# Slide Bank for Lightning Talk – Mars Dust/Soil

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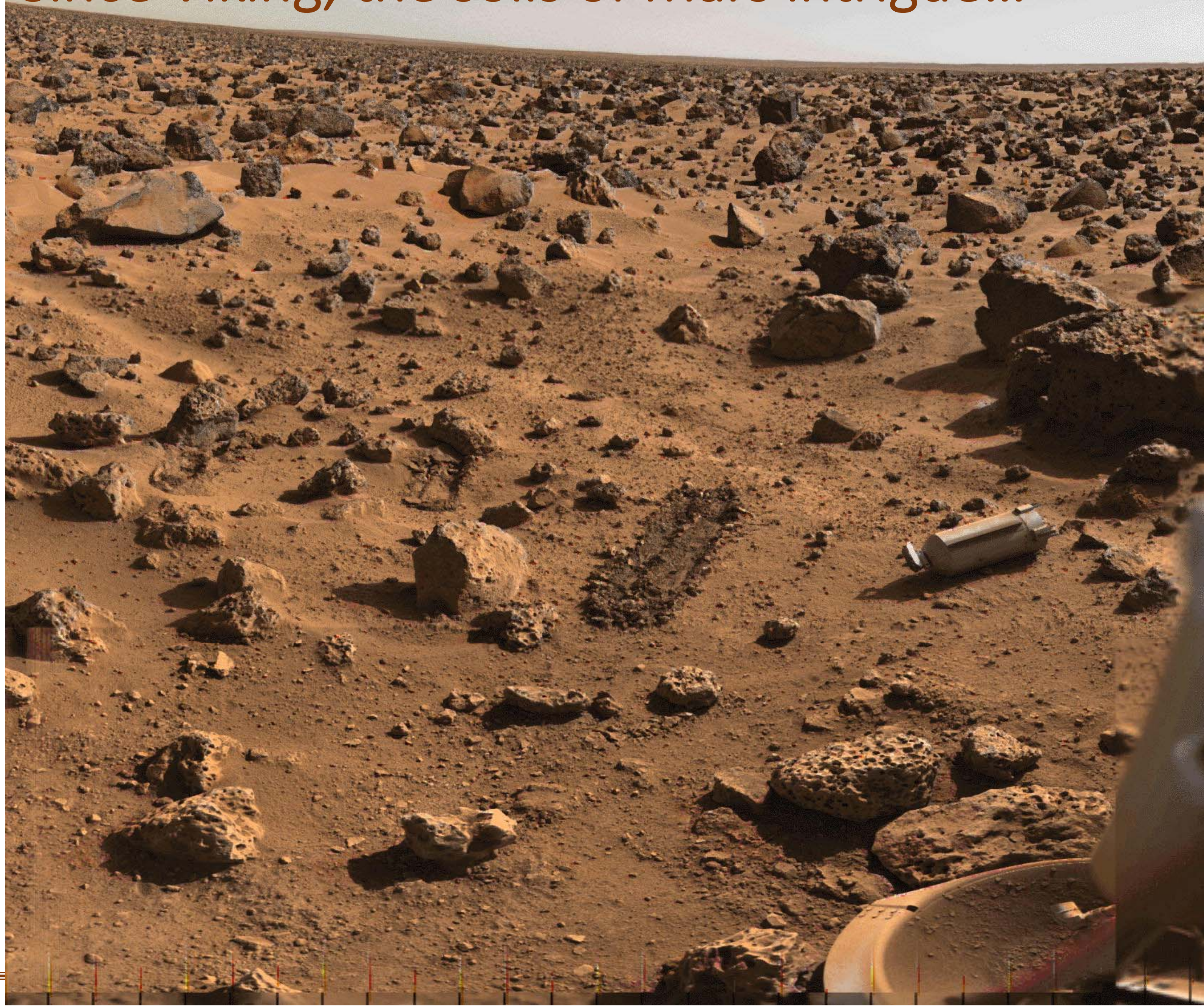
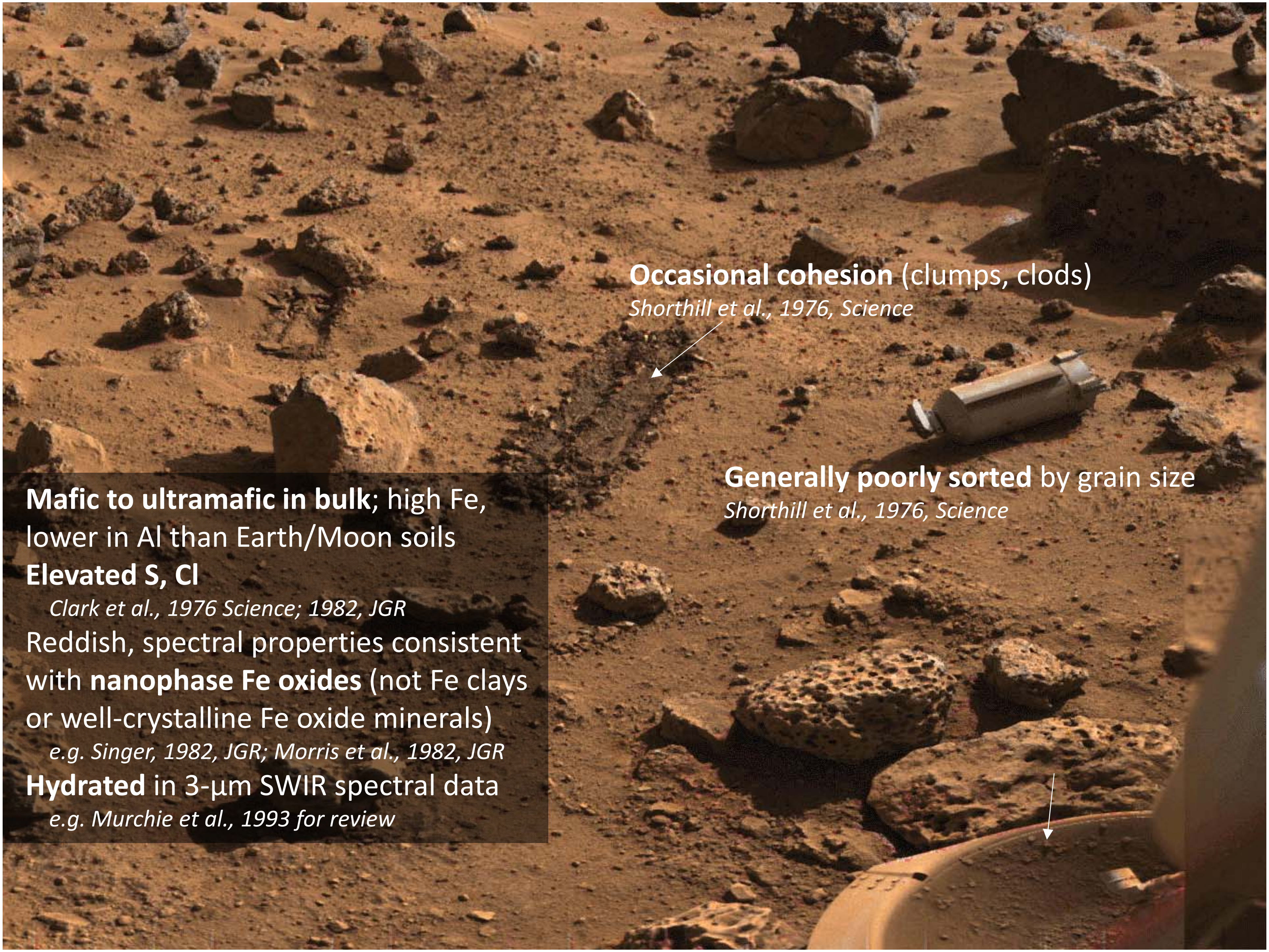
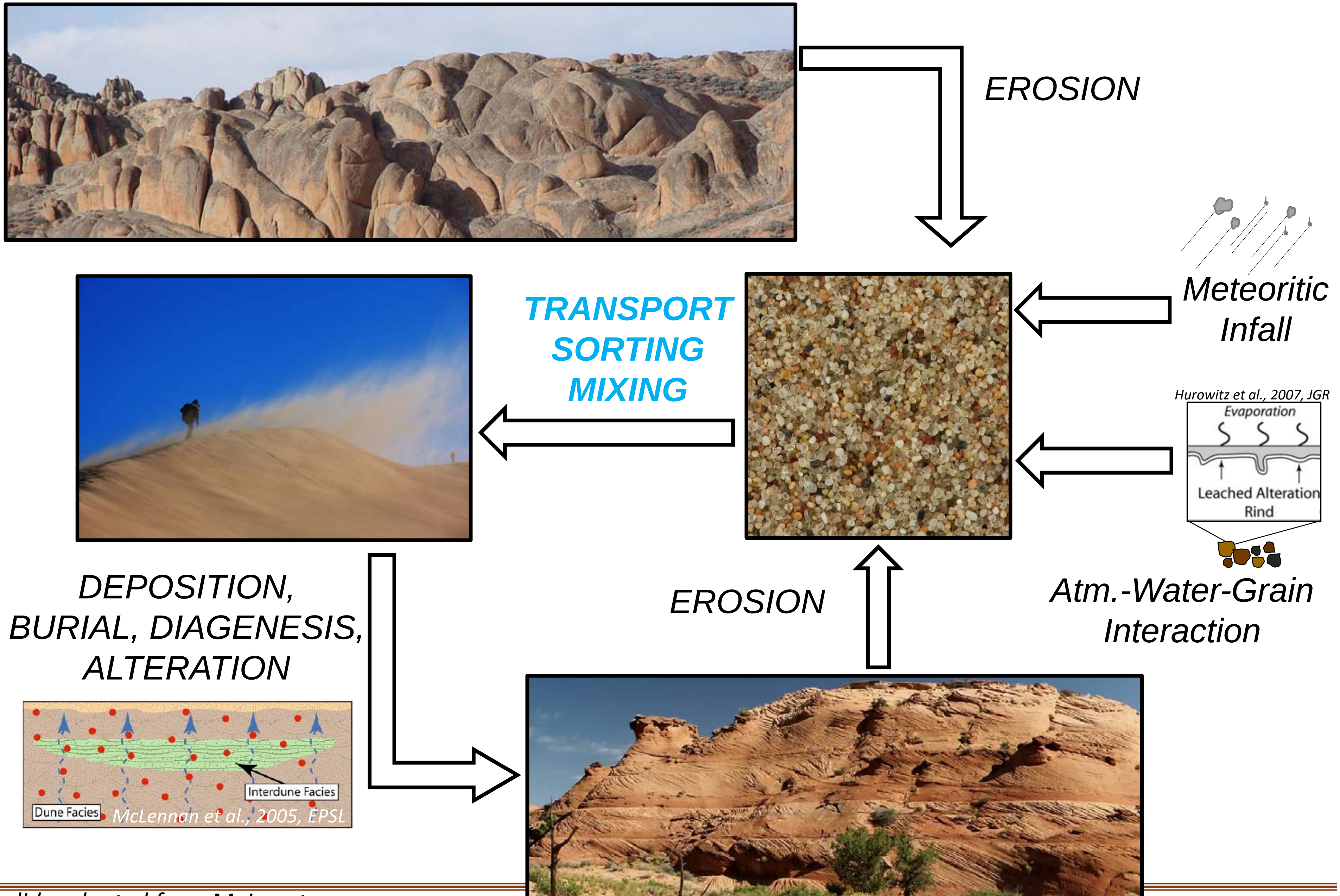
9 August 2017

