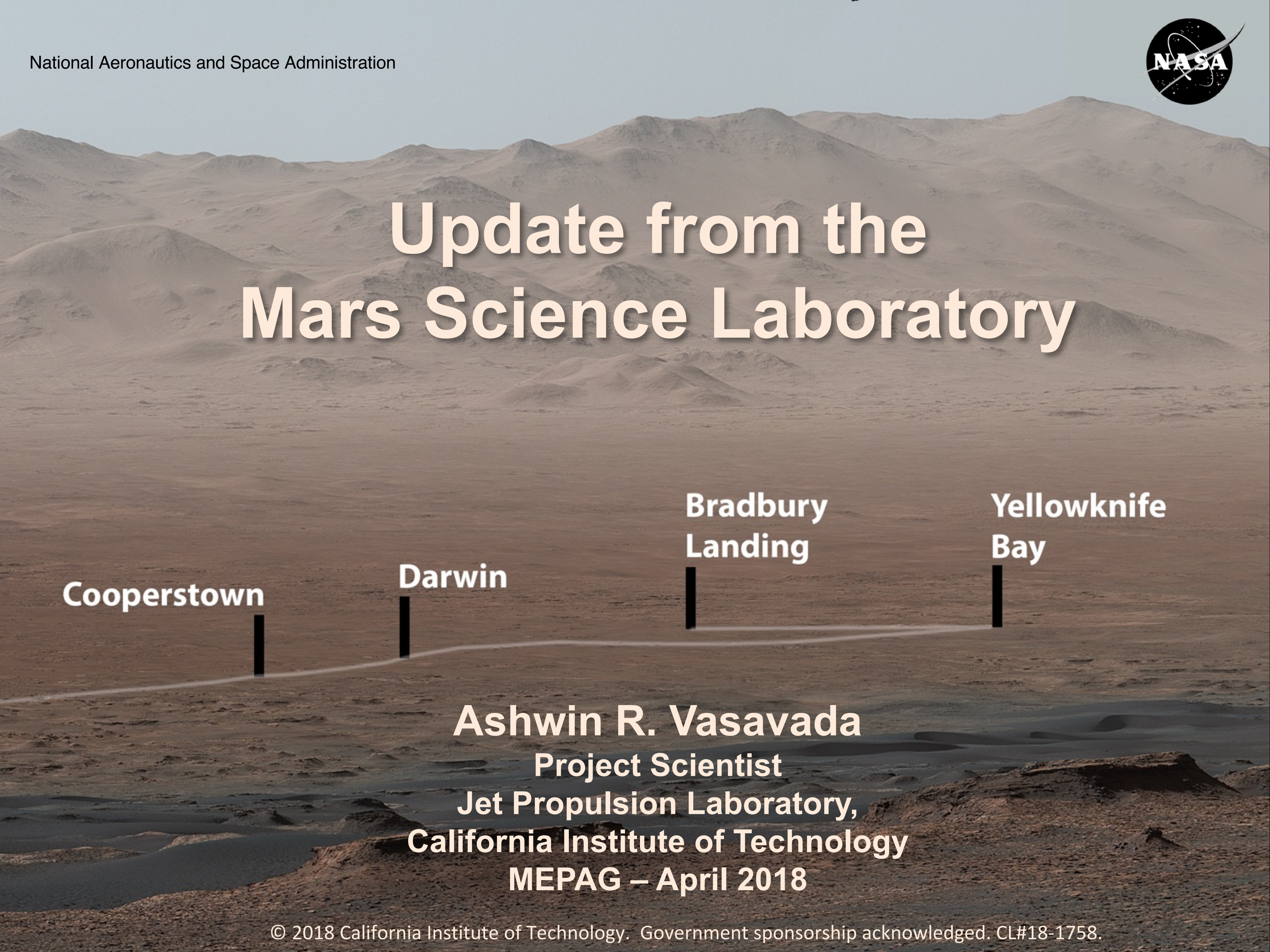
National Aeronautics and Space Administration

Update from the Mars Science Laboratory



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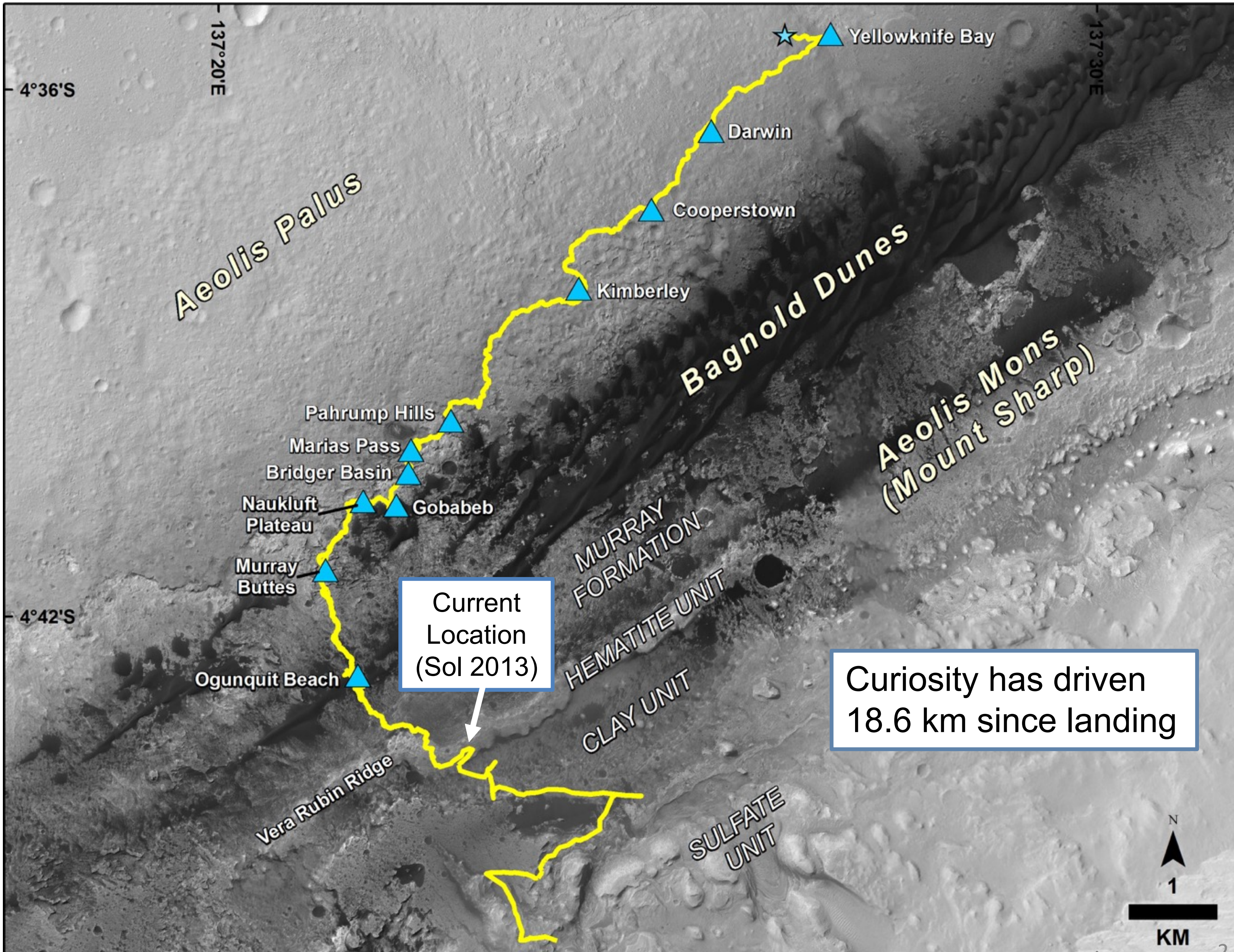
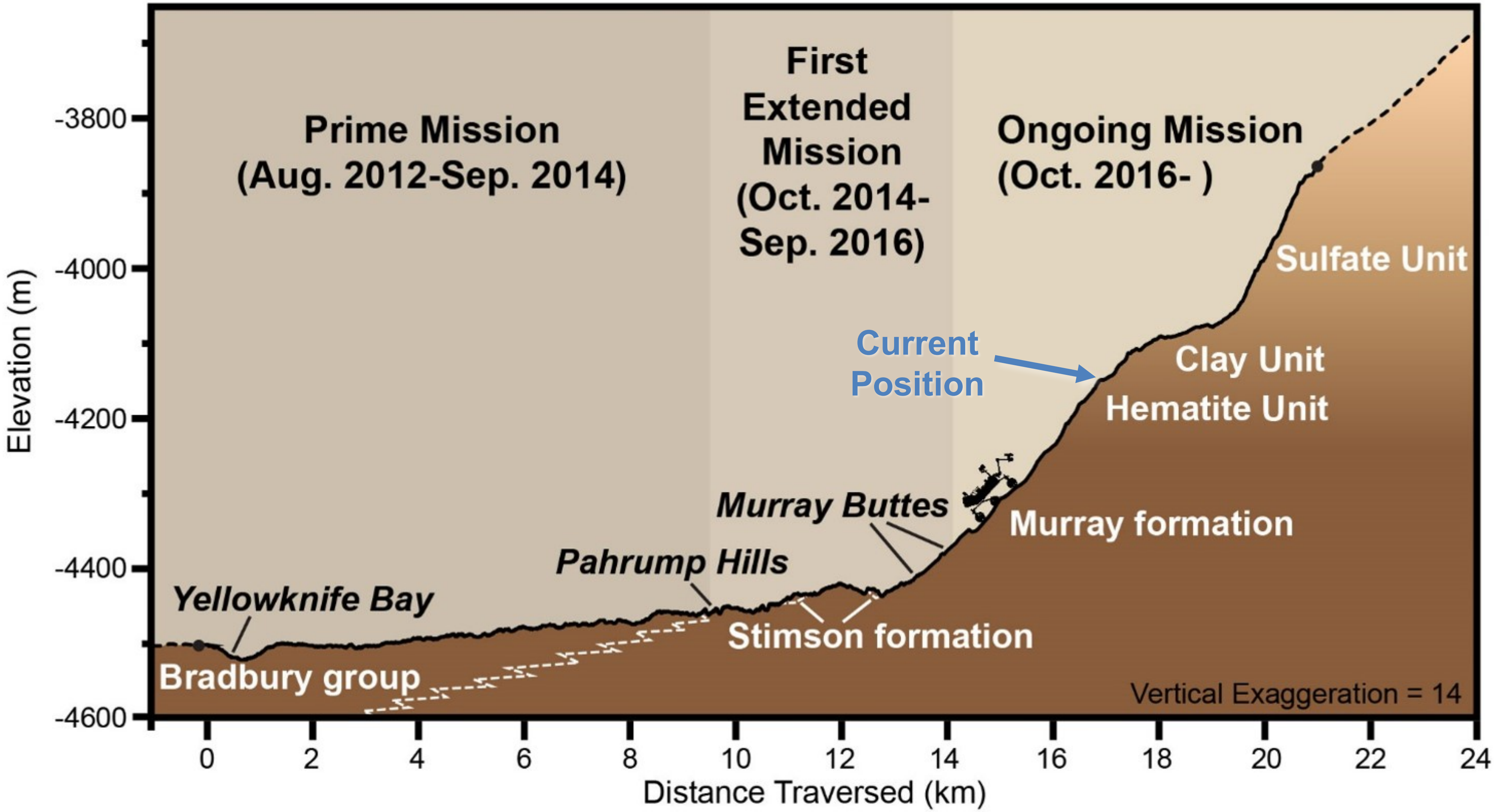
MEPAG – April 2018

