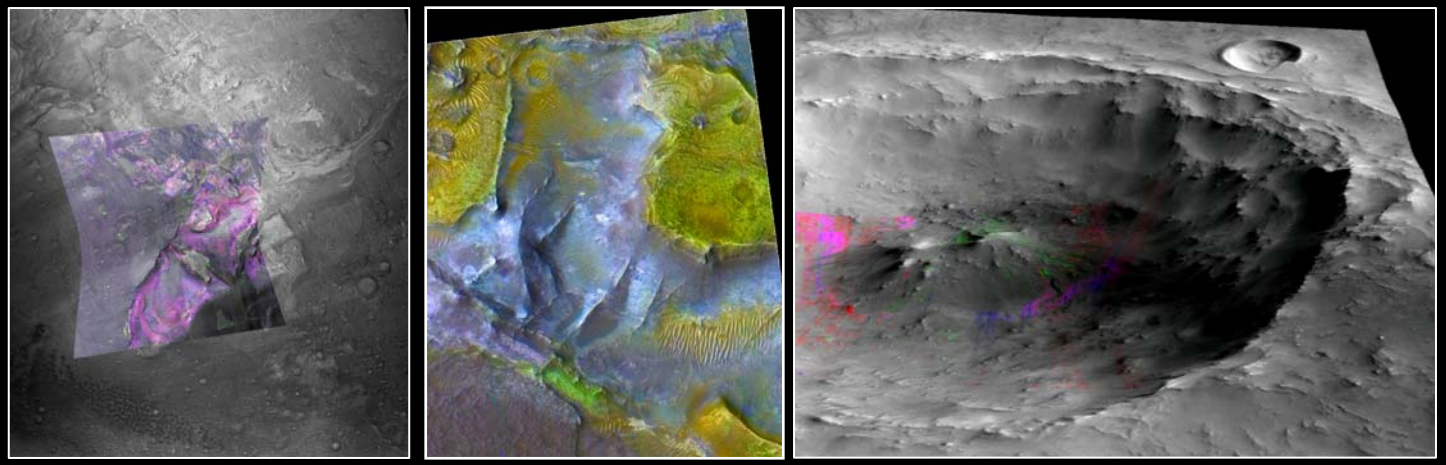
Phyllosilicates, Zeolites, and Carbonate near Nili Fossae, Mars: Evidence for Distinct Environments of Aqueous Alteration



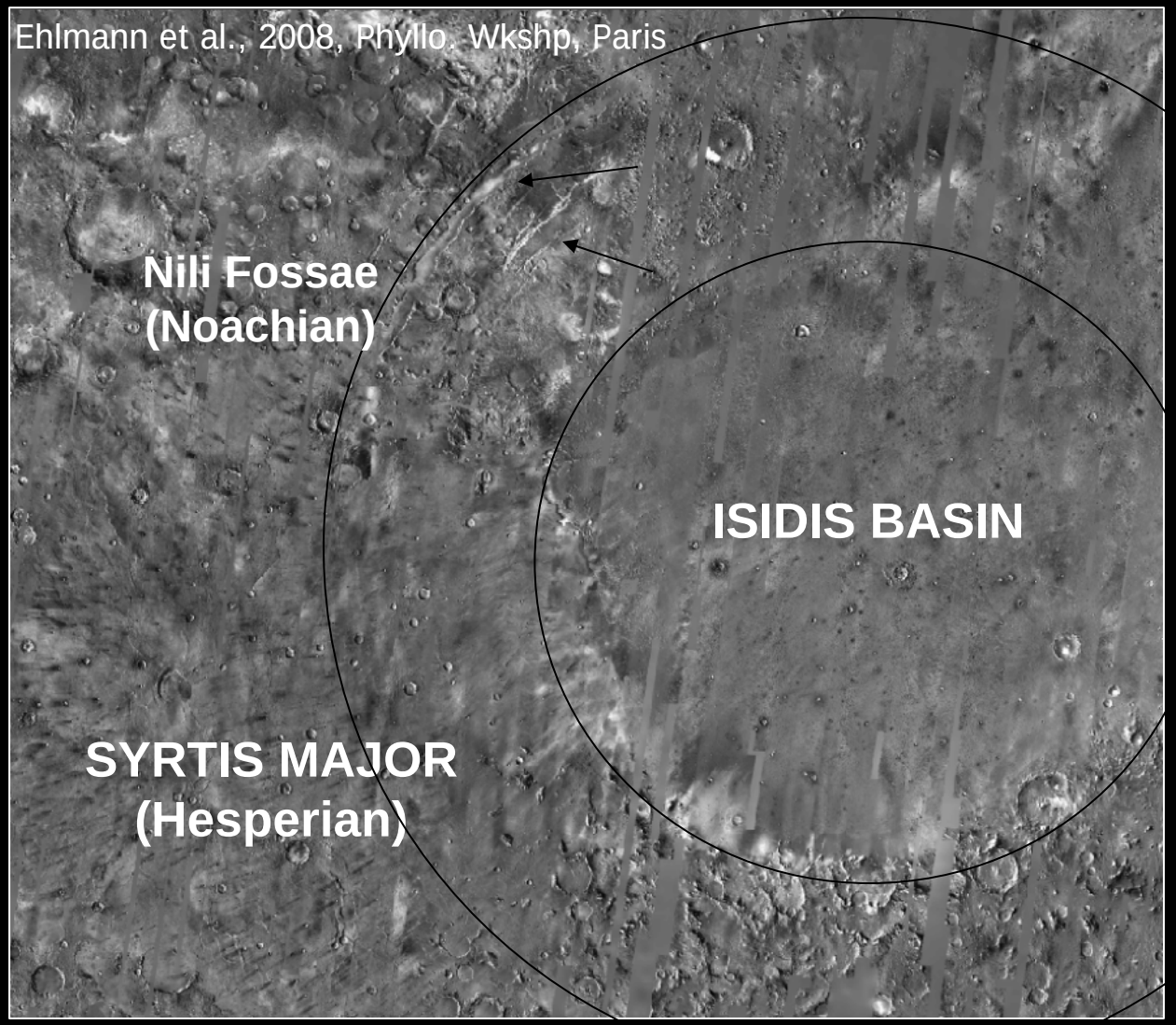
Bethany Ehlmann
Brown University

J.F. Mustard, G.A. Swayze, J.J. Wray, O.S. Barnouin-Jha, J.L. Bishop, D.J. DesMarais, F. Poulet, L.H. Roach, R.E. Milliken, R.N. Clark, S.L. Murchie,
and the MRO CRISM team

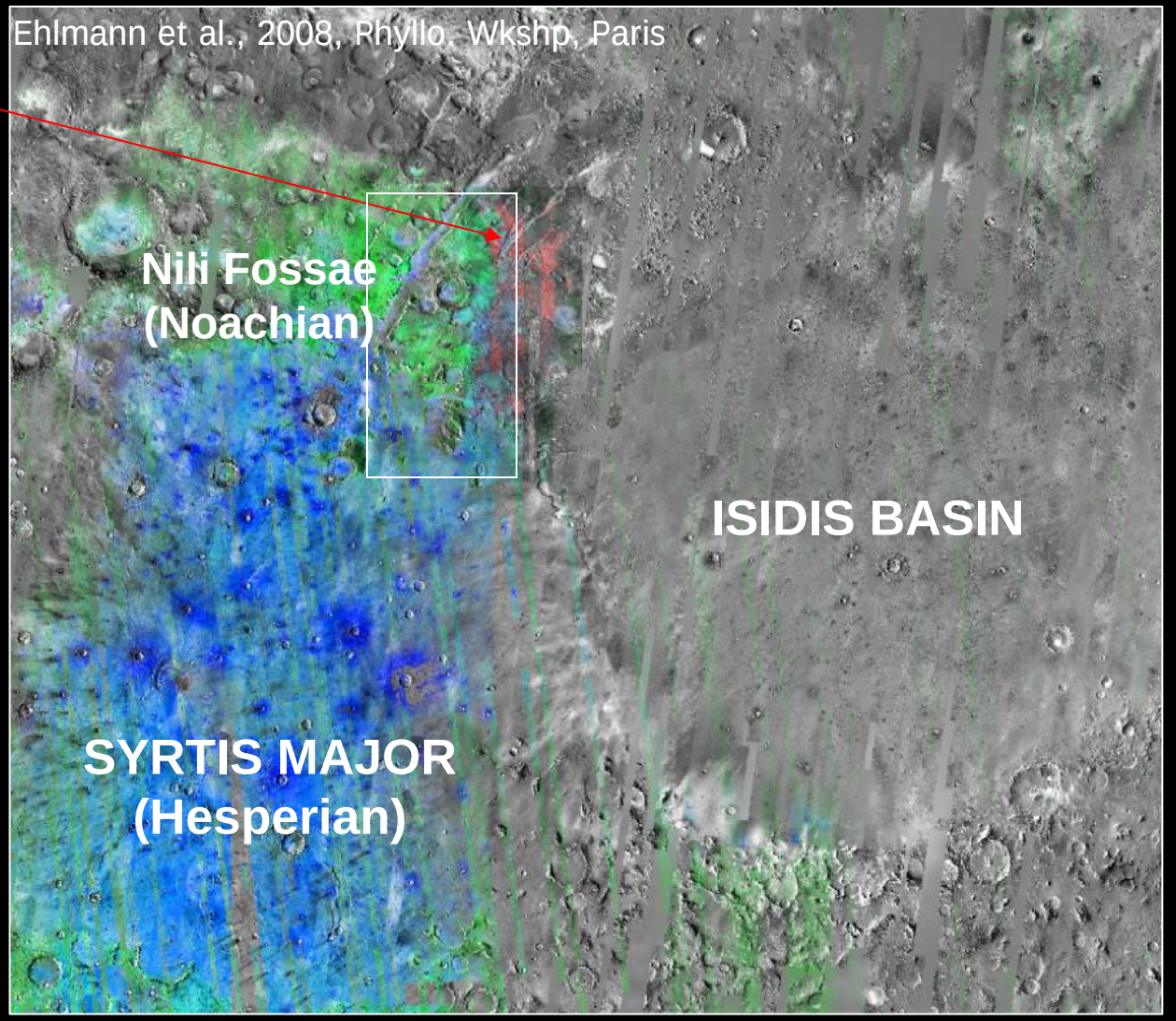
Nili Fossae Region Mineralogic Diversity

- Pyroxene
  - Low calcium
  - High calcium
- Olivine
- Phyllosilicate/ Hydrated phases
  - Fe/Mg smectite
  - Chlorite
  - Illite/Muscovite
  - Kaolinite
  - Hydrated silica
  - Zeolites (e.g. analcime)
  - Carbonate

Nili Fossae Region



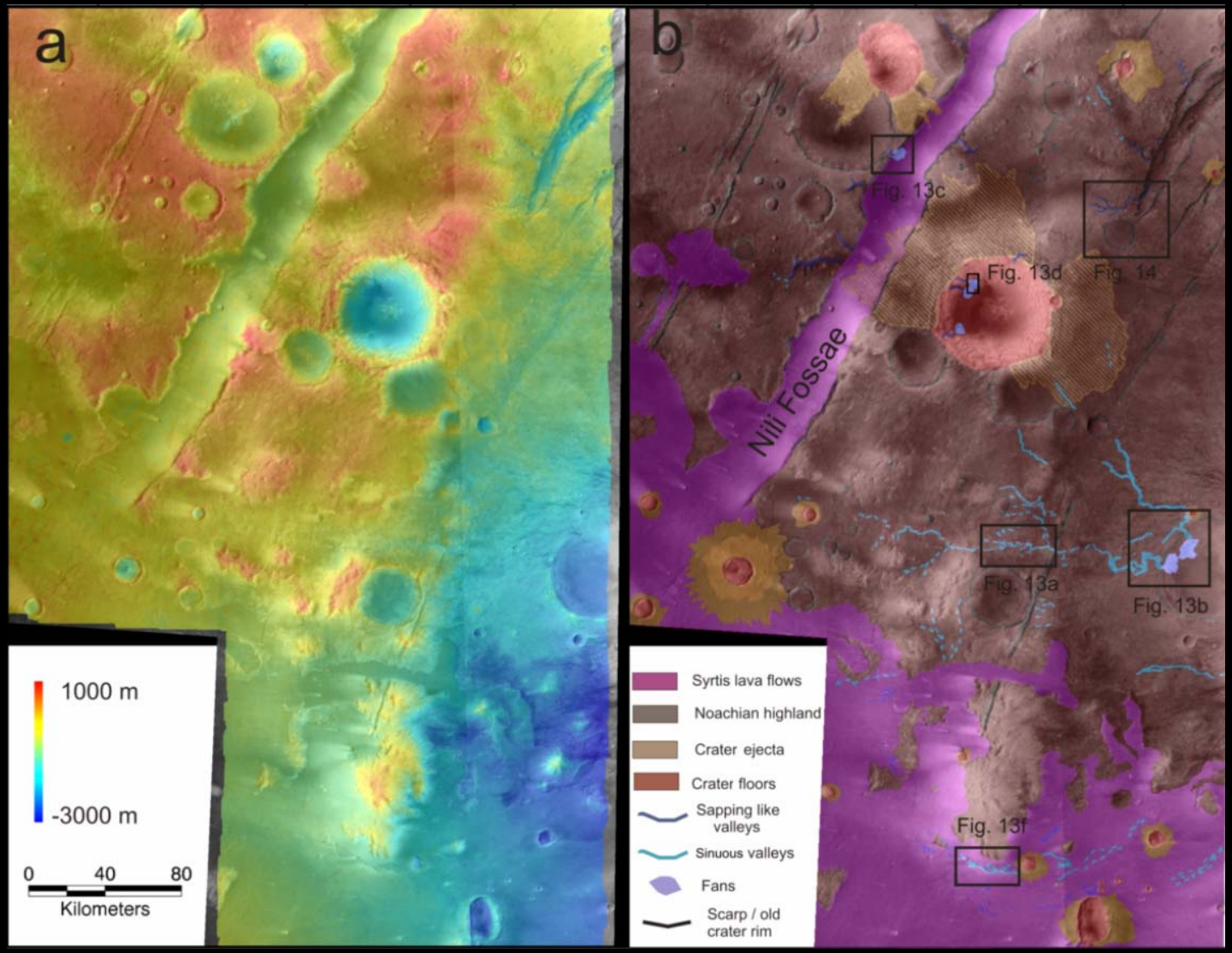
Nili Fossae Region – igneous composition



