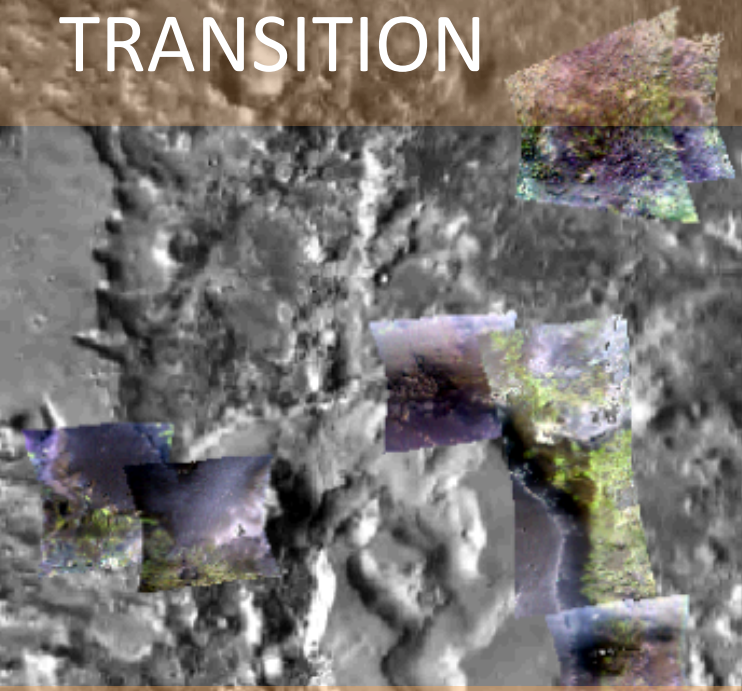
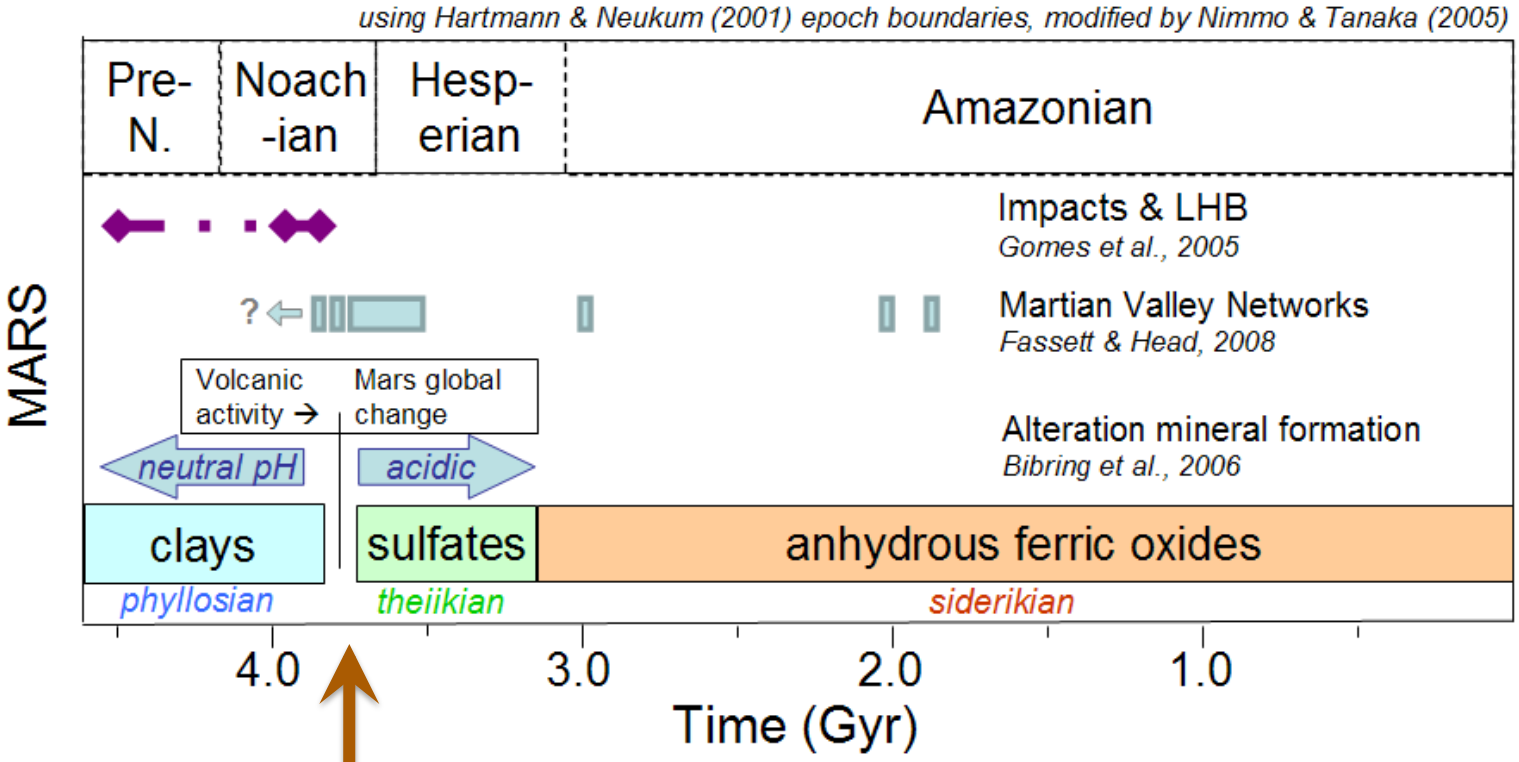
DIVERSE HABITABLE ENVIRONMENTS DURING THE NOACHIAN-HESPERIAN TRANSITION



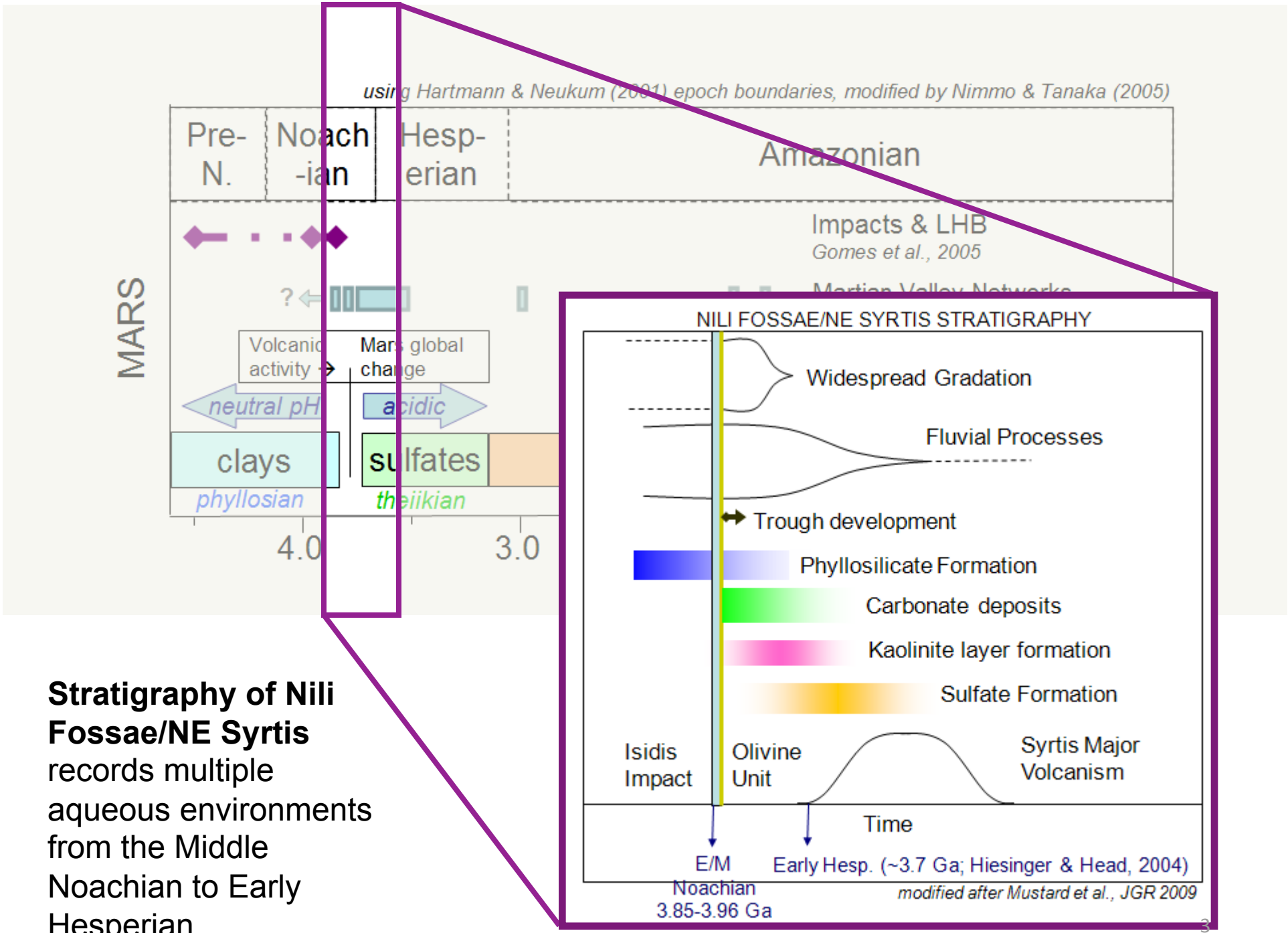
Jack Mustard, Bethany Ehlmann, J.R. Skok
Brown University and IAS-Paris

