Wednesday, 2 March 2011

Lecture 17 – Mars spectroscopy

Reading

Ch 4.7 Forest applications

What was covered in the previous lecture

LECTURES

Jan 05 1. Intro
Jan 07 2. Images
Jan 12 3. Photointerpretation
Jan 14 4. Color theory
Jan 19 5. Radiative transfer
Jan 21 6. Atmospheric scattering
Jan 26 7. Lambert' s Law
Jan 28 8. Volume interactions
Feb 02 9. Spectroscopy
Feb 04 10. Satellites & Review
Feb 09 11. **Midterm**
Feb 11 12. Image processing
Feb 16 13. Spectral mixing
Feb 18 14. Classification
Feb 23 15. Radar & Lidar
- **Feb 25 16. Thermal infrared previous**
- **Mar 02 17. Mars spectroscopy (Matt Smith)** **today**

Mar 04 18. Forest remote sensing (Van Kane)
Mar 09 19. Thermal modeling (Iryna Danilina)
Mar 11 20. Review
Mar 16 21. **Final Exam**

Friday' s lecture

Forest remote sensing

Today's lecture:
Mars spectroscopy

Next lecture – Forest remote sensing (Guest: Dr. Van Kane, CFR)

GEOLOGIC HISTORY OF QUARTZ-BEARING DEPOSITS IN SYRTIS MAJOR, MARS

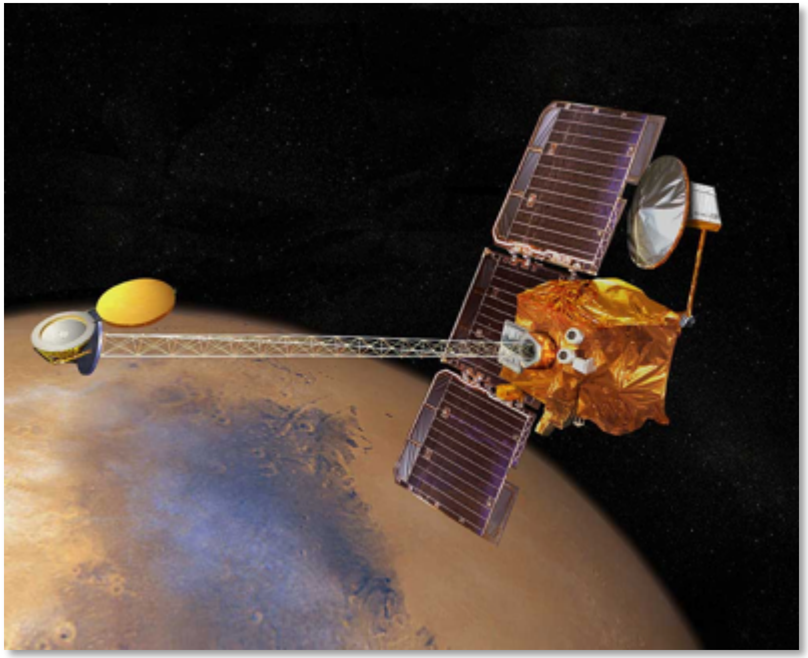
Matt Smith
University of Washington
ESS 421
March 2, 2011

MARS SPECTROSCOPY

- Rovers and satellites are the most common ways that we can observe the Martian surface

Rovers offer:

Very detailed geology
Chemistry, mineralogy, and imagery of rocks and soils
Limited mobility and range



Satellites offer:

Wide spatial coverage (regional and global)
Context for rover observations
Limited resolution and detection capability

MARTIAN ORBITAL SPECTROMETERS

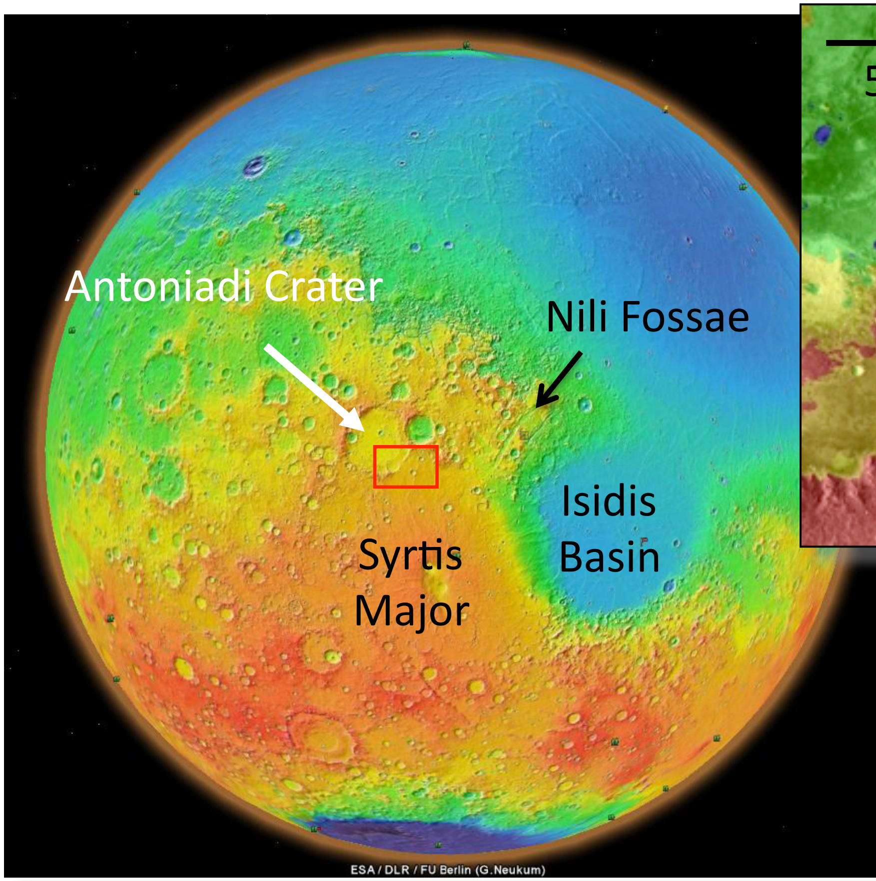
VISIBLE-NEAR INFRARED

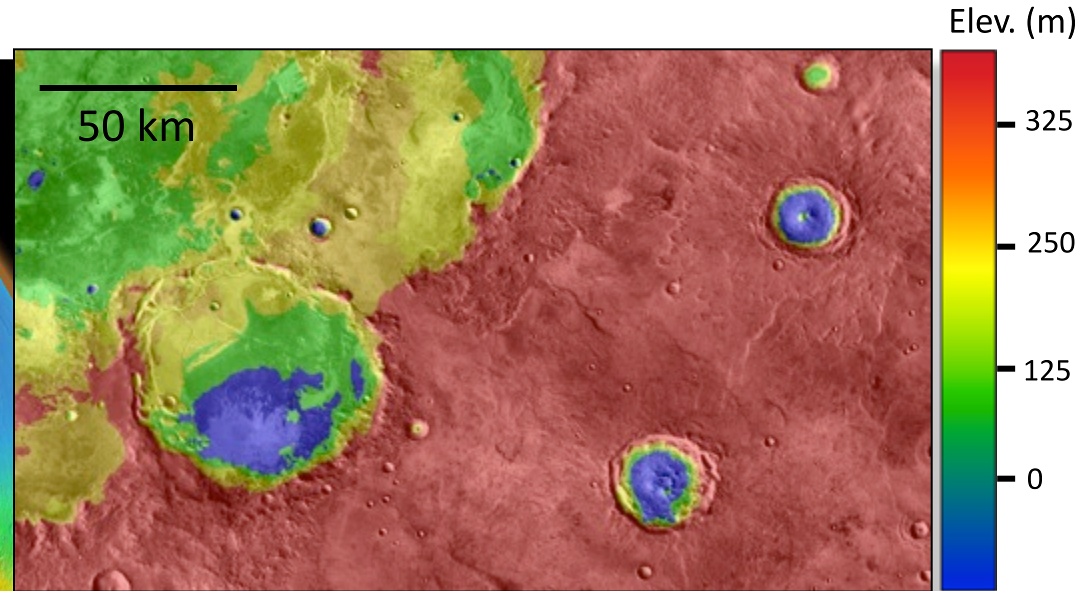
- *CRISM* (COMPACT RECONNAISANCE IMAGING SPECTROMETER FOR MARS)
  - 0.36 – 3.92 μm range, 16-20 m/pixel
  - Good for detection hydrated and iron-bearing minerals

THERMAL

- *TES* (THERMAL EMISSION SPECTROMETER)
  - 6-50 mm range, 3 km/pixel
  - Good for detecting bulk mineralogy (i.e. basalt vs. dust)
- *THEMIS* (THERMAL EMISSION IMAGING SYSTEM)
  - 10 infrared spectral bands between 6-15 mm, 100 m/pixel
  - Used to detect large mineralogical differences between units

ANTONIADI CRATER

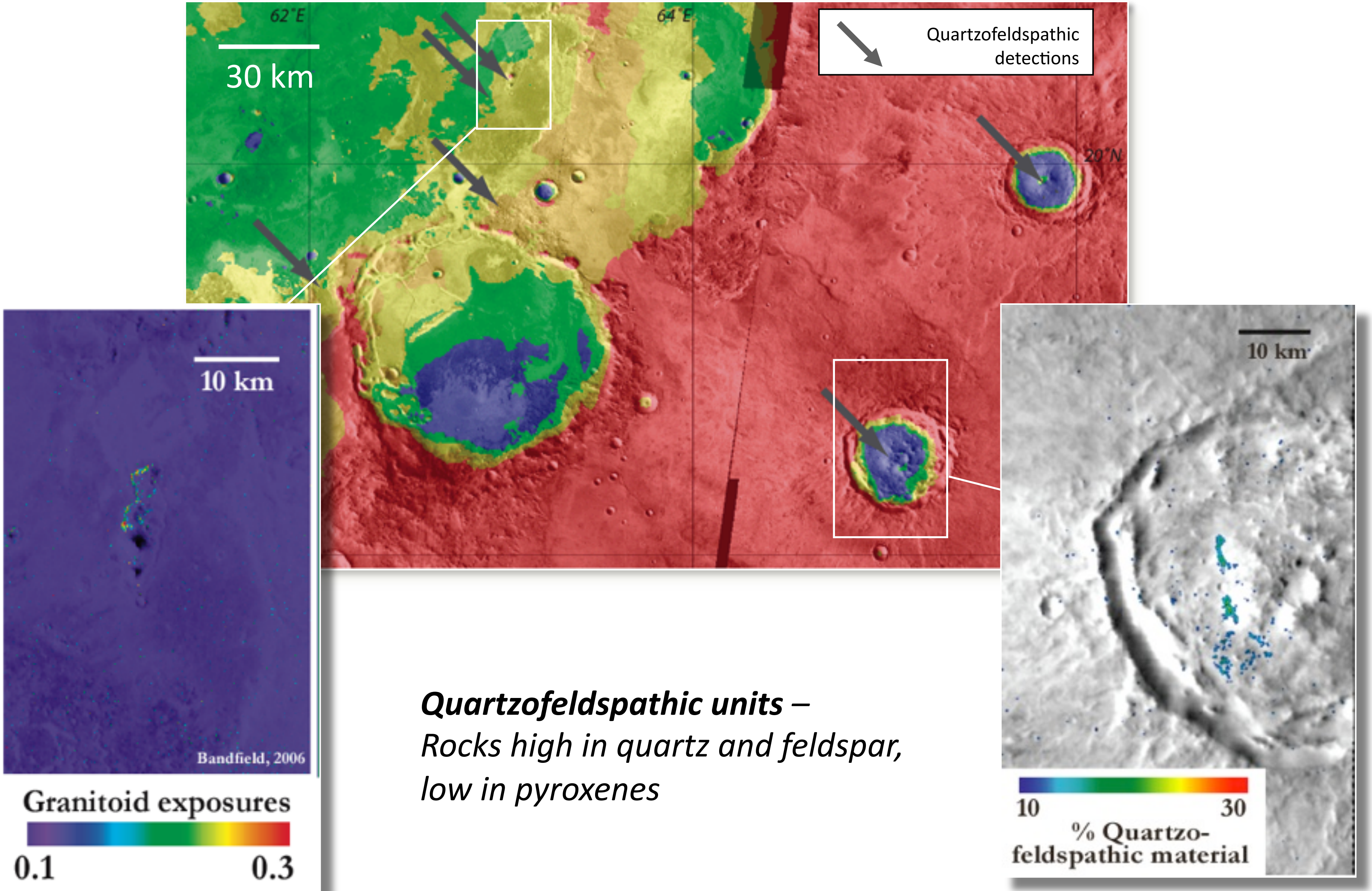




The Antoniadi Crater region has evidence of:

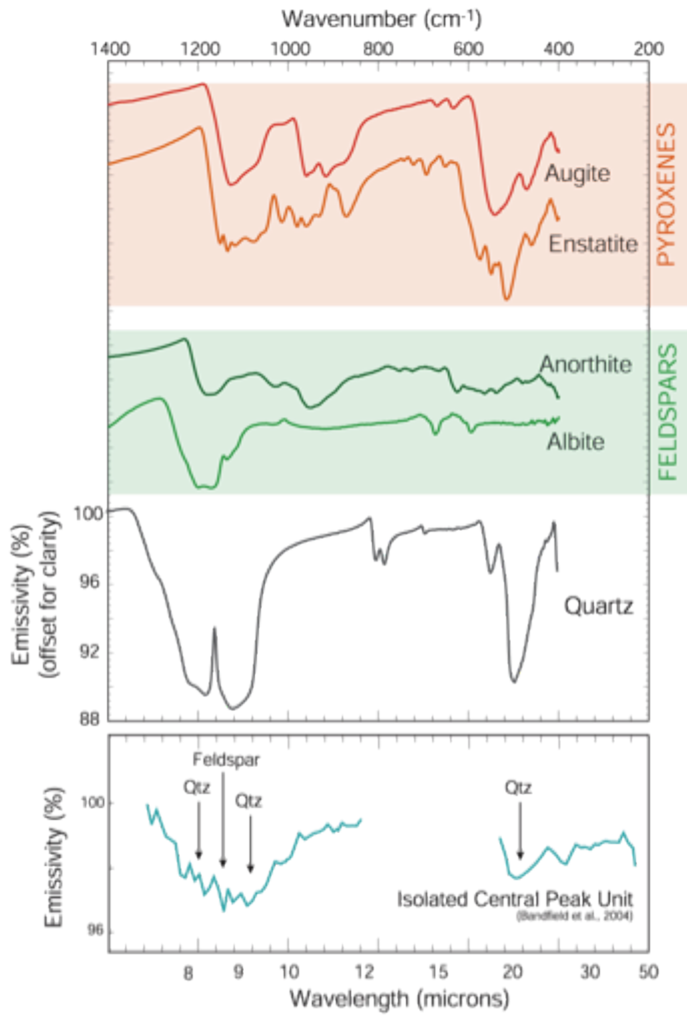
- Stable long-term water on ancient Mars
- Past volcanic activity
- Minerals (clays, quartz/silica) that indicate a hospitable and stable environment for life

