig 2c). Alternatively, the pitted texture may result from differential cementation or the presence of concretions. This facies contains high-angle, cm-scale cross stratification in sloping beds.

Recessive, vertically fractured facies – This laminated, recessive facies is characterized by the presence of vertical fractures that originate from the same bed and extend downward through several beds. The fractures are more resistant than the beds they disrupt. This facies has only been observed in the Shaler outcrop, but may be difficult to identify elsewhere because of its recessive and friable nature (Fig 2d).

Analysis of bedforms: Several types of cross-stratification and other bedforms have been identified in the Shaler outcrop, including simple (no superimposed bedforms) and compound cross-bedding (formed by the migration of superimposed bedforms); angular discontinuities between lamina sets; and potential soft-sediment deformation. Cross-bed sets range from centimeter to decimeter in scale. Trough cross-bedding suggests that bedforms had sinuous crestlines. In the vicinity of Rocknest, one block contains small cm-

Figure 1. Shaler outcrop, as viewed from Rocknest. M-100 mosaic acquired on sol 60.

scale climbing ripples, though the block is not in place (Fig 3). Where climbing bedforms are visible, they climb at subcritical angles, resulting in preservation of only the lee slopes.

Analysis of cross-bedding dip directions indicate a range of sediment transport directions. Bedding dips exposed in the Shaler outcrop are generally to the southeast. Bedding dips exposed in isolated outcrops near Rocknest generally dip to the north and northeast.

Paleo-depositional environment: Grain transport under turbulent flows was required to produce the observed cross-bedded facies. We consider three possible depositional environments: eolian, fluvial, and pyroclastic surge.

Pyroclastic surges are capable of producing cm-to-m-scale bedforms over a range of grain sizes. However, pyroclastic surge deposits often contain bedforms with supercritical angles of climb, resulting in stoss-side preservation, indicative of high rates of accumulation relative to migration. Pyroclastic surges transport sediment unidirectionally, radially away from a point source. Pyroclastic surge deposits additionally often contain volcanic indicators such as bombs and accretionary lapilli, and have distinct trends in grain size and facies from proximal to distal deposits or in vertical section [1-3]. No clear volcanic features such as bombs or lapilli have been observed in the cross-bedded deposits at Shaler and Rocknest thus far. The outcrops at Shaler and near Rocknest show evidence for multiple transport directions, which is inconsistent with the transport expected within pyroclastic surges. Based on these considerations, we find it unlikely that the cross-bedded facies at Shaler and near Rocknest represent pyroclastic surge deposits.

Eolian environments can produce bedforms of this scale, and may show evidence for a variety of sediment transport directions depending on the paleo wind regime. However, the grain size of Martian eolian dunes is thought to be ~500 microns (medium to coarse sand) [4]. If grain sizes at Shaler and near Rocknest are coarser than this, eolian deposition may not easily explain the observed crossbedding. Characteristic eolian stratification, such as windripple or grain flow features also have not been observed.

Fluvial deposition is consistent with observations of depositional features preserved at Shaler. Two examples of cross-lamination at Rocknest appear to be more similar to subaqueous ripple stratification, evidenced by cm-scale climbing ripples. The hypothesis for fluvial deposition can be tested by further observations from locations closer to the Shaler outcrop, particularly measurements of grain size distributions using the Mars Hand Lens Imager (MAHLI) instrument.

References: [1] Wohletz K. H. and Sheridan M. F. (1983) *Amer. Jour. Sci., 283*, 385-413. [2] Sohn Y. K. and Chough S. K. (1989) *Sedimentology, 36*, 837-855. [3] Branney M. J. and Kokelaar B. P. (2002) *Pyroclastic density currents and the sedimentation of ignimbrites.* [4] Edgett K. S. and Christensen P. R. (1991) *JGR, 96,* 765-776.

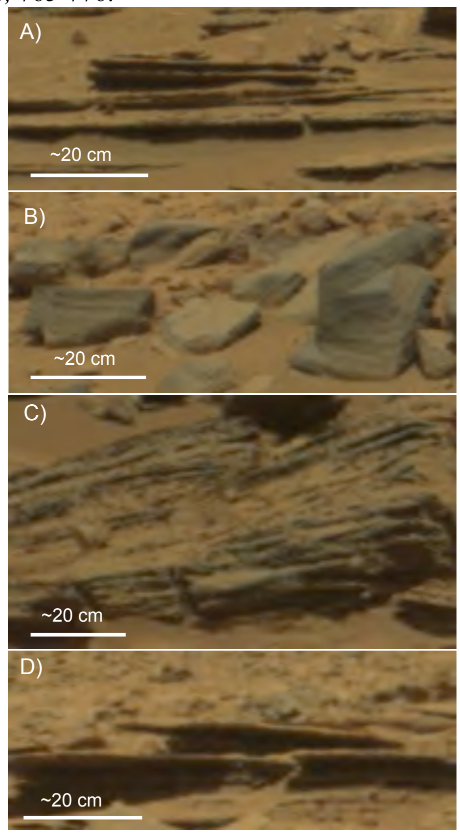

Figure 2: Facies in the Shaler outcrop from the sol 60 M-100 mosaic. A) Resistant cross-stratified facies. B) Smooth, fine-grained cross-stratified faceis. C) Dark gray, pitted facies. D) Recessive, vertically fractured facies.

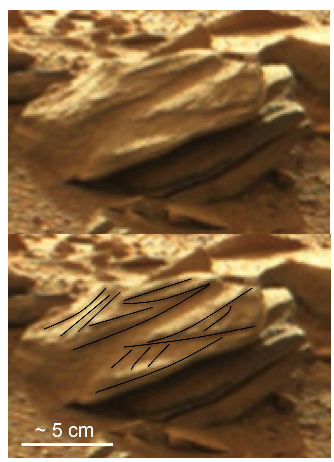

Figure 3: Centimeter-scale climbing ripples observed from Rocknest. M-100 mosaic acquired on sol 70.