

# Compositional data handling 3<sup>rd</sup> part – Mars surface mineralogy

# Mars' surface composition from orbit



- Mars Global Surveyor (NASA, 1997-2006)
  - **Thermal Emission Spectrometer (TES)** ➔ *Thermal IR (~6-50  $\mu\text{m}$ ) point spectroscopy (hyperspectral).*



- Mars Odyssey (NASA, 2001-present)
  - **Thermal Emission Imaging System (THEMIS)** ➔ *Thermal IR (6.7-14.8  $\mu\text{m}$ ) multispectral imaging.*

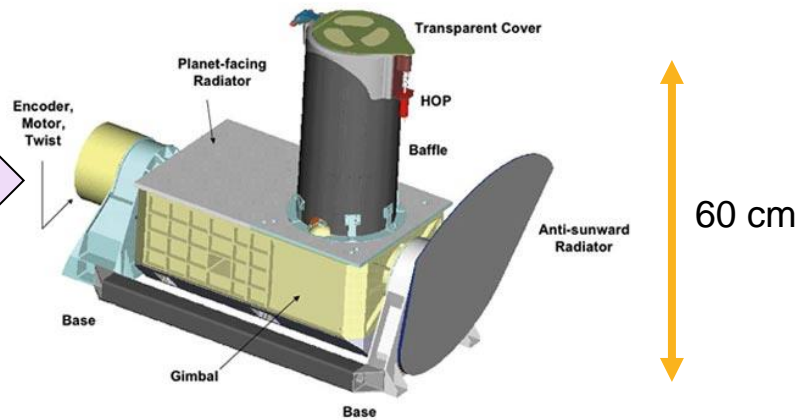
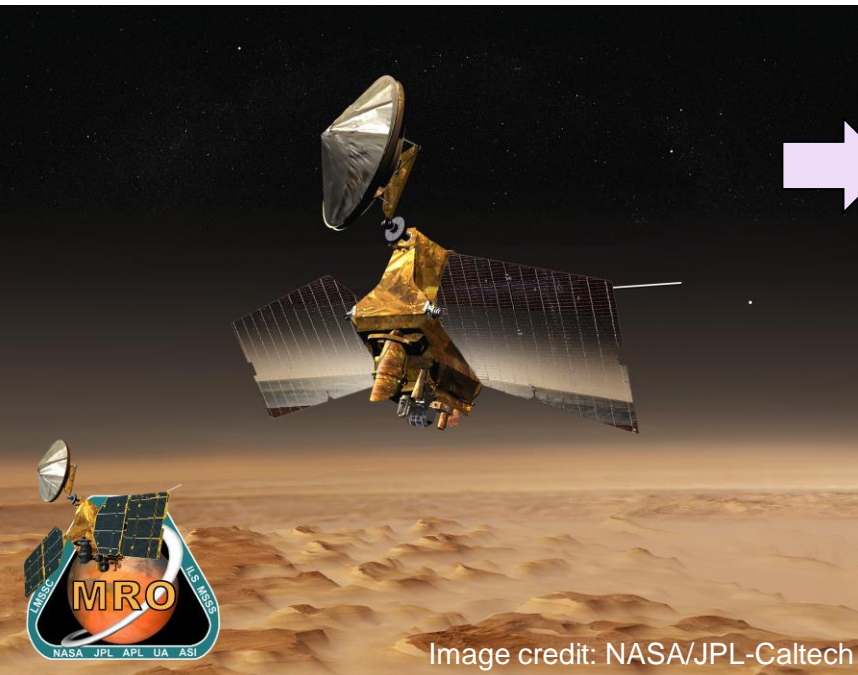


- Mars Express (ESA, 2003-present):
  - **Observatoire pour la Minéralogie, l'Eau, les Glaces et l'Activité (OMEGA)** ➔ *Hyperspectral visible-infrared (0.4-5.0  $\mu\text{m}$ ) imaging.*



