From Planetary Evolution to Potential Biosignatures: Achieving Mission Success with the Mars 2020 Rover and Instrument Suite at the Columbia Hills Site

Steve Ruff, Vicky Hamilton, Deanne Rogers, Christopher Edwards, Briony Horgan, and Martin Van Kranendonk

School of Earth and Space Exploration, Arizona State University · SwRI Southwest Research Institute · Stony Brook University · Northern Arizona University · Purdue University · UNSW Sydney

Overview

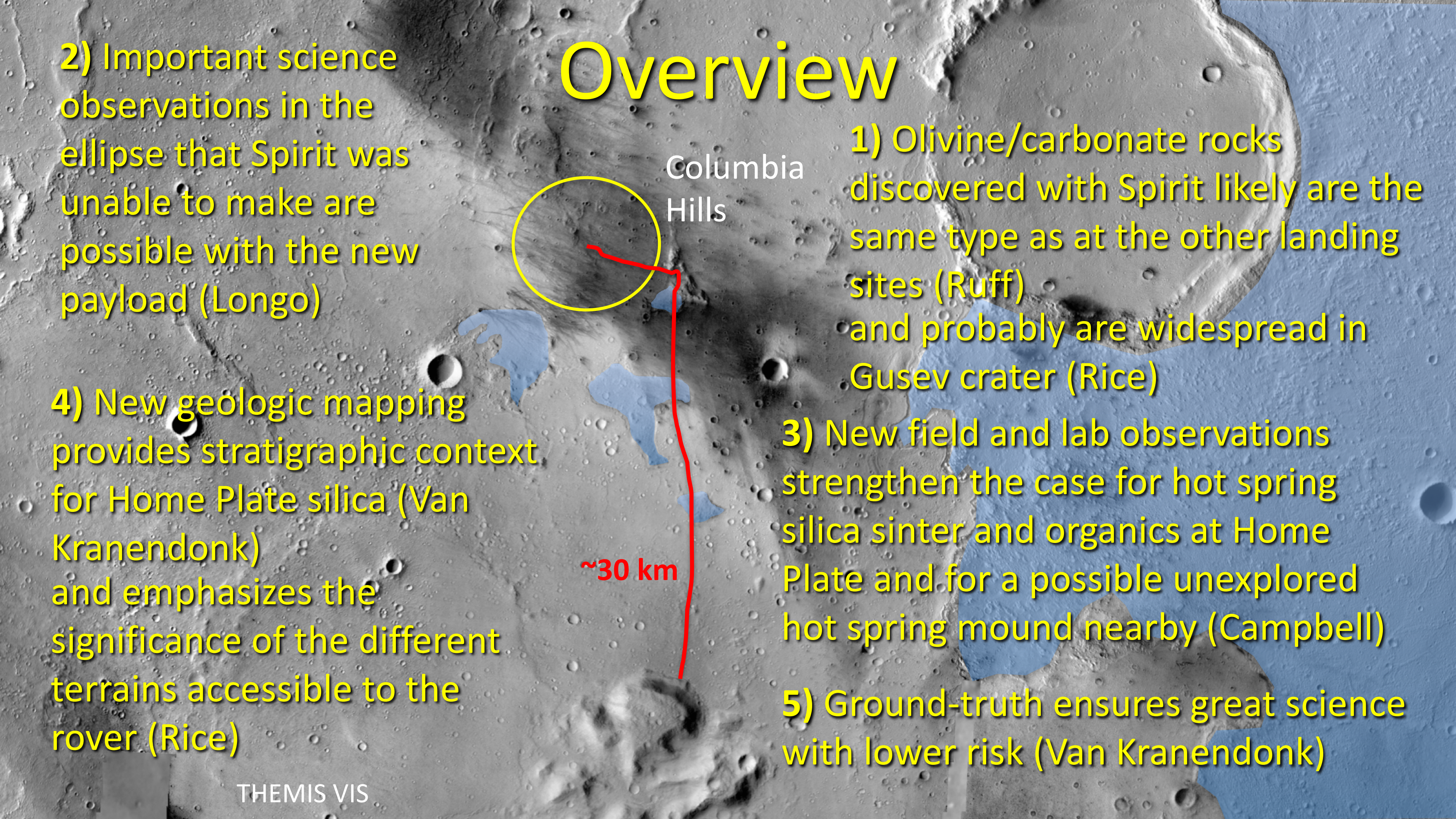
1) Olivine/carbonate rocks discovered with Spirit likely are the same type as at the other landing sites (Ruff)
and probably are widespread in Gusev crater (Rice)

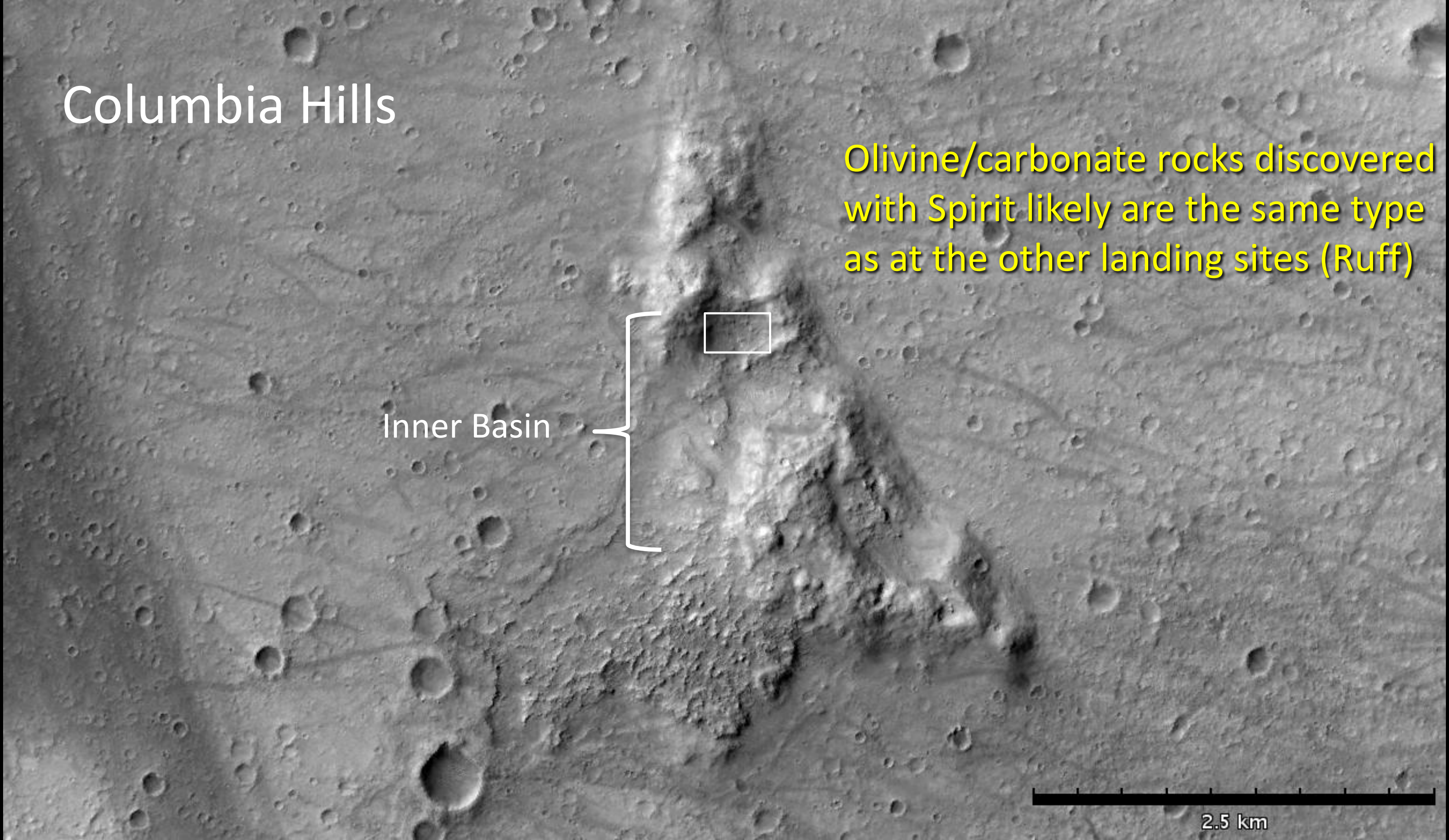
2) Important science observations in the ellipse that Spirit was unable to make are possible with the new payload (Longo)

3) New field and lab observations strengthen the case for hot spring silica sinter and organics at Home Plate and for a possible unexplored hot spring mound nearby (Campbell)

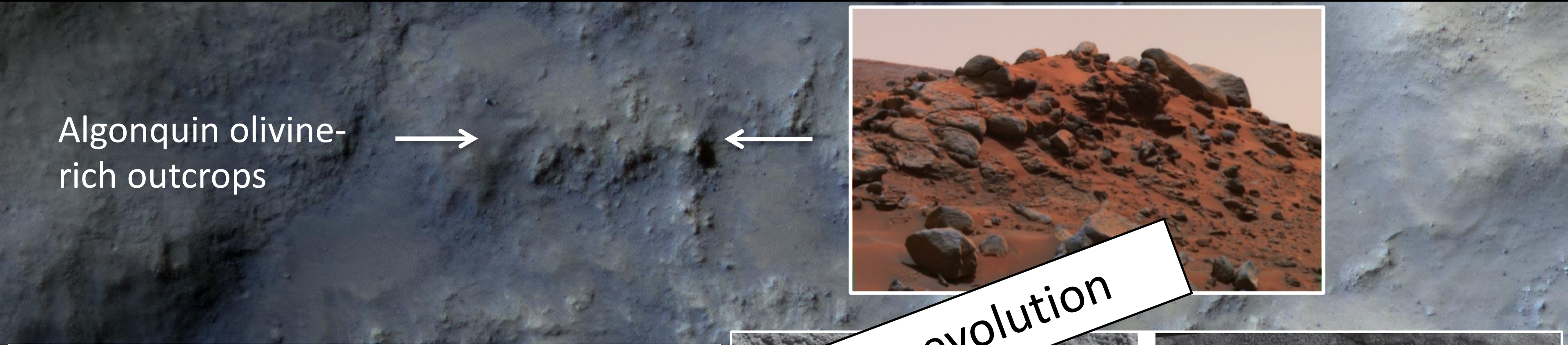
4) New geologic mapping provides stratigraphic context for Home Plate silica (Van Kranendonk)
and emphasizes the significance of the different terrains accessible to the rover (Rice)