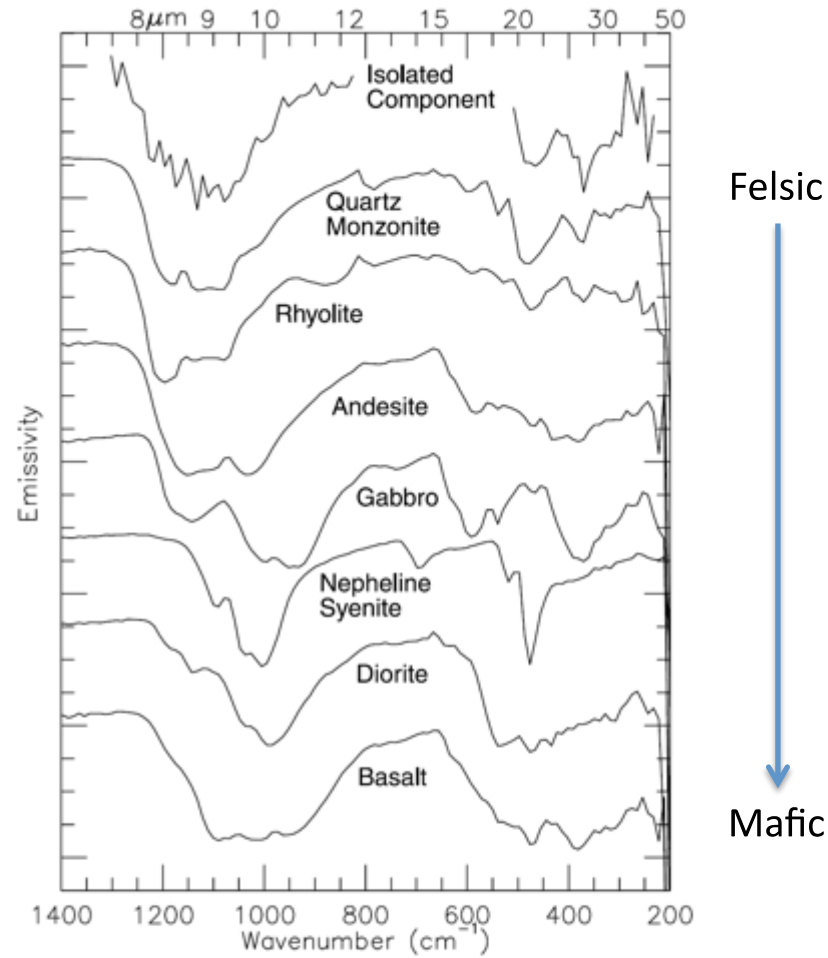
QUARTZOFELDSPATHIC UNITS



Quartzofeldspathic units – *Rocks high in quartz and feldspar, low in pyroxenes*

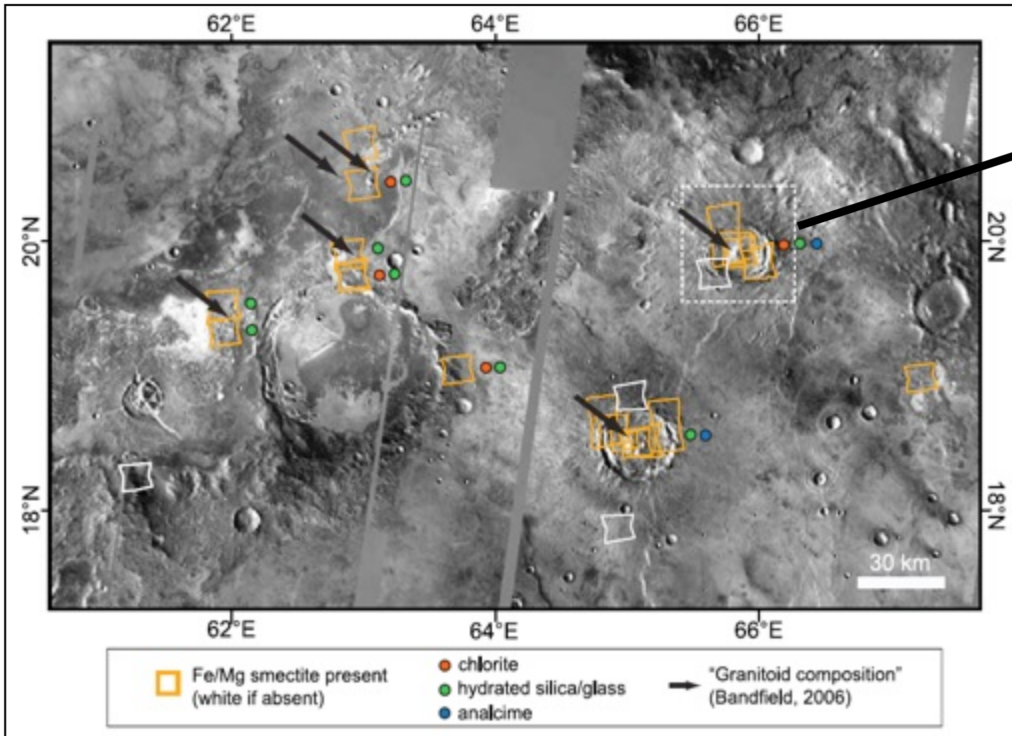
QUARTZOFELDSPATHIC DETECTION

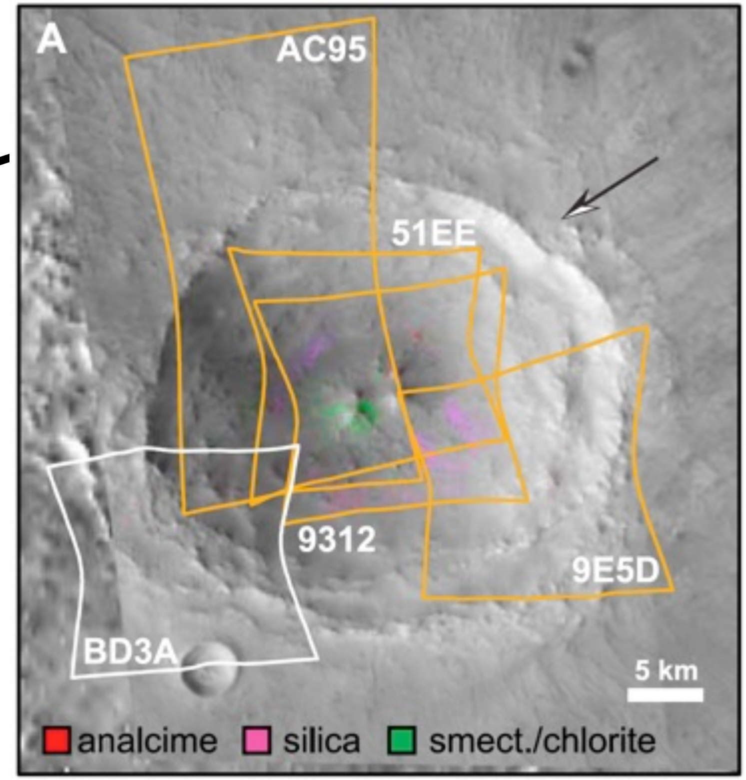




Bandfield et al., 2004

HYDRATED MINERALS





Ehlmann et al., 2009

Identification of hydrous alteration products with CRISM:
hydrated silica, phyllosilicates (smectite, chlorite), and zeolites (analcime)

MOTIVATION FOR STUDYING ANTONIADI CRATER

Locally

- Why do we find these minerals (quartzofeldspathic unit, hydrated silica and phyllosilicates) together?
- What does their location imply for past water, temperature, or life?

Regionally

- How do these deposits correspond to nearby Nili Fossae?

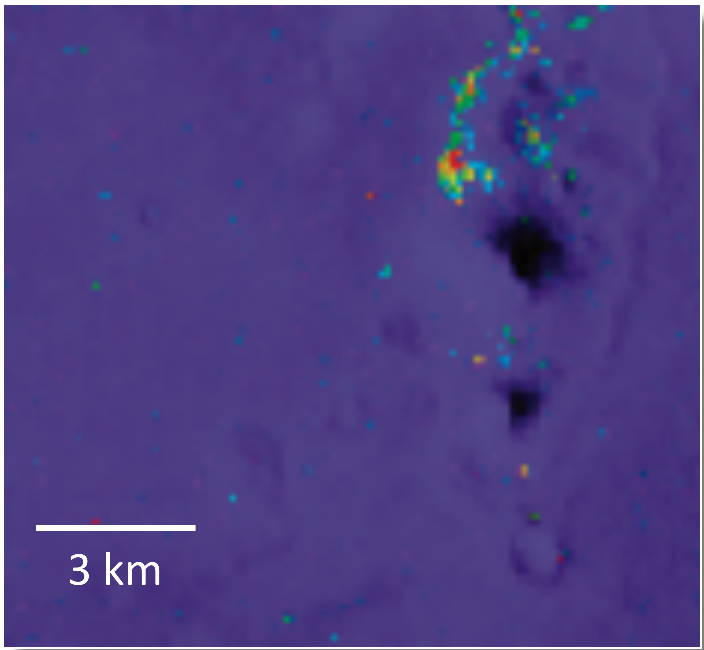
Globally

- Are these deposits similar to other mineral detections on the planet?

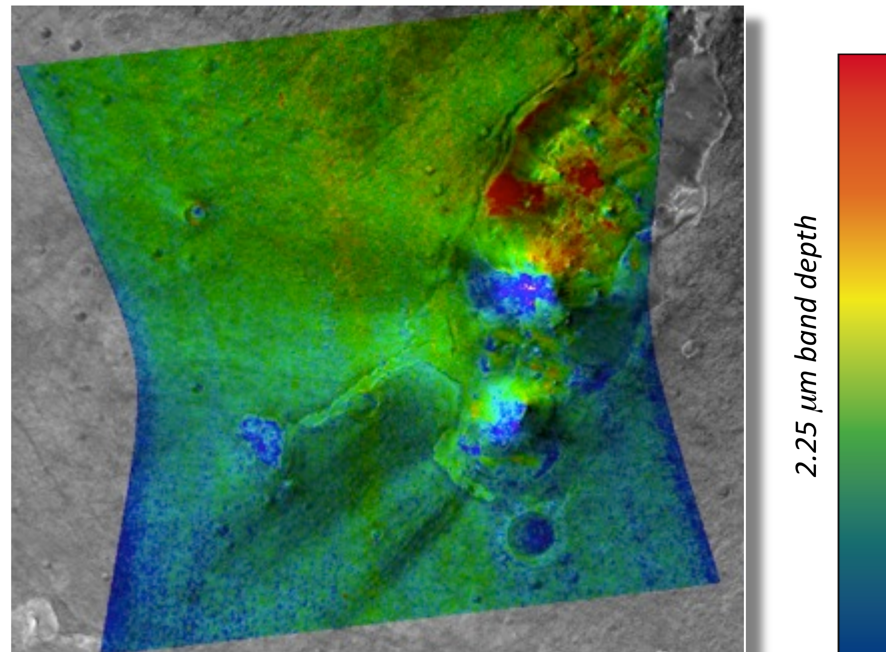
DESCRIPTION OF EXPOSURES:
QUARTZOFELDSPATHIC/HYDRATED SILICA UNITS

- All exposures of quartzofeldspathic material are found coincident with hydrated silica
- Silica-bearing units are in thin, mobile, dune-forming deposits in topographic lows
- Intensity of detection *increases* away from source, suggesting a lag deposit
- In shallowest fractures, only hydrated silica (no phyllosilicates) is detected, indicating shallower burial

SILICA-BEARING UNITS



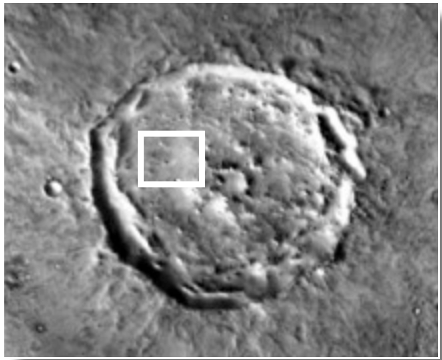
Quartzofeldspathic detection
(*Bandfield et al.,* 2004)

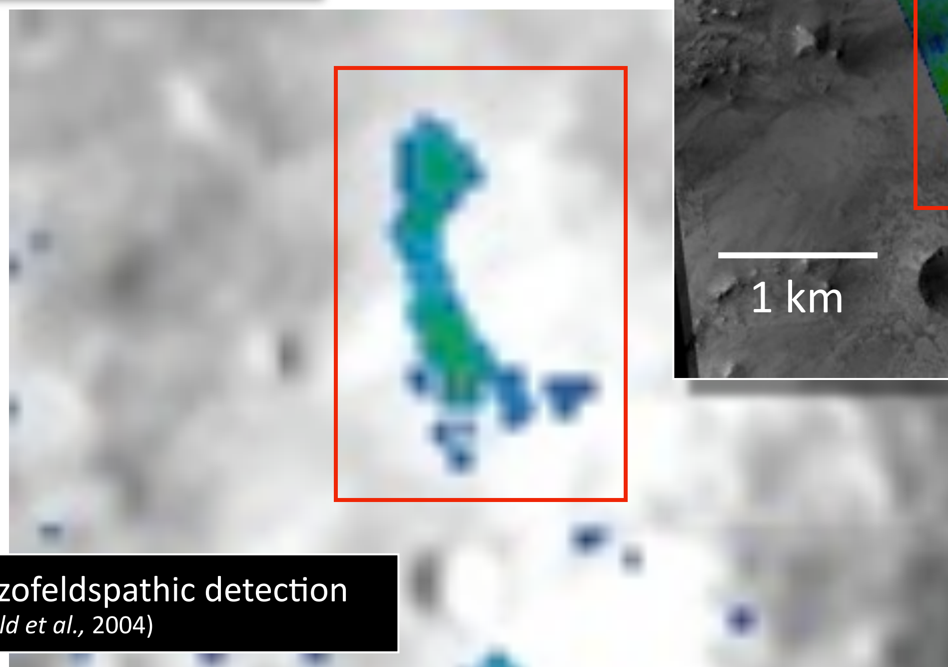


Hydrated silica detection

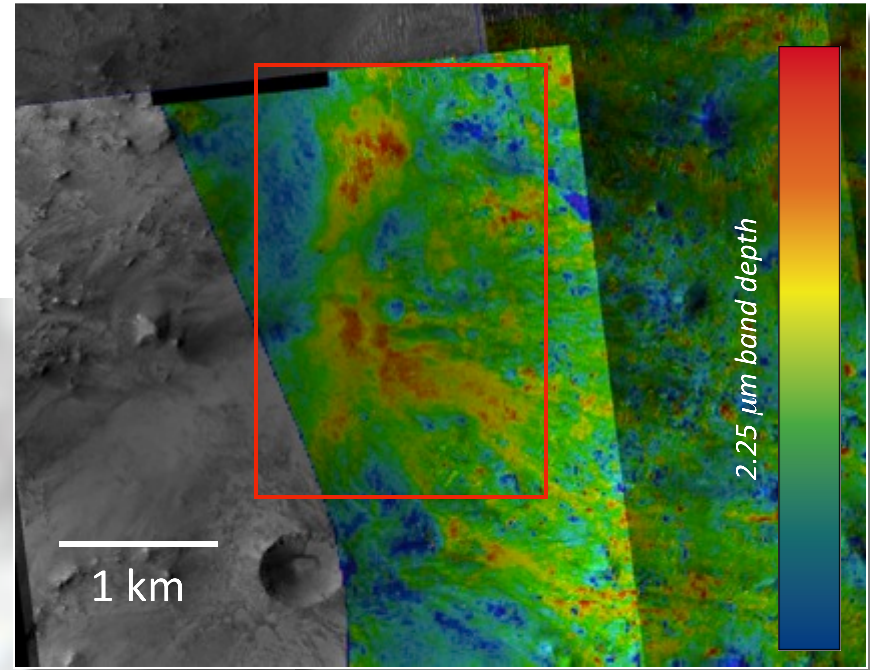
Quartzofeldspathic and hydrated silica units are co-located

SILICA-BEARING UNITS





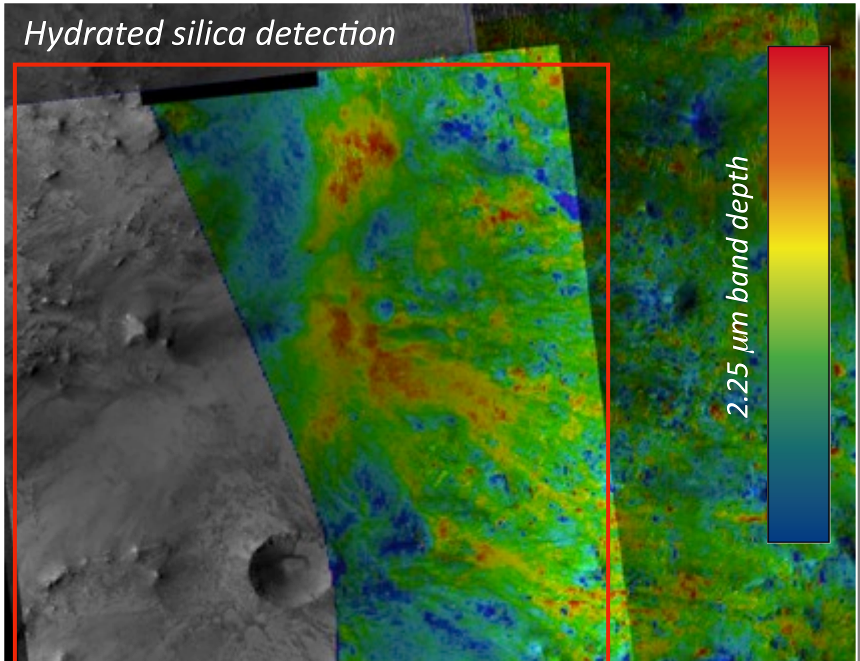
Quartzofeldspathic detection
(*Bandfield et al.*, 2004)