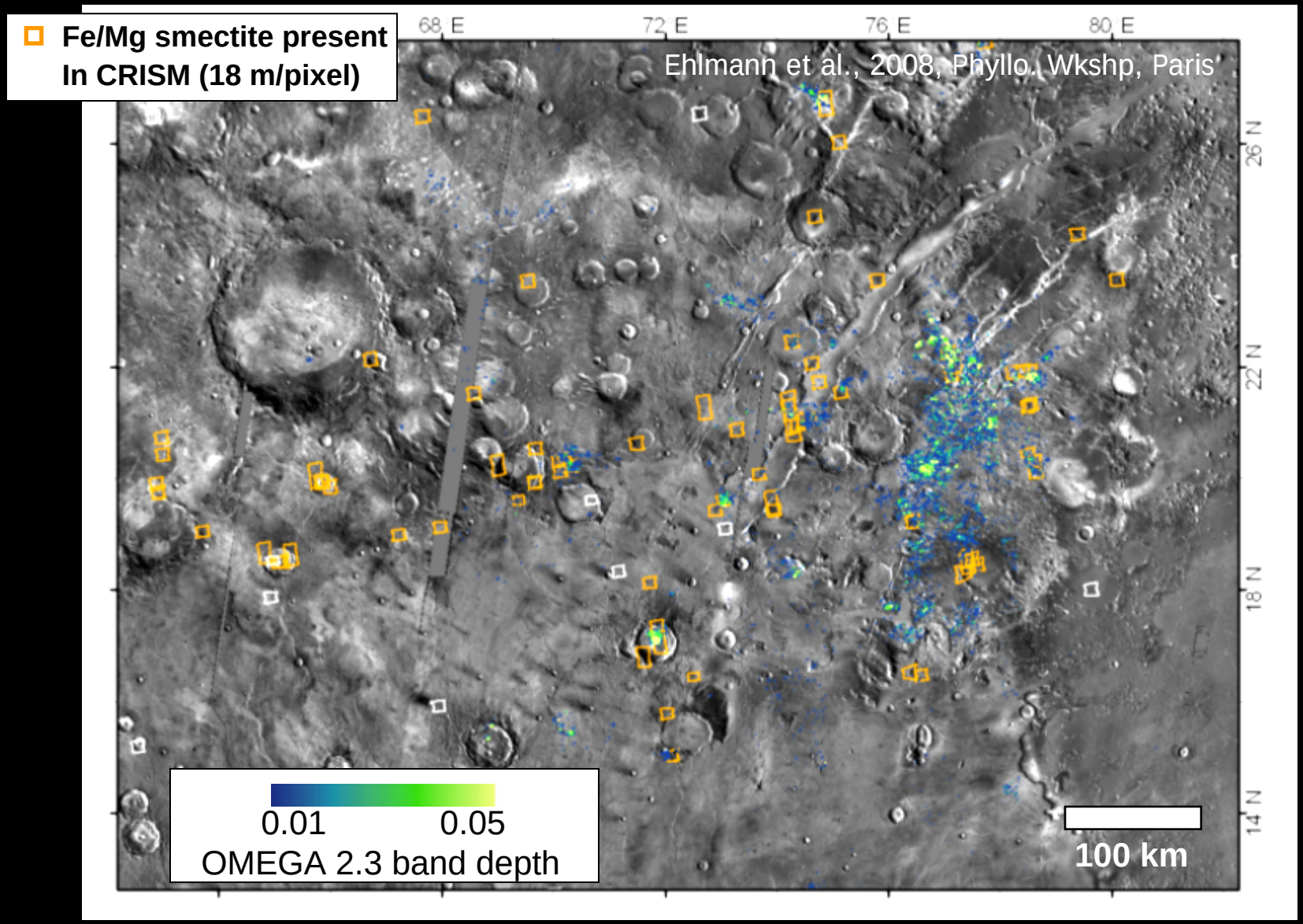
Mapping with OMEGA using MGM by P. Thollot

Geomorphic imprint of water

Mangold et al., *JGR*, 2007

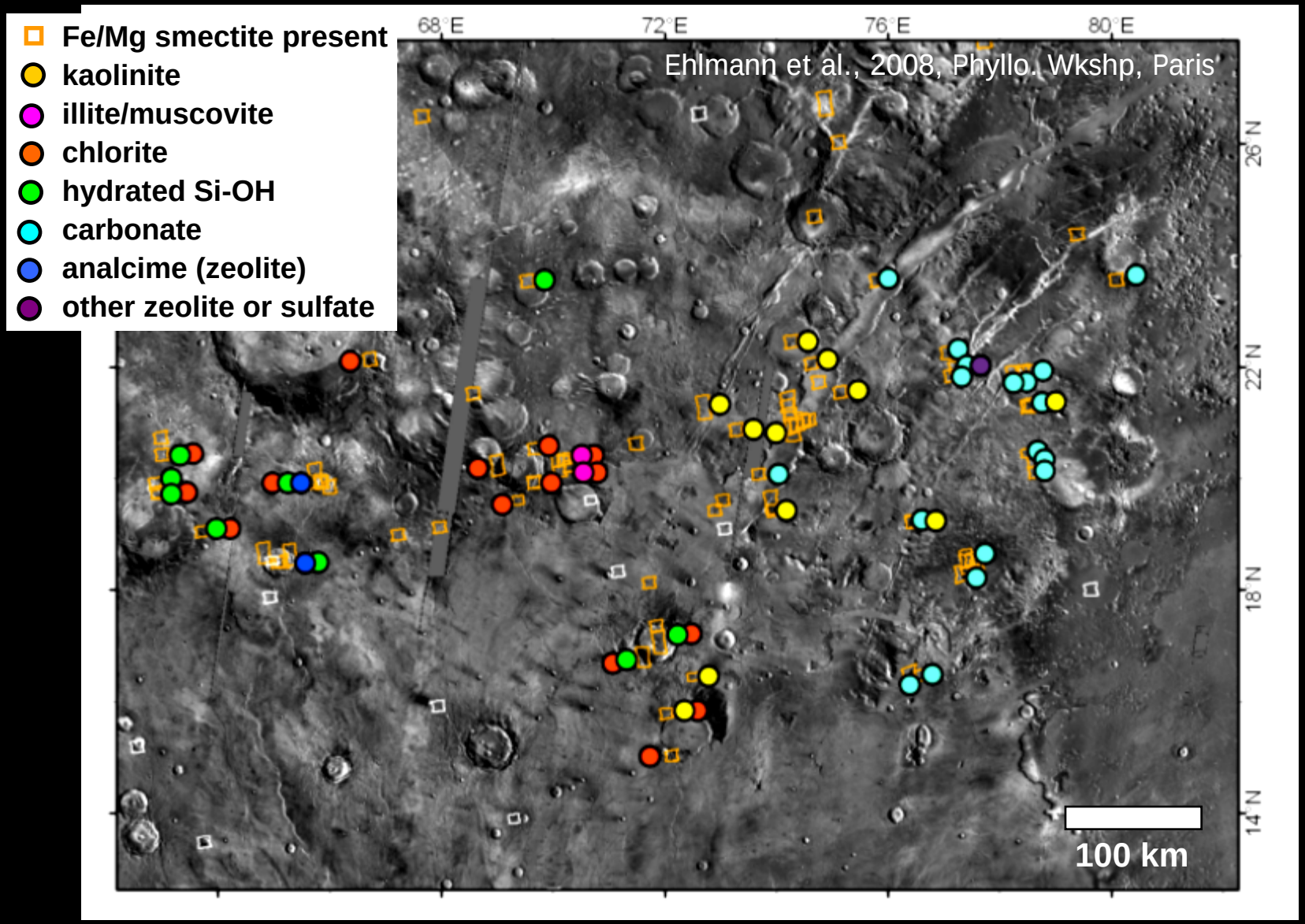


Phyllosilicate Distribution



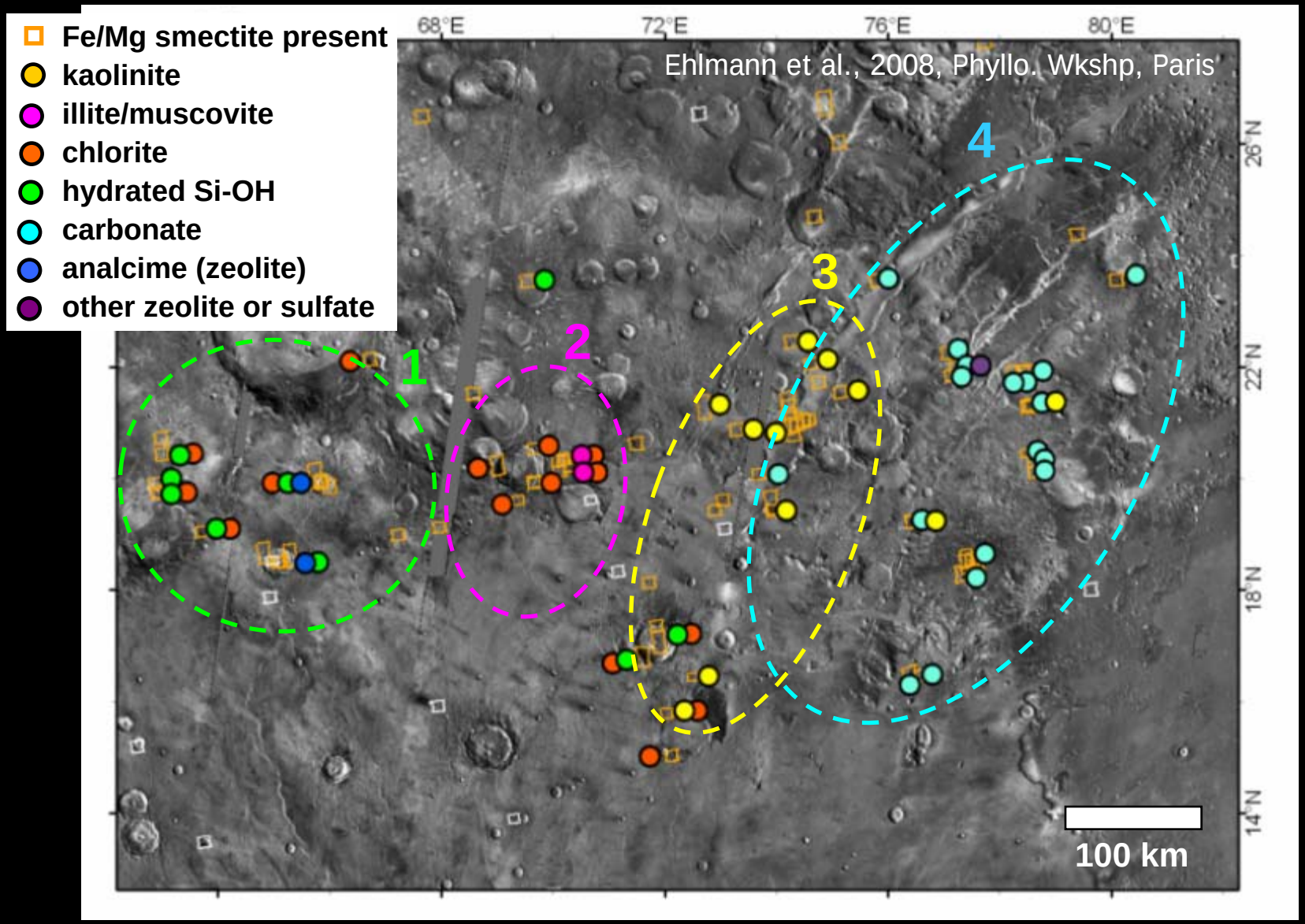
Phyllosilicate Diversity

Ehlmann et al., 2008, LPSC abstract (*JGR*, in prep.)