- Mars Reconnaissance Orbiter (NASA, 2005-present):
  - **Compact Reconnaissance Imaging Spectrometer for Mars (CRISM)** ➔ *Hyperspectral visible-infrared (0.4-4.0  $\mu\text{m}$ ) imaging.*

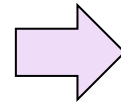
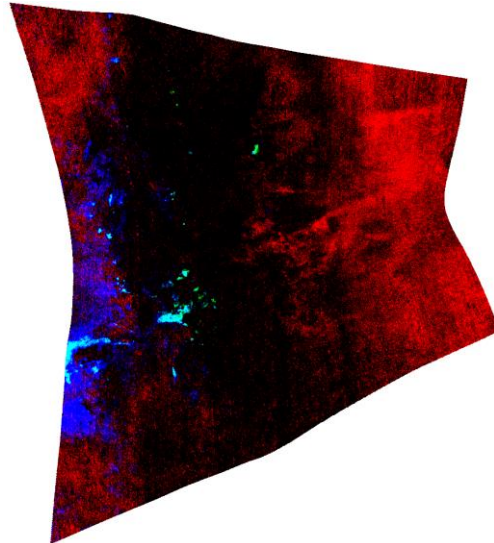
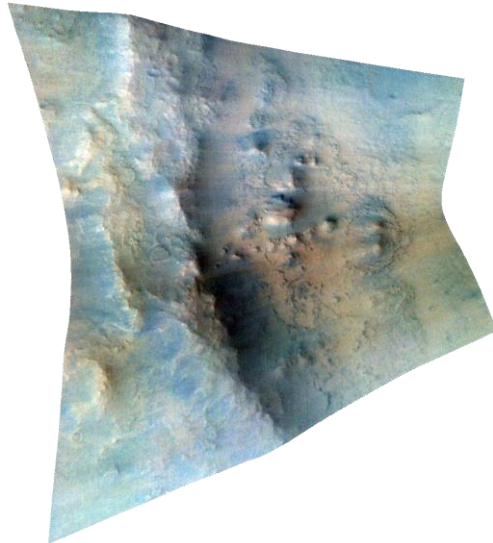
# Compact Reconnaissance Imaging Spectrometer for Mars (CRISM)



- Max spatial resolution: **18-36 m/pixel** @ 300 km;
- 544 spectral channels across the VNIR and IR range;
- Two sensors: VNIR (0.4-1.0  $\mu\text{m}$ ) and IR (1.0-4.0  $\mu\text{m}$ ).

# Compact Reconnaissance Imaging Spectrometer for Mars (CRISM)

Mineral maps (browse products): RGBs of spectral parameters



Example: mafic minerals browse product

RED = Olivine

GREEN = Low-Ca pyroxenes

BLUE = High-Ca pyroxenes

Specific mineralogy can be assessed easily and quickly

# Compact Reconnaissance Imaging Spectrometer for Mars (CRISM)

Mineral maps (browse products): RGBs of spectral parameters



Example: mafic minerals browse

More info about CRISM data products in the lecture  
***Spectral data in the sedimentary deposits of Mars***  
from last year

<https://www.planetarymapping.eu/404/fourth-day.html>

oxenes

roxenes

Specific mineralogy can be assessed easily and quickly

# Minerals detected on Mars

- CRISM observations, also combined with TES, THEMIS, and OMEGA previous observations, indicate widespread and highly diverse mineral deposits on Mars.
- Currently identified minerals:

Olivine

Plagioclase

Phyllosilicates

Carbonates

Ices

Pyroxenes

Iron Oxides

Sulfates

Halides and other hydrated silicates

# Minerals detected on Mars

Primary mafic silicates

Plagioclase

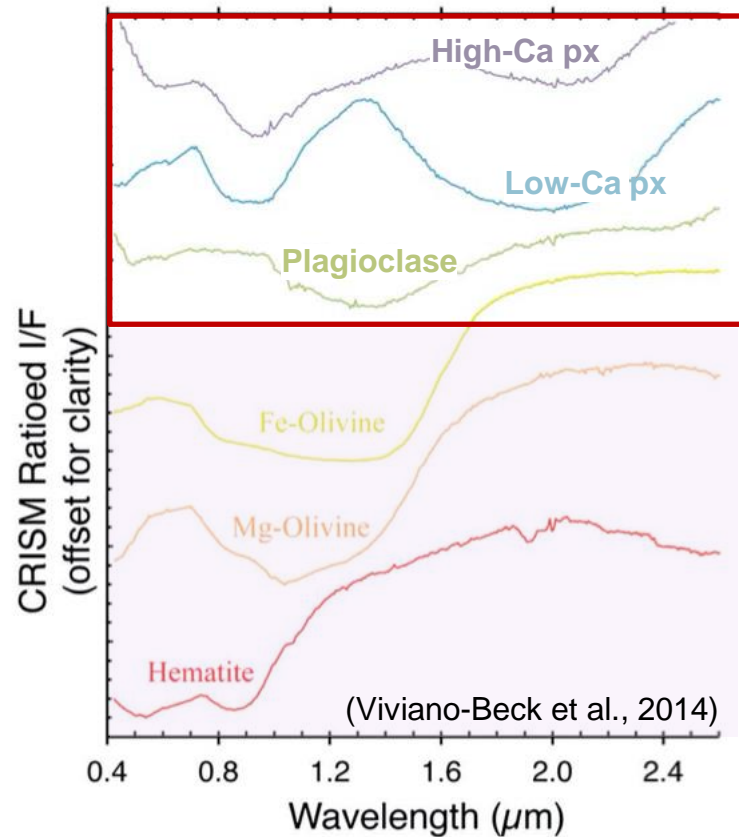


Pyroxenes



