Mawrth Vallis clay unit: probing the early Mars Habitability, Climate and Origin of Life

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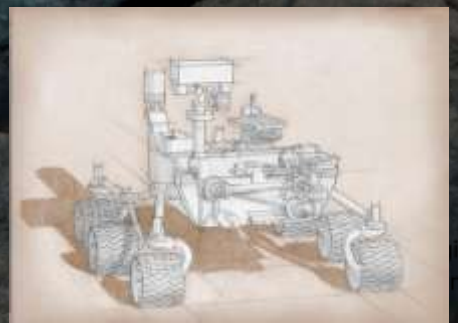
Mars 2020 Landing Site Workshop



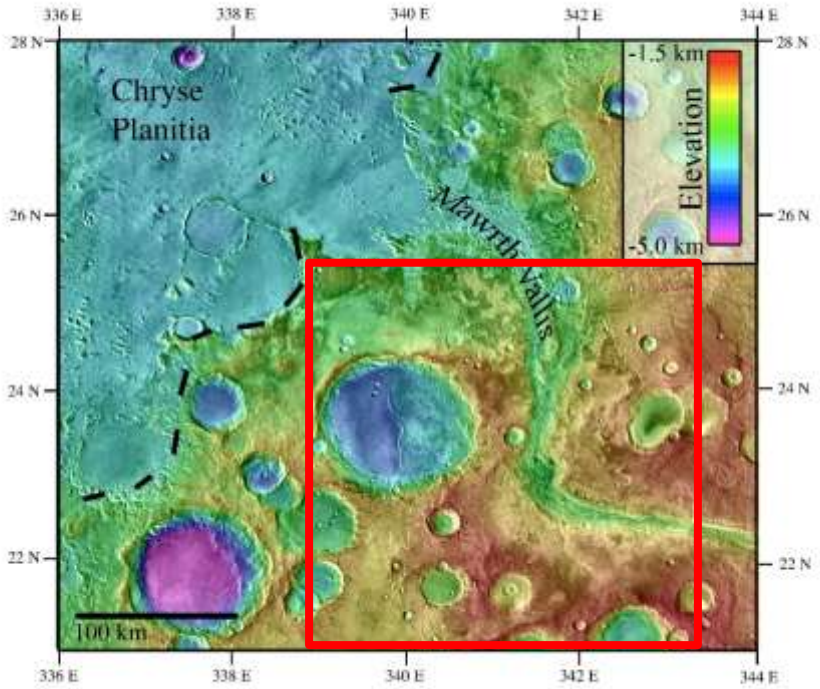
erc

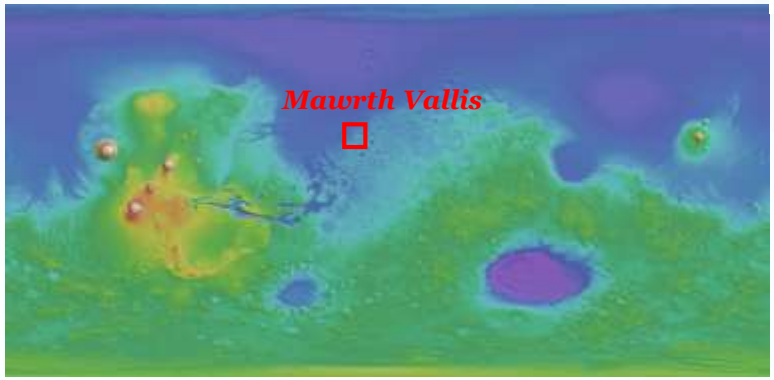
e-MARS

e-mars.geologie-lyon.fr

Regional Context

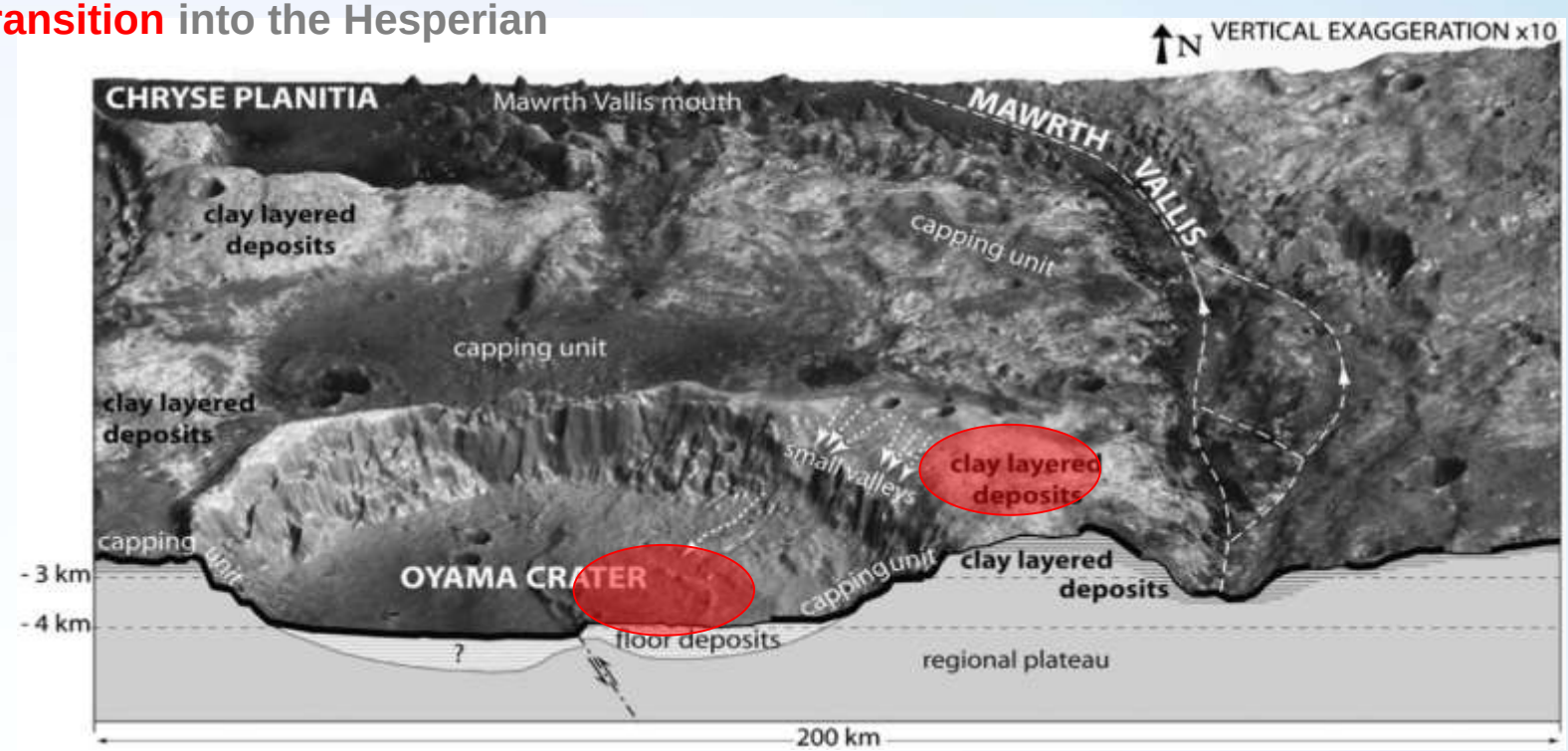
- Extended unit with a large variety of hydrated minerals associated with layers (several ellipses were studied)
- Largest clay content identified on Mars
- Numerous studies (40+ peer-reviewed papers including science and nature papers)





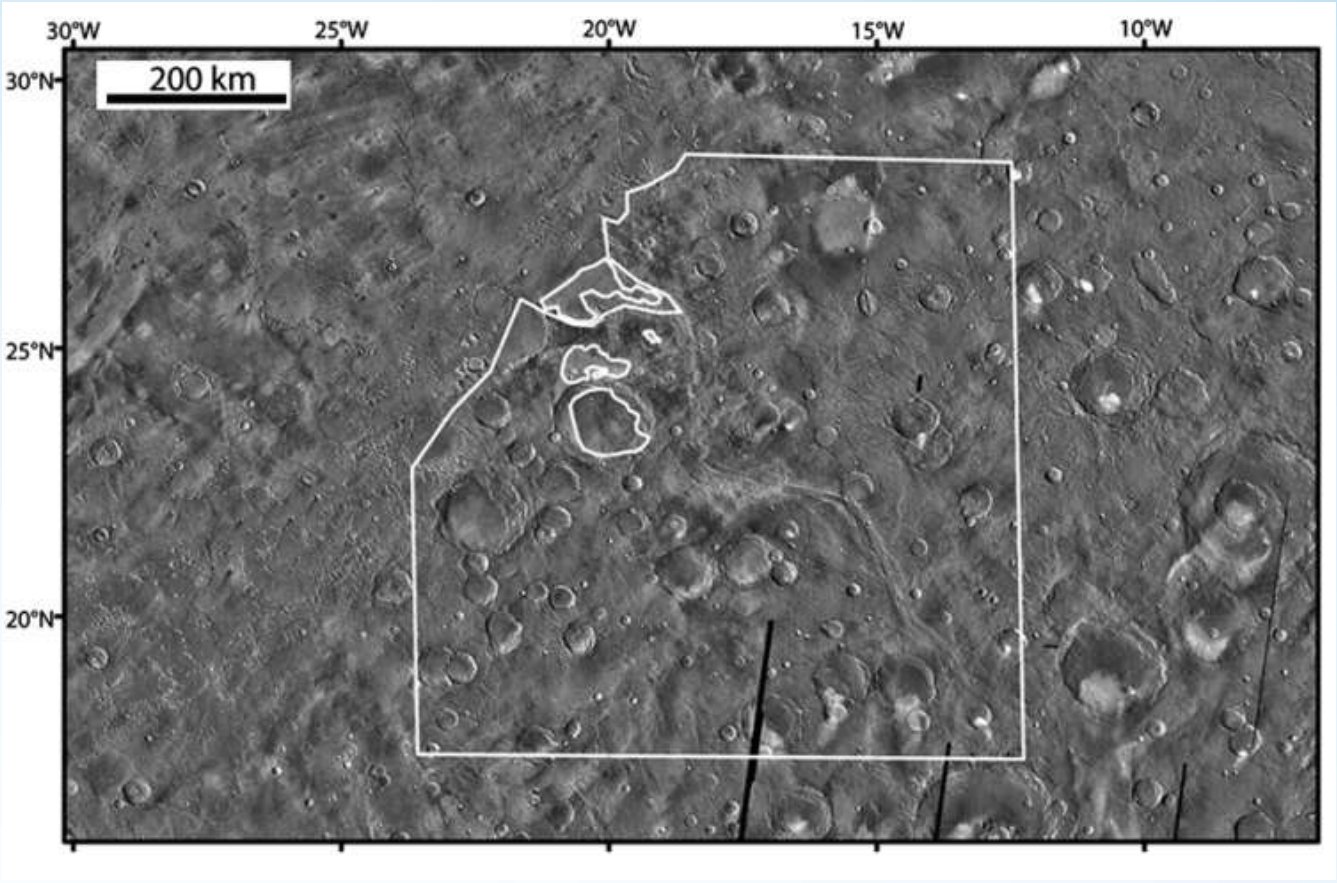
Attractive points

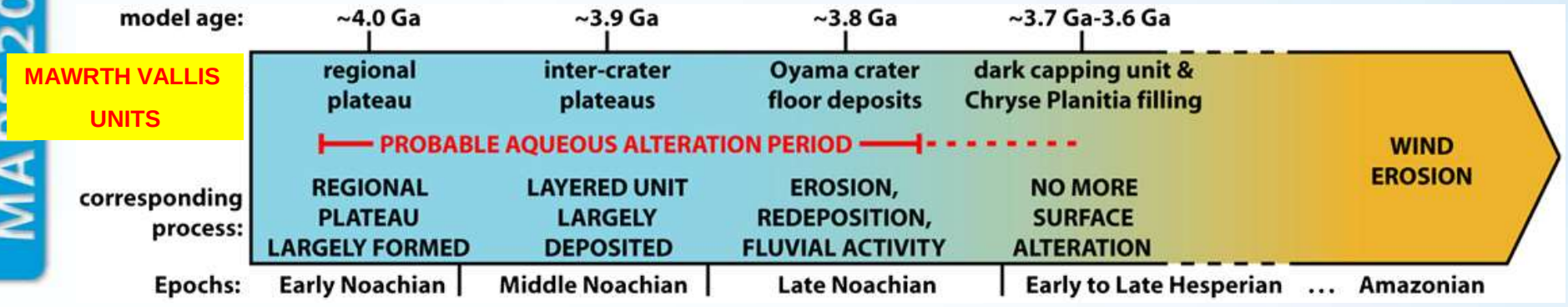
1. **Mineralogically very** diverse site
2. **Lithologically** diverse site that captures multiple environments
3. Both **ancient altered Noachian deposits** and **remobilized sediments**
4. Extremely **ancient section** of rocks probing an enigmatic epoch in Solar System history
5. **Several** types of science **(astrobiological) targets**
6. Opportunity to **sample rocks** from the deep Noachian up **through the global transition** into the Hesperian