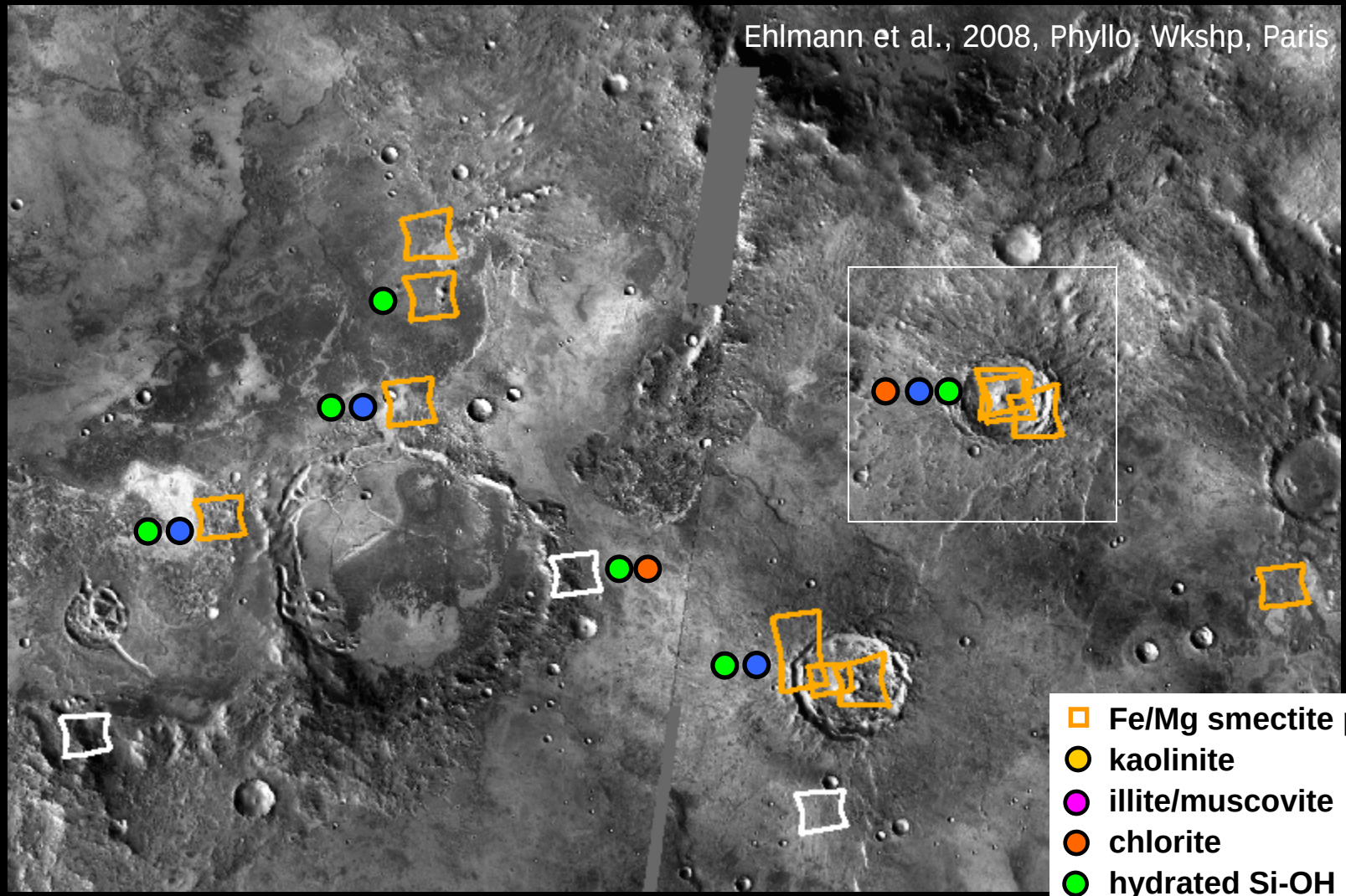


Distinct provinces/assemblages

Ehlmann et al., 2008, LPSC abstract (*JGR*, in prep.)



1. Western Nili Fossae craters (hydrated silica, zeolite)



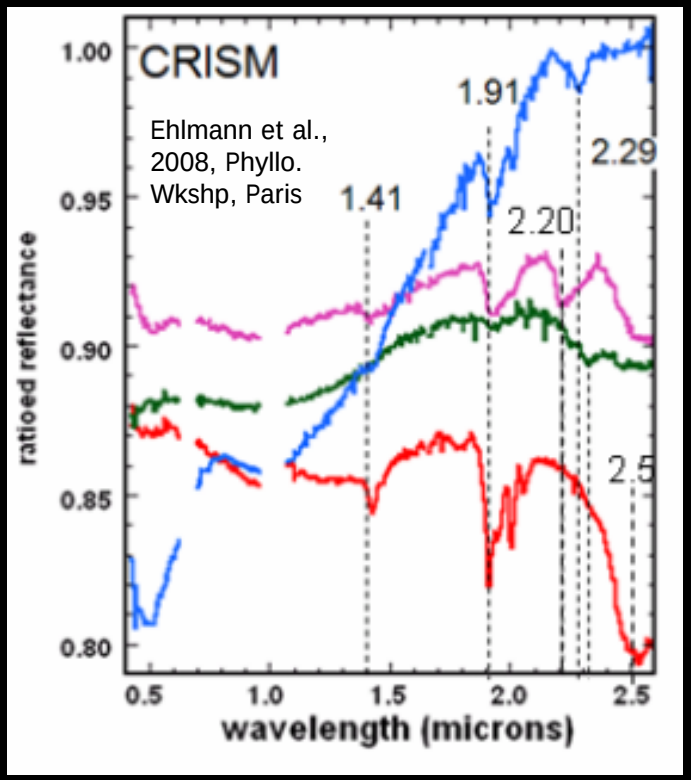
CRISM FRT00009312 mineral map + CTX mosaic

Ehlmann et al., 2008, Phyllo. Wkshp, Paris

hydrated silica/altered glass

zeolite (analcime)

chlorite and Fe/Mg smectite



R: BD2500, G: D2300, B: BD2200

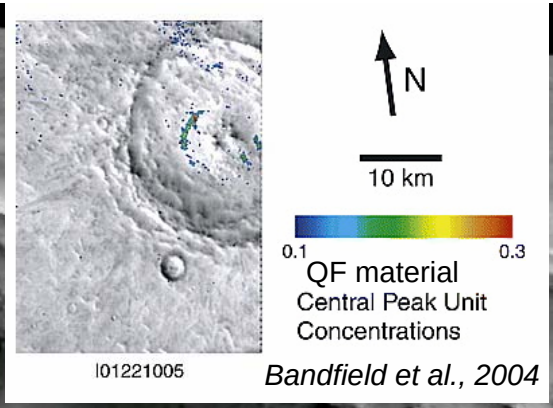
R: D2500, G: D2300, B: BD2200

hydrated Si-OH

zeolite (analcime)

chlorite and smectite

Ehlmann et al., 2008, Phyllo. Wkshp, Paris



Bandfield et al., 2004

zeolite knob

FRT 51EE CRISM band maps on CTX
with MOLA topography, looking south

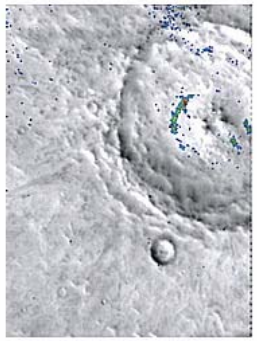
R: D2500, G: D2300, B: BD2200

hydrated Si-OH

zeolite (analcime)

chlorite and smectite

Ehlmann et al., 2008, Phyllo. Wkshp, Paris



Bandfield et al., 2004

hydrated Si-OH as aeolian debris

(same location as TES/THEMIS detection of QF unit)

Ehlmann et al., 2008, Phyllo. Wkshp, Paris

zeolite knob

FRT 51EE CRISM band maps on CTX with MOLA topography, looking south

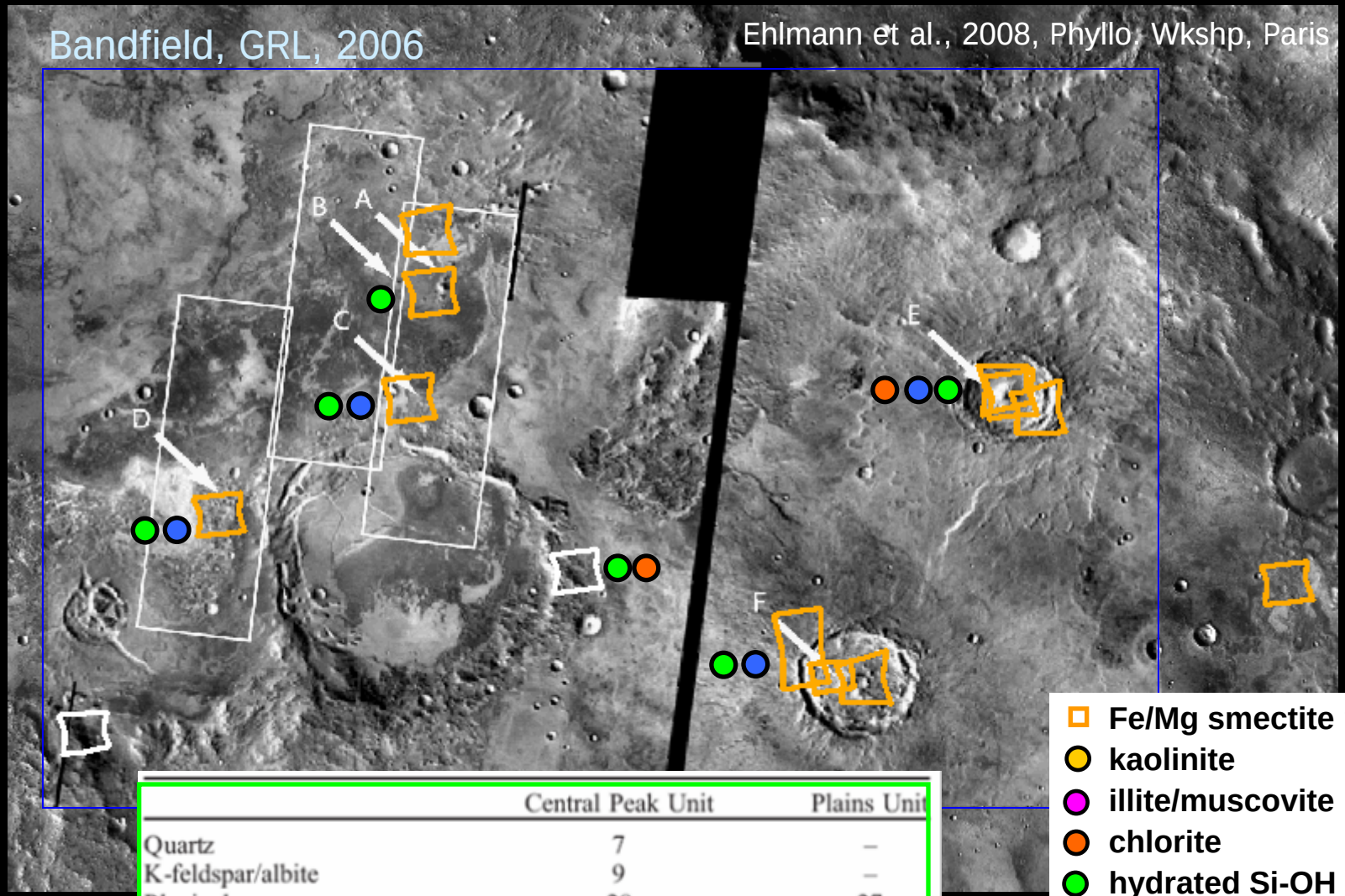
50 m

PSP_003205_2000_RED

1. Comparison to TES/THEMIS “Quartzofeldspathic”

Bandfield, GRL, 2006

Ehlmann et al., 2008, Phyllo. Wkshp, Paris



	Central Peak Unit	Plains Unit
Quartz	7	–
K-feldspar/albite	9	–
Plagioclase	28	27
Pyroxene	9	31
Sheet silicate/high-Si glass	33	23
Carbonate	12	11
Sulfate	2	9

- Fe/Mg smectite present
- kaolinite
- illite/muscovite
- chlorite
- hydrated Si-OH
- carbonate
- analcime (zeolite)
- other zeolite or sulfate

1. A hydrothermal process in Western province?

Observed Western assemblage:

Ehlmann et al., 2008, Phyllo. Wkshp, Paris

Fe/Mg smectite, chlorite, zeolite, hydrated silica/altered glass

Plagioclase, pyroxene, quartz, K, Na feldspars,

Terrestrial craters:

Typical crater alteration assemblage (Allen et al., 1982):

Smecite - chlorite - zeolite - quartz - k-spar

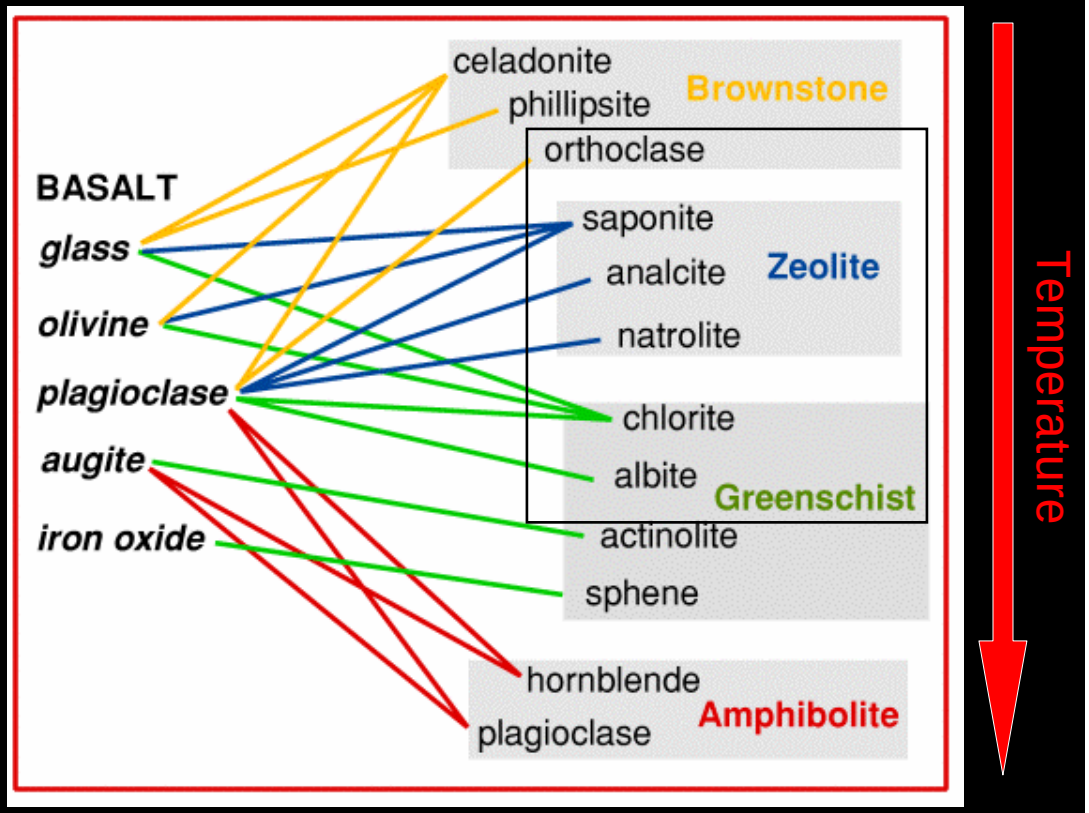
Usually also accompanied by either carbonate or sulfate

Pre-impact: subsurface and excavated

Vs.