# Since Viking, the soils of Mars intrigue…




**Occasional cohesion** (clumps, clods)
*Shorthill et al., 1976, Science*
**Generally poorly sorted** by grain size
*Shorthill et al., 1976, Science*
**Mafic to ultramafic in bulk**; high Fe, lower in Al than Earth/Moon soils
**Elevated S, Cl**
*Clark et al., 1976 Science; 1982, JGR*
Reddish, spectral properties consistent with **nanophase Fe oxides** (not Fe clays or well-crystalline Fe oxide minerals)
*e.g. Singer, 1982, JGR; Morris et al., 1982, JGR*
**Hydrated** in 3-µm SWIR spectral data
*e.g. Murchie et al., 1993 for review*

# “Soil” (Regolith) Creation on Mars

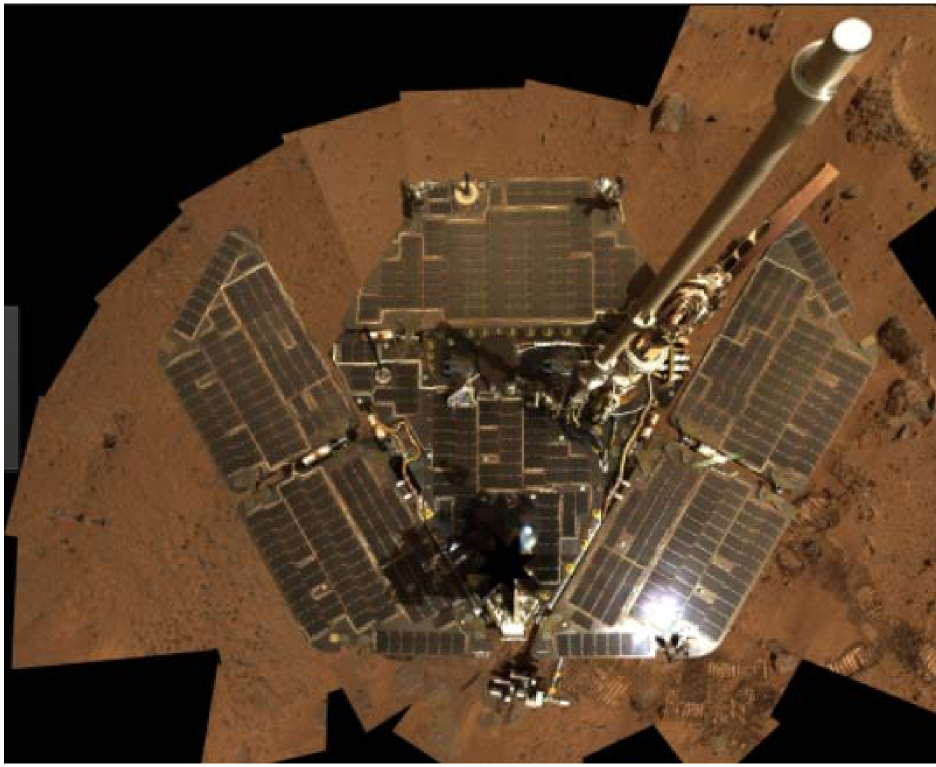


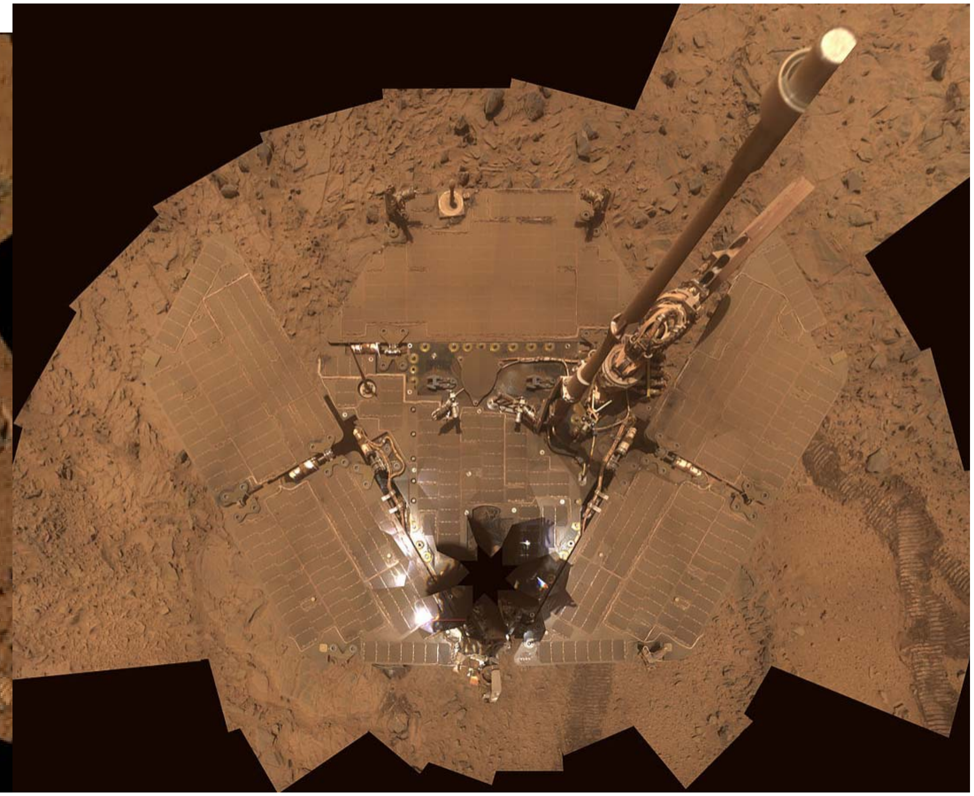

*slide adapted from M. Lapotre*

# Airborne Dust (conventionally, <~2 µm*)

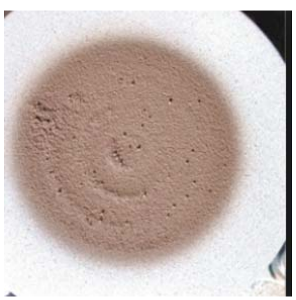
*M. Wolff et al., publications have details on airborne dust grain size and scattering properties

# Airborne Dust on the Rover Deck and Magnets





magnets

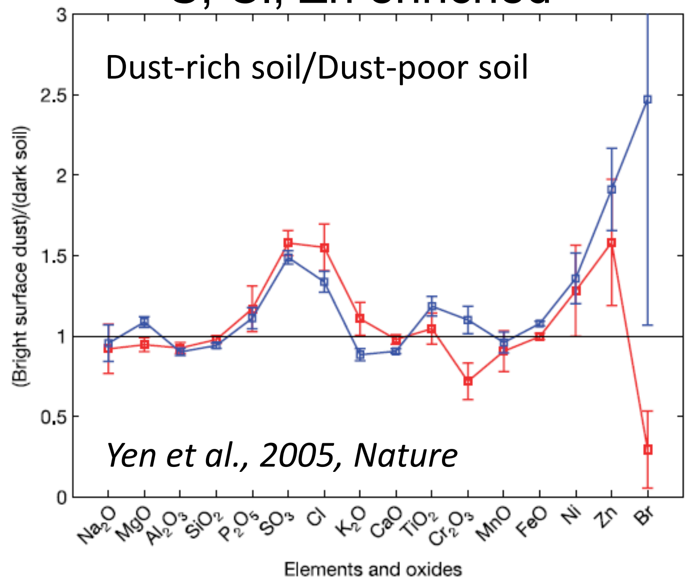


Rates of deposition and removal known
Composition characterized

*Goetz et al., 2005, Nature;*
*Kinch et al., 2015, JGR*

# What we know about Mars dust

S, Cl, Zn enriched




IN SITU: MER

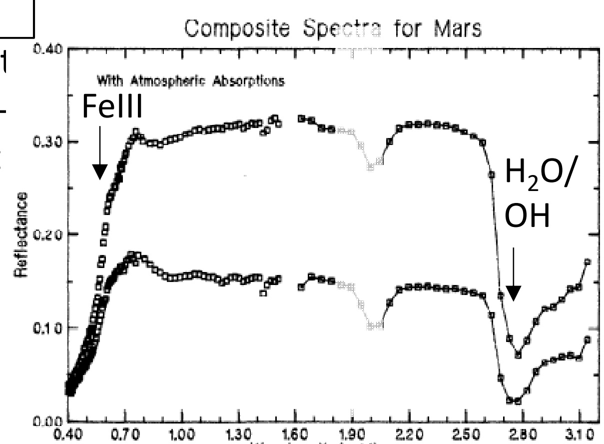
45% Fe(III)/FeT, mainly as ferric nanocrystalline oxides