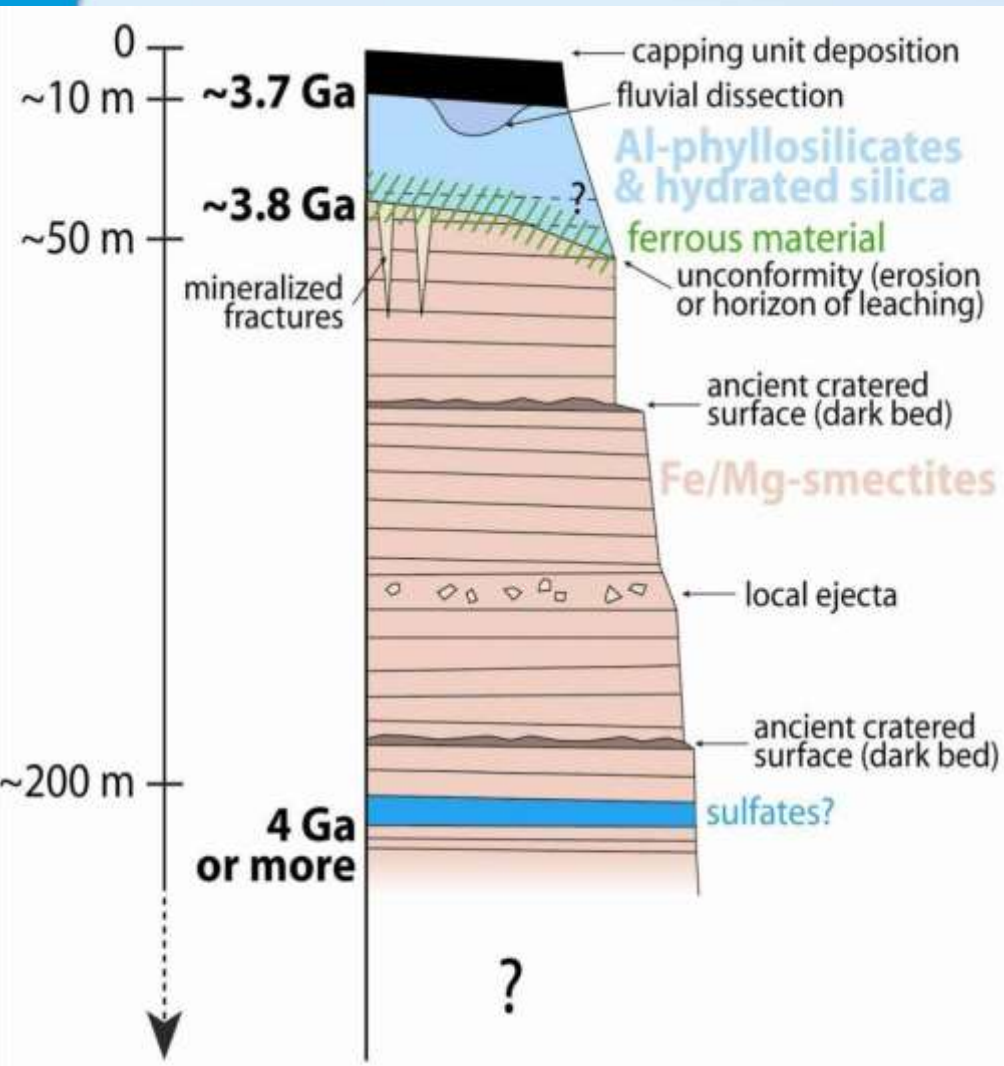
MARS 2020 at MAWRTH VALLIS

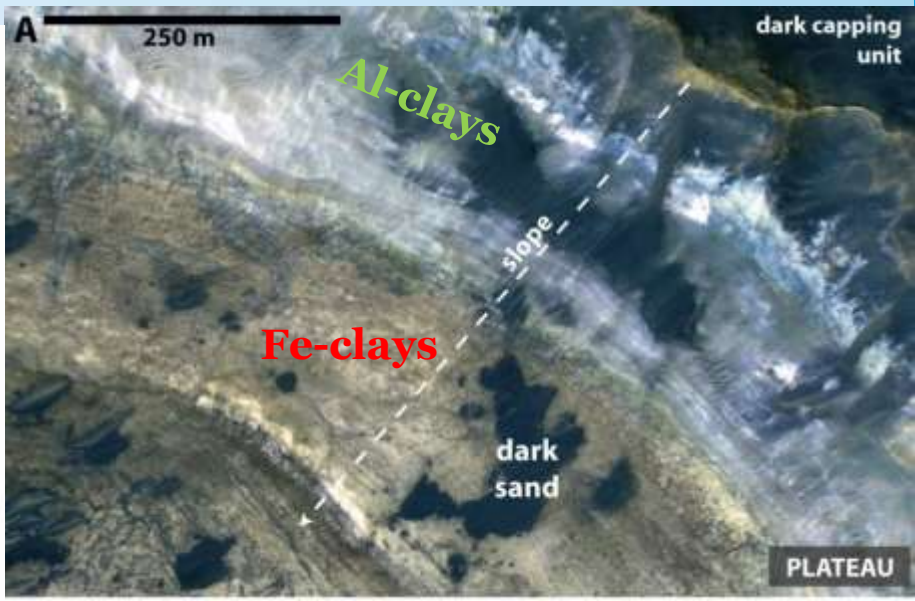
Early Noachian to the Hesperian





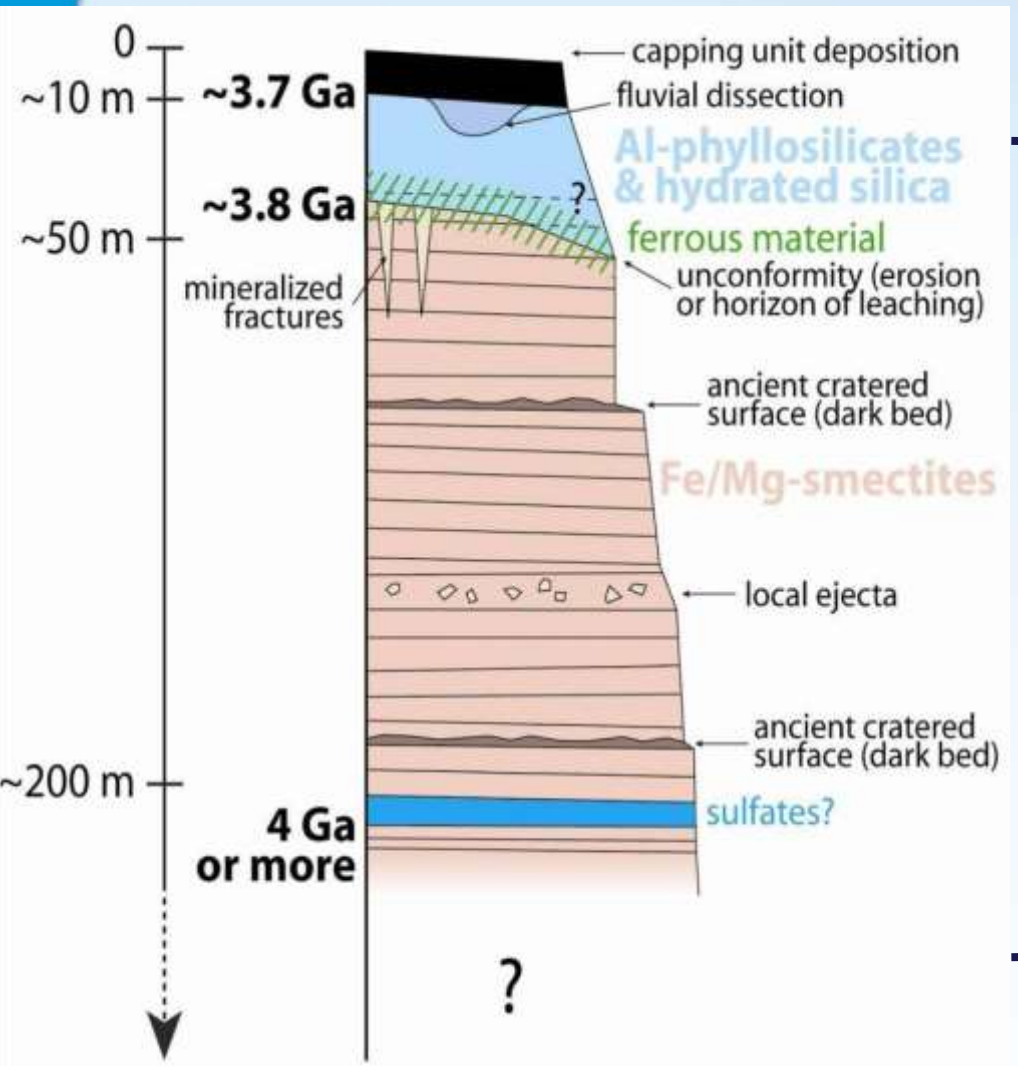
Complex aqueous diversity on Mars





Gale Crater	Mawrth Vallis
Fe/Mg-phyllosilicate	Fe/Mg-phyllosilicate
	Al-phyllosilicate
	Hydrated silica
	Kaolinite
	Acid-treated clays
Sulfates (polyhydrated)	Sulfates (bassanite jarosite)
	Alunite

Complex aqueous history on Mars



Phase 1

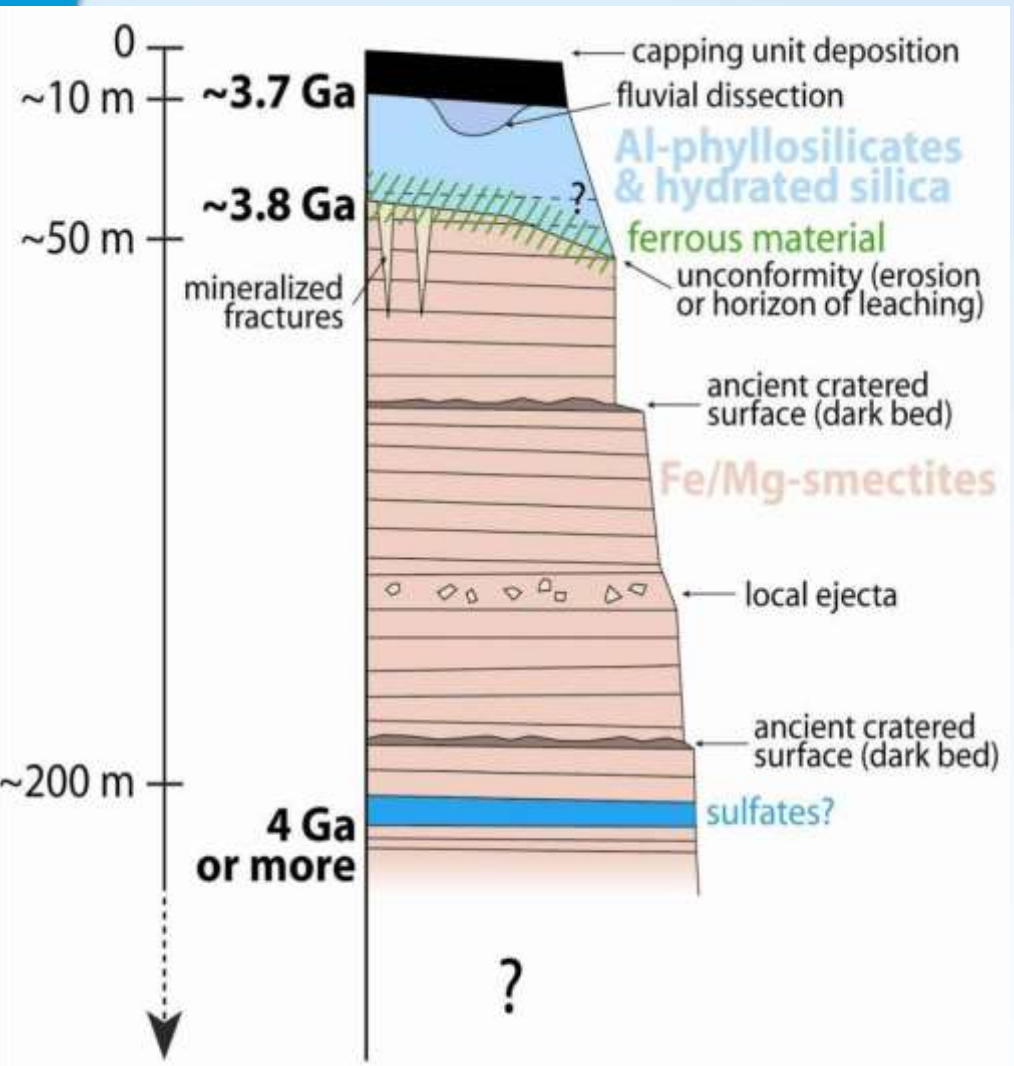
Progressive deposition and alteration of sediments or pyroclastic deposits => smectites

Early to middle Noachian

Moderate water rock ratio

Local precipitation of sulfates

Complex aqueous history on Mars



Phase 2

Continued surface weathering, greater or acidic leaching of the surface layers

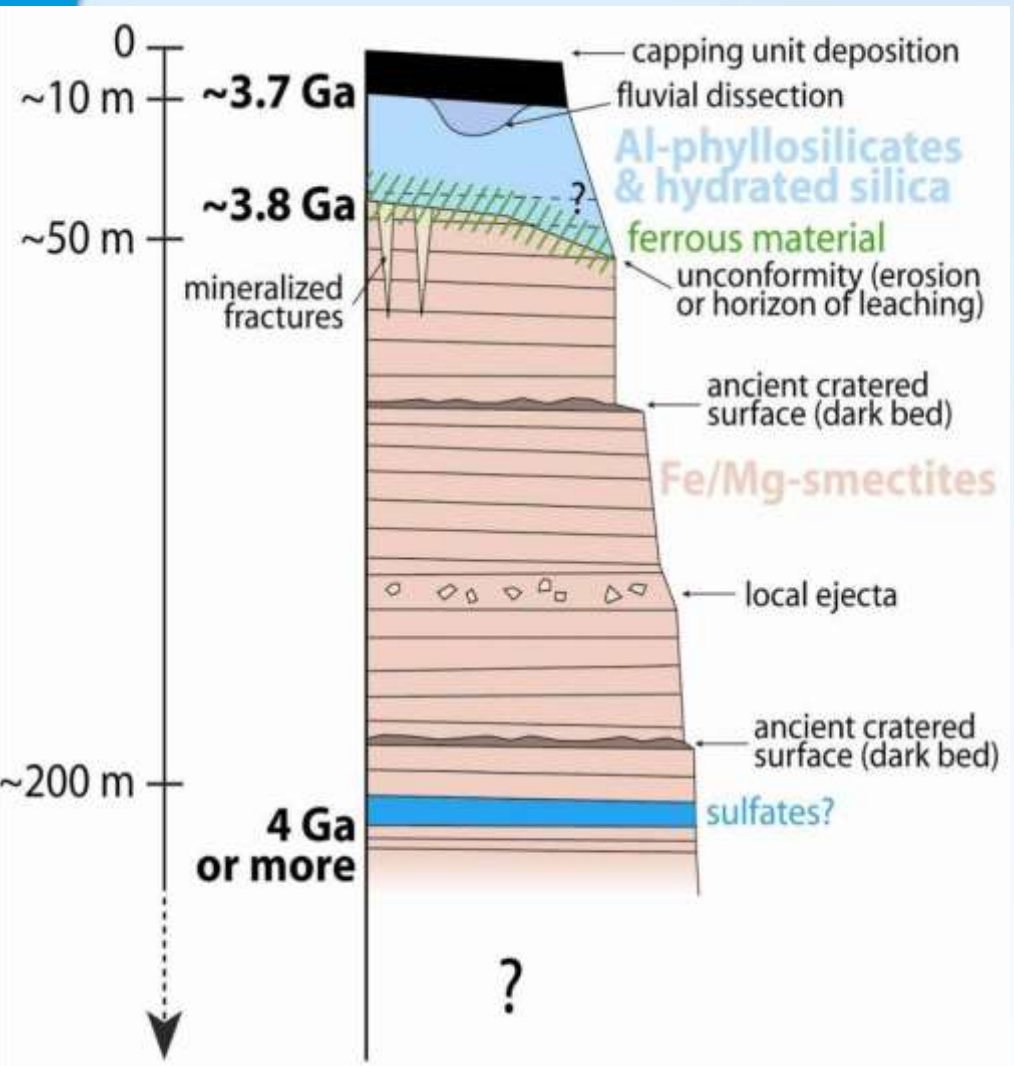
Surface assemblage: Kaolins, alunite, ferrous clays

Local precipitation of sulfates (jarosite)

Extreme Fe/S redox gradient: excellent source of energy for likely Martian microbes.