5) Ground-truth ensures great science with lower risk (Van Kranendonk)





Columbia Hills
Olivine/carbonate rocks discovered with Spirit likely are the same type as at the other landing sites (Ruff)
Inner Basin
2.5 km



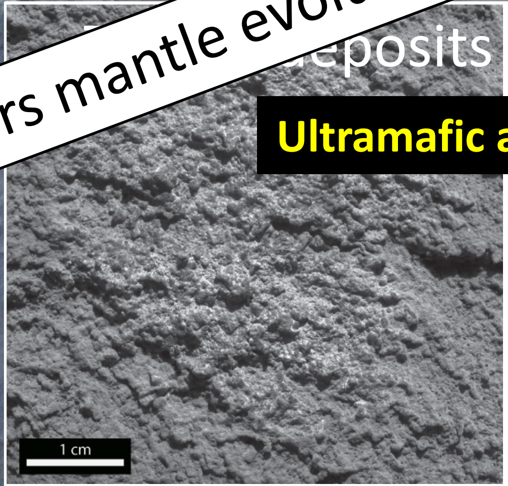
A tracer of early Mars mantle evolution

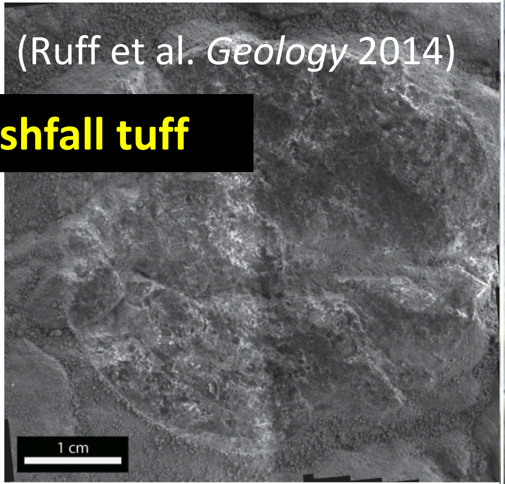
	Algonquin (APXS)	[1]Canadian ferropicrite tuff (2.7 Ga)	[2]Barberton komatiite tuff (3.3 Ga)
SiO_2	40.6	41.51	[illegible]
TiO_2	0.35	1.40	[illegible]
Al_2O_3	4.0	5.50	[illegible]
FeO_{tot}	21.2	18.7[illegible]	7.66
MnO	0.38	0.24	0.09
MgO	22.3	22.38	31.90
CaO	2.6	4.93	3.26
Na_2O	1.6	0.24	0.09
K_2O	0.12	0.05	0.01

[1] Goldstein and Francis, 2008; [2]Thompson Stiegler et al., 2010

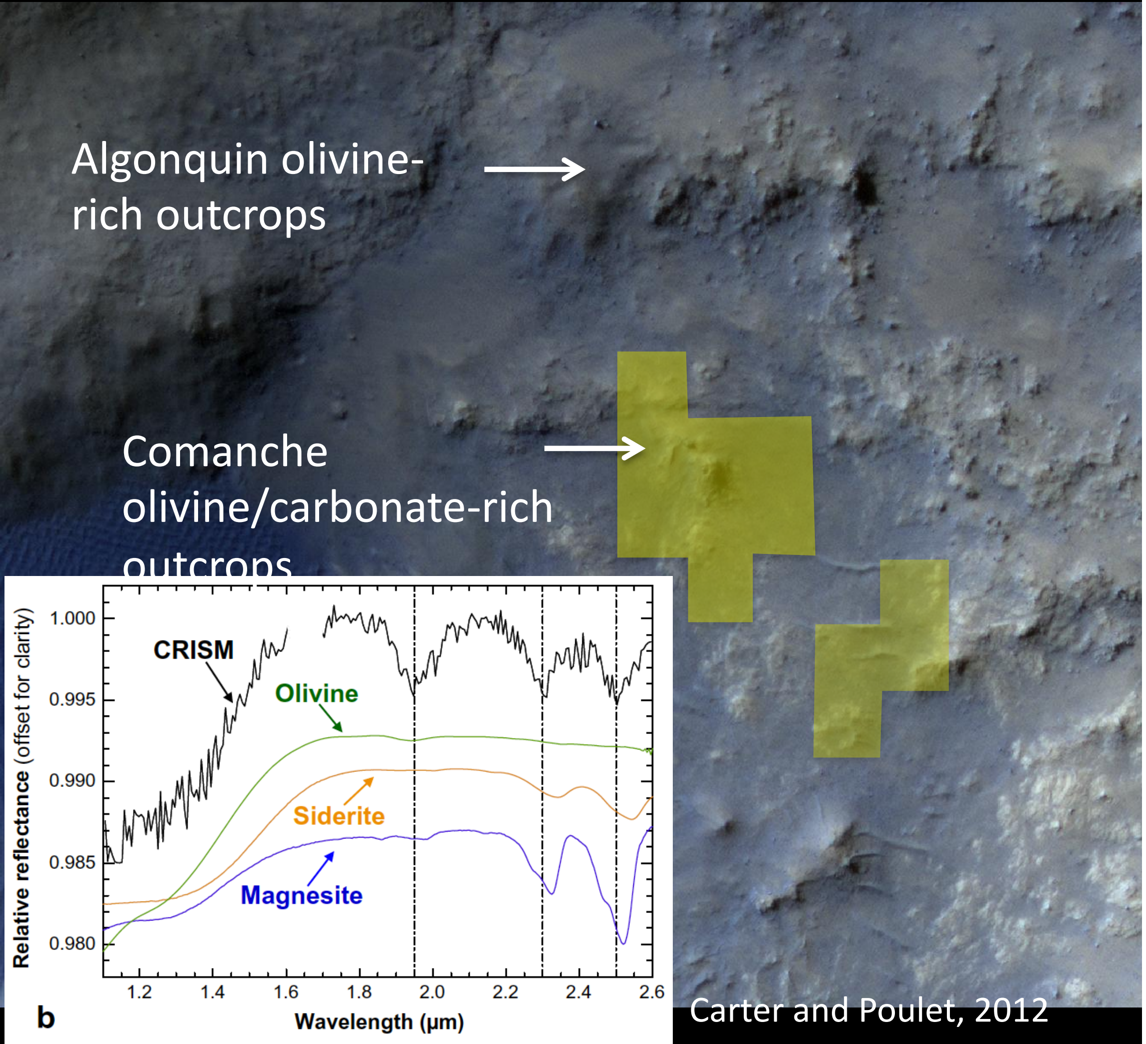
(Ruff et al. *Geology* 2014)

Ultramafic ashfall tuff

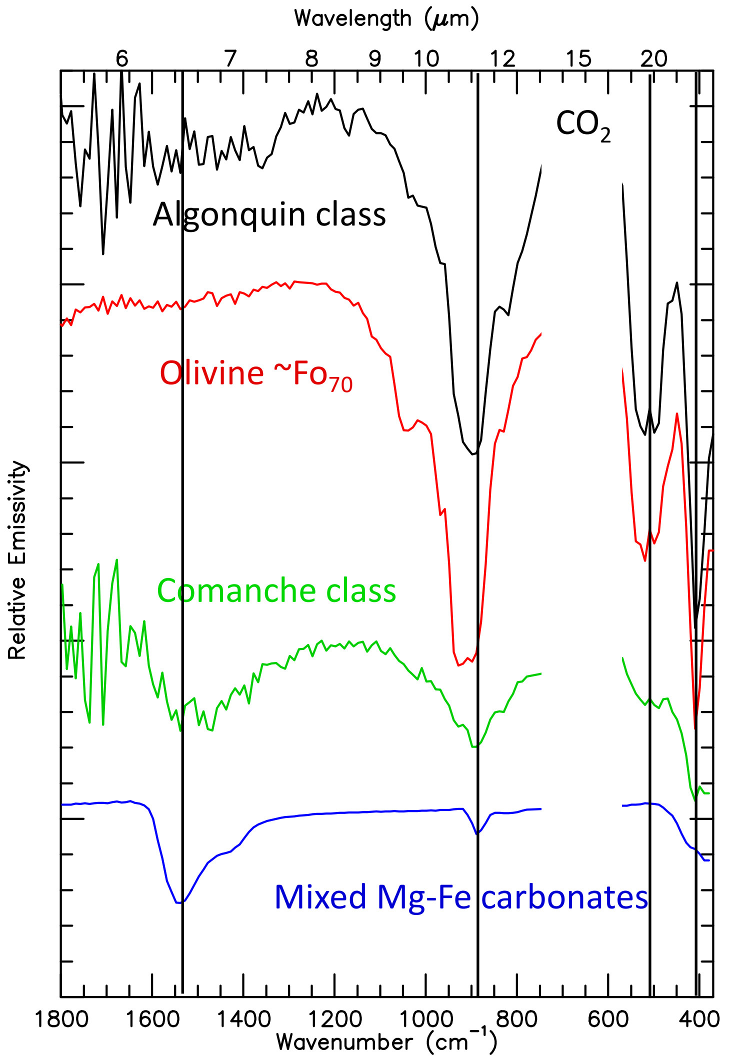




Microscopic Imager (MI)