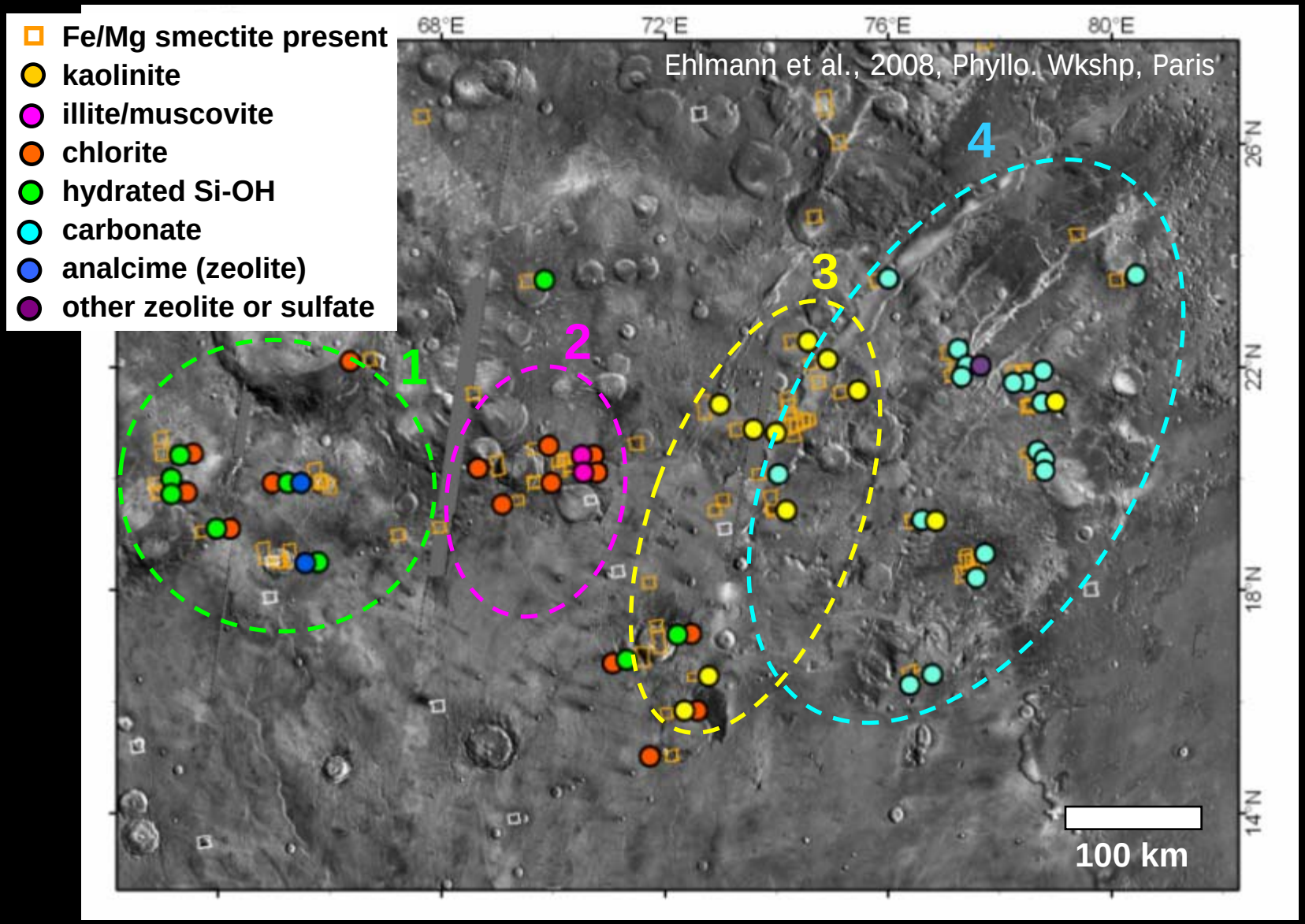
Post-impact: hydrothermal system fed by ground or surface water

Basalt-seawater interaction (Cann, 1979)



Distinct provinces/assemblages

Ehlmann et al., 2008, LPSC abstract (*JGR*, in prep.)



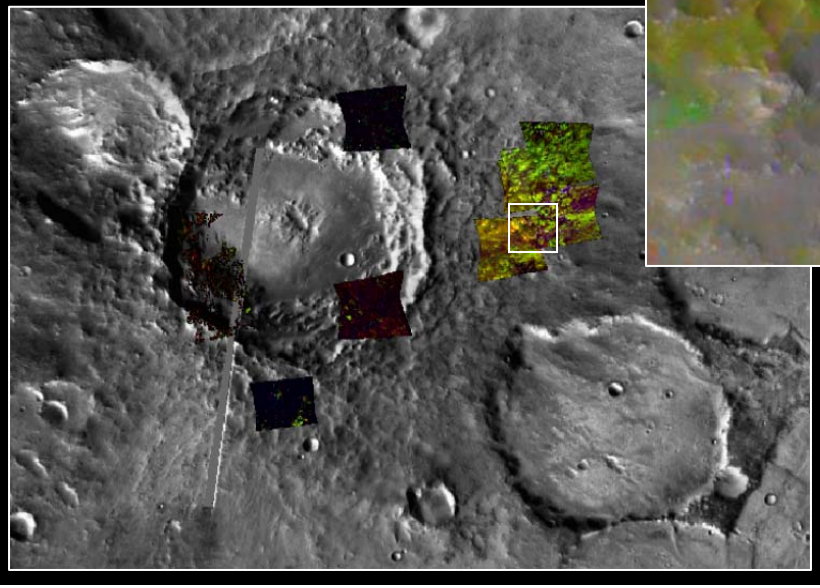
2. Chlorite-illite crater

CRISM mineral maps on CTX

Ehlmann et al., 2008, Phyllo. Wkshp, Paris

Chlorite-bearing
Illite/Muscovite-bearing

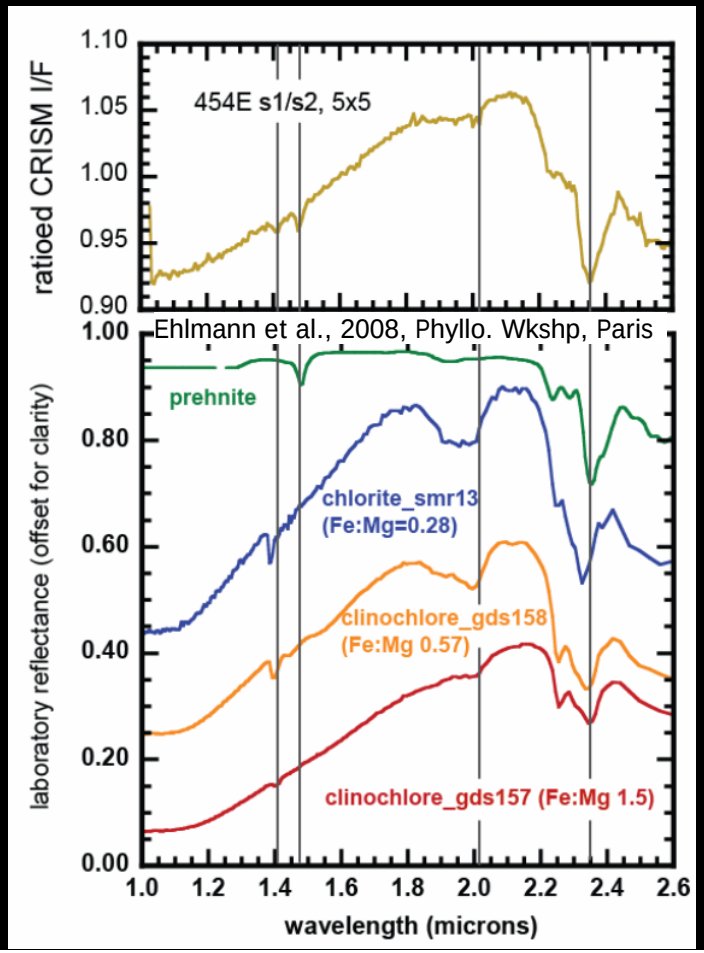
~50 km crater

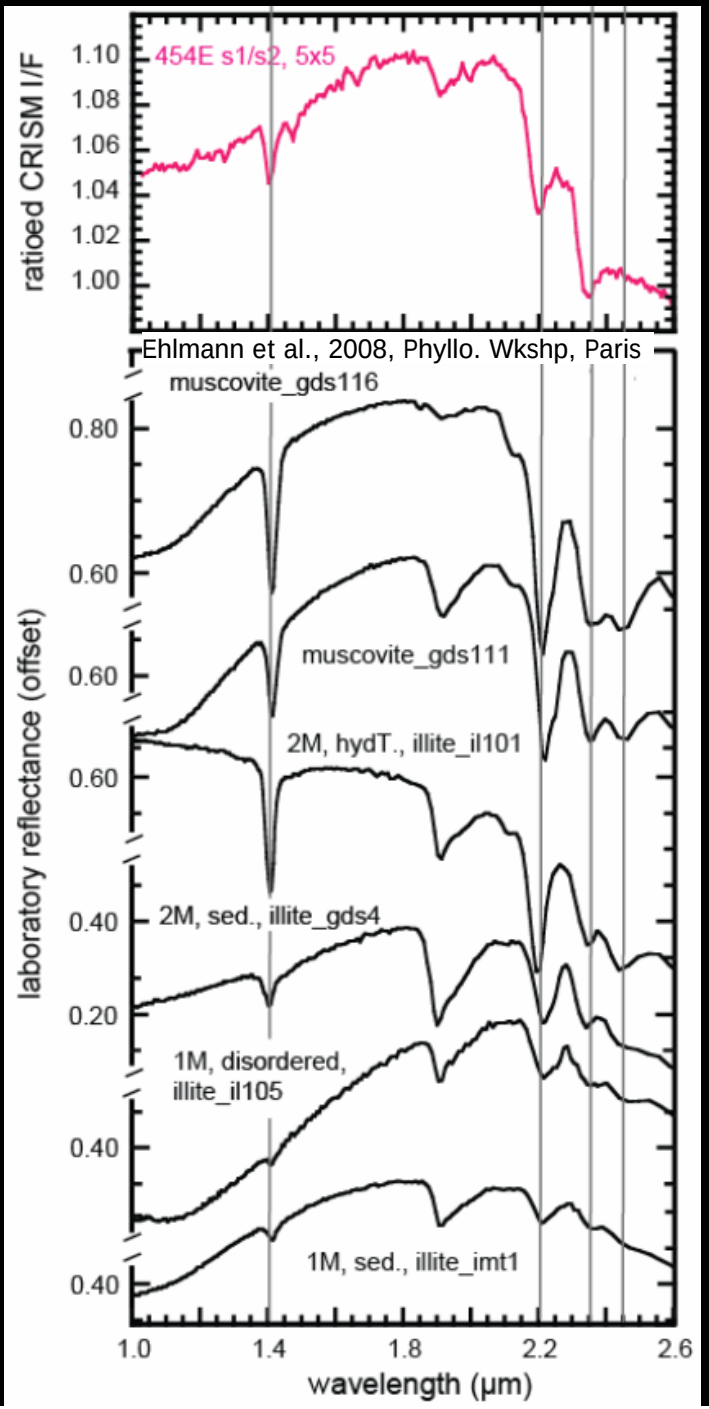


2 km

2. Spectral IDs

- "Chlorite": Chlorite + Prehnite
- "Illite/Muscovite" difficult to distinguish since sample likely contains chlorite