Fluid circulation in fractures => halo-bounded fractures

Complex aqueous history on Mars



Phase 3

Pyroxene-bearing dark cap deposition

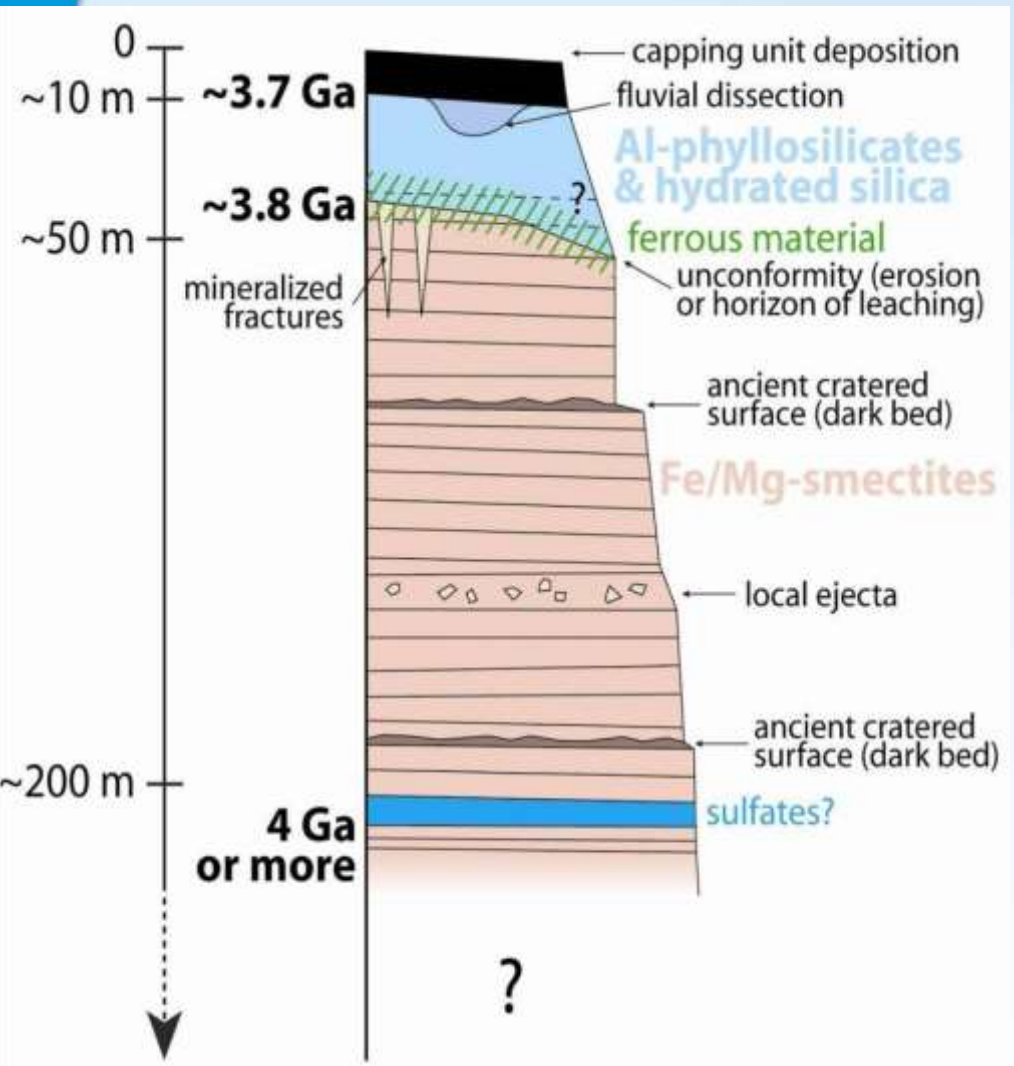
Early Hesperian

Probable volcanic/pyroclastic deposits

No more aqueous alteration

Preservation of clays and morphologic features (inverted valleys)

Complex aqueous history on Mars



Phase 4

Wind erosion

the whole section is progressively and continuously exhumed

Hesperian and Amazonian

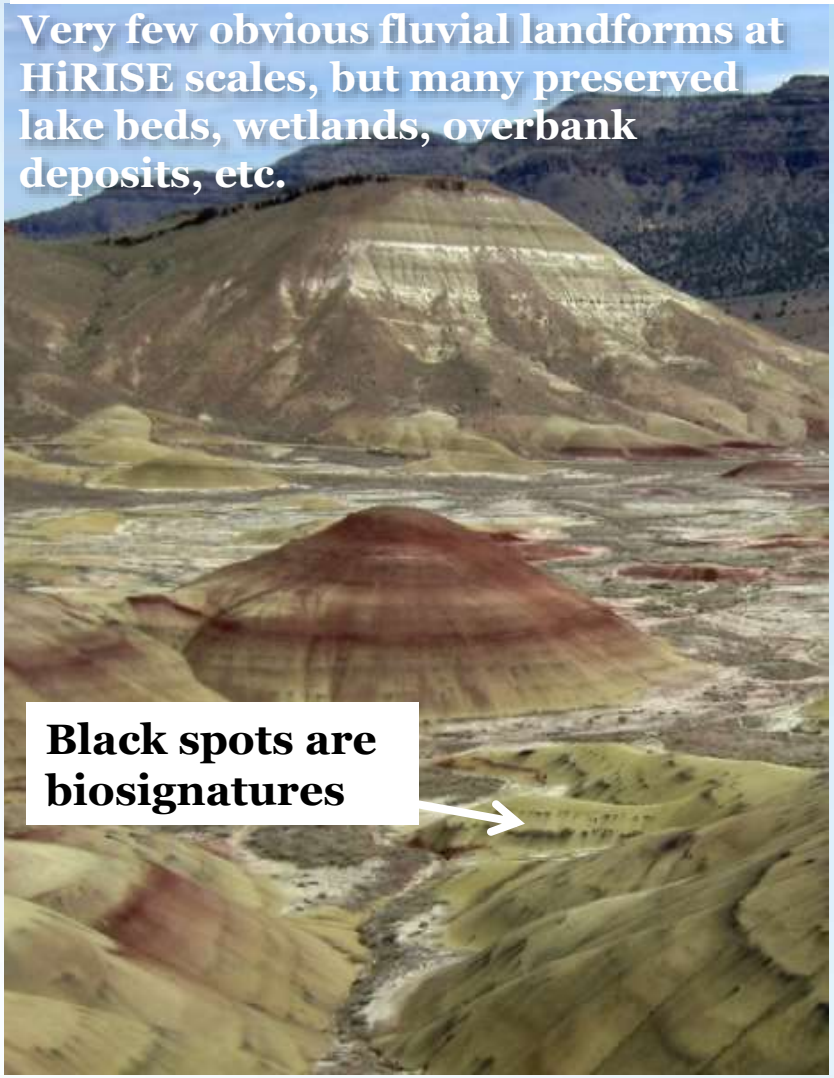
Best Terrestrial Analogs

Painted Desert, AZ: Floodplain soils formed in fluvial/ lacustrine/deltaic/aeolian sediments (~200 My)

Some fluvial landforms at HiRISE scales, but many other aqueous environments as well

John Day Fossil Beds, OR: Soils formed in pyroclastic sediments, modified by local fluvial/lacustrine activity (~30 My)

Very few obvious fluvial landforms at HiRISE scales, but many preserved lake beds, wetlands, overbank deposits, etc.



Horgan (2014,2015)

Habitability and Preservation of Organics

- Soils are highly habitable environments - energy, water, nutrients, etc.
- High clay content and rapid burial leads to organic preservation in paleosols
- Concentration of organics is overll low-mod, but can be locally high
- Reducing soils cause immediate preservation and can lead to concentrated organics in wetlands
- Reduced paleosols at Mawrth shall be excellent targets for *in situ* search for organics and biosignatures

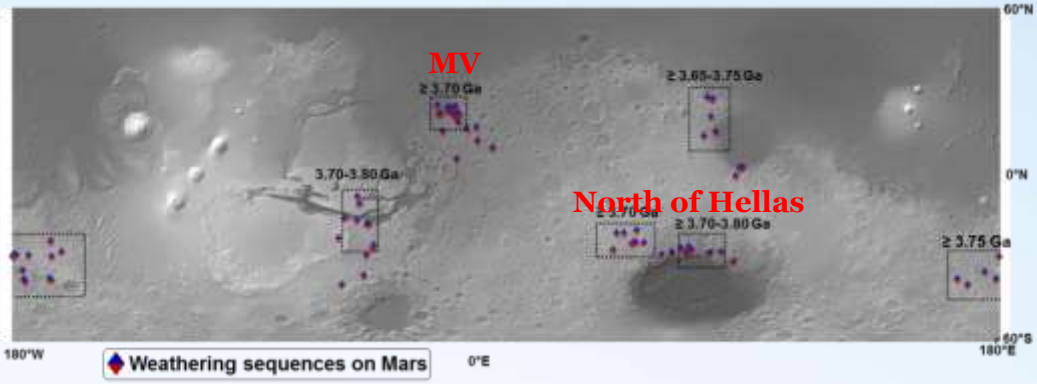
Archean paleosols preserve the oldest non-marine organics on Earth (1-3 Gy)

Dorset, UK tonstein. Mineralogical analog for Mawrth Vallis. Organic-rich!

Probing for past climatic conditions

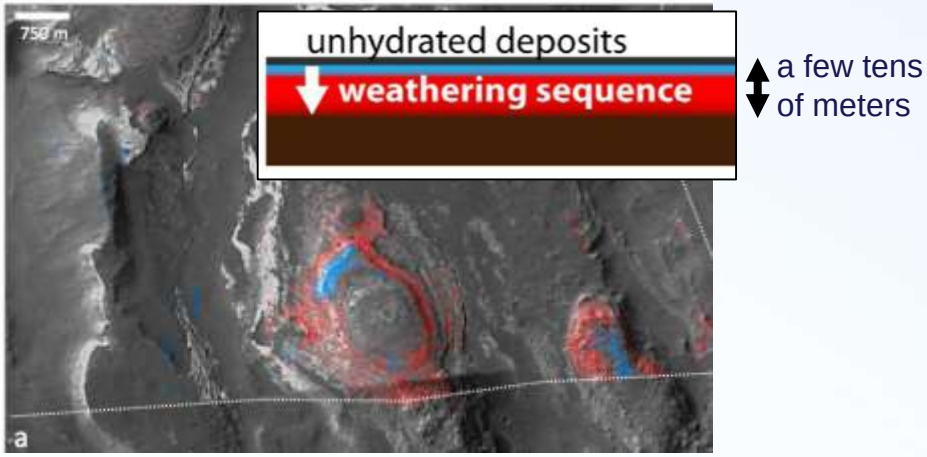
Al-clays over Fe/Mg-smectites sequence is common on Mars during this time period:

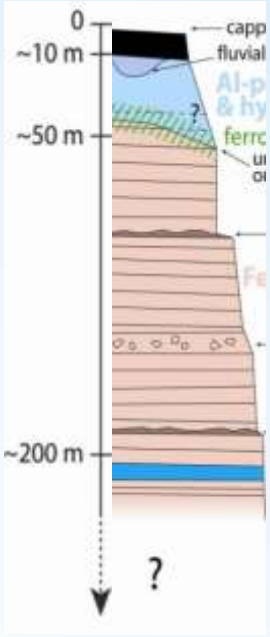
⇒ MV and its weathering profile allow to characterize Mars' ancient climate and underlying processes



Mawrth sequence is several time thicker than others and mineralogy much more complex

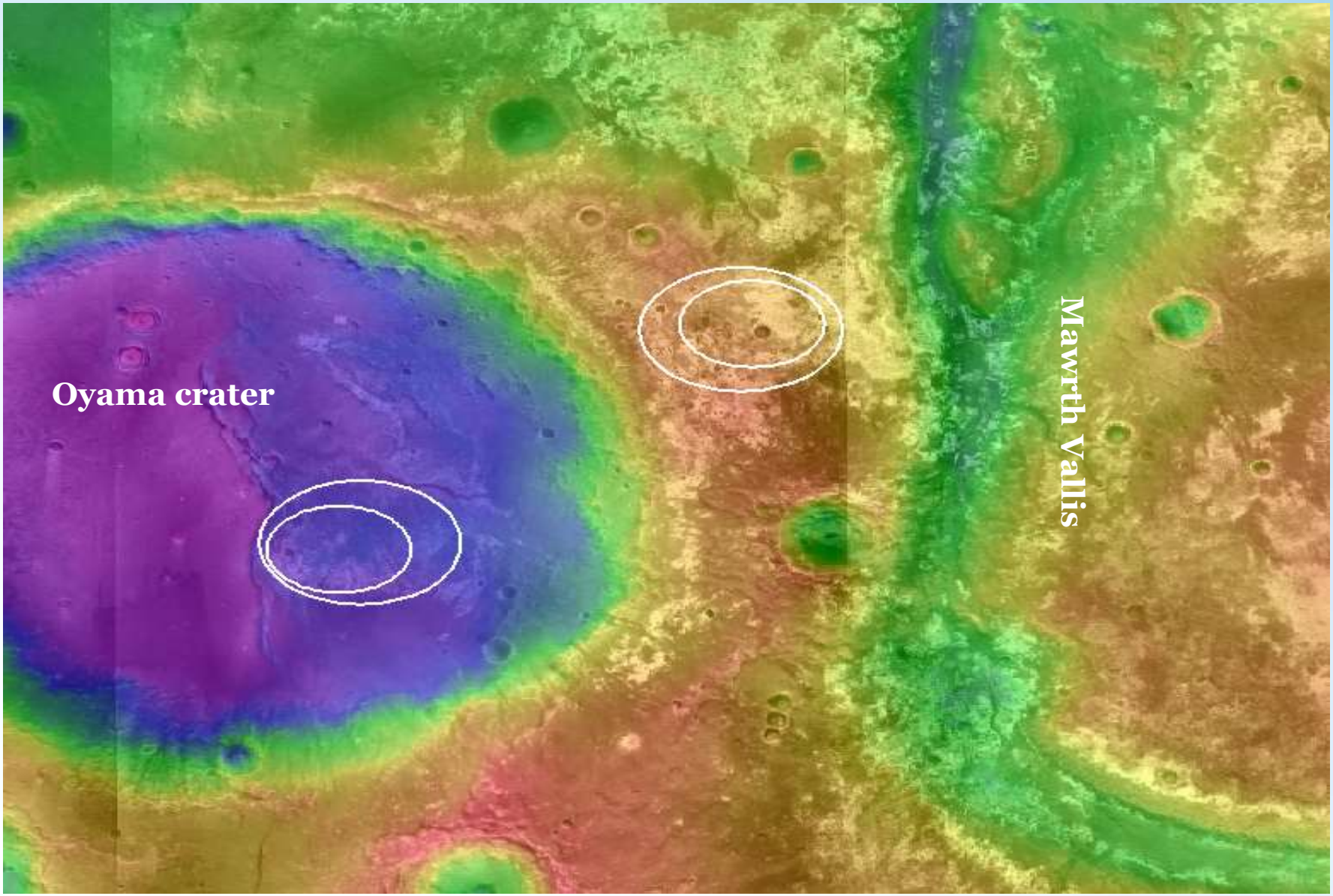
Consistent with long-term (~million years) leaching profiles in a wetter climate





