



# **Gale Crater Observations of Relevance to Planetary Protection**

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MSL Project Scientist  
12/8/15**



# Outline



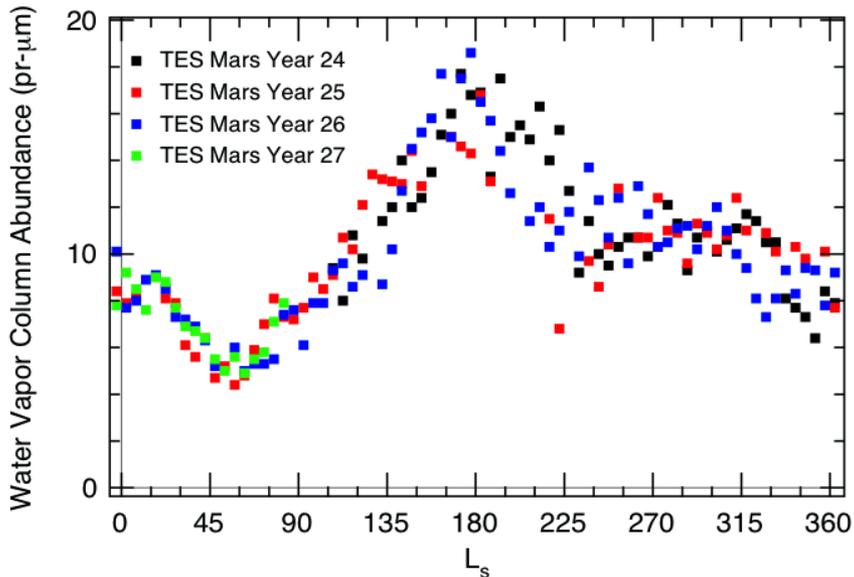
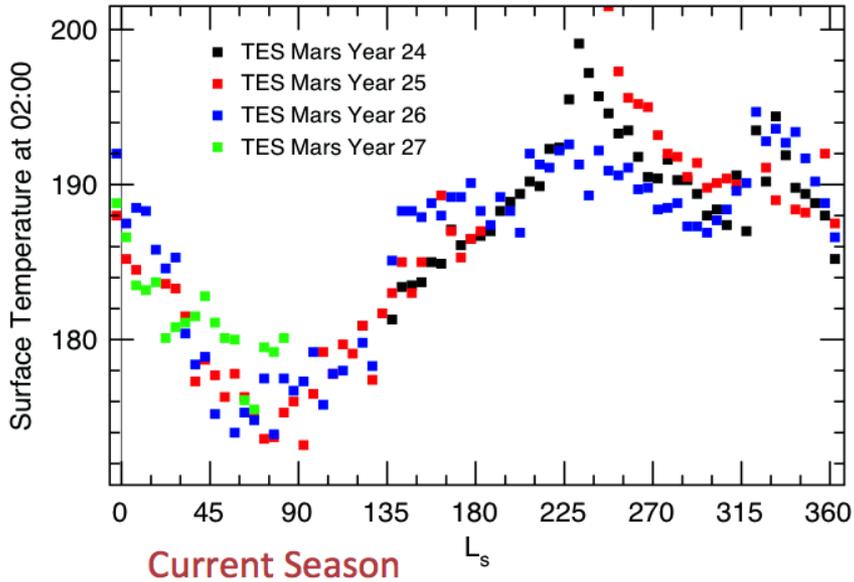
1. Measurements and Observations of Environmental Conditions in Gale Crater
2. Potential for Brine Formation
3. Dark Slope Features Observed Locally by Curiosity
4. Candidate Recurring Slope Lineae (RSLs) on Mount Sharp
5. In Work: New Operations Protocol for Planetary Protection

Have unexpected conditions been found by Curiosity?

Have features formed by liquid water been found in Gale Crater?

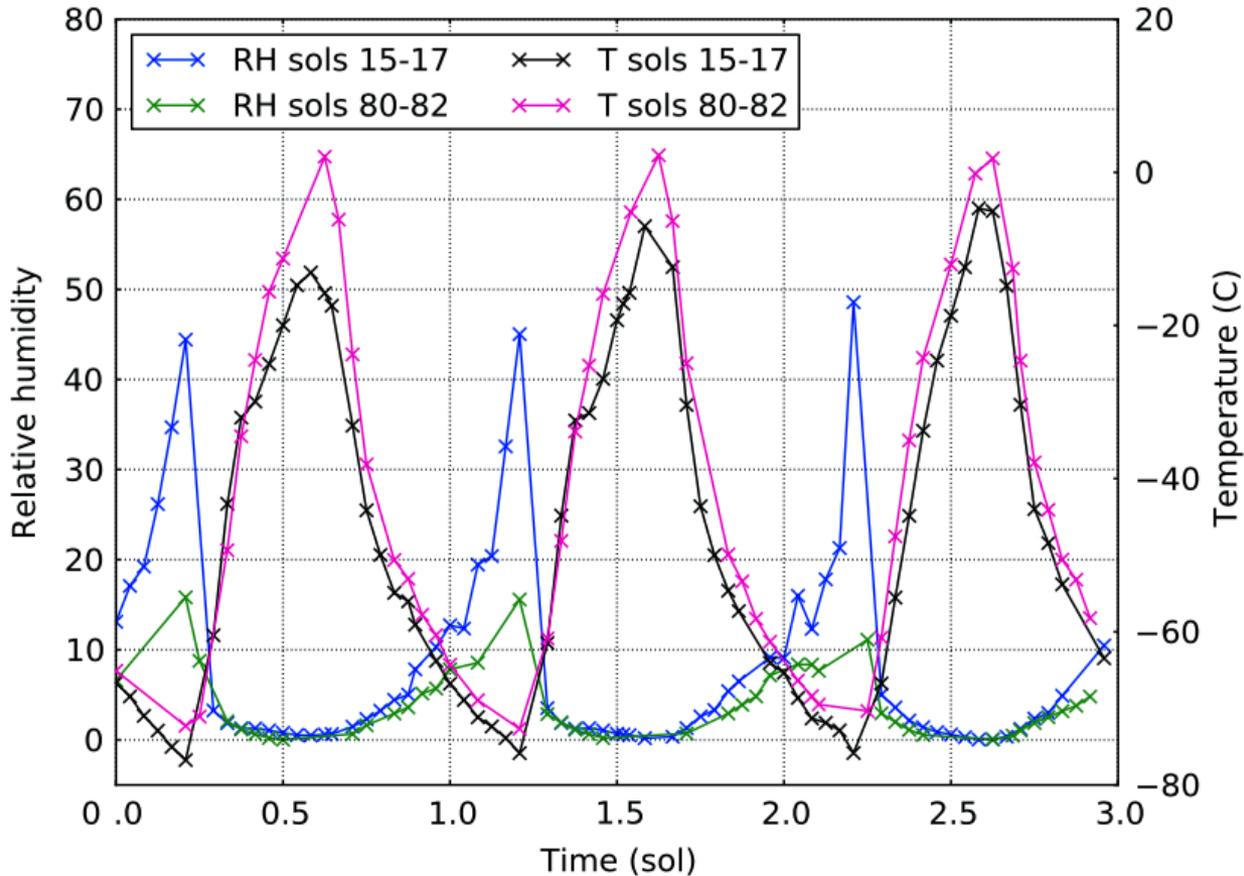


# Predicted Environmental Conditions



- Measurements of the Gale Crater region from Mars Global Surveyor's Thermal Emission Spectrometer (MGS-TES) found nighttime temperatures to be 175-200K.
- MGS-TES found the column abundance of water vapor to vary from 5-20 microns in thickness, if all the vapor were precipitated onto the surface as condensate.
- These values are typical of the very cold and dry condition across Mars.