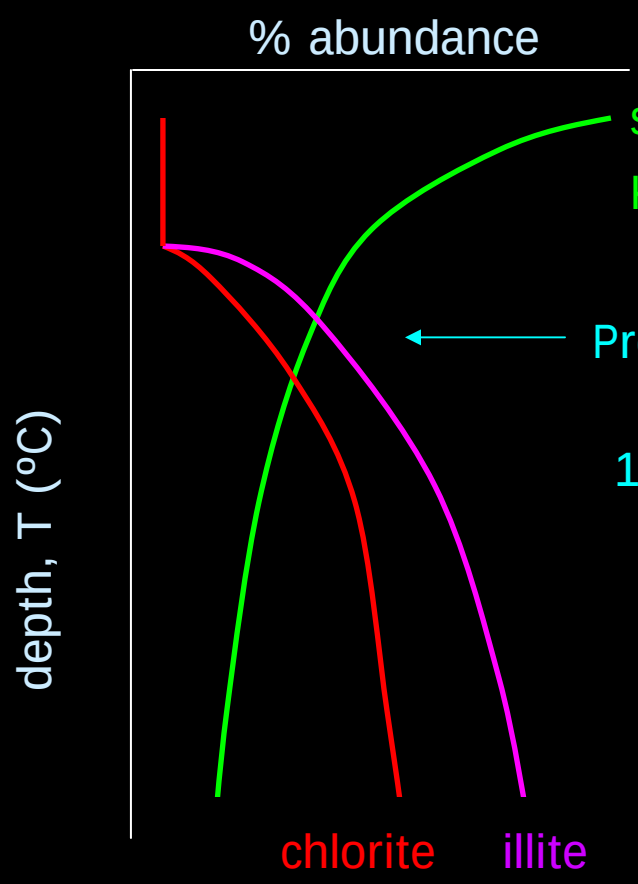




2. Hydrothermal or diagenetic origin for Central assemblage?

Observed Central assemblage: Ehlmann et al., 2008, Phyllo. Wkshp, Paris

Chlorite+prehnite, illite/muscovite (little to no Fe, Mg smectite)



(Hower, 1981)

Can form from hydrothermal solution or metamorphic/diagenetic alteration at depth

← Process begins T ~ 50-80°C (time & depth dependent)

1 smectite + K^+ →

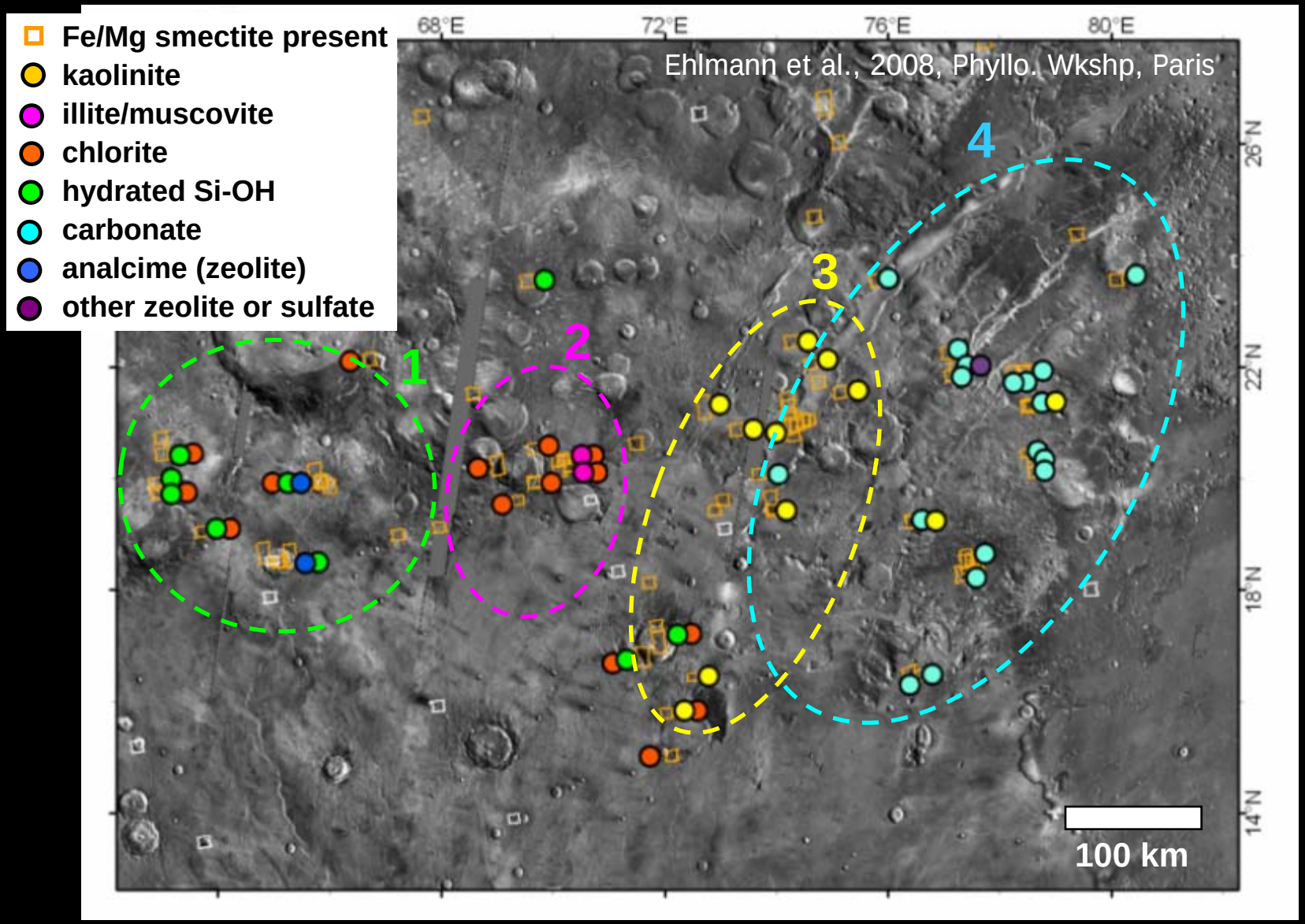
1 illite + Na^+ + Ca^{2+} + Si^{4+} + Fe^{2+} + Mg^{2+} + H_2O

pCO_2 — high → carbonates (Ca, Mg, Fe)

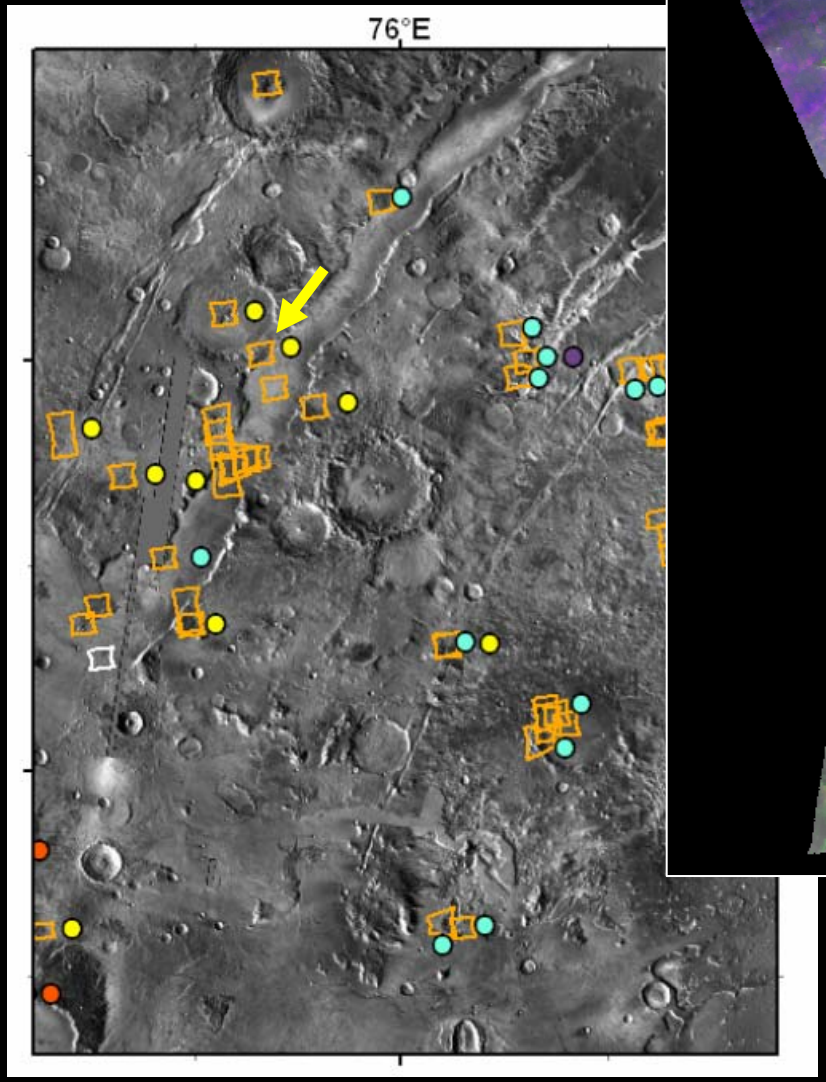
pCO_2 — low → Fe-rich chlorites

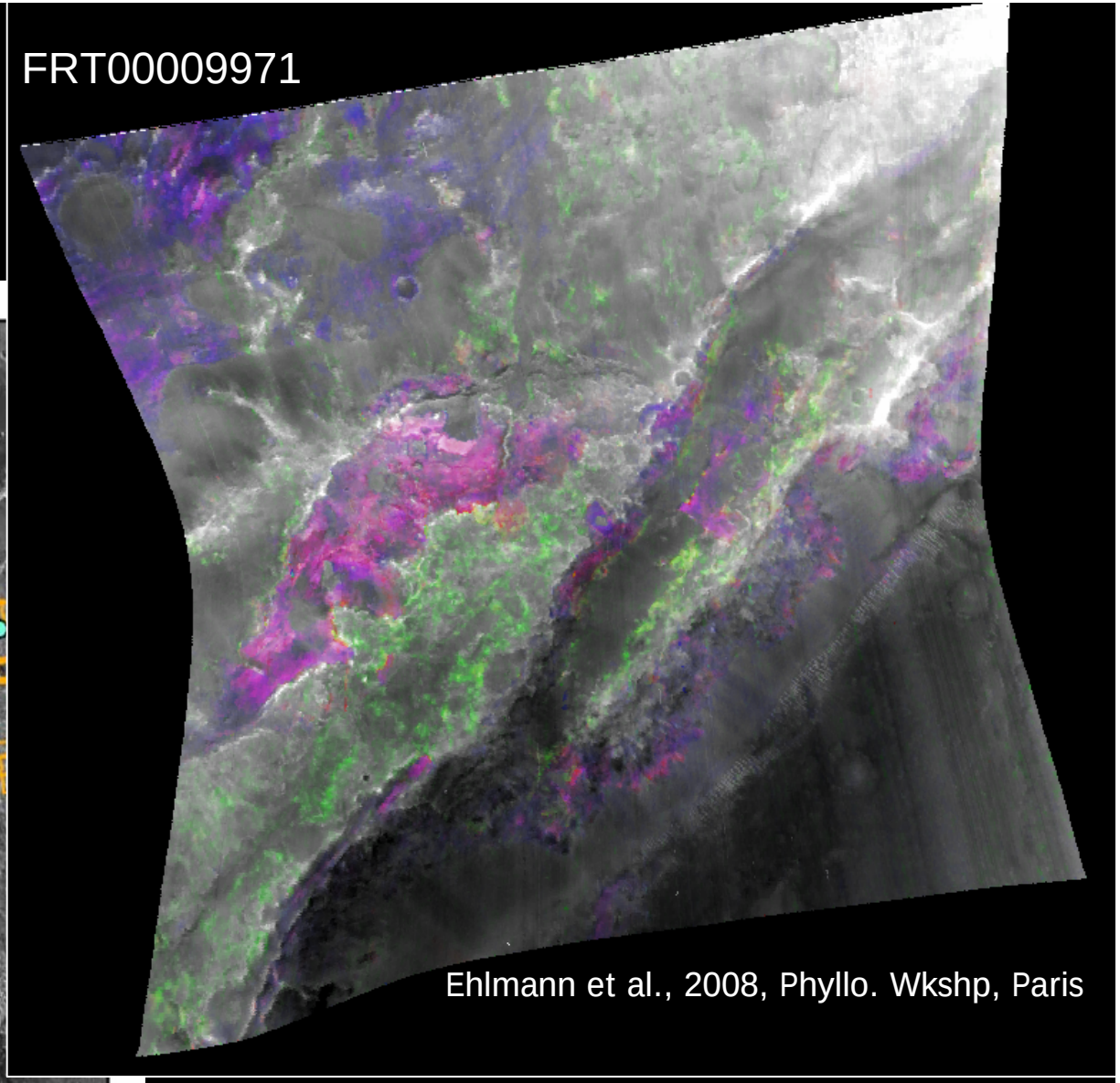
Distinct provinces/assemblages

Ehlmann et al., 2008, LPSC abstract (*JGR*, in prep.)