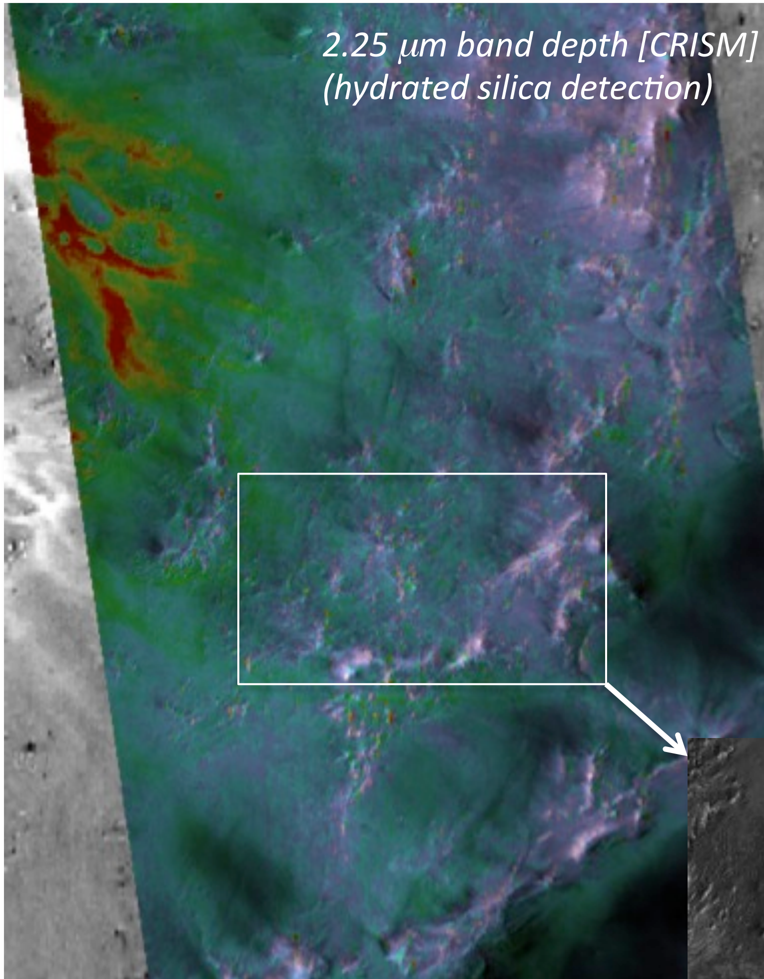
Hydrated silica detection

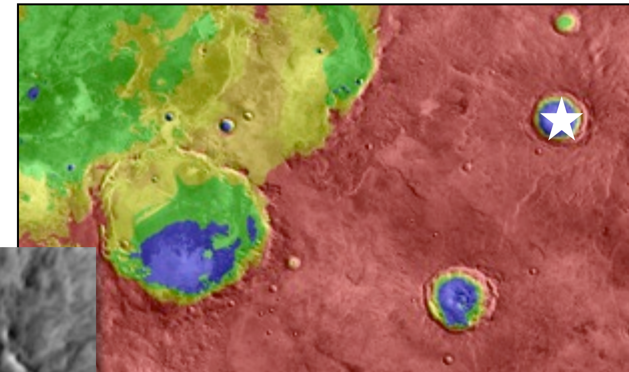
Quartzofeldspathic and hydrated silica units are co-located

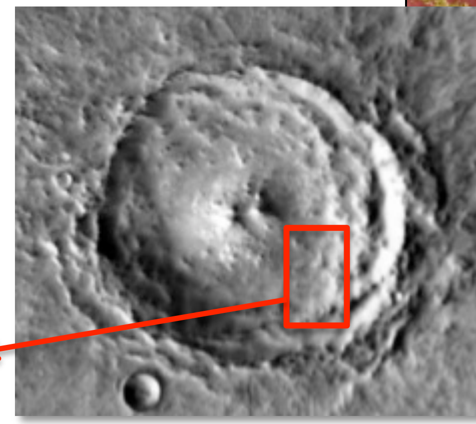
SILICA-BEARING UNITS

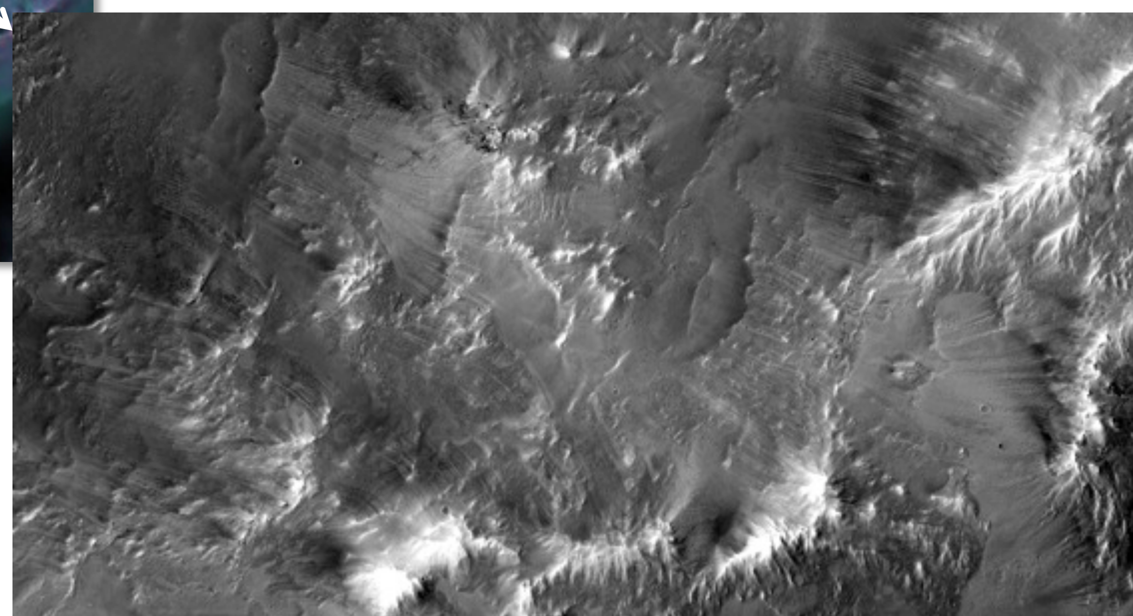


Hydrated silica/quartzofeldspathic units are associated with mobile, dune-forming units



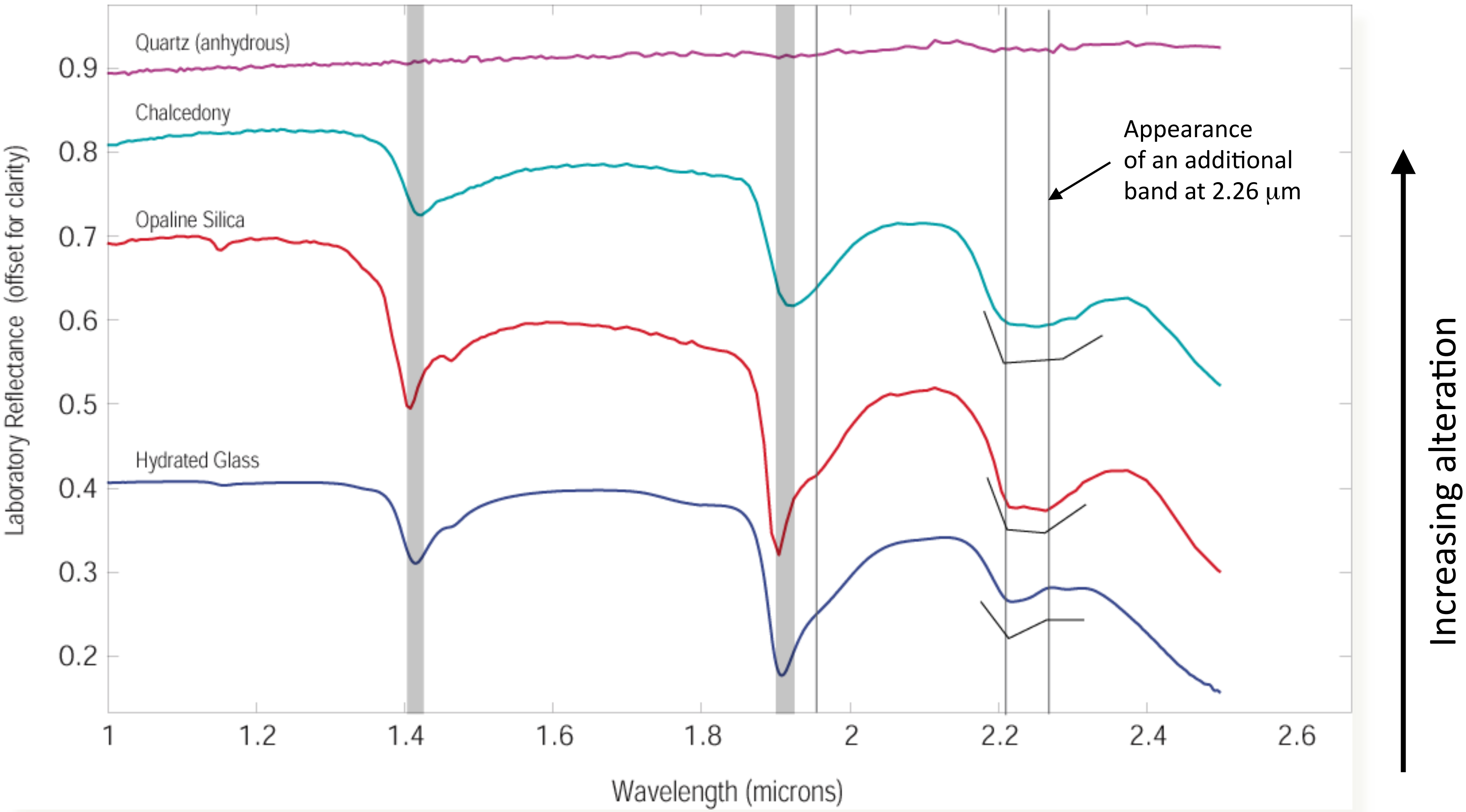






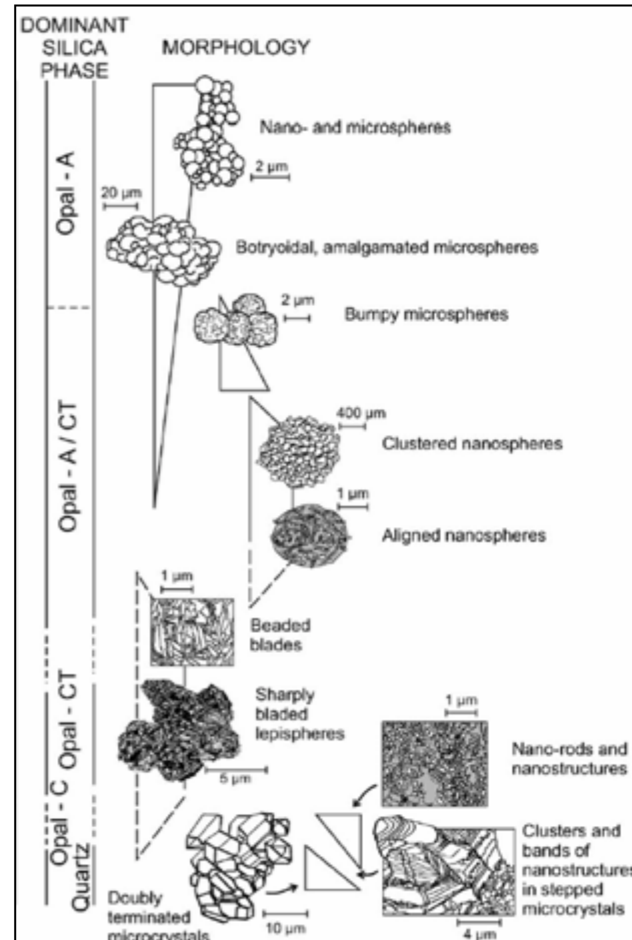
There is no obvious source stratum, and silica detection intensifies downslope, suggesting that this is a ***lag deposit***

HYDRATED SILICA



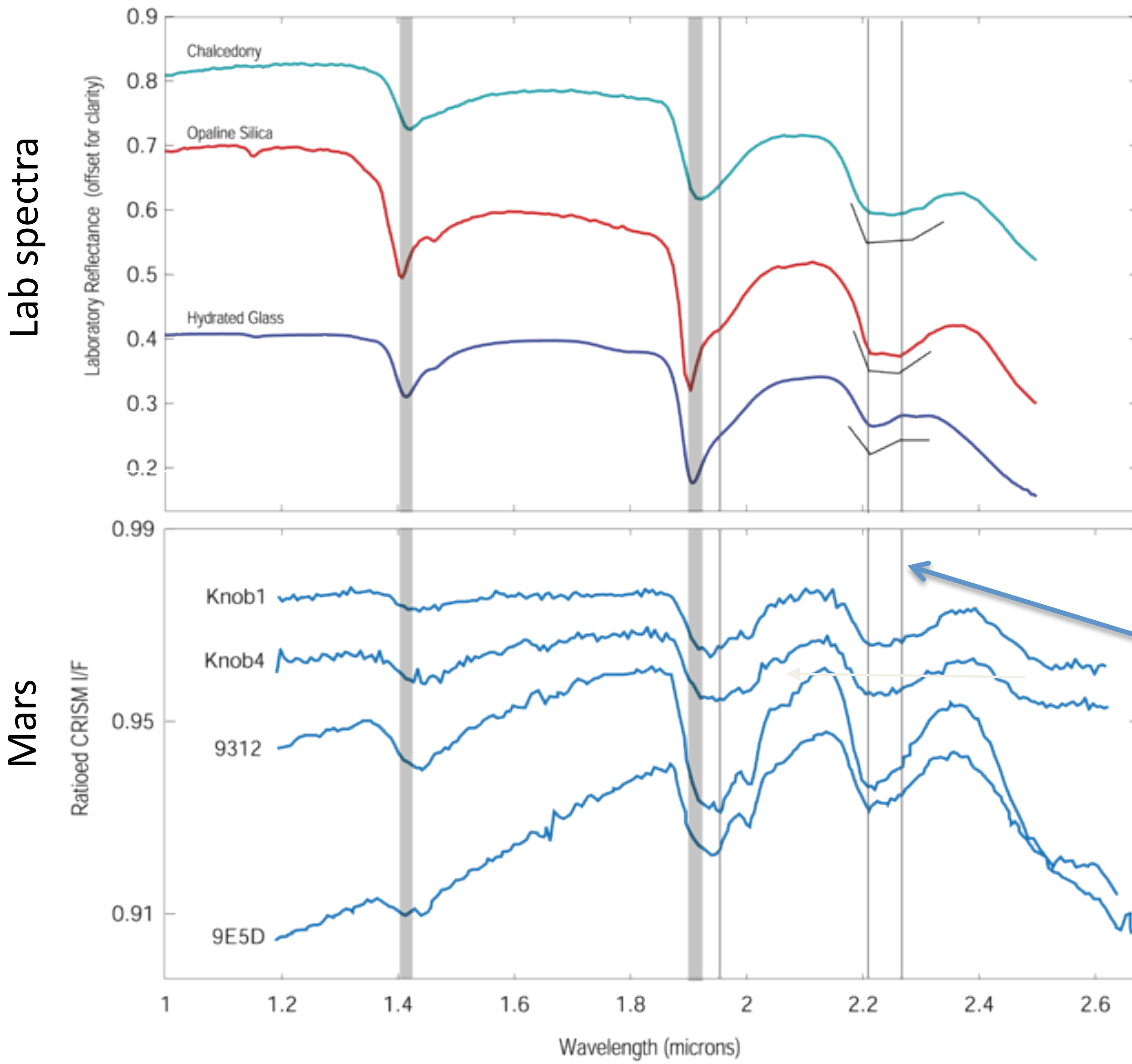
HYDRATED SILICA

- Forms under low temperature (<150°C) conditions on Earth, and typically found in near-surface environments (*Roberts et al.*, 1974)
- Alters to microcrystalline quartz (chalcedony) in the presence of water (*Lynne et al.*, 2005) in relatively short time scales; ~400 Ma (*Tosca and Knoll*, 2009)