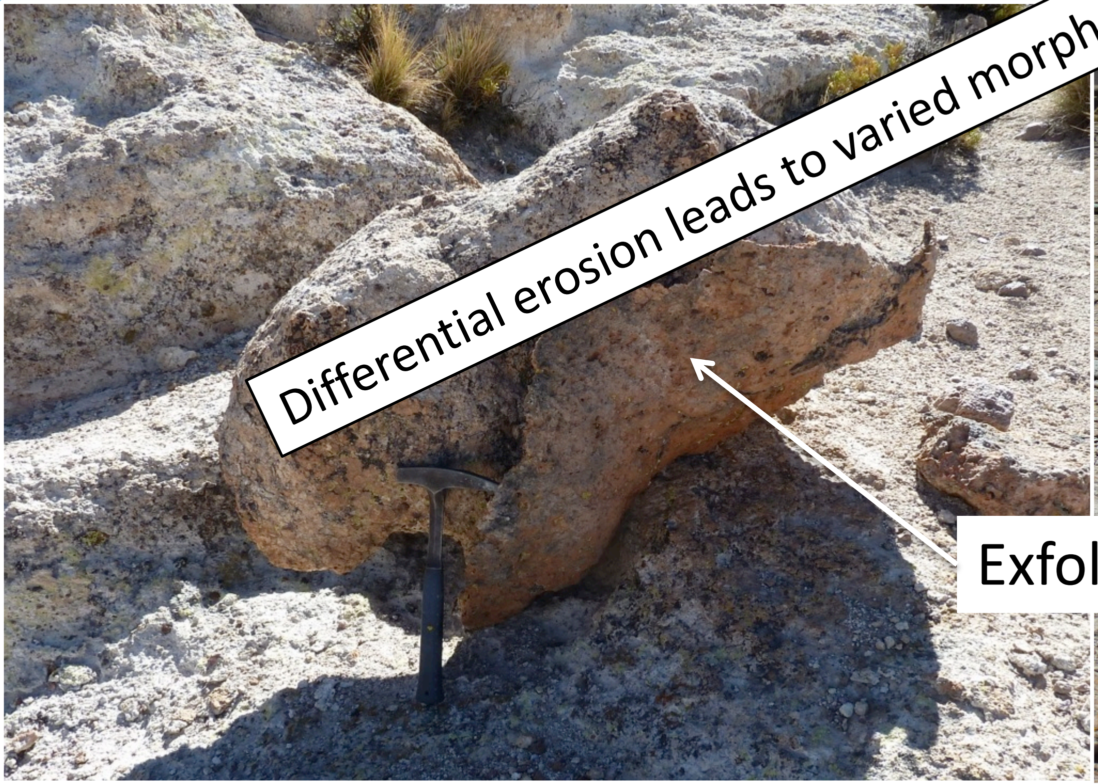


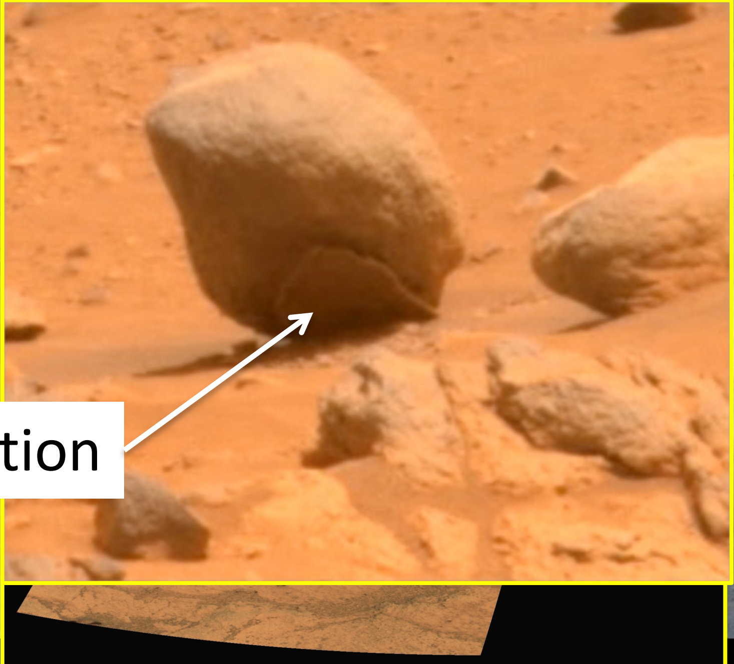
Carter and Poulet, 2012



Geomorphology: Bouldery knobs and ridges and light-toned fractured material – all the same?

Atacama ashfall tuff





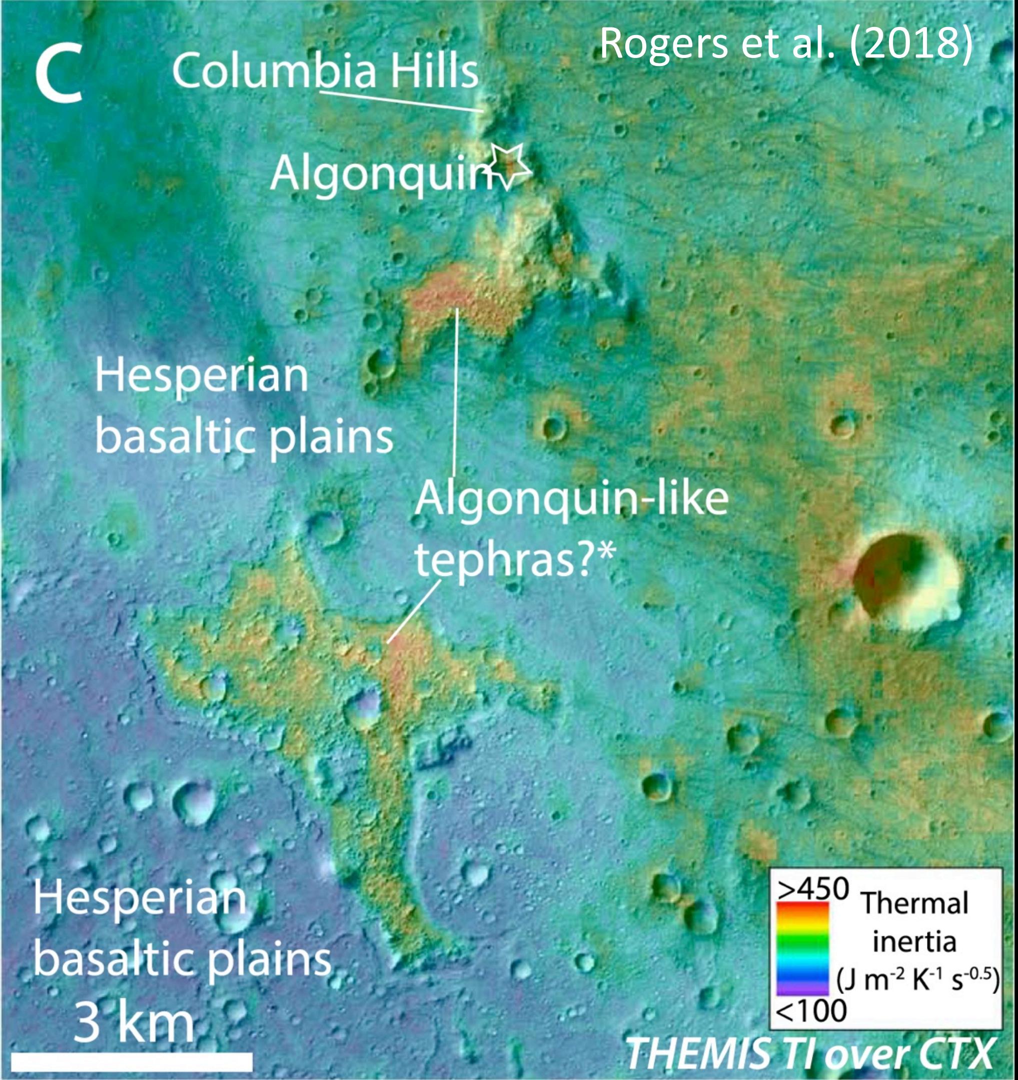
Differential erosion leads to varied morphologic expression

Exfoliation

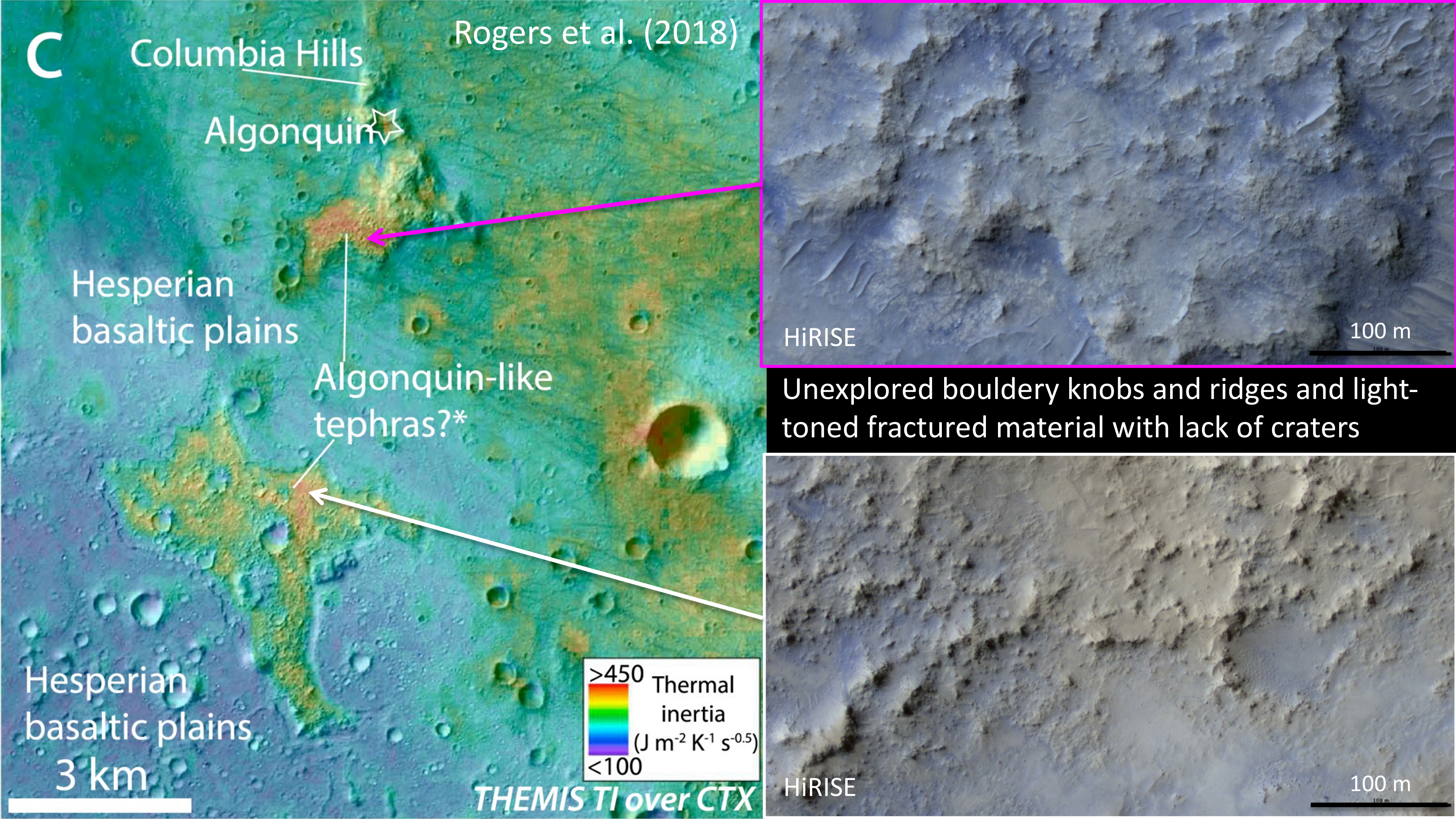

Note lack of craters among the bouldery knobs and ridges and light-toned fractured material
HiRISE
100 m