Era of Major Reorganization of Planetary-scale processes

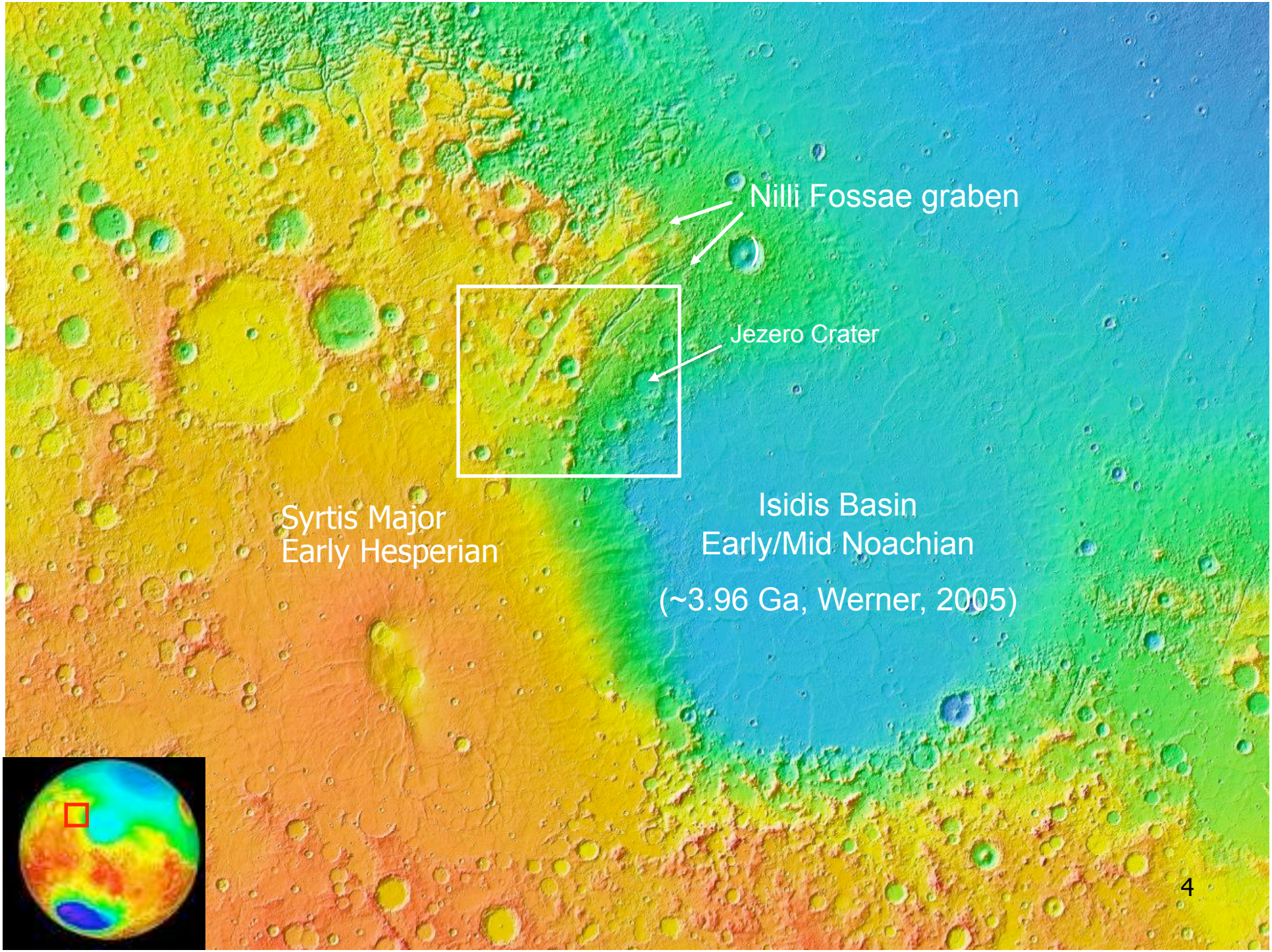


Distinct Geologic Units in Stratigraphic Relationship and Relative Ages

Do they Mineral Assemblages and Geologic Contexts Define Habitable Boundary Conditions?



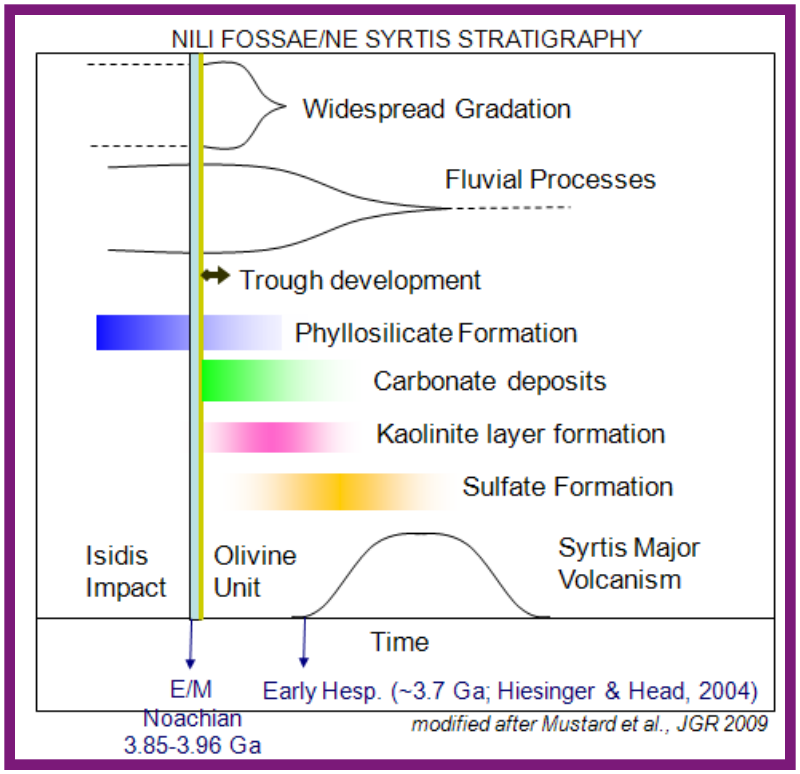
Stratigraphy of Nili Fossae/NE Syrtis records multiple aqueous environments from the Middle Noachian to Early Hesperian


Nilli Fossae graben
Jezero Crater
Syrtis Major
Early Hesperian
Isidis Basin
Early/Mid Noachian
(~3.96 Ga, Werner, 2005)

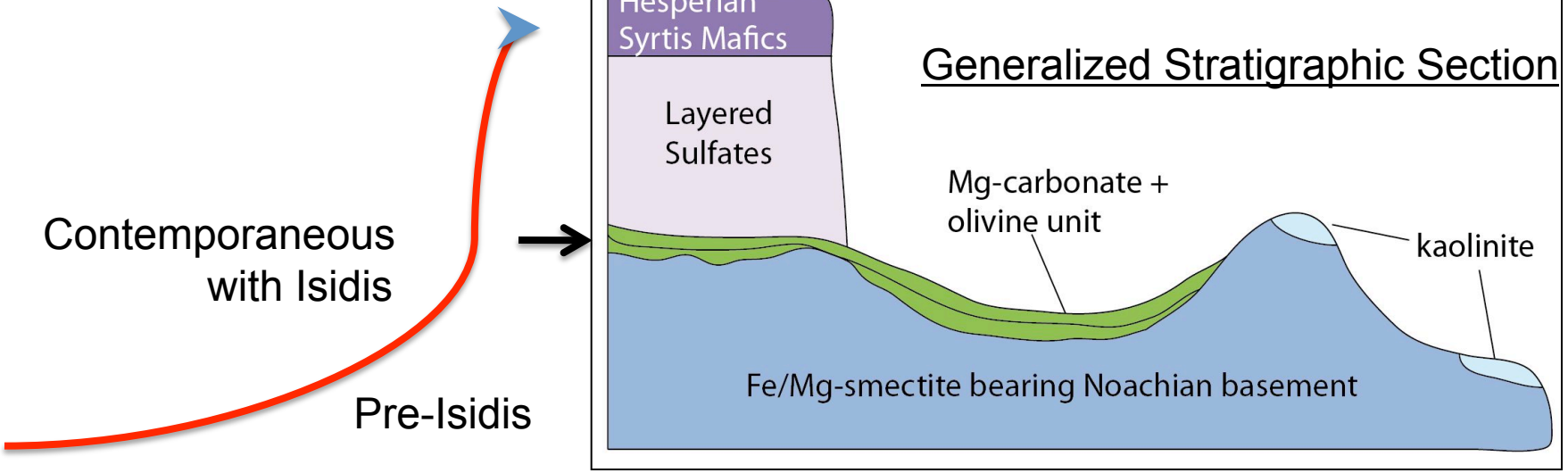
What are the processes and environments that formed early phyllosilicates?