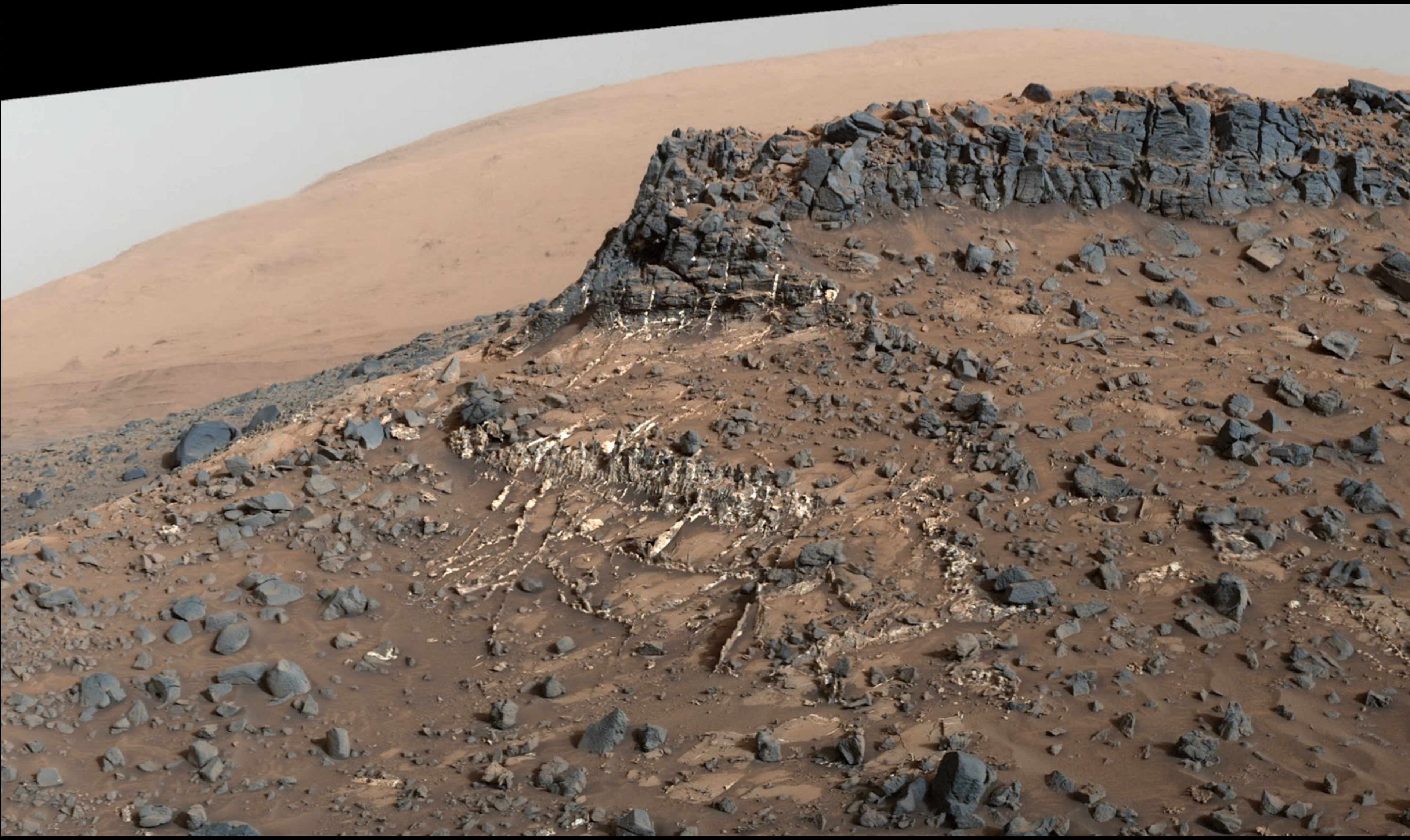


137°20'E
137°30'E
4°36'S
4°42'S
Yellowknife Bay
Darwin
Cooperstown
Kimberley
Aeolis Palus
Bagnold Dunes
Aeolis Mons
(Mount Sharp)
Pahrump Hills
Marias Pass
Bridger Basin
Naukluft
Plateau
Gobabeb
Murray
Buttes
MURRAY
FORMATION
HEMATITE UNIT
CLAY UNIT
SULFATE
UNIT
Ogunquit Beach
Vera Rubin Ridge
Current
Location
(Sol 2013)
Curiosity has driven
18.6 km since landing
N
1
KM



