NASA'S JOURNEY TO MARS

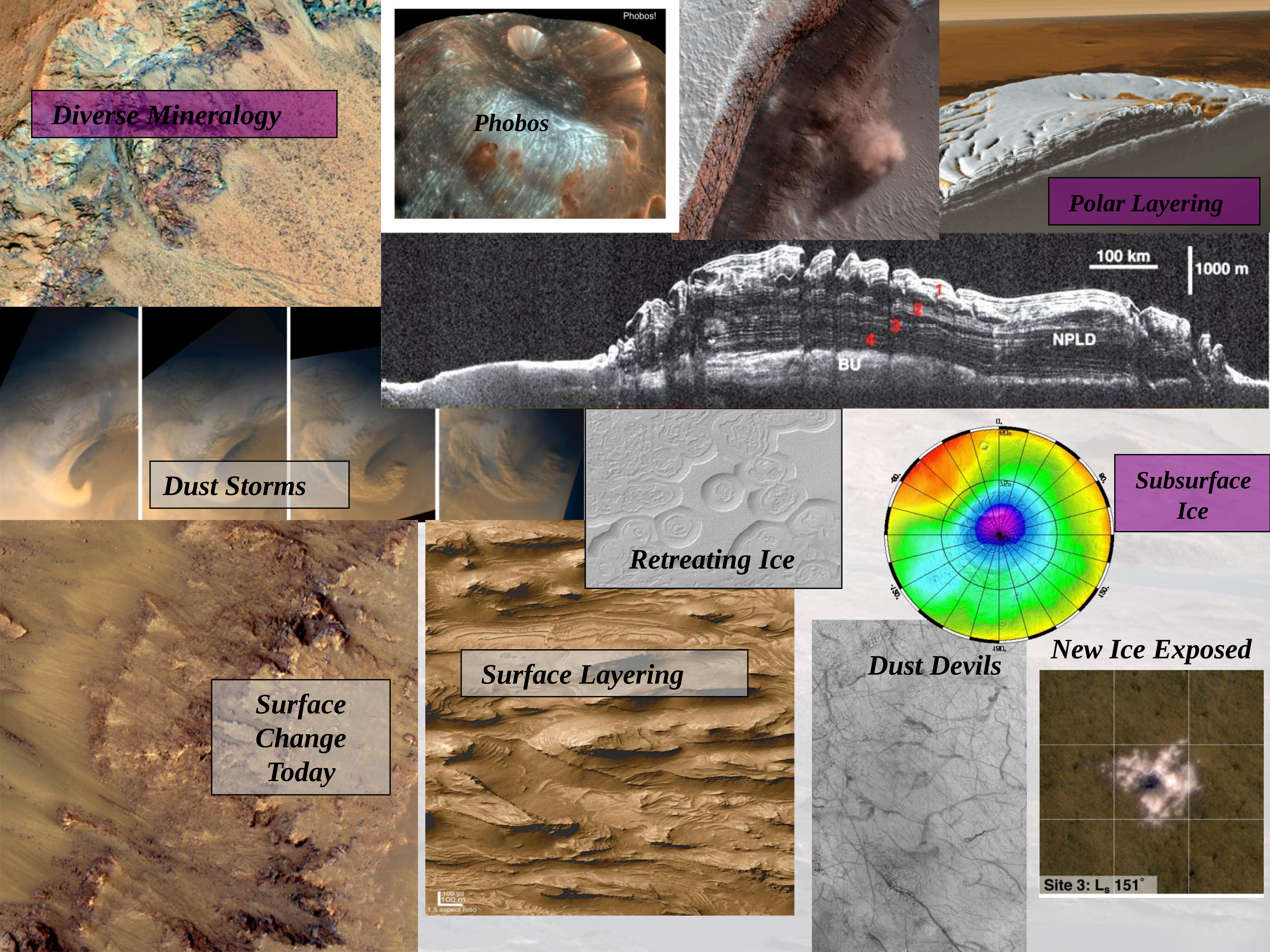
Mars Exploration Science

Michael Meyer, Lead Scientist
Mars Exploration Program

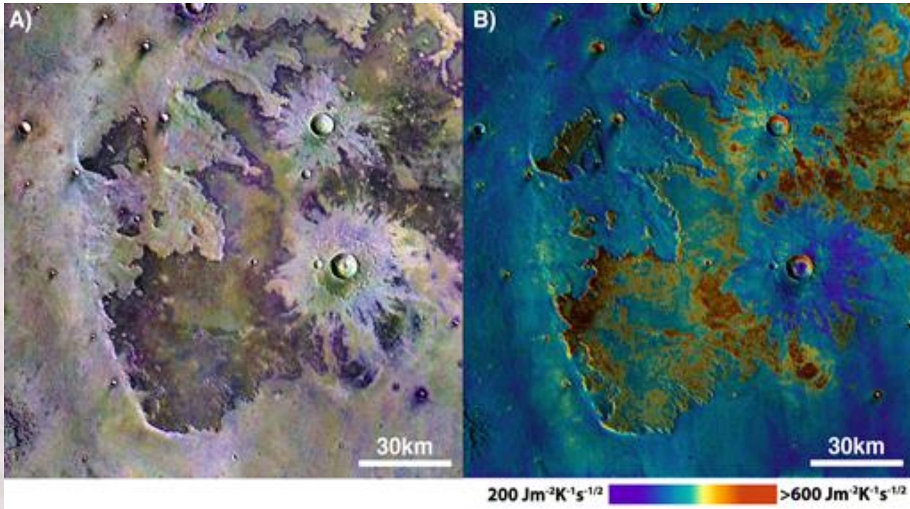
March 2016

Participating Scientists

- Purpose: to enhance the scientific return from MSL by including new investigations that broaden and/or complement the funded instrument investigations.
  - Proposals needed to include both science analysis and an operational component (mission operations)
- Results:
  - 116 step-1 proposals submitted
  - 89 Step-2 proposals submitted
  - 28 investigations selected

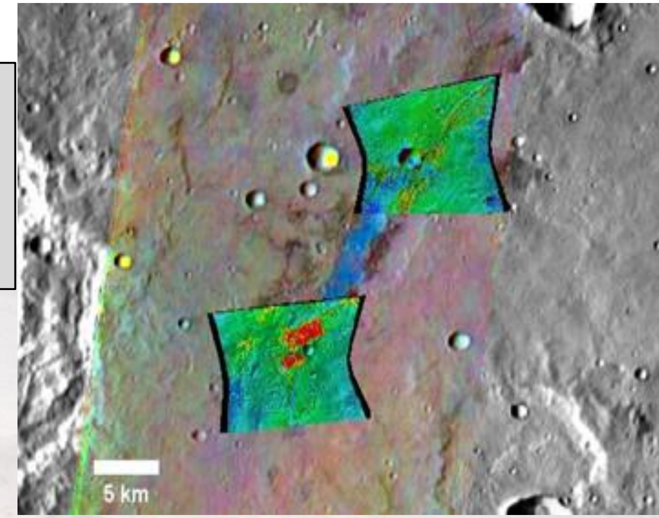

Diverse Mineralogy
Phobos!
Phobos
Polar Layering
100 km
1000 m
1
2
3
4
NPLD
BU
Dust Storms
Retreating Ice
Subsurface Ice
Surface Layering
Dust Devils
New Ice Exposed
Surface Change Today
Site 3: L_s 151°

ODY THEMIS



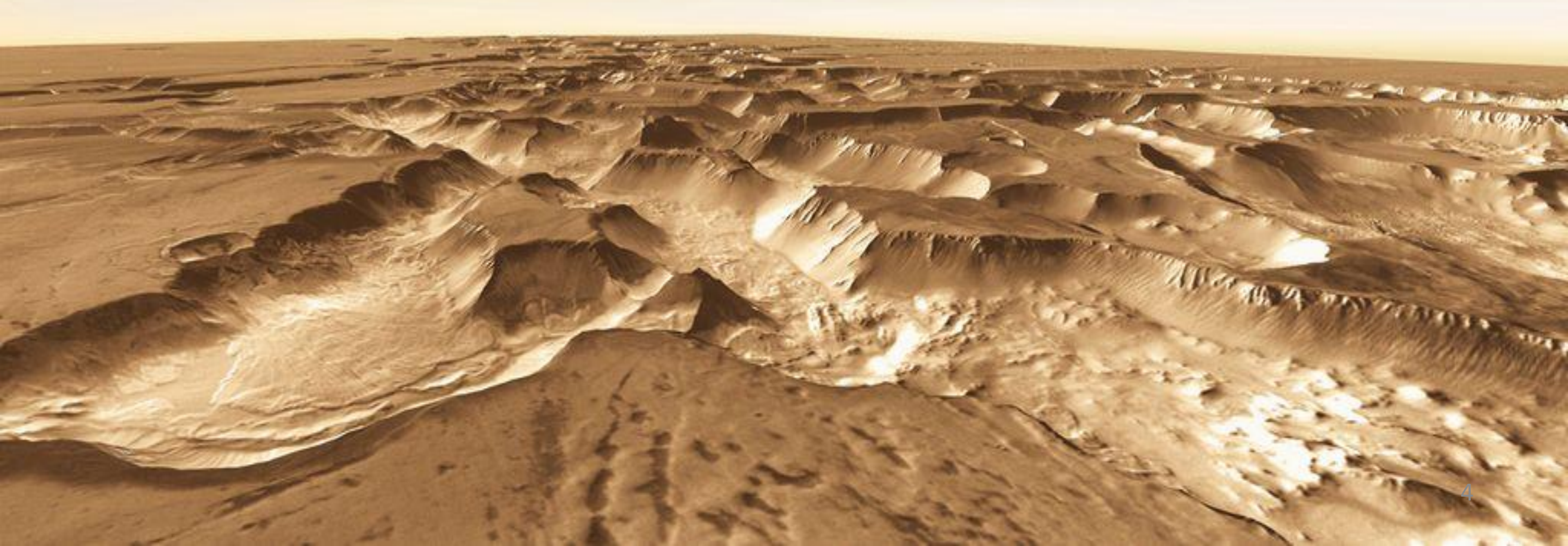
Olivine-rich outcrops (dark in left image) correlated with high thermal inertia materials (bedrock—yellow and red in right image).