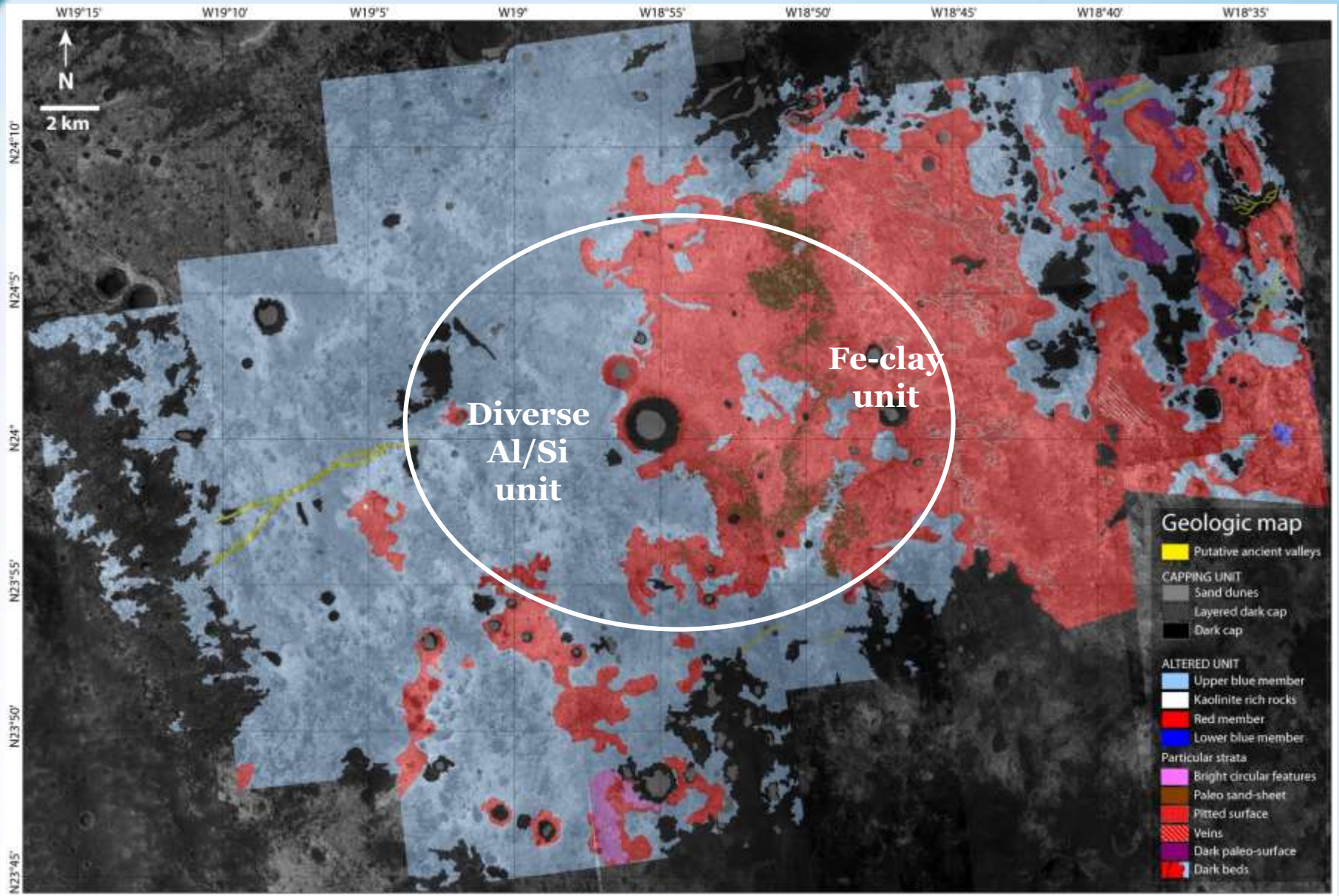
Carter et al. (2015)

Two ellipses: Plateau ellipse and Oyama



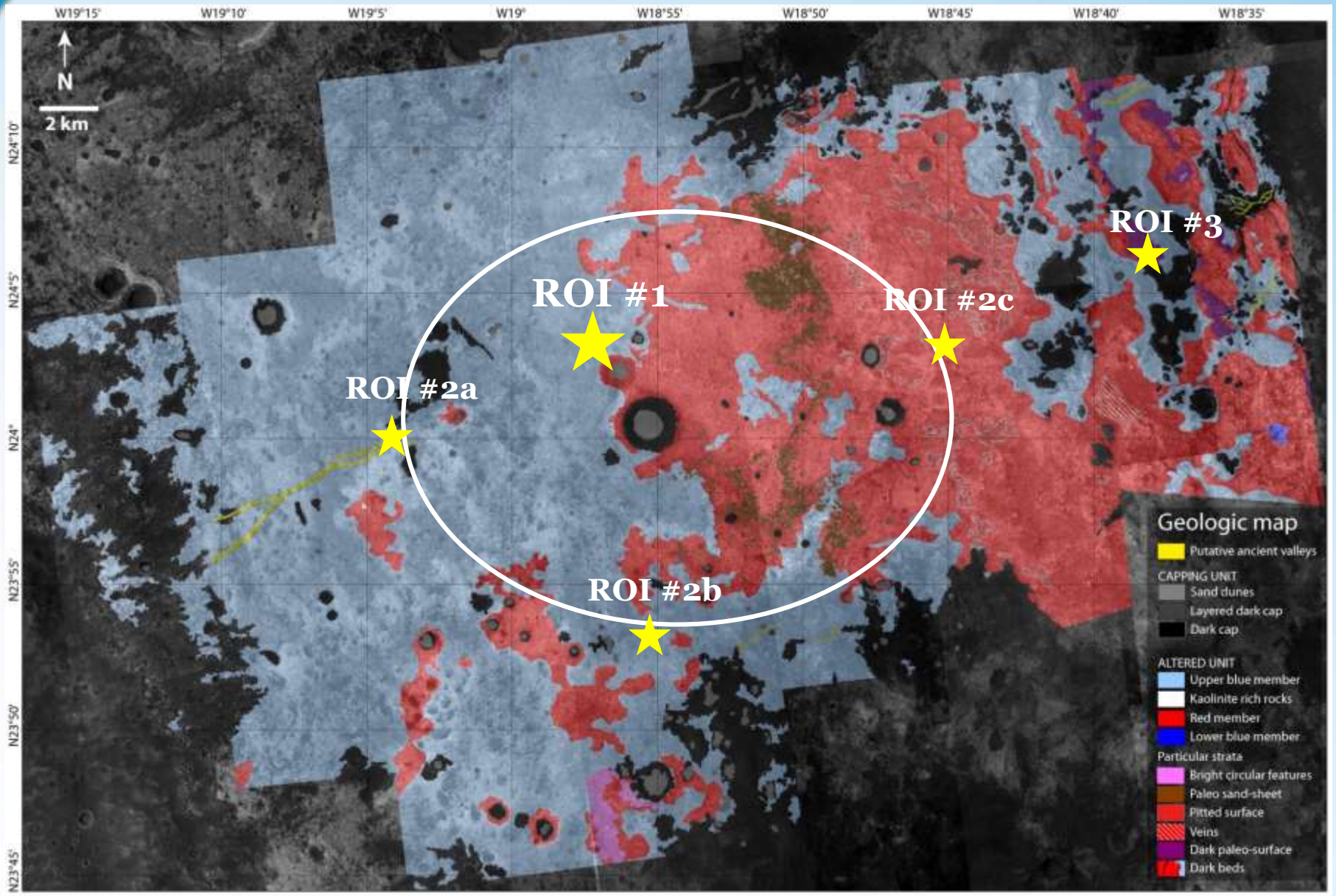
GEOLOGIC MAP

MARS 2020 at MAWRTH VALLIS

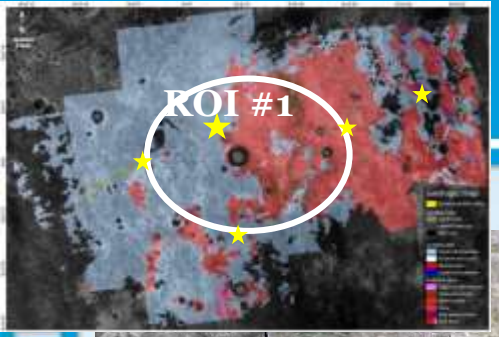


ROIs

MARS 2020 at MAWRTH VALLIS



ROI 1



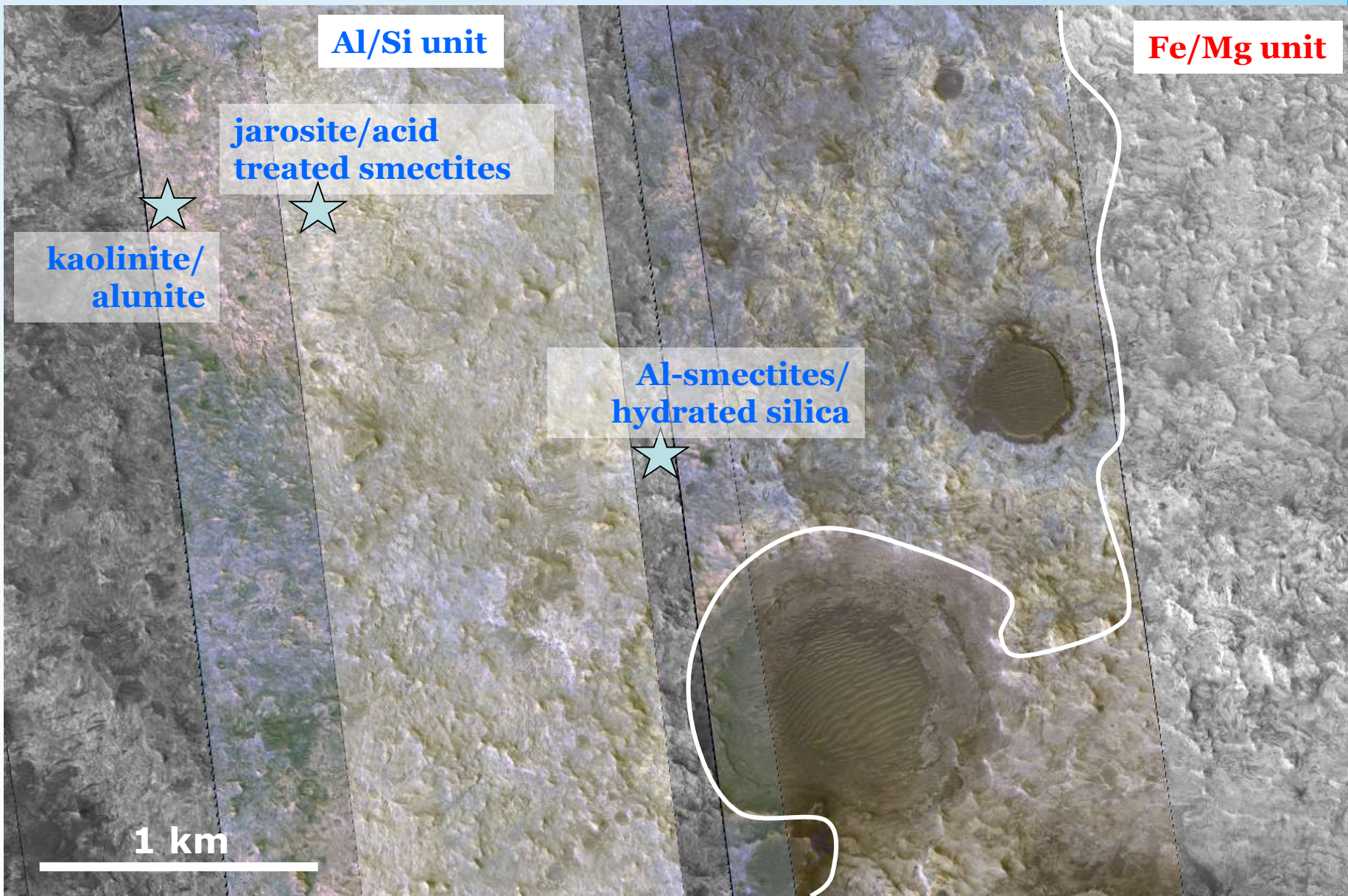
Al/Si unit

Fe/Mg unit

1 km

MARS 2020 at MAWRTH VALL

ROI 1



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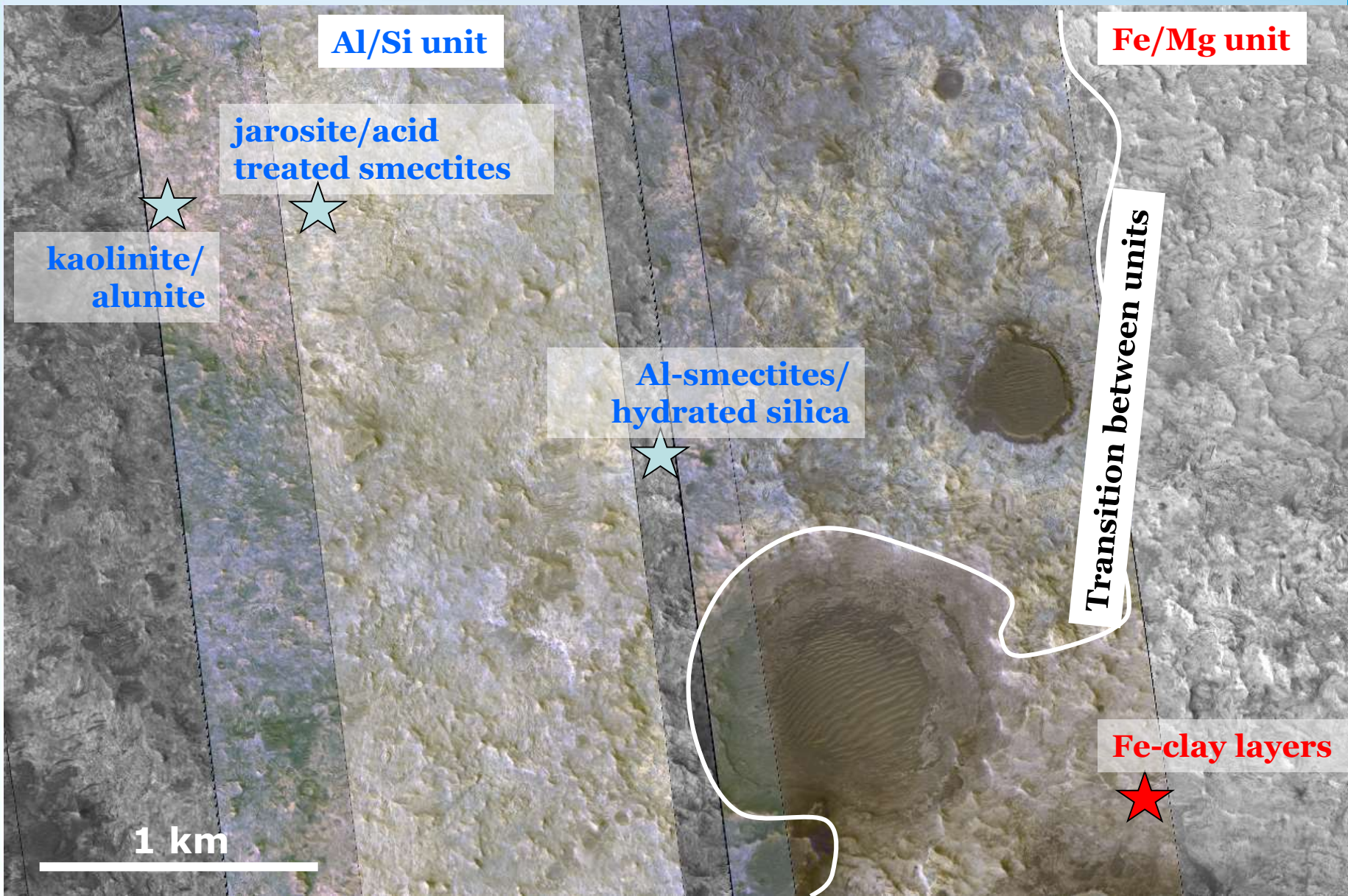
ROI 1