Lynne et al., 2005

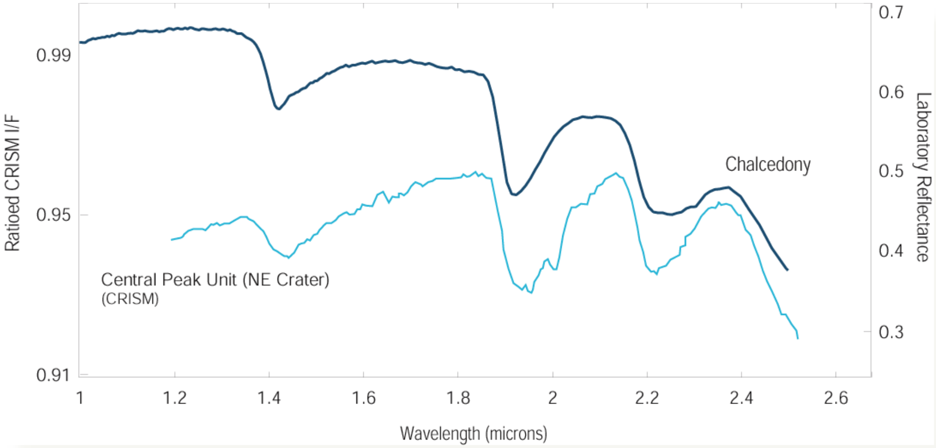
HYDRATED SILICA



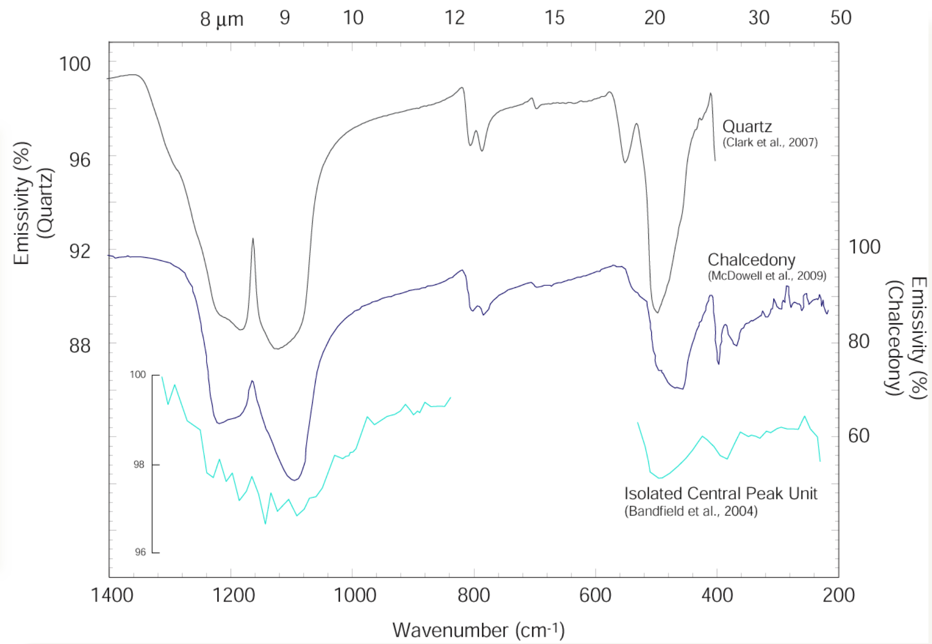
2.26 μm band indicates the presence of chalcedony (more heavily altered)

QUARTZ + HYDRATED SILICA = CHALCEDONY

Near-infrared



Thermal



Chalcedony indicates higher degree of alteration than opaline silica and locally *sustained* water (up to 400 Ma) in moderate (<150°C) temperatures

DESCRIPTION OF EXPOSURES: *PHYLLOSILICATES*

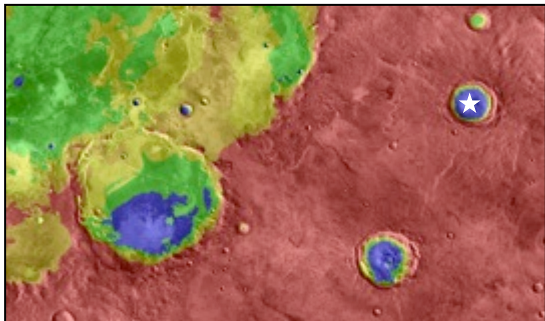
– CRISM detections of phyllosilicates are found mostly in megabreccia blocks

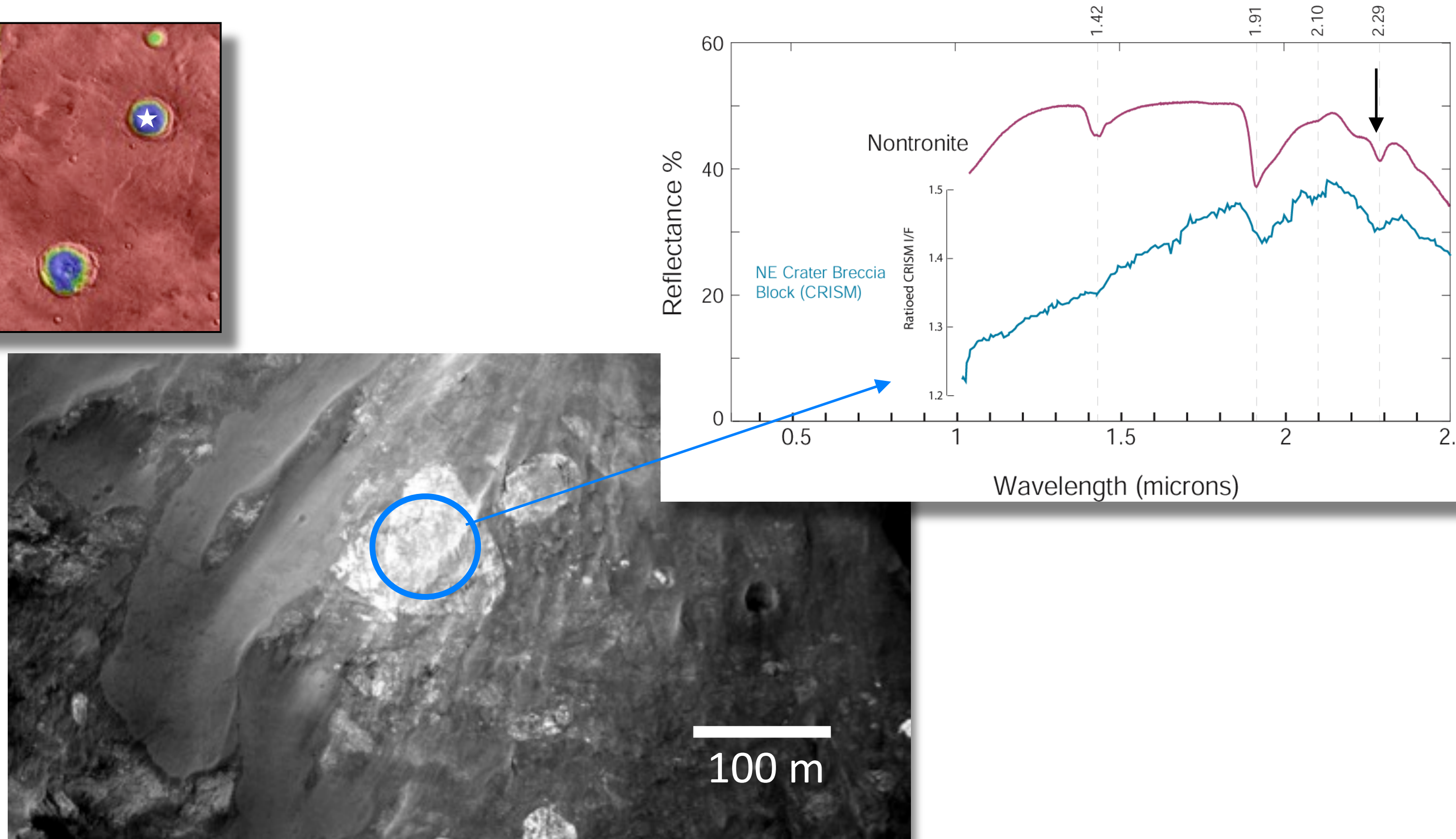
– Clays also associated with layered knobs (possibly ancient layered impact breccias)

– Detections of phyllosilicates are **not** mixed with hydrated silica

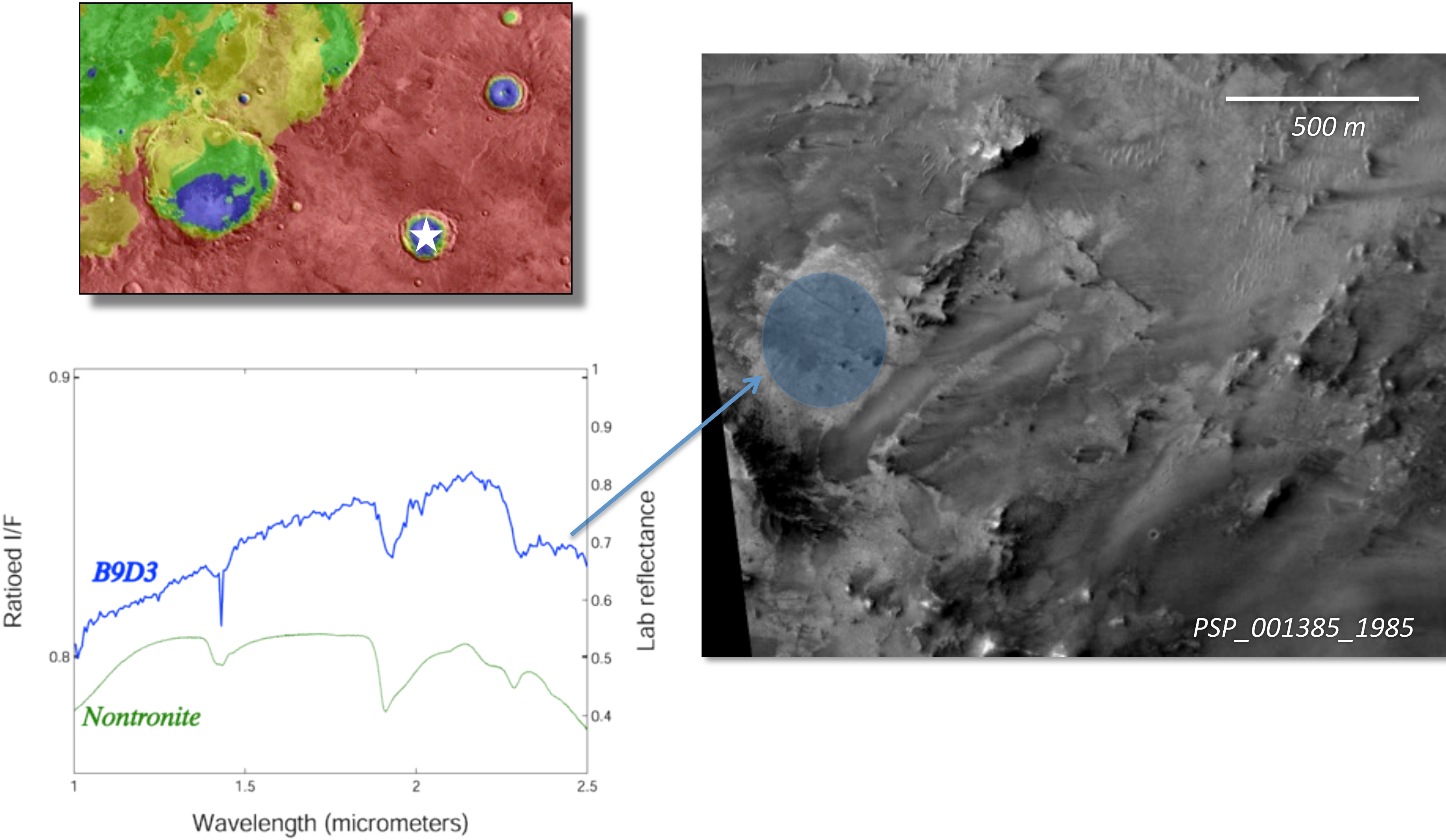
PHYLLOSILICATES

– Most exposures are in impact breccia clasts in crater central peaks and floors





Indicates that alteration ***pre-dates*** and is exposed by the impact event



0.9
0.8
1
0.9
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Ratioed I/F
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Wavelength (micrometers)
500 m
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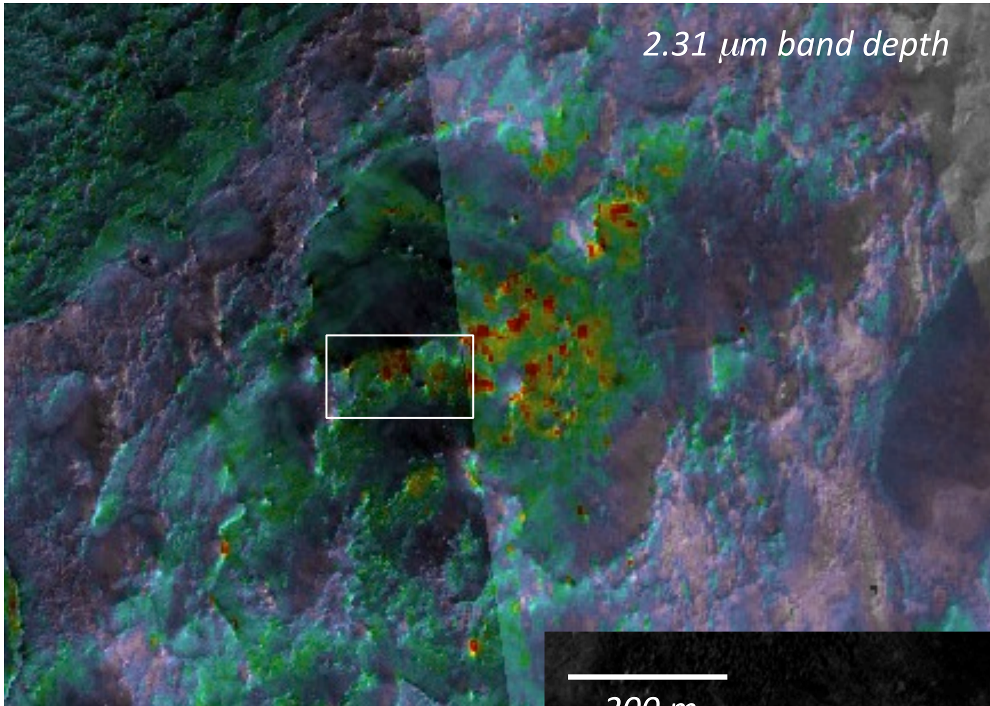