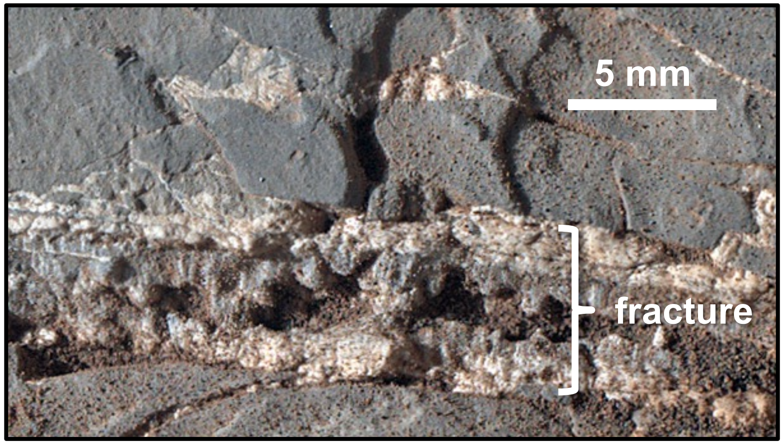
- Curiosity has gained ~ 370 m of elevation since landing. Over 300 m has been on Aeolis Mons.
- Sedimentary rock strata explored over this elevation range are interpreted to be a record of persistent fluvial, deltaic, and lacustrine environments.

Late Stage Diagenesis



Persistent Subsurface Habitable Conditions

- Curiosity can derive the formation age of geological materials by measuring the abundance of ^{40}K with APXS, and its daughter product, ^{40}Ar, with SAM. The first such experiment dated Gale crater sedimentary rocks at 4.2 +/- 0.4 Ga, consistent with expectations.
- A follow-up, two-step heating experiment derived the K-Ar age of jarosite (which decomposes at 500ºC) associated with evaporites and/or clay minerals, separately from the primary minerals.
- The younger age of 2.12 +/- 0.36 Ga (< 3 Ga accounting for some ^{40}Ar loss) for the jarosite suggests that aqueous processing persisted in Gale crater into the early Amazonian, after surface fluvial activity on Mars is thought to have largely ceased (Martin et al., 2017).



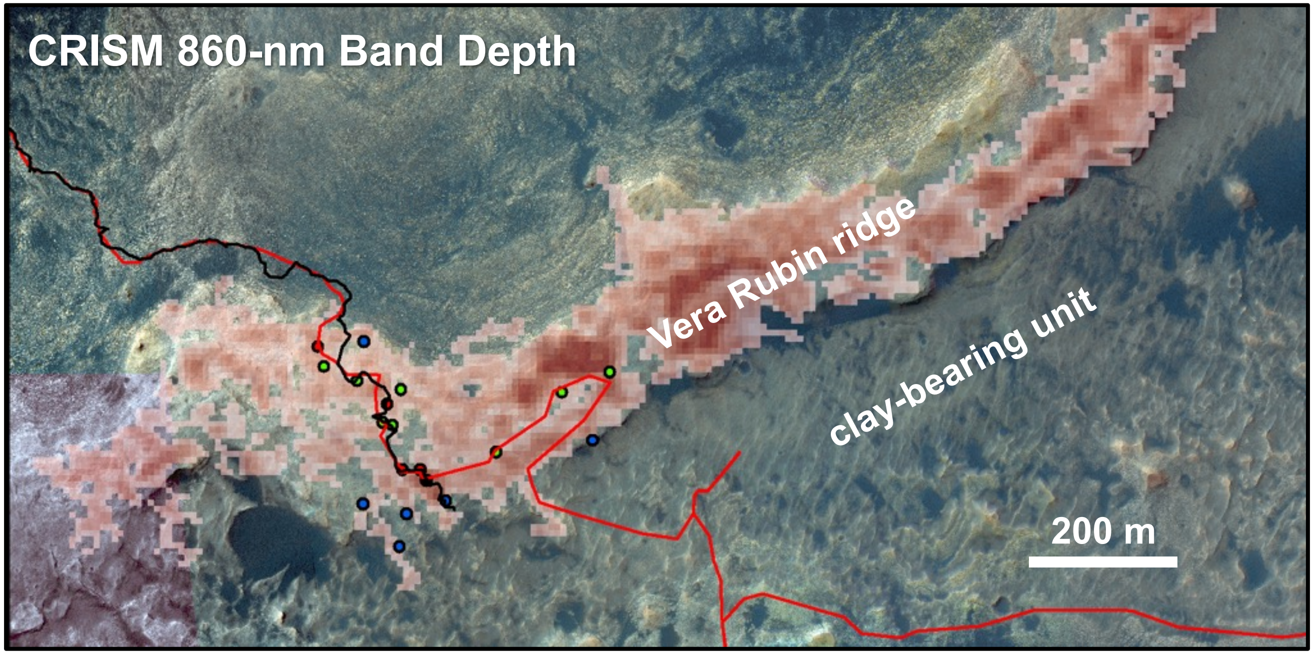
Bedrock fracture on the Vera Rubin Ridge filled first by precipitating calcium sulfate and subsequently by darker, iron-rich material

Mojave drill hole with jarosite-bearing tailings

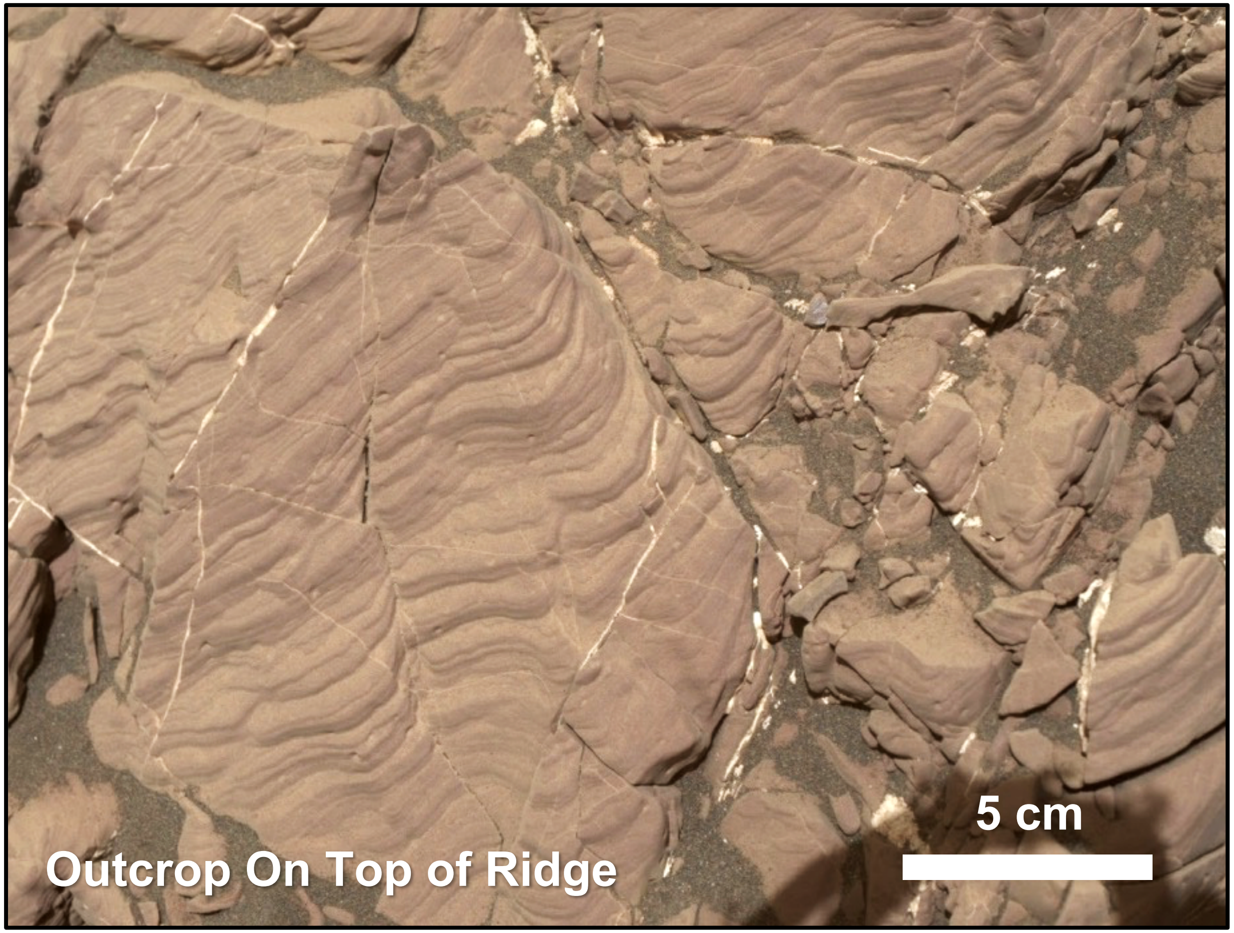
The Vera Rubin Ridge (Hematite Unit)