ASU / JPL / NASA



THEMIS warm surface data showing the chloride deposits (blue)compared to CRISM phyllosilicates (oranges and reds).

THEMIS Mosaic from 100 m daytime IR



Early Morning Cloud Observations

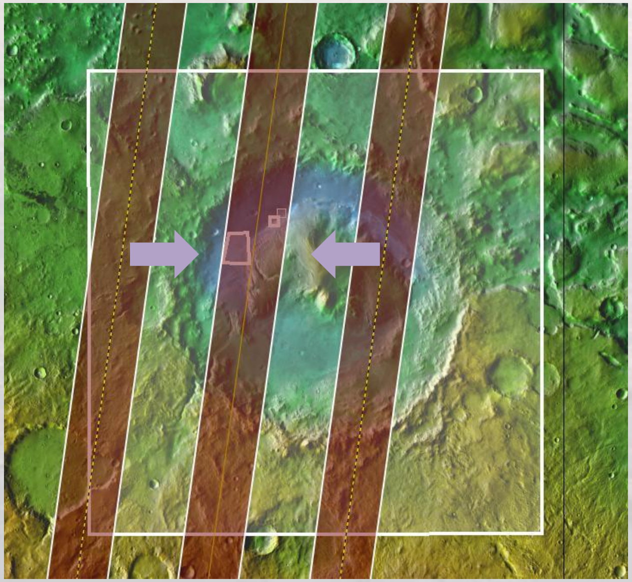
- **One goal of ODY's local time change**
  - Viking observed clouds/fogs/haze at early morning local times
  - ODY/THEMIS has never been able to observe at this local time, until now
- **Local time & season combination temporarily allowed early morning images (Aug 2014 – Dec 2014)**
  - Collected 10 band IR and 4-band VIS
  - Clouds/fogs/hazes observed in many areas with large topographic changes
- **Lighting conditions returning to post-sunrise again (August 2015).**
  - ROTOs will provide up to three observations of the same location, with ~48 hours between observations

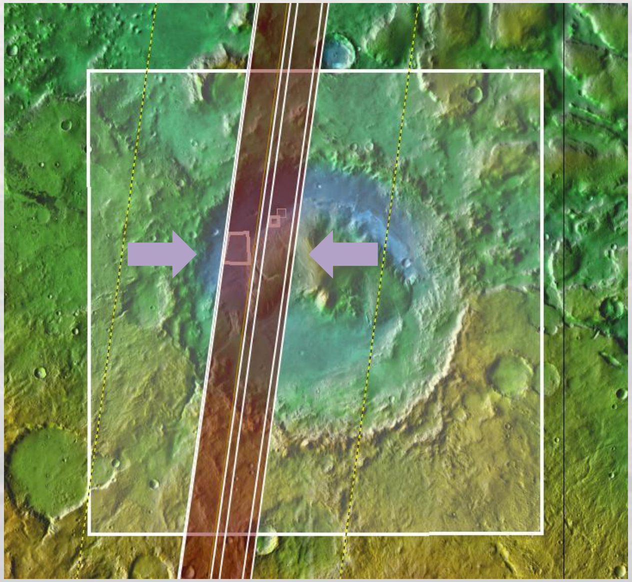
V56363015

V56450007

THEMIS / MSL (REMS) Coordination

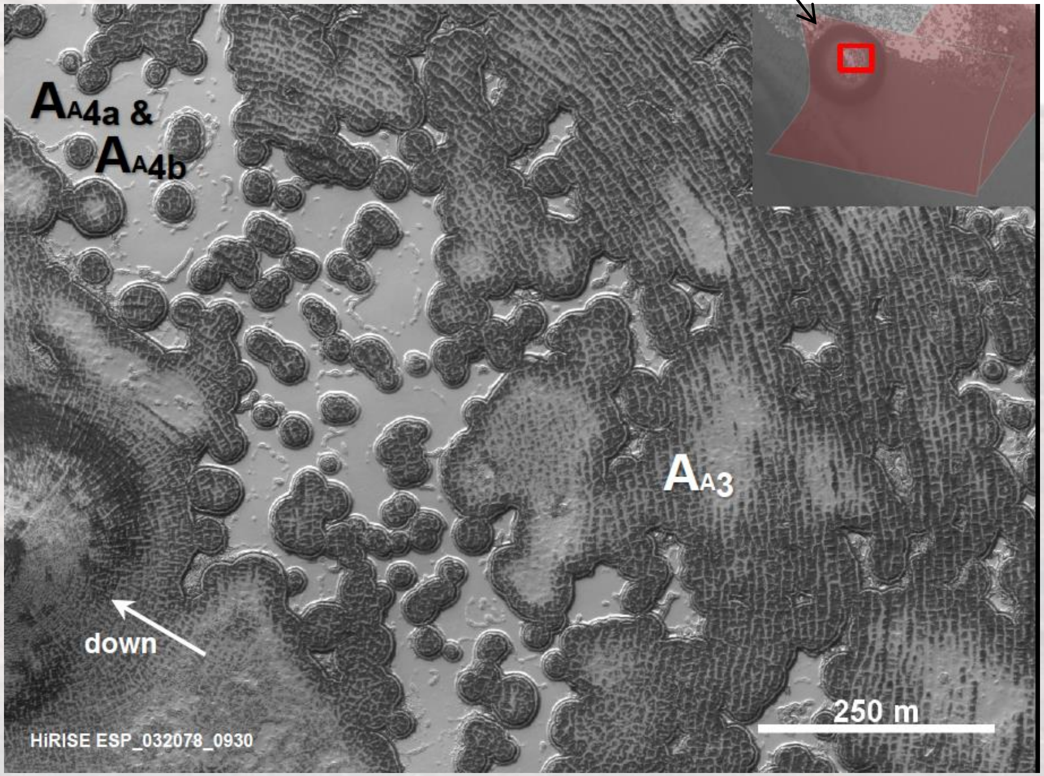
- **Coordinated observations with REMS during ODY/THEMIS overflights**
  - Nadir overflights occur every ~2 weeks, alternating between ascending and descending sides of the orbit
- **ODY's ROTO capability will increase the number and quality of coordination opportunities**
  - Center the MSL site in the THEMIS IR and VIS FOVs
  - Acquire observations of the MSL site on the nadir overflight, as well as the two "adjacent" orbits





Search for buried CO_2

CRISM footprint

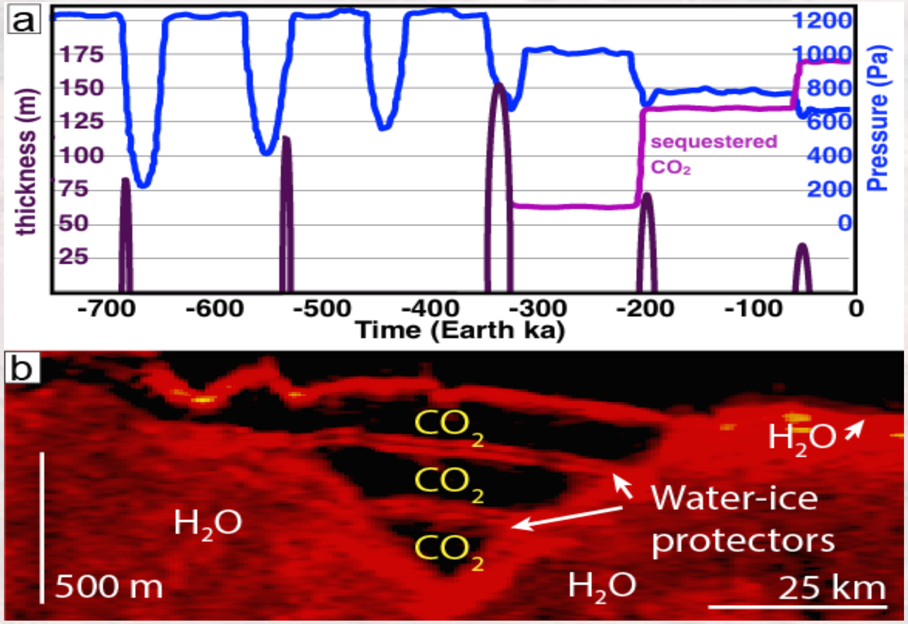


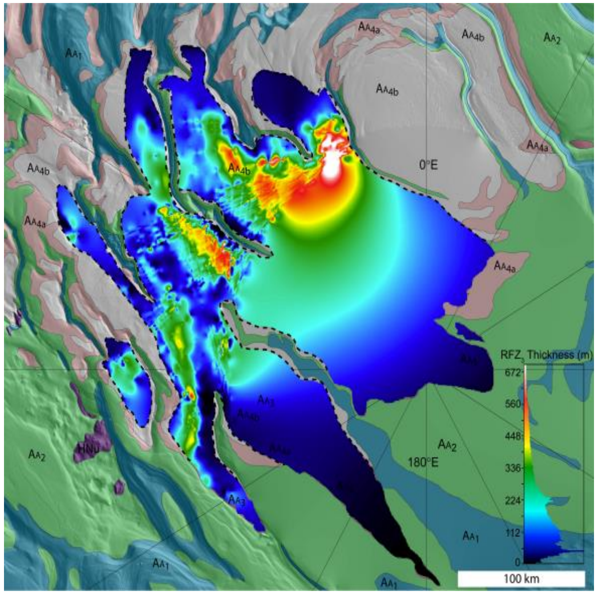
HiRISE image of South Polar Layered Deposits

CRISM activated its cooler for one planning cycle (out of sequence) to acquire key south polar surface spectra during the period of maximum exposure of geological unit A_{A3} to test its correlation with the Reflection Free Zones (RFZs) seen by SHARAD and hypothesized to be buried CO_2 ice.

These areas are now accumulating seasonal CO_2 frost as southern fall begins.