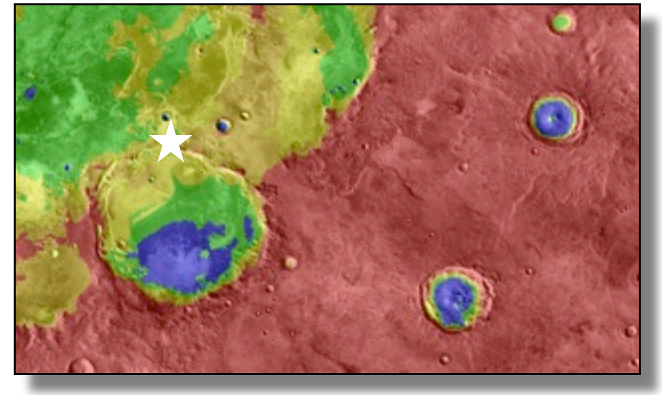

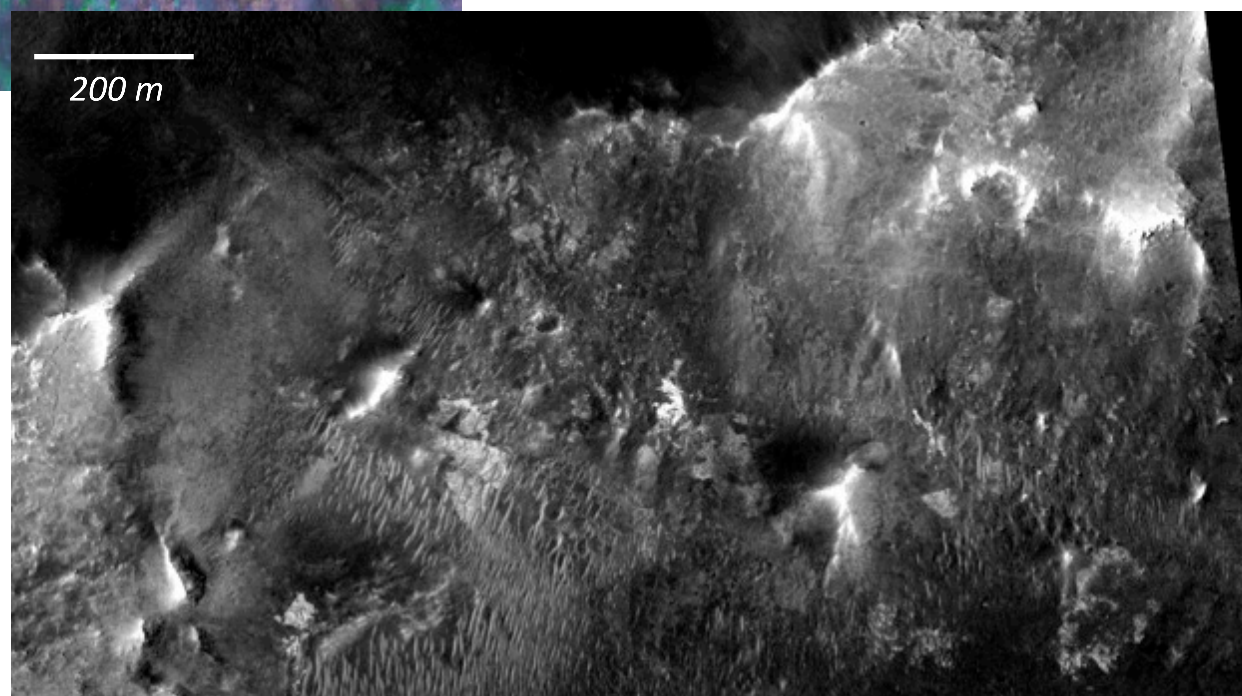

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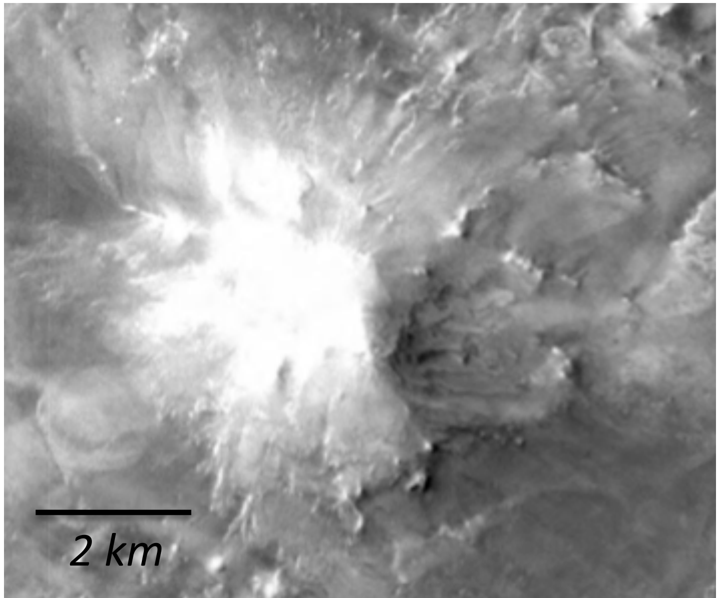

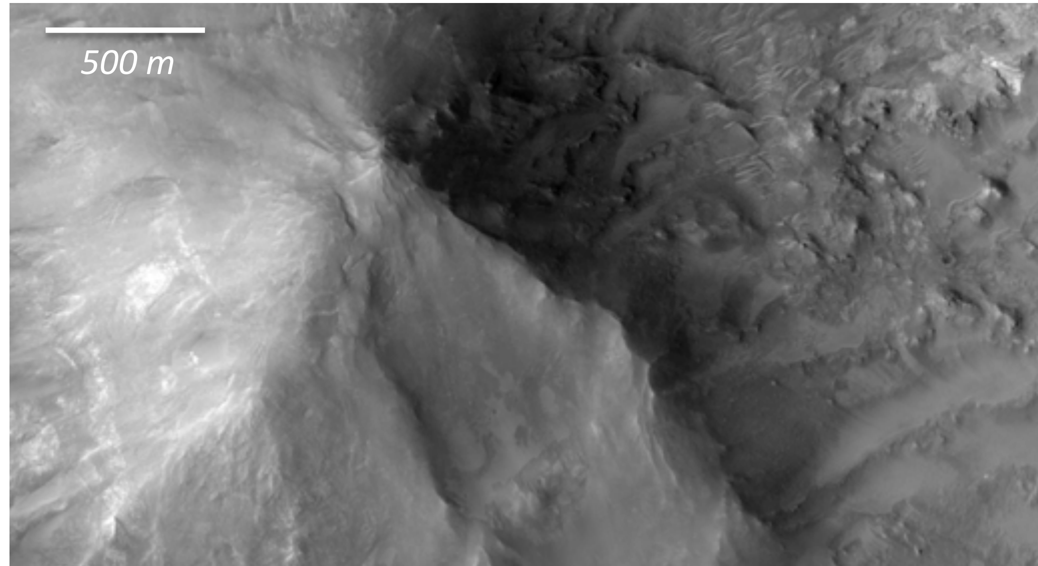

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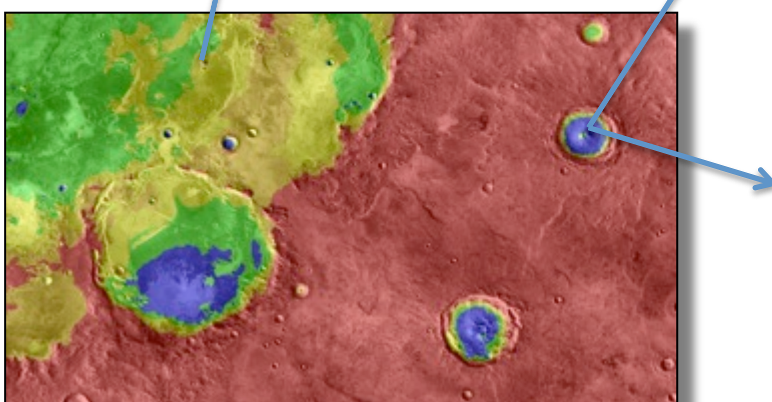

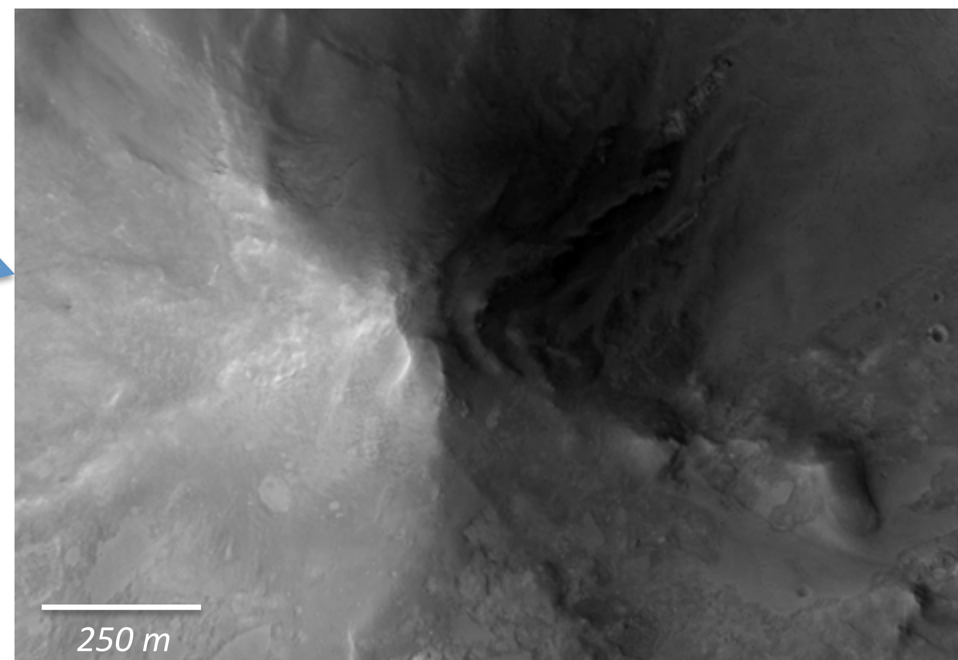

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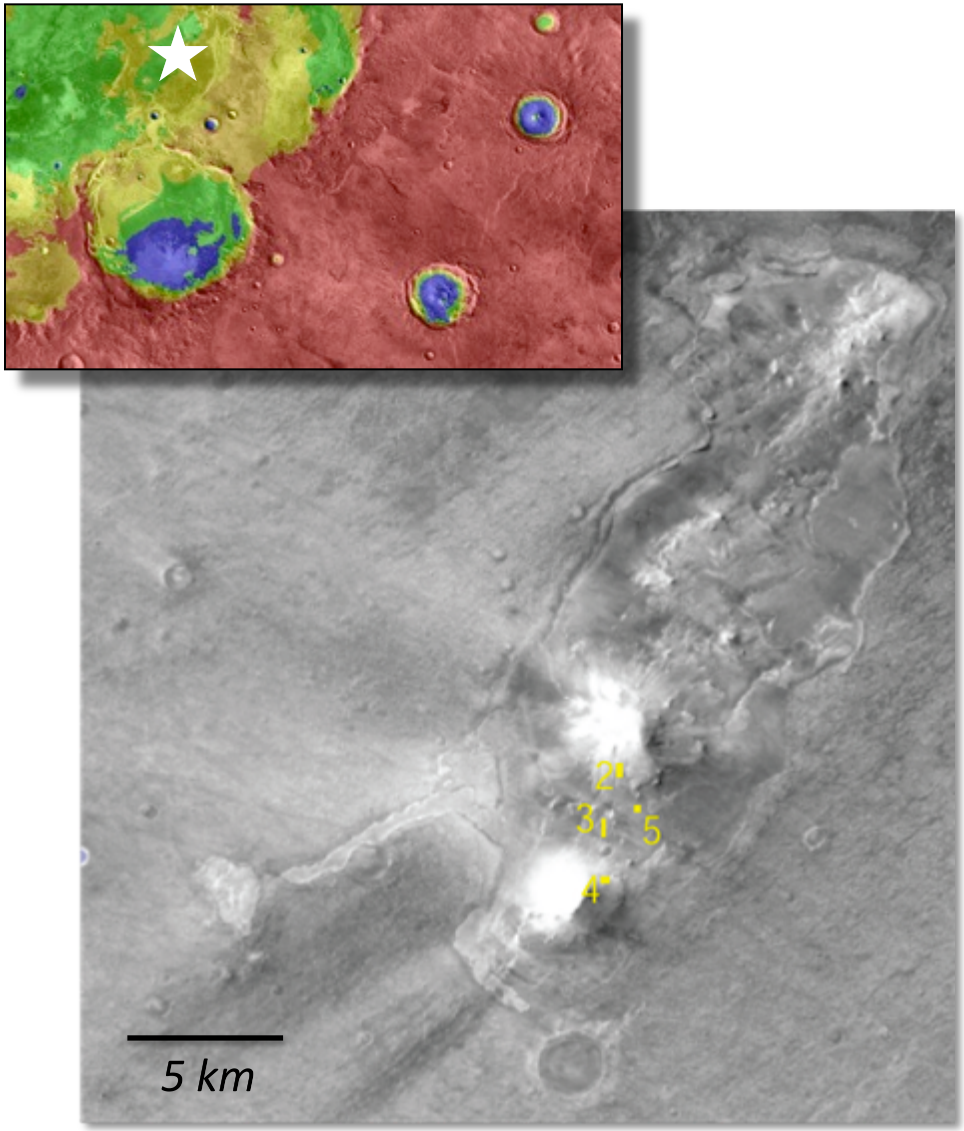
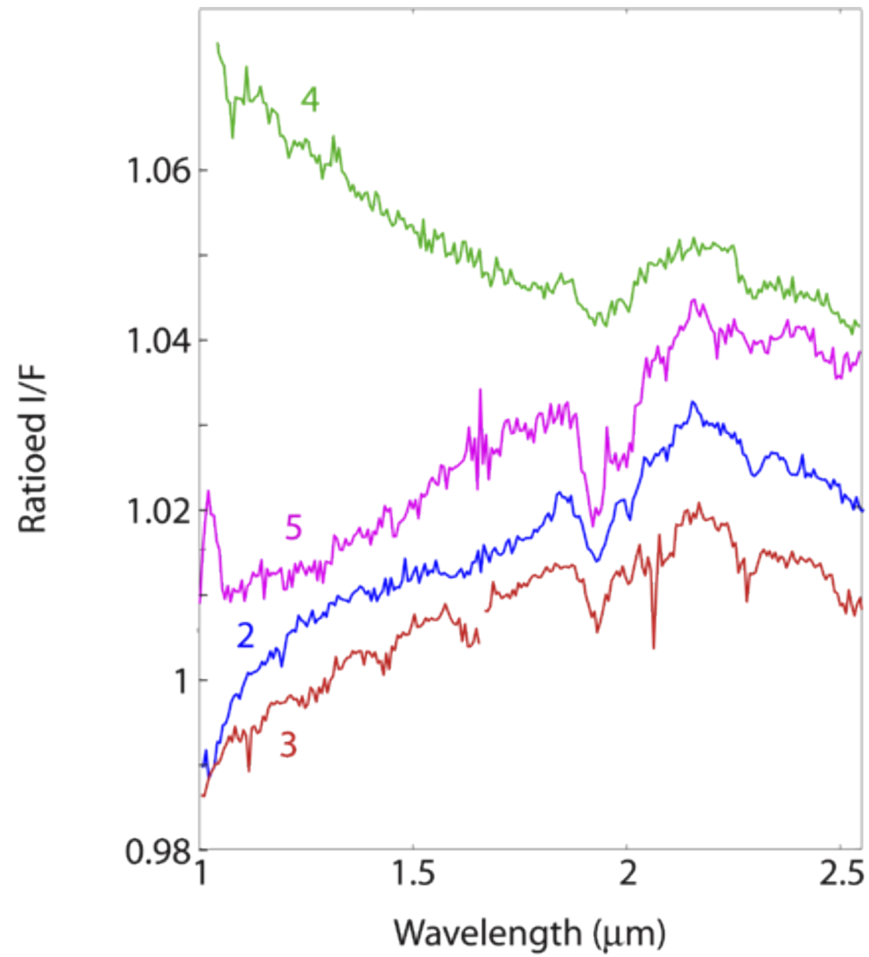
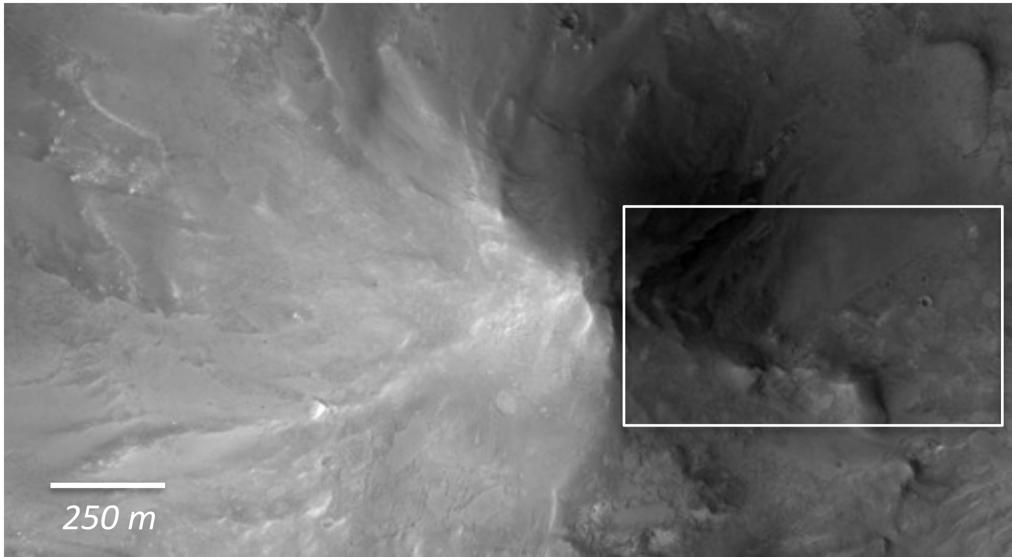
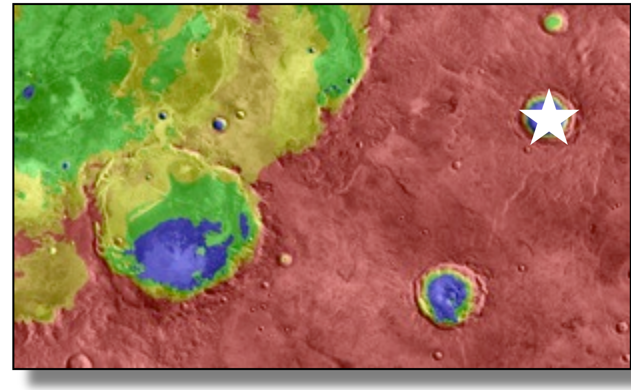
Layered knobs