3. Kaolinite-smectite stratigraphy





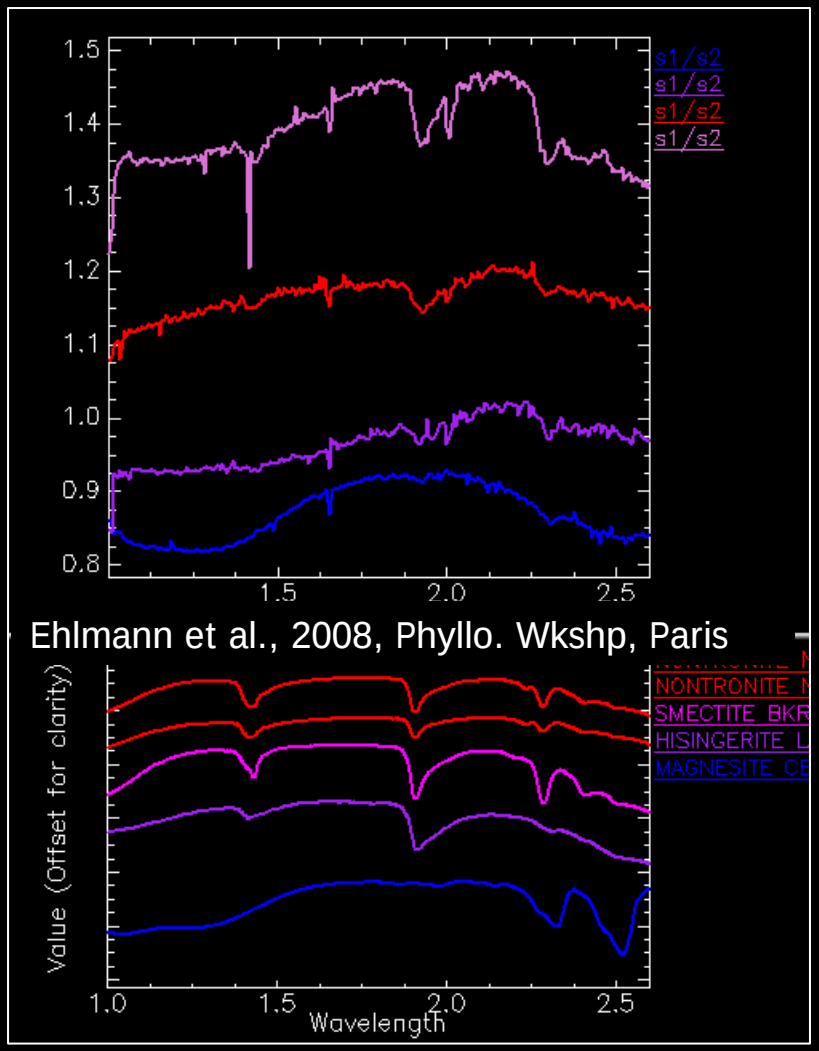
Kaolinite (BD2200)

Hydration Band (BD1900)

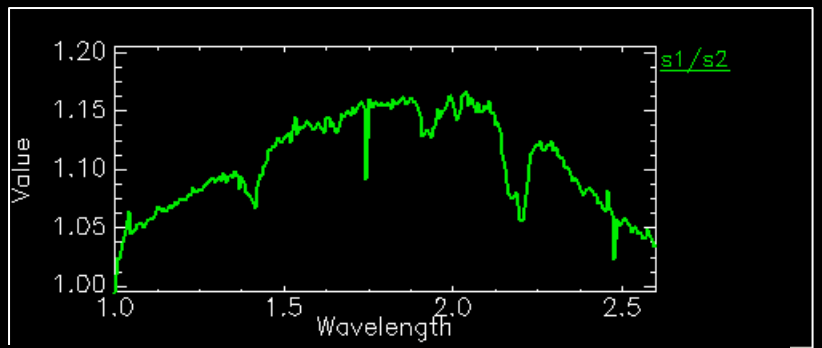
Fe/Mg Smectite (BD1900, D2300)

3. Spectral Identification – typical spectra

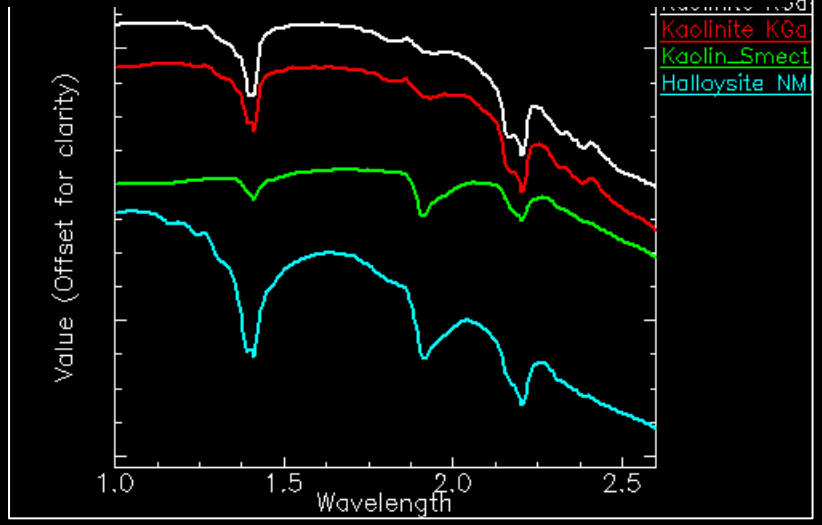
5x5 average, ratioed spectra



Ehlmann et al., 2008, Phyllo. Wkshp, Paris



Ehlmann et al., 2008, Phyllo. Wkshp, Paris



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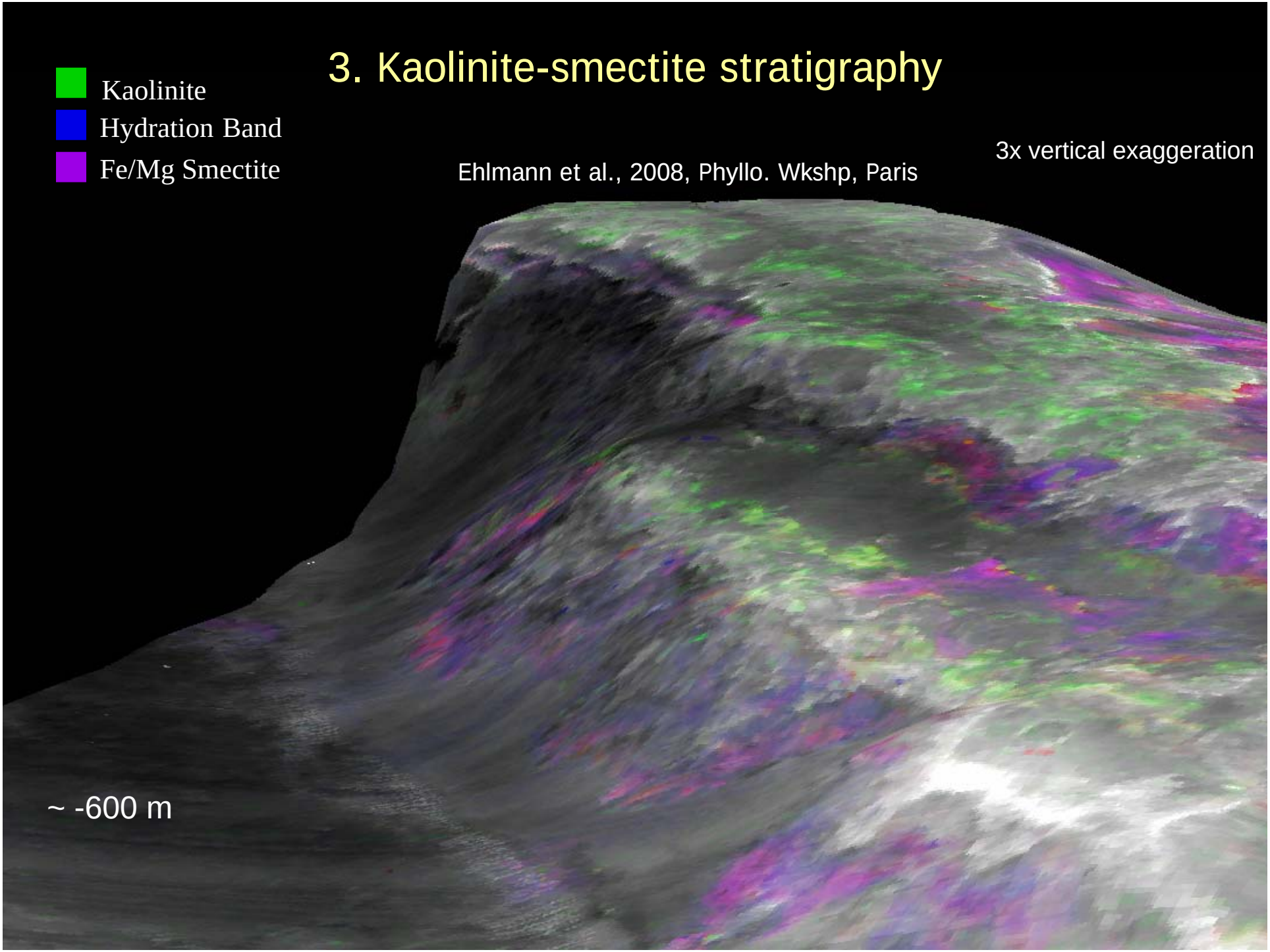

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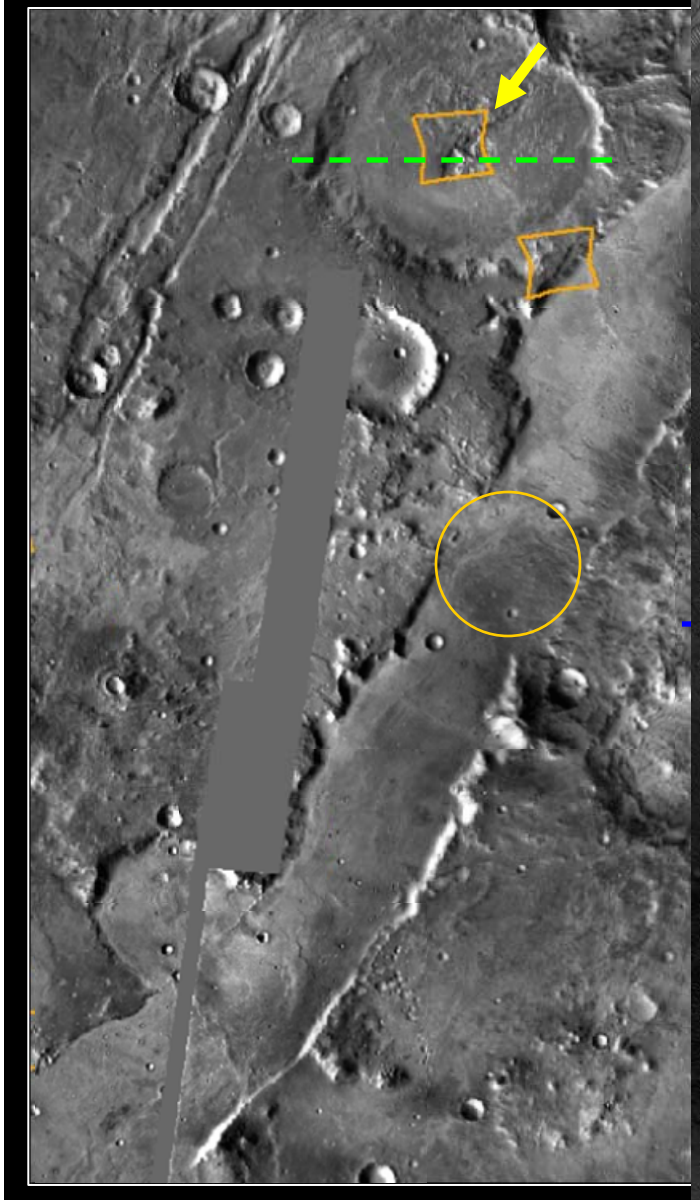
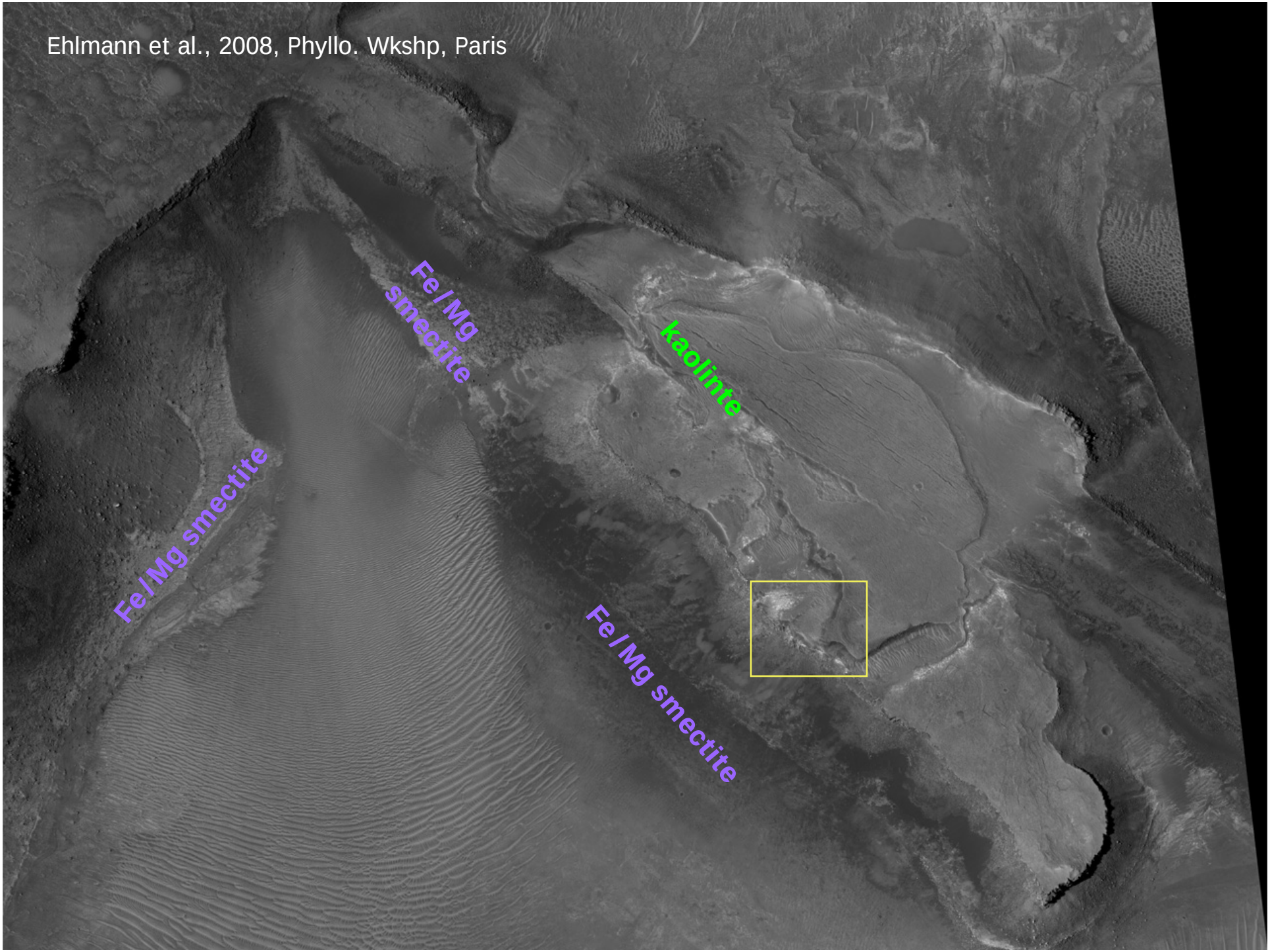


