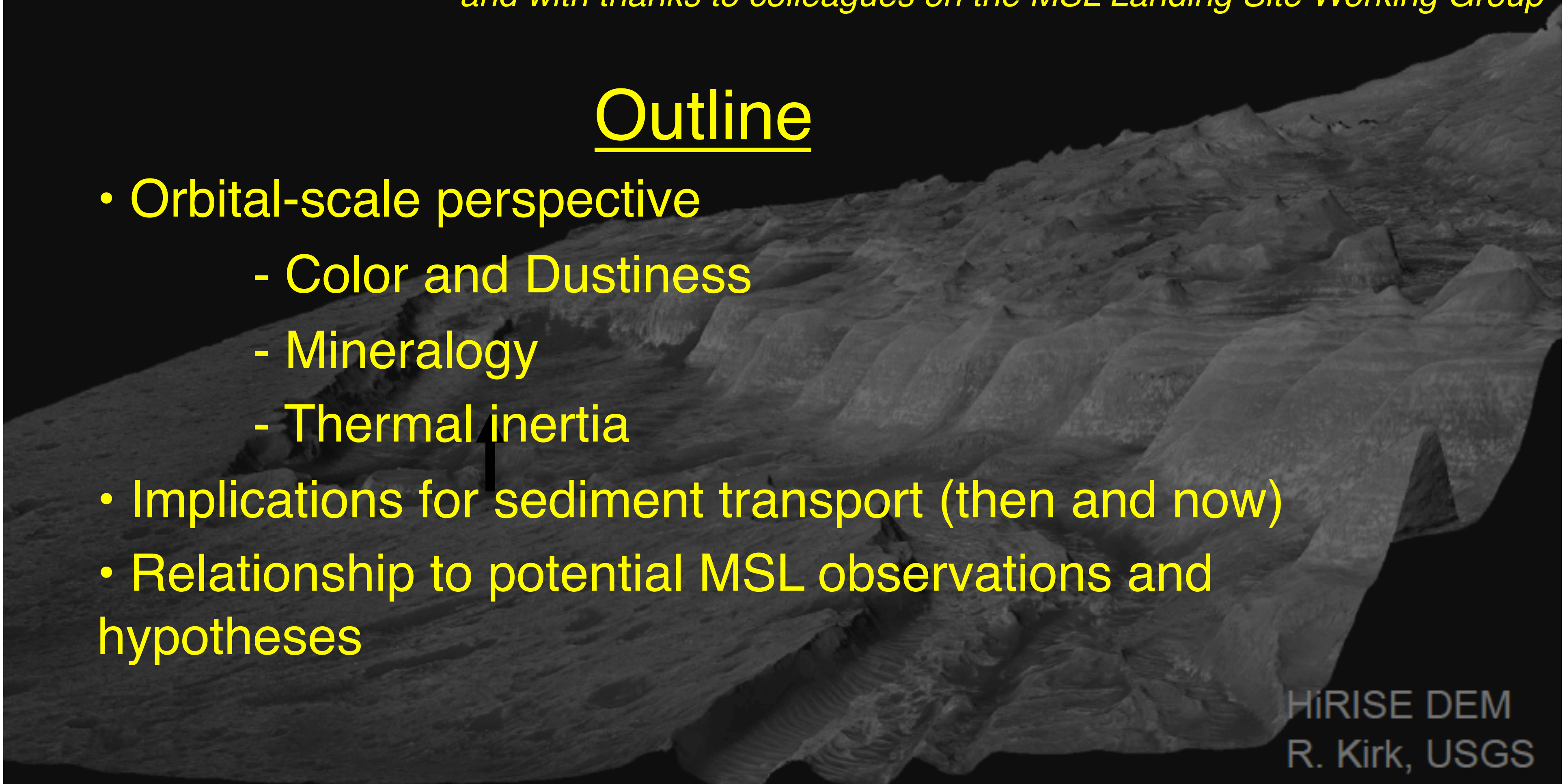
Mineralogy and Physical Properties of the Proposed Gale Crater MSL Field Site

Jim Bell, Ryan Anderson, Ralph Milliken, Ken Edgett, ...

and with thanks to colleagues on the MSL Landing Site Working Group

Outline

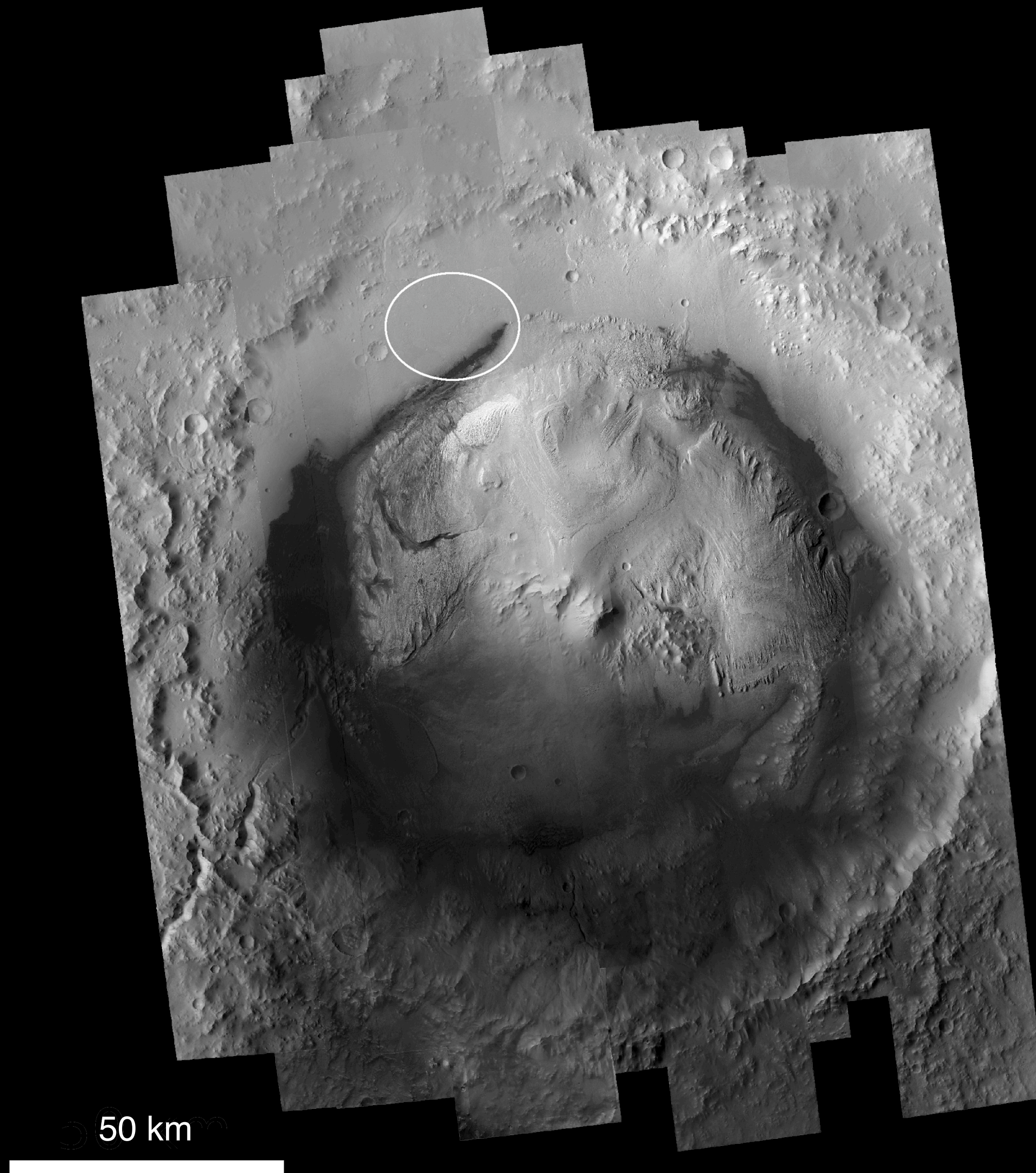
- Orbital-scale perspective
  - Color and Dustiness
  - Mineralogy
  - Thermal inertia
- Implications for sediment transport (then and now)
- Relationship to potential MSL observations and hypotheses



MRO/CTX
Gale Crater Mosaic

General context...

Base map for overlays from a variety of remote sensing data sets...



(Anderson & Bell, 2010)

NASA/JPL/MSSS

MRO/MARCI
Gale Crater Mosaic

NASA/JPL/MSSS

MARCI visible wavelength color composite

RGB=653, 546, 437 nm

Upper mound and surrounding highlands to the E, N, and W: Dusty

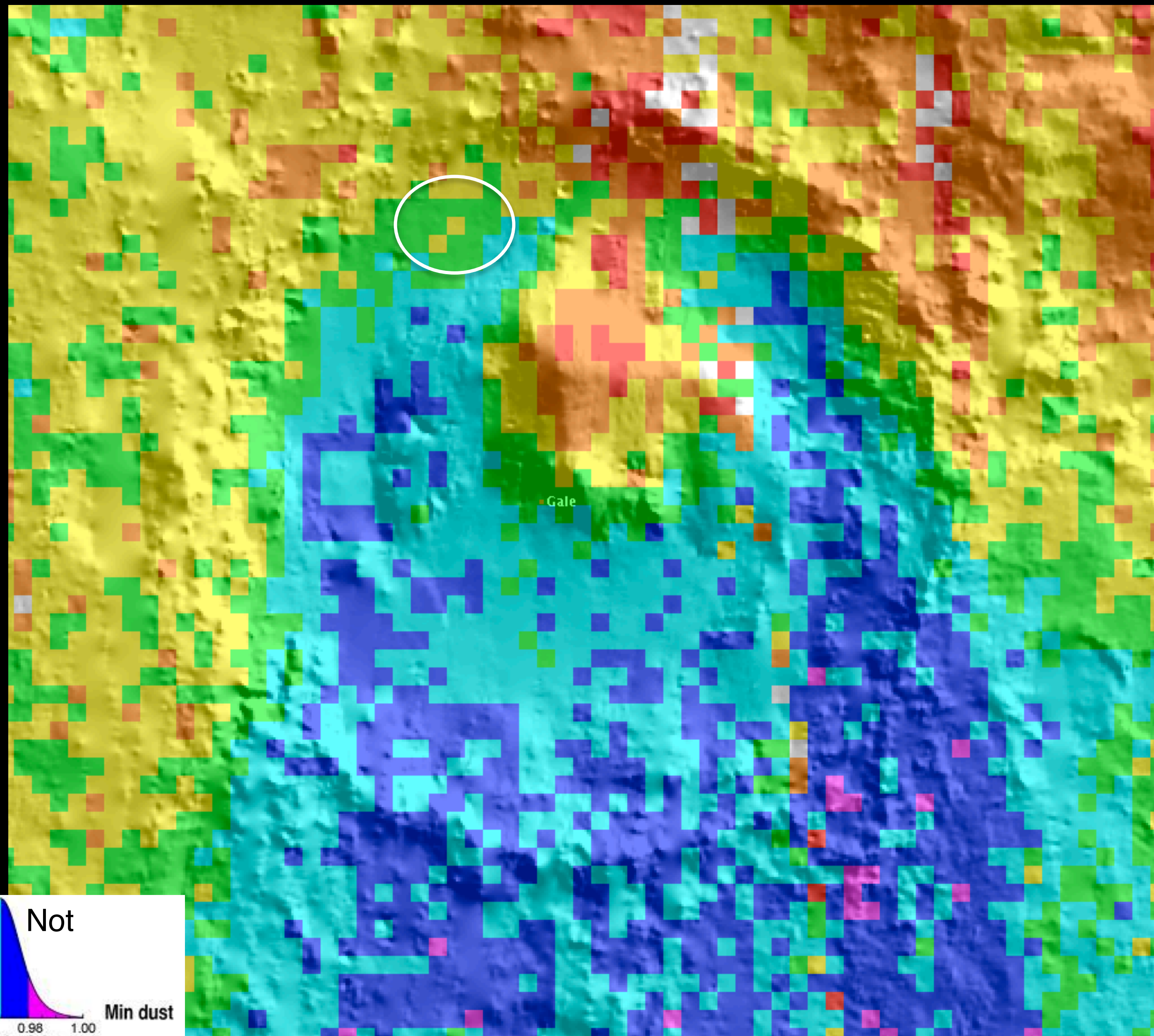
Much of crater floor and highlands S of the crater: Sandy/cleaner...