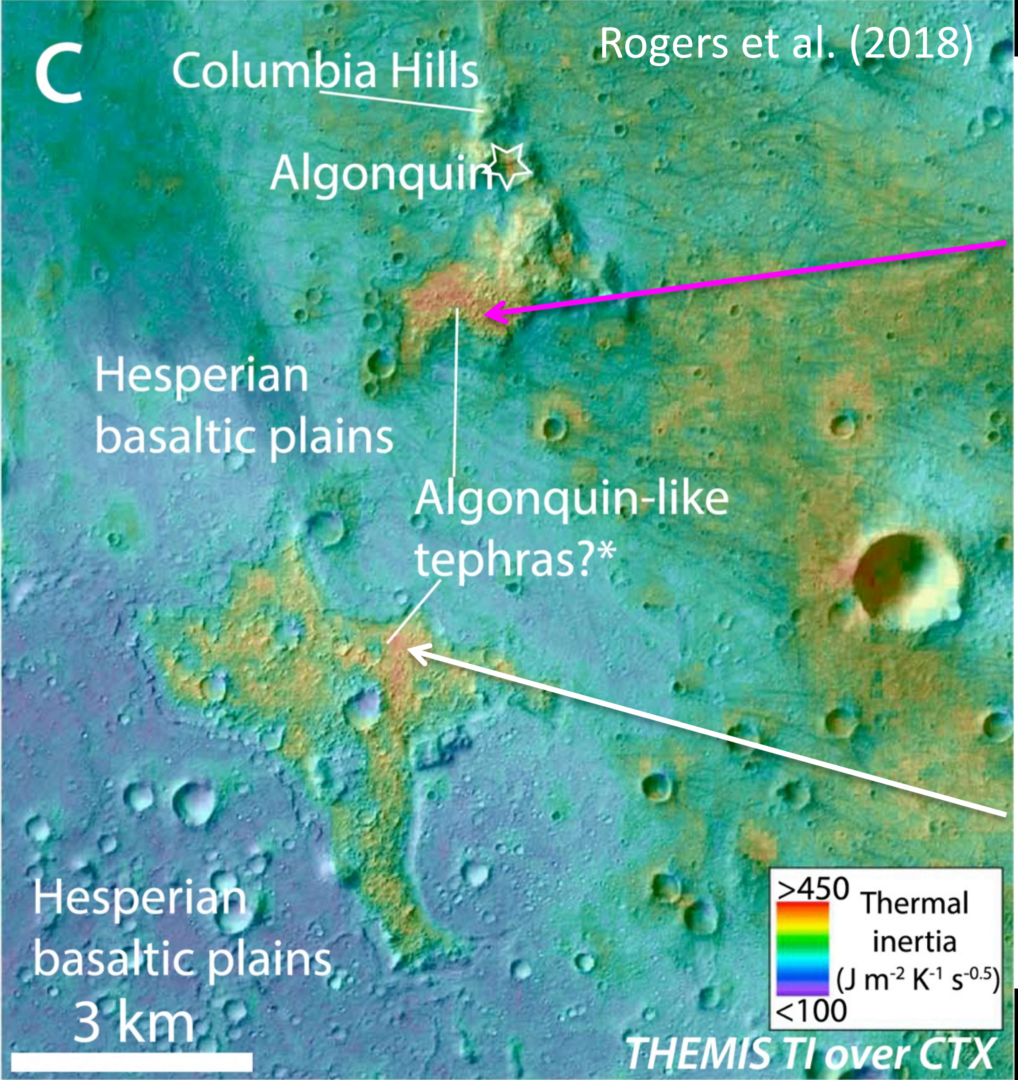
Comparison at same scale with cratered basaltic plains around Spirit's lander (arrow)

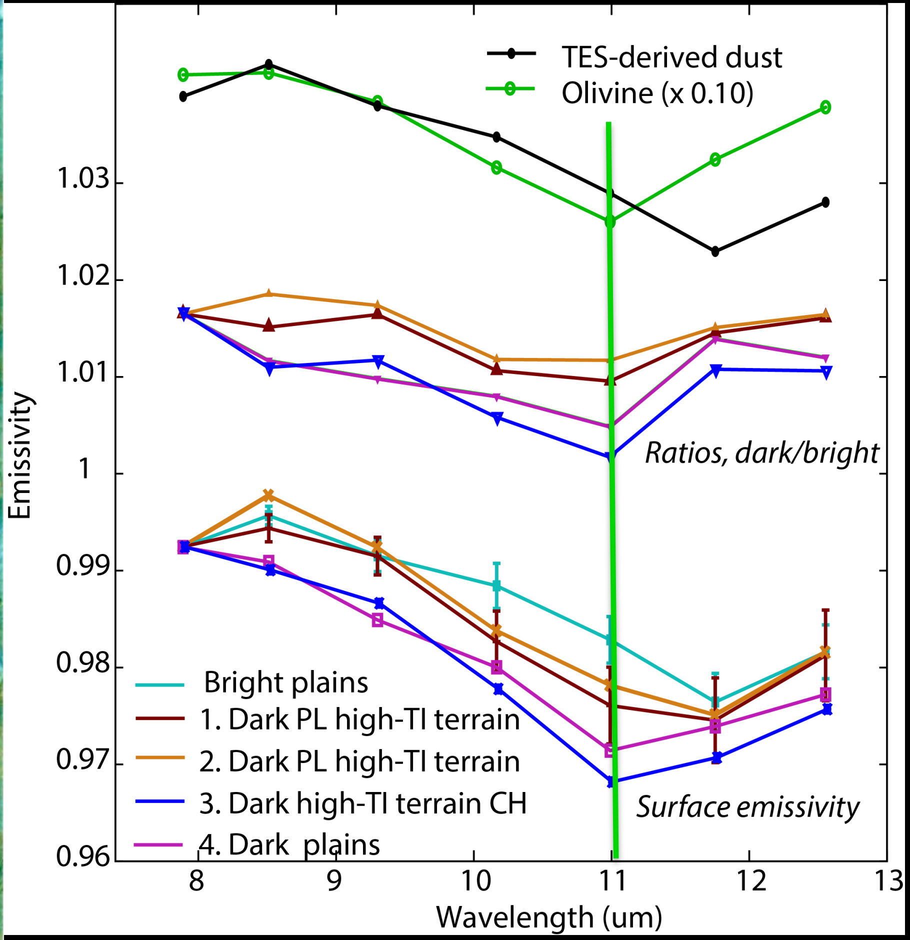

Note lack of craters among the bouldery knobs and ridges and light-toned fractured material
Erosion out paces impacts due to friable (erodible) material
HiRISE
100 m



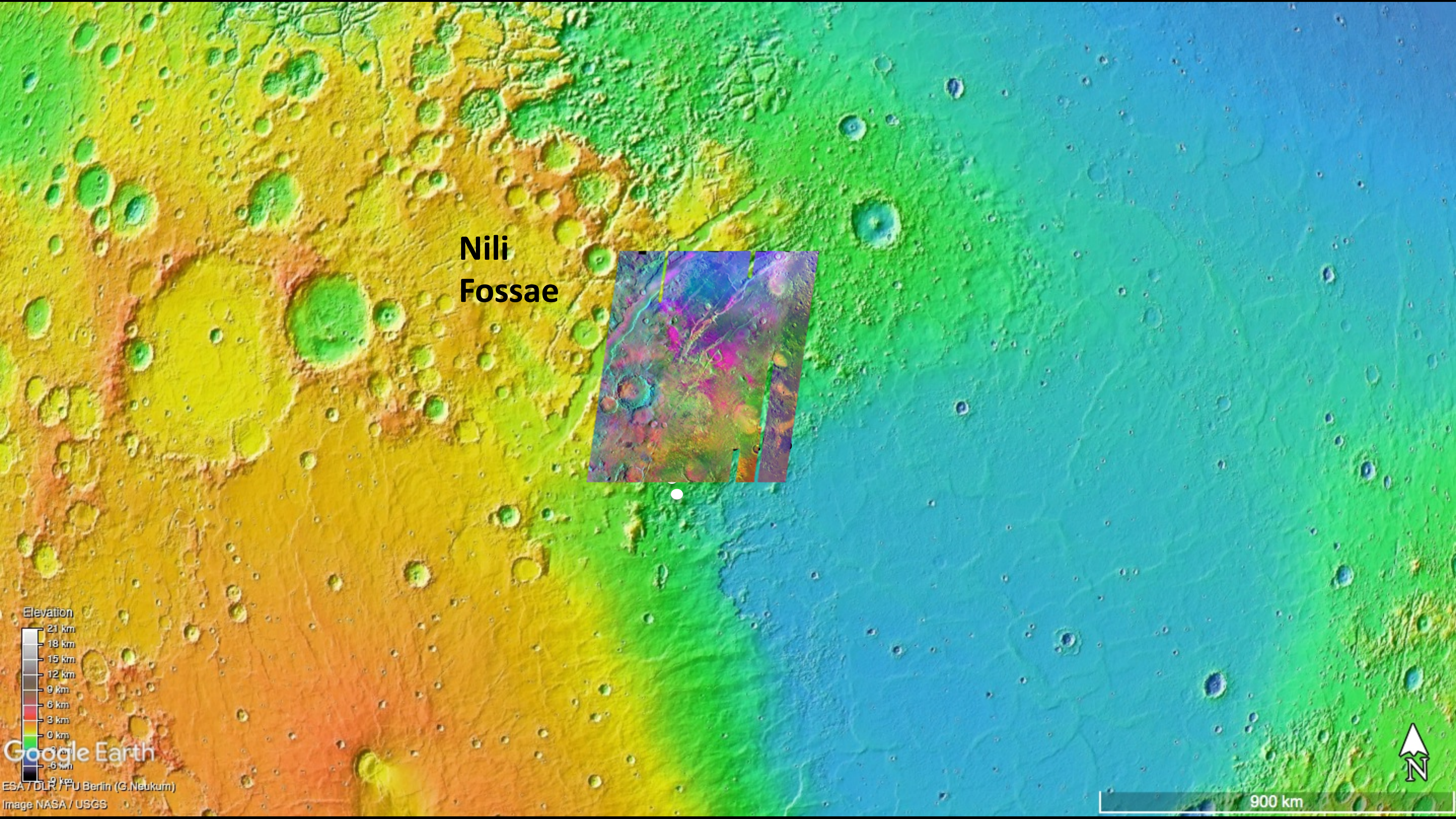
New paradigm: Olivine-rich, higher inertia surfaces with poor retention of small craters are friable bedrock vs. lower inertia, crater retaining lava flows, which are regolith (Rogers et al., 2018)