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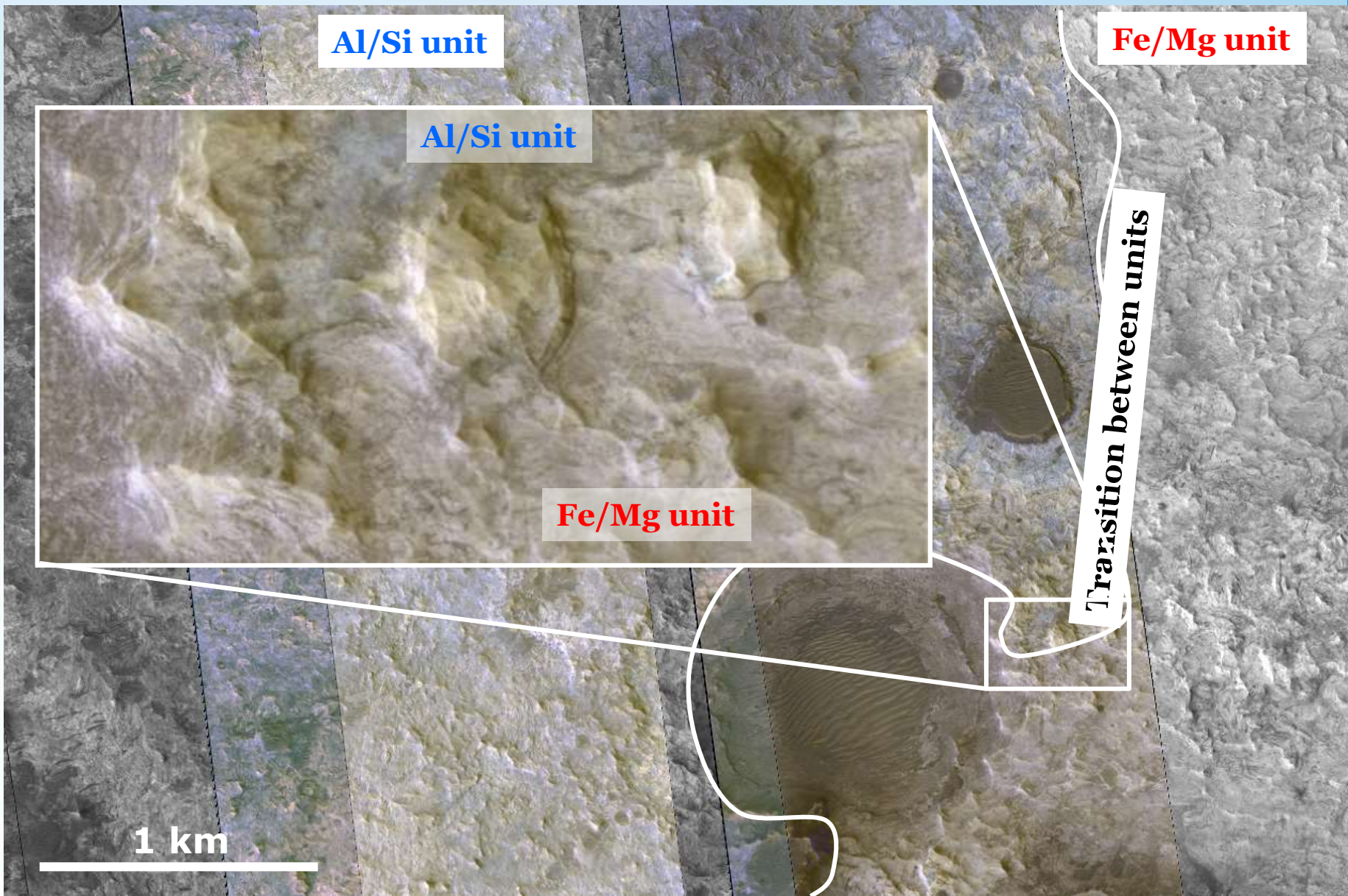

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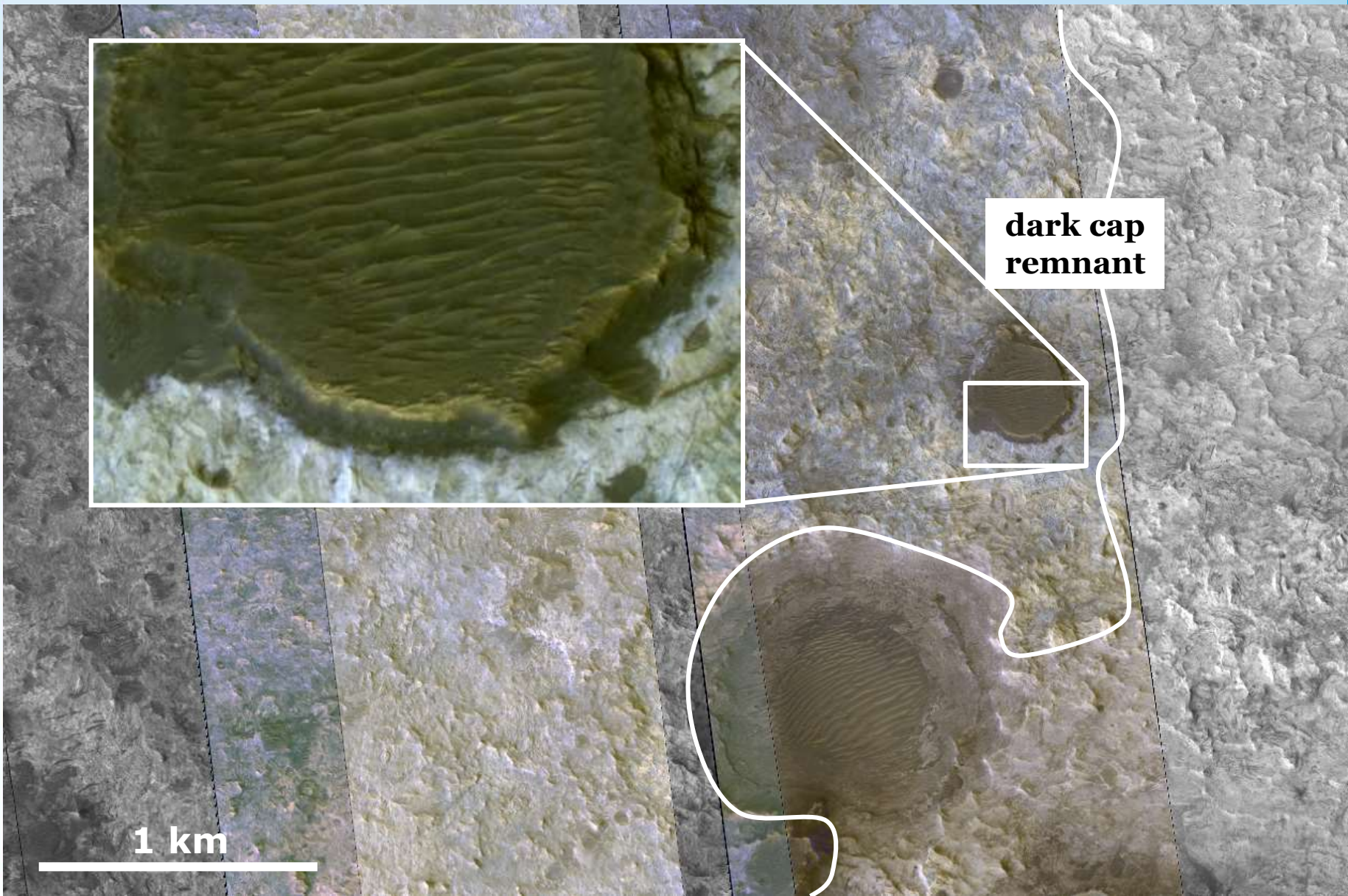
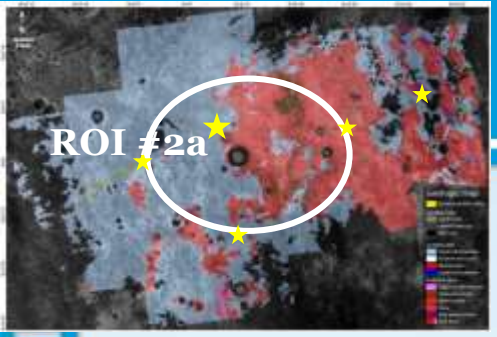
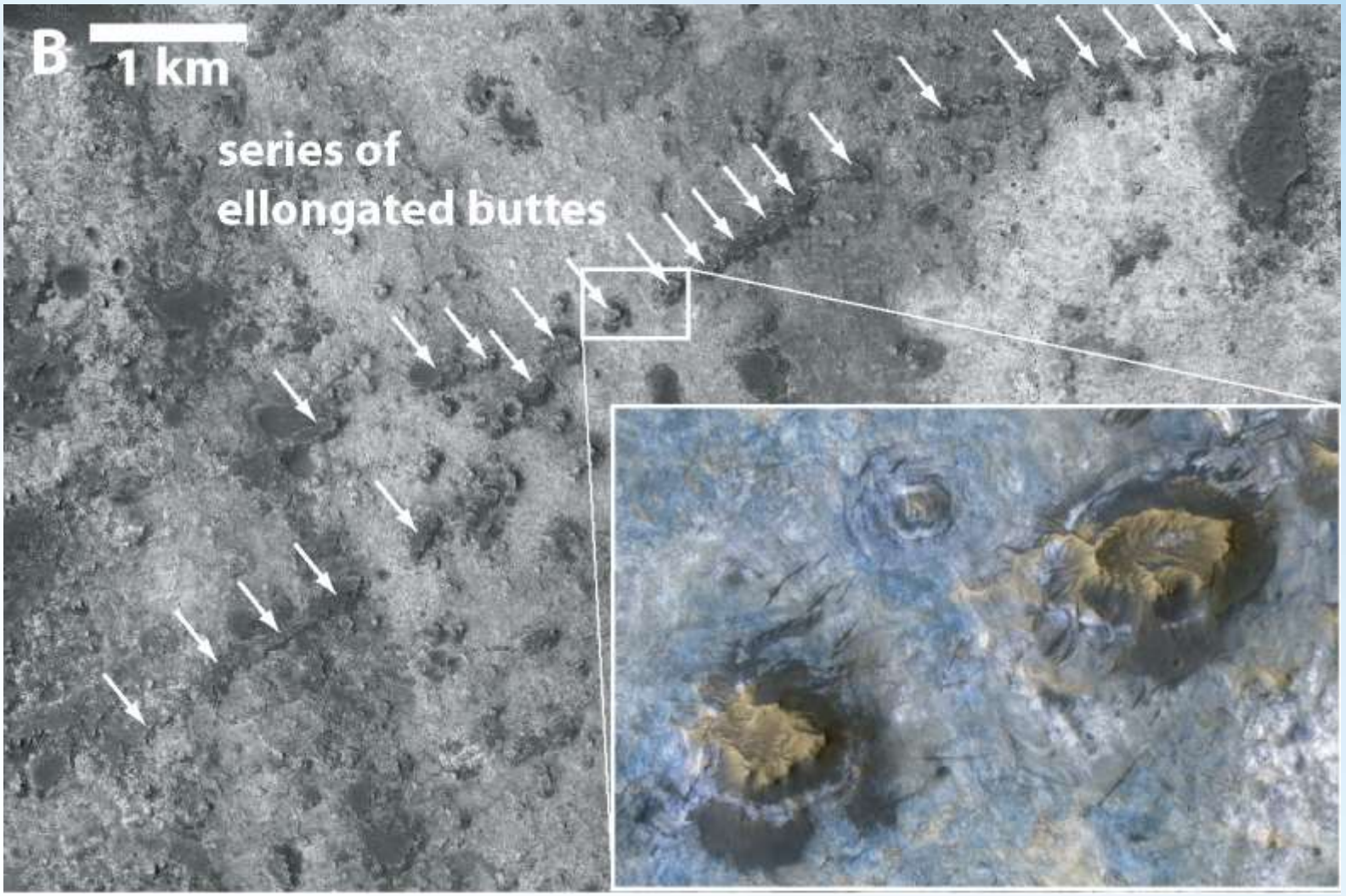