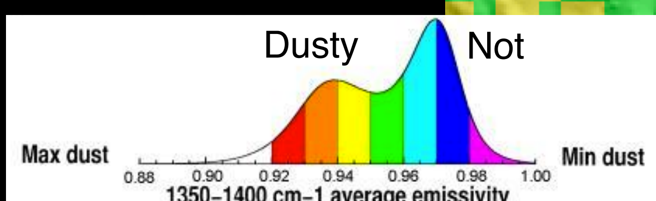
(Bell *et al.*, 2009)

MGS/TES
Dust Cover Index

Upper mound and surrounding highlands to the E, N, and W: Dusty

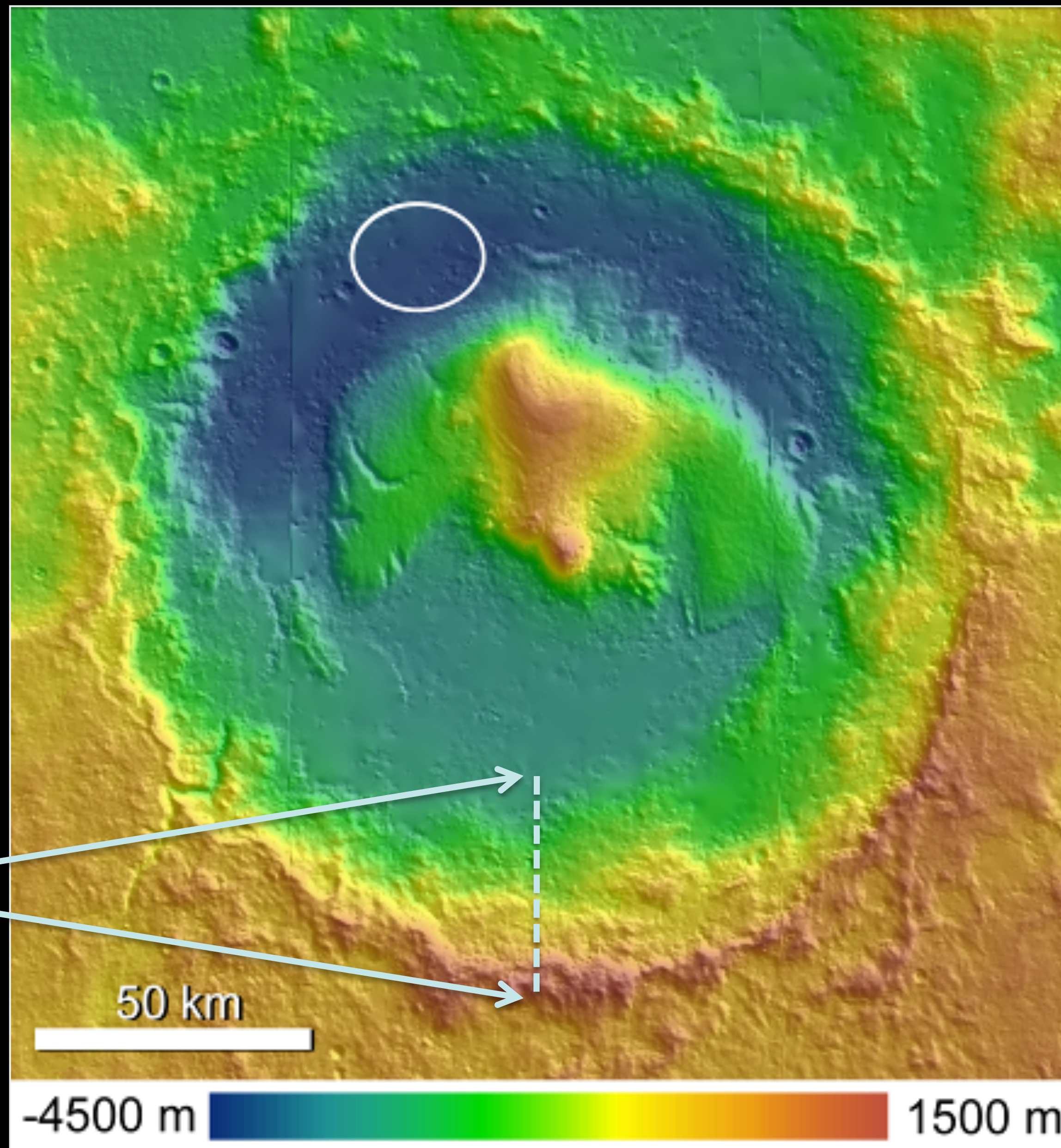
Much of crater floor and highlands S of the crater: Sandy/ cleaner...





(Ruff & Christensen, 2002)

MGS/MOLA
Elevation



~ 4 km difference

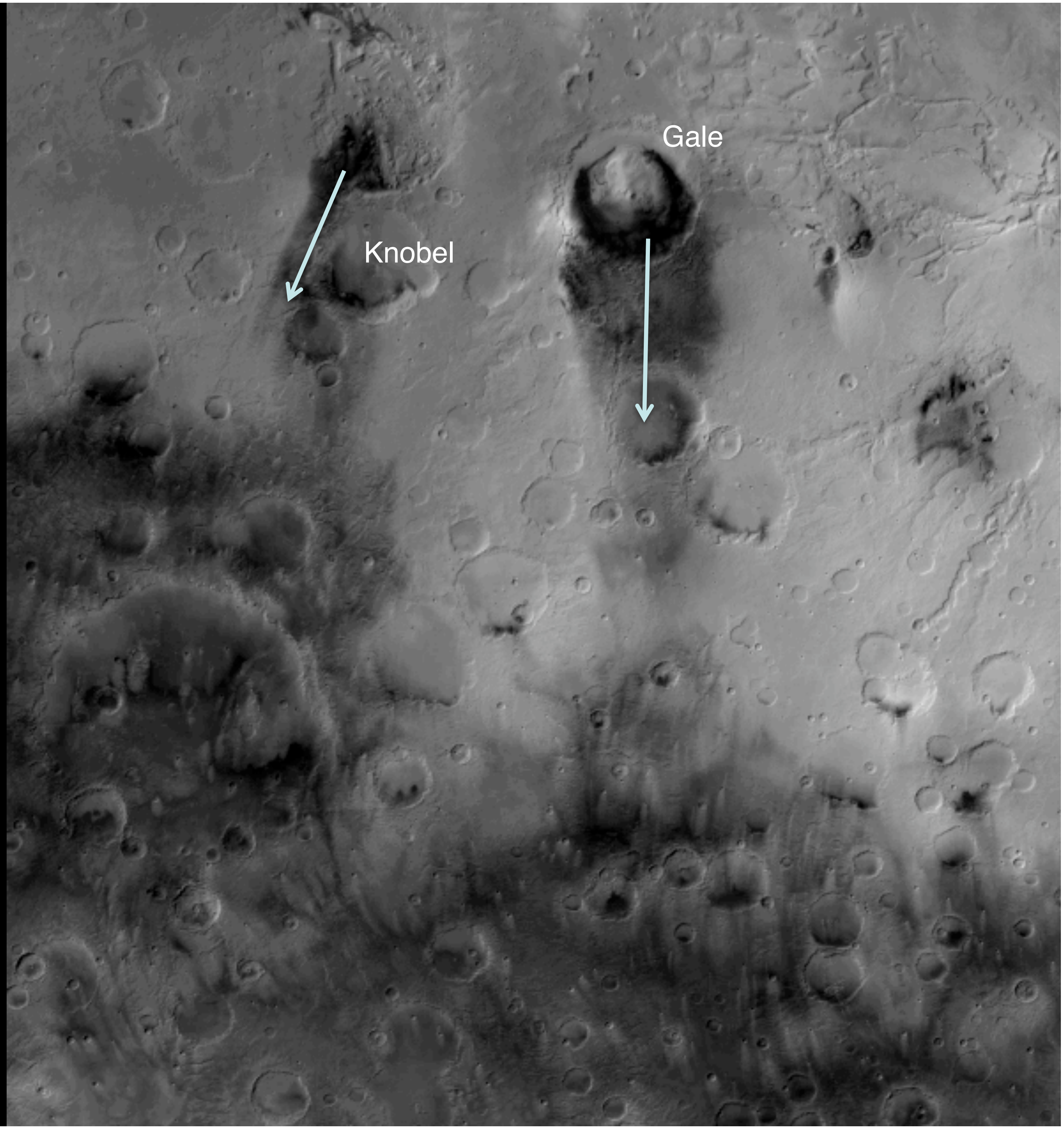
avg. slope ~5°

MOLA Team/NASA/GSFC/Google

The dark wind streak coming out of Gale and spreading to the south (as well as the one coming out of the southern end of the crater north of Knobel) may demonstrate that sediment can indeed be transported up and out of these holes, even (apparently) in the present climate regime...

...or are they just areas of preferential dust removal?