Campaign Science Goals

- What is the primary depositional environment and what is its stratigraphic relationship to Mount Sharp?
- Is the hematite primary or secondary, and what is its relationship to hematite detected previously in the Murray formation?
- What were the primary and secondary geochemical environments?
- What are the implications for habitability and the preservation of organic molecules?

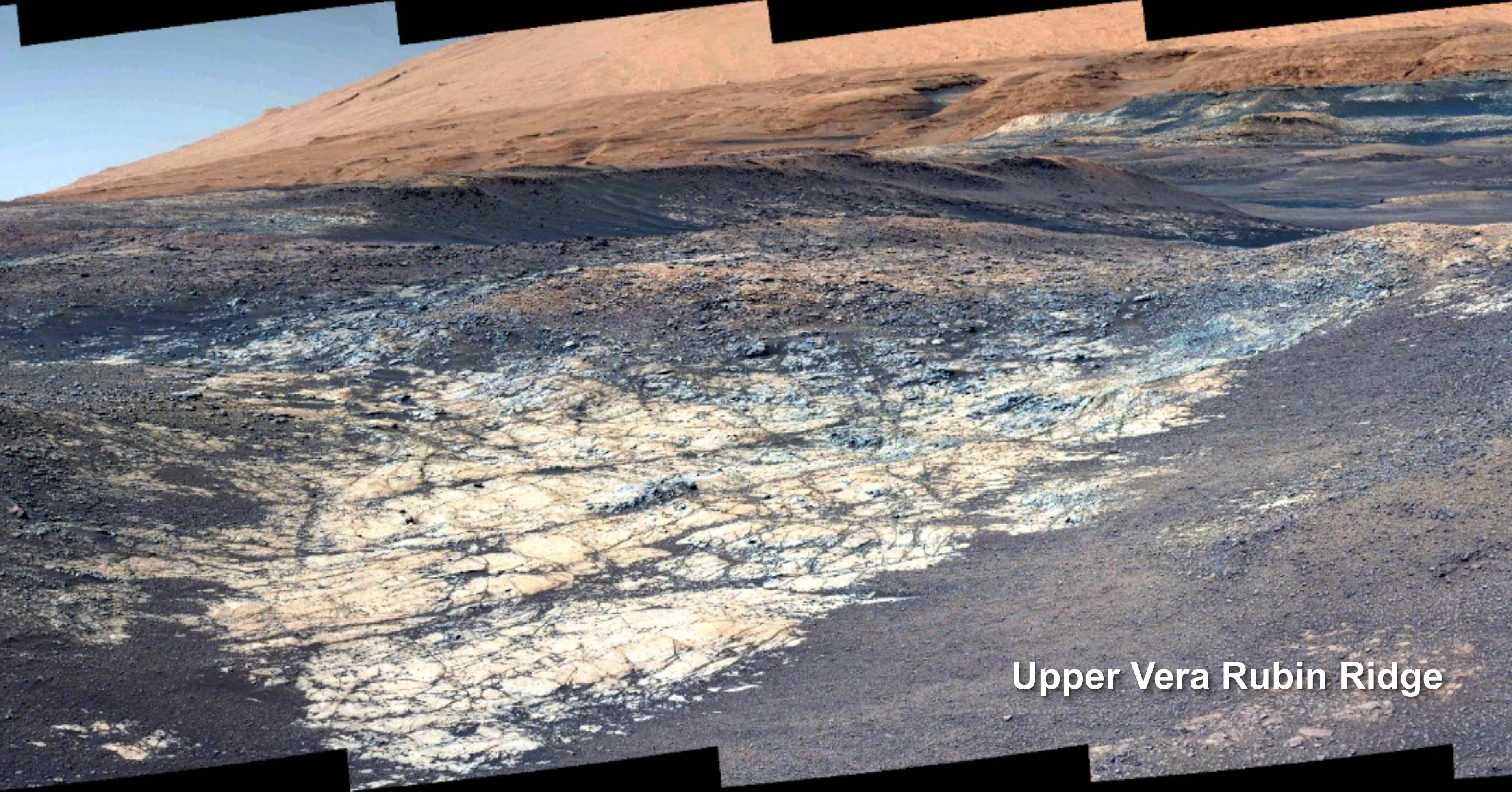


- The ridge strata appear to be a continuation of the Murray formation with no significant gap in the stratigraphic record.
- The northern face of the ridge is cross-cut by calcium sulfate veins that can make bedding appear to be non-planar, as well as larger filled fractures.



- The strata of the Vera Rubin ridge record deposition in a dominantly low-energy environment (interpreted as lacustrine), as evidenced by fine-grained, thinly laminated, parallel stratified bedrock.
- Minor outcrops of low-angle stratification suggest possible influences by aeolian or subaqueous transport processes.

- In situ spectroscopy shows that hematite is present throughout the rocks of the lower ridge. This supports the idea that oxidation was pervasive, as was apparent throughout the lacustrine strata on Mount Sharp.
- Curiosity's exploration is showing how the hematite spectral signature is controlled by a complex interaction between composition, rock texture, and the presence of sand and dust. Observations on the ground are helping extrapolate orbital mapping to broader areas.

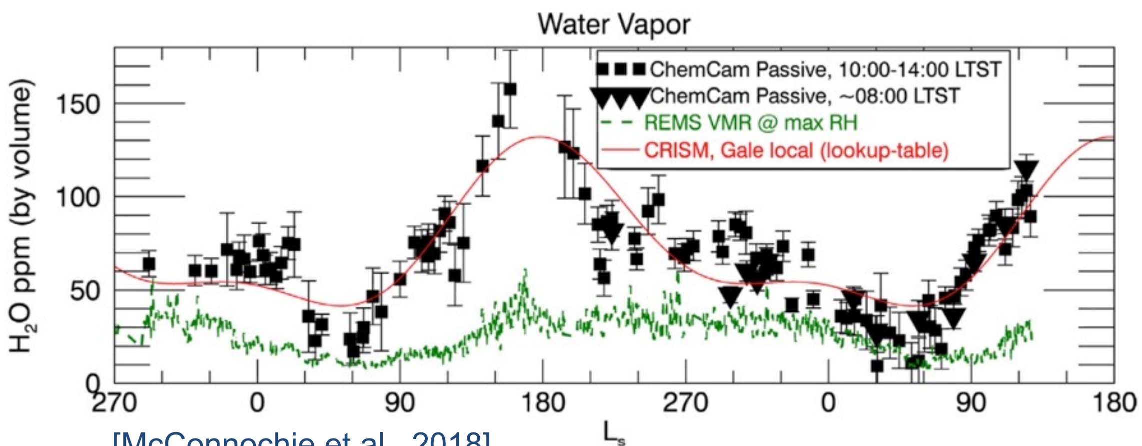


- Smooth, gray bedrock patches in topographic lows on the upper ridge show no ferric spectral signature, distinct from anything else explored by Curiosity on Mount Sharp.
- They may represent a facies change or diagenetic alteration. If a redox interface, they could be favorable environments for habitability.