MARS 2020 at MAWRTH VALLIS

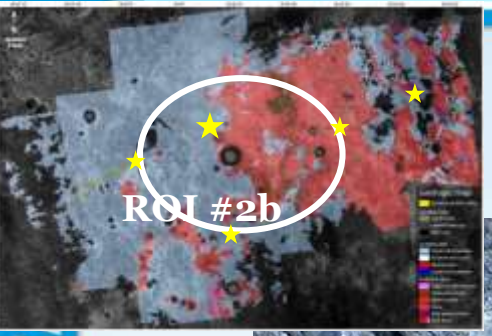
ROI: ancient inverted valleys

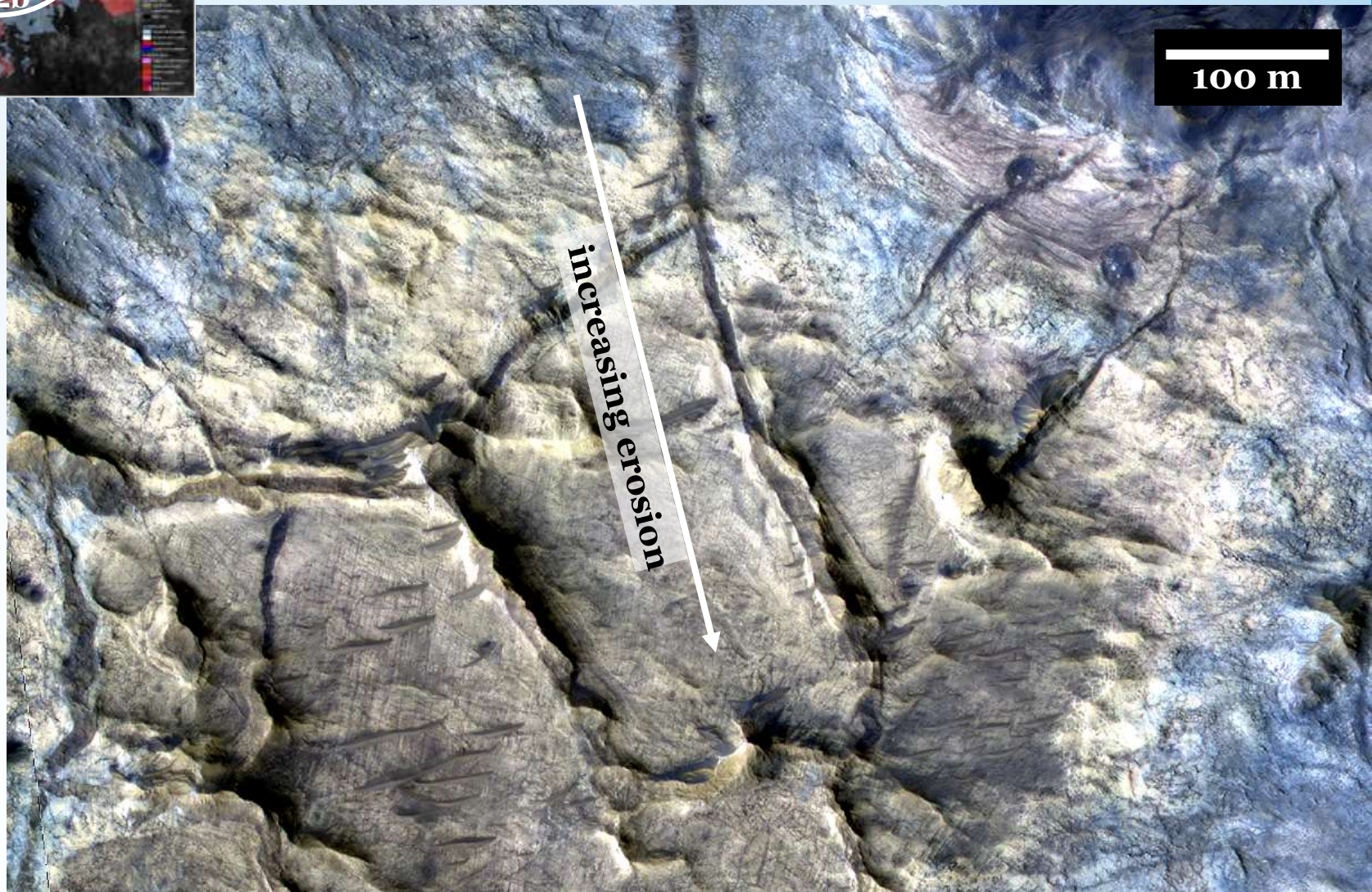




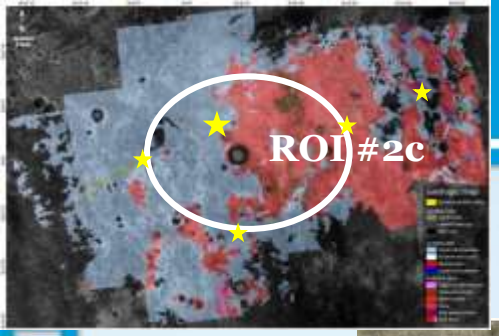
MARS 2020 at MAWRTH VALL

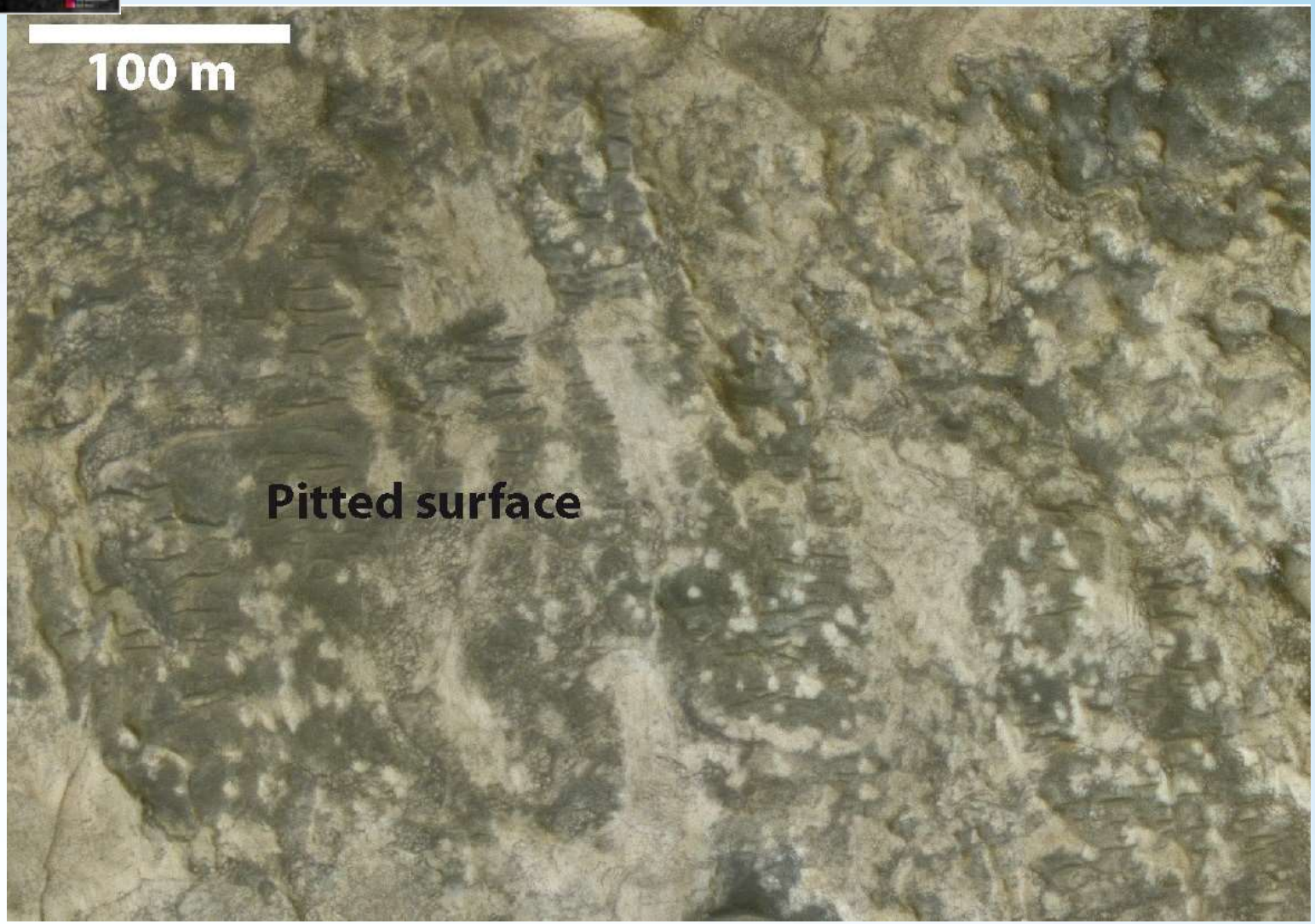
ROI: Halo-bounded fractures and veins

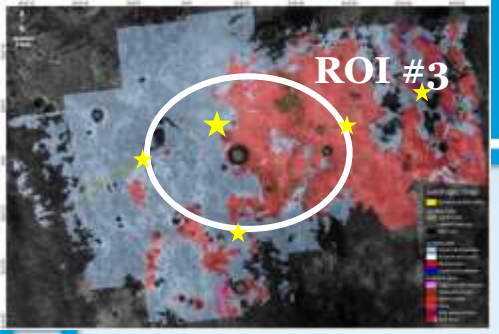




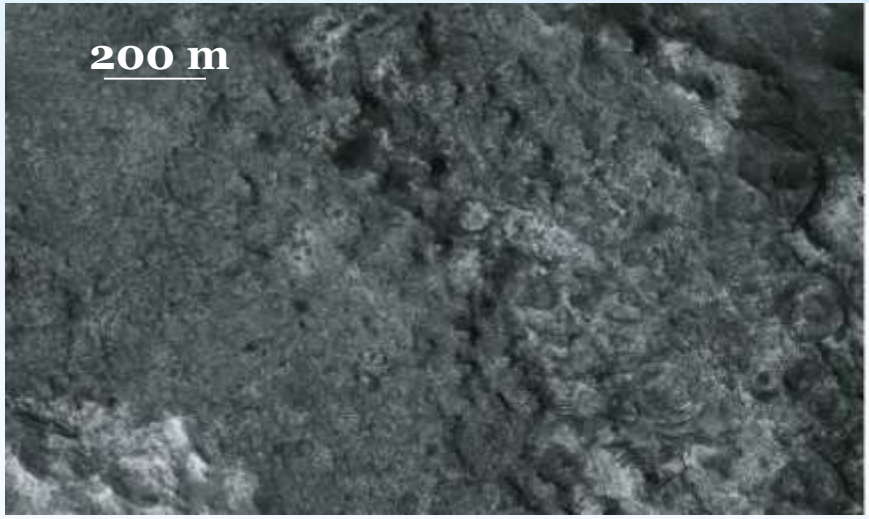
ROI: Pitted layers

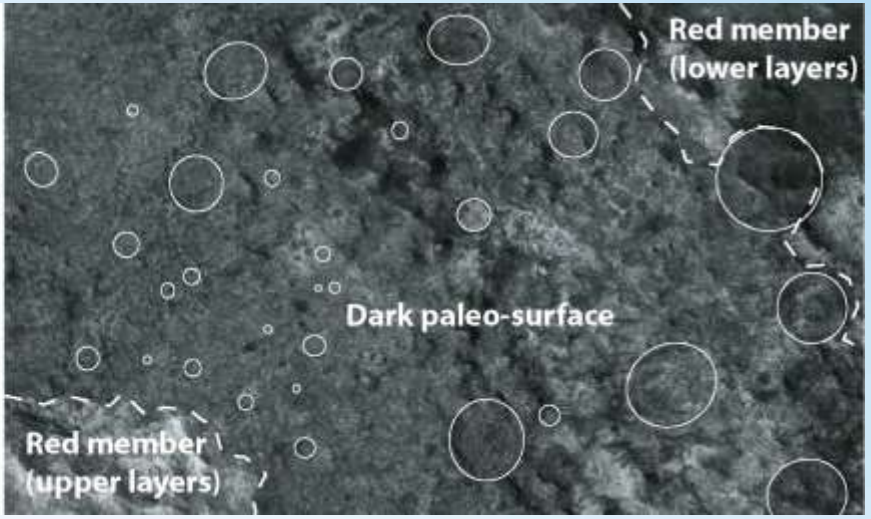


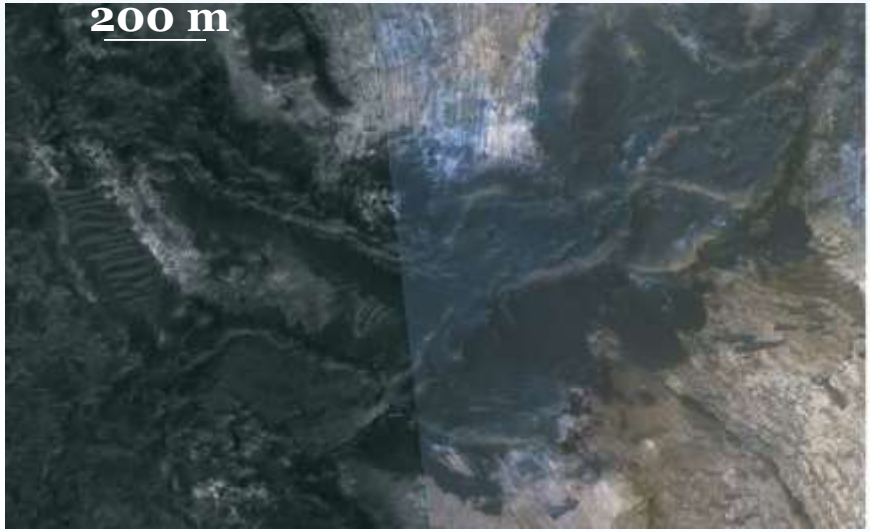




ROI: Paleo-features





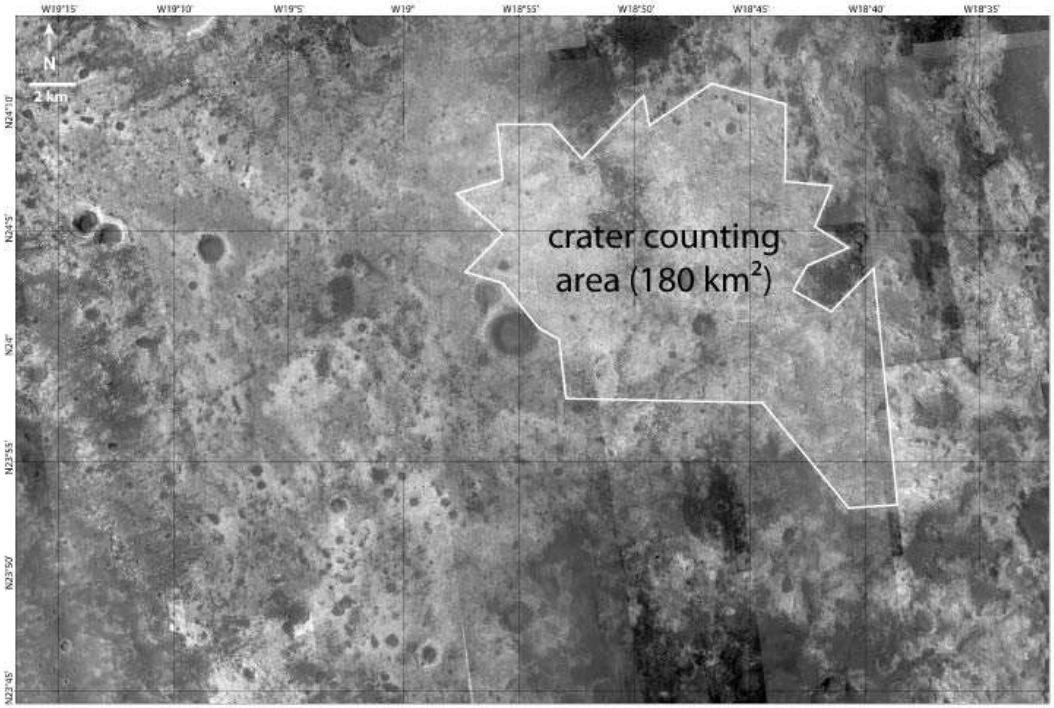


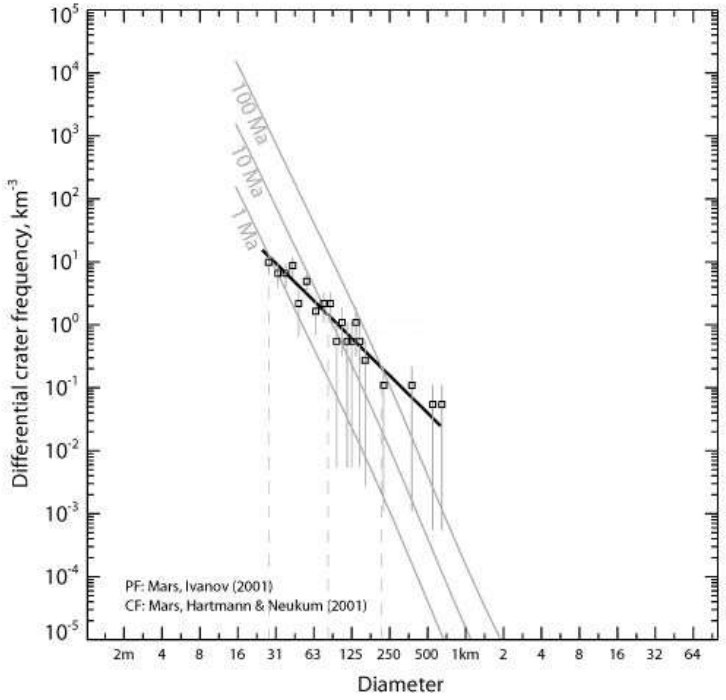
TARGETS & ROIs

MARS 2020 at MAWRTH VALLIS

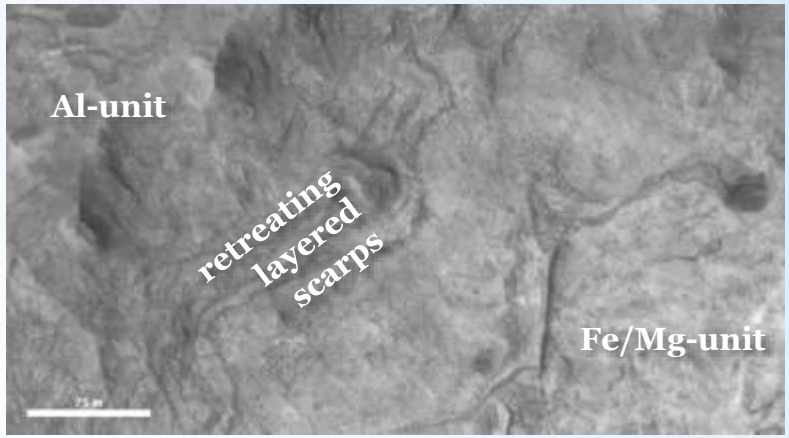
Unit	Morphology	Mineralogy	Objectives	Ranking
Dunes	in local lows, generally ancient craters and valleys, direction: W-E in eatern part, SW-NE in western part	no hydrated signature, maybe basaltic sand if erosion product from the dark cap	...	5
Dark cap	flat-top mesas or crater filling, surrounded by dark tallus: probably a "duricrust" protecting more easily erodible material	no hydrated signature, weak pyroxene signature (Loizeau et al., 2007)	Sample caching	4
Upper blue member	gentle slope forming unit, generally regular polygons 0.5-1.5 m across*	Al-phyllosilicates (montmorillonite, kaolinite), hydrated silica, ferrous component at the contact with the red unit	Habitability, biosignatures, sample caching	1
Red member (above paleo-sand-sheet)	generally irregular polygons 2-5 m across, with variation in fracture styles, few exposed layers*	Fe-smectite, ferrous component at the contact with the upper blue unit	Habitability, biosignatures, sample caching	1
Bright circular features	similar to red unit, but with many quasi-circular features 15-50m across	Fe-smectite	Habitability, biosignatures, sample caching	3
Paleo-sand sheet	rough, linear features trending NW-SE (different direction than surface dunes)*	no hydrated signature	Sample caching	3
Red member (on the plateau, below the paleo-dunes)	generally irregular polygons 2-5 m across, with variation in fracture styles, few exposed layers*, very eroded areas	Fe-smectite	Habitability, biosignatures, sample caching	2
Red member (on Mawrth Vallis flank and floor)	generally irregular polygons 2-5 m across, with variation in fracture styles*, with many exposed layers	Fe-smectite	Habitability, biosignatures, sample caching	2
Lower blue member	partly fractured in blocks up to 1.5 m across, exposed layers	possibly bassanite, or zeolite (spectrally close minerals when weak signal)	Habitability, biosignatures, sample caching	2
Dark paleo-surface	hummocky terrain with many quasi-circular features 10 to 100 m across, interpreted as exhumed filled craters	Fe-smectites	Habitability, biosignatures, sample caching	2
Putative Ancient Valleys	Part of ancient valleys, or inverted valleys, or a series of buttes that could be an ancient inverted valley	Eroded inside the clays, often filled by dark cap	Habitability, biosignatures, sample caching	2