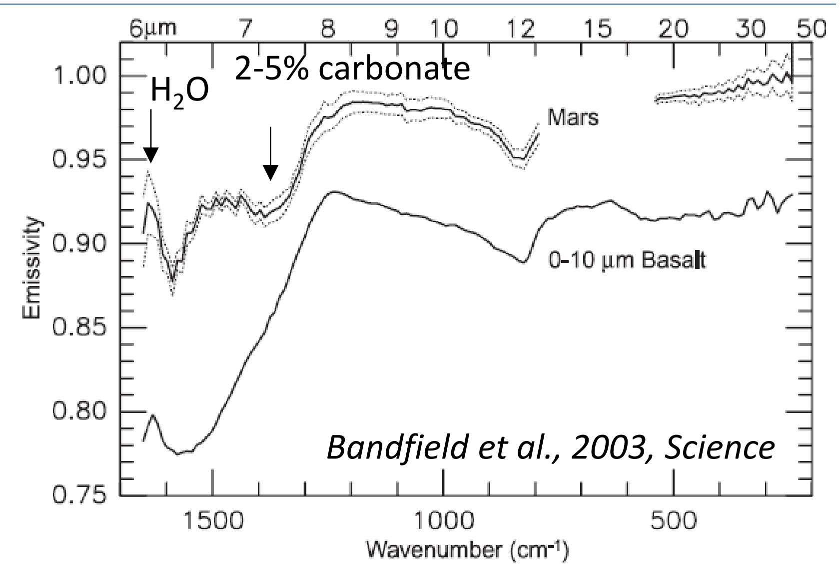
55% FeII/FeT, incl. olivine, pyroxene, titanomagnetite

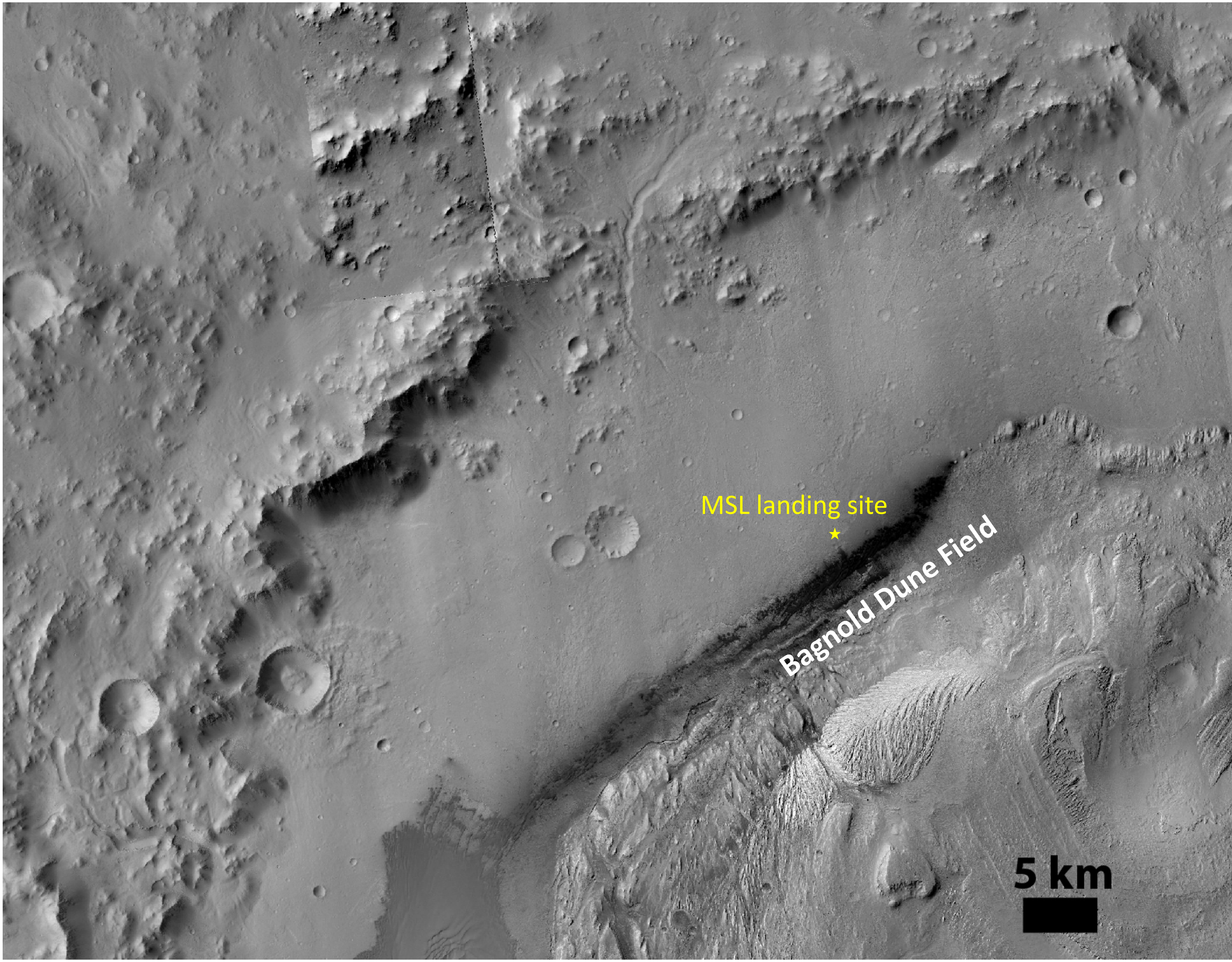
*Goetz et al., 2005, Nature*

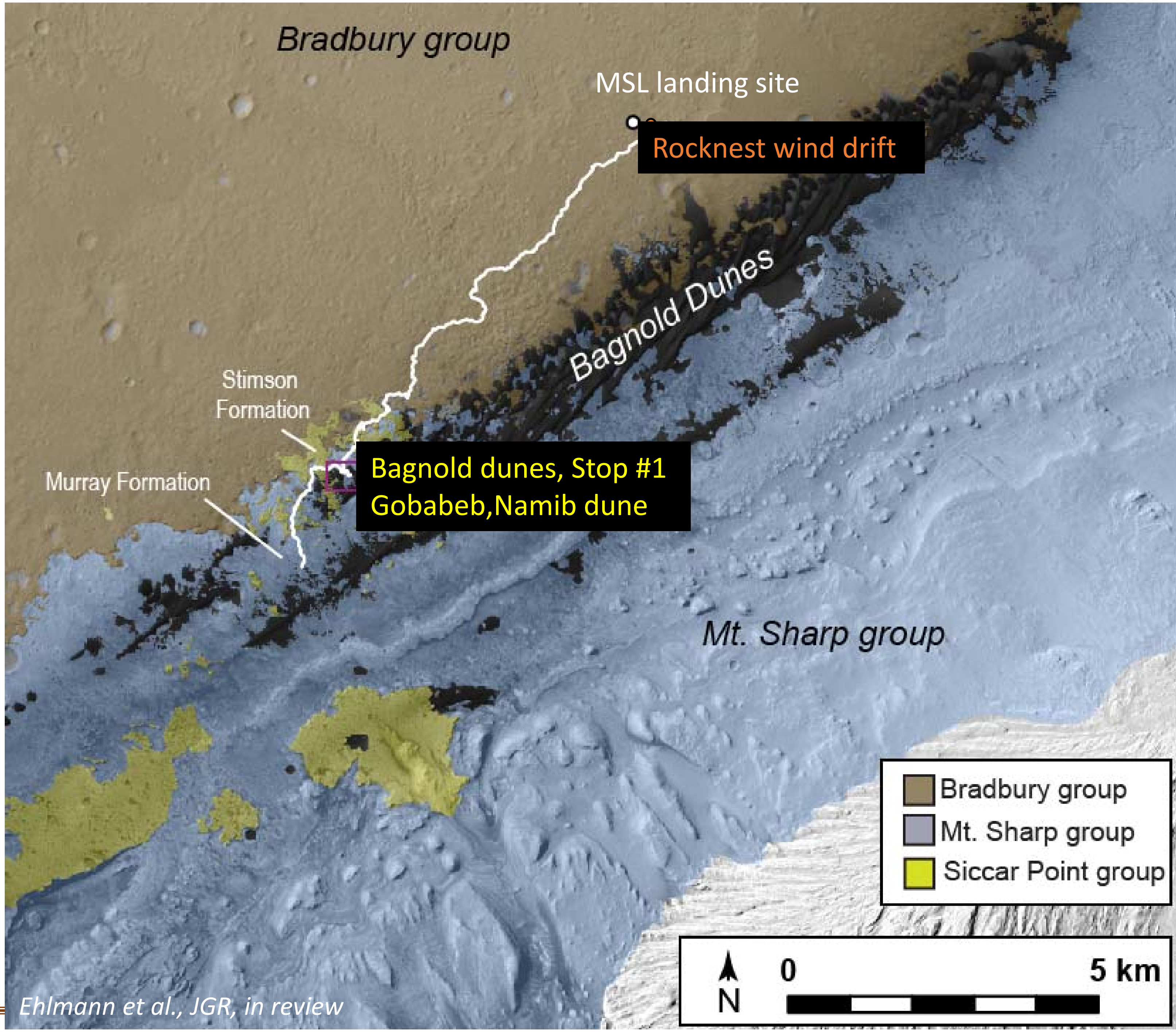
REMOTE SENSING

A strong FeIII absorption but lack the absorptions of well-crystalline oxides (Morris et al. 2000).
Dominantly plagioclase and framework hydrated silicates, lesser amounts of olivine, pyroxenes, and sulfates (Hamilton et al. 2005).