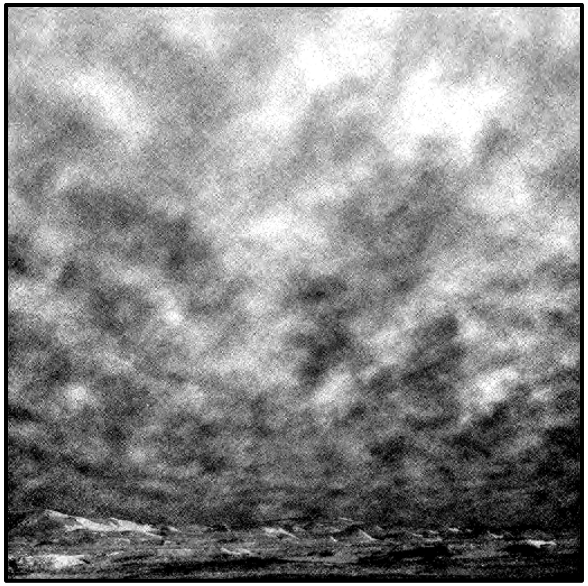
mm-Scale Crystal Molds in Gray Rocks

Atmospheric Monitoring

- Curiosity has collected unprecedented, hourly records of atmospheric pressure, humidity, ground and air temperature, and UV flux continually over three Mars years. These records are complemented by regular observations of winds, clouds, dust lifting, and measurements of atmospheric water vapor.
- These data provide unique insights into the effects of atmospheric dust and the crater's shape on thermal tides, limits on atmospheric mixing within the crater, the effects of topography on winds, the temporal variability of the Aphelion Cloud Belt, and much more.

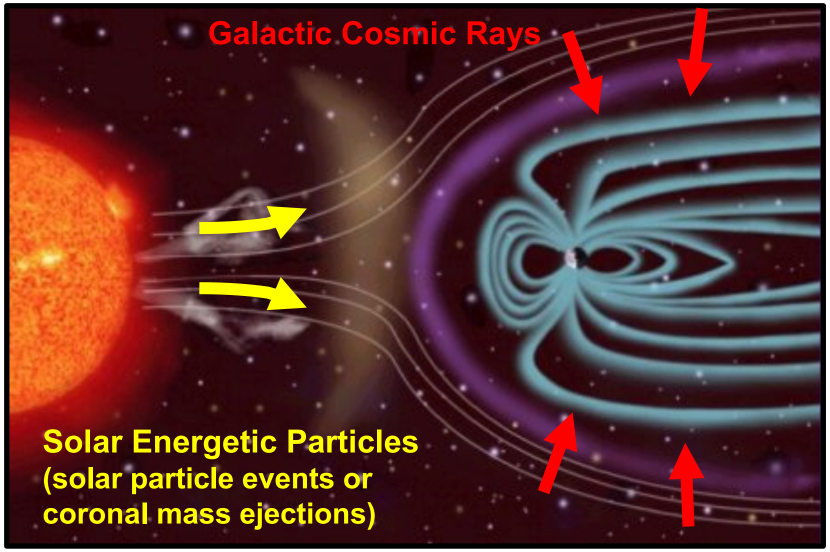


[McConnochie et al., 2018]

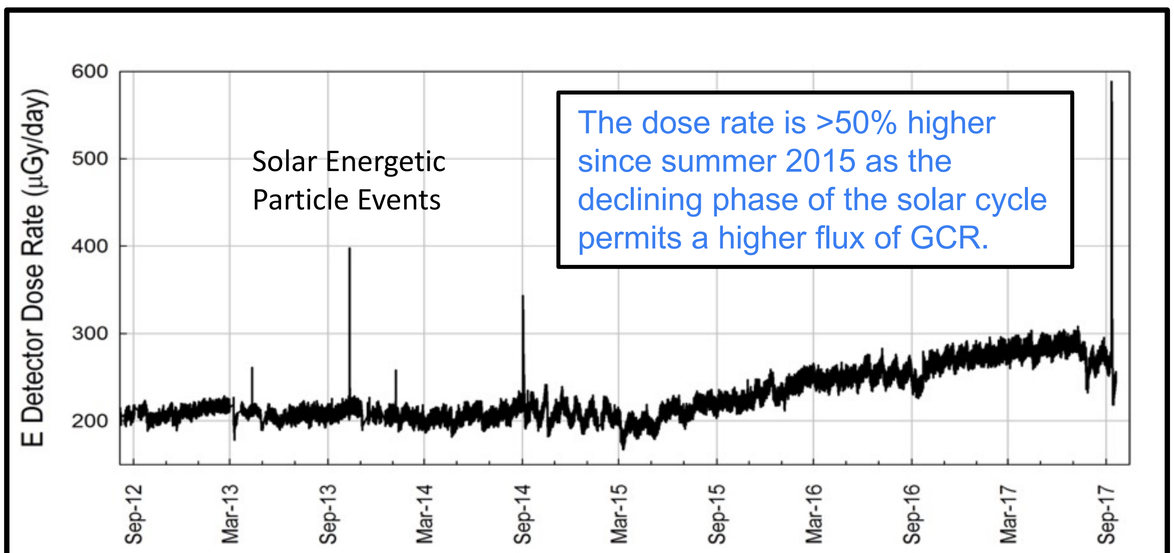


Left: column-avg. mixing ratios from ChemCam and CRISM, and in situ mixing ratio from REMS at the time of maximum humidity on each sol. Right: movie of water ice clouds over Mount Sharp.

Radiation Assessment

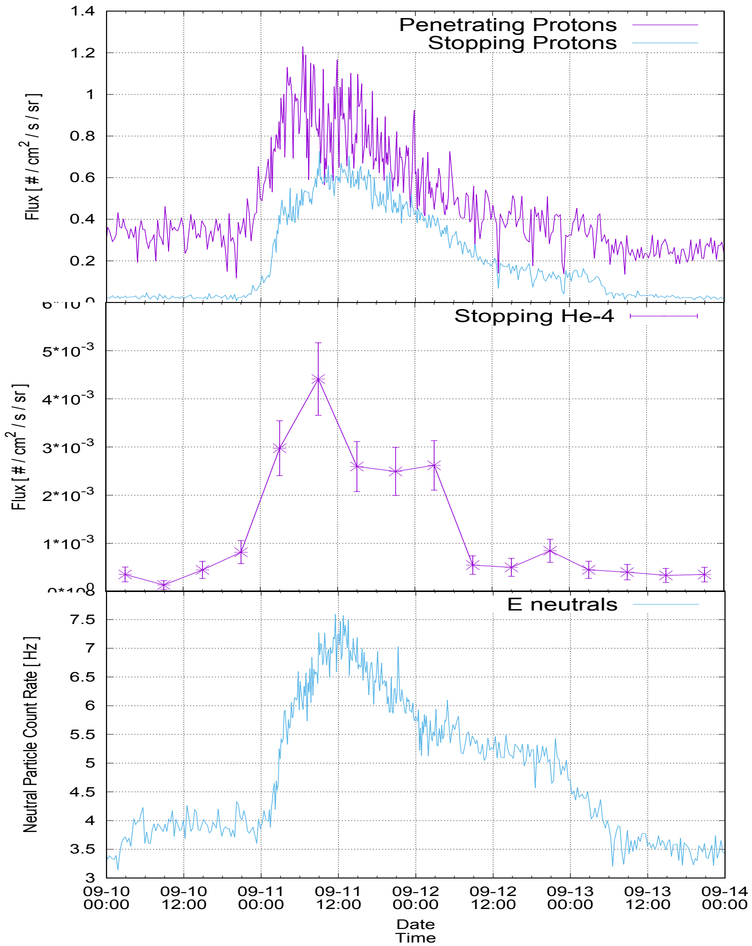


- MSL's Radiation Assessment Detector is characterizing the radiation environment on Mars over the solar cycle in order to support future human exploration of Mars.
- The RAD team hosted a workshop to conduct the first quantitative comparison of the measured environment with six community transport models.