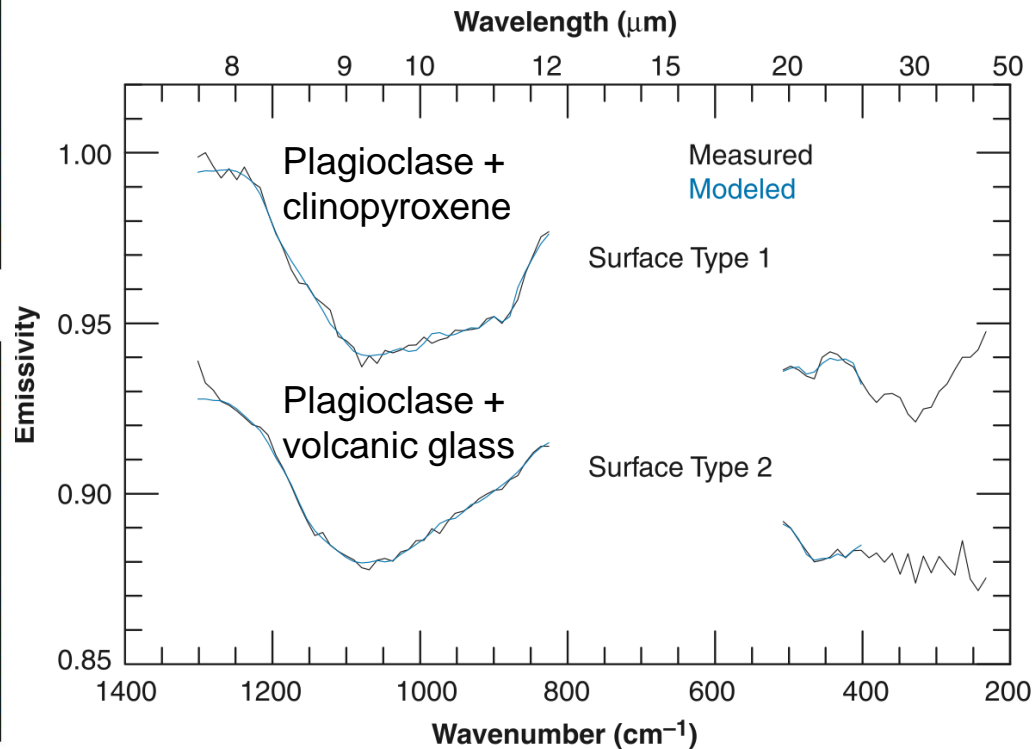
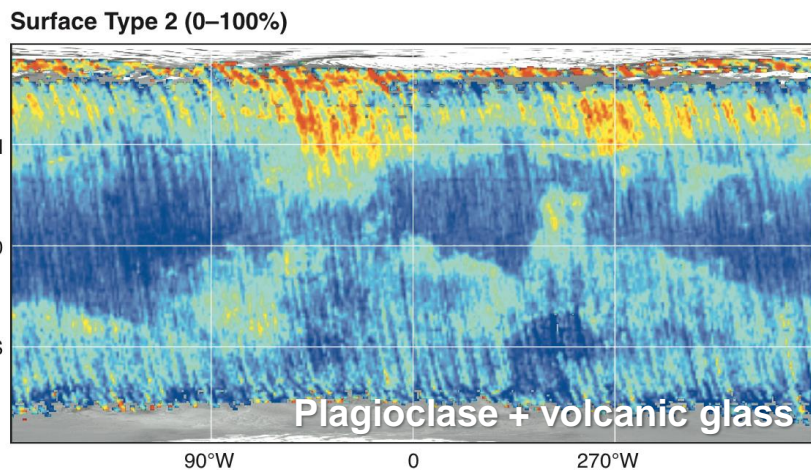
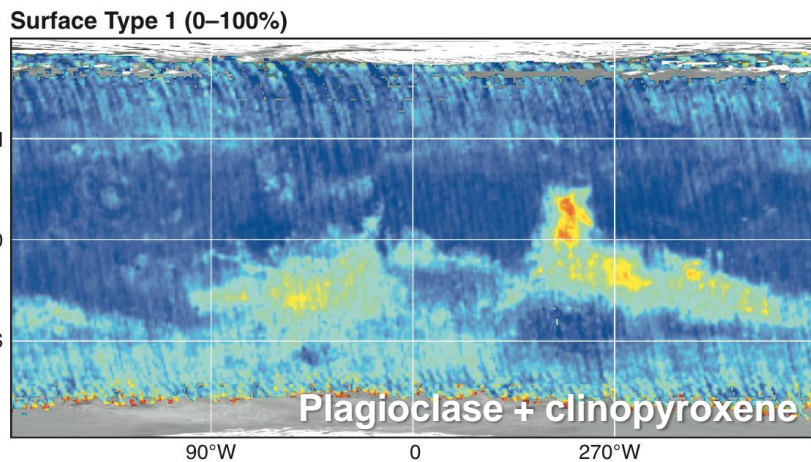
© Rob Lavinsky & iRocks.com

➤ Most abundant minerals of Mars' crust



# Primary mafic silicates from TES

(Bandfield et al., 2000)