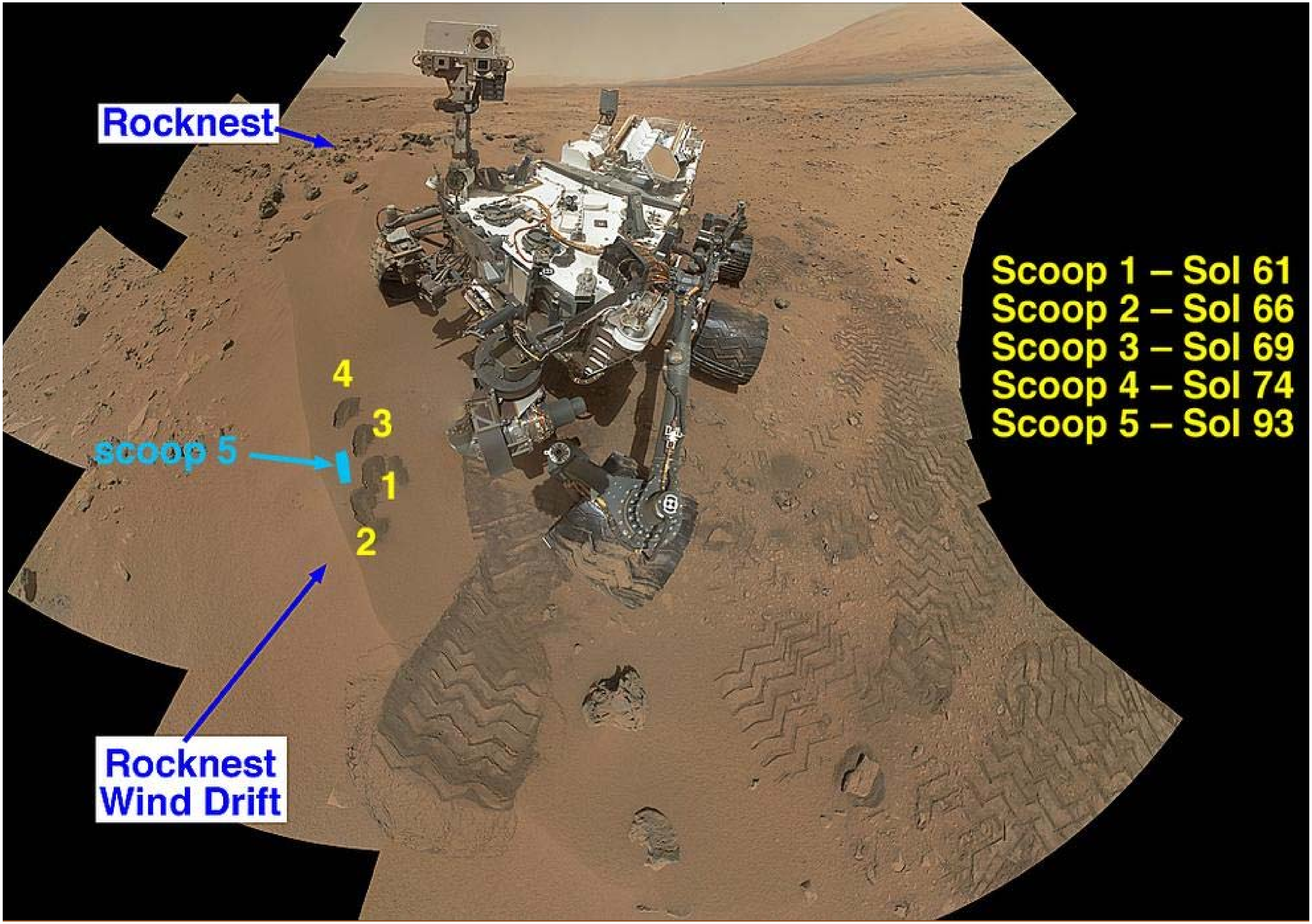




MSL landing site
Bagnold Dune Field
5 km



Bradbury group
MSL landing site
Rocknest wind drift
Bagnold Dunes
Stimson Formation
Murray Formation
Bagnold dunes, Stop #1
Gobabeb,Namib dune
Mt. Sharp group
Bradbury group
Mt. Sharp group
Siccar Point group
N
0
5 km
Ehlmann et al., JGR, in review


# Windblown sand at the Rocknest site

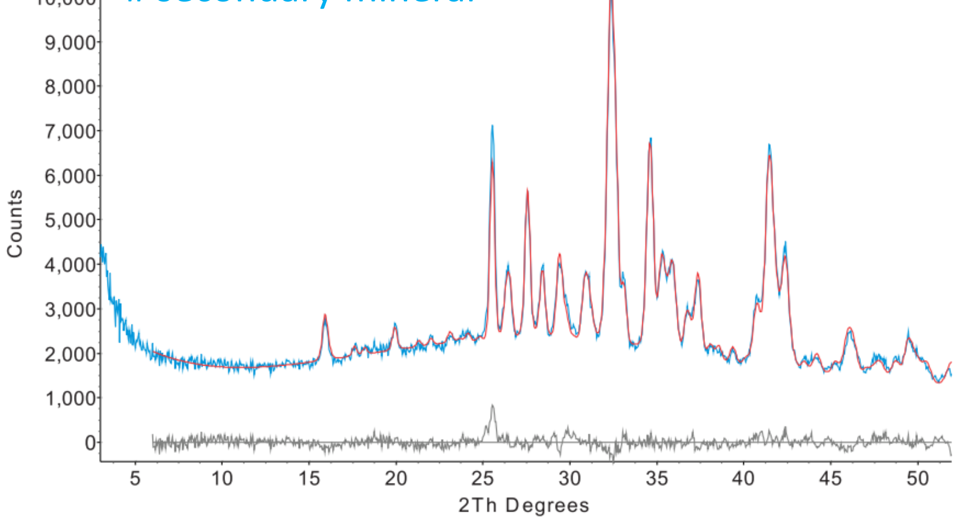

Rocknest
4
3
scoop 5
1
2
Rocknest
Wind Drift
Scoop 1 – Sol 61
Scoop 2 – Sol 66
Scoop 3 – Sol 69
Scoop 4 – Sol 74
Scoop 5 – Sol 93

# Rocknest Sand Mineralogy: Basaltic, as expected…

| | Mineral | Weight (%) | 2σ (%) |
|---|---|---|---|
| | Plagioclase (~An57) | 40.8 | 2.4 |
| | Forsterite (~Fo62) | 22.4 | 1.9 |
| | Augite | 14.6 | 2.8 |
| | Pigeonite | 13.8 | 2.8 |
| | Magnetite | 2.1 | 0.8 |
| # | Anhydrite | 1.5 | 0.7 |
| # | Quartz | 1.4 | 0.6 |
| | Sanidine* | 1.3 | 1.3 |
| # | Hematite* | 1.1 | 0.9 |
| | Ilmenite* | 0.9 | 0.9 |

*At or near detection limit

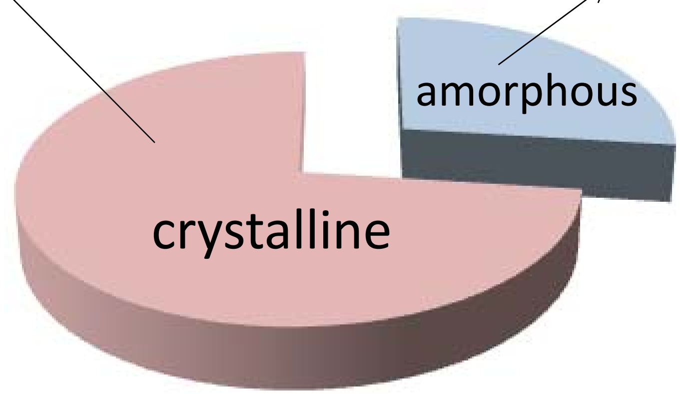
# secondary mineral




96% anhydrous phases formed by igneous processes

<4% from chemical alteration

<u>…however, 27% of the sample is unknown mineralogically</u>




*Blake et al., 2013, Science; Bish et all, 2013, Science*

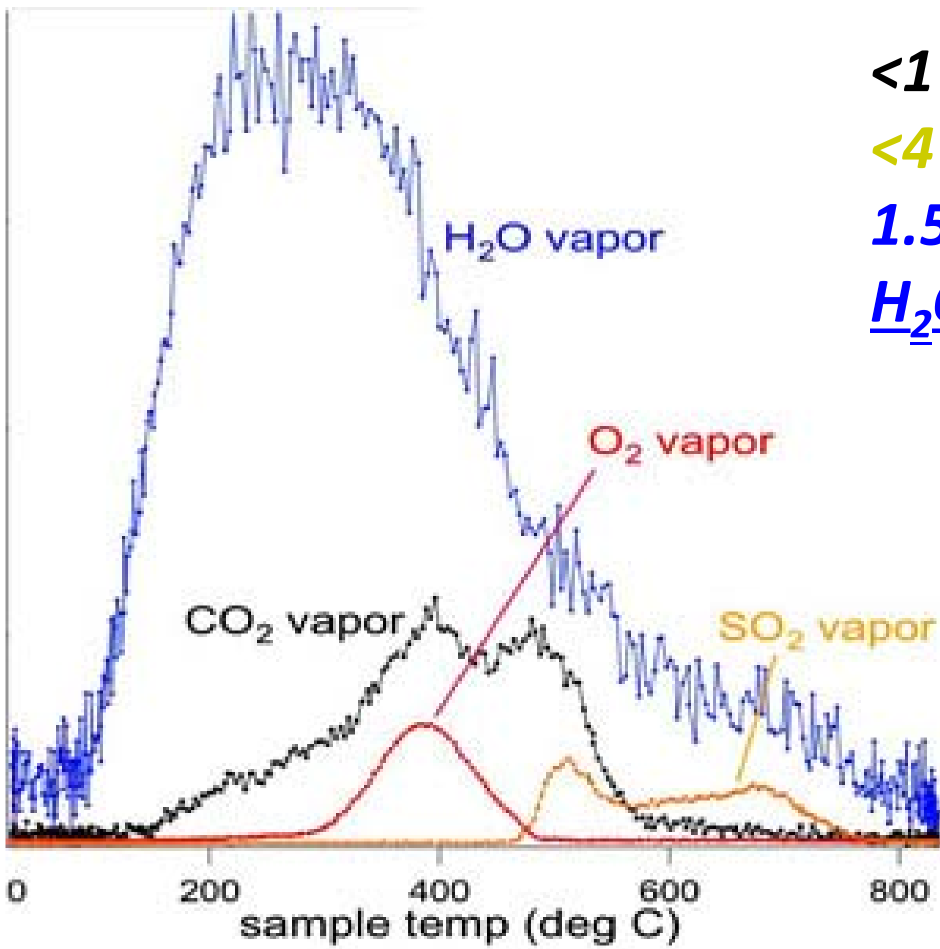
**Volatile, Isotope, and Organic Analysis of Martian Fines with the Mars Curiosity Rover**
L. A. Leshin *et al.*
*Science* **341**, (2013);
DOI: 10.1126/science.12389

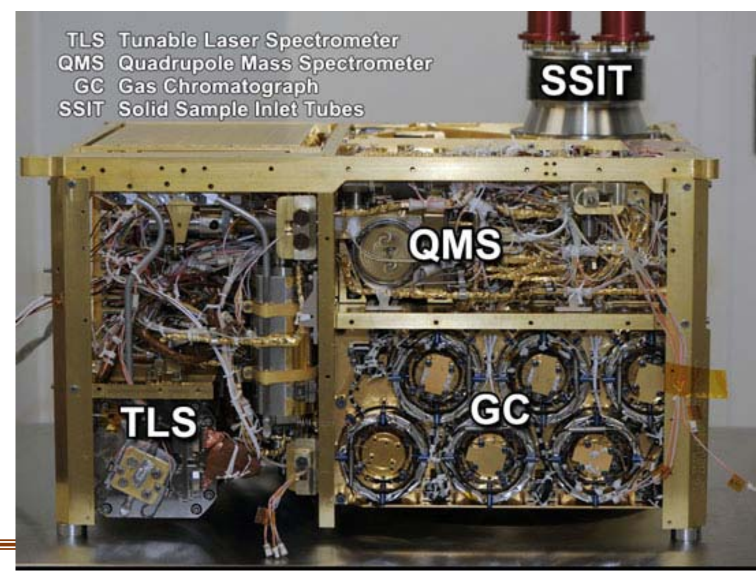
**Key Discovery: abundant hydrous amorphous phase in "boring" Mars soils**
For Mars Polar Dust: Do the volatiles change? Record volcanic processes?