Amazonian Ice Ages and Atmospheric Collapse



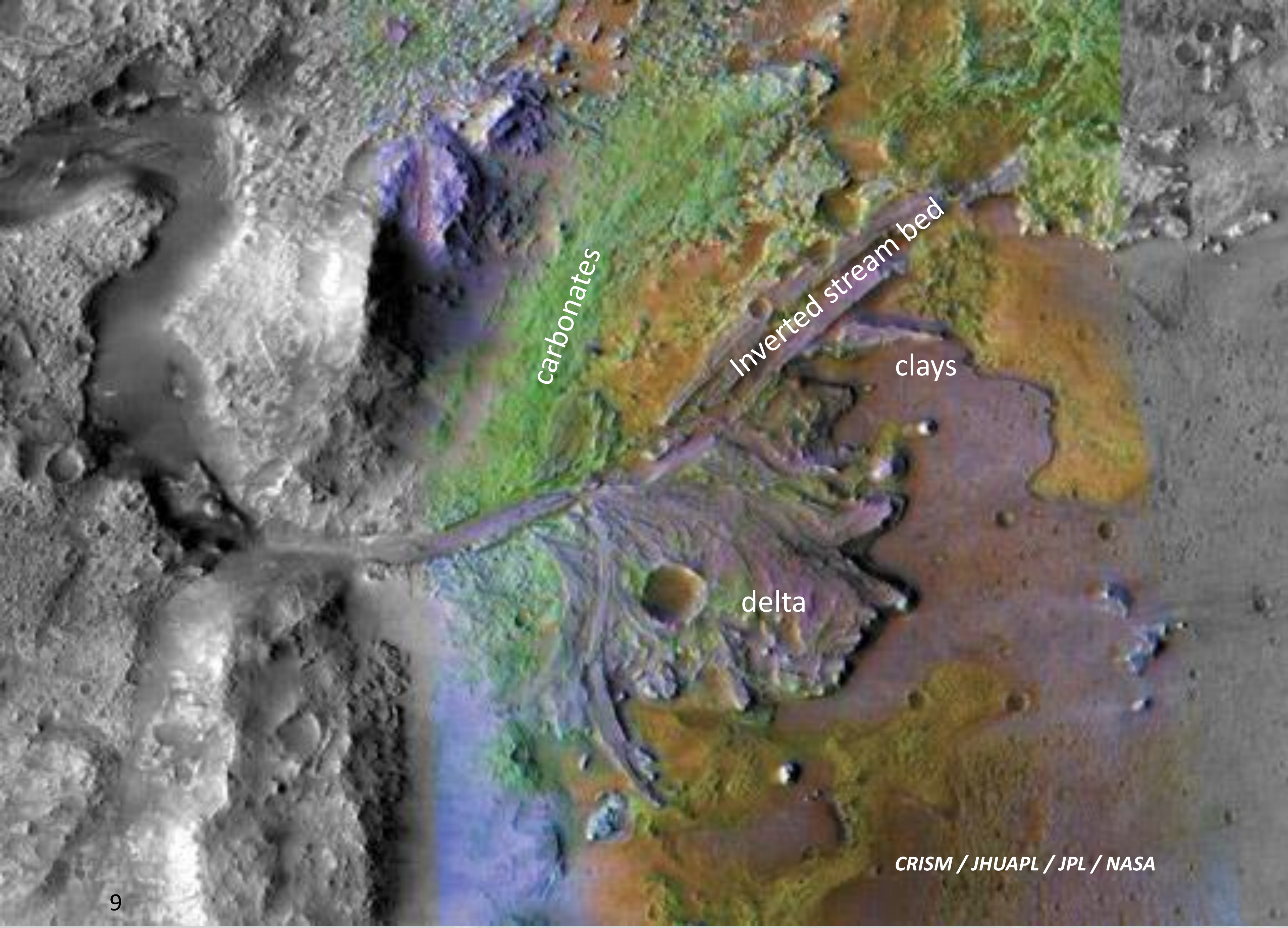


(Right): Thickness of buried CO_2 ice based on orbital radar profiles (SHARAD)

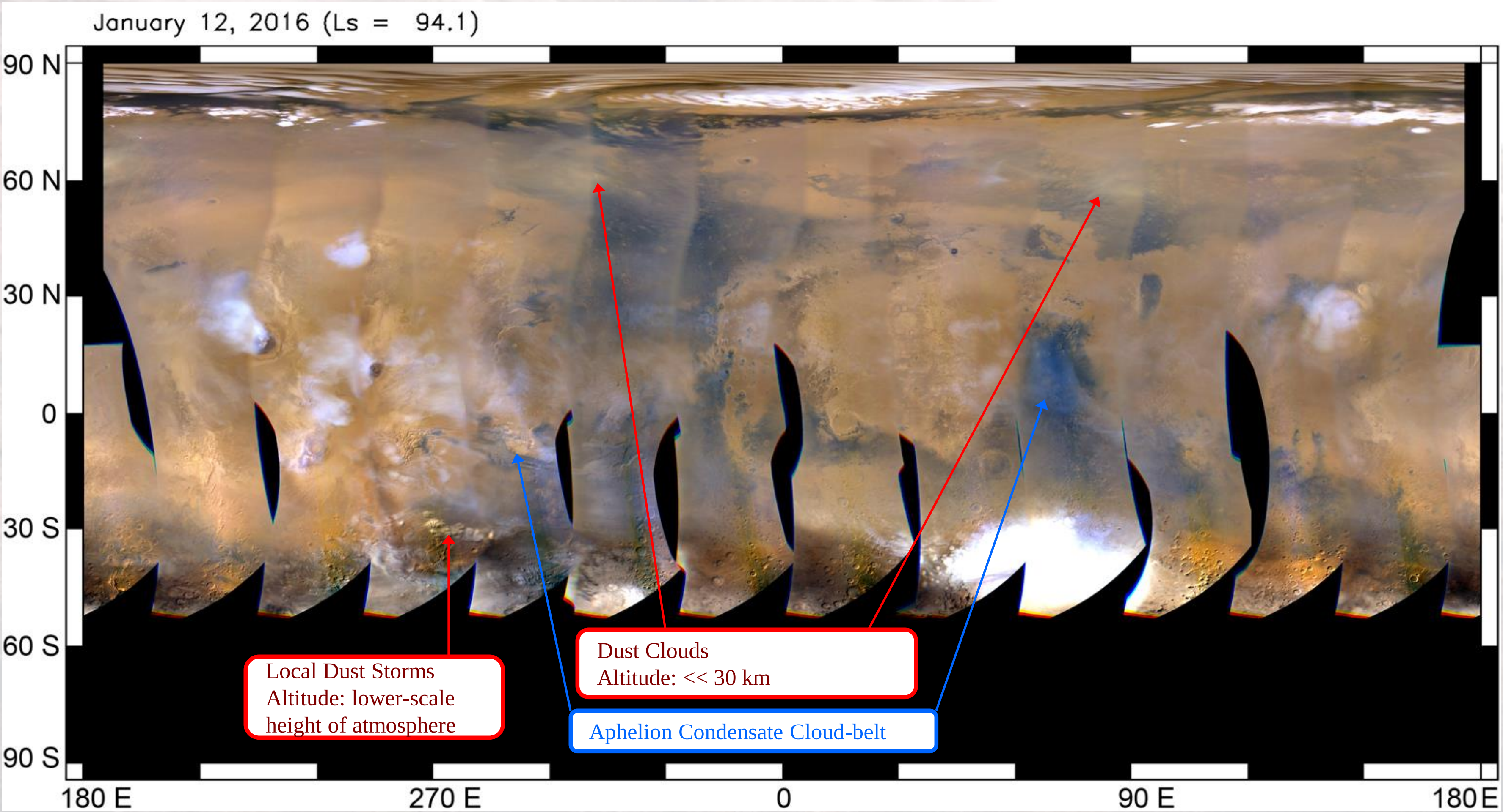
(a) Possible history of CO_2 ice at the south pole for last 800,000 Earth years. Polar accumulation is episodic during periods of low obliquity and short-lived (purple) unless water ice caps the CO_2 ice occurs (magenta).

When CO2 builds up, atmosphere collapses (surface pressure drops).

(b) Section of a SHARAD radargram showing three layers of CO_2 ice, each capped by a protective layer of water ice, that may correspond to the sequestered CO_2 events modeled in (a).


carbonates
Inverted stream bed
clays
delta
CRISM / JHUAPL / JPL / NASA

Recent MARCI Daily Global Map



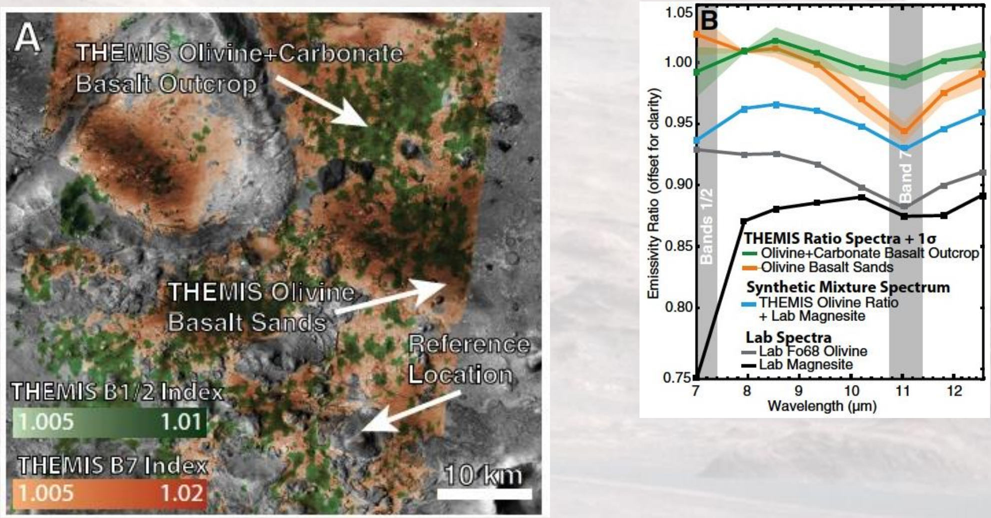
Where Did the Atmosphere (CO_2) Go?