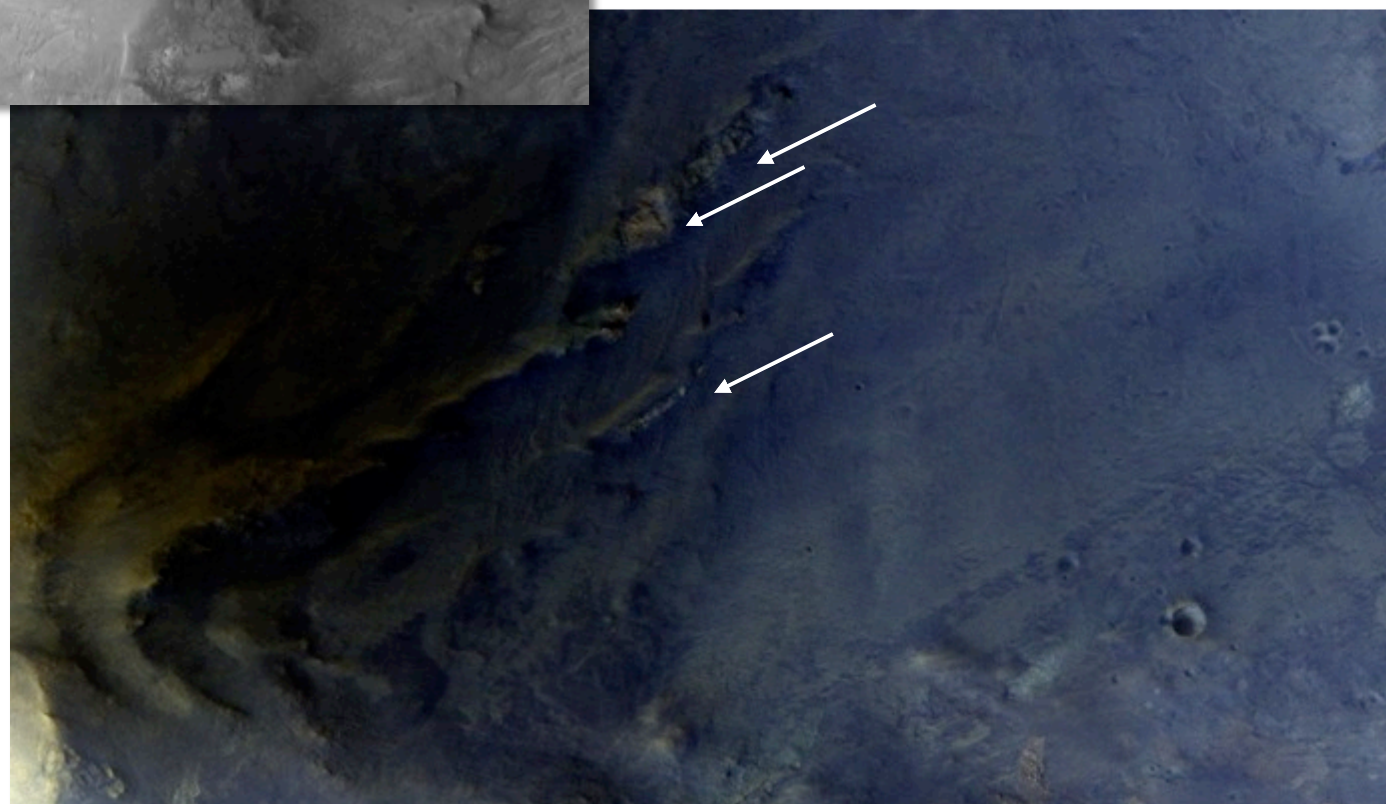
PHYLLOSILICATES IN LAYERED KNOBS



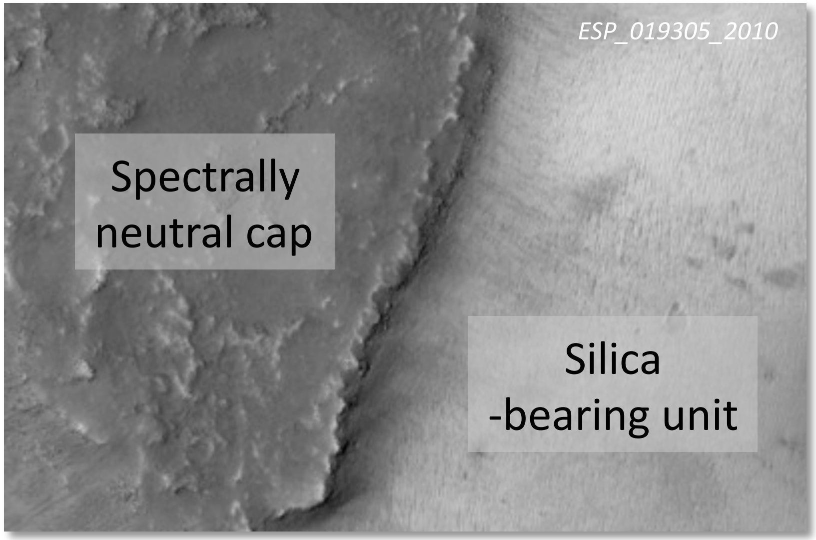


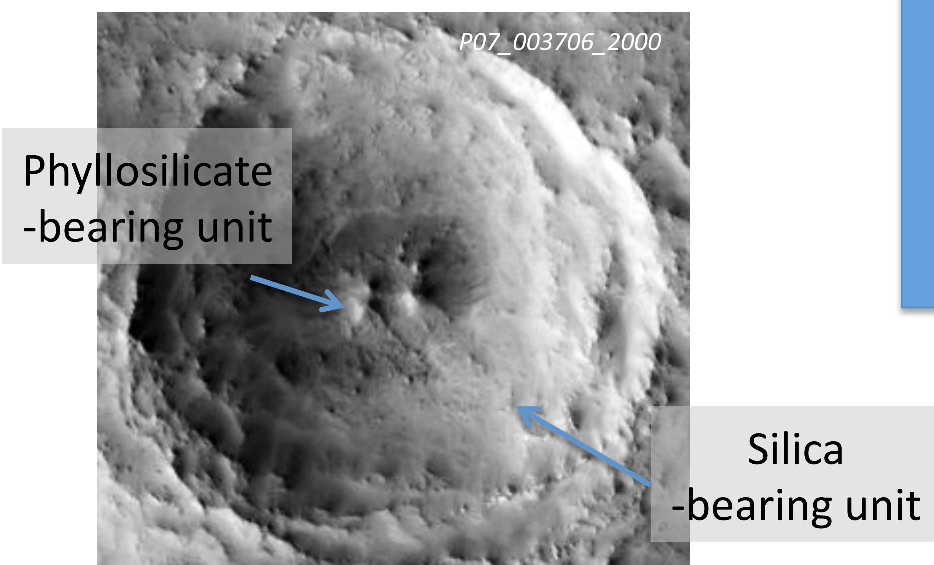

250 m

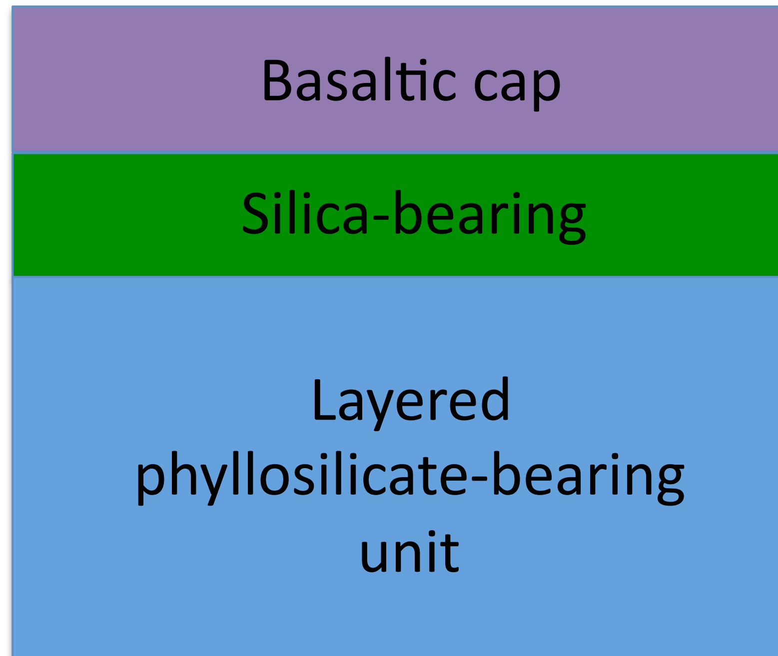


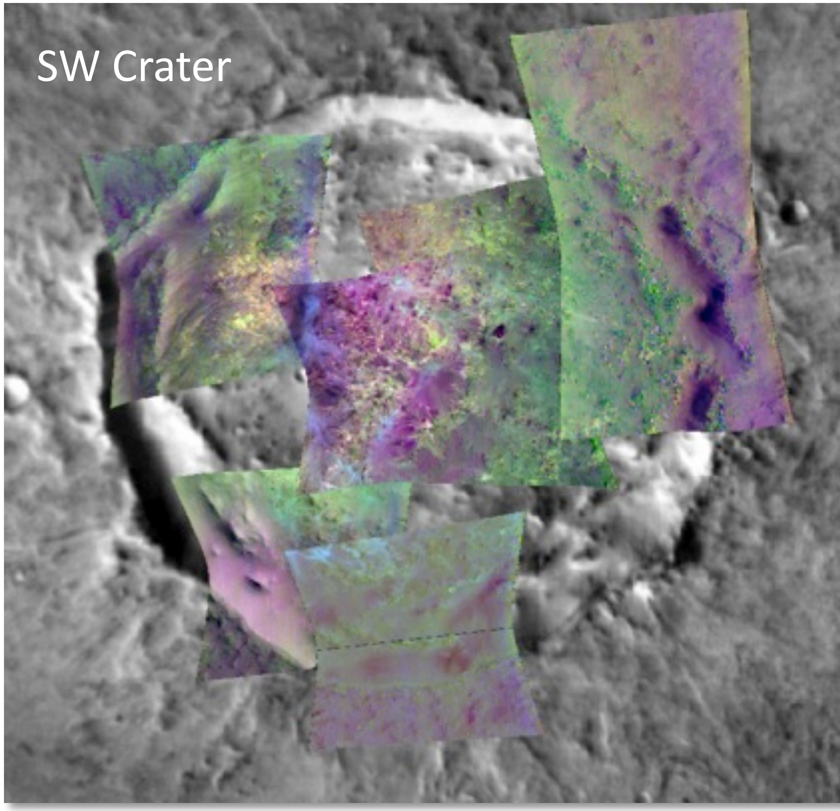


ANTONIADI CROSS-SECTION

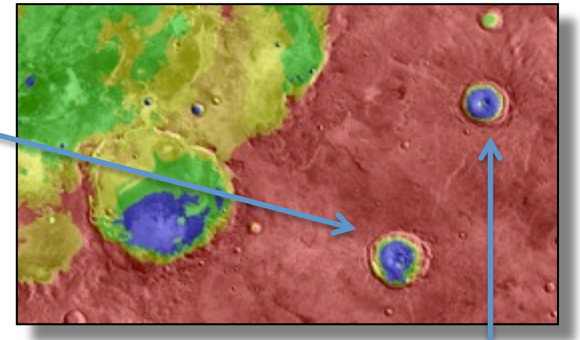


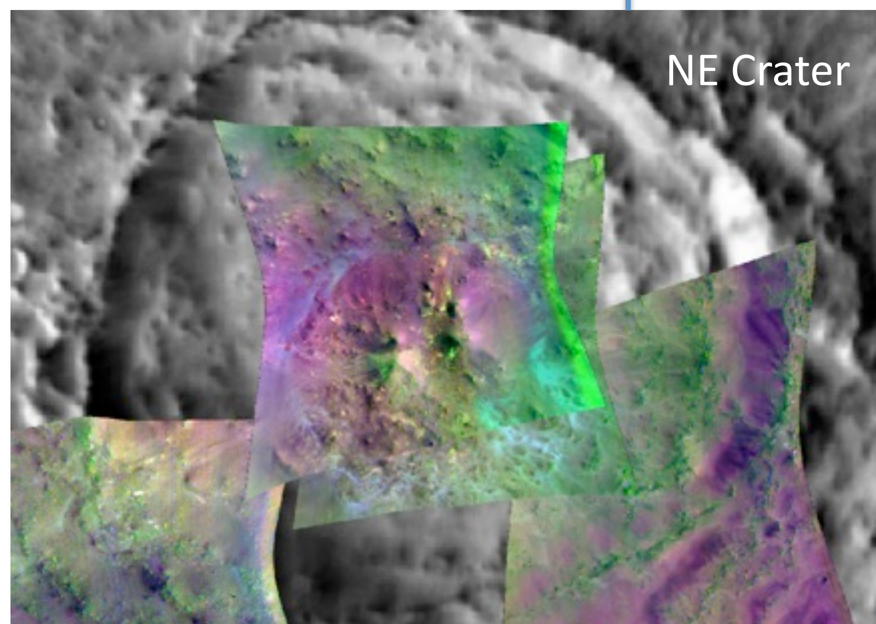


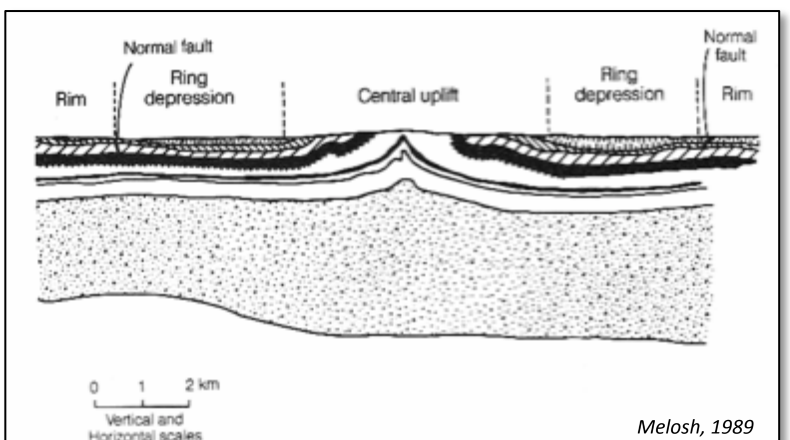




Blue = hydrated silica

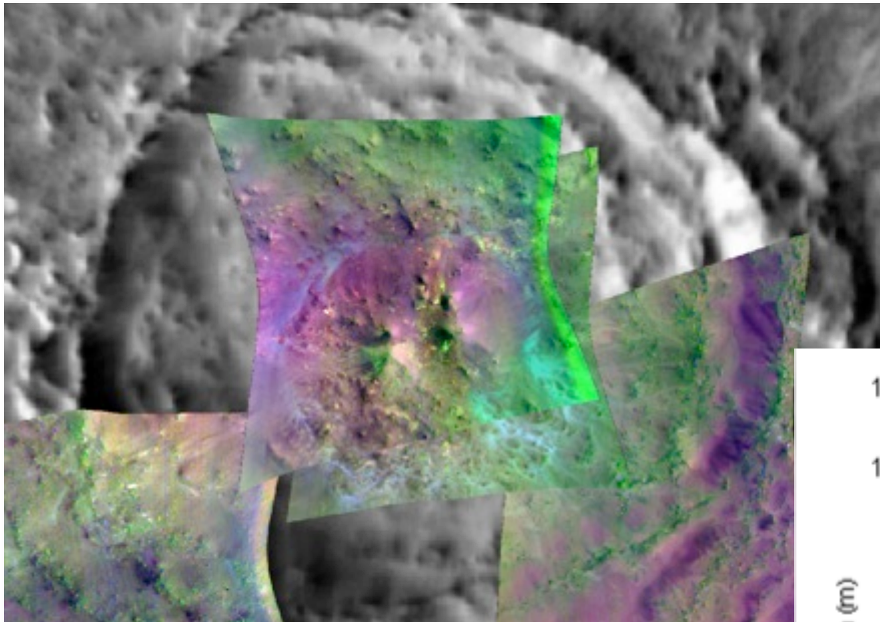


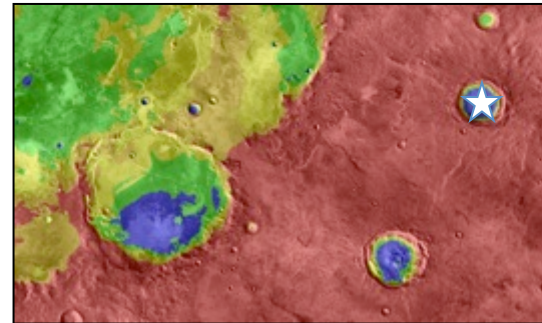


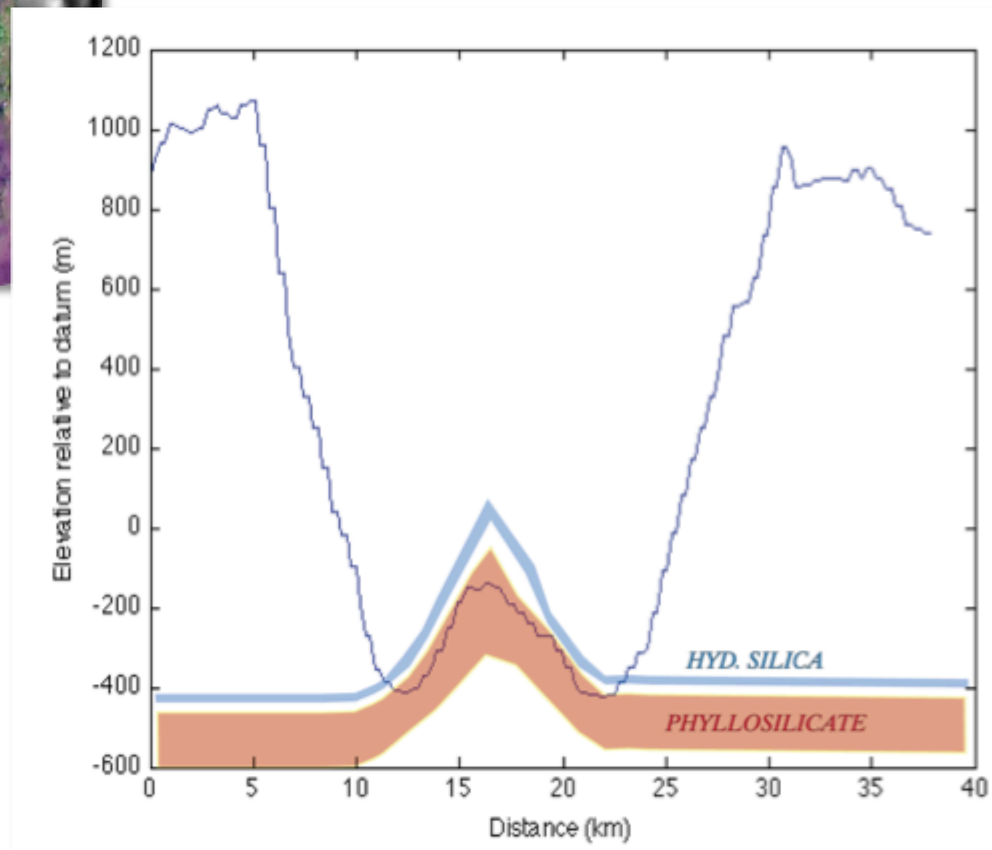