# Measured Environmental Conditions

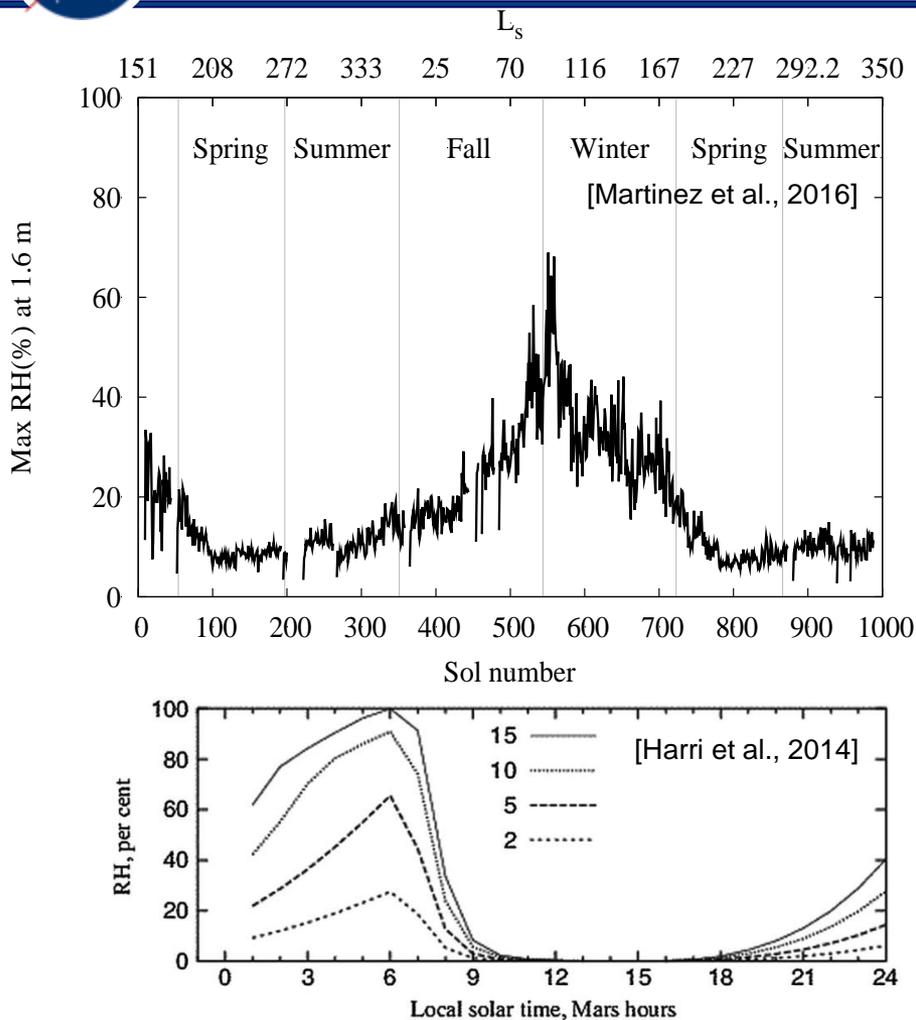


[Savijarvi et al., 2014]

Curiosity measures air temperature and relative humidity ( $RH_a$ ) at 1.6 m above the ground.  $RH_a$  is near zero during the daytime but increases at night, when temperatures are at their minimum.



# Measured Environmental Conditions



- The upper left plot shows the maximum  $RH_a$  each sol, which occurs pre-dawn when temperatures are coldest ( $\ll 0^\circ \text{C}$ ).
- The lower left plot shows that the measured  $RH_a$  values are consistent with the MGS-TES measurements of column water abundance.

**Figure 14.** Simulated relative humidity values at 1 m altitude for the MSL landing site using an atmospheric column model [Savijärvi et al., 2004]. The simulation assumed water being initially uniformly mixed in the atmosphere with absolute precipitable water contents of 2, 5, 10, and 15 pr  $\mu\text{m}$ .



## Summary

- Gale Crater is extremely cold and dry, as predicted prior to landing, and similar to Mars in general.
- Water vapor is present at 10s of parts per million in the atmosphere, equivalent to several microns in thickness if the entire vertical column were condensed.
- As is possible across Mars, water vapor near the surface likely adsorbs onto regolith, resulting in a daily or seasonal surface-atmosphere exchange [Savijarvi et al., 2016]. Water vapor may also exchange with hydrated minerals or salts. These processes are difficult to directly observe with other instruments. They do not involve the liquid phase (with the exception of deliquescence, discussed later).
- Relative humidity is near zero for most of each sol. However, when temperatures become very cold at night,  $RH_a$  can increase to several 10s of %. This raises the possibility of frost or brines at ground level, where temperatures are even colder.



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# Transient liquid water and water activity at Gale crater on Mars