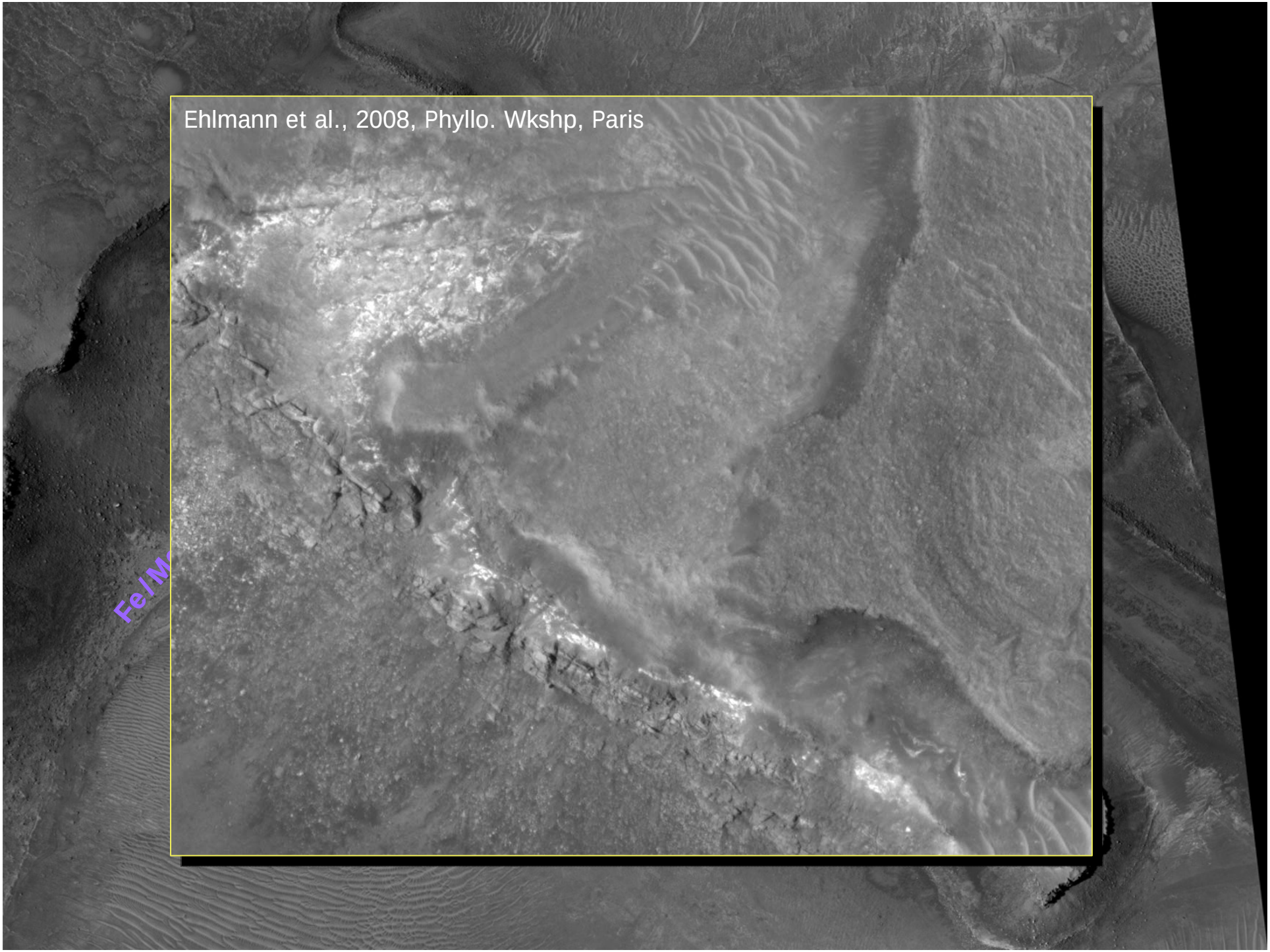
Kaolinite
Hydration Band
Fe/Mg Smectite

FRT0000A053

Ehlmann et al., 2008, Phyllo. Wkshp, Paris

10 km


Ehlmann et al., 2008, Phyllo. Wkshp, Paris
Fe/Mg smectite
kaolinte
Fe/Mg smectite
Fe/Mg smectite


Ehlmann et al., 2008, Phyllo. Wkshp, Paris
Fe/M

3. Kaolinite-smectite stratigraphy - hypotheses

Why do we see a distinct kaolinite layer capping both in-situ and transported smectite?

- Enhanced weathering

Ehlmann et al., 2008, Phyllo. Wkshp, Paris

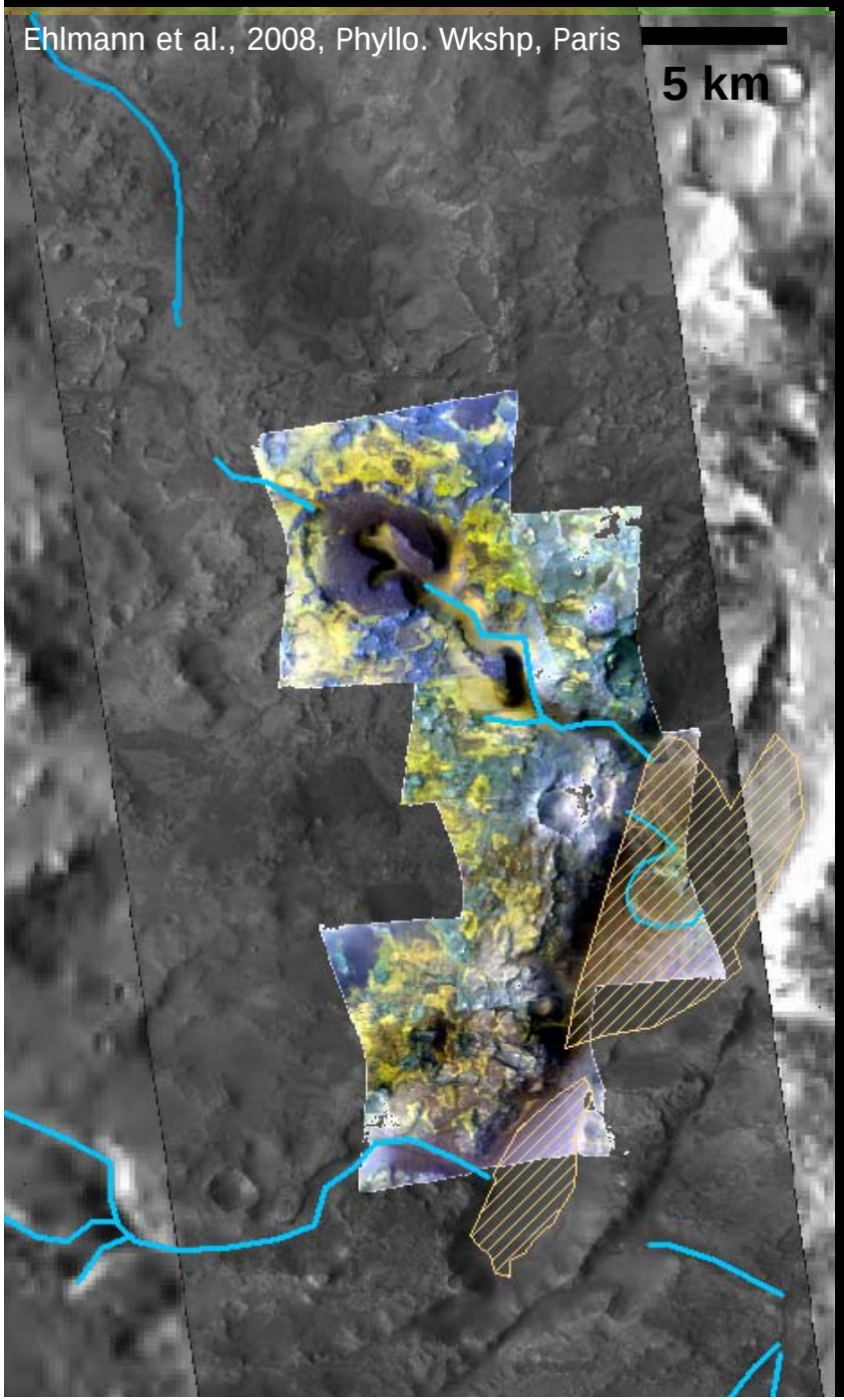
1) basalt → Fe/Mg smectite [e.g. $(Fe, Mg)_2(Si, Al)_4O_{10}(OH)_2$]

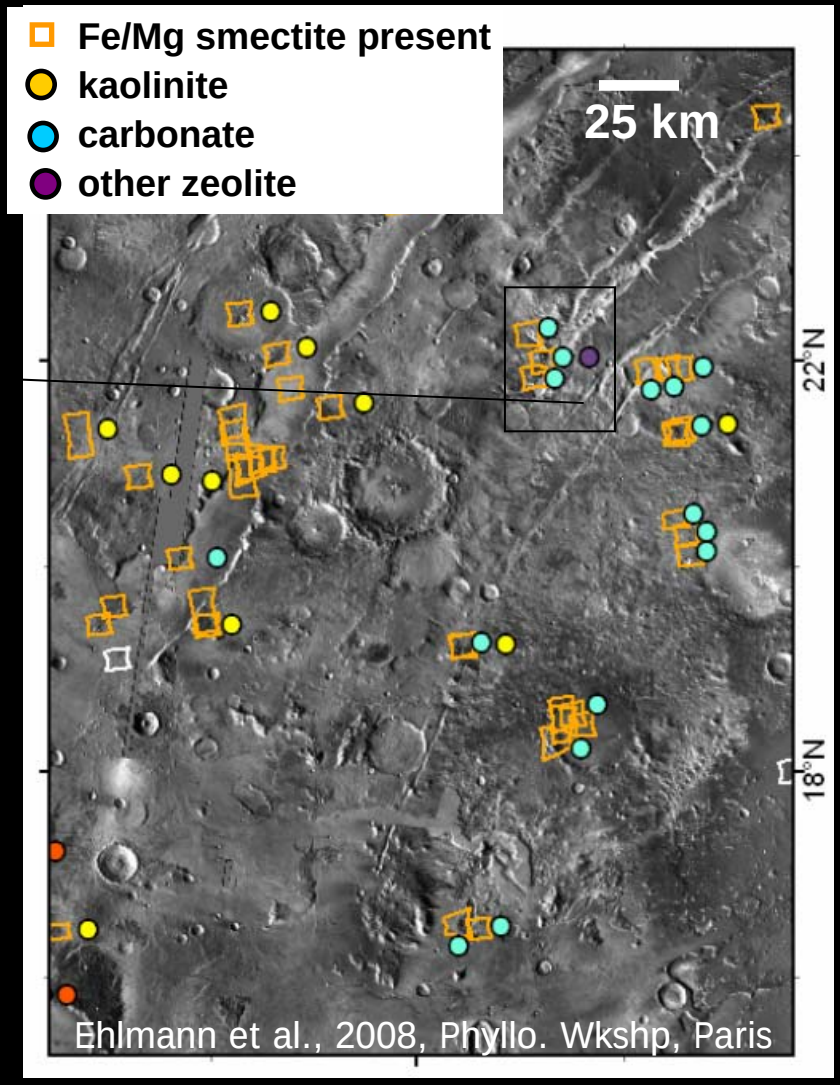
2) more leaching → loss of Ca^{2+}, Mg^{2+}, Fe^{2+} ions → kaolinite - $Al_2Si_2O_5(OH)_4$