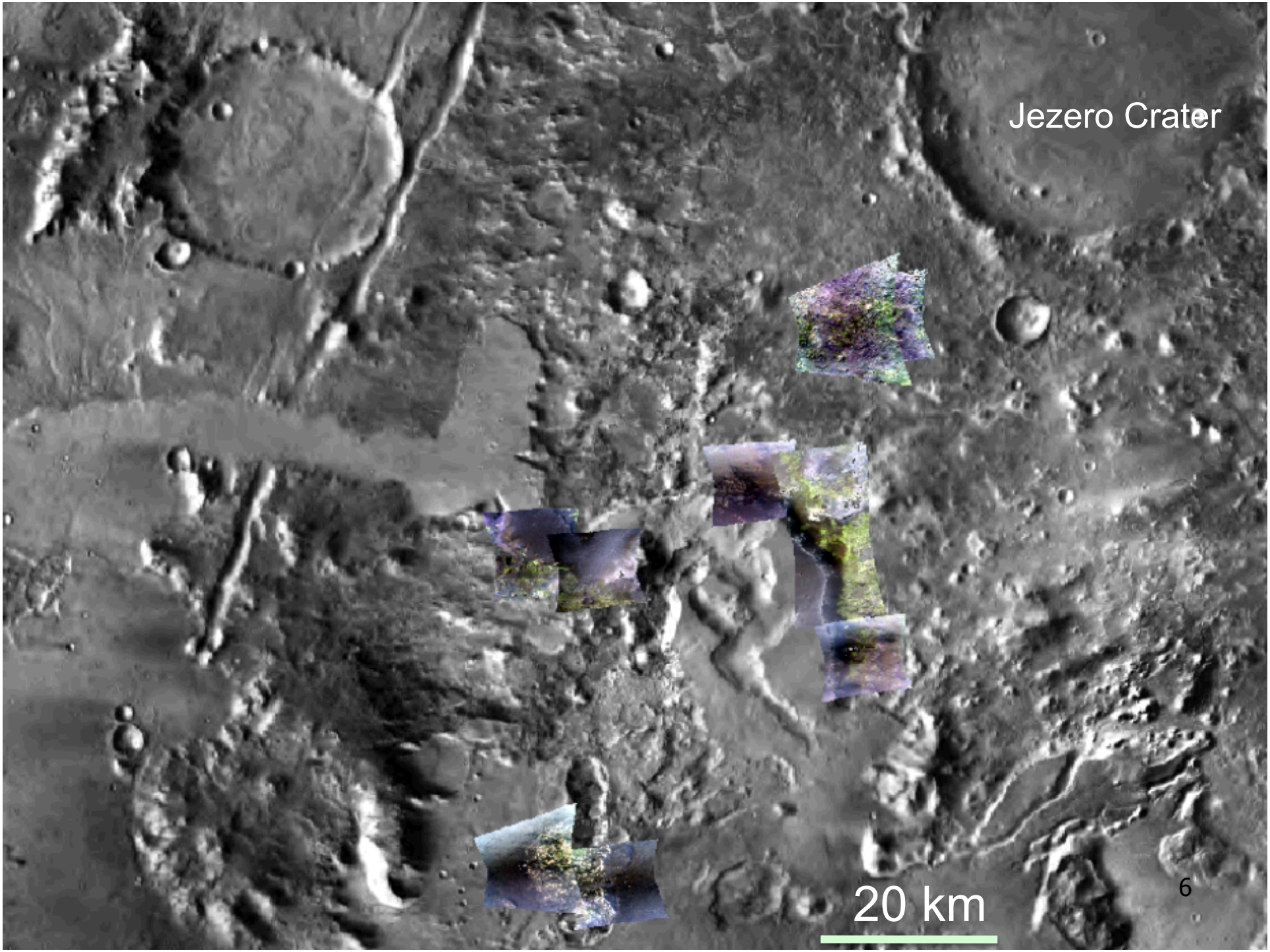
How did conditions change with carbonate formation?

How rapid was the transition to a more acidic, sulfate (jarosite) forming era?