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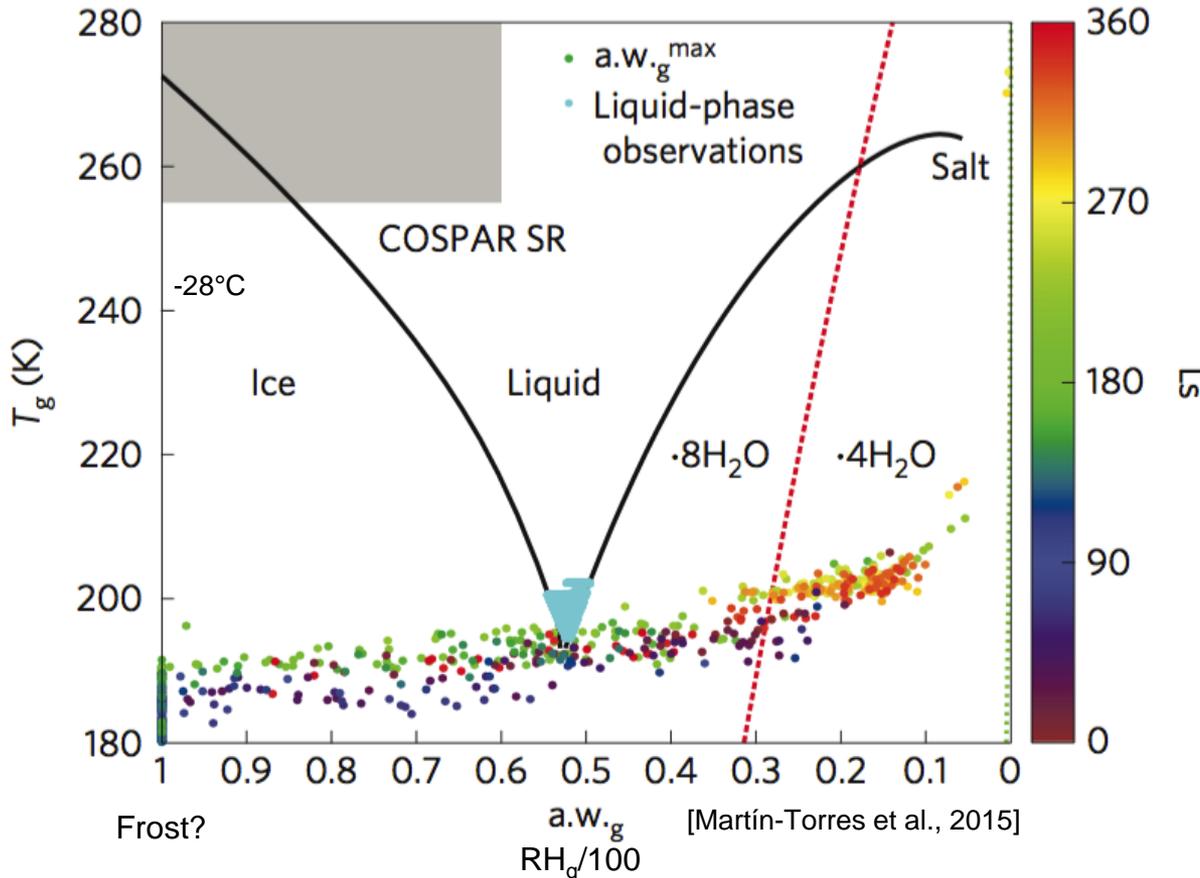
**Water is a requirement for life as we know it<sup>1</sup>. Indirect evidence of transient liquid water has been observed from orbiter on equatorial Mars<sup>2</sup>, in contrast with expectations from large-scale climate models. The presence of perchlorate salts, which have been detected at Gale crater on equatorial Mars by the Curiosity rover<sup>3,4</sup>, lowers the freezing temperature of water<sup>5</sup>. Moreover, perchlorates can form stable hydrated compounds and liquid solutions by absorbing atmospheric water vapour through deliquescence<sup>6,7</sup>. Here we analyse relative humidity, air temperature and ground temperature data from the Curiosity rover at Gale crater and find that the observations support the formation of night-time transient liquid brines in the uppermost 5 cm of the subsurface that then evaporate after sunrise. We also find that changes in the hydration state of salts within the uppermost 15 cm of the subsurface, as measured by Curiosity, are consistent with an active exchange of water at the atmosphere–soil interface. However, the water activity and temperature are probably too low to support terrestrial organisms<sup>8</sup>. Perchlorates are widespread on the surface of Mars<sup>9</sup> and we expect that liquid brines are abundant beyond equatorial regions where atmospheric humidity is higher and temperatures are lower.**

Science Laboratory (MSL) landed and has been operating since 6 August 2012.

However, here we show that the RH, air temperature ( $T_a$ ) and ground temperature ( $T_g$ ) observations at Gale by the Rover Environmental Monitoring Station<sup>14</sup> (REMS) on the Curiosity rover at the MSL mission<sup>15</sup> are compatible with the presence of liquid brines during night time due to the increased RH associated with night-time lower ambient temperatures. Figure 1a shows the diurnal variation of the ground relative humidity and temperature ( $RH_g$  and  $T_g$ ) for the sols (Martian days) corresponding to the beginning of each season: Ls = 90 (winter), 180 (spring), 270 (summer) and 360 (autumn). When one full martian year is analysed and compared with the phase diagram of Ca-perchlorate, the diurnal variation crosses at night time the boundary of liquid stability (REMS corresponding measurement data set shown in cyan) allowing for transient liquid stability at the ground surface (see Fig. 1b, and the diurnal cycle in Supplementary Figs 2 and 3). As shown in Supplementary Fig. 4, the local diurnal cycle also allows for transient liquid water stability in the uppermost 5 cm of the subsurface at night time during the full winter season. These conditions allowing for transient liquid water are not compatible with the known requirements for replication and metabolism of terrestrial

# Potential Brine Formation

- Measured ground temperature and **estimated**  $RH_g$  pass through the equilibrium conditions required for liquid brine formation for ~ hours during some nights around the winter season.
- The conditions are far outside those defined as COSPAR special regions.