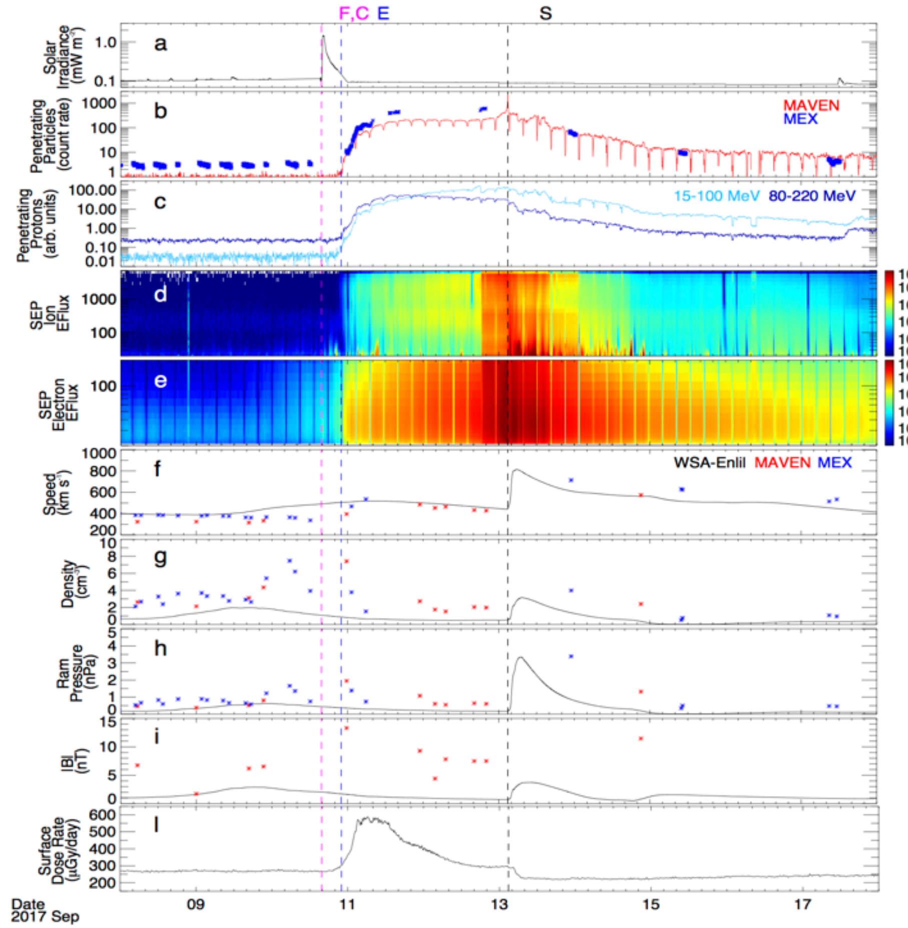


- During cruise, several medium-sized solar particle events were observed. Those observed since landing have mostly been small.
- In September 2017, RAD observed the strongest solar particle event seen since Curiosity's landing.

Radiation Assessment



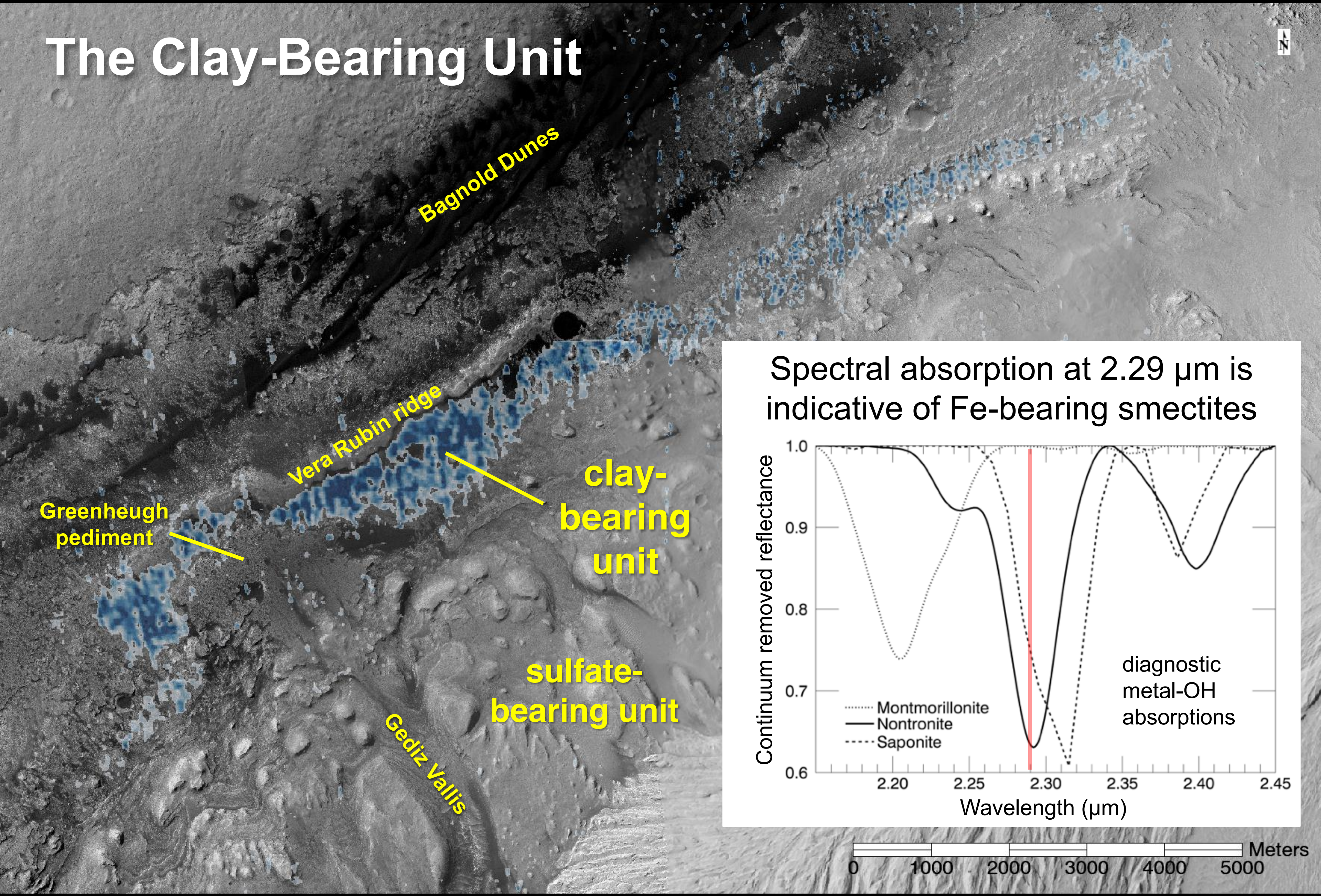
[Ehresmann et al., *GRL*, in press.]



[Lee et al., *GRL*, in press.]

- Joint observations from the September 2017 solar storm. RAD protons, He & neutral particles (left). Comparison with MAVEN and Mars Express (right). Also observed at ISS and at Earth's surface.