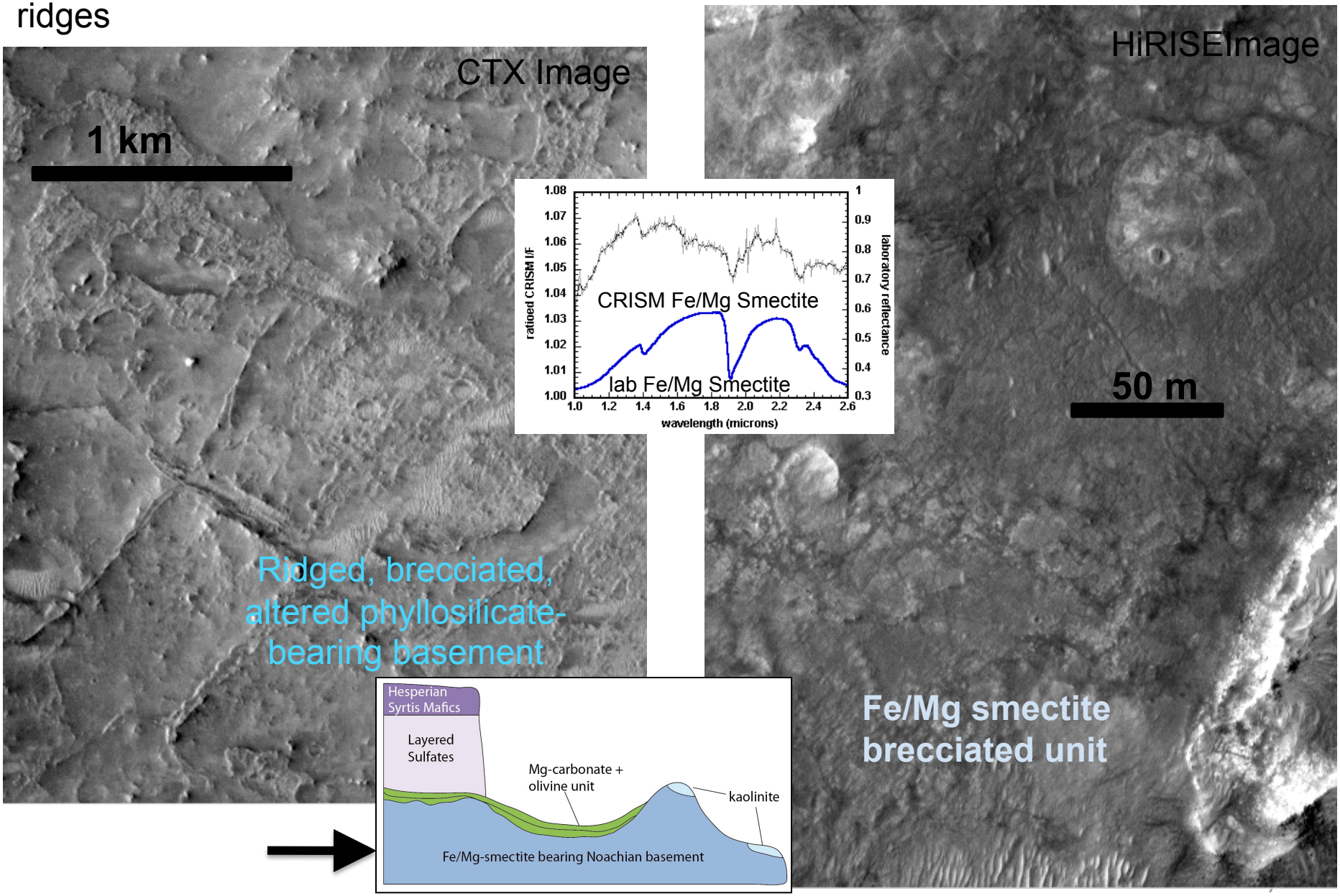


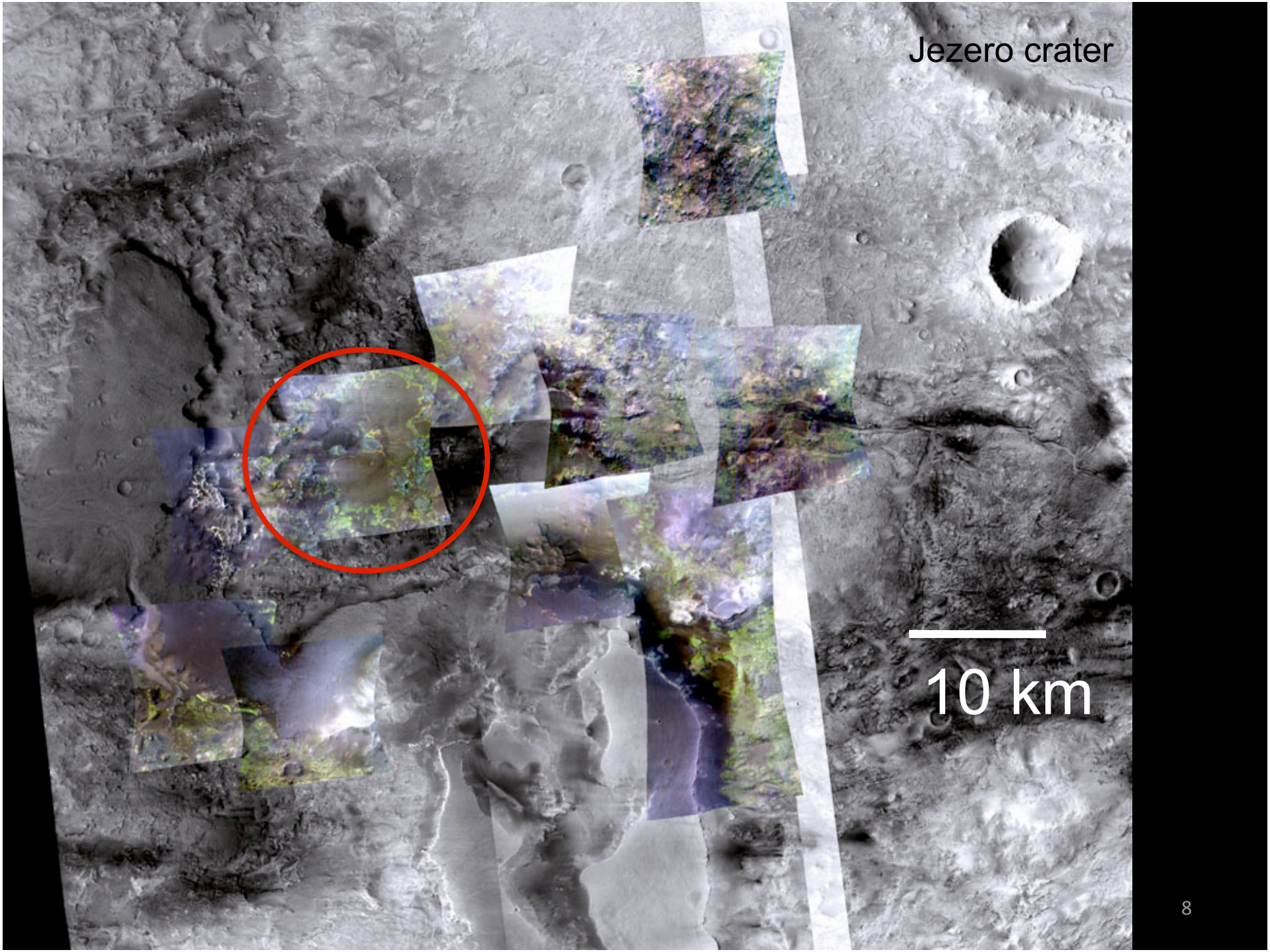
A Traverse Up the Section




Jezero Crater
20 km

Noachian Basement exposed on the plains shows breccia blocks of unaltered pyroxene-bearing rocks set in a matrix of Fe/Mg phyllosilcate and laced with raised ridges



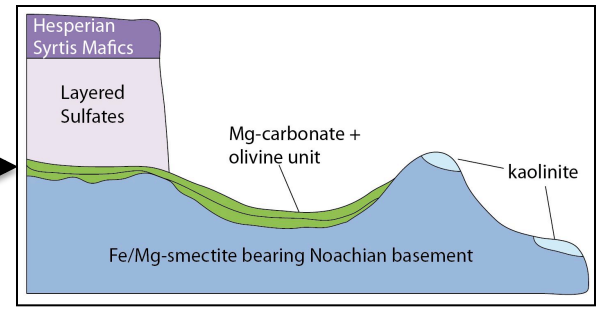

Jezero crater
10 km

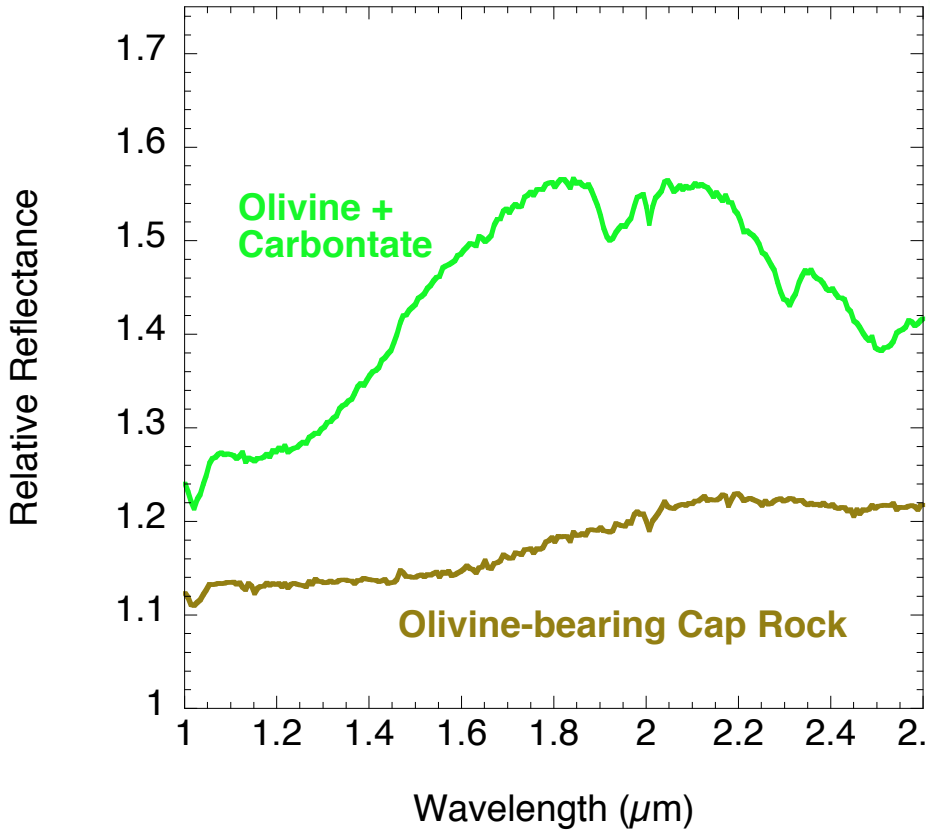
Distinct Mafic to Ultramafic Deposit (regional in scope) that is post Isidis in age but pre-fossae:

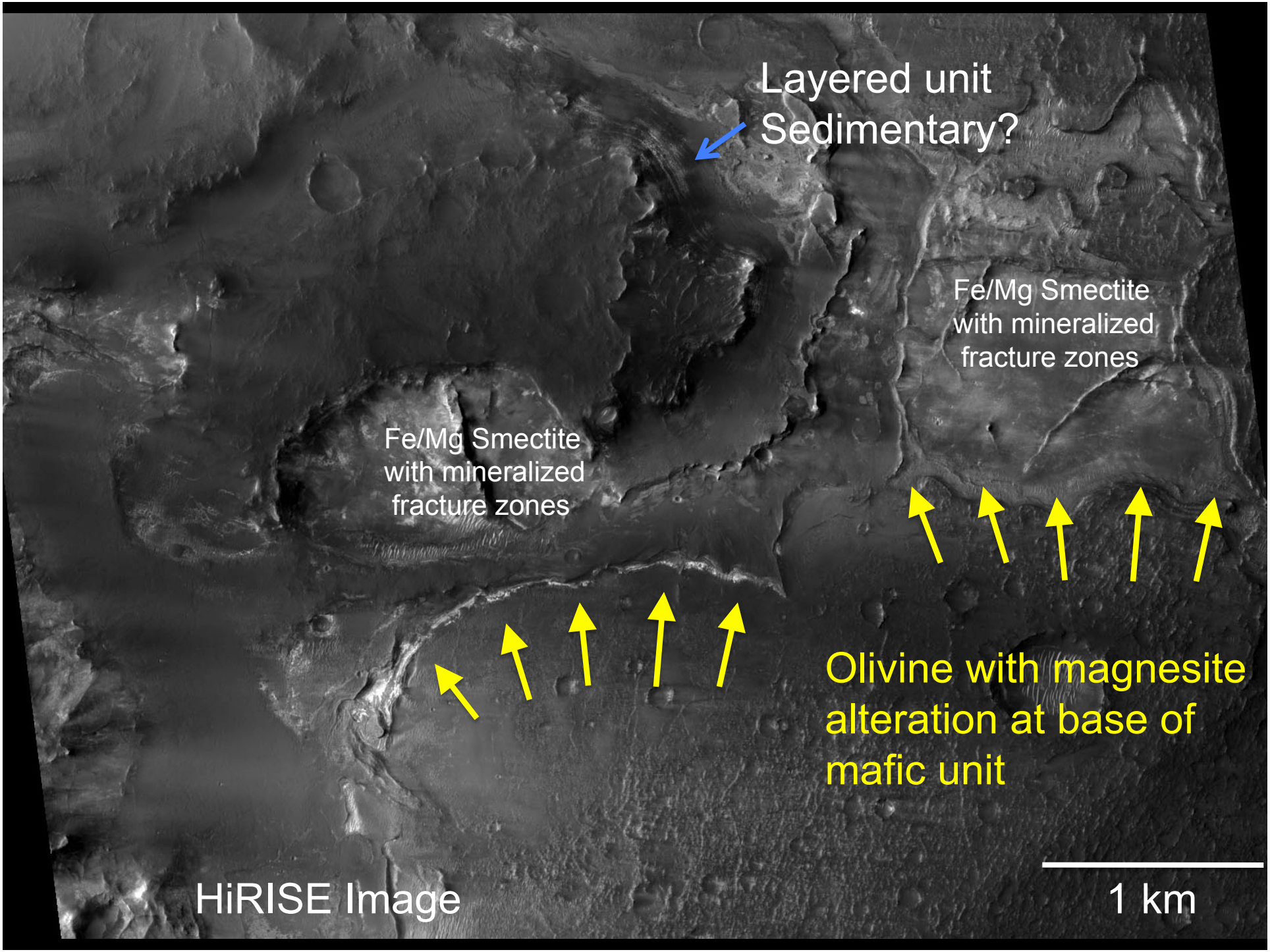
Impact melt or ultramafic lava flows

Rests directly on Fe/Mg altered basement

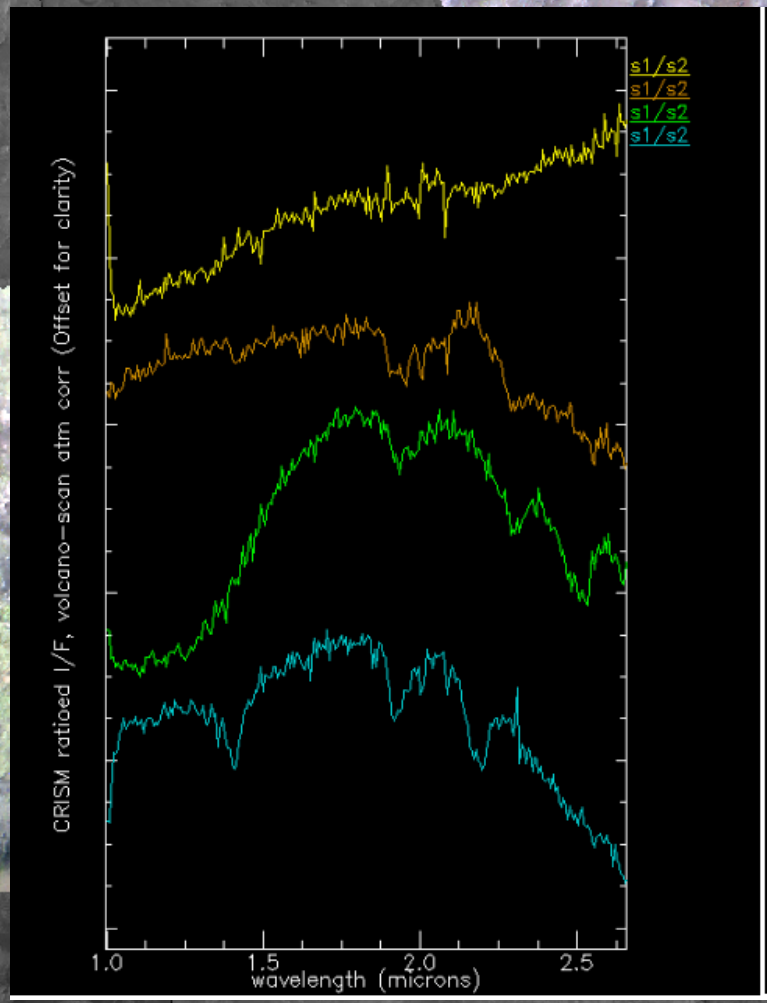
The base of the deposit hosts the Mg-carbonate deposits

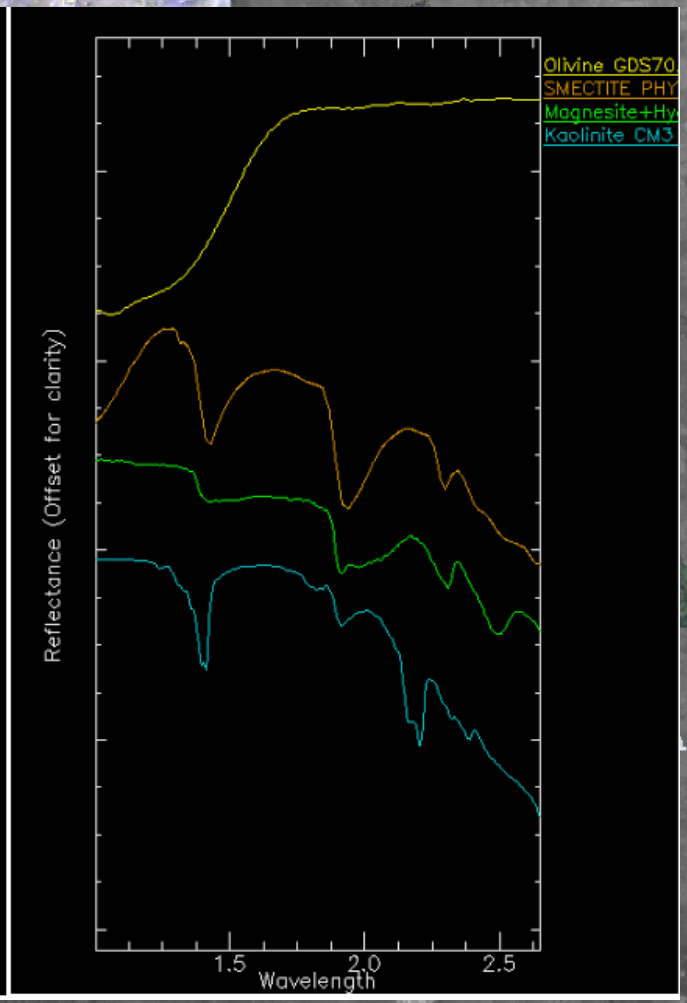


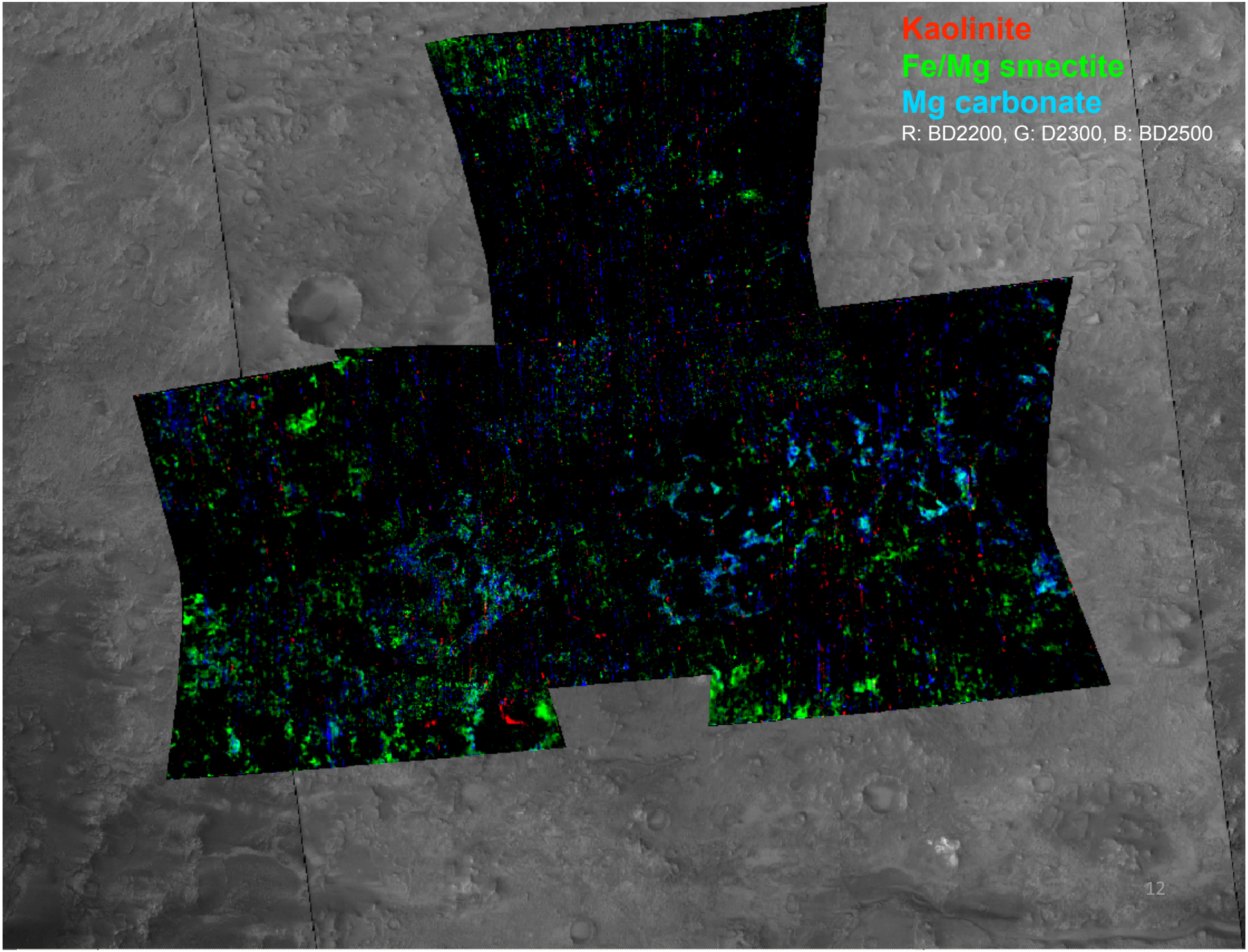



Layered unit
Sedimentary?
Fe/Mg Smectite
with mineralized
fracture zones
Fe/Mg Smectite
with mineralized
fracture zones
Olivine with magnesite
alteration at base of
mafic unit
HiRISE Image
1 km