MGS/MOC
NASA/JPL/MSSS



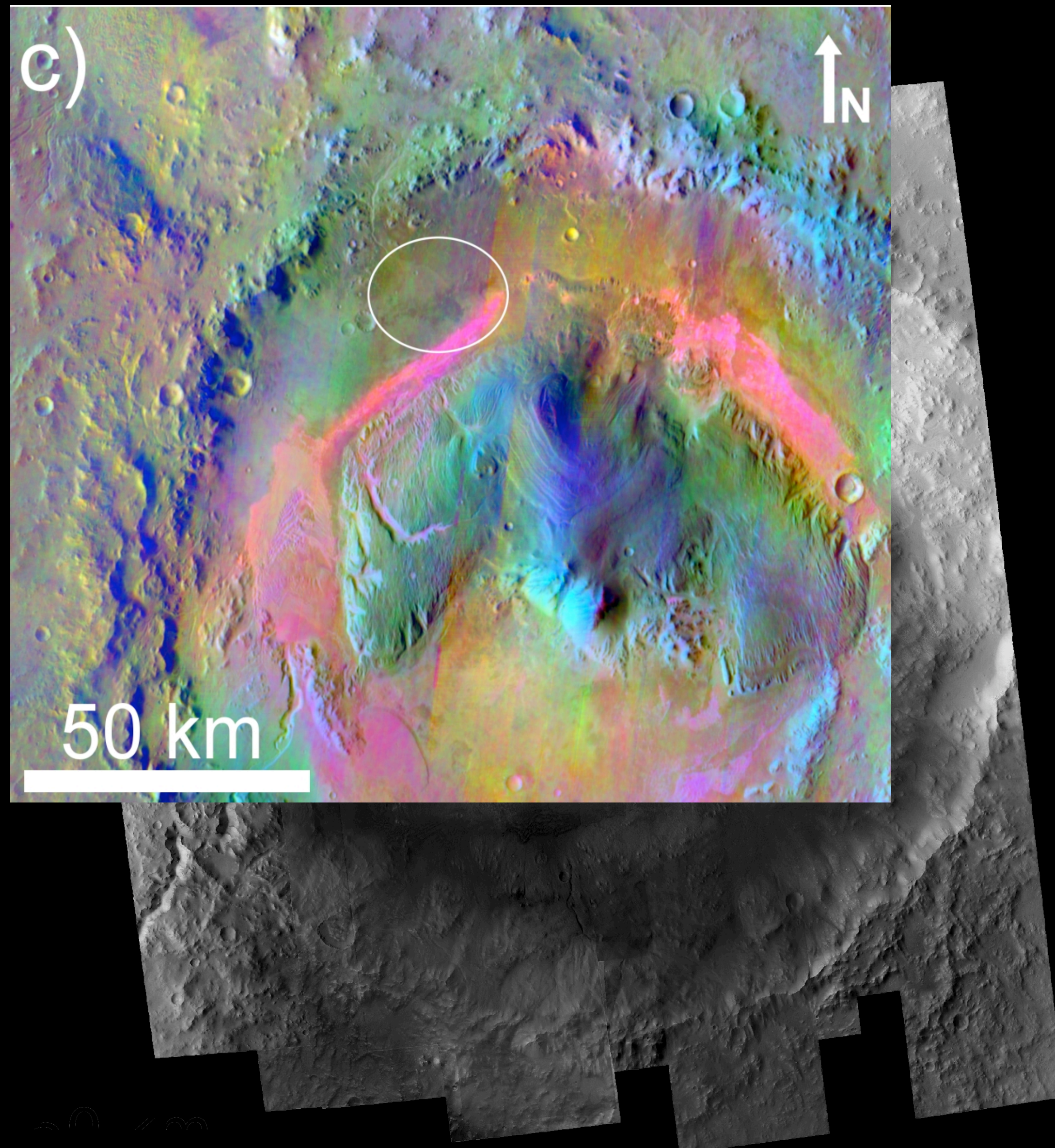
ODY/THEMIS
Decorrelation Stretch

RGB = Bands 8,7,5

Mafic (Olivine-bearing) and generally more dust-free materials appear as pink/ magenta

More Felsic materials appear as yellowish

Low inertia, dusty surfaces appear blue

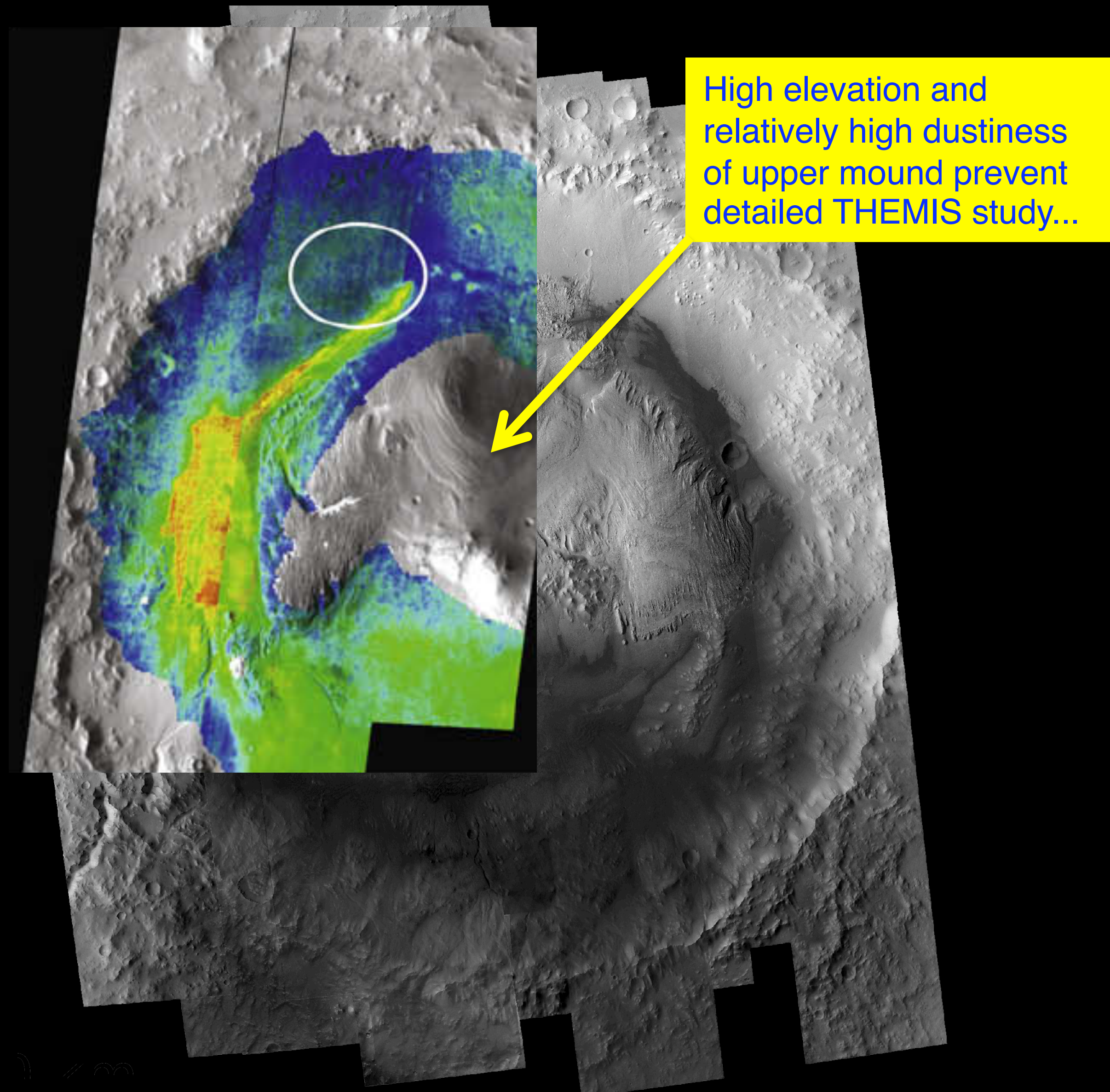


(Hamilton *et al.*, 2009)
(also Stockstill *et al.*, 2007)

NASA/JPL/ASU

ODY/THEMIS
Olivine basalt endmember map
(Rogers & Bandfield, 2009)

MGS/TES
- Dark Material: Surface emissivity spectra are similar to Surface Type 1
- Mineral abundances consistent with ~65% ol+px +plag basalt, ~10% sulfate, and ~20% "high silica phases" (*e.g.,* zeolite, amorphous Si, alkali glass)
- No TES smectite doublet:
  - outcrops too small?
  - abundances < 10-20%?
  - texture/particle size?

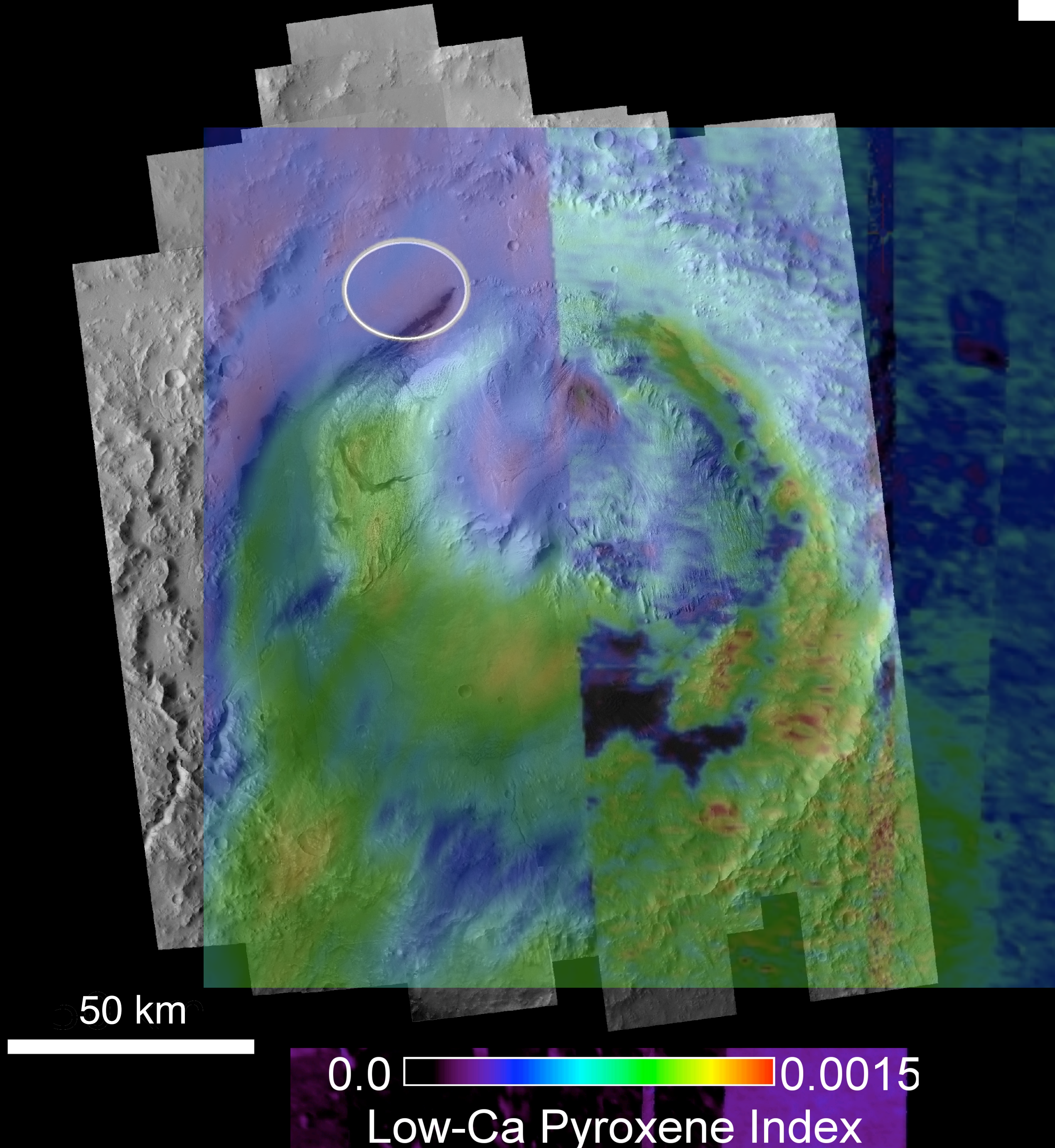


(Also Pelkey & Jakosky, 2002; Pelkey *et al.,* 2004; Stockstill *et al.,* 2007)