Terrestrial analog: soil formation

- Further east, the presence of olivine changes the dominant alteration mineral from kaolinite to magnesium carbonate

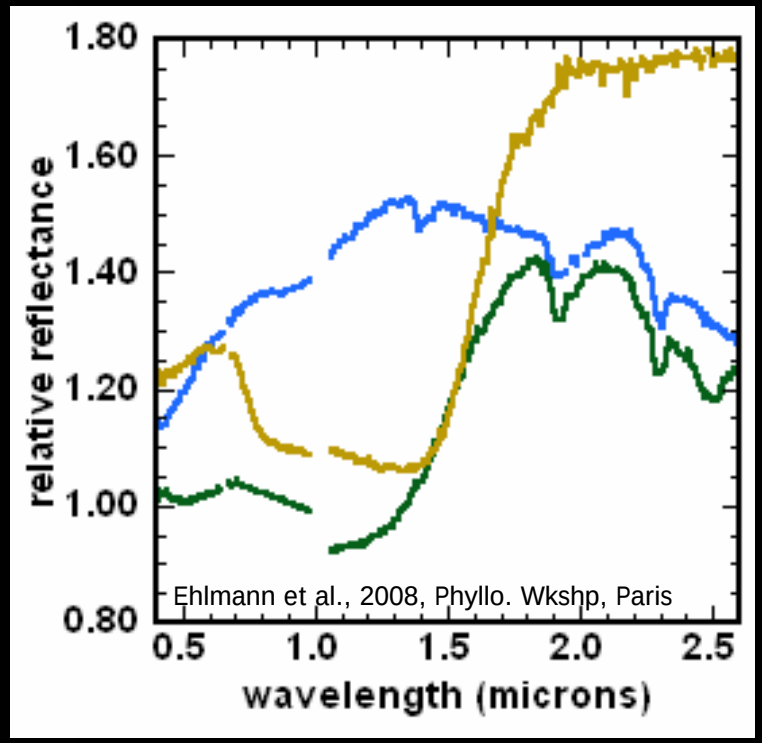
4. Carbonate-olivine-smectite stratigraphy





Ehlmann et al., 2008, Phyllo. Wkshp, Paris

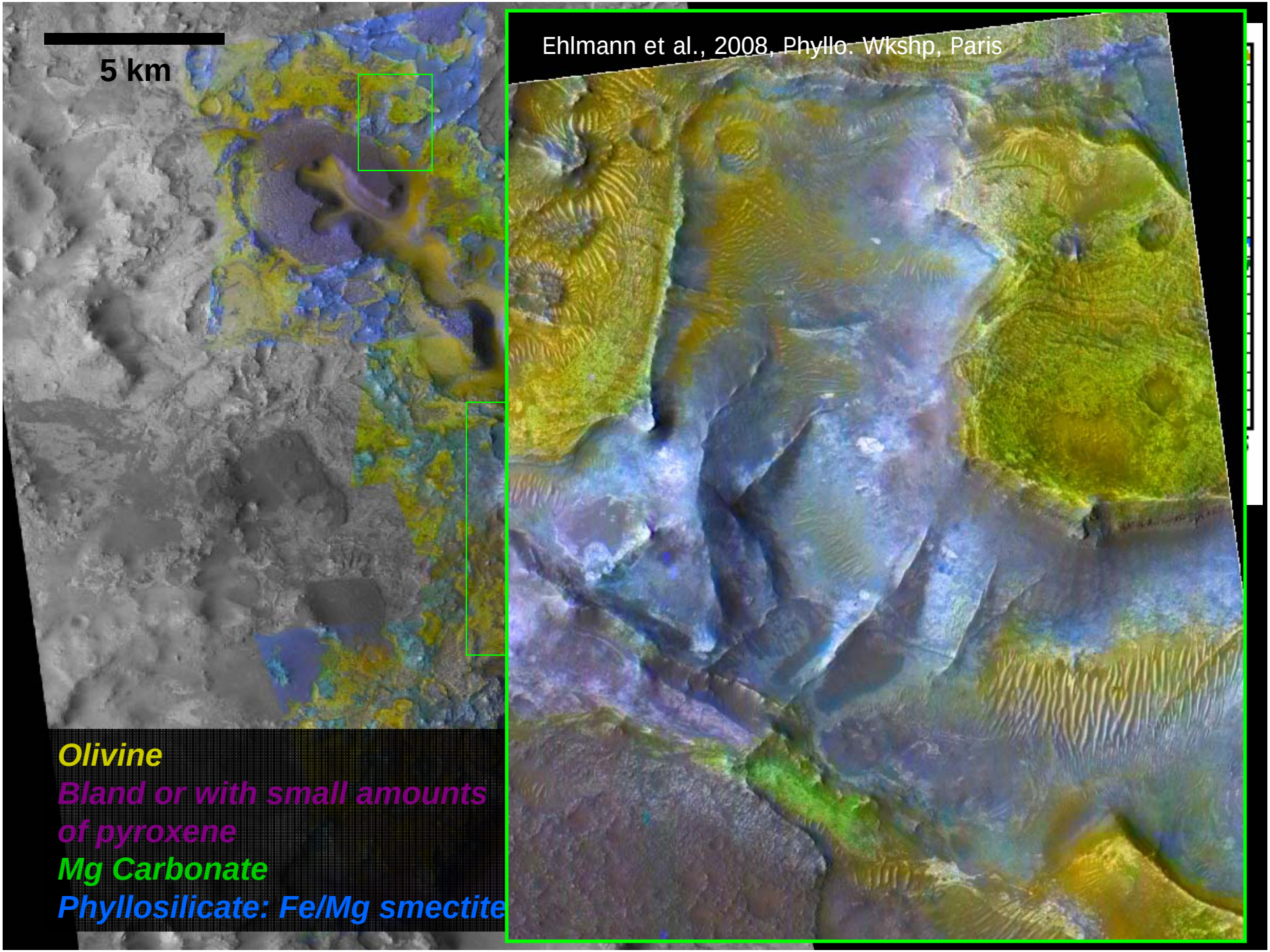
5 km



Carbonate identification: Ehlmann et al., *Science*, in revision

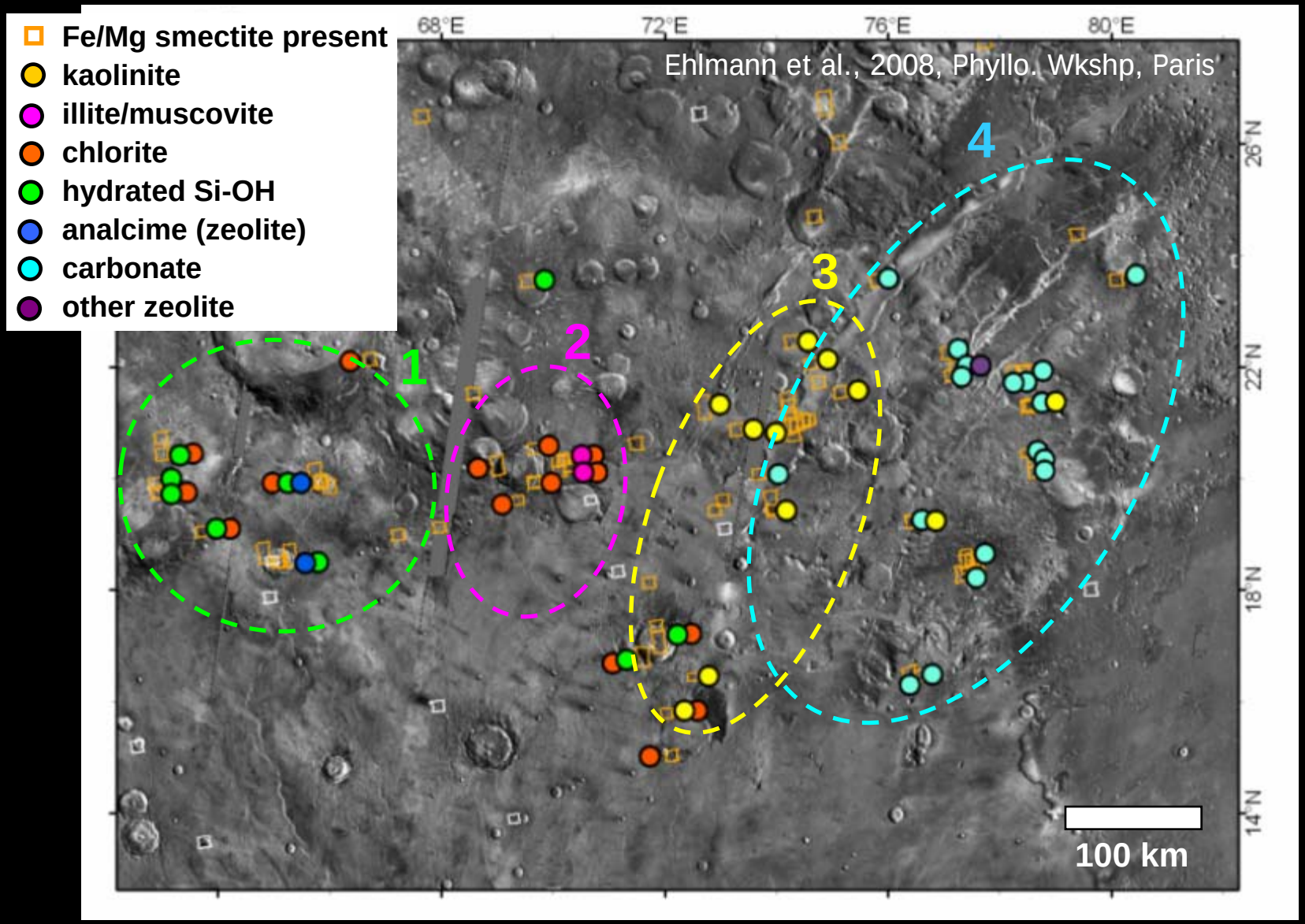
Olivine
Bland or with small amounts of pyroxene
Mg Carbonate
Phyllosilicate: Fe/Mg smectite

Mafic cap unit


5 km
Ehlmann et al., 2008, Phyllo. Wkshp, Paris
Olivine
Bland or with small amounts of pyroxene
Mg Carbonate
Phyllosilicate: Fe/Mg smectite

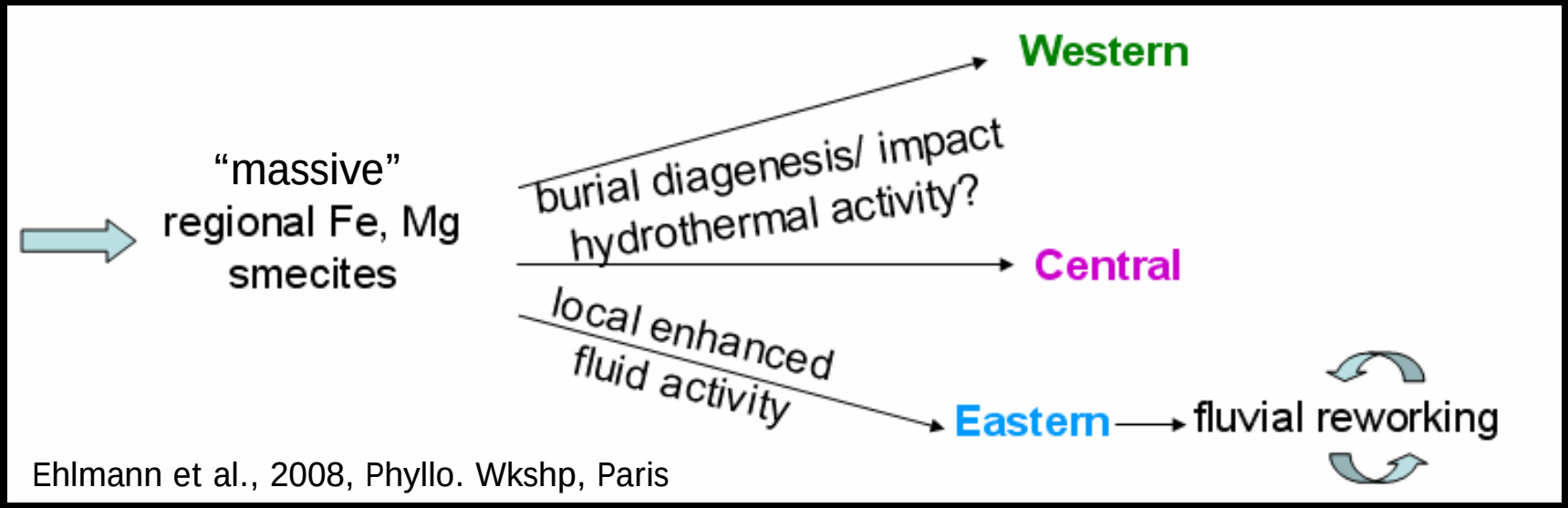
Distinct provinces/assemblages

Ehlmann et al., 2008, LPSC abstract (*JGR*, in prep.)



Multiple episodes of aqueous activity → distinct provinces of alteration

Nili Fossae hydrated mineral formation scenario



Ehlmann et al., 2008, Phyllo. Wkshp, Paris

- Understanding the terrestrial settings for hydrated mineral assemblages found in Nili Fossae will be essential to understanding their formation setting on Mars.