Centrally uplifted rocks are sourced from the deepest strata

NORTHEAST CRATER



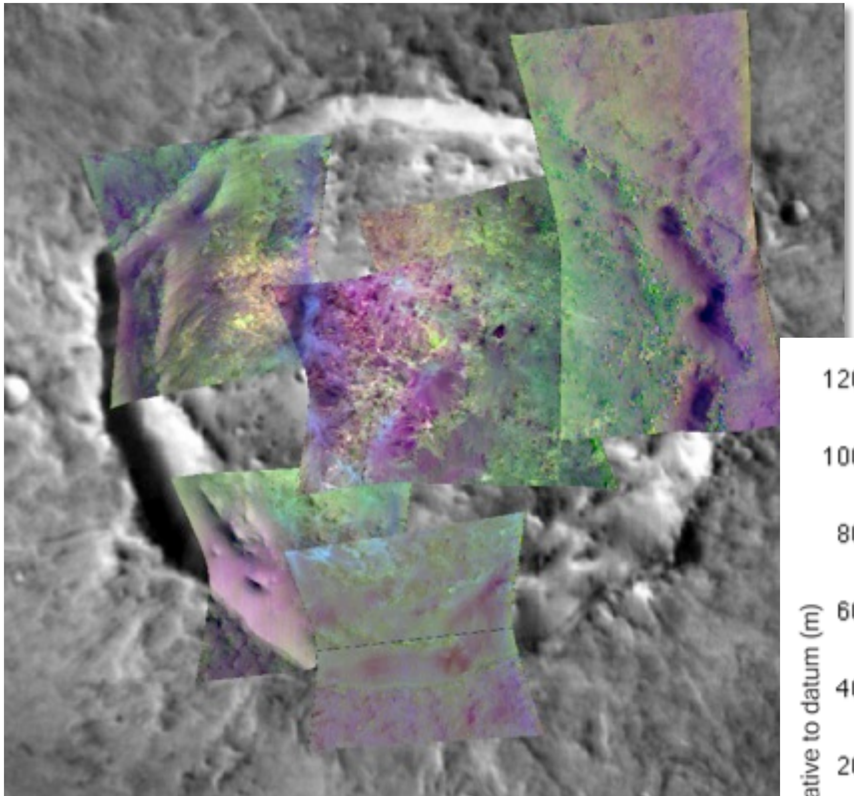


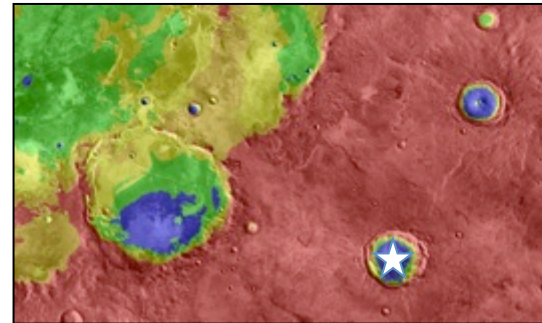


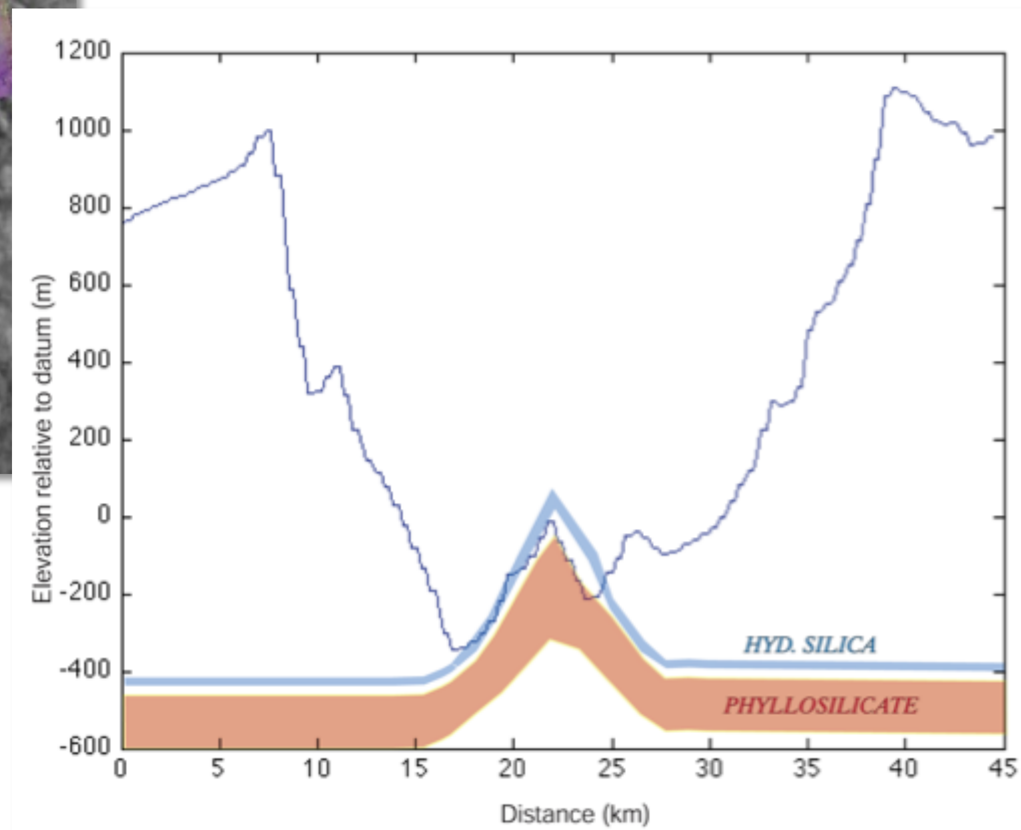
Hydrated silica is emerging from the walls, not from the central peak

Phyllosilicates exposed in the central peak are mostly detected in pre-existing layered terrain

SOUTHWEST CRATER



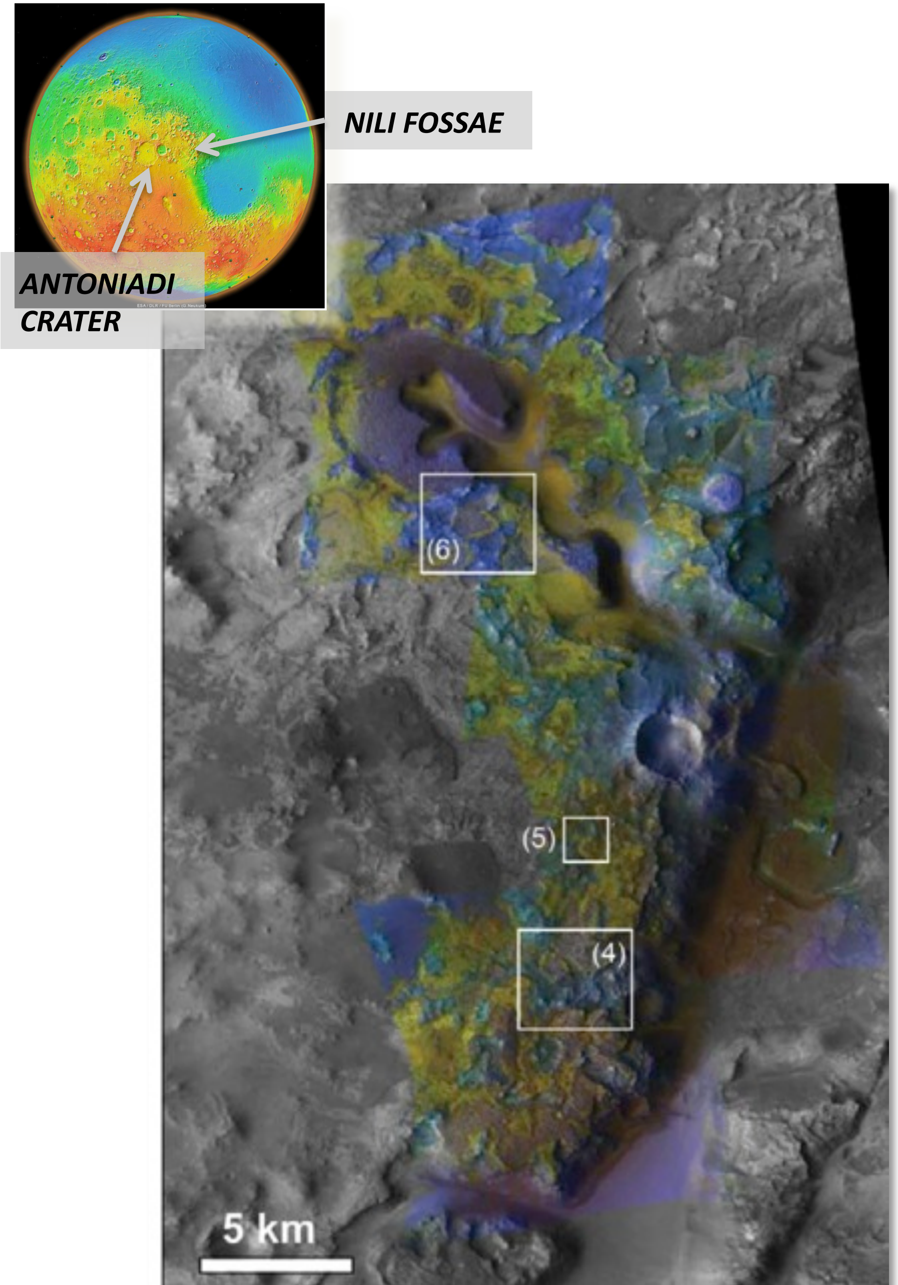




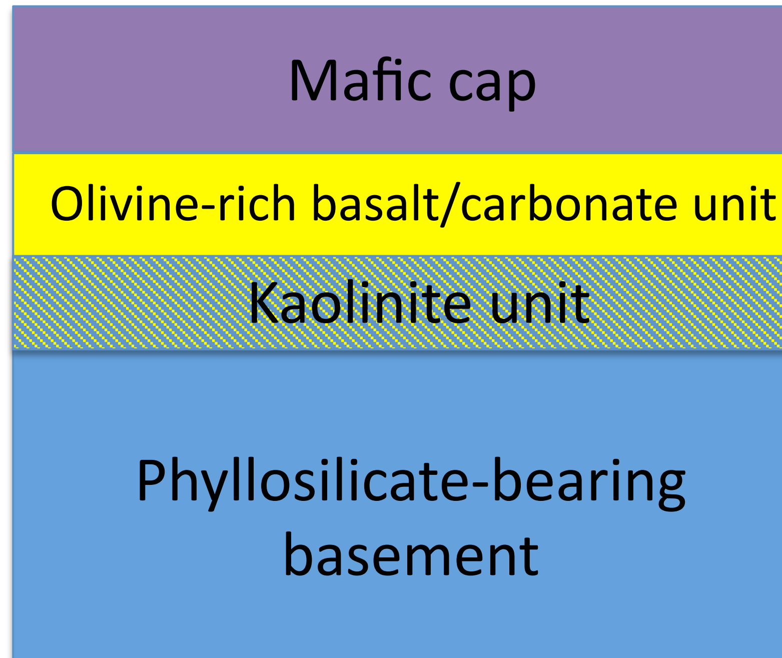
Hydrated silica is eroding from the central peak, instead of the walls