NASA/JPL/ASU

MEx/OMEGA
Mineral Index Images

Low Calcium Pyroxene

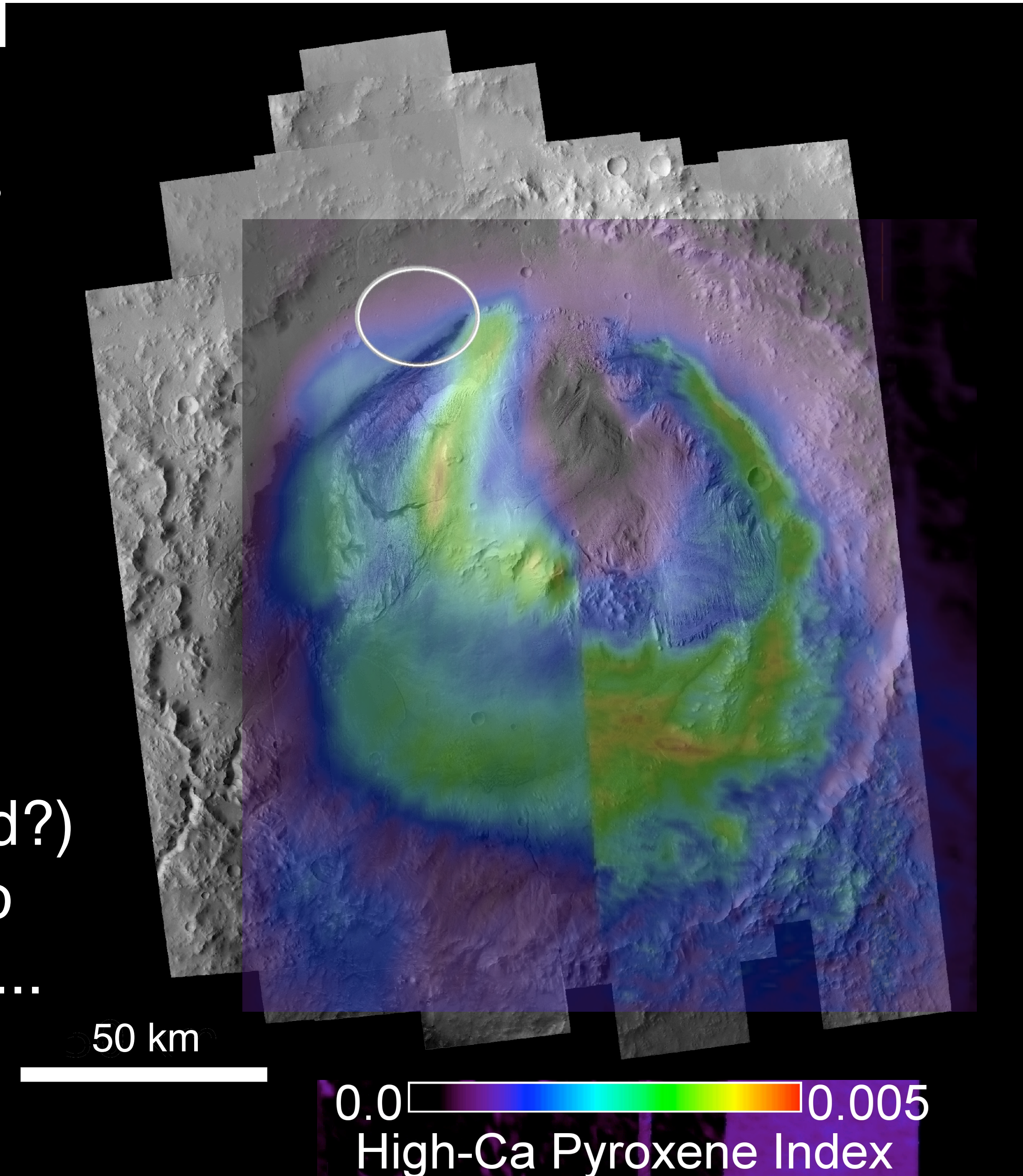


(Anderson & Bell, 2010)

MEx/OMEGA
Mineral Index Images

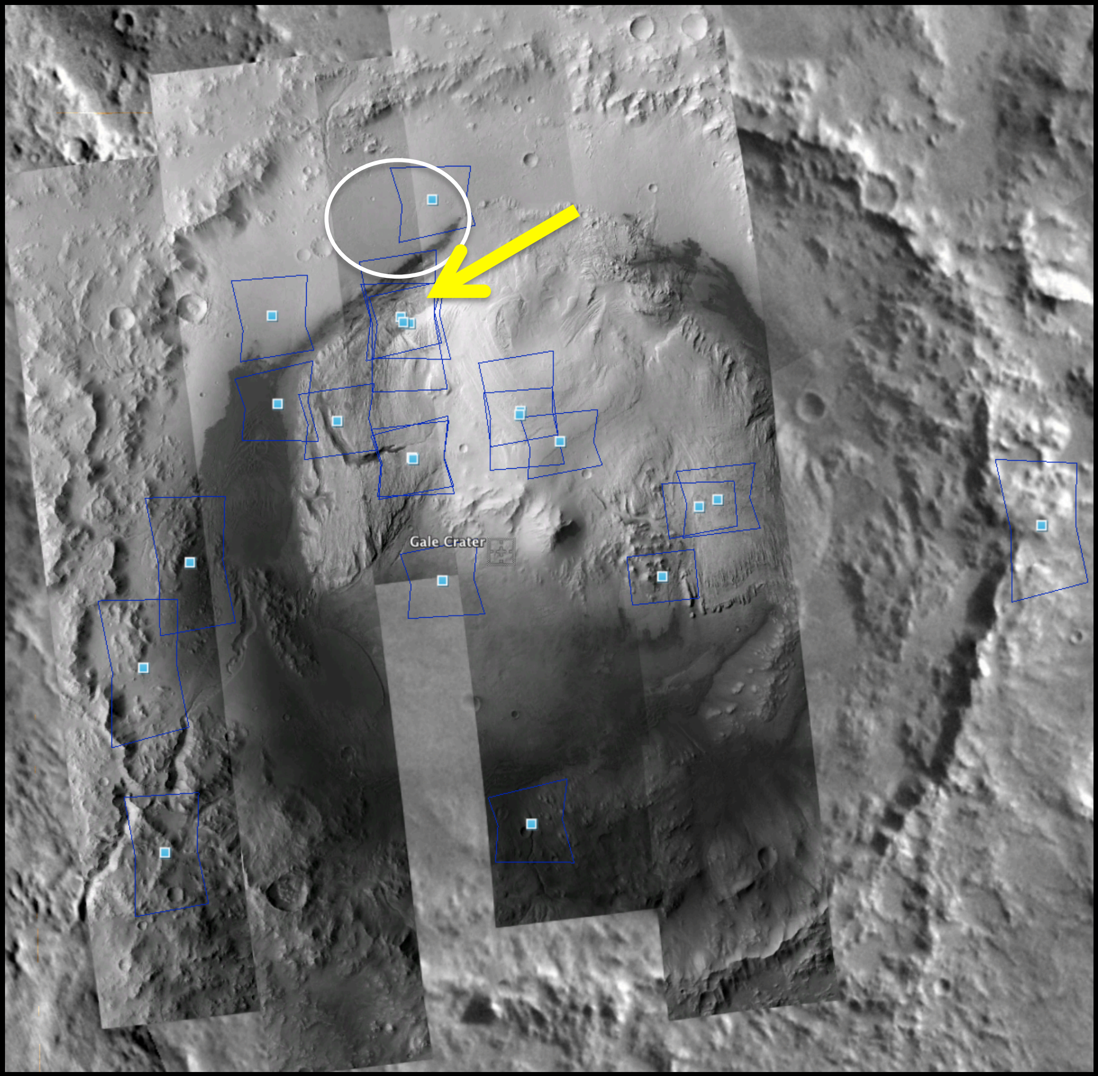
High Calcium Pyroxene

→ significant basaltic (sand?) component to lower mound...



(Anderson & Bell, 2010)

MRO/CRISM
FRT, HRL Images



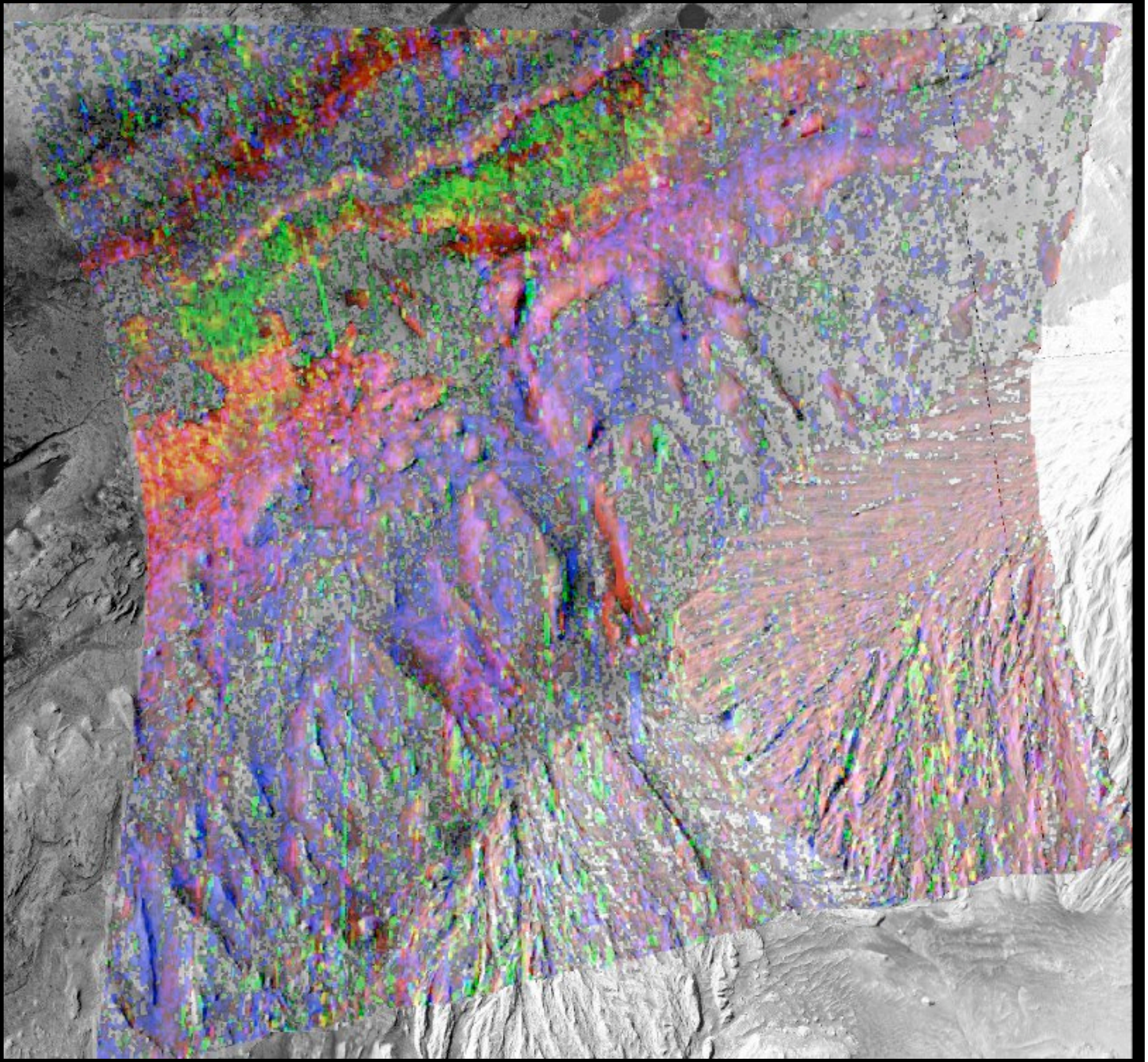
(Milliken *et al.*, 2010)