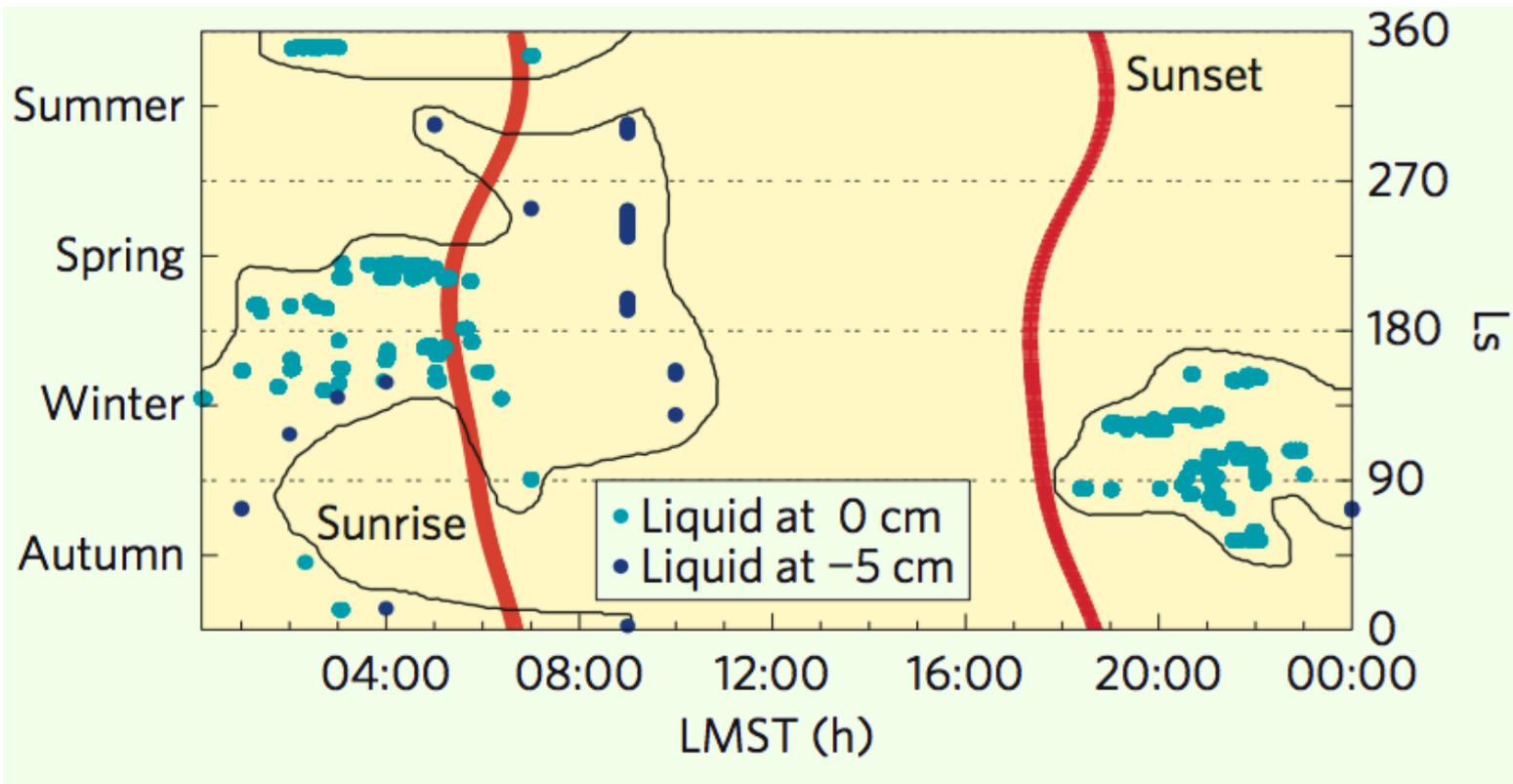


Left: phase diagram for calcium perchlorate showing where ice, brines, and hydrated phases may exist.

The dots are REMS measurements when water activity is maximum (colored dots) and when brine conditions are met (light blue).

# Potential Brine Formation

- REMS measurements were within equilibrium conditions for Ca-perchlorate brine for several hours on nights around the winter season (at some locations) and more transiently at other times of the year.



[Martín-Torres et al., 2015]



## Summary

- Calculations using measured temperatures and  $RH_a$ , and extrapolating to  $RH_g$ , find that equilibrium conditions for perchlorate brines are predicted during the night on some sols of the mission, primarily around winter.
- Equilibrium conditions do not necessarily result in brine formation. Formation would also depend on the kinetics of the phase change and the availability of water. Conditions at Gale Crater are on the edge of stability and exist for short durations (hours).
- No direct evidence of brines (or the frost that also is predicted with the estimated  $RH_g$ ) has been found at Gale Crater.
- Key implications of our Martín-Torres et al. paper:
  - Equilibrium conditions for brine in Gale Crater are far from those considered relevant for Special Regions, due to both extreme cold and low water activity.
  - Given that perchlorate salts may be widespread across Mars, brine formation may be more likely than previously thought, especially where water is more abundant than in Gale Crater.



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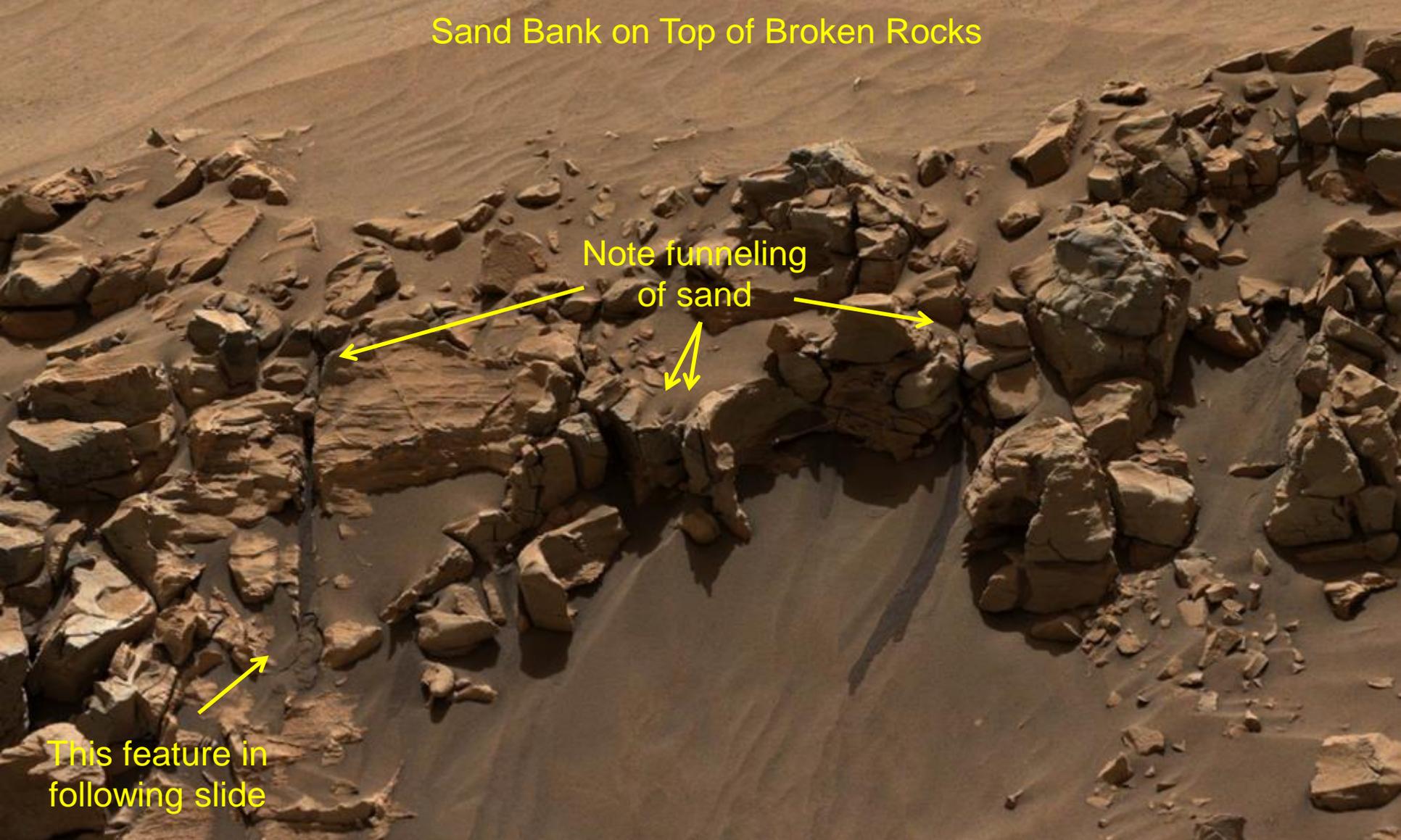