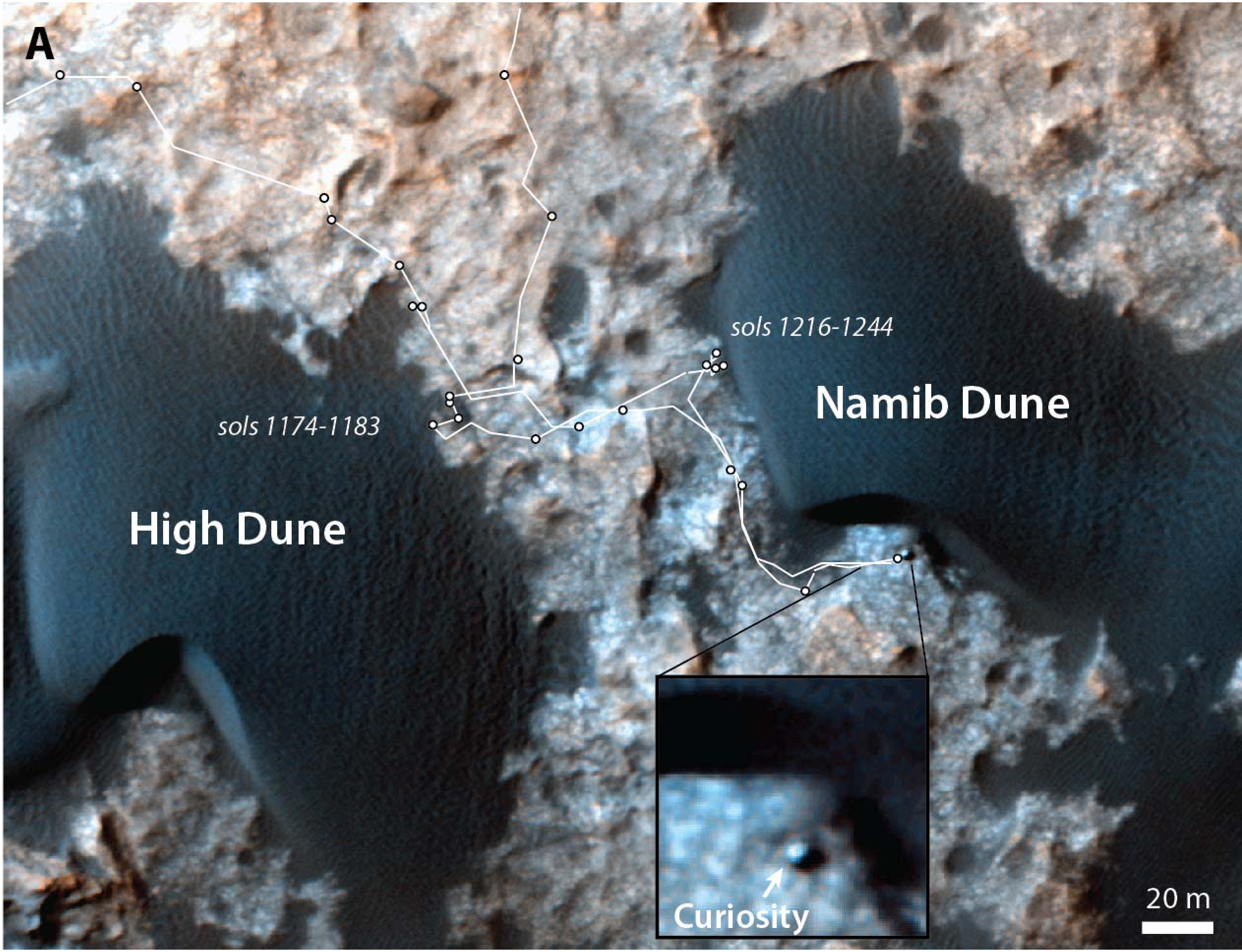
*<1 wt% carbonate*

*<4 wt% sulfate/sulfide*

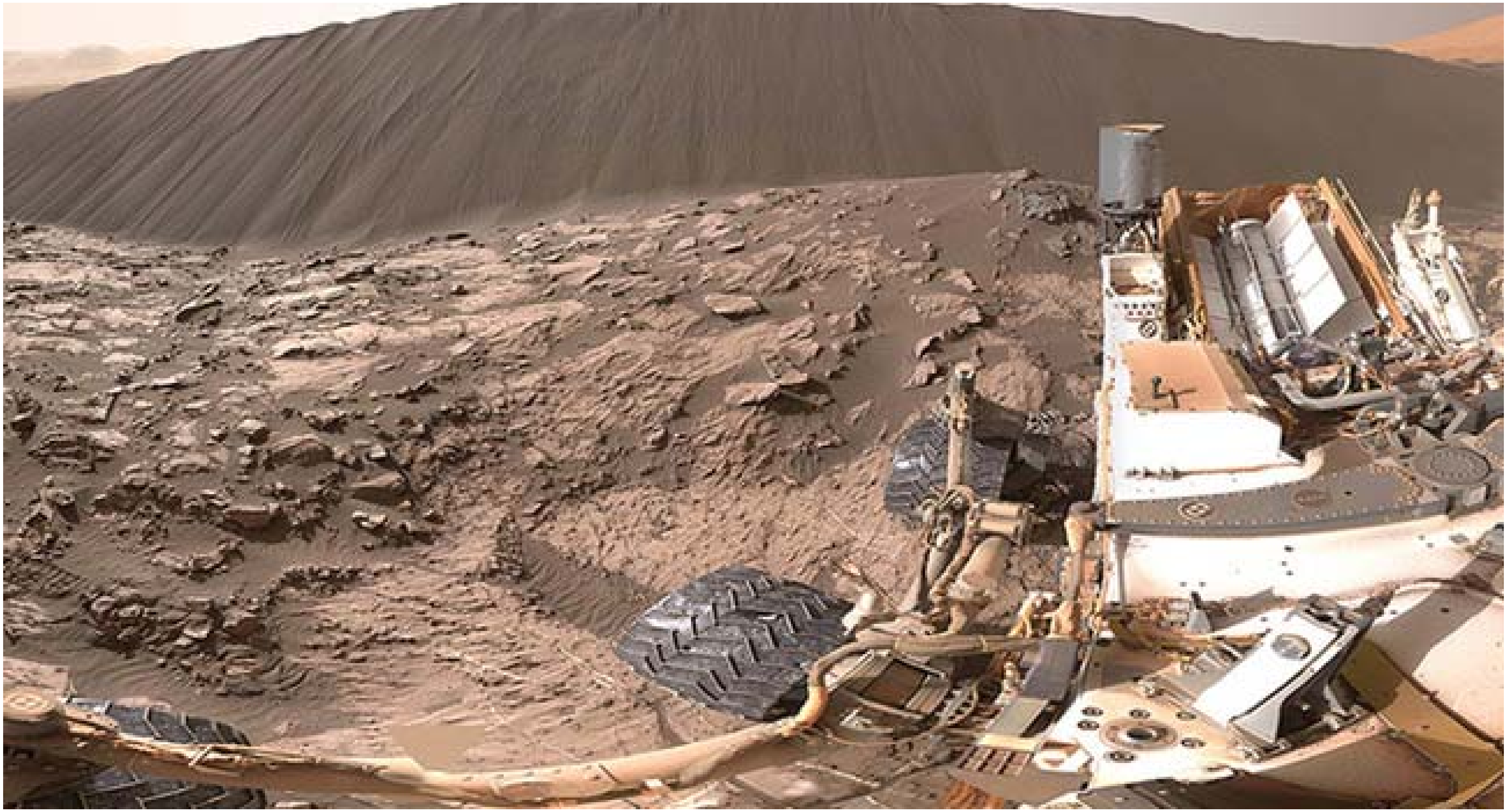
*1.5-3 wt% $H_2O$ total, up to 6wt% $H_2O$ in the amorphous fraction*