olivine (dunes); $(Mg,Fe)_2SiO_4$

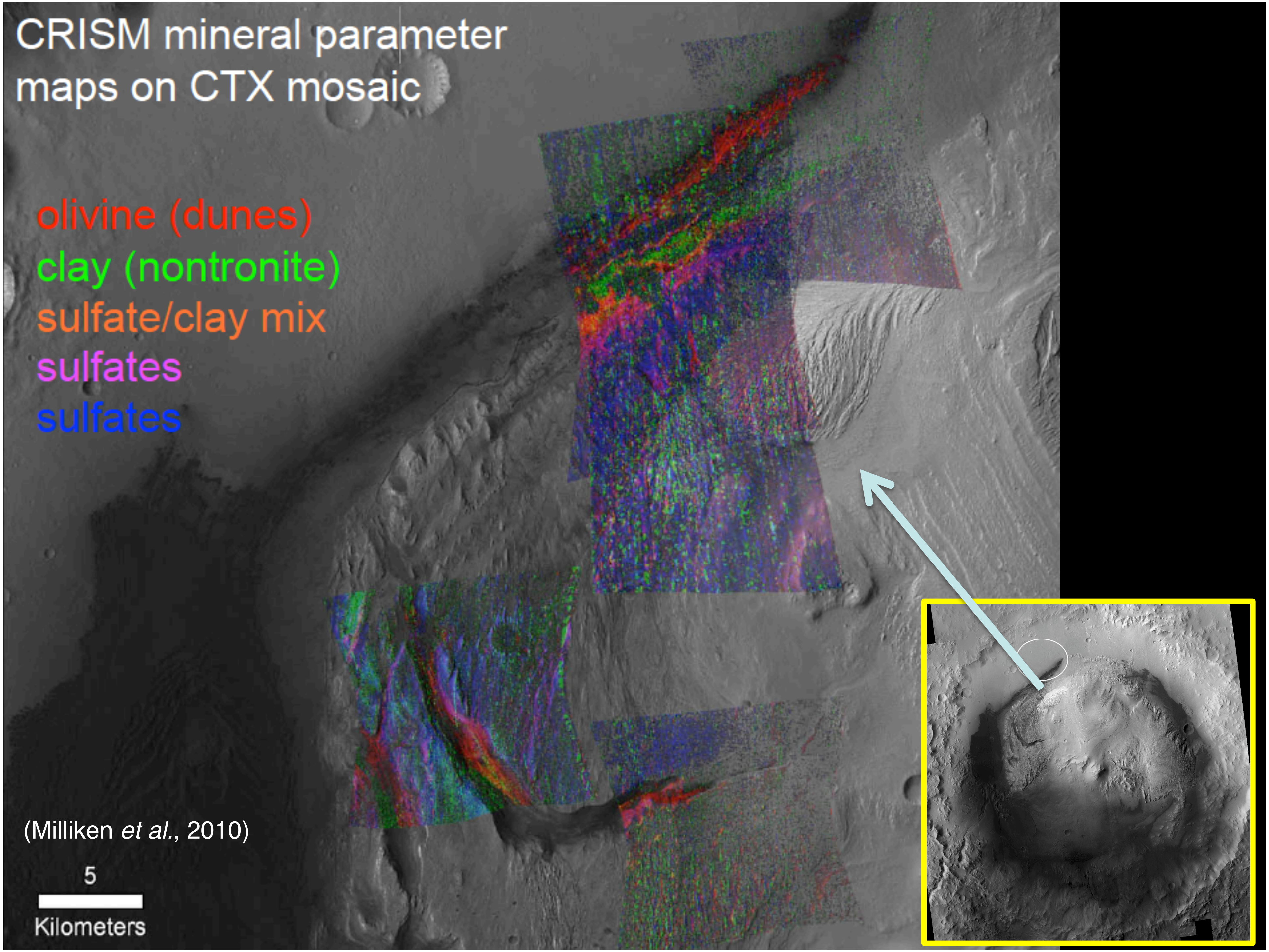
(Fe, Mg) smectite clays; *e.g.,* nontronite $Fe_2(Si,Al)_4O_{10}(OH)_2 \cdot n(H_2O)$

sulfates (monohyd.) *e.g.,* kieserite $MgSO_4 \cdot H_2O$;
sulfates (polyhyd.)

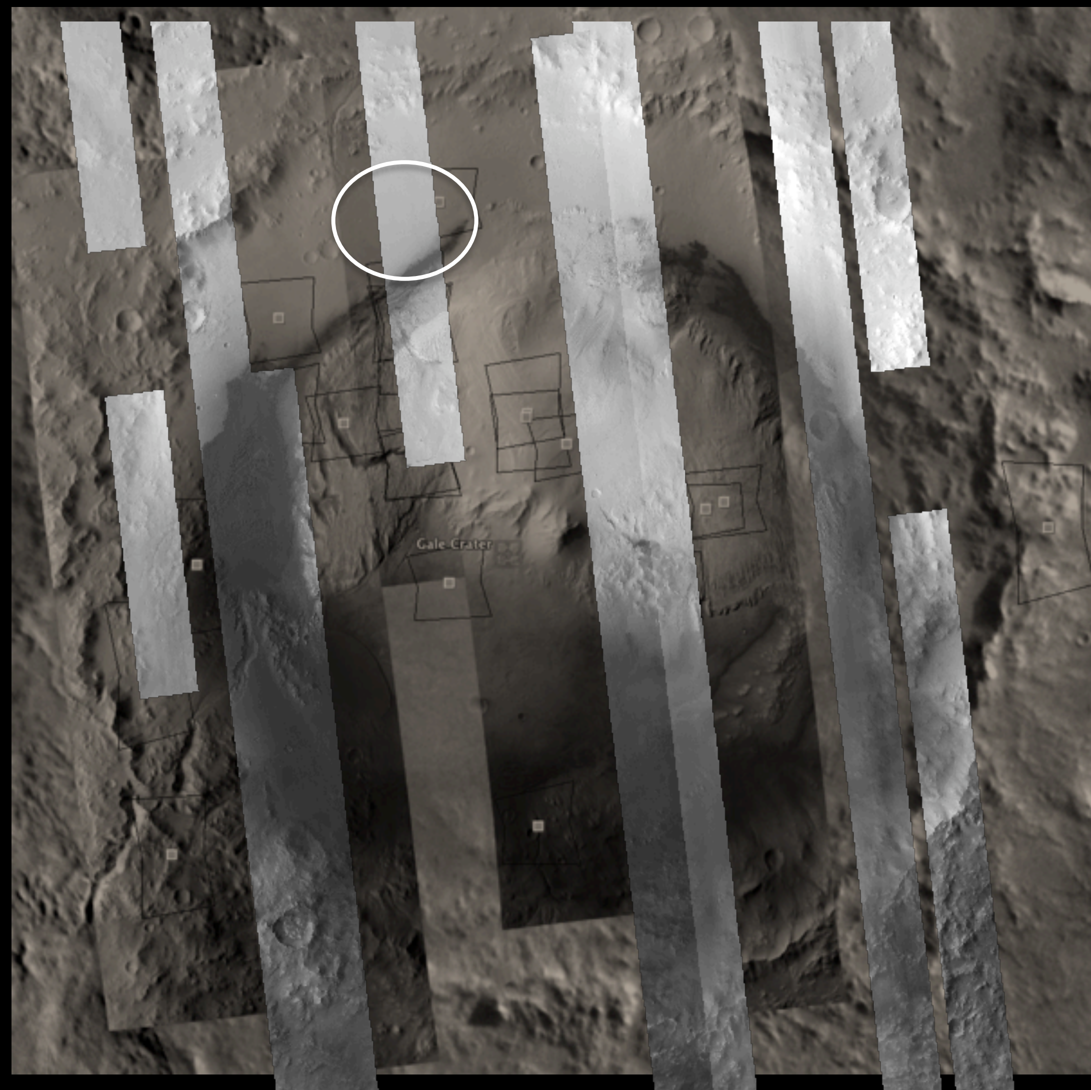
sulfates & clays



(Milliken *et al.*, 2010)


CRISM mineral parameter maps on CTX mosaic
olivine (dunes)
clay (nontronite)
sulfate/clay mix
sulfates
sulfates
(Milliken *et al.*, 2010)
5
Kilometers

MRO/CRISM
Survey Mode Images
(F. Seelos *et al.*, 2007)