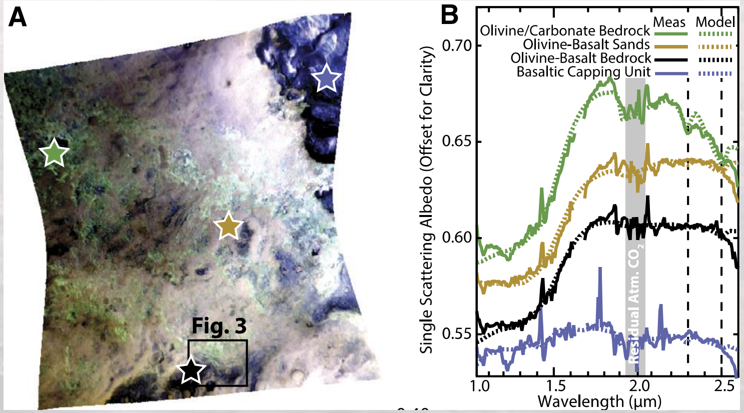
Carbon Sequestration on Mars

C. S. Edwards and B. L. Ehlmann, <u>Geology</u>, 2015

- On Earth, carbon sequestration in geologic units plays an important role in scrubbing CO_2 from the atmosphere
- On Mars, no massive carbonate rock reservoir has been identified to date.
- The lack of large ancient Noachian carbonate-bearing deposits on Mars implies:
    1) A thin atmosphere (≤ 500 mbar) during valley network formation,
    2) Extensive post-Noachian atmospheric loss to space, or
    3) Diffuse, deep sequestration (burial) by a yet-to-be understood process.

(A) Outcrops containing carbonate and olivine observed by THEMIS. (B) THEMIS ratio and laboratory spectra of Fe-Mg carbonate solid solution.



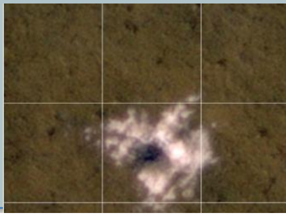


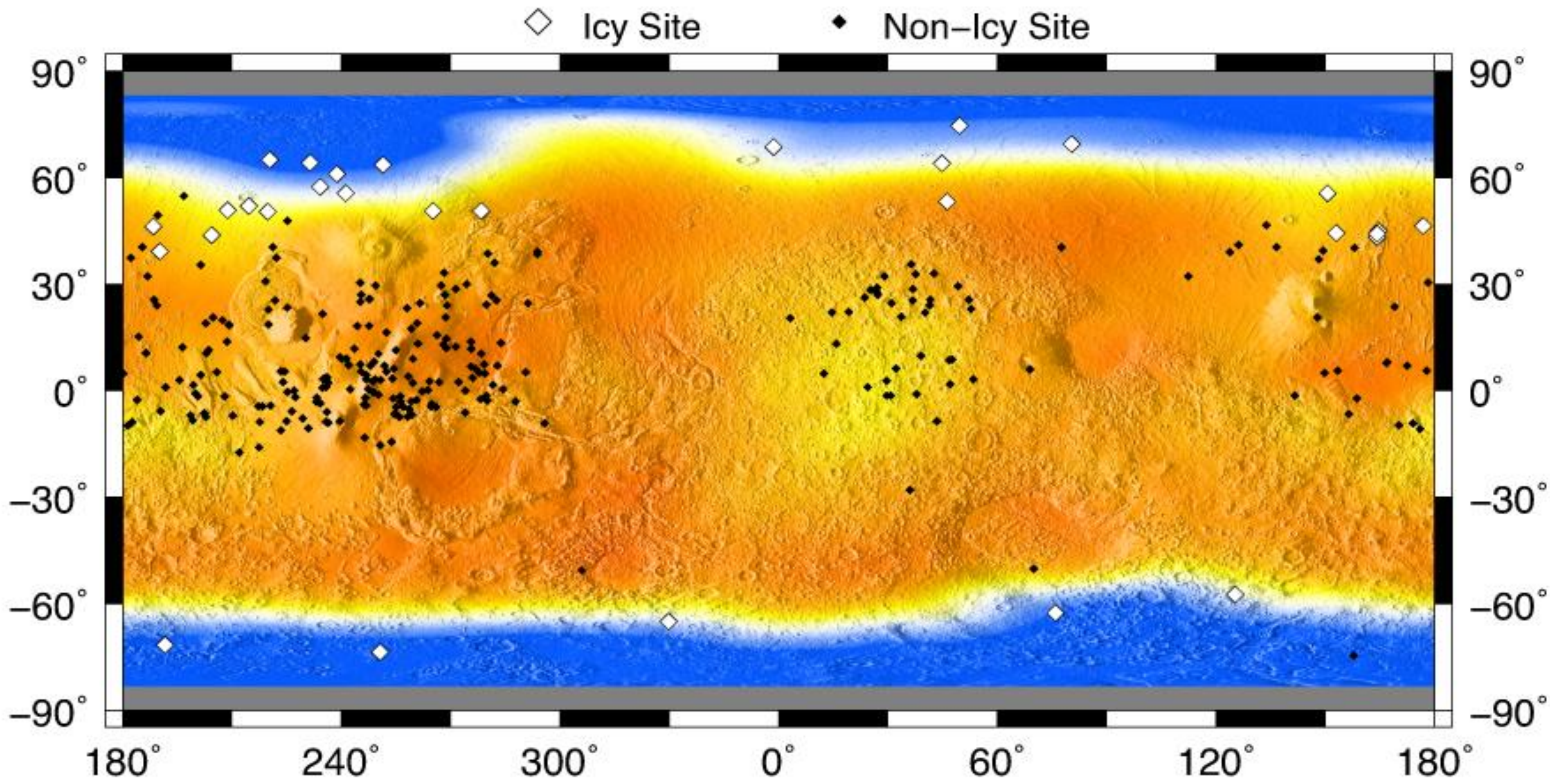
(A) CRISM single-scattering albedo (SSA) image.
(B) SSA spectra and forward Hapke model fits from locations in (A).