Plains Deposits Show Kaolinite Mineral Deposits Indicative of Surface Water

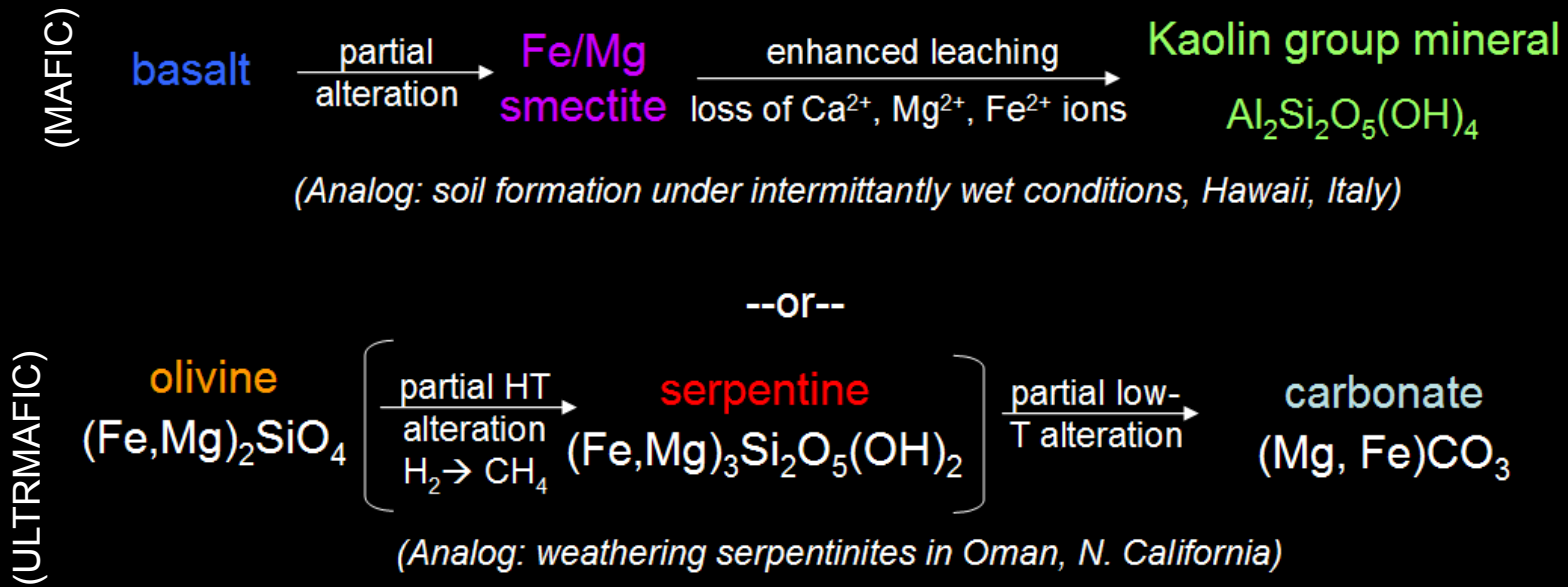




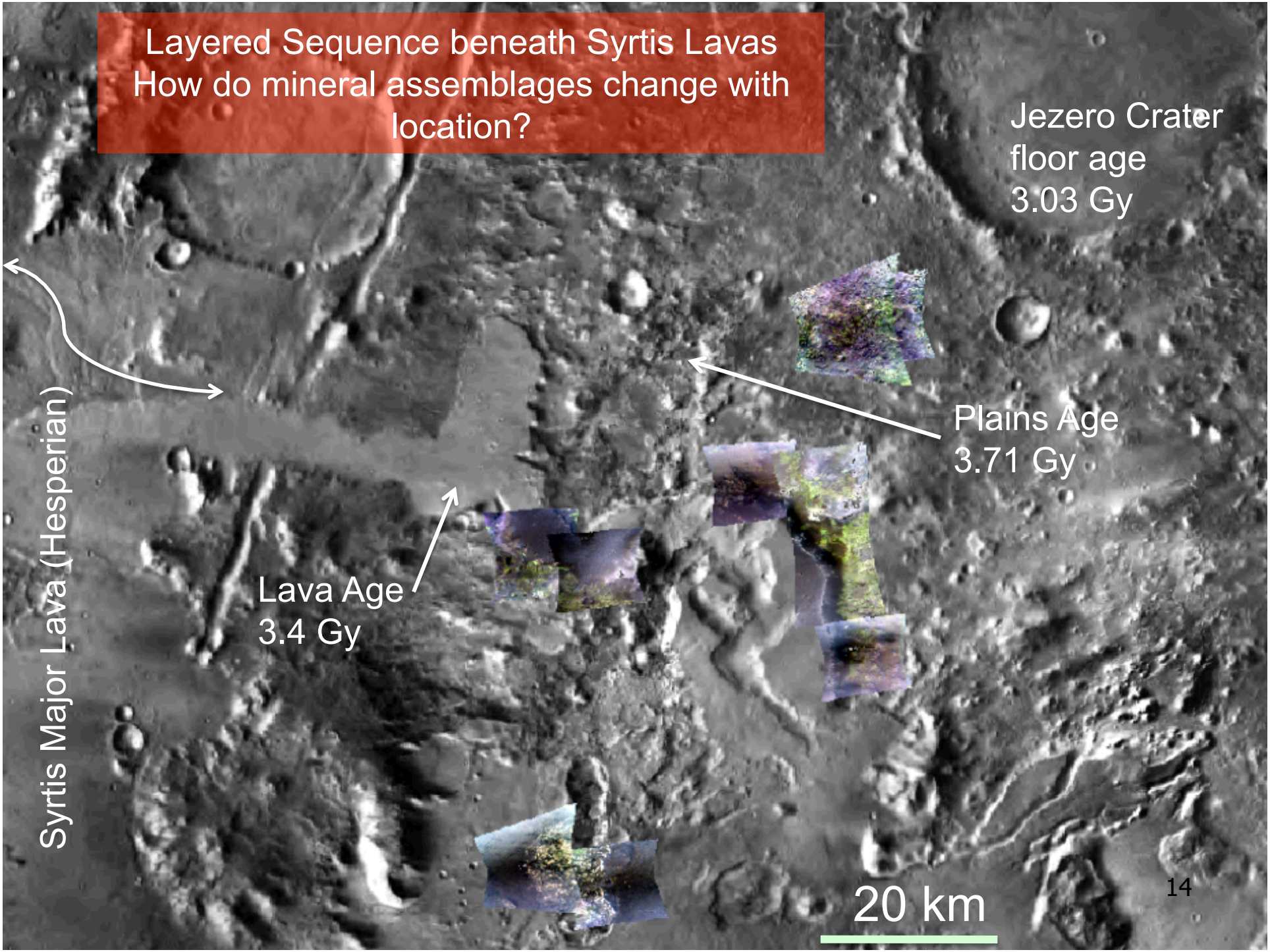

Kaolinite
Fe/Mg smectite
Mg carbonate
R: BD2200, G: D2300, B: BD2500

Kaolinite, carbonate, and serpentine mineralization

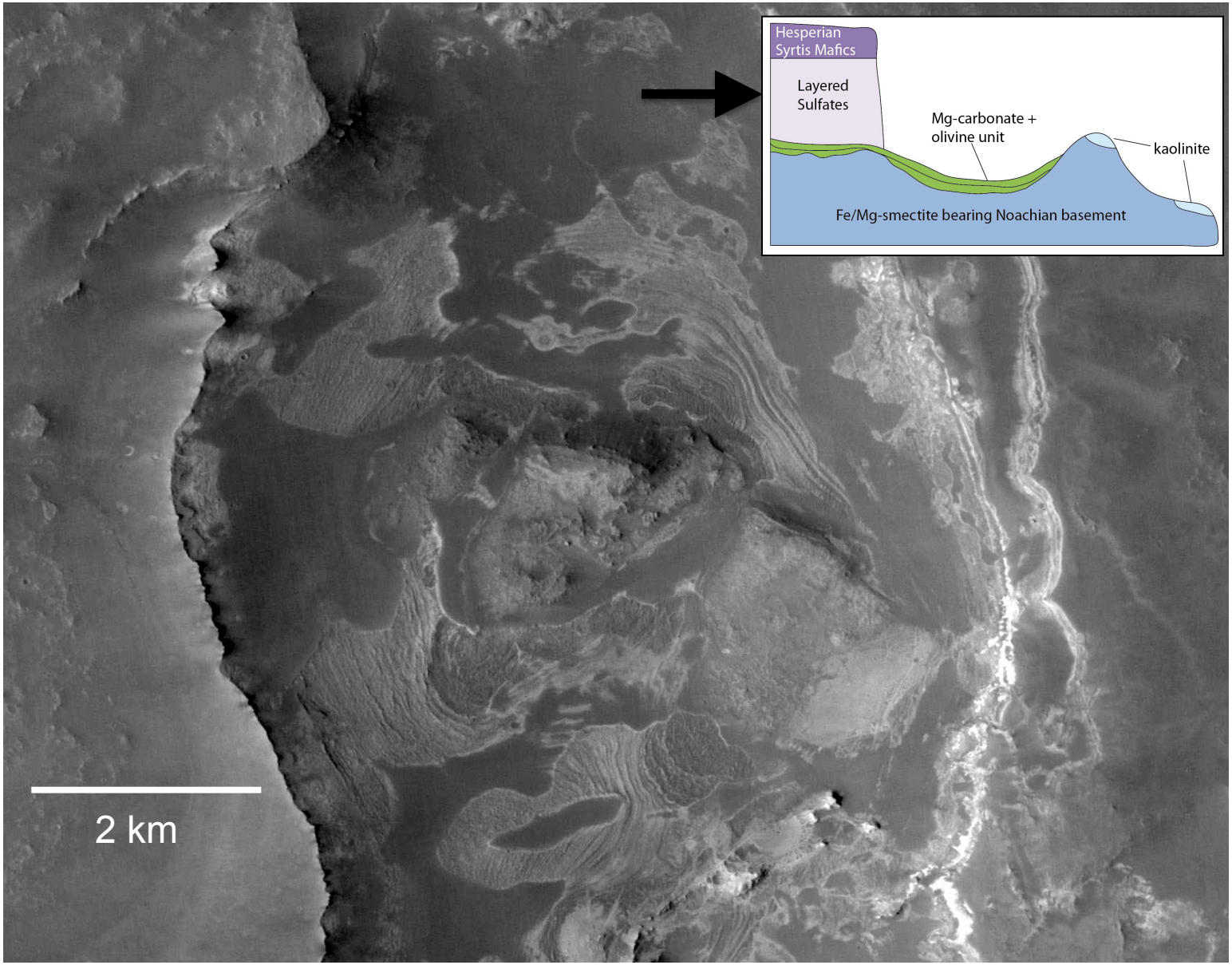
- Chemistry controlled by precursor mineralogy