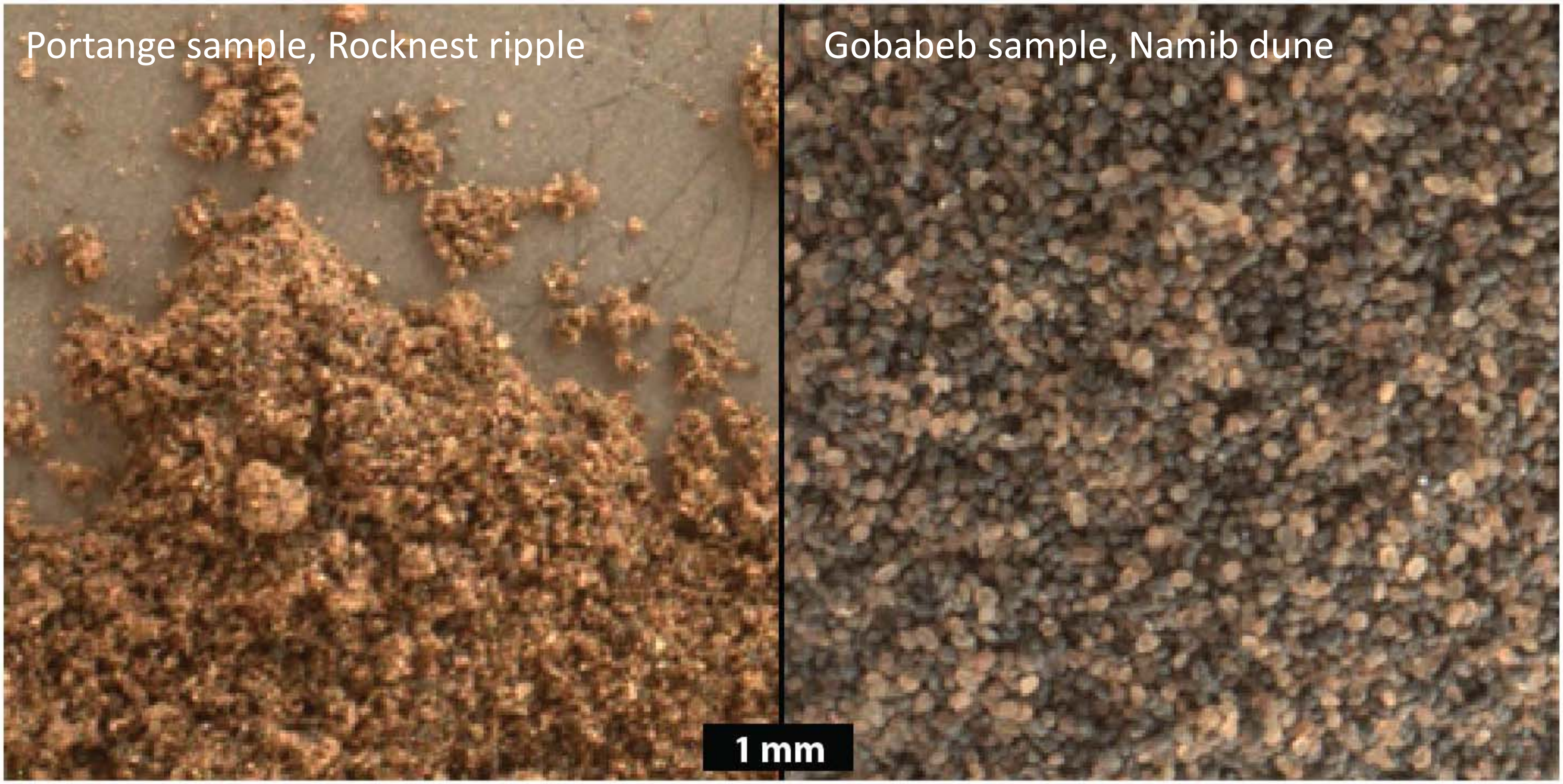

A
sols 1216-1244
Namib Dune
sols 1174-1183
High Dune
Curiosity
20 m

# Namib dune slip face: active, sorted sands



NASA/JPL-Caltech/MSSS

# Appearance relative to previously analyzed samples

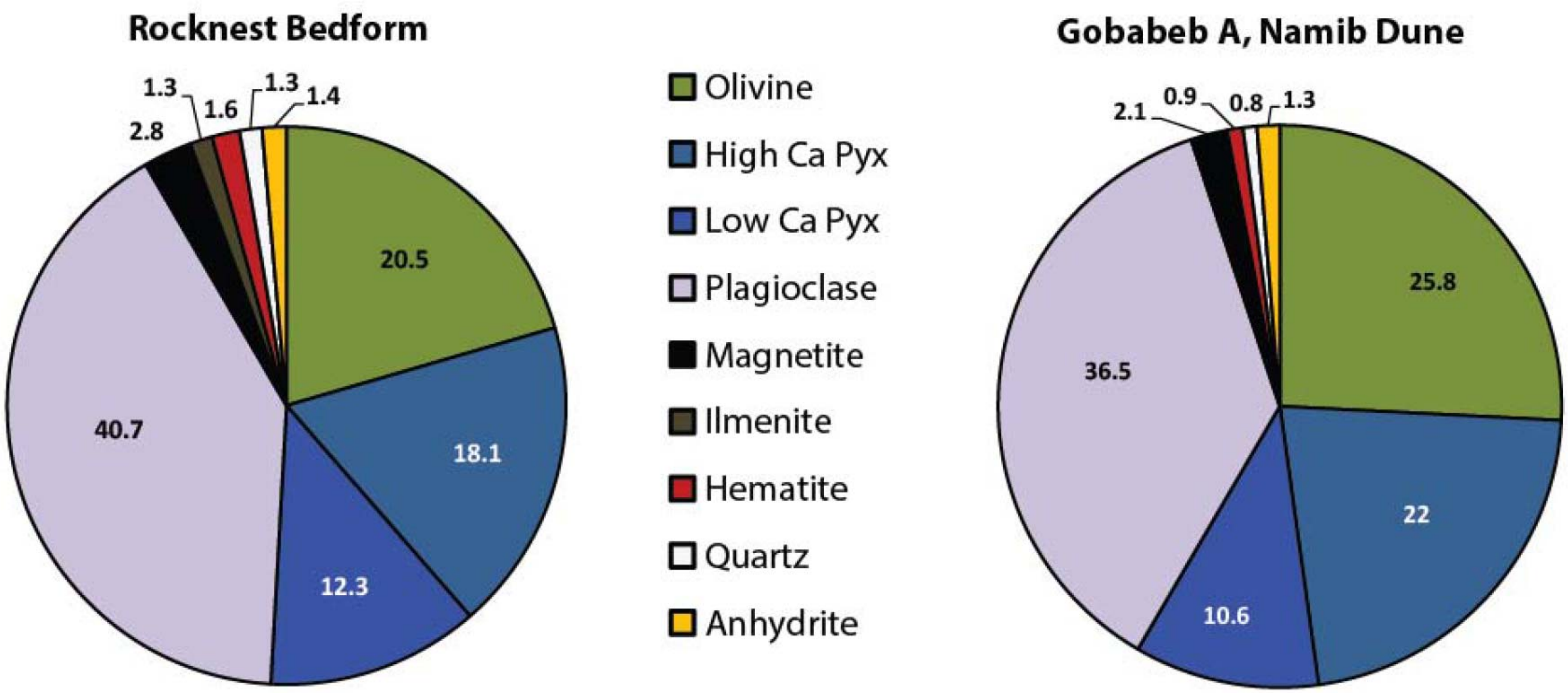



Dust-rich (some sand)

Sand-rich (no dust)