Locations of New Impact Craters

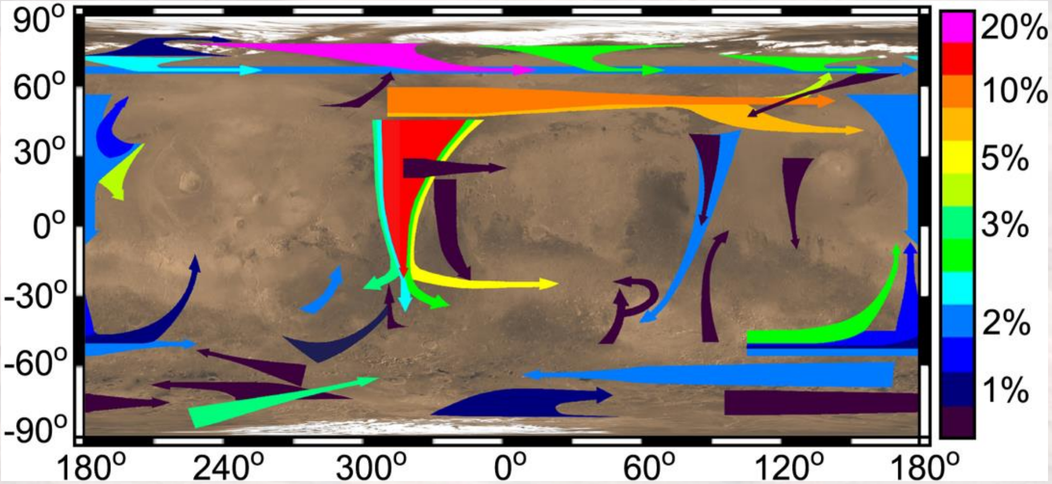
White Diamonds Are Those Exposing Ice

HiRISE / USGS / U. Arizona / JPL-Caltech / NASA



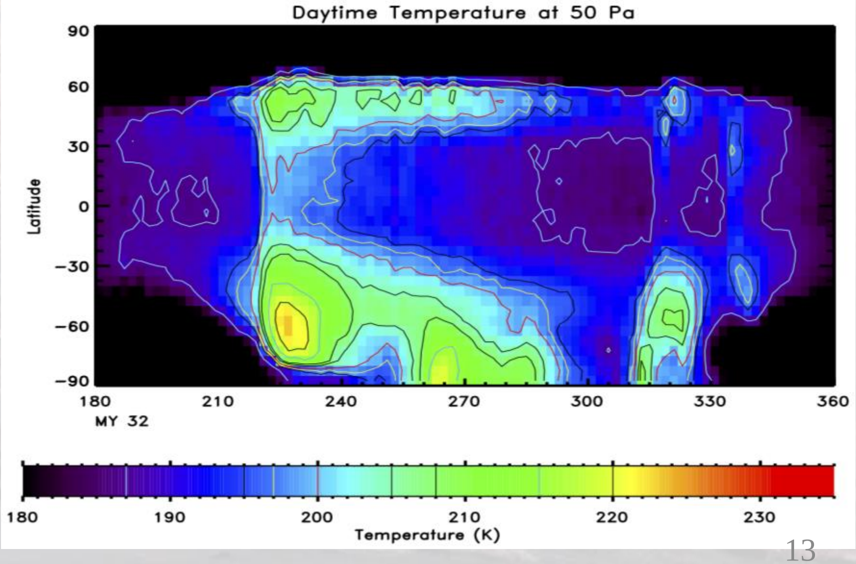


Martian Dust Storm Climatology

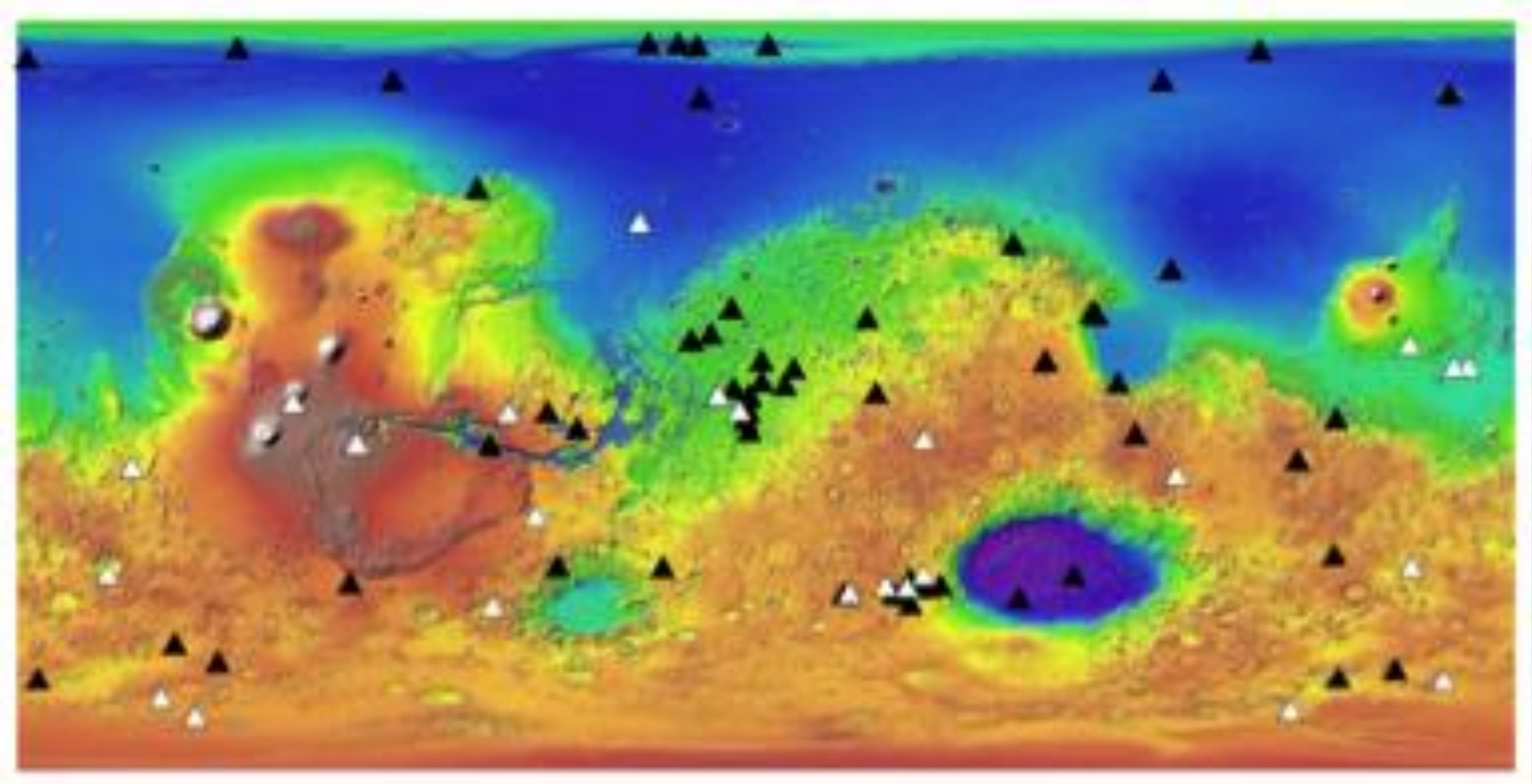


Climatology of Martian regional dust storm tracks (MY 23–32) using MGS and MRO data. The color bar indicates percentage of total regional dust storms during this period. *Cantor et al., 2016, MARCI*

Daytime zonal mean temperatures at 50 Pa (~25 km) from MCS retrieved profiles. The dusty season shows the occurrence of the very late dust storm and the relatively dusty (warm) atmosphere early in the year.
Kass et al. 2016, MCS

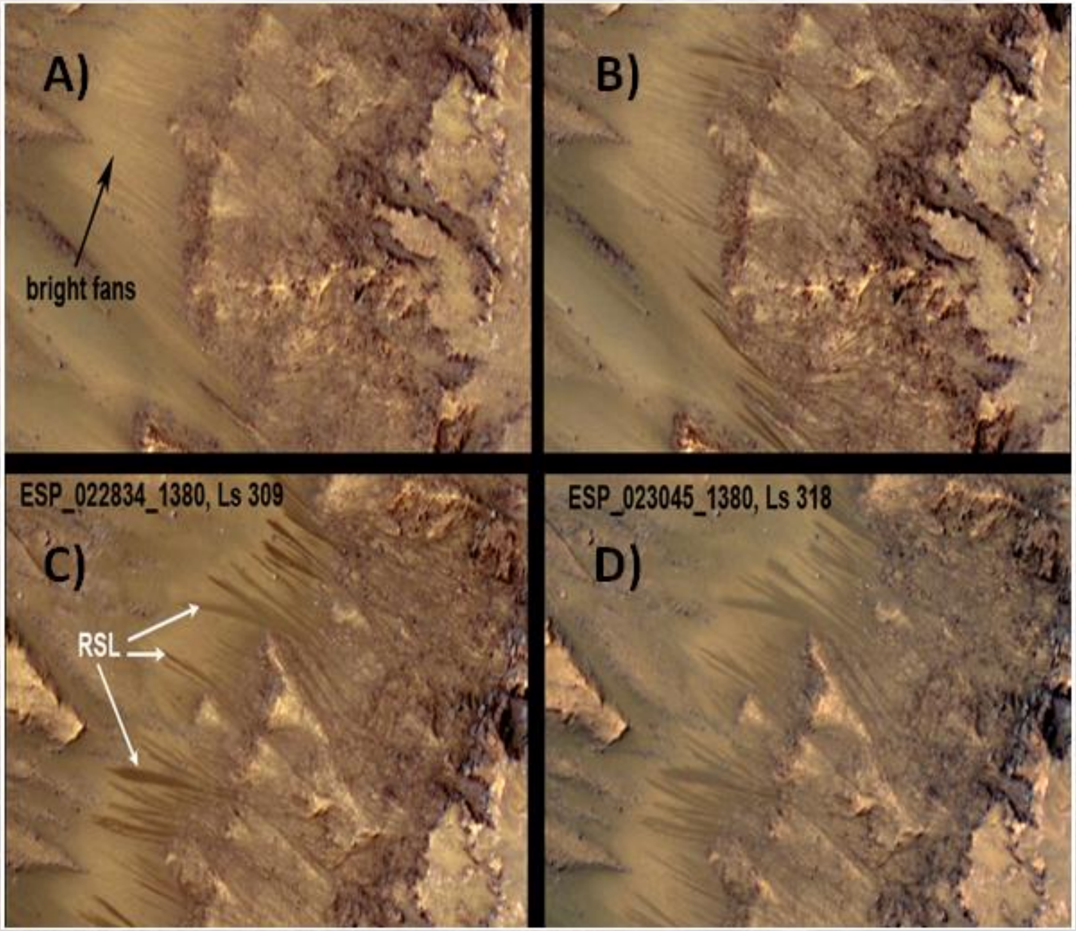


Active Sand Dunes on Mars



Global map of active dunes; black = motion detected, white = no motion detected so far [*Banks et al.*, 2015a].

New Discoveries: Recurring Slope Lineae

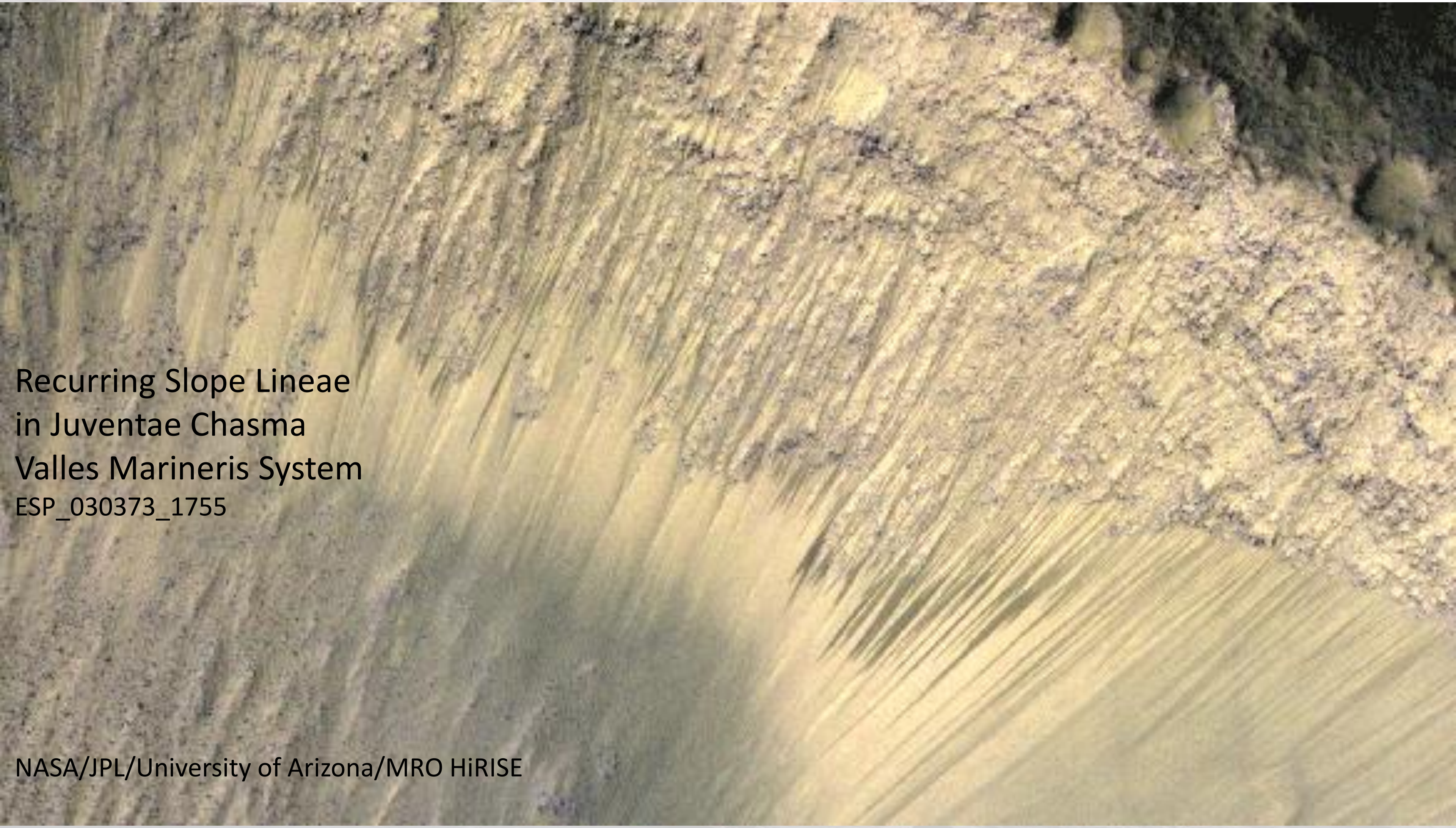


Series of orthorectified images of Palikir Crater in Newton Basin
NASA / JPL / U. Arizona::MRO HiRISE