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**Sol 712 Navcam mosaic taken from the floor of Hidden Valley. The arrow marks a dark slope feature.**

Sand Bank on Top of Broken Rocks

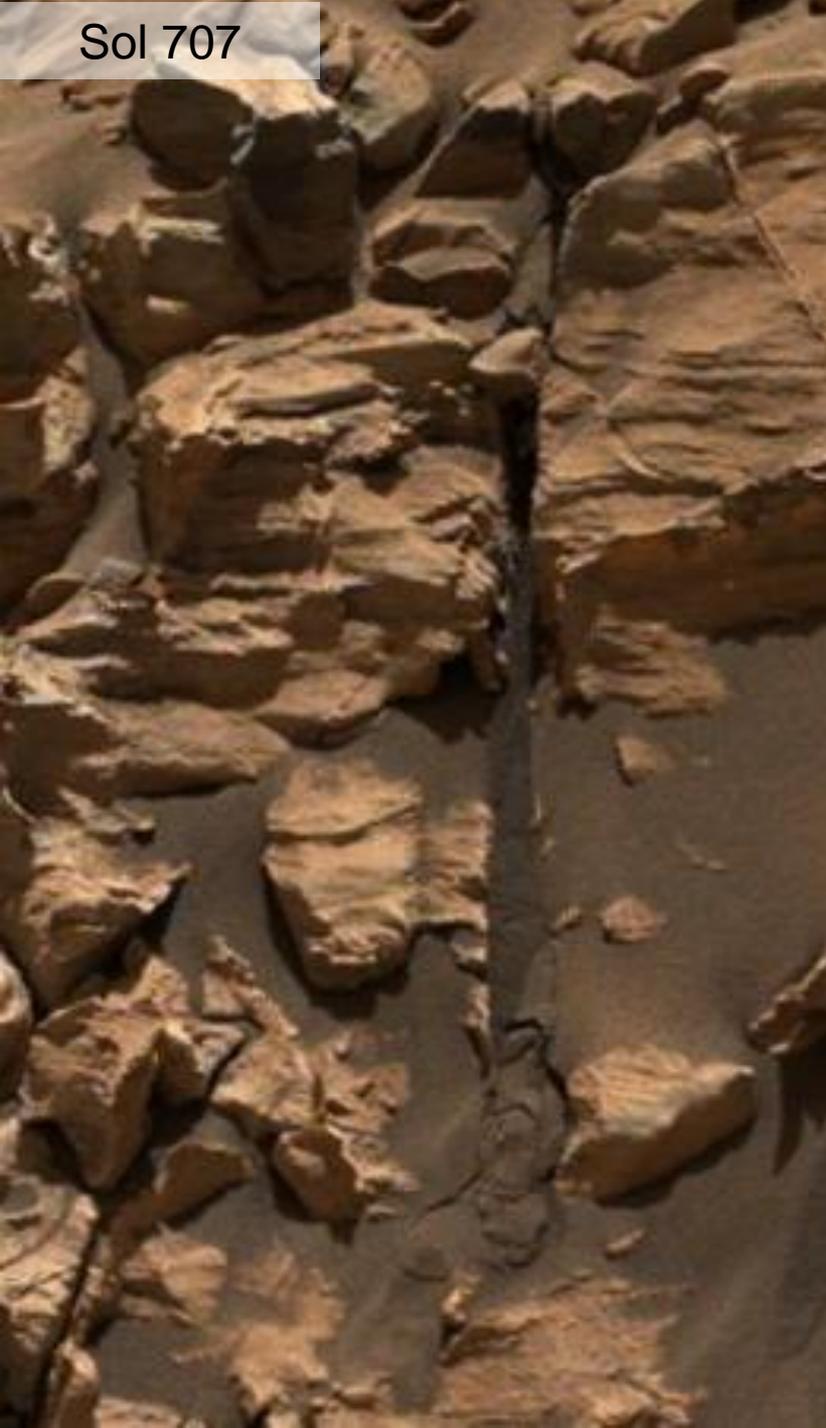


Note funneling  
of sand

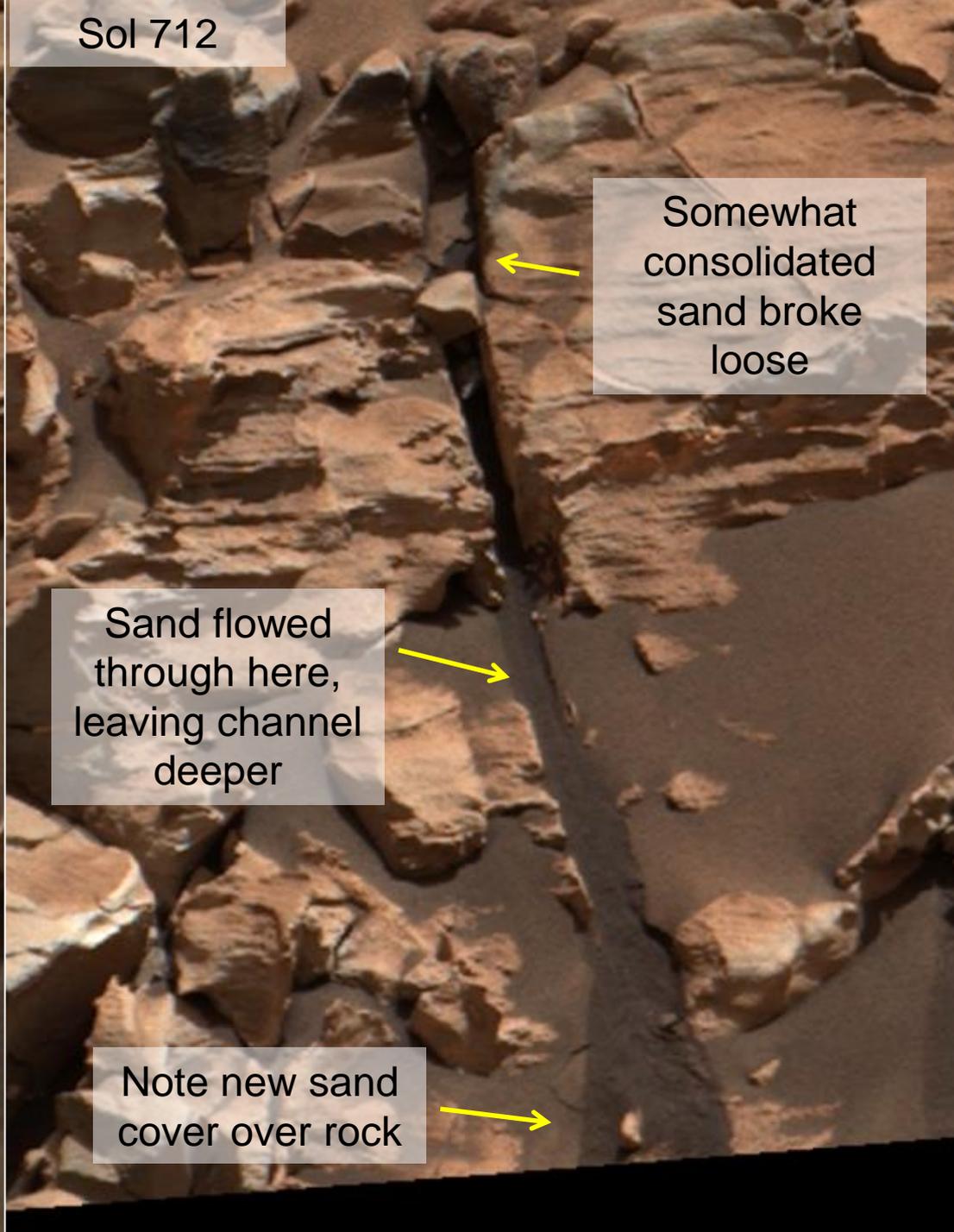
This feature in  
following slide

**This dark slope feature was observed along the wall of the “entrance ramp” into Hidden Valley on sol 707. The rover was there in August, 2014. Mars was at Ls=171, near southern spring equinox.**

Sol 707



Sol 712



Somewhat  
consolidated  
sand broke  
loose

Sand flowed  
through here,  
leaving channel  
deeper

Note new sand  
cover over rock

# Dark Slope Features

- Geologists on the MSL Science Team interpret the dark slope features observed near Hidden Valley to be dry avalanches of sand caused by small collapses of over-steepened sand near a layer of rock in the valley wall.
  - The features are dark due to the fresh sand exposed that is otherwise covered by bright dust. This is common on Mars (see below).
  - The feature that was observed to lengthen while the rover was in the area clearly is due to mass movement of loose sand.
- The fine sand has a larger surface area and lower thermal inertia relative to other surface materials. It is possible that the avalanches are triggered seasonally by vapor adsorption, frost, thermal contraction, etc.

Rover Tracks



Scoops in Rocknest





# Slumping Sand at Kimberley (sol 584, winter)



# Slumping Sand at Kimberley (sol 584, winter)



Jet Propulsion Laboratory

Mars Science Laboratory Project





# Slumping Sand (sol 969, summer)





# Slumping Sand (sol 1146, fall)





# Dark Slope Features



## Summary

- Small dark (and not so dark) slope features have been seen throughout the mission and have been interpreted as mini-avalanches.
  - Whether they are dark is dependent on the color of the underlying sand in contrast to overlying dust.
  - They have not attracted any particular attention from the science team. No contact has been made with rover hardware.
  - Although ChemCam has the capability to detect/measure hydrogen, and has been used as a survey instrument, no significant hydration has been detected.
  - These slope features have been seen at all seasons.
  - One team member raised the question of whether the dark slope features at Kimberley (sol 584) were related to recurring slope lineae. This hypothesis was not found credible enough to pursue.
- Ongoing, systematic measurements by the MSL payload (e.g., ChemCam, DAN) will catch excess hydration at the surface, if it is present. The MSL Science Team would certainly take note of such a result because of its importance to mission goals. No such discoveries have occurred to date.