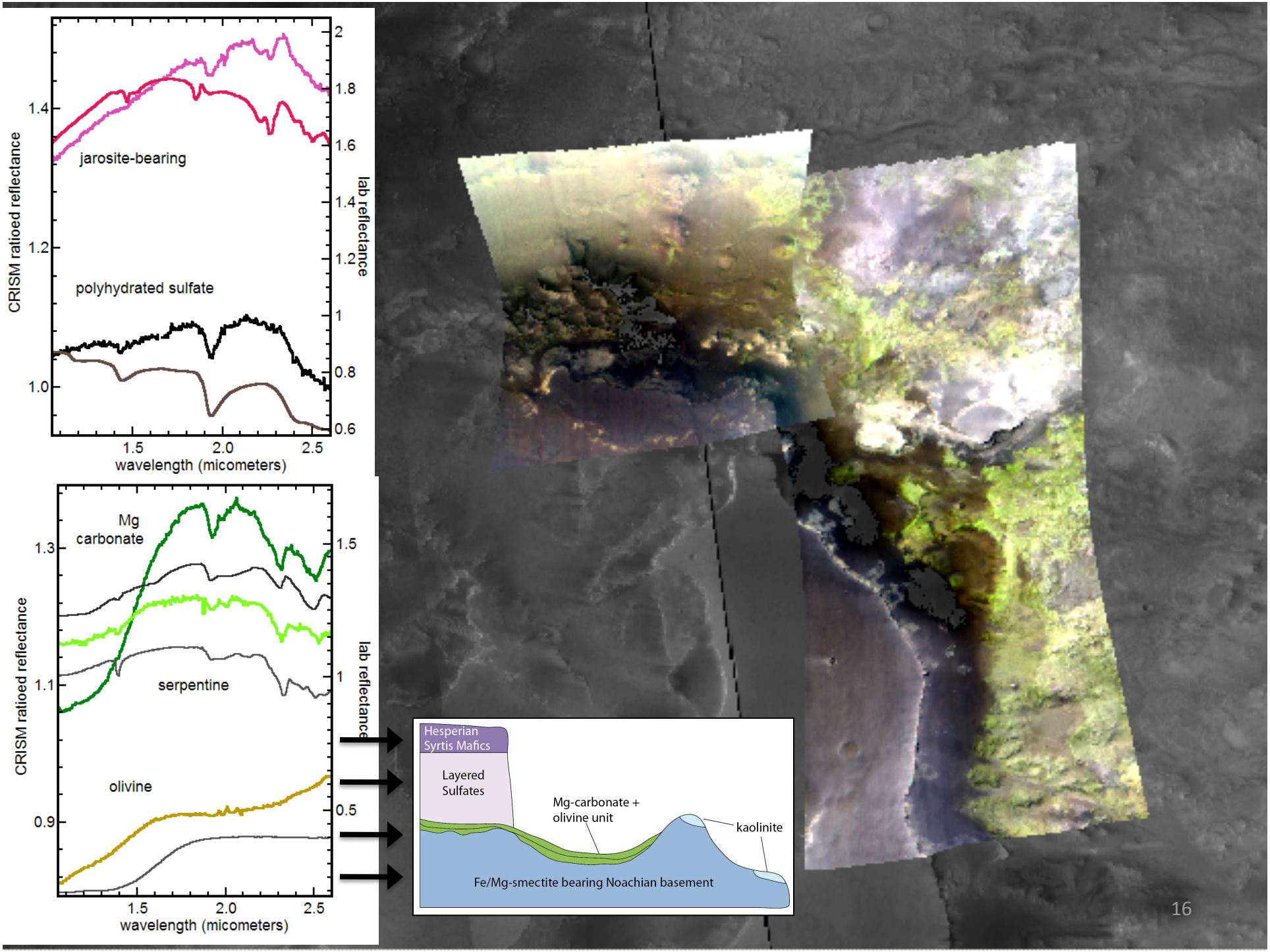


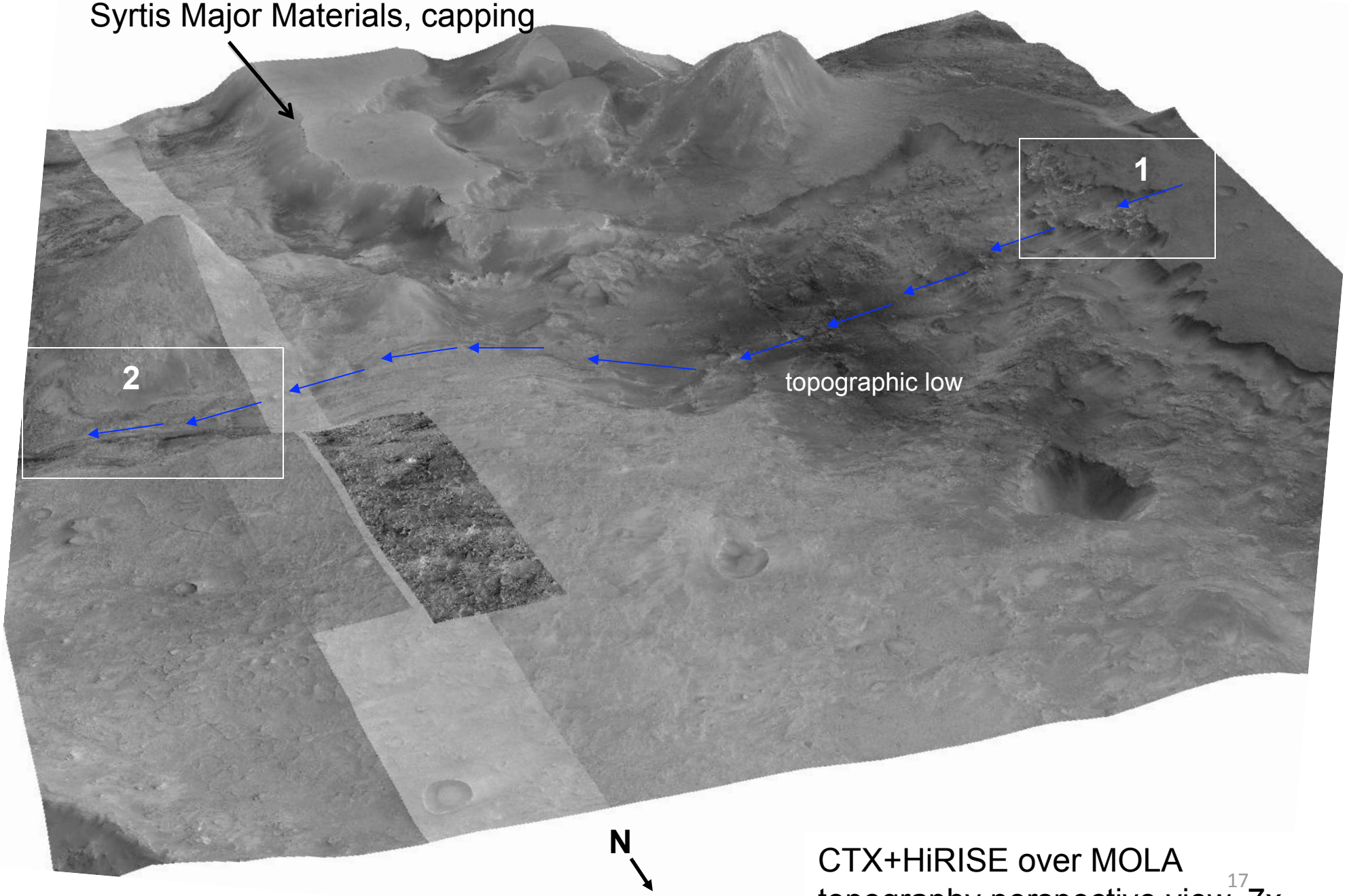
- Carbonate(/Serpentine): Carbonate alteration mostly related to near-surface hydrology? Or mostly generated by hydrothermal systems?
  - H_2 an energy source for organisms, potential for methane production during serpentine formation
- Kaolinite: Leaching from an active hydrologic system?


