Physical Sedimentology in Gale Crater, Mars*

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Abstract

Gale Crater was selected as the Mars Science Laboratory landing site largely because remote images suggested the crater contains a thick sequence of sedimentary rocks interpreted to be eolian, fluvial, and lacustrine deposits (previous work summarized by Anderson and Bell, 2010). In the year since landing, the rover, Curiosity, identified and examined deposits of all three of these depositional environments. Eolian deposits examined by Curiosity include the Rocknest sand shadow (unconsolidated sand in the lee of rocks on the surface described by Blake et al. in press) and thin sandstones beds with pinstripe laminae deposited by migrating wind ripples. On its route to Mt. Sharp, it is likely that the rover will pass near active eolian dunes and “washboard” deposits that have previously been interpreted as preserved eolian dunes. Fluvial deposits examined by Curiosity include both conglomerates and sandstones. The conglomerates have textures of fluvial conglomerates and contain rounded pebbles indicating substantial abrasion (Williams et al., 2013). The fluvial sandstones are cross-bedded (including compound cross-bedding), with dip directions indicating transport generally toward the southeast (toward Mt. Sharp rather than away from it). Fractures interpreted to be desiccation cracks and interbedded eolian (pinstriped) sandstones suggest that fluvial activity alternated with dry, windy, periods. Curiosity also examined deposits interpreted as distal fluvial or lacustrine mudstones (Sheepbed mudstone) at a location that is topographically lower than the fluvial sandstones and conglomerates. That unit is discussed in other abstracts in this session.
References Cited


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Lacustrine deposits
Fluvial deposits
  Conglomerates
  Sandstones
  Mudstones
Aeolian deposits
  Sandstones
  Dunes
    Sand-shadow dunes
    Polygonal dunes
    Bagnold dunes
Upcoming highlights

NASA/JPL-Caltech/MSSS
Goulburn, scoured by Curiosity’s descent rockets, first revealed bedrock.
Curiosity at Shaler, as seen by HiRISE
Lacustrine Sheepbed mudstone.
Many veins, but few (if any) primary physical structures documented.
Shaler outcrop context

Sheepbed Mbr

Gillespie

Grotzinger et al. 2013
Stratigraphic architecture

Shaler ‘Upper’ Unit

Gillespie Mb

Shaler basal surface (erosional relief exaggerated due to outcrop geometry)
Cross-bedded facies

Set boundary

~10 cm
This grain is ~2.5 mm diameter

MAHLI image - sol 323 Target Gudrid
Cross-stratification
Compound cross-stratification
Compound cross-stratification

Rubin & Carter (2005)
Mean dips for each Mastcam sequence

Dip azimuths curve around the outcrop, from E to SSE, roughly parallel to the upper contact of Shaler (yellow)
Recessive facies with desiccation cracks
Convoluted facies

Sol311_mcam01279

NASA/JPL-Caltech/MSSS
Vertical variability in grain size (fining upward)

~ 50 cm

NASA/JPL-Caltech/MSSS

Sol309_mcam01275
Presenter’s notes: Daily cycles in river discharge. Peak discharge can suspend more sand (top) and coarser sand (lower plot). Positively correlated trends indicate flow-regulated transport.
Aeolian sandstone at Shaler

Aeolian wind-ripple pin-stripe laminae (Hunter, 1977), in Entrada Sandstone.
Spatial variability in grain size and sedimentary structures

**NE Shaler**
- More recessive
- Soft sediment deformation
- Desiccation cracks
- Aeolian reworking

**SW Shaler**
- More resistant
- Compound cross-bedding
- Higher abundance of gravel
Stratification (lenses) or veins?

Cross-bedding

NASA/JPL-Caltech/MSSS
Sol 392
The sand shadow is about 12–15 cm high at crest.

The sand shadow is oriented approximately north-south.
Sand-shadow dunes in Qaidam Basin, China
Sand accumulates in weak flow in lee of obstacles (Bagnold).
MAHLI focus merge product from Sol 58

- Surface
- Interior
- Wall ≈ 5 cm high
- Talus
- Imprint of wheel grouser
- Note fine wheel manufacture milling marks
- ≈ 6.5 cm
surface grains are ~1 mm in size
• coarse & very coarse sand

bulk material is < 150 µm in size
• mostly fine and very fine sand
• some silt/clay-sized grains

wall ~5 cm high

MAHLI focus merge product from Sol 58
MAHLI focus merge product from Sol 58

- banding
- re-entrant
- blocks w/surface grains

4 cm

3rd Scoop Sol 69

4th Scoop Sol 74
MAHLI image from Sol 66

1st Scoop Sol 61

blocks w/surface grains

banding
Assume Application of Law-of-the-Wall

\[ u_z = \frac{u_*}{k} \ln \left( \frac{z}{z_0} \right) \]

\( u_z \) = wind speed at height \( z \)
\( k = 0.407 \)
\( z_0 \) varies with grain size and height of surface features such as wind ripples (Bagnold 1941), but also the height and intensity of the saltation cloud (Owen 1964).

Assume \( z_0 = 0.3 \) mm where \( z_0 = k/30 \) and \( k \) is 10 mm ripple height.

\[ u_{1m} = 51 \text{ m/s (114 mph)} = \text{Fluid threshold speed} \]

\[ u_{1m} = 37 \text{ m/s (84 mph)} = \text{Impact threshold speed} \]

Kocurek and others, 2013.
Dunes in crater, sol 426.
NASA/JPL-Caltech/Univ. of Arizona
NASA/JPL-Caltech/MSSS. Dunes in crater, sol 426.
NASA/JPL-Caltech/MSSS. Dunes in crater, sol 426.
Polygonal dunes, Victoria Crater, Mars

100 m

CREDIT: NASA/JPL/Univ. of Arizona
Observe streamlines in recirculating flow in cylinder with open top.

From Haigermoser, Scarano, Onorato, 2009, Experimental Fluids
Direction of sand flux if dunes are longitudinal.
Curiosity Traverse Map

Direction of sand flux indicated by belt of dunes

Direction of sand flux if dunes are longitudinal
Presenter’s notes: So what is the potential origin of the washboard unit. It has been previously suggested that they might represent either preserved sedimentary bedforms, or the exposure and differential erosion of preferentially lithified strata. We suggest that both of these suggestions are, in part correct. Easily see how these could be interpreted as preserved bedforms.
Fire ring

NASA/JPL-Caltech/MSSS; Sol 528
Daily cycles in flow cause daily cycles in grain size of sediment. In this case (Colorado River), daily flow cycles are dam releases for hydropower.
Kimberley (where *Curiosity* is now)
Mt. Sharp foothills
This boulder is the size of Curiosity.

Layers, Canyons, and Buttes of Mount Sharp
Most of these images from our 20-month journey were taken using *Curiosity*’s Mastcam.