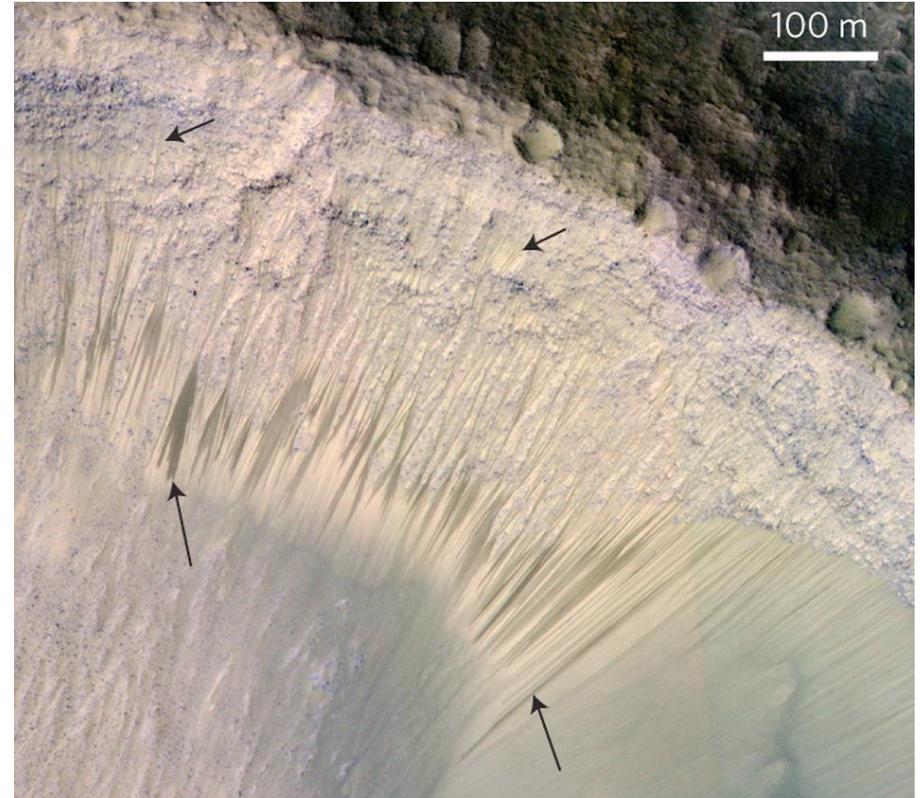


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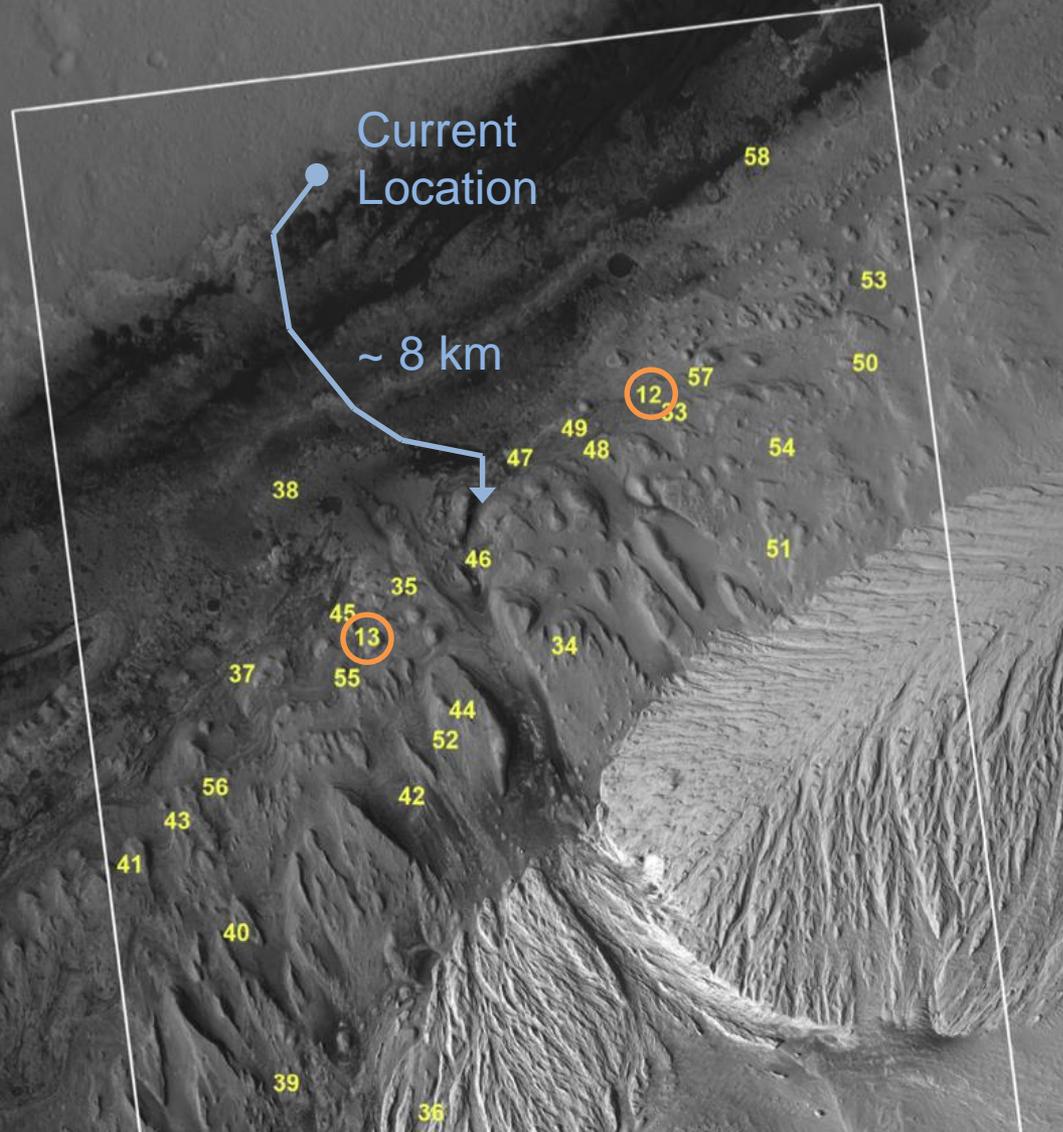
- Recurring Slope Lineae are a class of mass wasting features that:
  - incrementally grow over a period of weeks to months,
  - fade when inactive, and
  - recur annually
- They have been observed at mid and equatorial latitudes
- In September 2015, NASA announced the detection of salts associated with some RSLs, providing strong evidence that brines are involved



RSL on the south-facing slope of a crater on the floor of Melas Chasma. McEwen *et al.*, 2014.