Layered Sequence beneath Syrtis Lavas
How do mineral assemblages change with location?
Jezero Crater floor age 3.03 Gy
Plains Age 3.71 Gy
Lava Age 3.4 Gy
Syrtis Major Lava (Hesperian)
20 km

Beneath the capping lava is a 500 m stack of layered rock that appears sedimentary

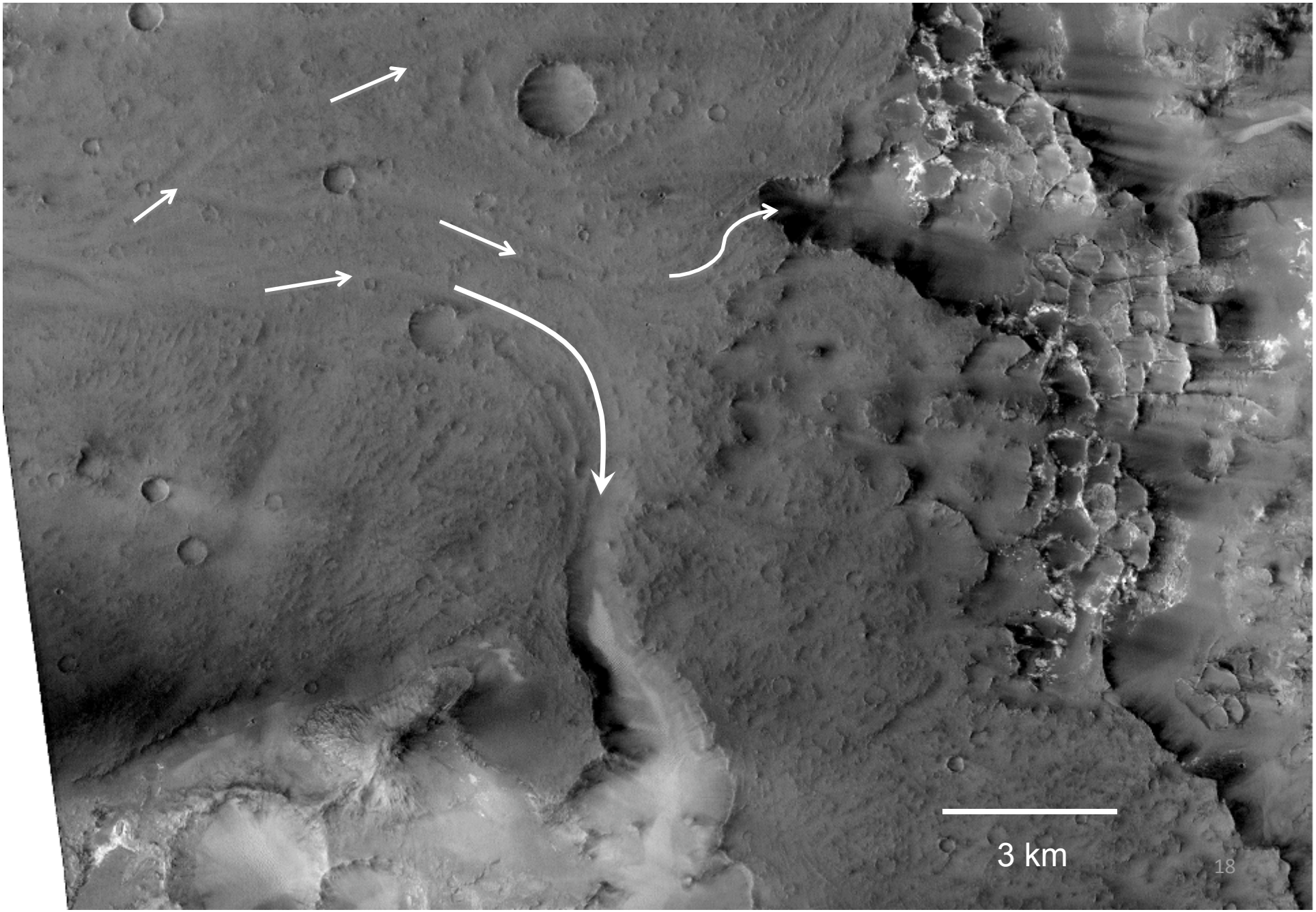



jarosite-bearing
polyhydrated sulfate
CRISM ratioed reflectance
lab reflectance
wavelength (micometers)
Mg carbonate
serpentine
olivine
Hesperian Syrtis Mafics
Layered Sulfates
Mg-carbonate + olivine unit
kaolinite
Fe/Mg-smectite bearing Noachian basement



CTX+HiRISE over MOLA topography perspective view, 7x

1. NE Syrtis inflow

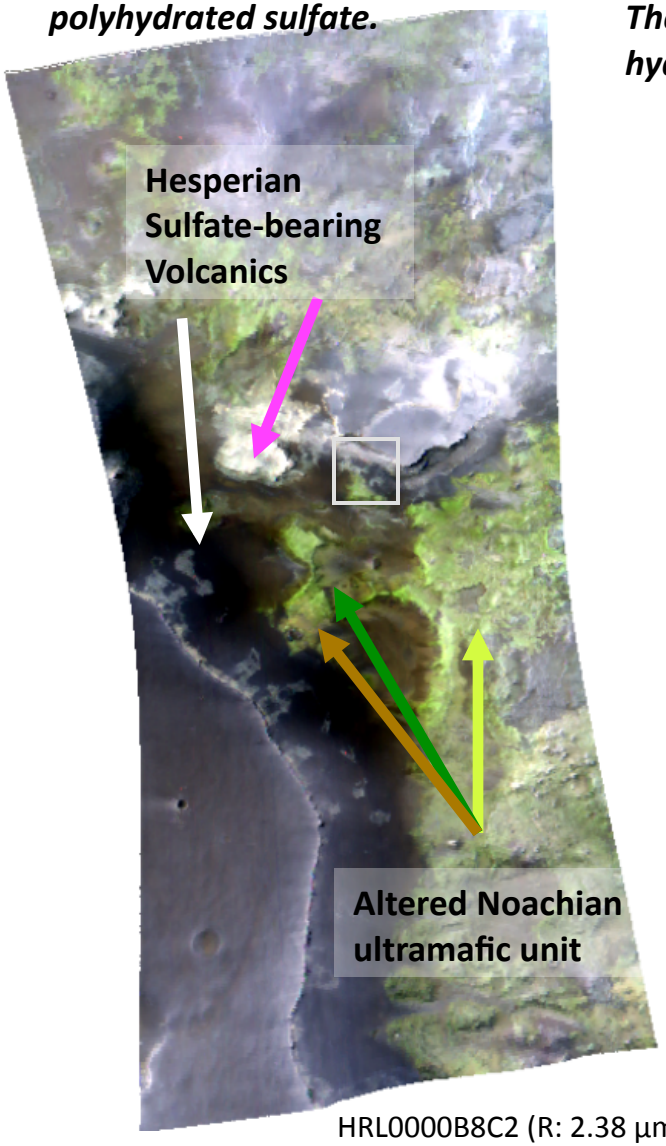


Noachian to Hesperian Transition: An Acid-Alkaline Processes

This Noachian-Hesperian stratigraphy transitions from ancient phyllosilicate to carbonate (alkaline) and kaolinite to sulfate (acidic)

Lavas emplaced in a volatile-rich environment overlie (sedimentary?) sulfate-bearing deposits that include jarosite and polyhydrated sulfate.

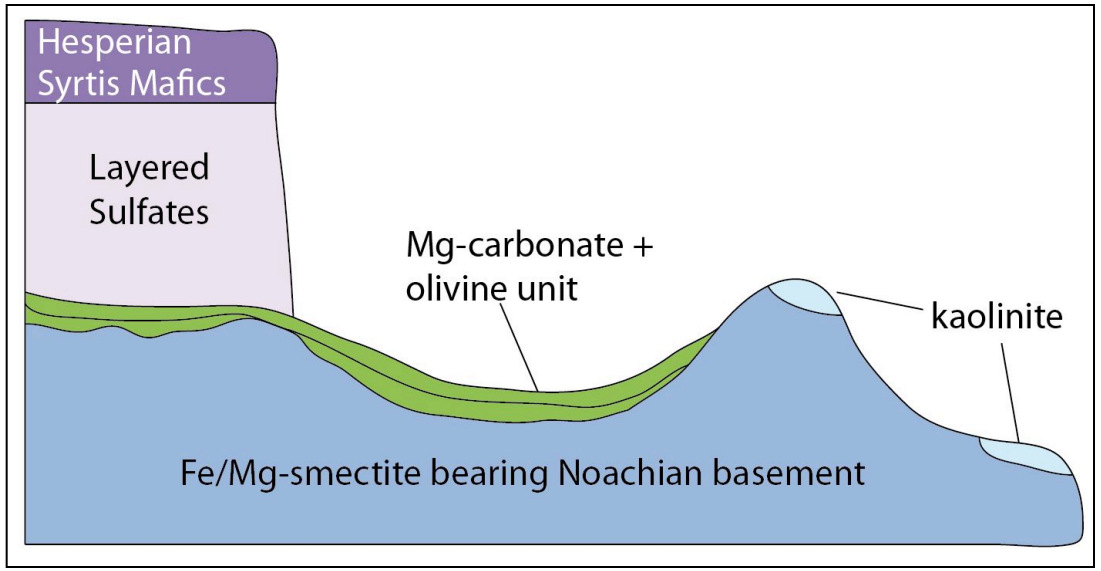
There is evidence for circulation of fluids by heat of lava source and thus hydrothermal systems in a volcano-ice environment



HRL0000B8C2 (R: 2.38 µm, G: 1.80 µm, B: 1.15 µm)

Clear stratigraphy of unaltered volcanic units, sulfates, carbonate-serpentine-olivine unit and Fe/Mg smectite basement

Long record of aqueous geochemistry recorded by alteration minerals



Diversity of Habitable Environments (1)

- Shallow Subsurface Hydrothermal Systems
  - Fe/Mg Phyllosilicate with evidence of fluid flow
- Surface Fluvial Systems
  - Network of fluvial channels and low regions showing open basin lake system (e.g. Jezero)
  - Kaolinite in capping rocks indicative of water flow in regolith-pedogenesis
- Reactant-product Mineral associations
  - Olivine => Serpentine: production of H_2-CH_4
  - Olivine => Magnesite (Mg-carbonate)

Diversity of Habitable Environments (2)

- Volcano-ice Interaction at the Isidis Basin Edge
  - Volcanic morphology suggests lava-ice interaction
- Layered Material Beneath Hesperian Lava
  - Sulfate rich with polyhydrated and jarosite minerals
  - Pre-Syrtis sedimentary deposits (in an area predicted to have upwelling groundwater (e.g. Andrews-Hanna)
  - Alteration of Syrtis lava flows
- Transition in preserved habitable environments and major Mars Environmental Change