PRESERVATION: RECENT EXPOSURE





- very few small craters
- widespread aeolian activity and erosion due to dark sands
- easily erodible, very fine grained deposits



Ellipse Plateau :To Summarize

- Very diverse aqueous alteration (from low to strong) inside the ellipse
- Long and continuous stratigraphic altered section
- Diverse lithologies that capture multiple environments (deposition, alteration & erosion)
- Reducing conditions, silica and very high clay content - high preservation potential
- Fresh surfaces (continuous erosion of clays) and no diagenetic overprinting
- Sample biosignatures in the habitable environment in which they were formed

Ellipse Plateau :To Summarize

- Consistent with a paleosol sequence ending in a wetlands-like environment
- Reducing terrains (soils) cause immediate preservation and can lead to concentrated organics if a biological cycle is active
- Unique window into climate of early Mars (EN to H)
- Dateable ~EH surface (mafic capping unit) present at numerous locations inside the landing ellipse

Ellipse Plateau :To Summarize

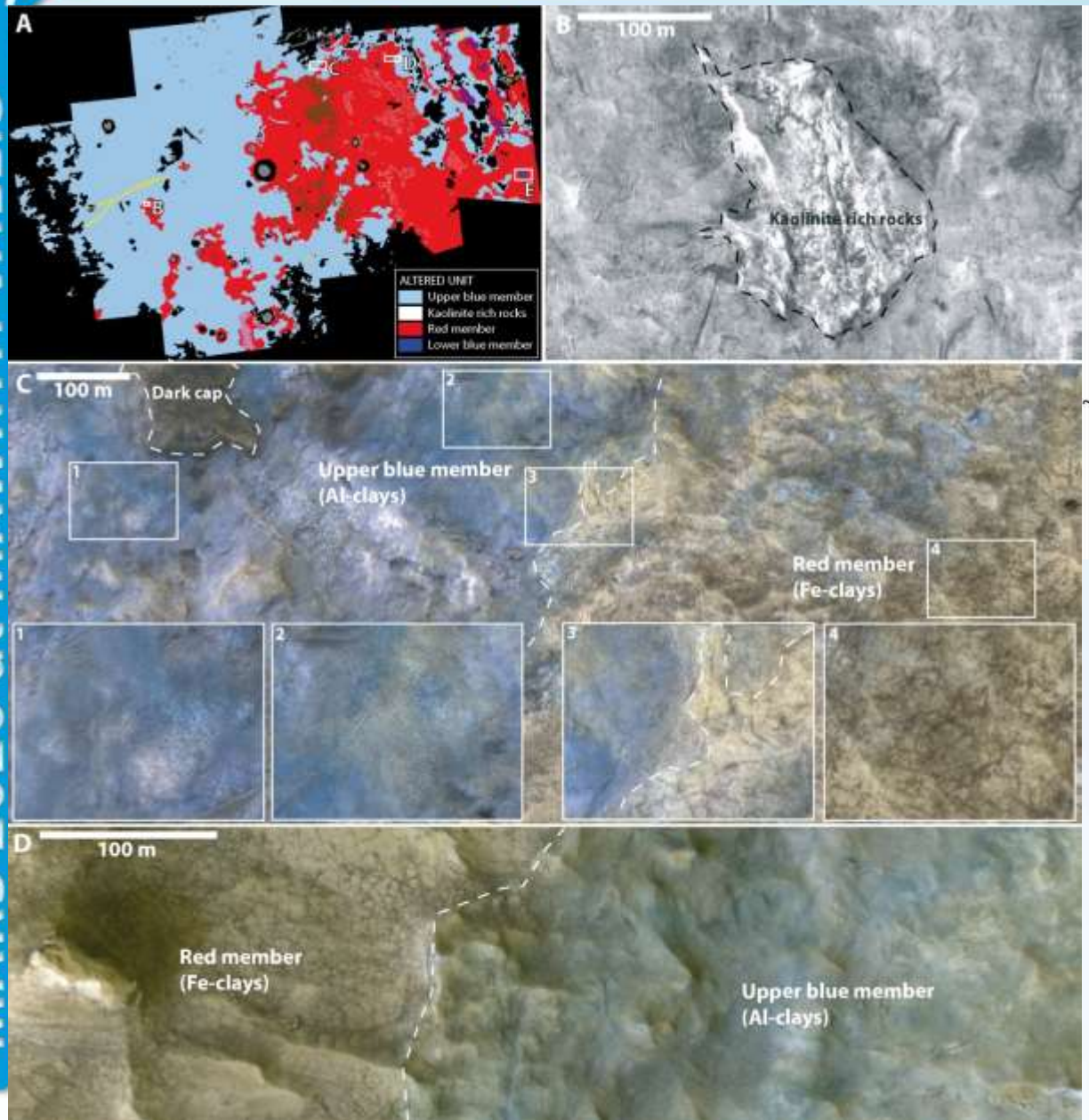
- **Rubric is supported by tens of papers**

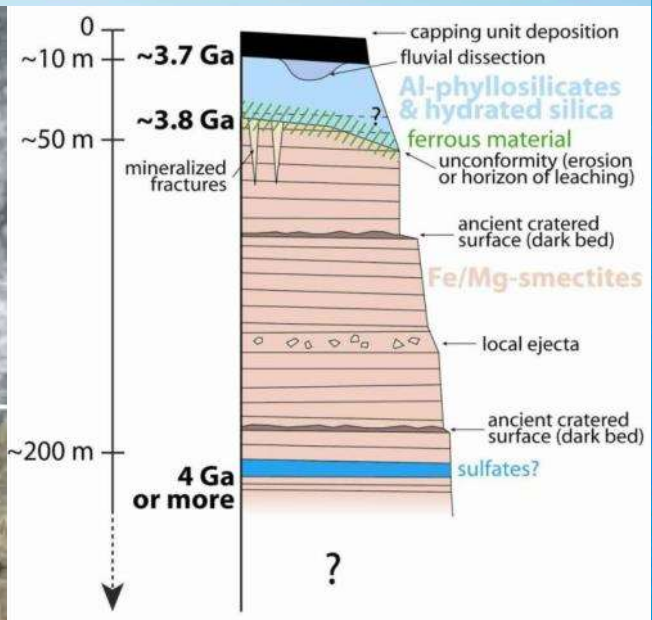
Landing Site Factor	Mars 2020 Mission and Decadal Priority Science Factors																					
	Environmental Setting for Biosignature Preservation and Taphonomy of Organics								Type 1A & 1B Samples: Aqueous Geochemical Environments indicated by Mineral Assemblages								Type 2 Samples: Igneous		Context: Martian History Sampled, Timing Constraints				
	Deltaic or Lacustrine (perennial)	Lacustrine (evaporitic)	Hydrothermal (< 100°C) surface	Hydrothermal (< 100°C) subsurface	Pedogenic	Fluvial/Alluvial	No diagenetic overprinting	Recent exposure	Crustal phyllosilicates	Sedimentary clays	Al clays in stratigraphy	Carbonate units	Chloride sediments	Sulfate sediments	Acid sulfate units	Silica deposits	Ferric Ox./Ferrous clays	Igneous unit (e.g, lava flow, pyroclastic, intrusive)	2nd Igneous unit	Pre- or Early-Noachian Megabreccia	Oldest stratigraphic constraint	Youngest stratigraphic constraint	Stratigrapy of units well-defined	Dateable surface, volcanic (unmodified crater SFD)
Mawrth Vallis plateau		○		~	●	●	●	●	~	●	●			○	●	●	●	●	○		EN	EH	●	●

⇒ Perfect site to address in detail the questions of habitability & the potential origin and evolution of life on Mars

⇒ Minimizes the quantity of driving to maximize the quantity of field characterization and coring

ALTERED UNIT, priority 1





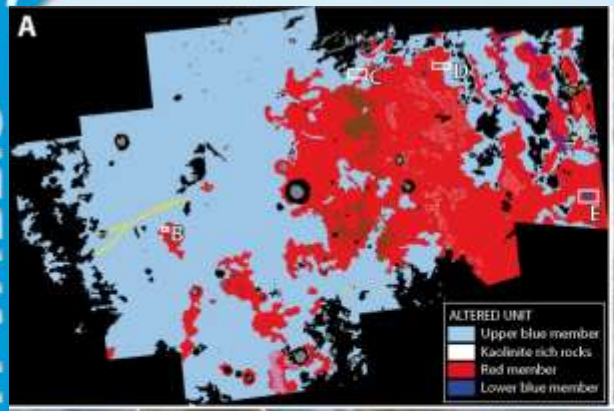
Transition from the Upper-blue to Red member

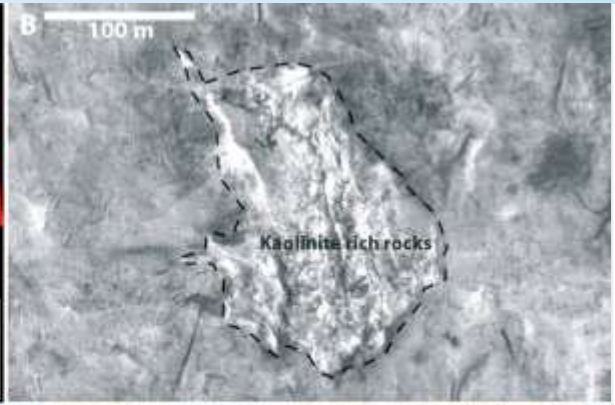
Highest priority

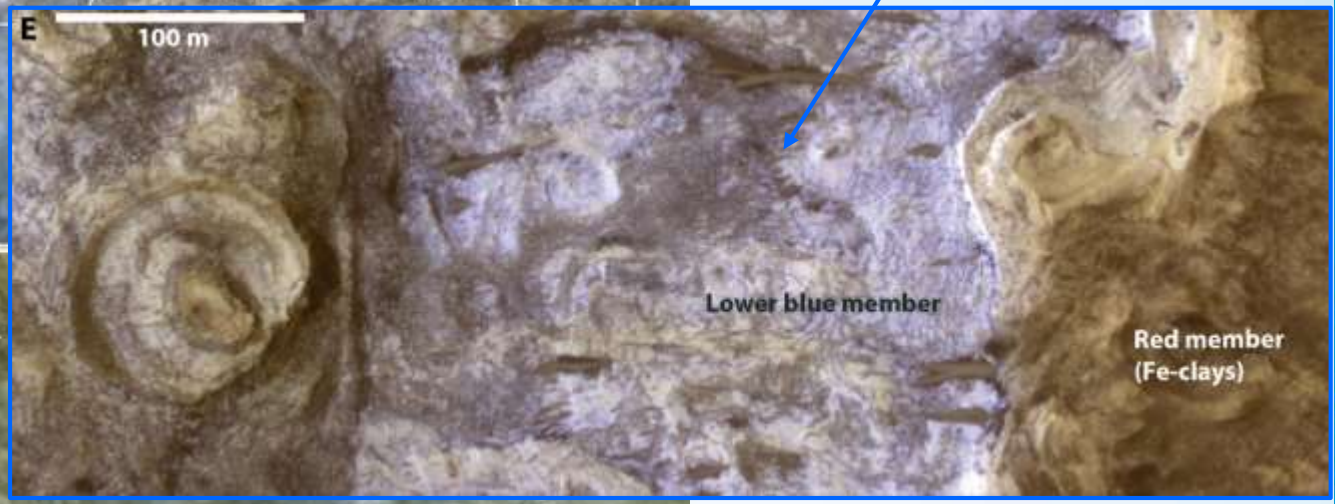
The alteration is also revealed by difference in color and texture

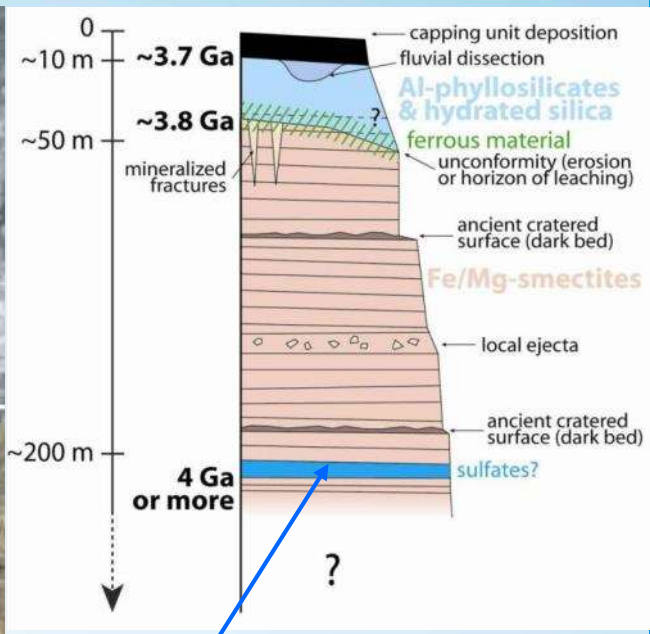
ALTERED UNIT, priority 1

MARS 2020 at MAWRTH VALLIS









SPECIAL STRATA, priority 2

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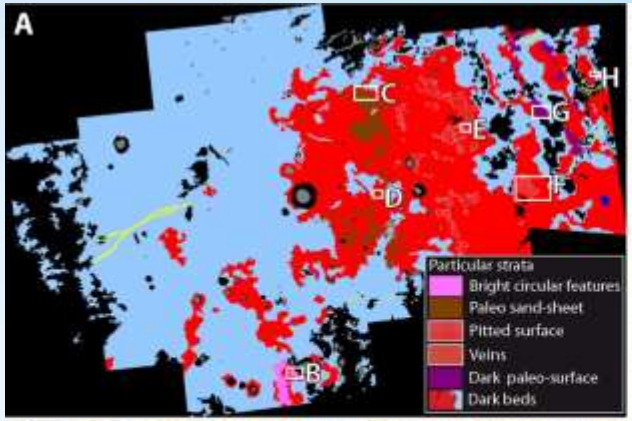
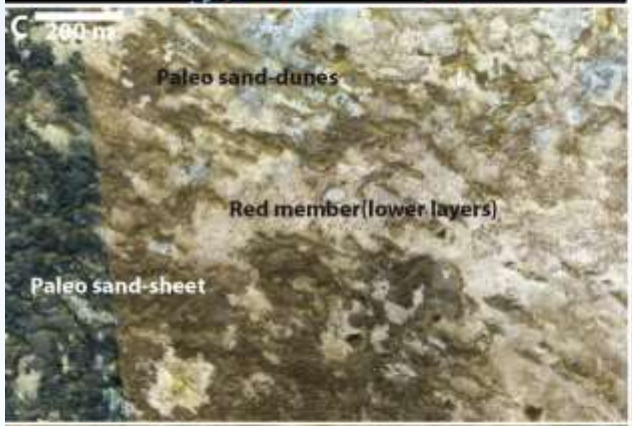
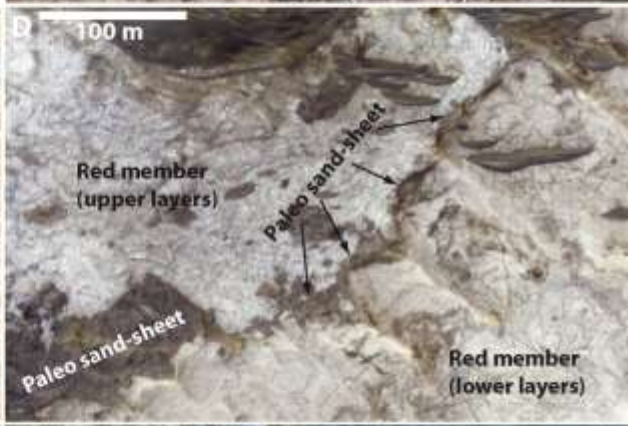
Special strata in the Red member