C
Columbia Hills
Rogers et al. (2018)
Algonquin
Hesperian basaltic plains
Algonquin-like tephras?*
Hesperian basaltic plains
3 km
>450
Thermal inertia
(J m-2 K-1 s-0.5)
<100
THEMIS TI over CTX
HiRISE
100 m
Unexplored bouldery knobs and ridges and light-toned fractured material with lack of craters
HiRISE
100 m

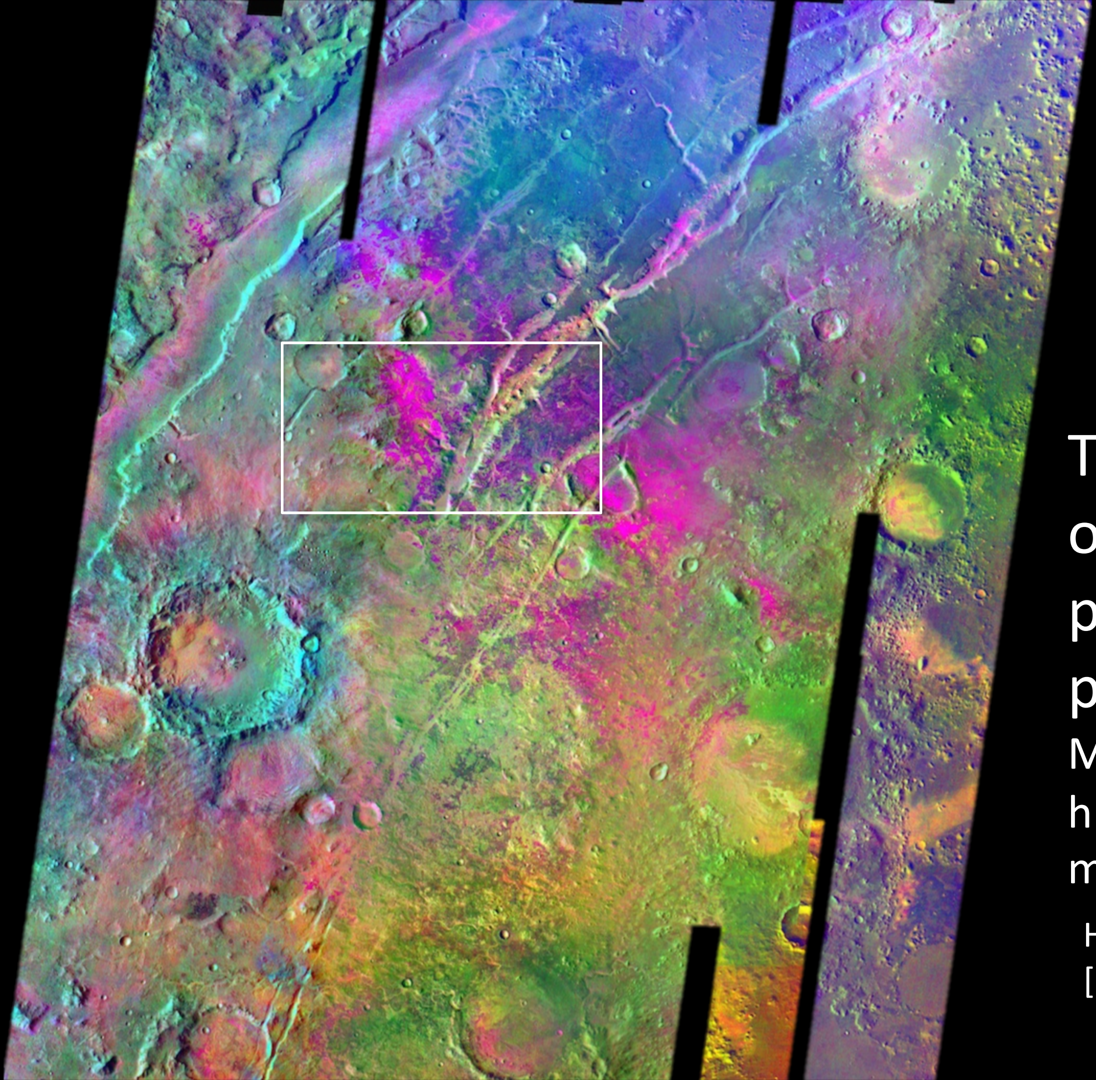




THEMIS Spectra


Nili
Fossae
Elevation
21 km
18 km
15 km
12 km
9 km
6 km
3 km
0 km
Google Earth
ESA / DLR / FU Berlin (G.Neukum)
Image NASA / USGS
900 km
N

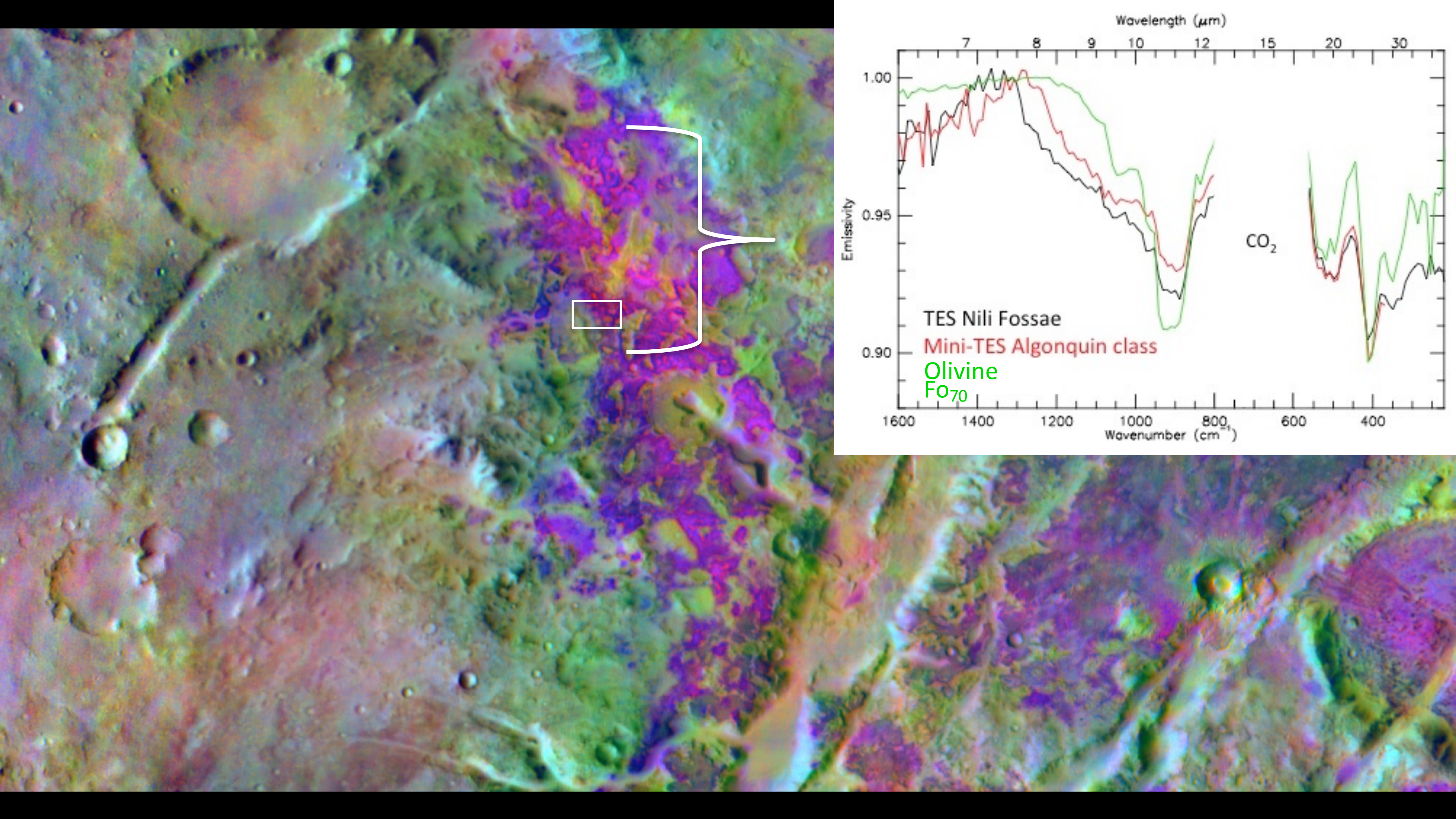
THEMIS
Bands 9/7/5
Decorrelation
Stretch (DCS)