The Clay-Bearing Unit

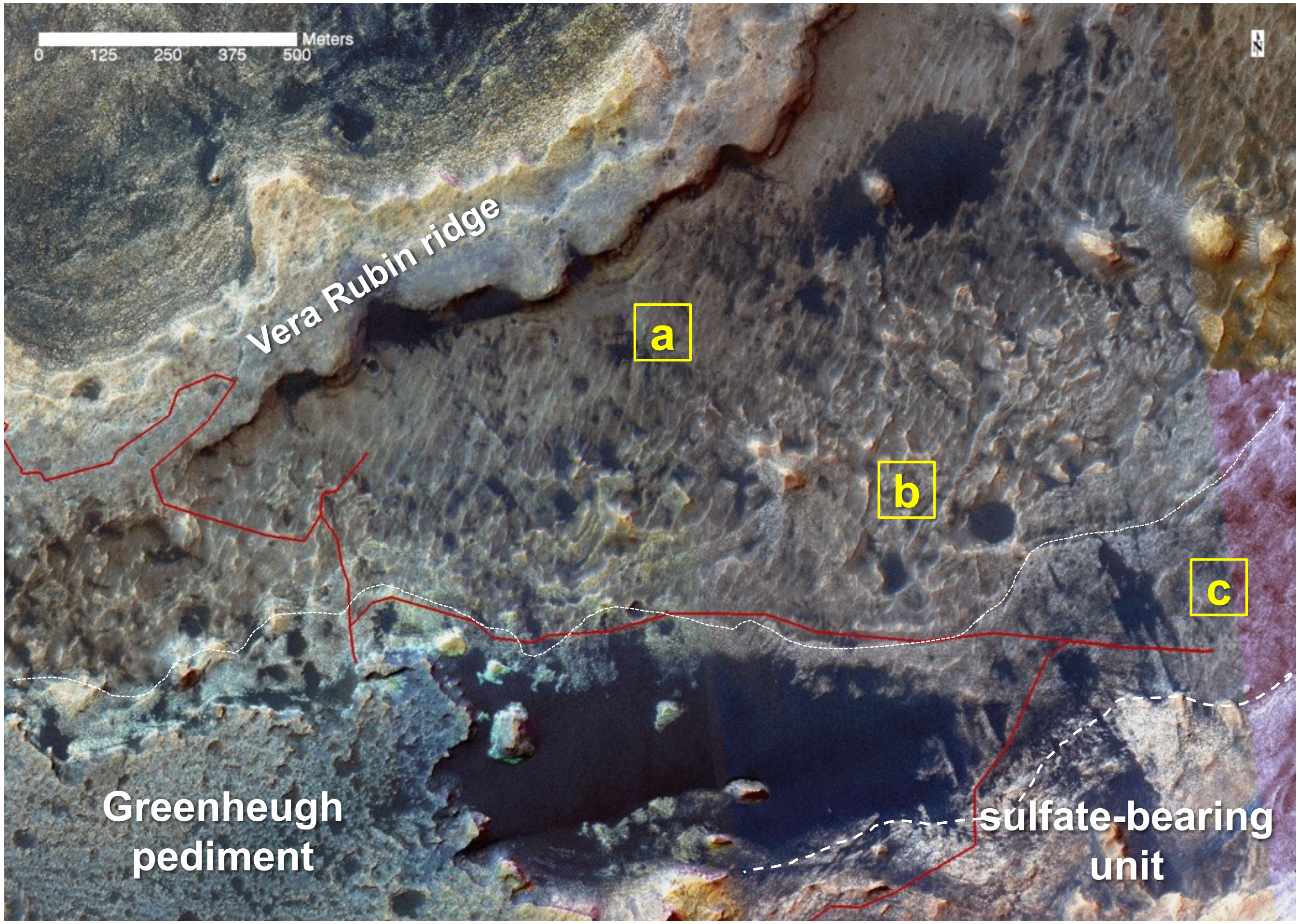


Investigations in the Clay-Bearing Unit (Draft)

Sampling the clay-bearing unit will provide a new perspective about clay minerals as general indicators of habitable environments on Mars, as well as their role in preserving organic molecules.

1. **What is the stratigraphic context of the clay-bearing unit?**
   - Is it part of the Mount Sharp sequence?
   - What is its relationship to the Vera Rubin ridge and sulfate-bearing unit?
2. **What is the origin of the clay minerals and what geologic environment(s) does the unit represent?**
   - What are the chemical compositions of the clay minerals?
   - Were they formed in place or were they transported?
   - How was the sediment that makes of up the clay-bearing unit deposited?
   - What processes altered and shaped the unit?
   - How does the clay mineralogy compare with previous exposures?
3. **What are the implications for habitability and the preservation of organic molecules?**
   - Does the unit preserve any organic molecules?
   - Are there chemical, structural, or environmental factors that might have aided or inhibited preservation?

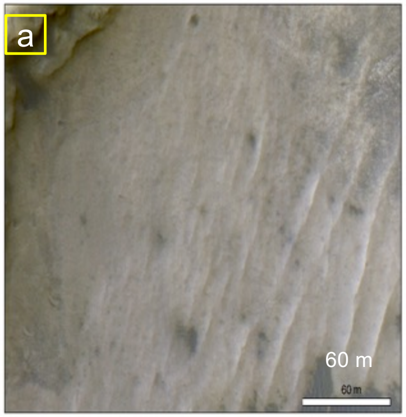
Mapping the Clay-Bearing Unit



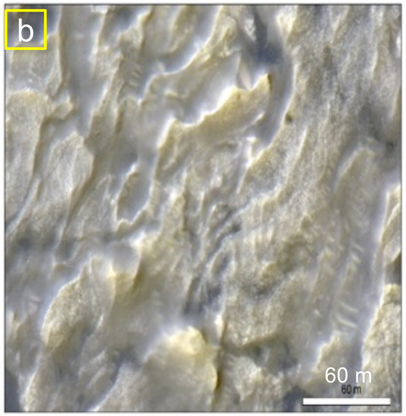
Clay-bearing strata are confined to a 20-30 m thick interval.

Orbital mapping indicates two distinct sub-units (a) and (b) within the clay-bearing unit and a transitional unit (c) between the clay- and sulfate-bearing units.