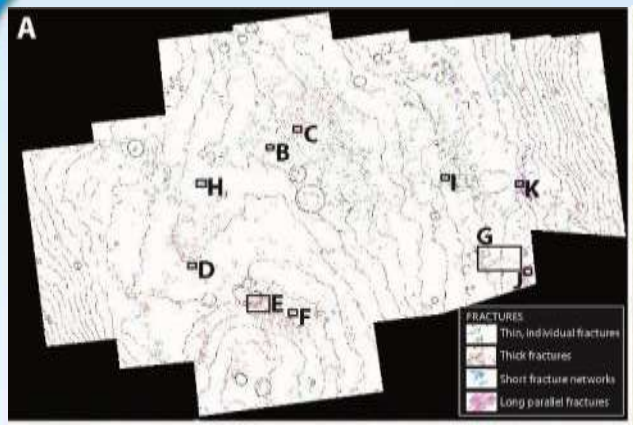
- rounded deposits
- paleo-sand sheet (parallel dunes)
- pits differential erosion
- veins differential erosion

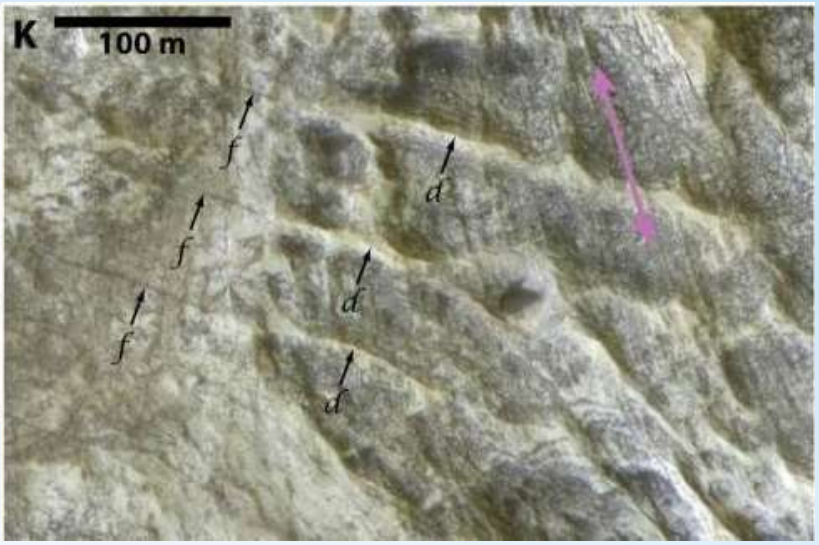






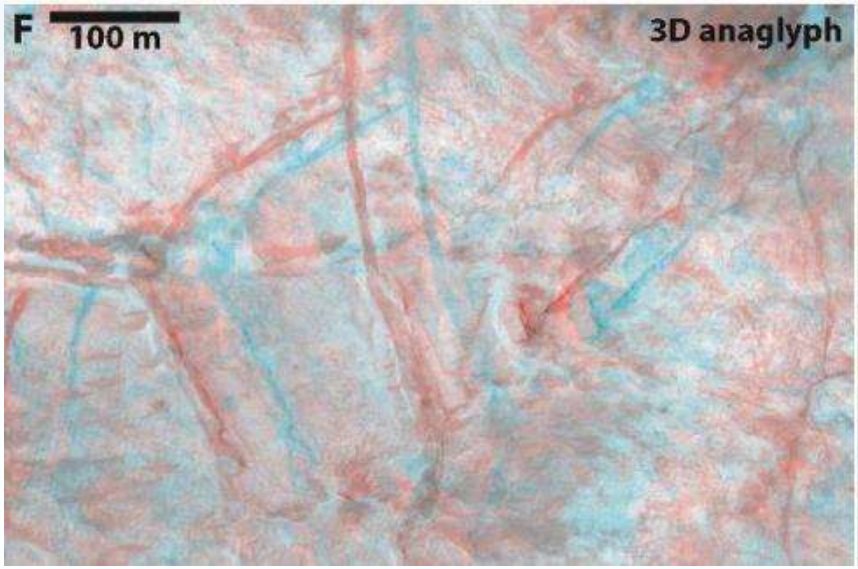
FLUID CIRCULATION, priority 2

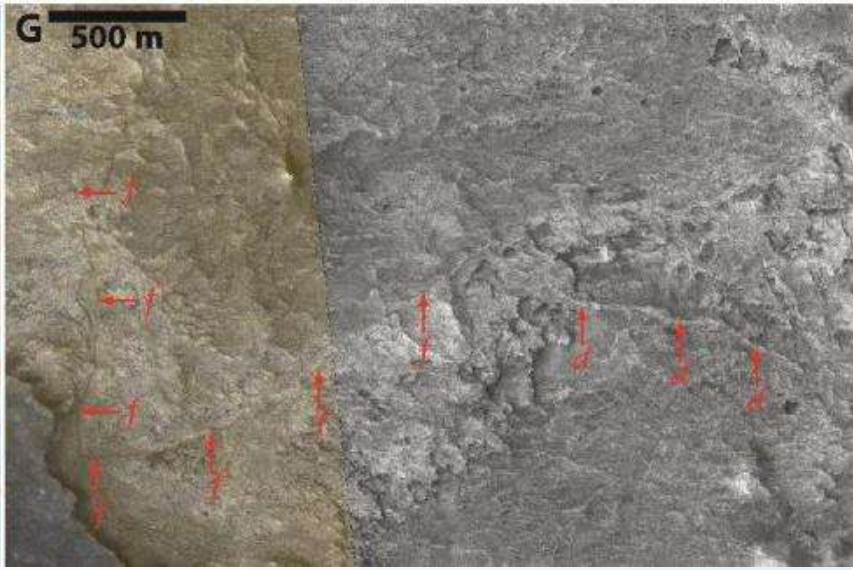




- **halo-bounded fractures**
- **veins**
- **dense networks of fractures**

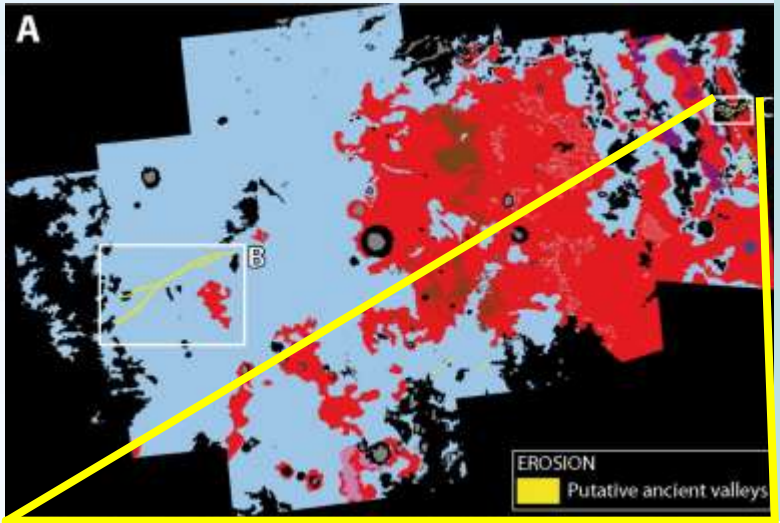
=> alteration in the subsurface through fluid circulation

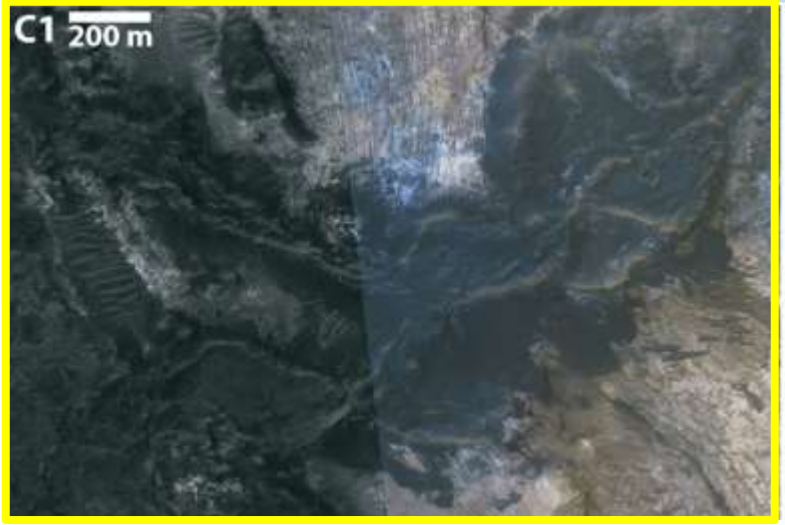


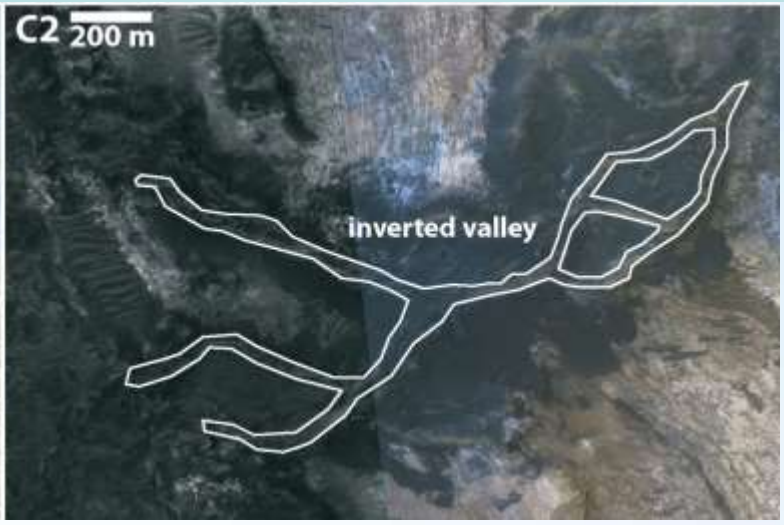


INVERTED VALLEYS, priority 2

- **Fluvial features are present throughout units but are only obvious below capping unit due to inverted relief in resistant unit**
- **Relief inversion shows the softness of the clays wrt the dark cap**

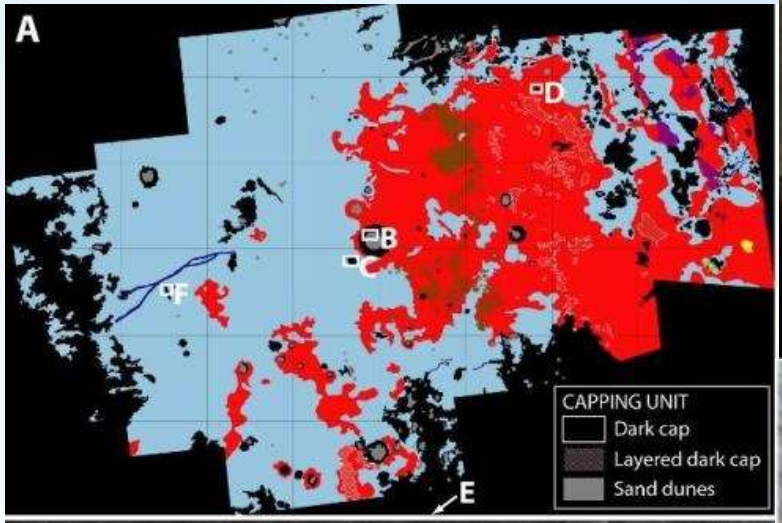


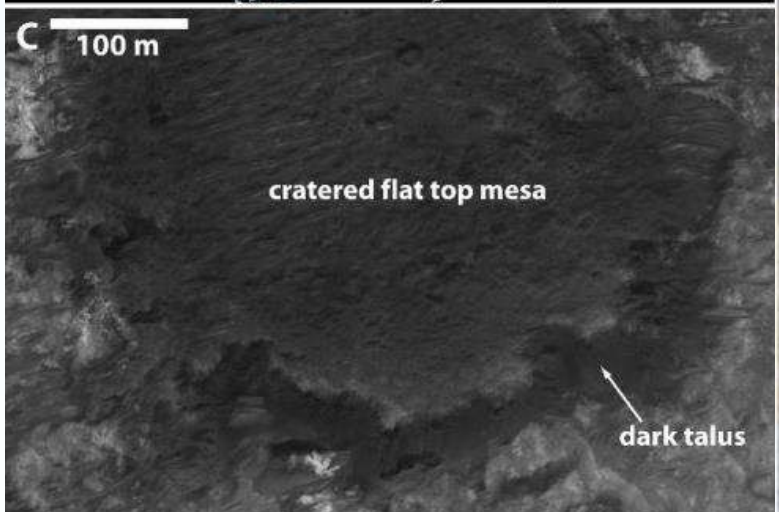


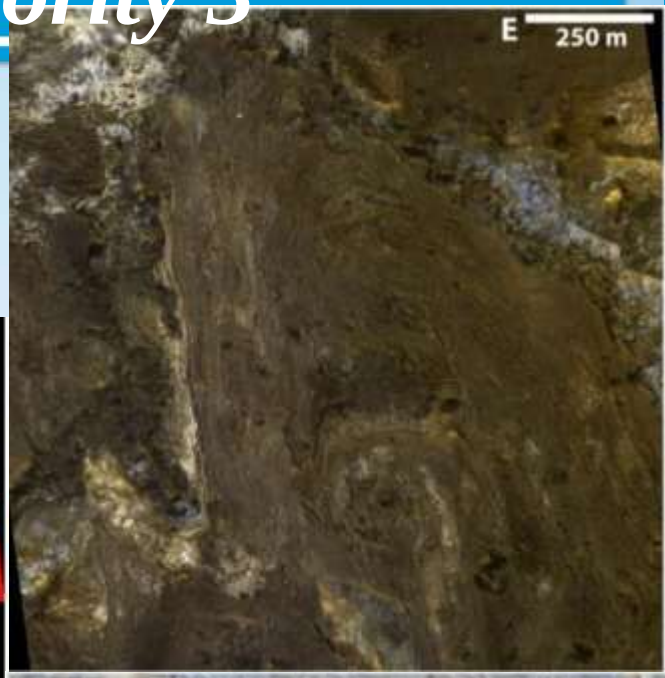


CAPPING UNIT, priority 3

- dateable igneous surface, regionally extensive
- eroded and redeposited (tallus, layered filling, dunes)
- rests of ejecta (15 km fresh crater south of the site)







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