A. *Faded RSL on bright fans from the previous Mars year and a hint of new RSL in bed-rock regions;*
B. *New RSL appear;*
C. *The RSL lengthen downslope in early southern summer;*
D. *The RSL are fading by mid-summer.*

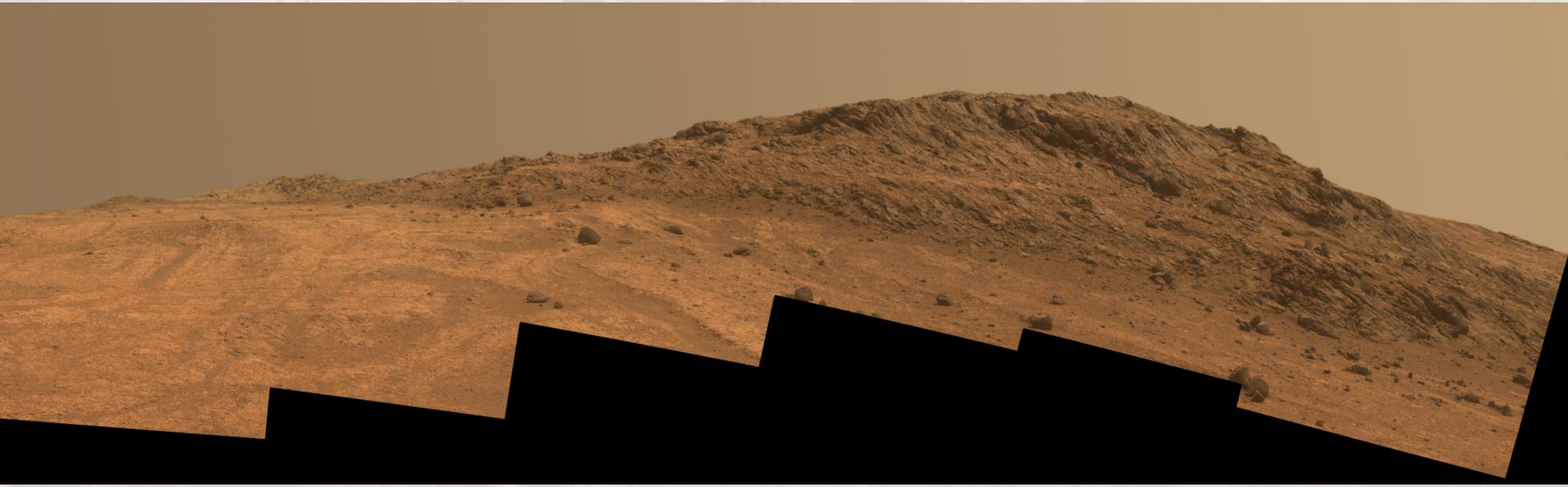
Changes in hydration state of perchlorate salts have been detected in association with the RSL
(MRO CRISM)
Ohja et al. (2015, Nature Geoscience)

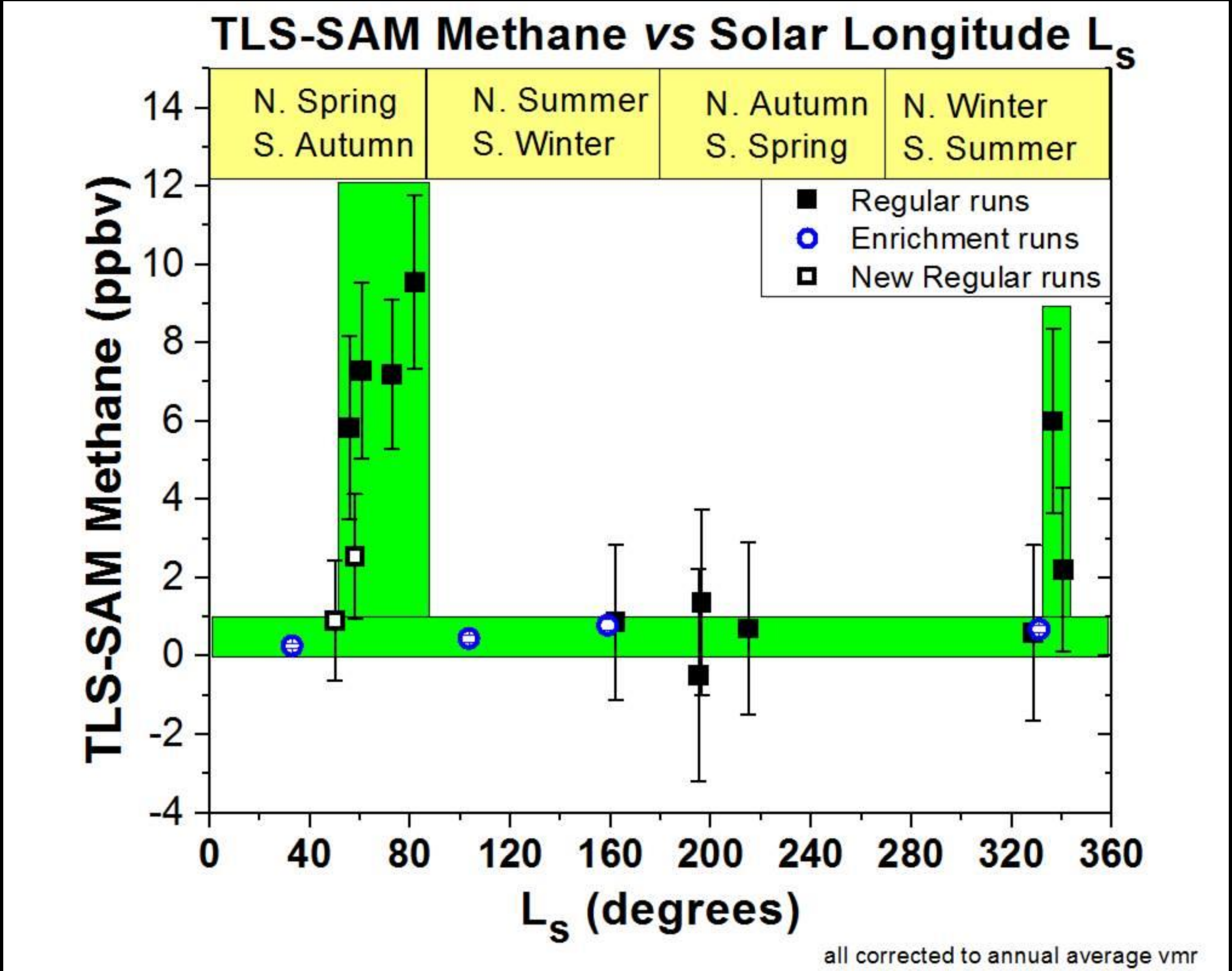
RSL in Valles Marineris



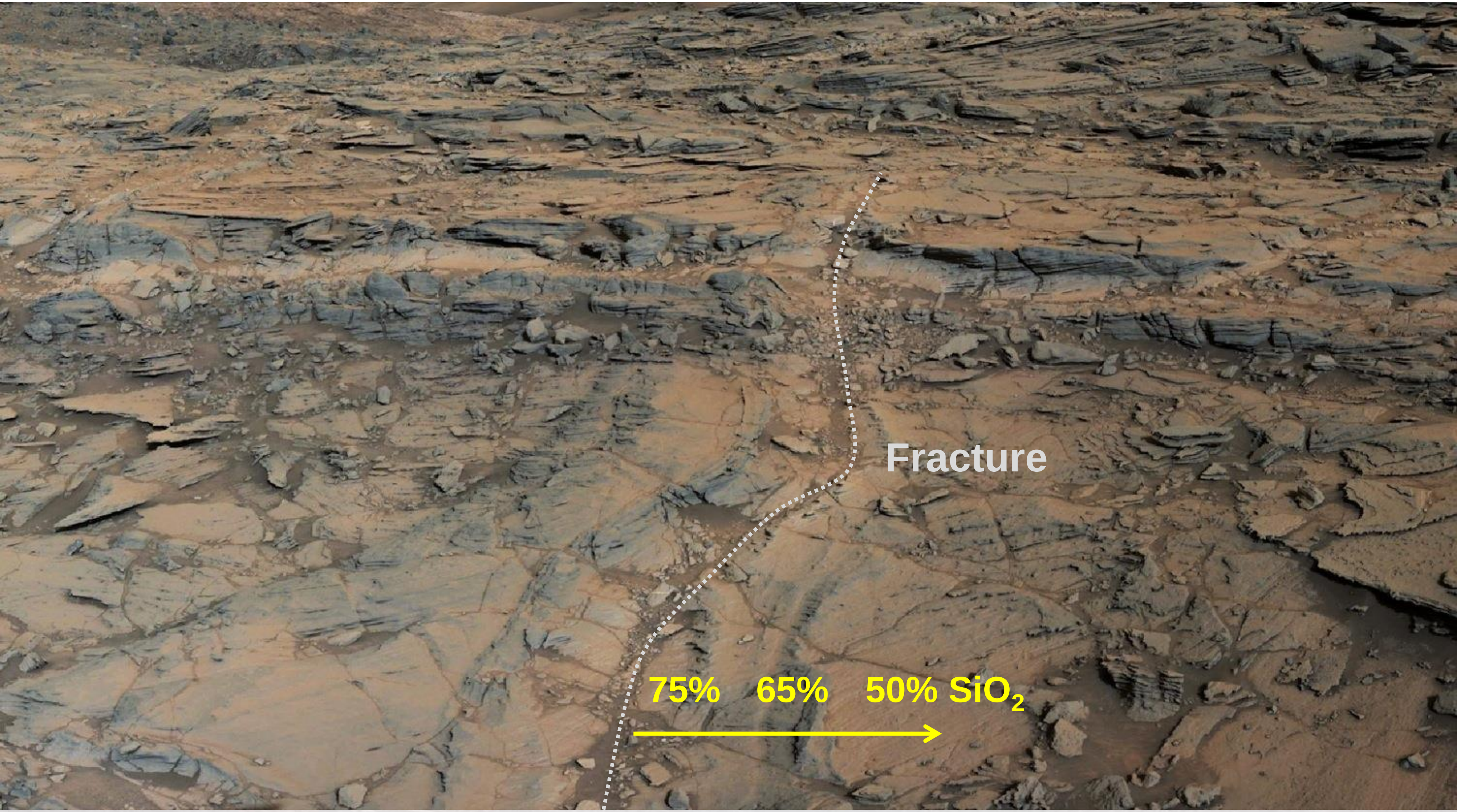
North Wall of Marathon Valley ('Hinners Point')