*Ehlmann et al., 2017, JGR*

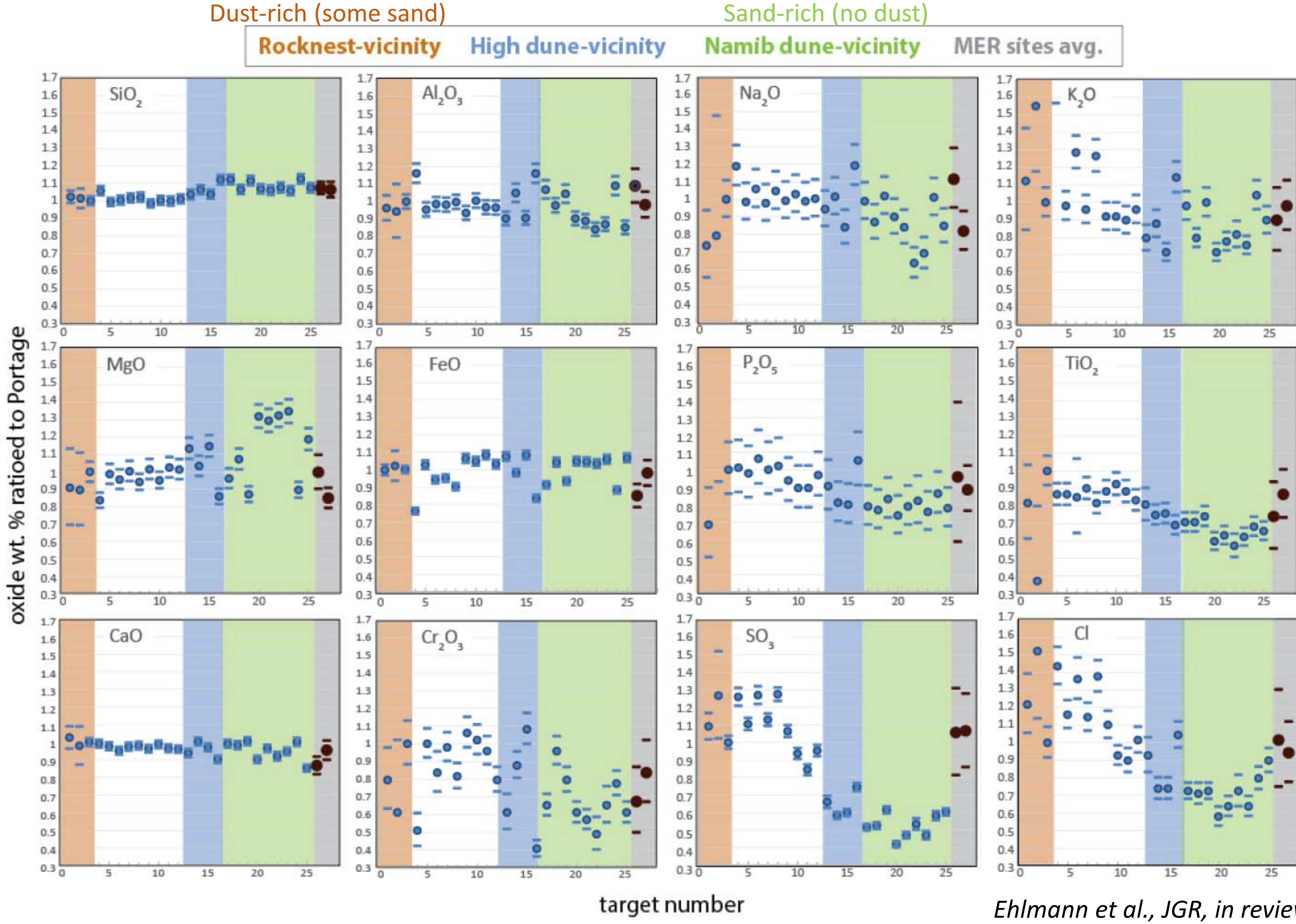
# Crystalline Mineralogy from CheMin




**But each has 35% ± 15% amorphous materials that cannot be characterized with XRD**

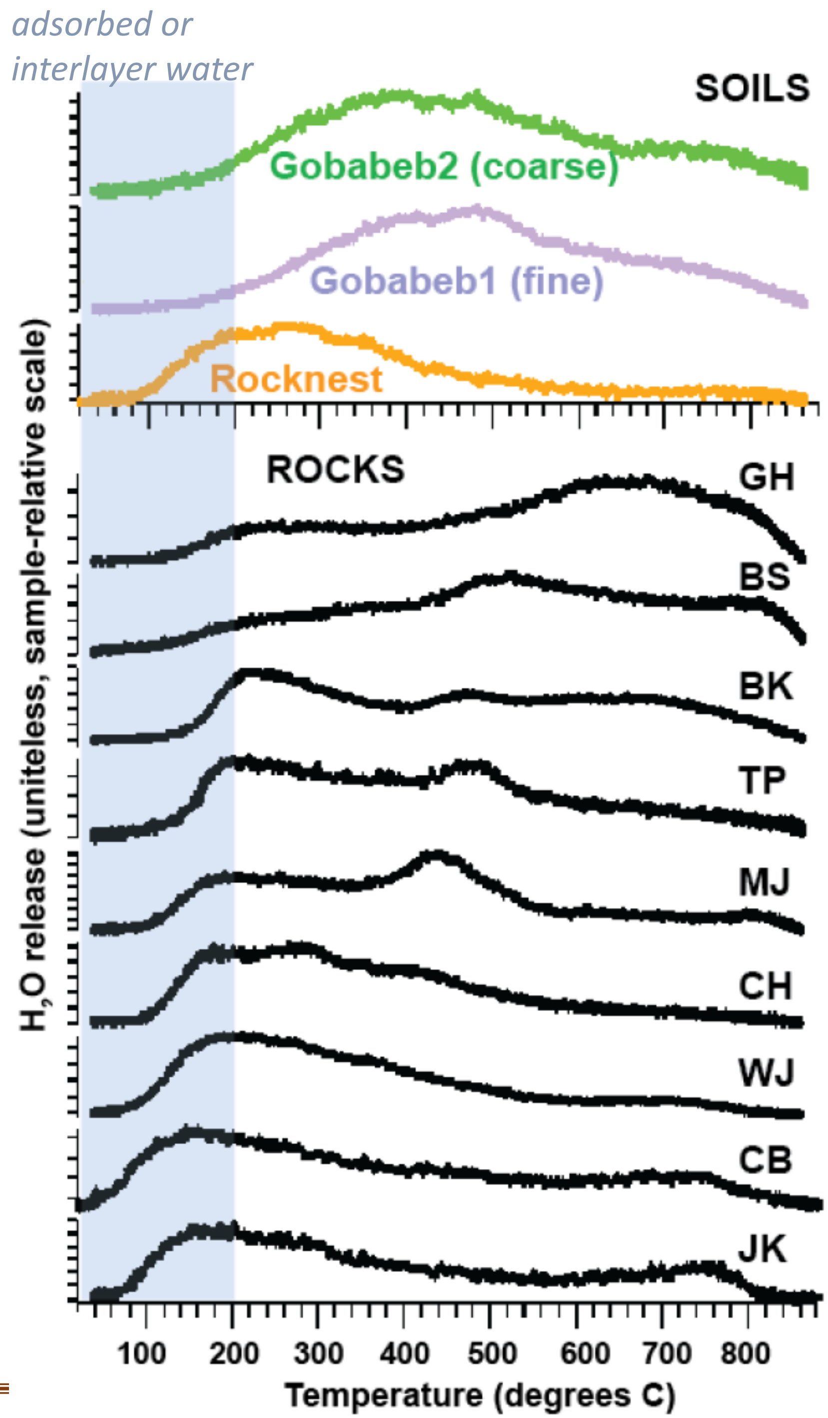
*Achilles et al., 2017, JGR; Ehlmann et al., JGR, 2017*

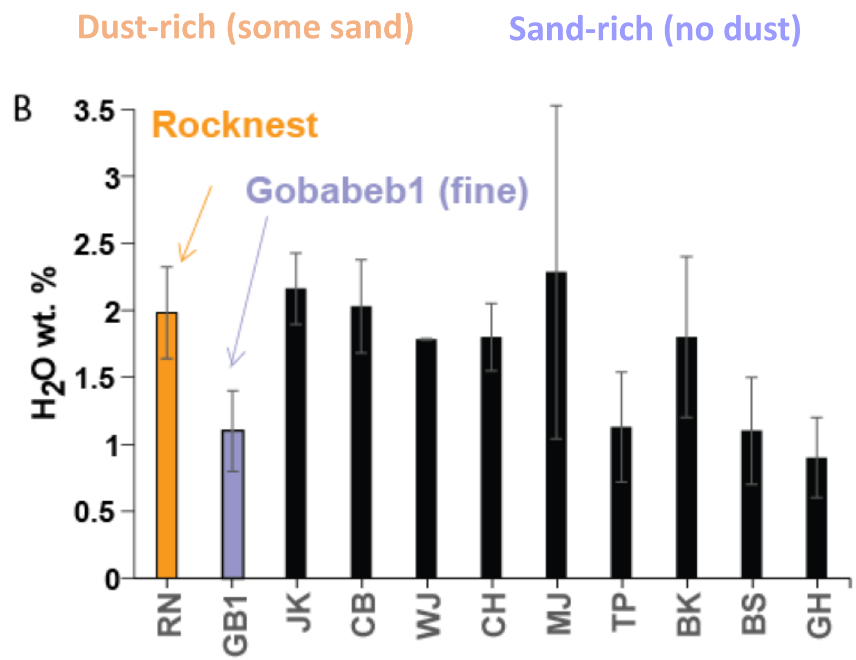
# APXS data show active Namib dune is chemically distinct among soils