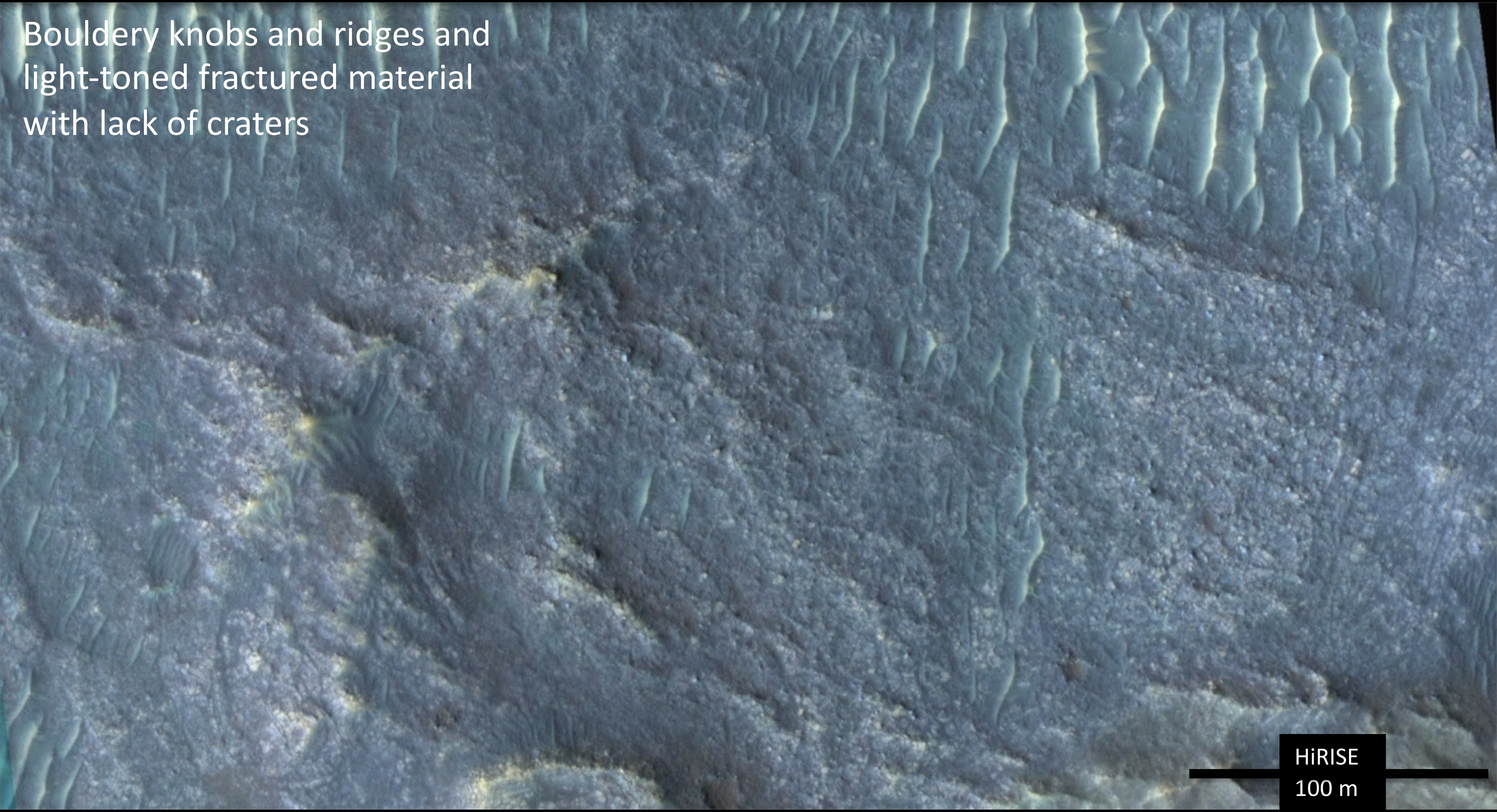


The most
olivine-rich
place on the
planet

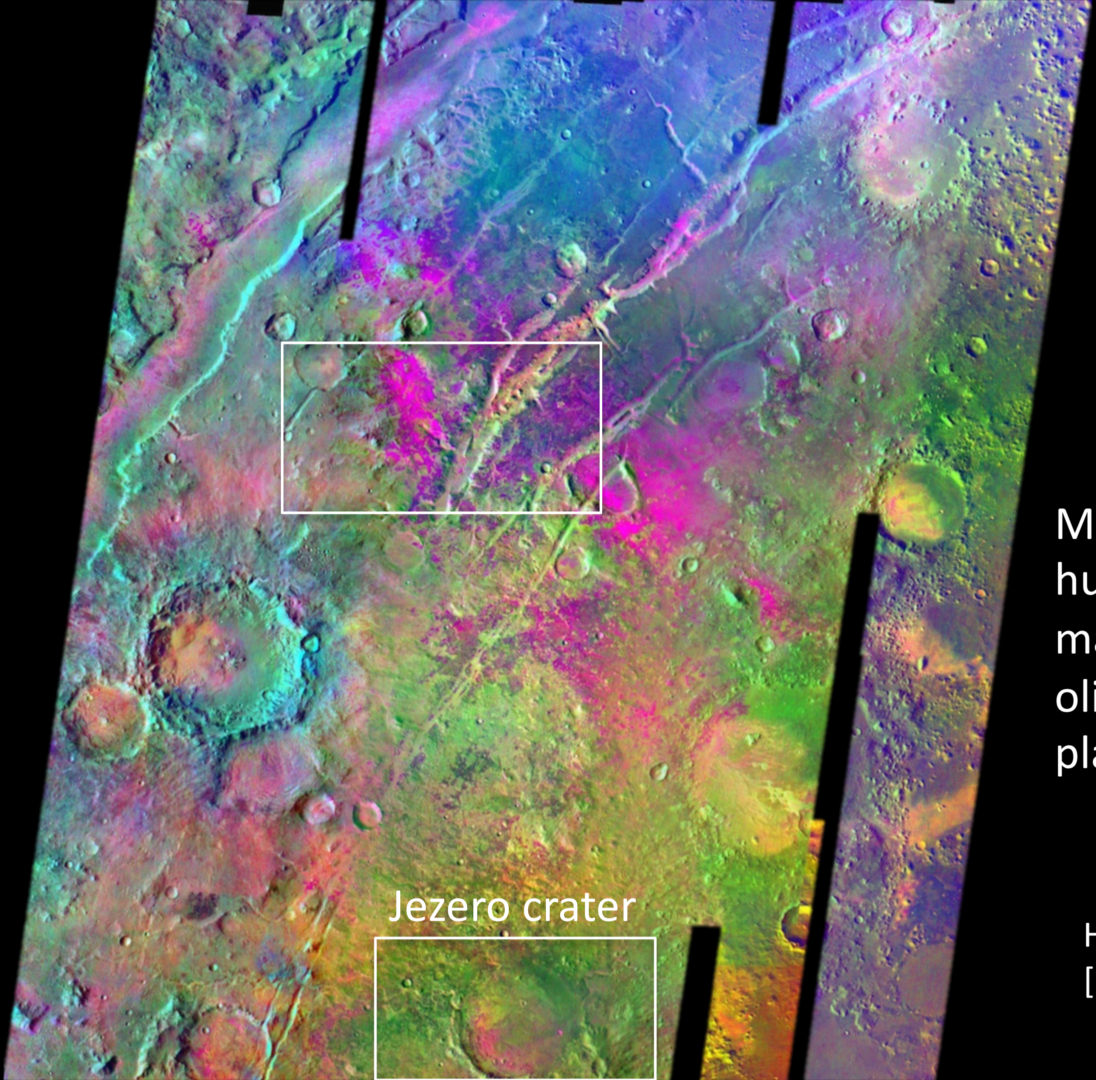
Magenta to purple
hues are olivine-rich
materials

Hamilton and Christensen
[2005]


Wavelength (μm)
7
8
9
10
12
15
20
30
1.00
0.95
0.90
Emissivity
CO2
TES Nili Fossae
Mini-TES Algonquin class
Olivine
Fo70
1600
1400
1200
1000
800
600
400
Wavenumber (cm⁻¹)


Bouldery knobs and ridges and
light-toned fractured material
with lack of craters
HiRISE
100 m

THEMIS Bands 9/7/5 Decorrelation Stretch (DCS)

