Geophysical Research Abstracts
Vol. 15, EGU2013-14031, 2013
EGU General Assembly 2013

Cross-stratified Facies Observed by the Mars Science Laboratory Rover at Gale Crater, Mars

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The Mars Science Laboratory Curiosity rover has investigated a number of sedimentary rock outcrops since landing in Gale crater. 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. Observations using the Mast Cameras of cross-bedding both at Shaler and Rocknest enabled the recognition of several distinct cross-bedded facies. Analysis of cross-bedding geometries provides insight into the depositional environment.

On the basis of inferred grain size, erosional resistance, color, and sedimentary structures, we have identified four facies: 1) resistant cross-stratified facies, 2) smooth, fine-grained cross-stratified facies, 3) dark gray, pitted facies, and 4) recessive, vertically fractured facies. Sedimentary structures include simple and compound cross-bedding, angular discontinuities between lamina sets, and potential soft-sediment deformation. Trough cross-bedding suggests that bedforms had sinuous crestlines. Cross-bed sets range from centimeter to decimeter in scale. Small cm-scale climbing ripples were identified in the vicinity of Rocknest. 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.

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 surge deposits often contain bedforms with supercritical angles of climb, evidence for unidirectional transport radially away from a point source, contain volcanic indicators such as bombs and accretionary lapilli, and display distinct trends in grain size and facies from proximal to distal deposits or in vertical section. These characteristics do not match the observations at Shaler and Rocknest, and it is unlikely that the cross-bedded facies represent pyroclastic surge deposits. Eolian environments can produce bedforms of this scale, and may show evidence for a variety of transport directions. However, if grain sizes at Shaler and Rocknest are coarser than medium-to-coarse sand, eolian deposition may not easily explain the observed crossbedding. Characteristic eolian stratification, such as windripple or grain flow features have not been observed. Fluvial deposition is consistent with observations at Shaler and Rocknest. Cm-scale climbing ripples appear to be more similar to subaqueous ripple stratification. The hypothesis for fluvial deposition can be tested by further observations from locations closer to the Shaler outcrop, particularly measurements of grain size using the Mars Hand Lens Imager instrument.