- Orbital data indicate presence of clay minerals in Marathon Valley

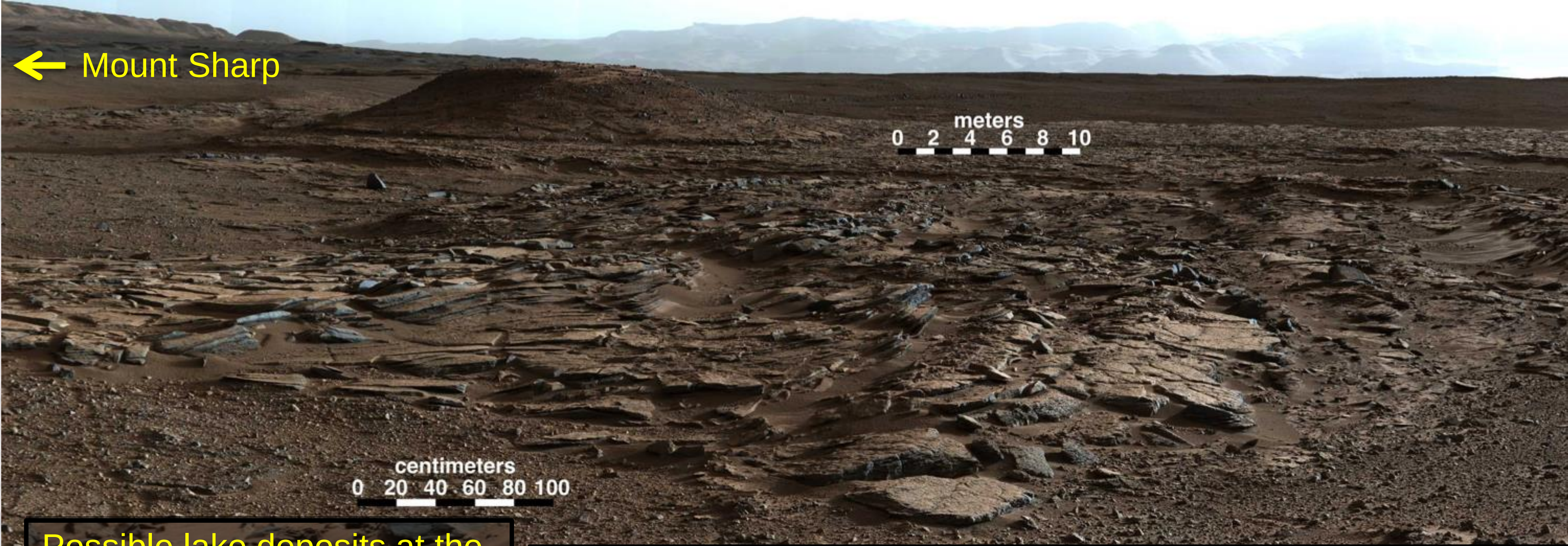


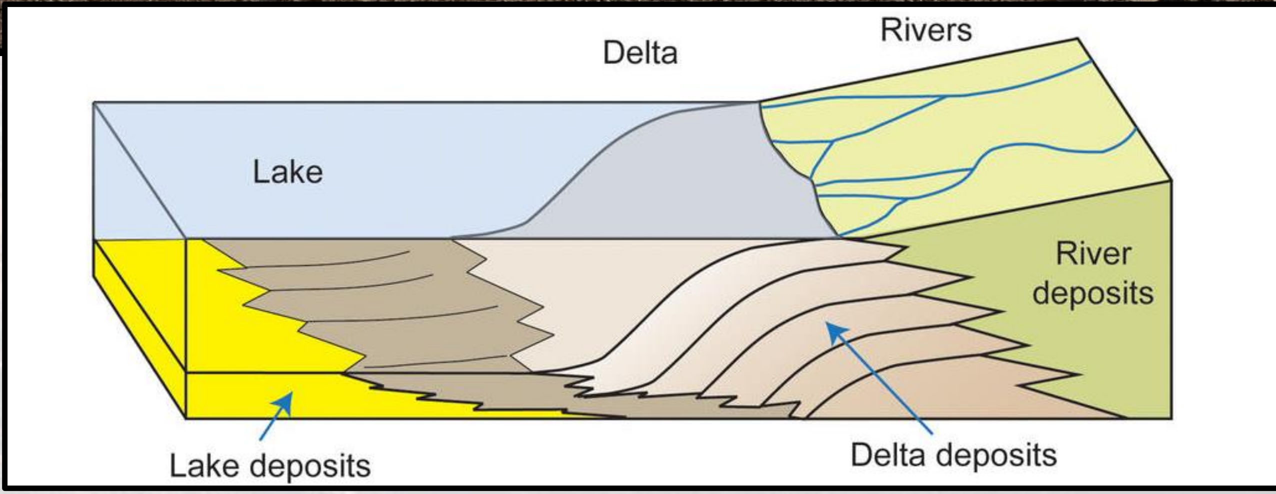


Curiosity detected a background methane abundance of 0.7 parts per billion (by volume) and a mysterious, ten-fold enhancement that lasted about 60 Mars days (sols)

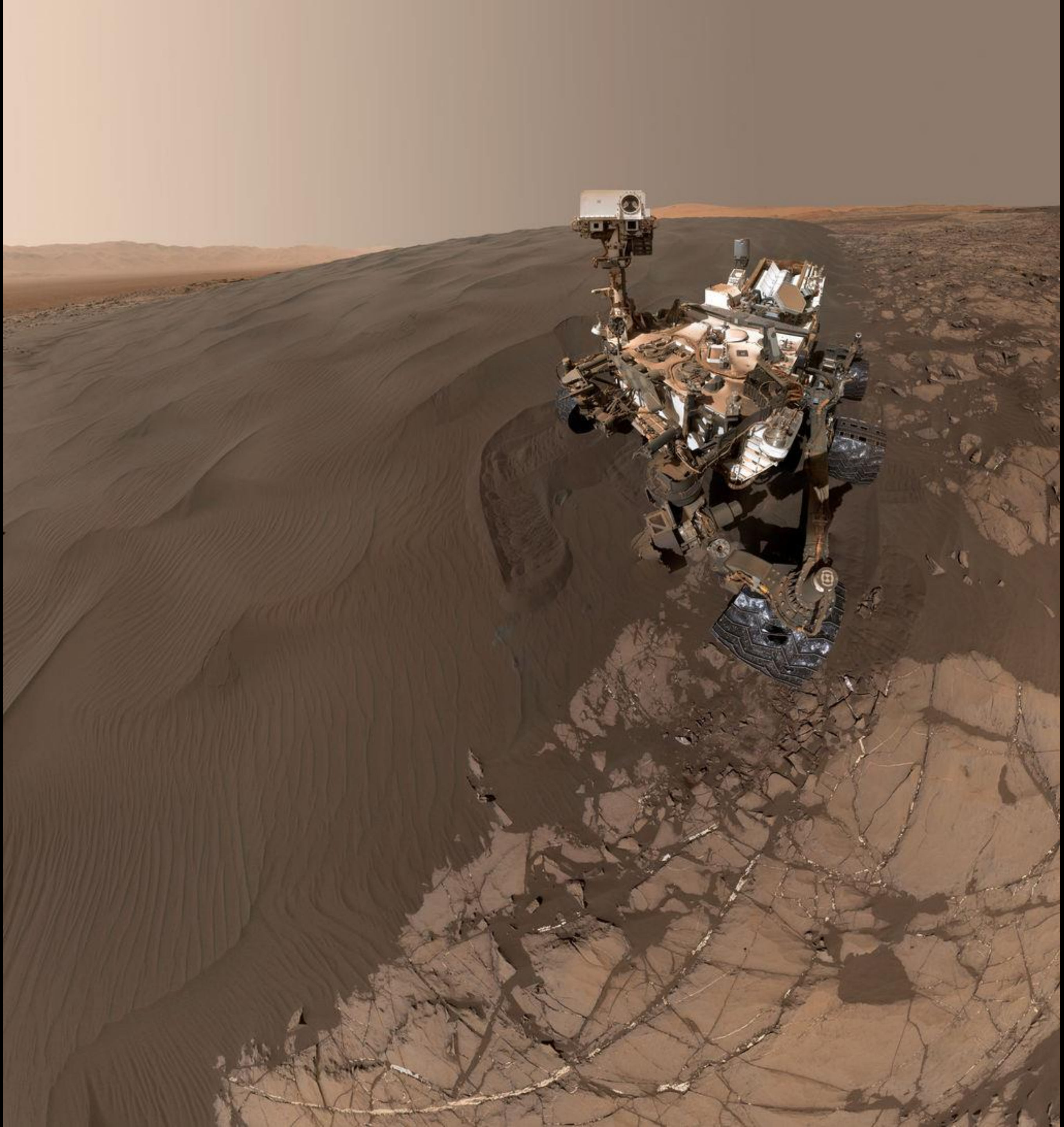


Groundwater circulated through large fractures in the bedrock, highly altering its composition and explaining a new class of high-silica rocks