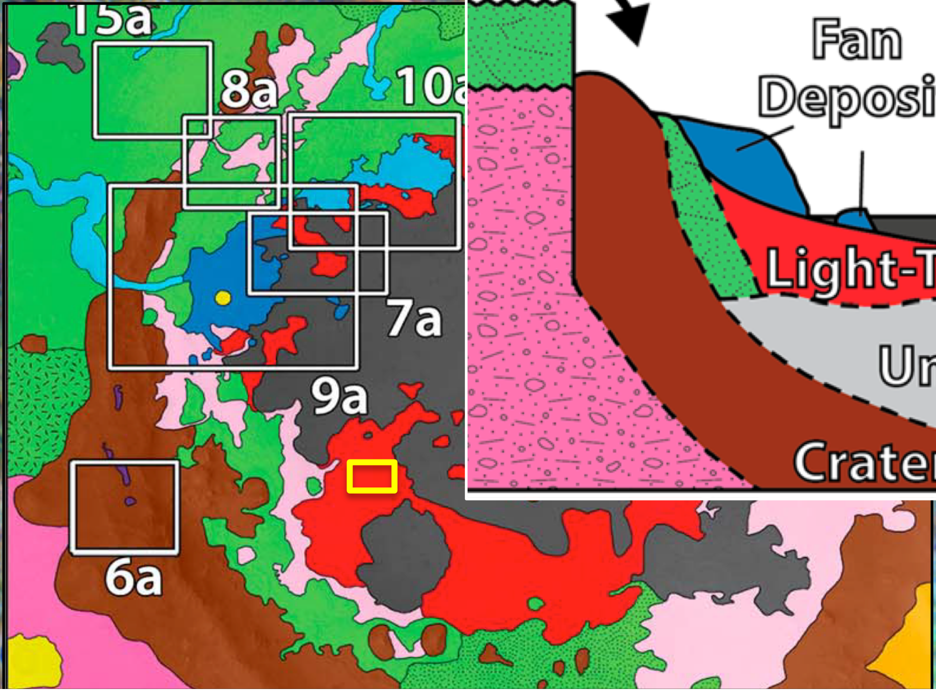


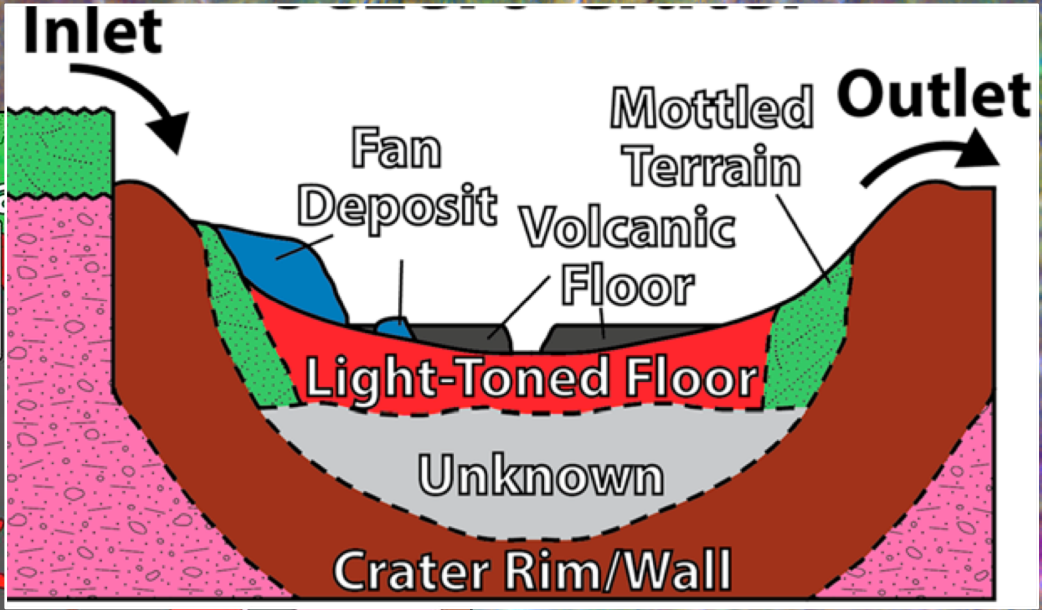
Magenta to purple hues are olivine-rich materials (the most olivine-rich on the planet)

Hamilton and Christensen [2005]

Jezero crater THEMIS 9/7/5 DCS

Magenta to purple hues are olivine-rich materials





Goudge et al., 2015

MT	LTF

Mottled Terrain (MT): Part of a larger, regionally identified olivine- and carbonate-bearing unit [Ehlmann et al., 2008b, 2009; Mustard et al., 2009];

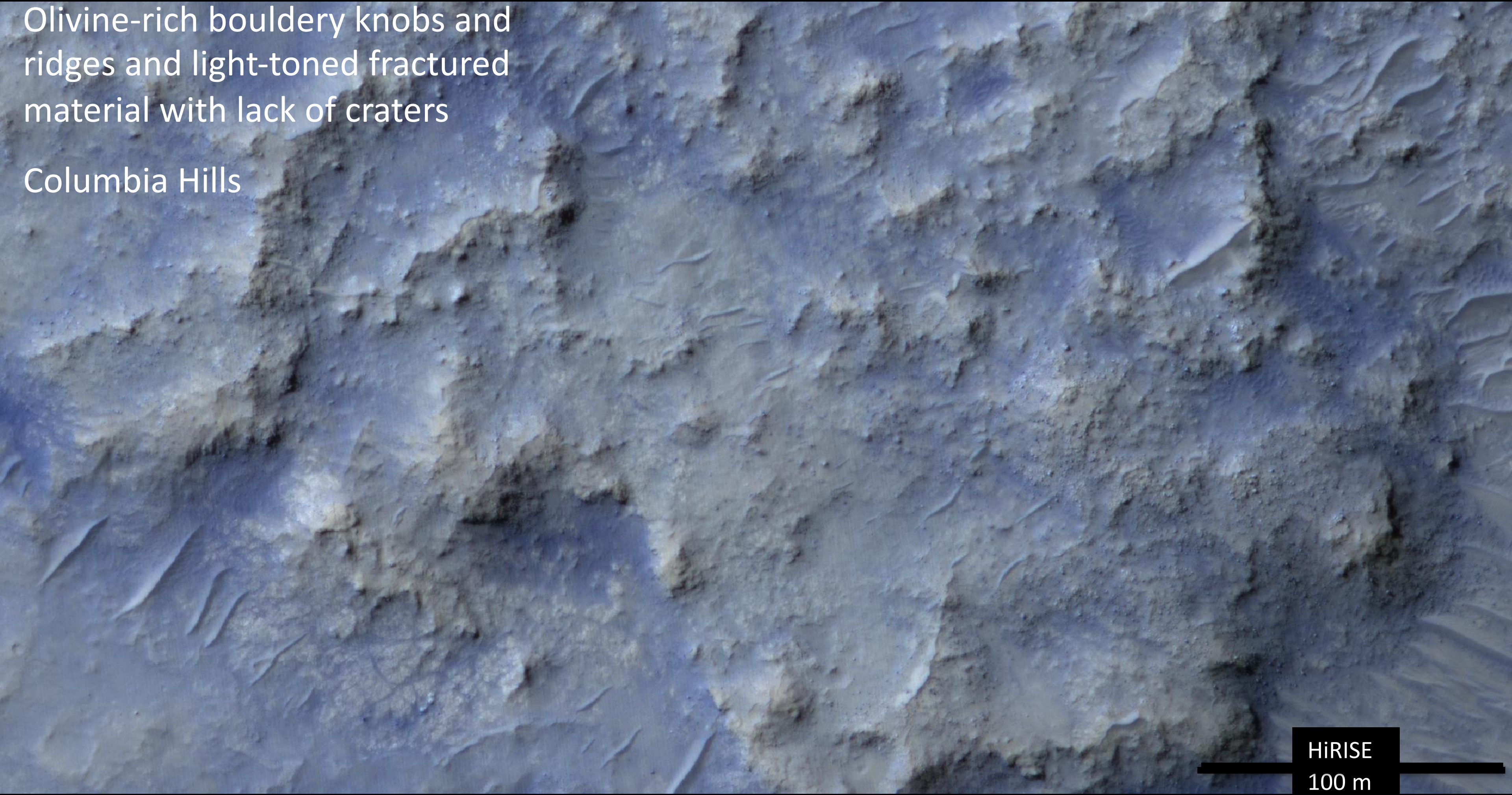
Light-Toned Floor: Potentially equivalent to MT