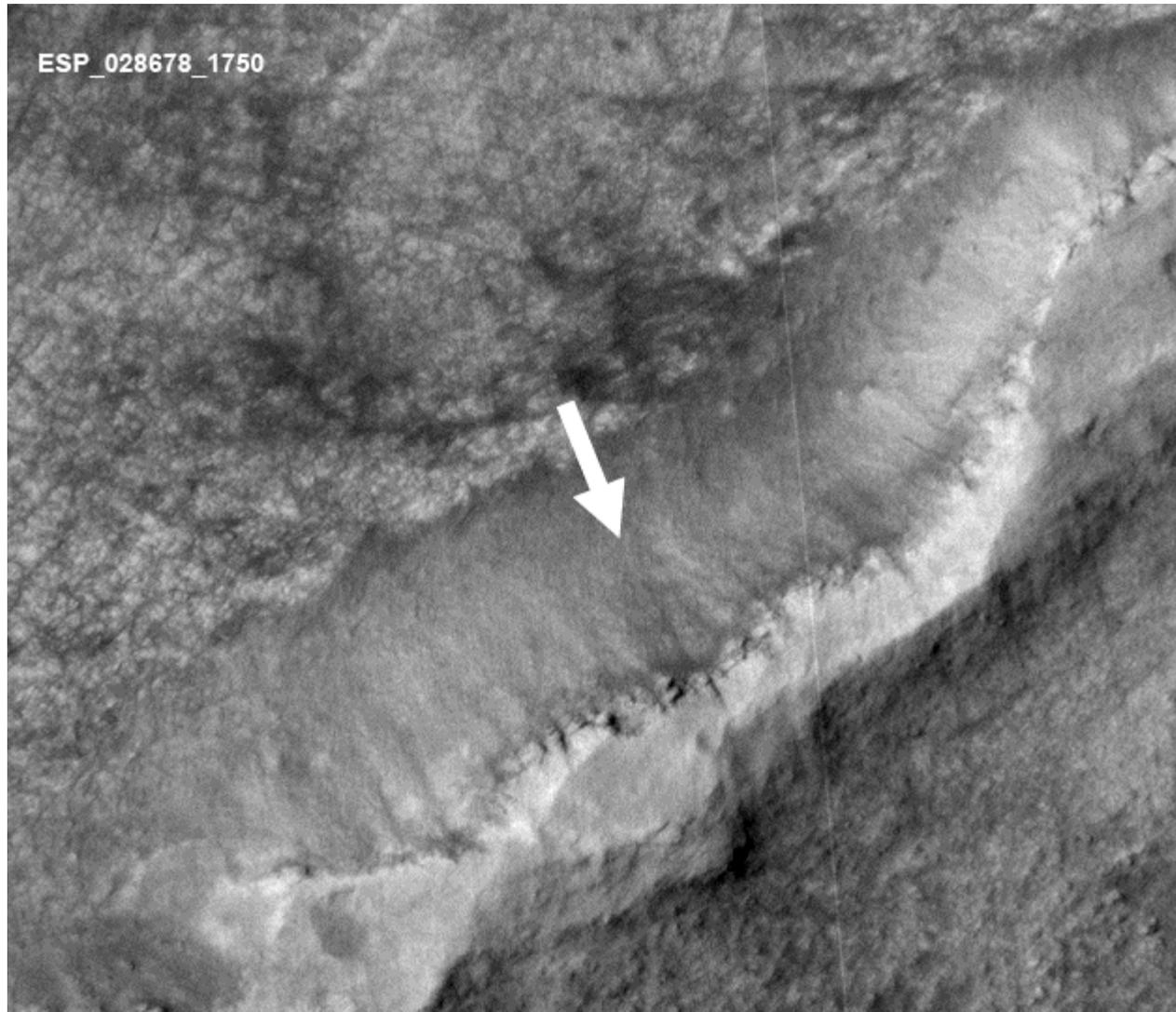
# Recurring Slope Lineae

Dundas and McEwen, 2015



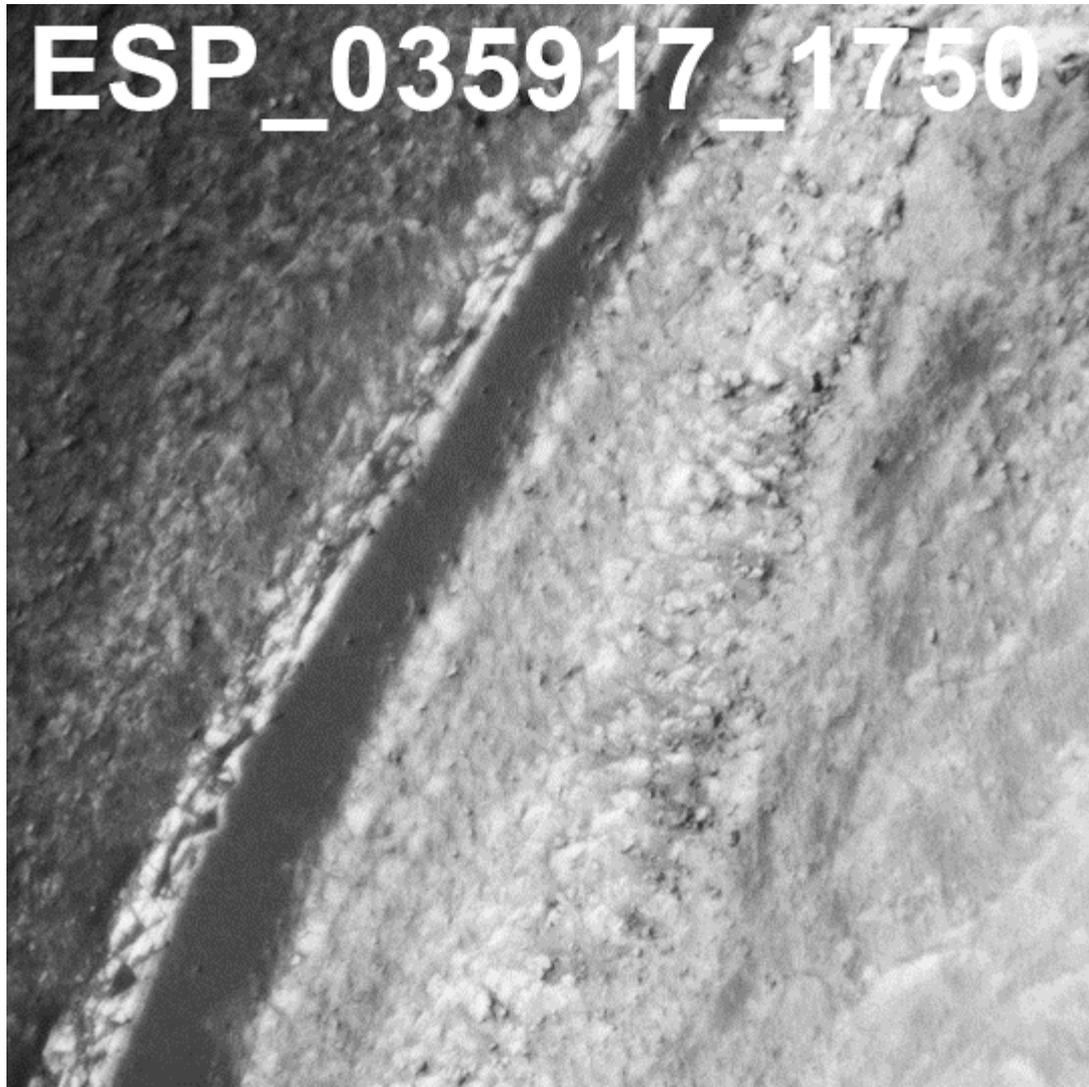
- Numbered locations are dark lineae identified by HiRISE
- These were assessed in successive images to look for RSL behavior. Two sites on northern Aeolis Mons (orange) show possible growth *at the limit of HiRISE resolution*.
- These two are candidate RSLs, pending additional observations.
- The rest do not indicate behavior consistent with RSLs, but may be active slope processes
- “Some of the observed slope features have characteristics similar to RSLs, but none is confirmed to be RSL and most have some characteristics suggesting other origins.” (Dundas and McEwen, 2015)

HiRISE Image	Date
PSP_009149_1750	9 Jul 2008 03:28pm
ESP_027834_1755	4 Jul 2012 03:31pm
ESP_028678_1755	8 Sep 2012 03:41pm



Site #12

HiRISE Image	Date
PSP_009294_1750	20 Jul 2008 03:25pm
ESP_026924_1750	24 Apr 2012 03:15pm
ESP_035917_1755	26 Mar 2014 03:24pm



Site #13



# Recurring Slope Lineae



## Summary

- There are no confirmed RSLs in Gale Crater, but there are two candidates, as well as dozens of dark slope streaks that are not considered RSLs by the HiRISE Team.
- As outlined in the previous slides, a thorough and ongoing search by the MRO HiRISE team has found two candidate RSLs, both poorly resolved by the camera, and neither of which fully demonstrates RSL behavior.
- MSL has updated the PPO on all information that we know from HiRISE and will continue to do so. At quarterly intervals we request an update from the MRO project.
- The planned route up Mount Sharp will keep the rover  $> 2.5$  km from the candidate RSLs. At the closest distance, Curiosity's imaging will be higher resolution than HiRISE and will contribute to the study of these candidate RSLs.



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# MSL Operations Protocol for PP



- The MSL Project is finalizing a new protocol for use in MSL operations to formally ensure that daily rover activities are compliant with the mission's Planetary Protection categorization.
- This protocol will be implemented immediately after approval and be subject to revision as additional studies are undertaken regarding the rover's potential for forward contamination, and regarding whether specific geological features at the Gale Crater landing site are Special Regions.
  - Should MSL approach and study a dark slope feature?
- The protocol is intended to be responsive to the MSL PP Categorization, the criteria for Special Regions in NPR 8020.12D, and direction from John Grunsfeld received by MSL on 11/17/15.