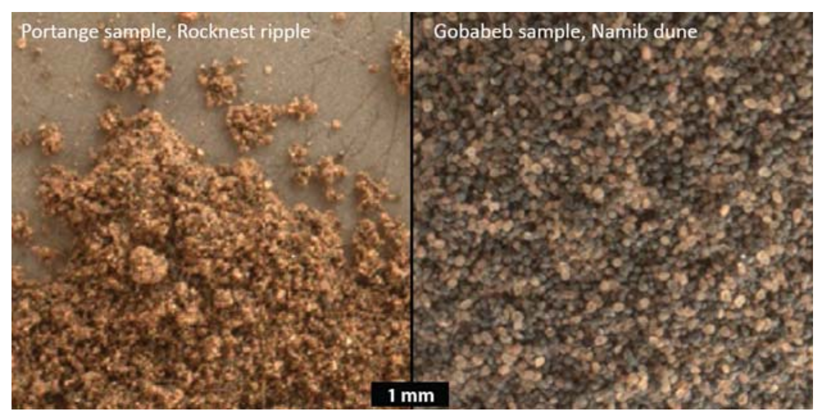



*Ehlmann et al., JGR, in review*

# SAM Evolved Gas Analysis

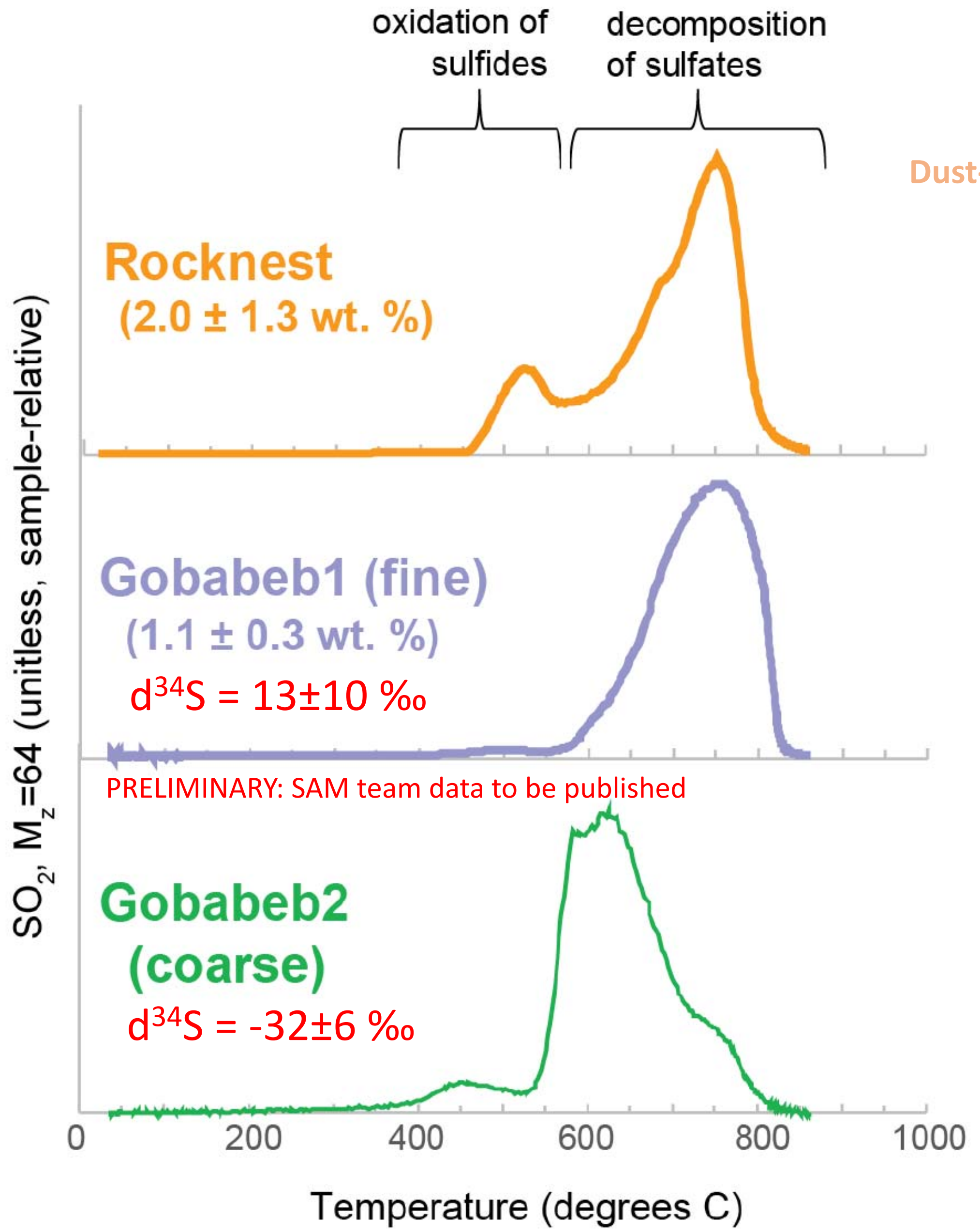


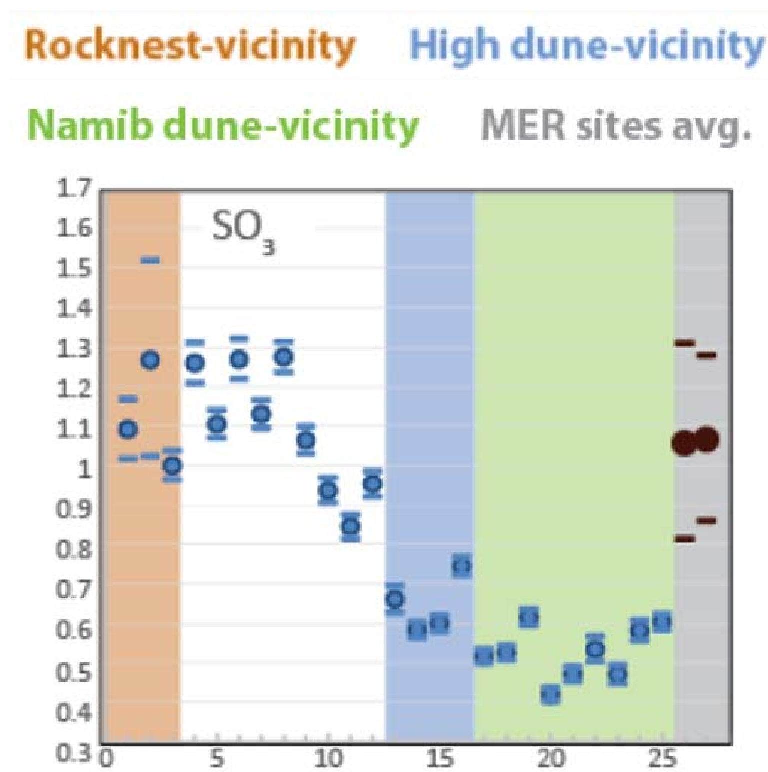

*Sutter et al., 2017 & Ehlmann et al., JGR, submitted*

# SAM EGA




Dust-rich (some sand)

Sand-rich (no dust)



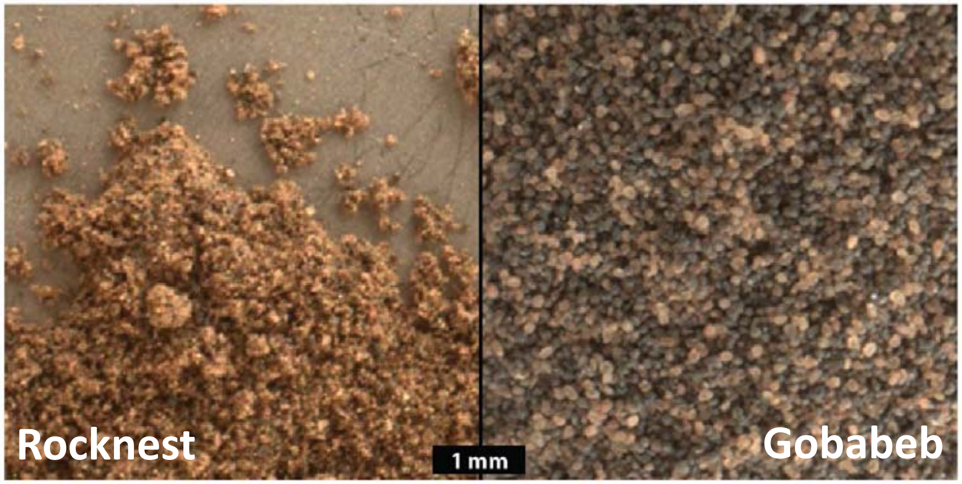

*Sutter et al., 2017 & Ehlmann et al., JGR, submitted*

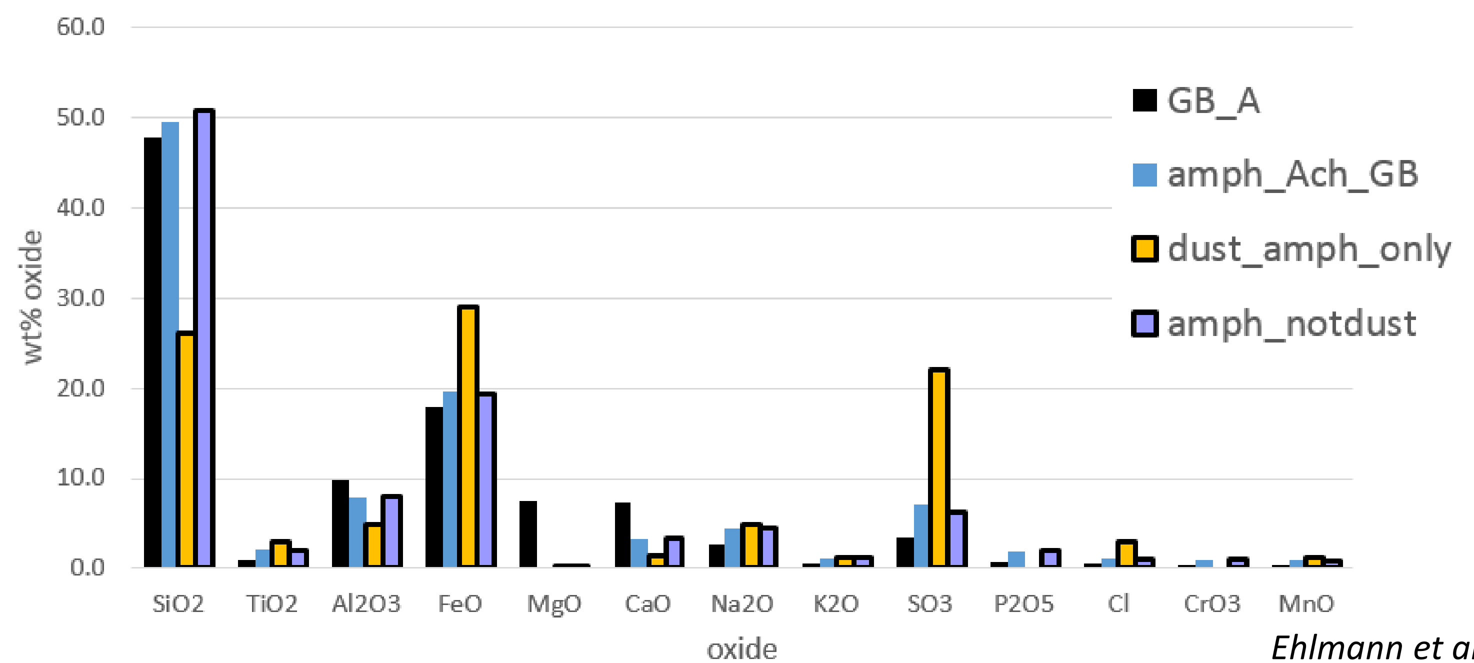
# Key Result: 2 Distinct Amorphous Phases IDed in Mars Soils

Our team's detailed investigation of Rocknest soil and well-sorted Gobabeb sands enables isolation of **two discrete reservoirs of volatiles in the <u>amorphous phase(s)</u>**

1. **Dust & Silt Fraction: Fe-rich, Si-poor, S-rich, Cl-rich and w/ adsorbed $H_2O$** (low T SAM release) [Fe oxides, sulfates, Cl-bearing]
2. **Sand Fraction: Si-rich, Al-/Fe- phase(s), w/ mineral-bound $H_2O$ or hydroxylation** (higher T SAM release) [hydrated silicates]

Both fractions have nitrates and carbonates




*Ehlmann et al., JGR, 2017*

# Key “Dust”-Related Questions for Mars PLD

- What is the grain size of the non-ice fraction? What is the concentration? Does it change and if so why?
  - Wind-borne suspension (dust-sized, expected to be <~2 µm) vs. reworked/inherited saltation products or ashes (could include silt- or sand-sized)

- What is the composition of the non-ice fraction and does it change?
  - Is it “global dust” and homogeneous (temporally and spatially)?
  - Are there discrete ash layers?
  - Are there salts/volatiles that signify contributions from volcanic gas release to the atmosphere or aqueous, salt-forming processes?

# EXTRAS

# Key Findings on Sand Composition Bagnold Dunes

- Elevated Si, Mg, Mn
- Low Al, Na, K, P, Ti, Cr, S, Cl, H
- Mafic enrichment in coarse fraction
- Diverse grains; silt and dust fraction absent
- Bagnold has low water and high water release temperatures
- DIfferent SO2, CO2, CO, NO release temperatures; high CO2, NO
- Mg and Ni enrichment in coarse fraction (consistent with mafics, esp olivine)
- No mineral differences with dust Rocknest: the amorphous phase is crucial
- Two distinct amorphous fractions: one in dust (Fe-rich, Si-poor, S-rich, Cl-rich and w/ adsorbed $H_2O$ ); one hydrous silicate

Ehlmann et al., JGR, 2017

# Implications

- Most of soil is crystalline igneous minerals, indicating little interaction with water
- Two distinct types of amorphous phases indicate multiple types of alteration affecting Mars soils
  - The dust Fe-oxdies, S-phases, Cl-phase, with low $H_2O$ release temperatures may indicate more modern atmosphere-soil exchange (i.e., active exchange ongoing)
    - Source of ~2.5 wt% water in Rocknest sample means 3-5 wt.% water in this phase
  - The Si-enriched phase with high temperature water release may be due to more permanent water-rock exchange with silicates. Incipient alteratoin
    - Source of 1 wt% water in Rocknest samples means ~2 wt % water in this amorphous phase
- Interesting implications for (1) volatile sequestration over time and (2) accessibility of soil water resources for human explorers