Phyllosilicates are found entirely in isolated blocks ringing the central peak, excavated during the impact process

REGIONAL CONTEXT: *NILI FOSSAE*



Mustard et al., 2009



Olivine-bearing unit is inferred to be impact melt from nearby Isidis impact

NILI FOSSAE AND ANTONIADI CRATER

- Pre-Isidis phyllosilicate-bearing basement is consistent between sites

However,

- *Isidis* contains an olivine/carbonate- and kaolinite-bearing layer, denoting a second and more extensive diagenetic event
- *Antoniadi* has a secondary-quartz-bearing unit, also suggesting extended periods of alteration

Differences in *protolith* composition can account for these differing mineralogical expressions of alteration

GLOBAL CONTEXT

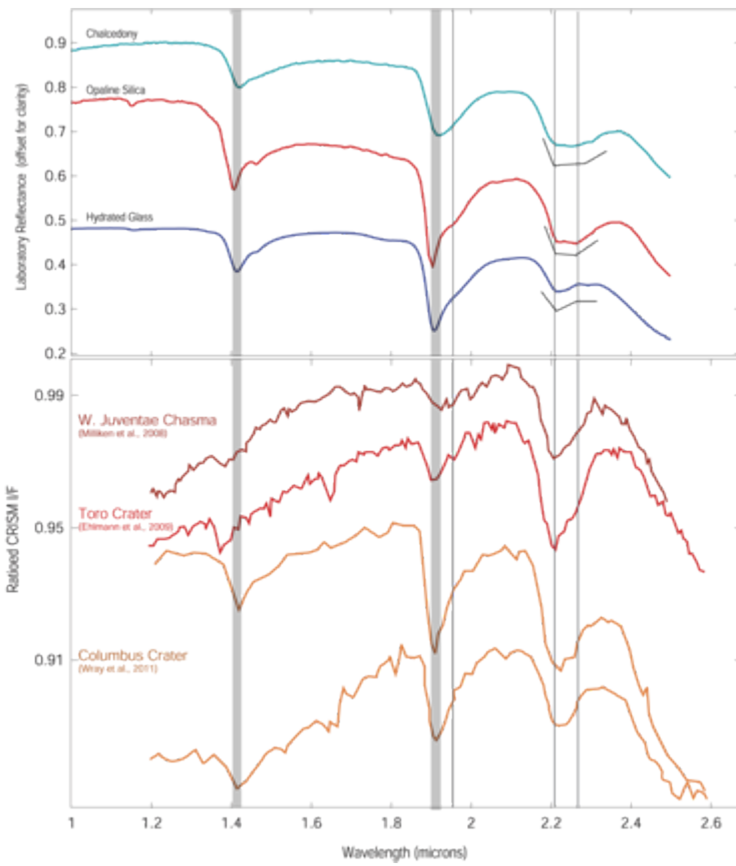
Unique detection of silica

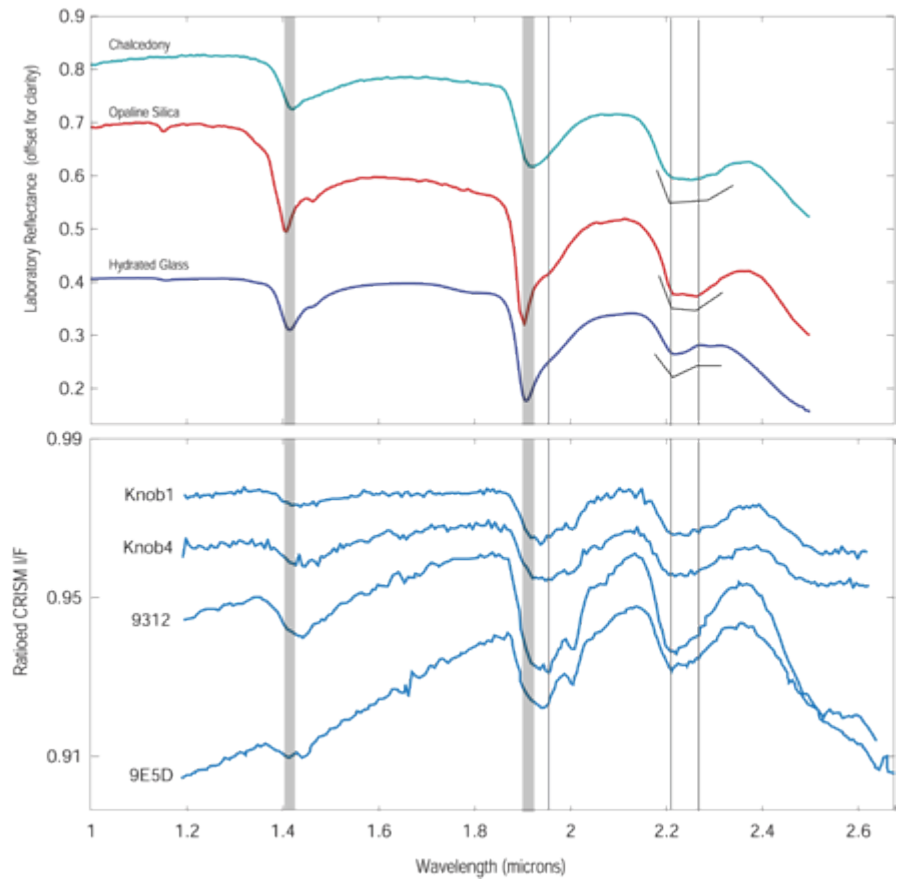
- High-silica deposits form in two ways:
    1) Dissolution and reprecipitation of silica in an alkaline environment
    2) Dissolution of *everything else* in an acidic environment, leaving silica behind
- Hydrated silica is **not** associated with sulfates, unlike identifications at Valles Marineris (*Milliken et al.*, 2008) and Gusev Crater (*Squyres et al.*, 2008)
- Sulfate deposition indicates alteration in an acidic environment (*Formation #1*), clay deposition suggests alkaline (*Formation #2*)

GLOBAL CONTEXT

Unique detection of silica

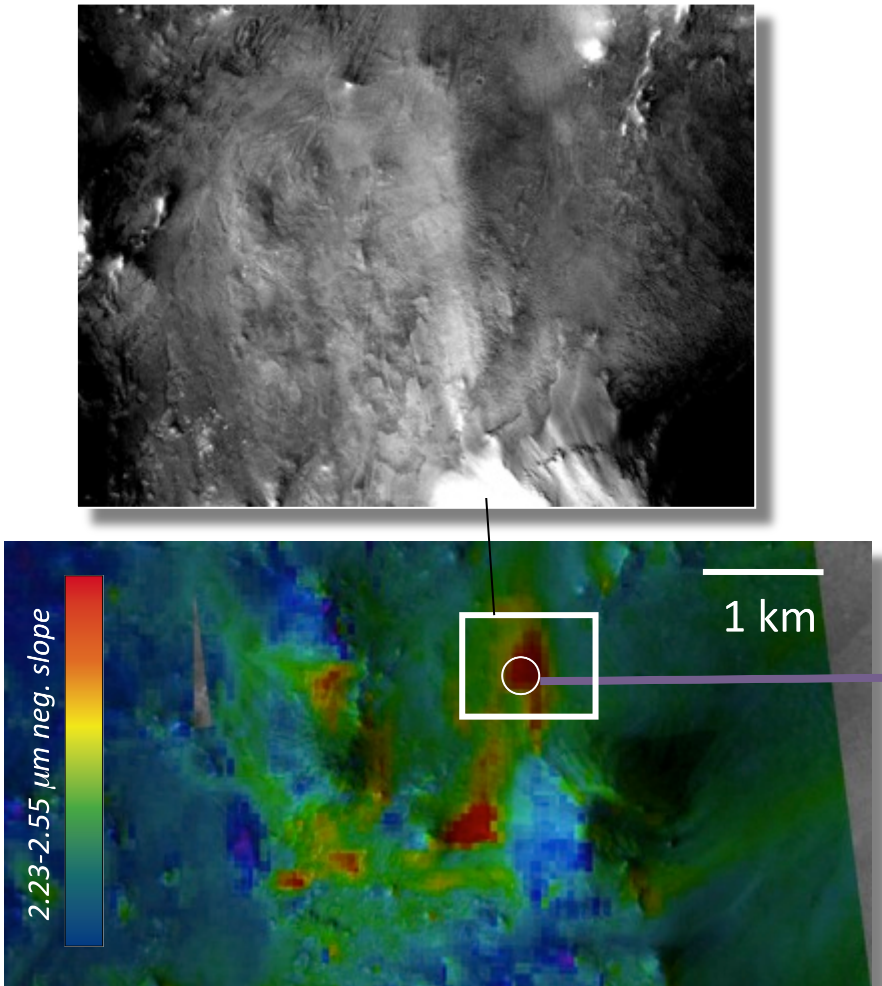
– VNIR spectra show greater alteration than elsewhere on Mars



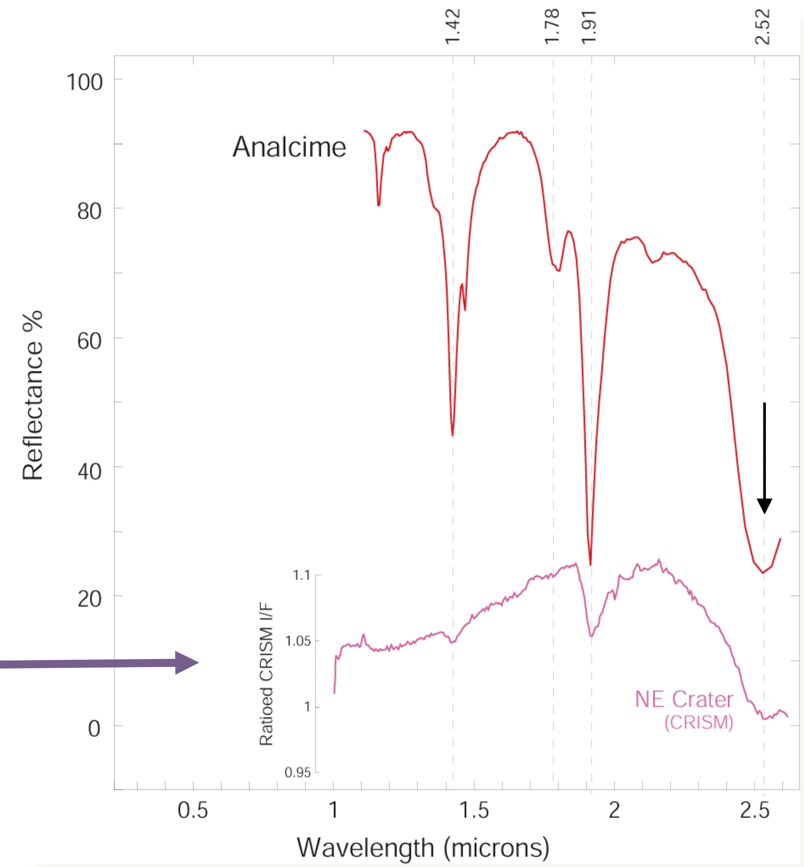


OUTSTANDING QUESTIONS

DO WE DETECT ZEOLITES?

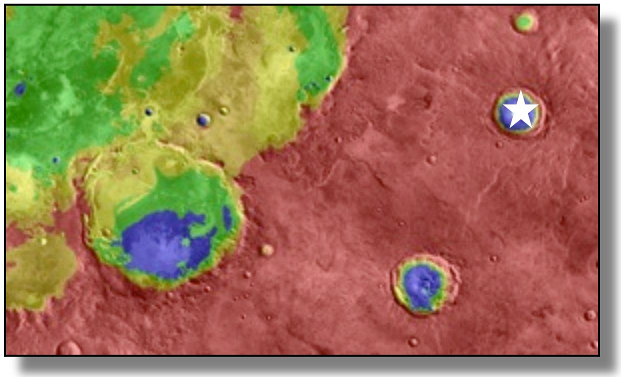


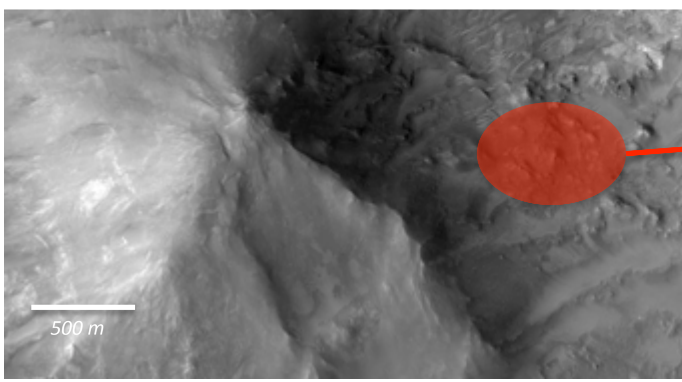
Zeolite detection



OUTSTANDING QUESTIONS

ARE WE ALSO DETECTING CARBONATES?





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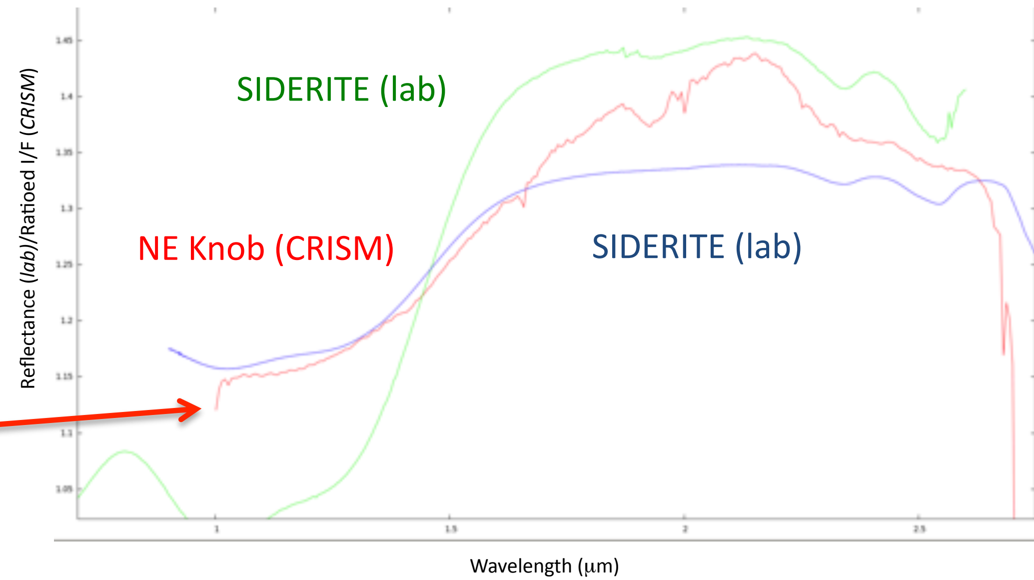

CONCLUSIONS

- Coincident with prior quartzofeldspathic detections, we detect chalcedony (in TES/CRISM) suggesting sustained local water-rock contact, and greater alteration than for other hydrated silica detections elsewhere on Mars

- We construct a regional stratigraphy with a Noachian phyllosilicate-bearing basement beneath a silica-bearing unit, suggesting multiple periods of wetting and alteration

- The stratigraphy is similar to nearby Nili Fossae, sharing both a phyllosilicate-bearing basement beneath a more altered layer suggesting multiple stages of wetting/ alteration