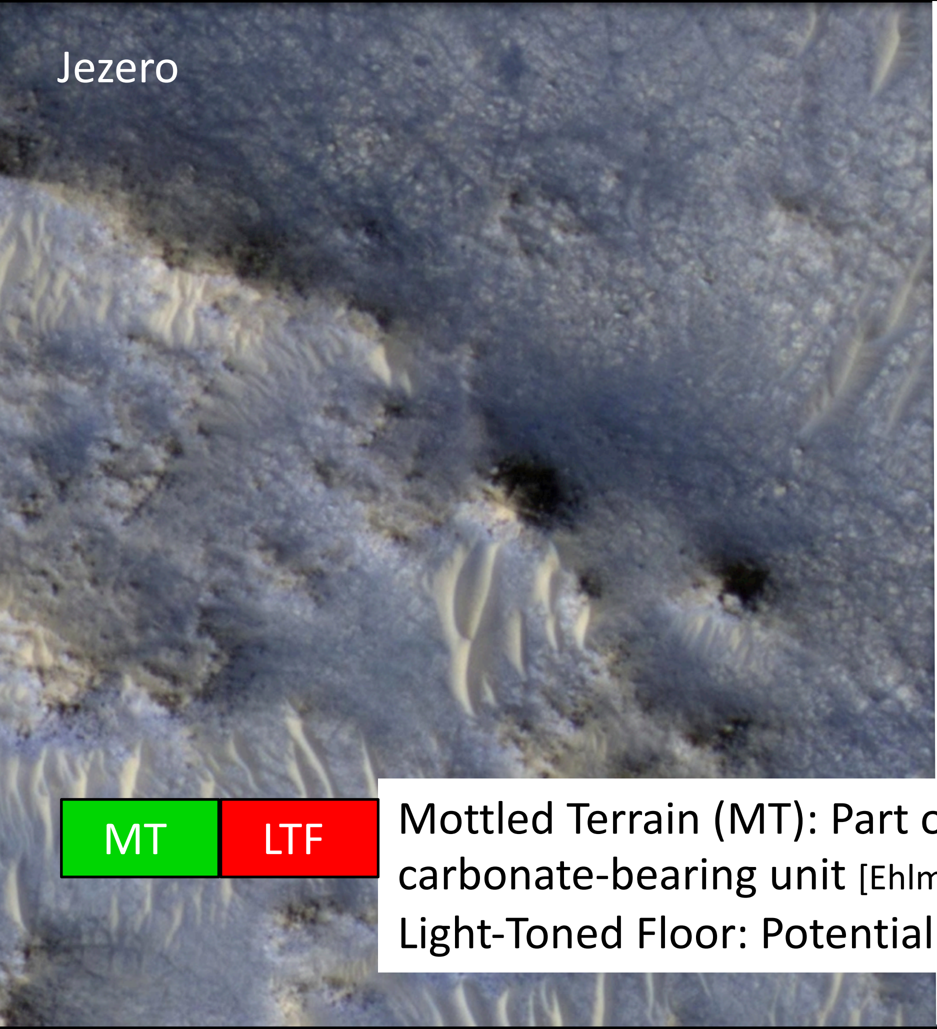
Goudge et al., 2015

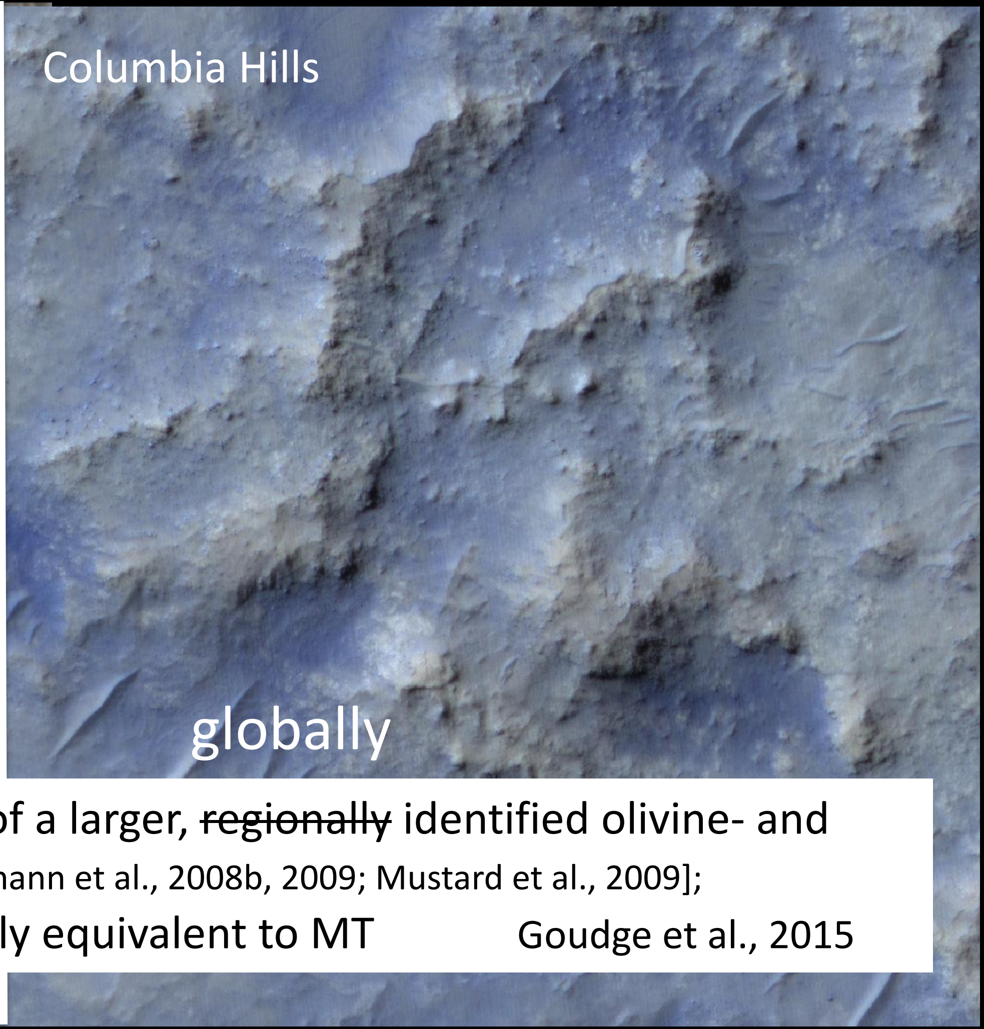

Olivine-rich bouldery knobs and ridges and light-toned fractured material with lack of craters
HiRISE
100 m

Olivine-rich bouldery knobs and ridges and light-toned fractured material with lack of craters

Columbia Hills







MT | LTF

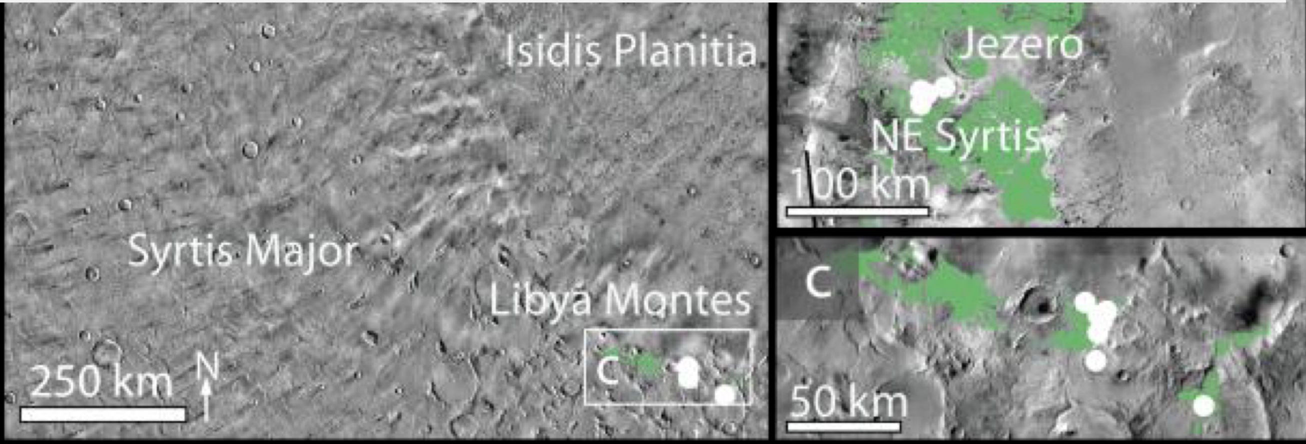
Mottled Terrain (MT): Part of a larger, ~~regionally~~ identified olivine- and carbonate-bearing unit [Ehlmann et al., 2008b, 2009; Mustard et al., 2009];

Light-Toned Floor: Potentially equivalent to MT

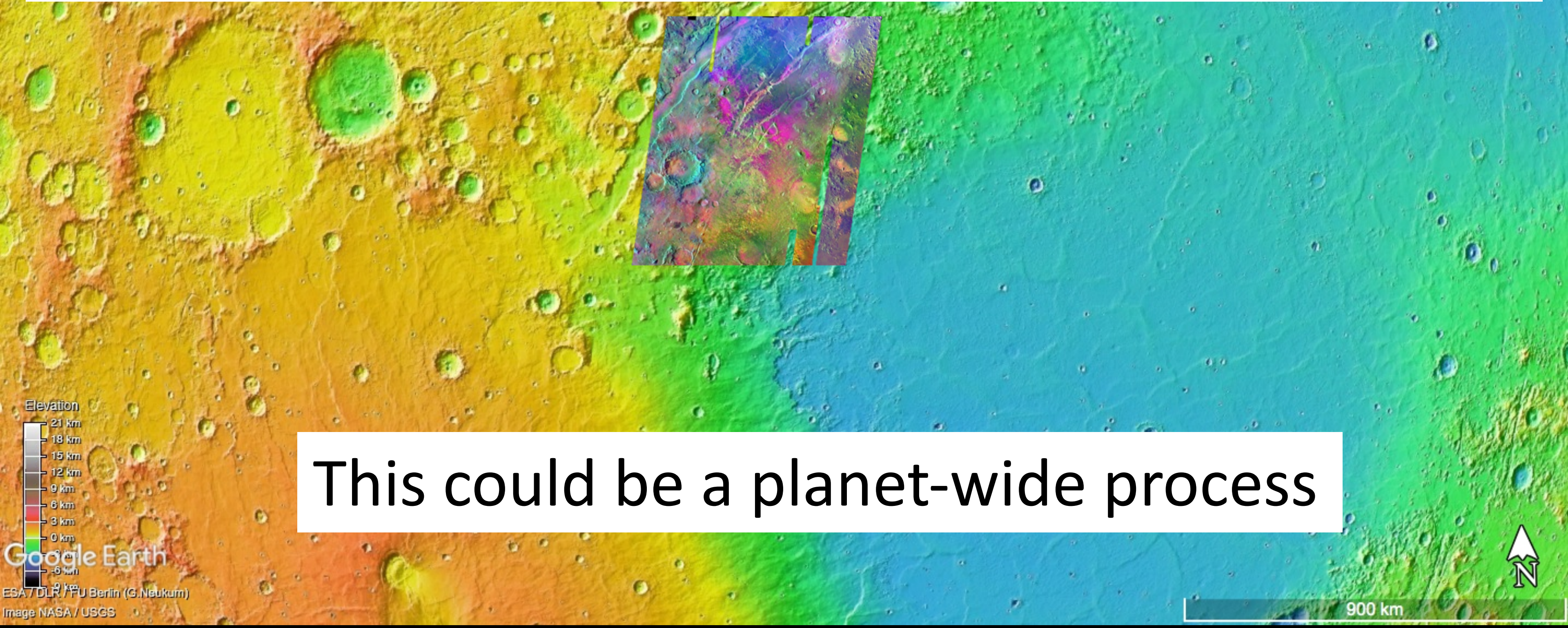
Goudge et al., 2015

ORIGIN AND EMPLACEMENT OF THE CIRCUM-ISIDIS OLIVINE-RICH UNIT. C. H. Kremer[1*], J. F. Mustard[1], and M. S. Bramble[1], [1]Department of Earth, Environmental and Planetary Sciences, Brown University, Providence, RI 02912 ([*]christopher_kremer@brown.edu)

Conclusion: The circum-Isidis olivine-rich unit is likeliest to have been emplaced as an ash fall deposit.



A carbonate origin hypothesis: Widespread alteration of Mg-rich olivine tuff by carbonic acid rain could lead to Mg-rich carbonates; Catling (1999) notes that water in equilibrium with a 1 bar CO_2 atmosphere would produce carbonic acid with pH =3.9 and stoichiometric dissolution of olivine, resulting in carbonates; *Jakosky et al.* (2018) model at least a 0.8 bar CO_2 atmosphere on early Mars.



This could be a planet-wide process

Jezero

Conclusions

Columbia Hills

- Olivine-rich ferropicritic ashfall tuff best describes the Algonquin class rocks in the Columbia Hills, which alter to produce Mg-Fe-rich carbonates
- Terrains in the Nili Fossae region display comparable characteristics
- Together, these rocks likely represent mantle evolution and volcanic processes on early Mars
- The carbonate alteration may represent a planet-wide process, like carbonic acid rain from a dense CO_2 atmosphere