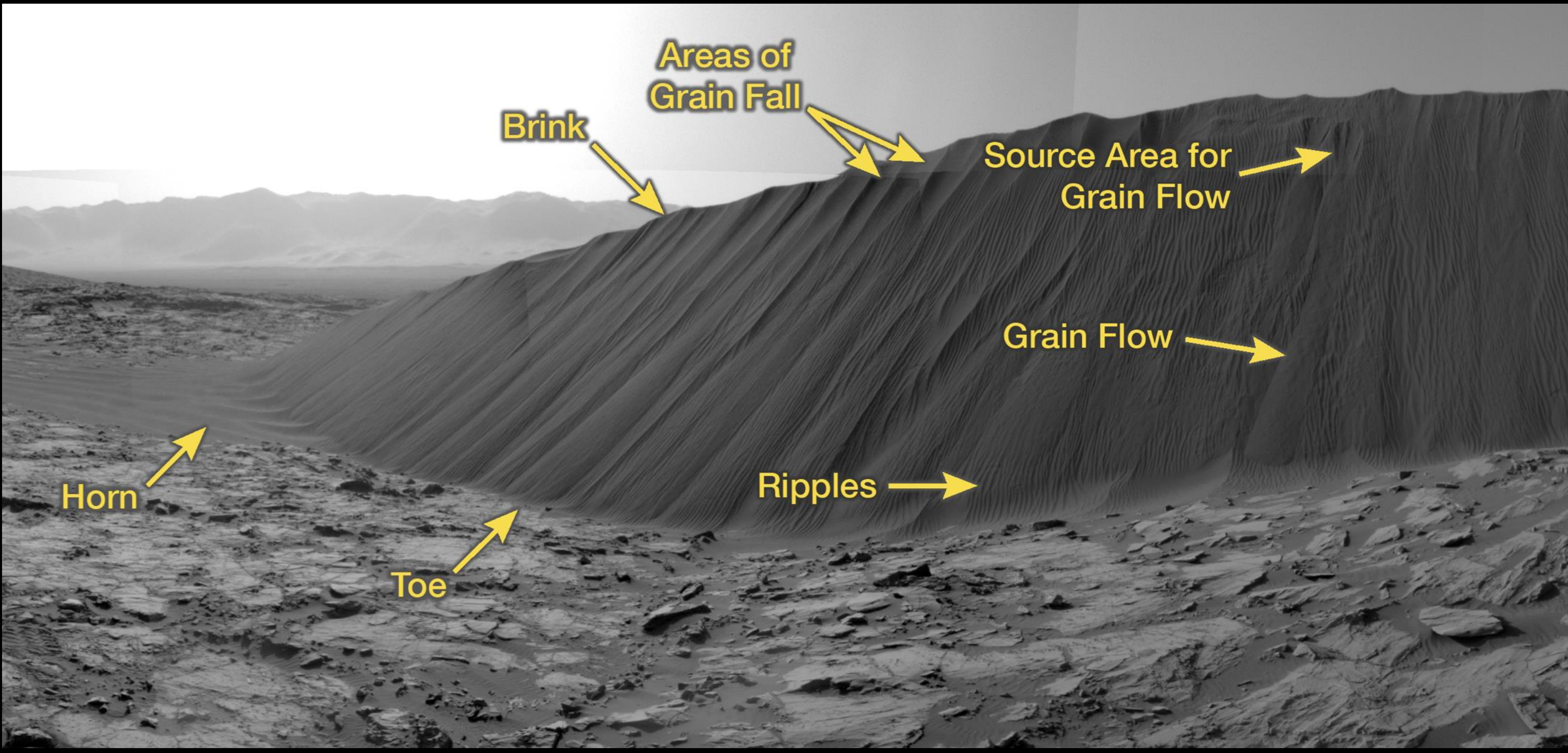




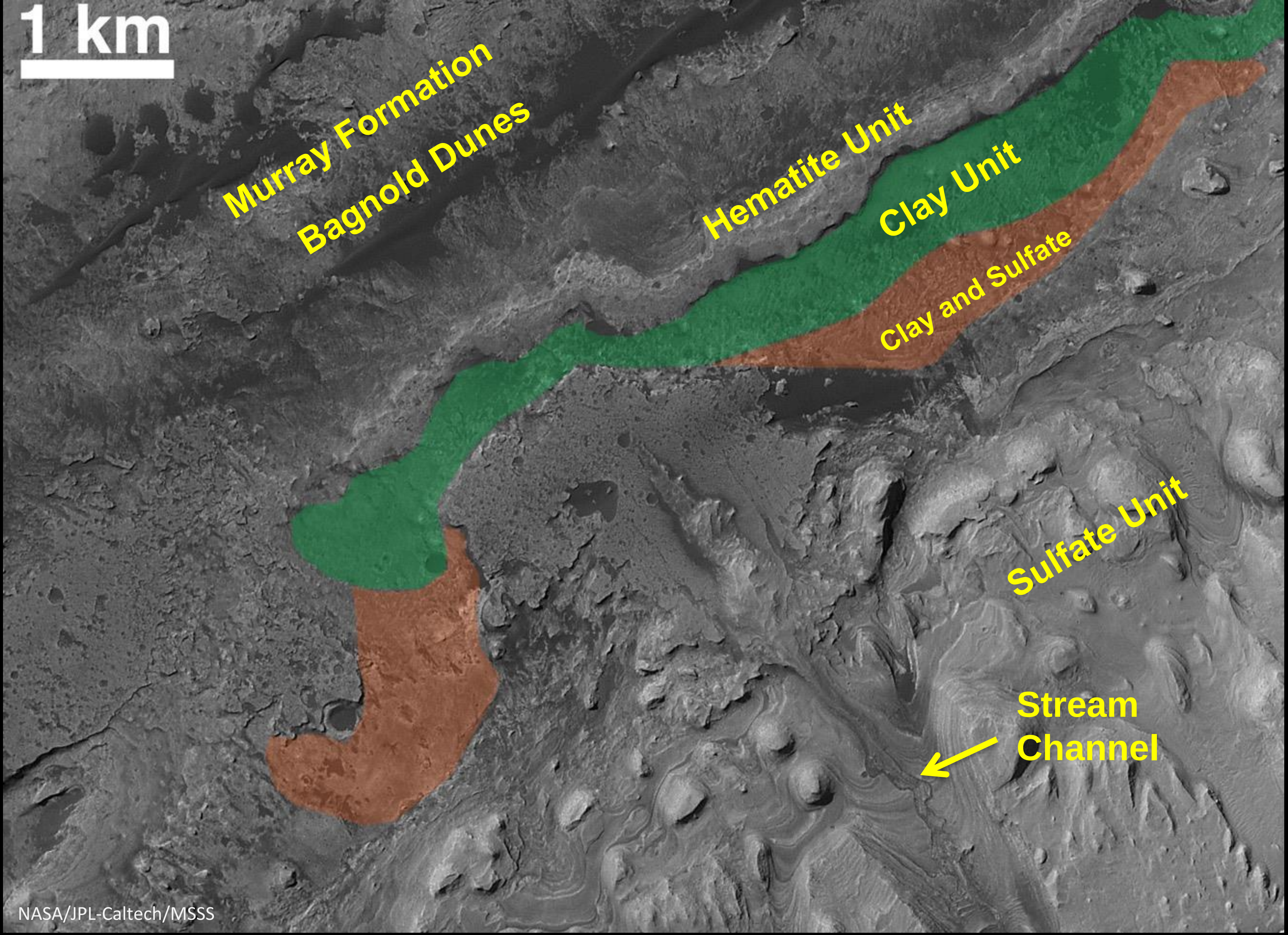
Curiosity discovered south-tilted sandstone beds on Gale Crater's plains that indicate water-driven transport of sediment, building lower Mount Sharp from lake deposits.




Stimson Sandstone
Murray Formation
Bagnold Dunes Study Areas


Areas of
Grain Fall
Brink
Source Area for
Grain Flow
Grain Flow
Horn
Ripples
Toe


Curiosity / JPL / NASA
NASA/JPL-Caltech/MSSS



CURIOSITY

Major Features on Lower Mount Sharp

Current/Future Activities

Gale Crater Special Regions Evaluation Panel - Since the MSL landing in Gale Crater, the McEwen team has identified a few candidate RSLs in Gale Crater.

- Determine the degree of confidence to which we can know whether or not Gale Crater has modern Special Regions.
- Recommend how additional MRO and MSL measurements can contribute to the understanding of Special Regions in Gale Crater, specifically should MSL encounter a feature that is uncertain with respect to being a Special Region.
- Recommend specific criteria the MSL mission can use to identify (and avoid) Special Regions.

Mars Water ISRU Planning Study

- Prepare an initial description of hypothetical “reserves” that may exist on Mars.
- Estimate the rough order-of-magnitude mass/power/complexity of the ISRU engineered system (mining/acquisition, extraction, transportation, processing and storage) needed to produce a given quantity of water.
- Prepare a sensitivity analysis of the major inter-relationships between geological attributes of the water deposits (Task #1 above), and the engineering attributes of the production and processing systems (Task #2 above), in order to propose preliminary minimum acceptable thresholds for “reserves”.

Sunset on Mars
MSSS / JPL / NASA