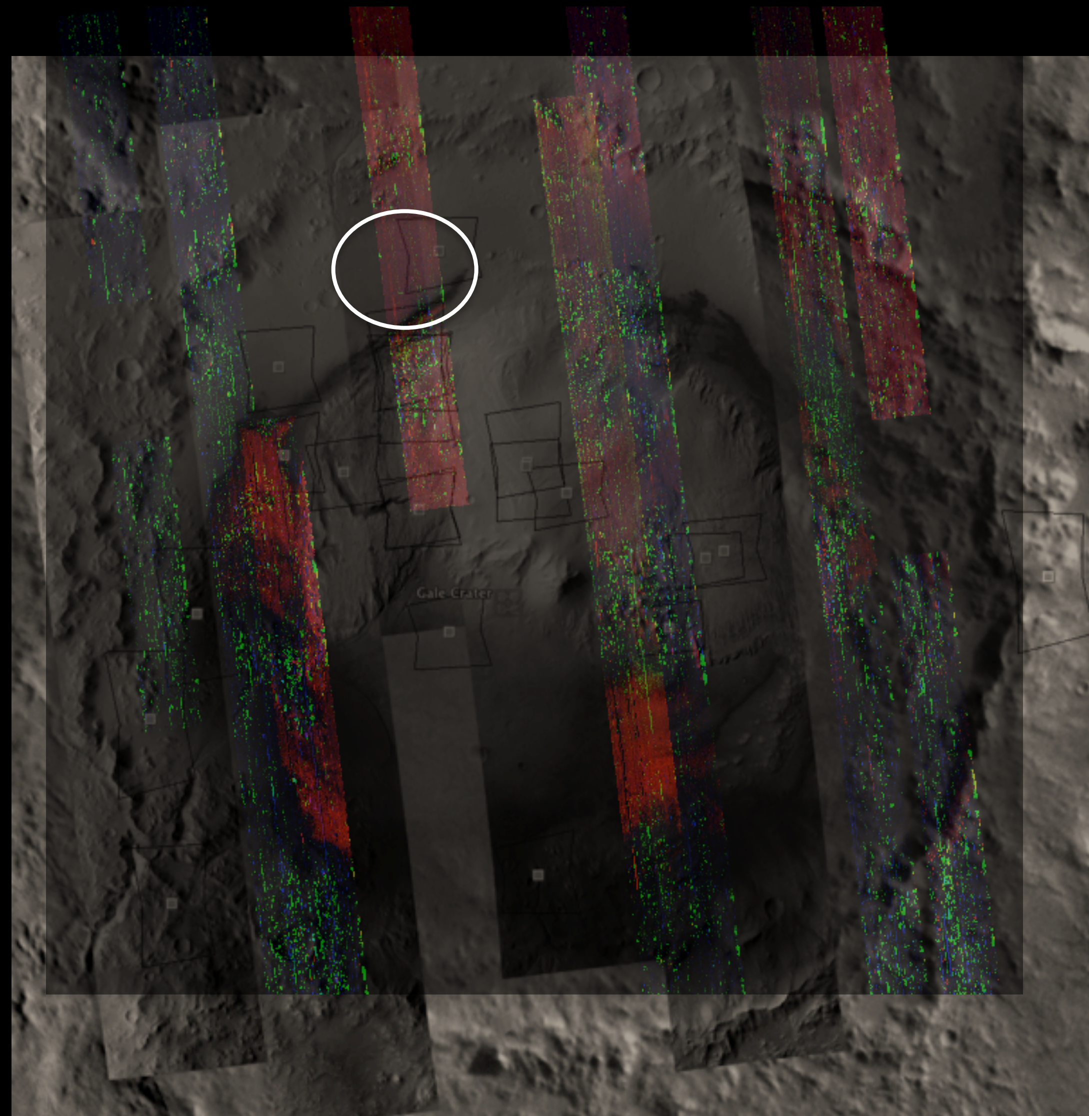
MRO/CRISM
Survey Mode Images
(F. Seelos *et al.*, 2007)

Similar RGB composite
as Milliken *et al.* (2010):

Red = Fe minerals
(OLINDEX)

Green = Fe/Mg clay
(D2300)

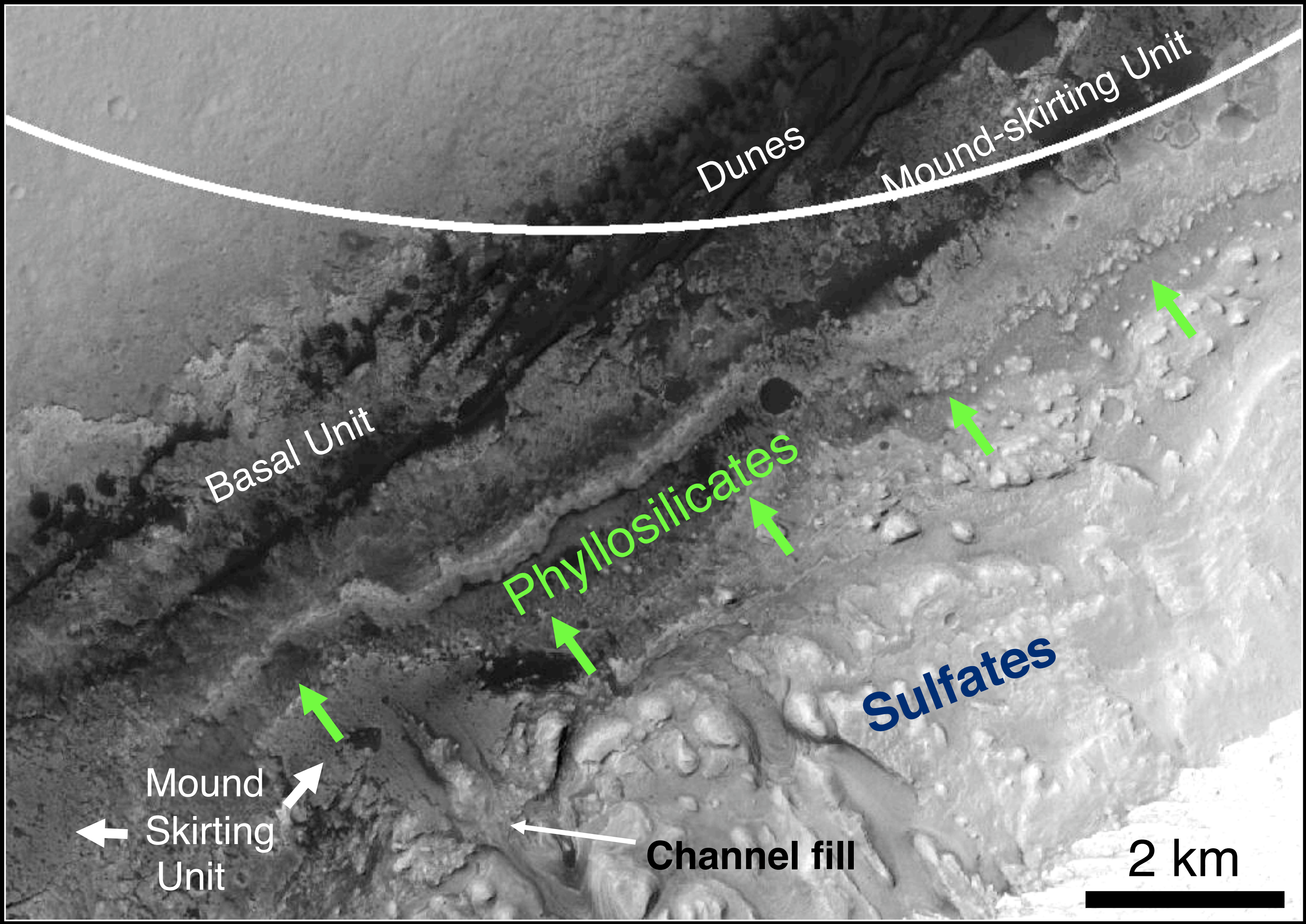
Blue = sulfates
(SINDEX)



- CRISM survey mode view so far mostly points out the extensive "basaltic detritus" signature, even in sulfate/clay areas...
- Consistent with OMEGA data and MER "dirty evaporites" story in Meridiani?

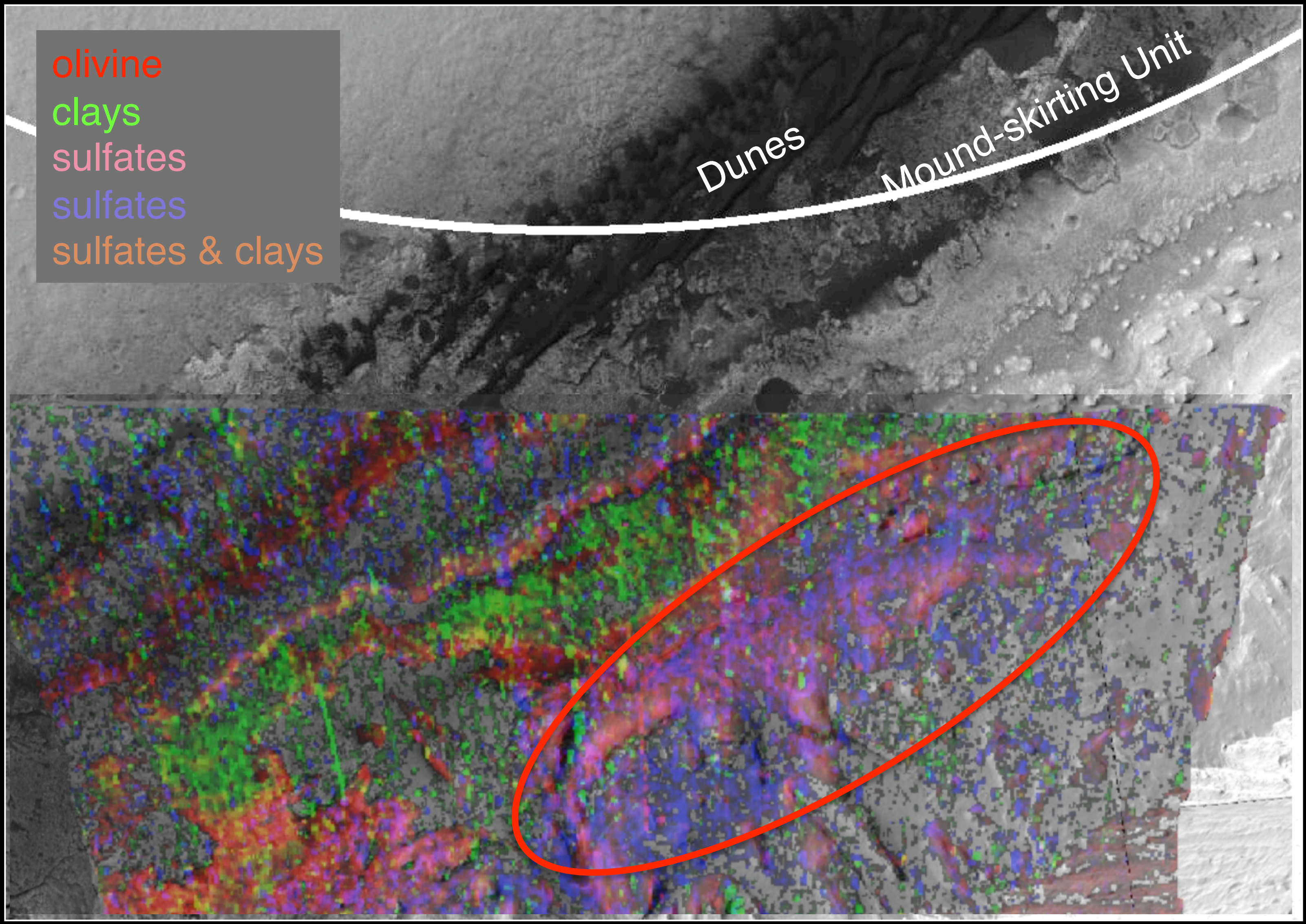
How Much Clay, Sulfate, Ol, Px, ...?

- Important to remember that there is a fundamental ambiguity between grain size and abundance in near-IR spectroscopy:
  - An absorption band could be X% deep because there is a small amount of relatively coarse-grained (10s-100s of microns) material, or a large amount of relatively fine-grained (submicron-10s of microns) material
  - Despite a number of admirable efforts, *abundance estimates of clays, sulfates, etc. in and around the proposed MSL field sites are still strongly dependent upon model assumptions* (grain size, presence/absence of spectrally-neutral phases, opt. const., etc.)
- Whether alteration products are major components of these surfaces or minor (accessory) phases will likely require the MSL payload to determine!