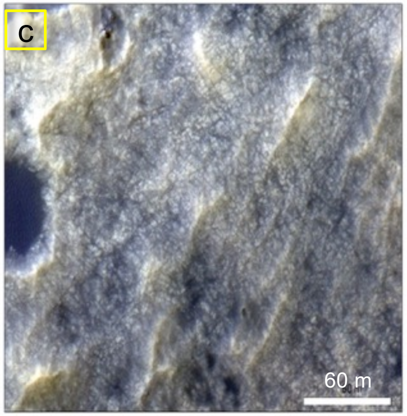
smooth ridged clay-bearing unit



fractured clay-bearing unit

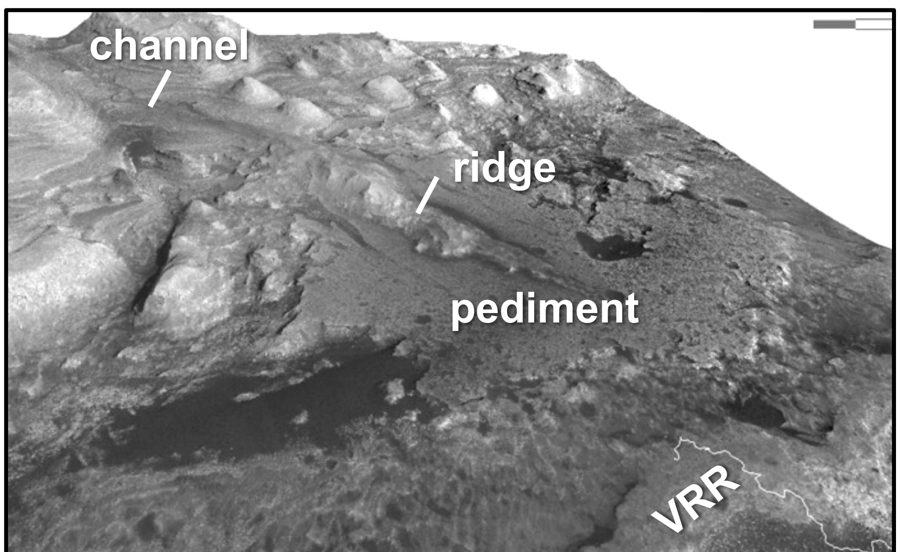


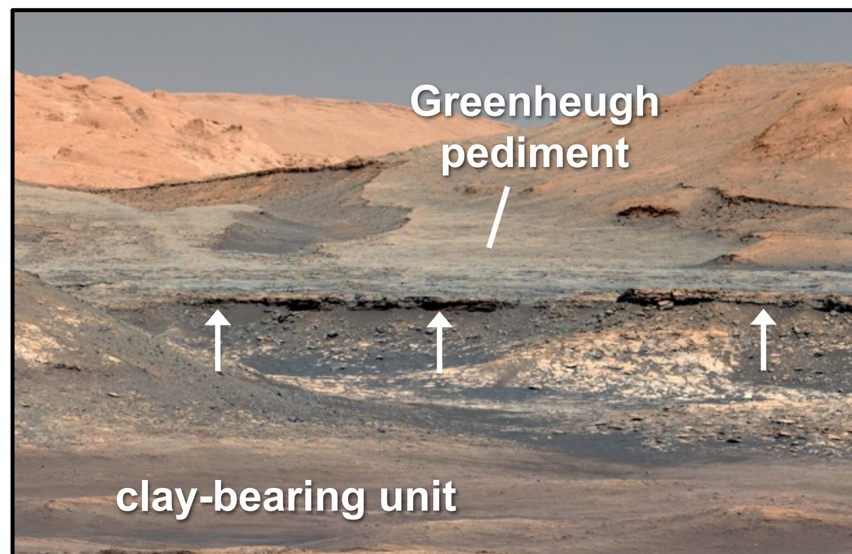
fractured intermediate unit



Greenheugh Pediment

- The Greenheugh pediment is a gently sloping surface that unconformably overlies strata of the Mount Sharp group. Its upper surface retains pits and craters, has a high thermal inertia, and is covered by parallel ridges suggestive of lithified aeolian bedforms. It forms a 1-m thick resistant ledge.
- The pediment is adjacent to the outlet of Gediz Vallis, a major channel originating higher on Mount Sharp. The Gediz Vallis ridge lies on top of the pediment and is hypothesized to represent alluvial deposits from Gediz Vallis.
- What are the pediment and ridge, and how did they form? Are the apparent bedforms aeolian or subaqueous?

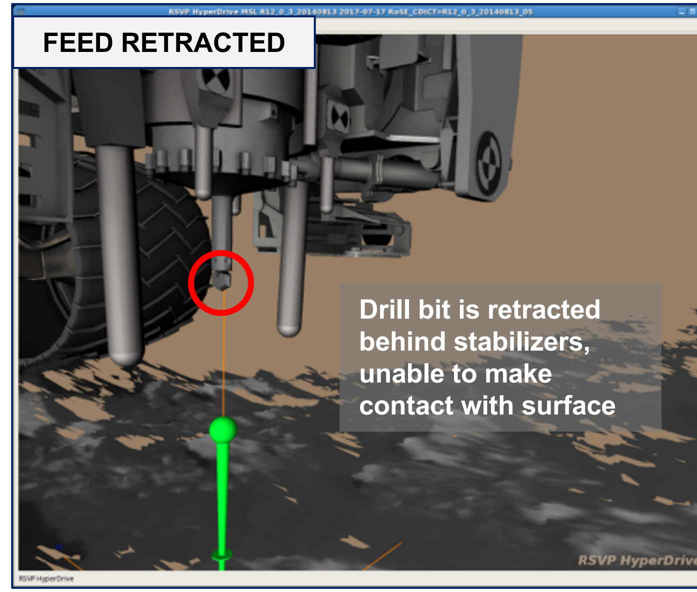




The Clay-Bearing Unit

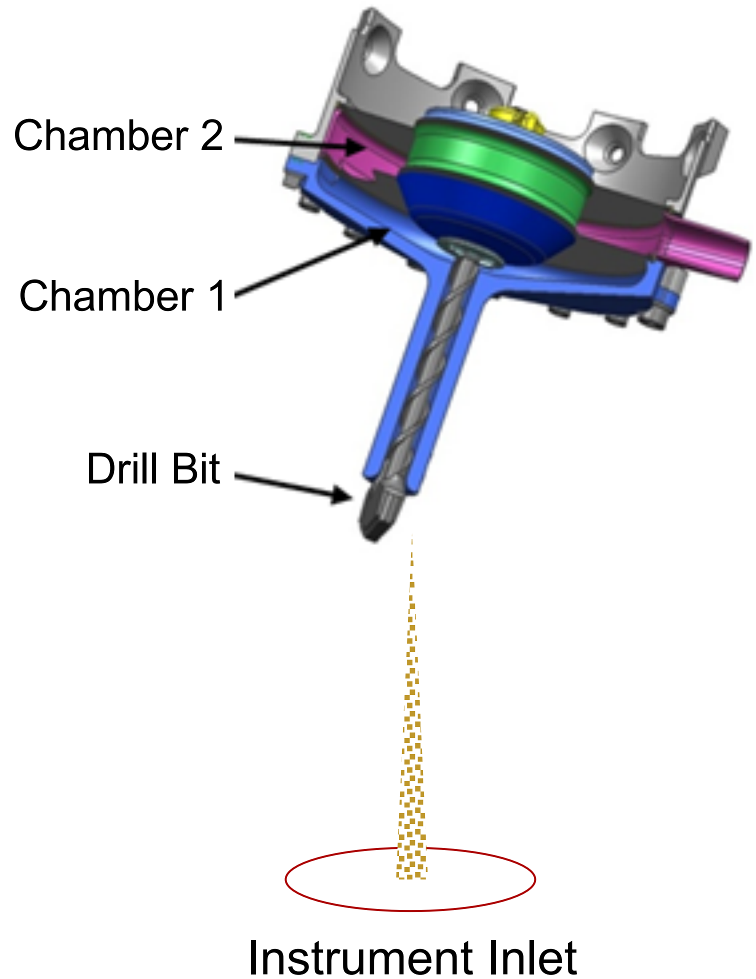
Feed-Extended Drilling (FED)

- The MSL drill feed mechanism has been unreliable since December 1, 2016 (Sol 1536)
  - A once-per-motor-revolution "friction zone" inhibits nominal drilling operations, particularly at the low speeds required for drilling
  - Most likely root cause is that the friction brake is not fully disengaging
- In its fully extended state, the drill can attain full depth before drill stabilizers make contact
  - The feed was successfully fully extended beyond the drill stabilizers in August, 2017
- The objective of FED is to replace flight software control of drill feed with sequenced control of robotic arm for drilling
- One significant challenge is to drill straight, since a crooked hole can inhibit retraction
  - This risk has been mitigated using feedback from the force/torque sensor located in the turret to manage side loads on the drill bit that build up during drilling



Feed-Extended Sample Transfer (FEST)

- The drill feed must be fully retracted in order to transfer acquired sample material into the sample processing and delivery system
  - The project considers it too risky to use the unreliable drill feed to transfer sample in the traditional way
- The objective of FEST is to provide an alternate means of delivering sample material to the instrument inlets
- FEST delivers sample material directly from the drill bit, bypassing the sieve and portioner
  - FEST uses bursts of rotation and percussion to create portions that approximate the desired volume
  - No control of particle size is possible, but the particle size distribution was measured in dozens of tests
  - The CheMin and SAM instrument teams have evaluated and accepted the risks from the greater uncertainty in sample volume and particle size distribution



FED/FEST Status

- Completed development of FED using non-percussive (rotary only) drilling method and FEST
  - Demonstrated end-to-end using JPL testbed rover
  - Tests on Mars are important for revealing any issues from Mars environment
- Conducted initial FED tests on Mars in February and March 2018
  - Side-load nulling executed as planned
  - Achieved 10 and 2 mm hole depths, less than 20 mm required to acquire sample material in drill stem
  - Low rate of penetration likely due to rock properties, a known limitation of non-percussive drilling
- Project is focusing on expanding FED to use percussive drilling to overcome rock properties that prevent successful non-percussive drilling
  - Expected in May 2018 timeframe
  - A key project risk involves intermittent electrical shorts seen during operation of the percussion mechanism. Accordingly, use of percussion will be minimized and employed only on targets of high science value.

Sol 1977 FED Test