- The trough between the light-toned ridge and the rest of the mound shows the strongest CRISM phyllosilicate signature in Gale. (Milliken *et al.* 2010)

CTX: MSSS/JPL/NASA

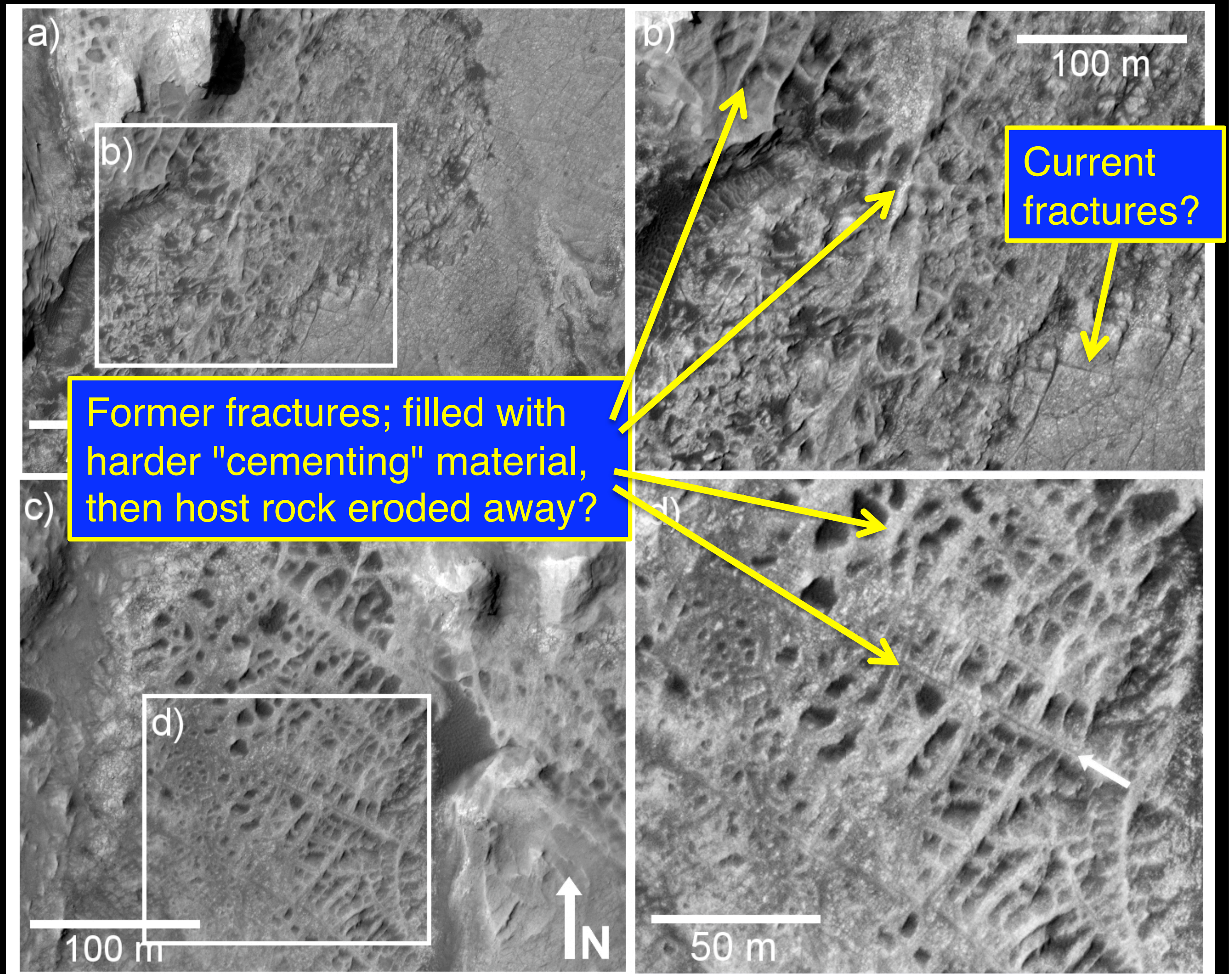


- The trough between the light-toned ridge and the rest of the mound shows the strongest CRISM phyllosilicate signature in Gale. (Milliken *et al.* 2010)

CTX: MSSS/JPL/NASA

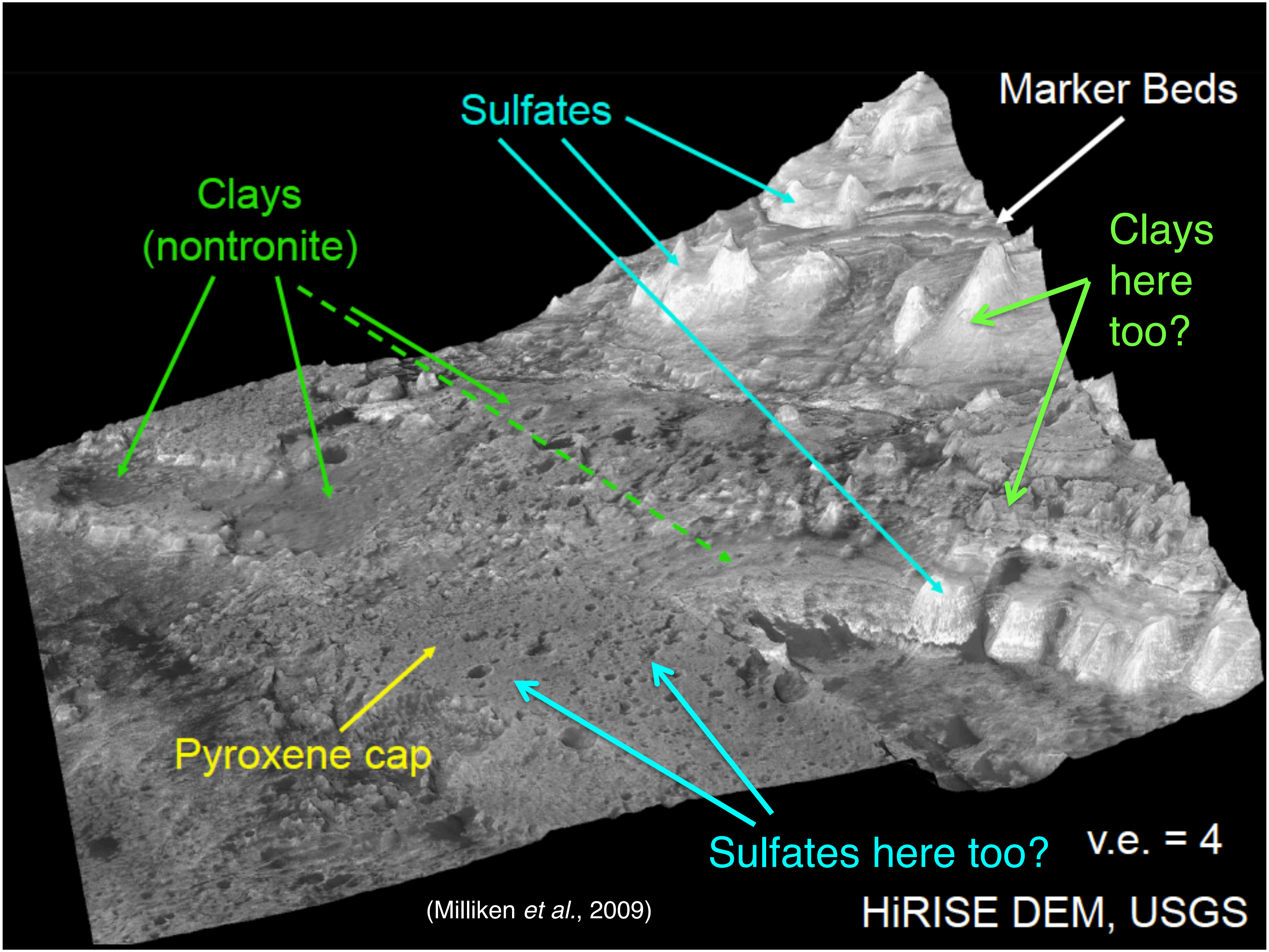
Erosion-resistant ridges occur in the sulfate-bearing unit...

These kinds of features are relatively common in Gale, both on the mound and along the traverse out of the ellipse...

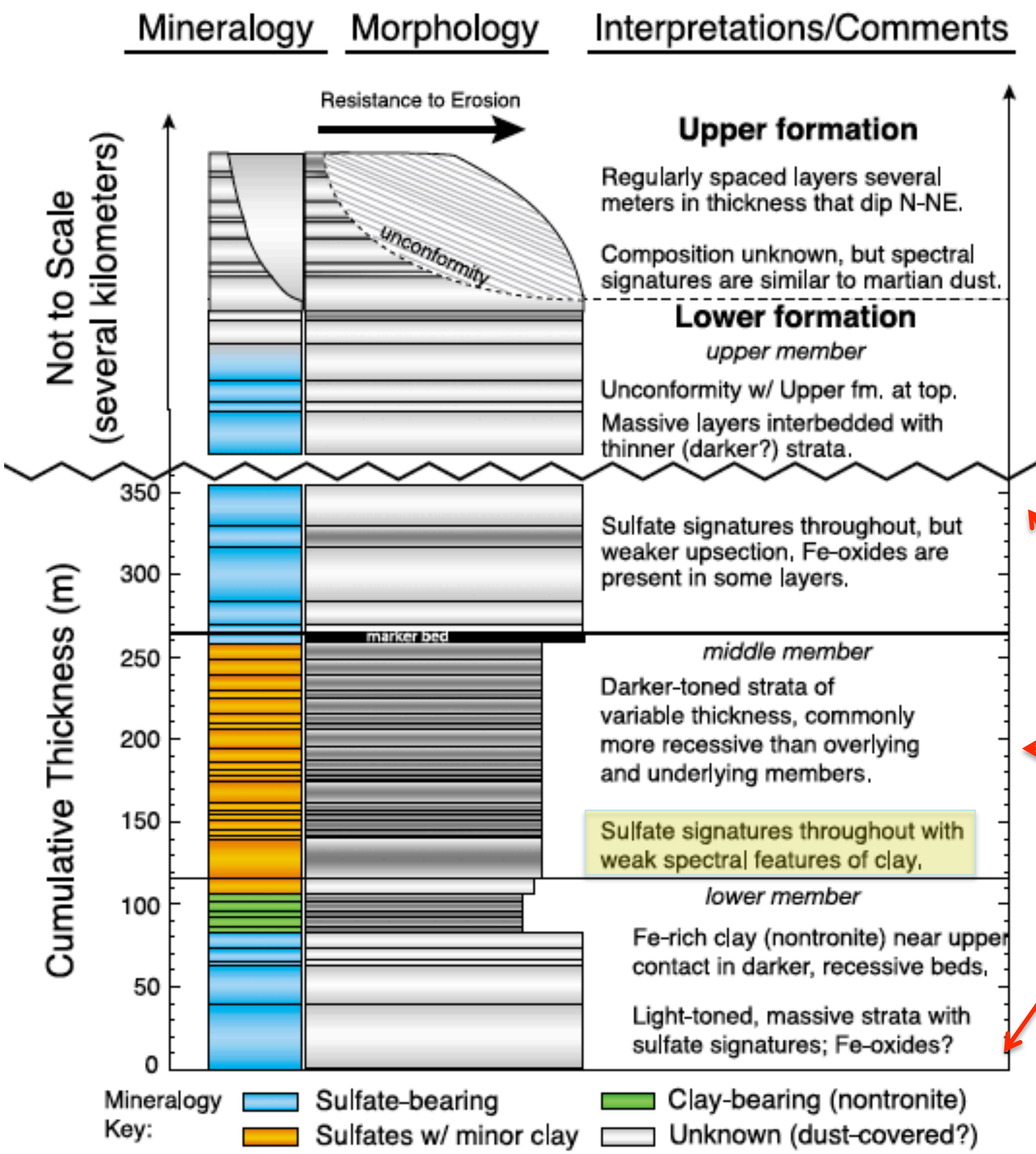


(Anderson & Bell, 2010)

from HiRISE PSP_001752_1750; NASA/JPL/Univ. Arizona


Sulfates
Marker Beds
Clays
(nontronite)
Clays
here
too?
Pyroxene cap
Sulfates here too?
v.e. = 4
(Milliken *et al.*, 2009)
HiRISE DEM, USGS

An Inferred Stratigraphic Column for a Section of the Gale Mound



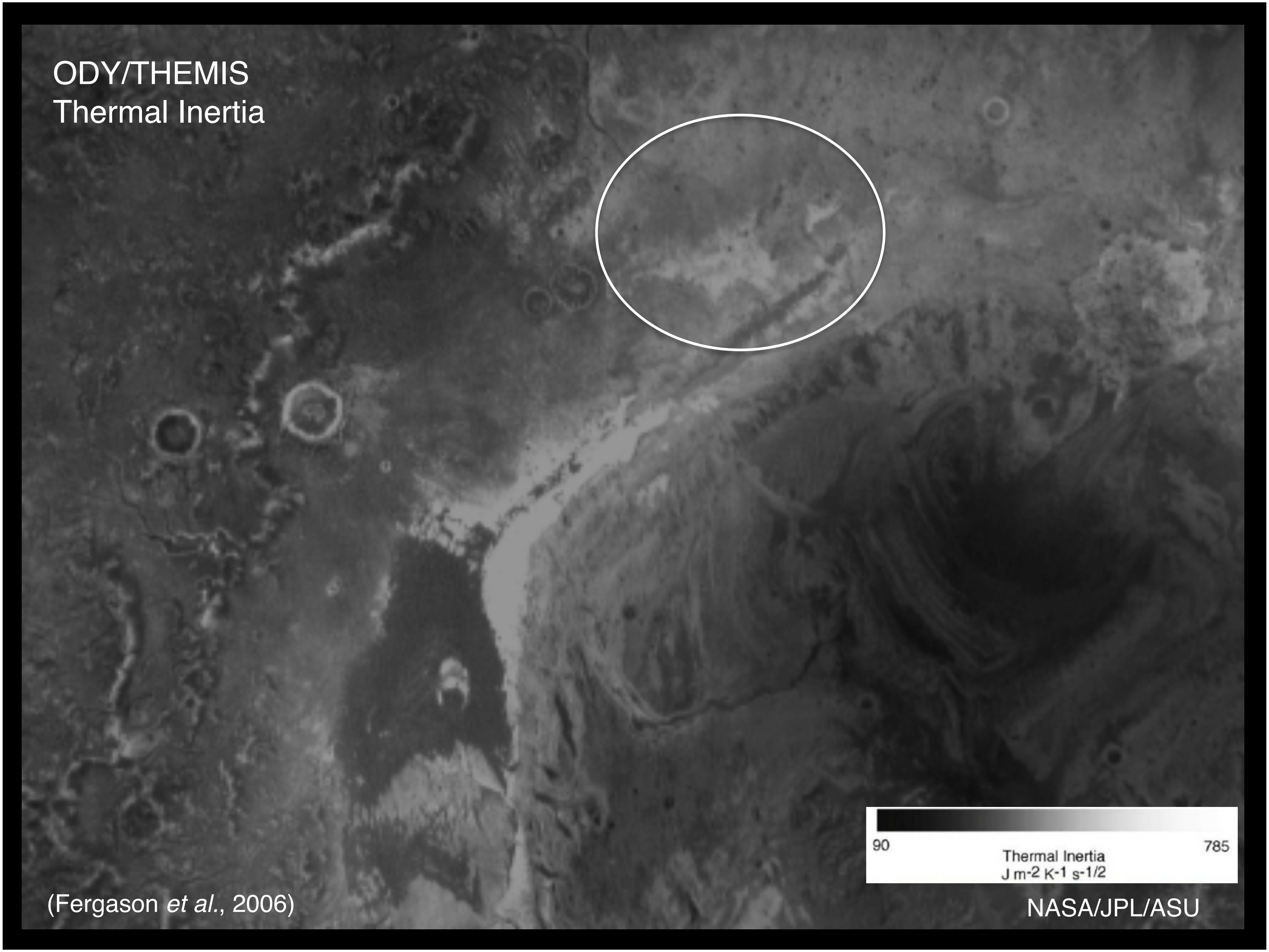
This part of the section would be the primary focus of study by MSL

(Milliken *et al.*, 2010)

ODY/THEMIS
Thermal Inertia

(Fergason *et al.*, 2006)
(also Hobbs *et al.*, 2010)

NASA/JPL/ASU

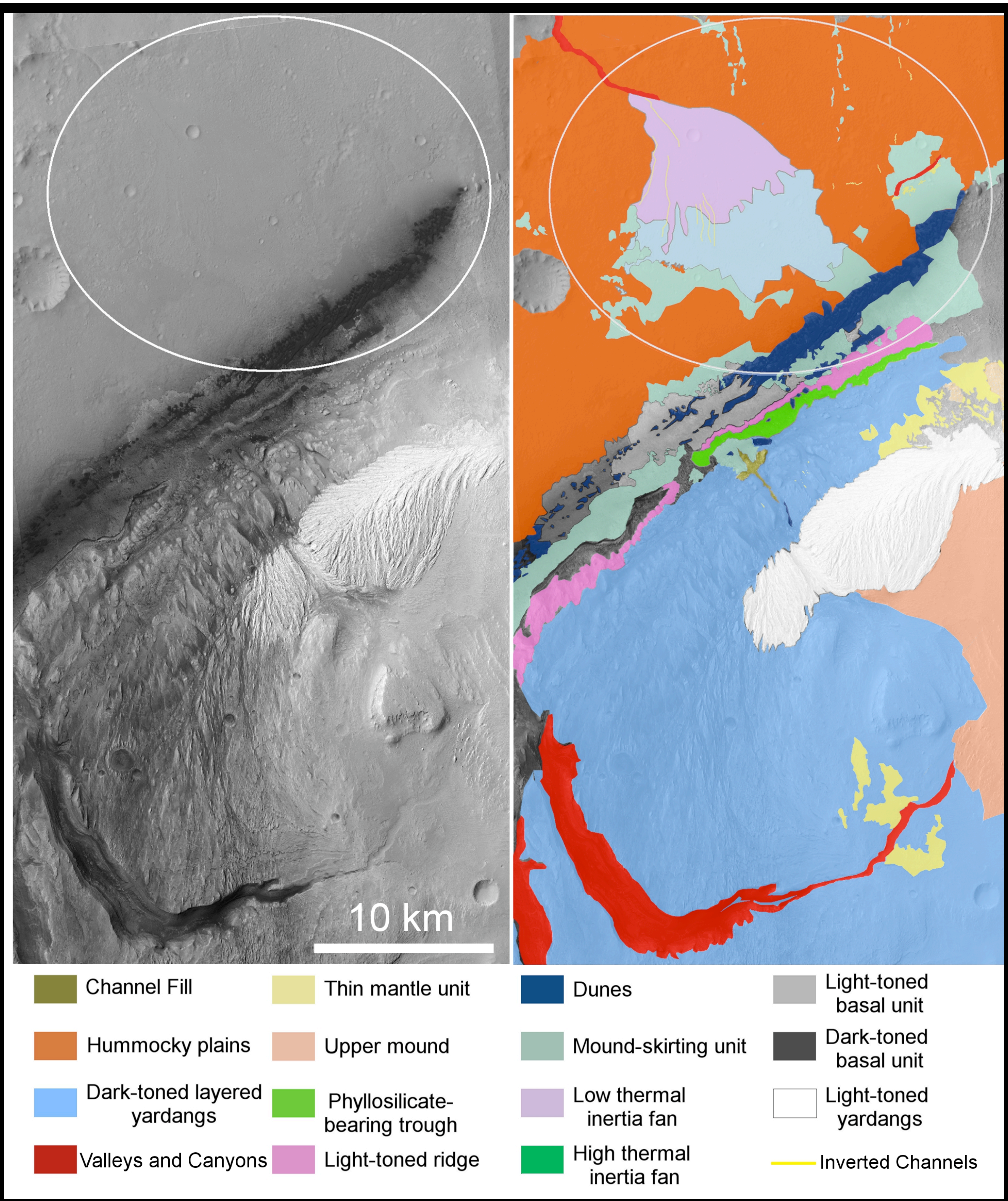

ODY/THEMIS
Thermal Inertia
90
785
Thermal Inertia
J m-2 K-1 s-1/2
(Fergason et al., 2006)
NASA/JPL/ASU

Gale Unit Mapping

- thermal inertia
- geomorphology
- mineralogy

Lots more detail in Ryan Anderson's paper that just came out in the online *Mars* journal: http://dx.doi.org/doi:10.1555/mars.2010.0004

(Anderson & Bell, 2010)



Science Traceability: Goals → Measurements → Instruments

(Partial) Science Traceability Matrix for the MSL Payload at Gale Crater

Science Goal	*Measurement Objective*	*Instruments/Observations*
Determine the origin, style, and history of aqueous alteration at the field site	Identify specific alteration minerals	CheMin, SAM, APXS, ChemCam
	Characterize grain sizes, shapes, textures, and their relation to other constituents	MAHLI, ChemCam, Mastcam
	Assess style and degree of alteration and biologic habitability potential	CheMin, SAM, APXS, Chemcam
Determine the origin(s) of the observed layers	Detailed examination of constituent particles: grain size, degree of sorting, shape, texture, degree of alteration	MAHLI, ChemCam, Mastcam
	Identify and characterize bedding relationships and sedimentary structures	Mastcam, ChemCam (+ HiRISE)
	Identify primary mineralogies as well as secondary alteration products and cementing agent	CheMin, SAM, APXS, ChemCam

Updated from Thomson *et al.* (2007)

Summary

- Some key observations about the Gale mound:
  - It has layers of interbedded phyllosilicates and sulfates
    - Changing (but not simple) environmental and alteration conditions
    - Fe/Mg clays and (to a lesser extent) Mg sulfates suggest moderate pH and good biologic preservation potential...
  - Large and apparently cemented ridges
    - Do these characterize the post-depositional alteration of mound materials?
  - Many km thickness of continuous (?) strata
    - Exploration of the preserved stratigraphy of ancient Mars!
- Enigmatic sediment transport processes—even today?
- While the lower mound is the primary target, the traverse also offers opportunities for mineralogic and morphologic studies of aqueous/fluvial processes (Ryan's talk)