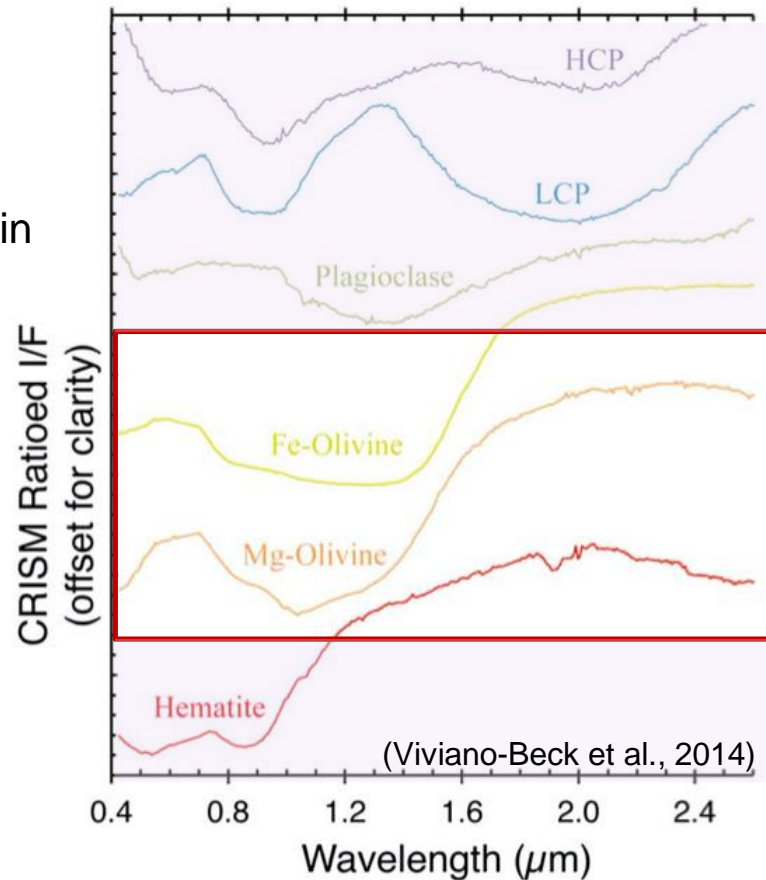
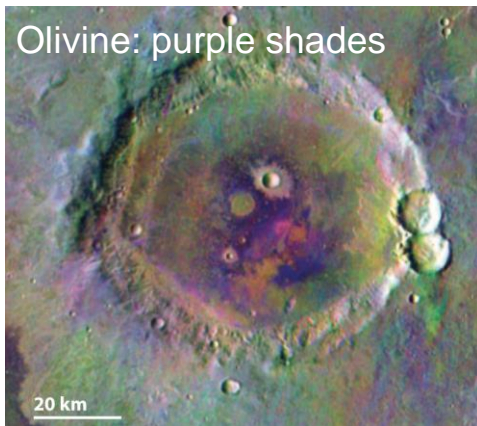


# Minerals detected on Mars

## Primary mafic silicates

Olivine

- Usually detected when old materials are **exposed from depth** (e.g., by impacts) and in some **ancient lavas**.

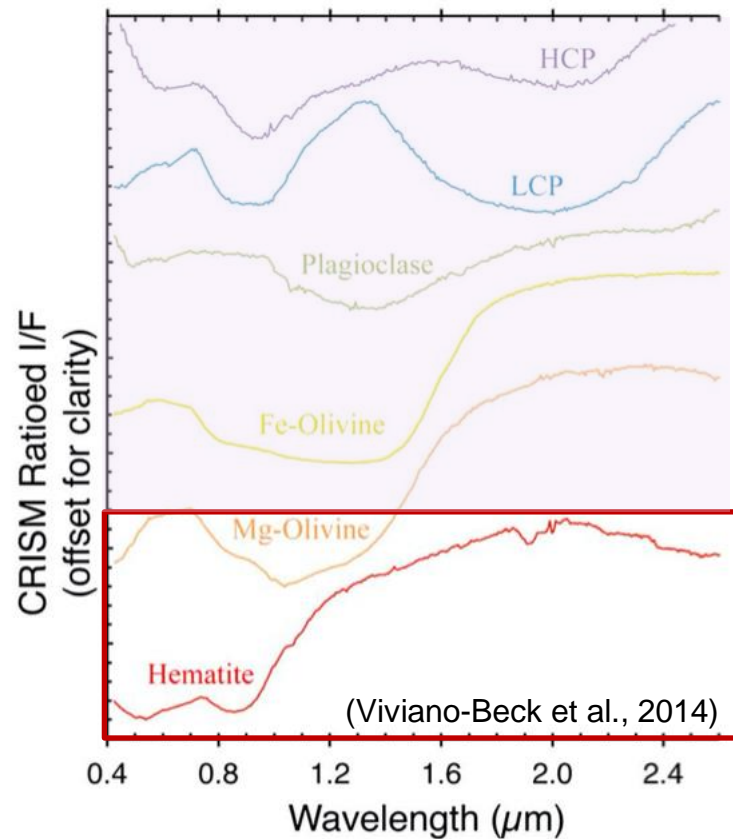


# Minerals detected on Mars

## Iron Oxides

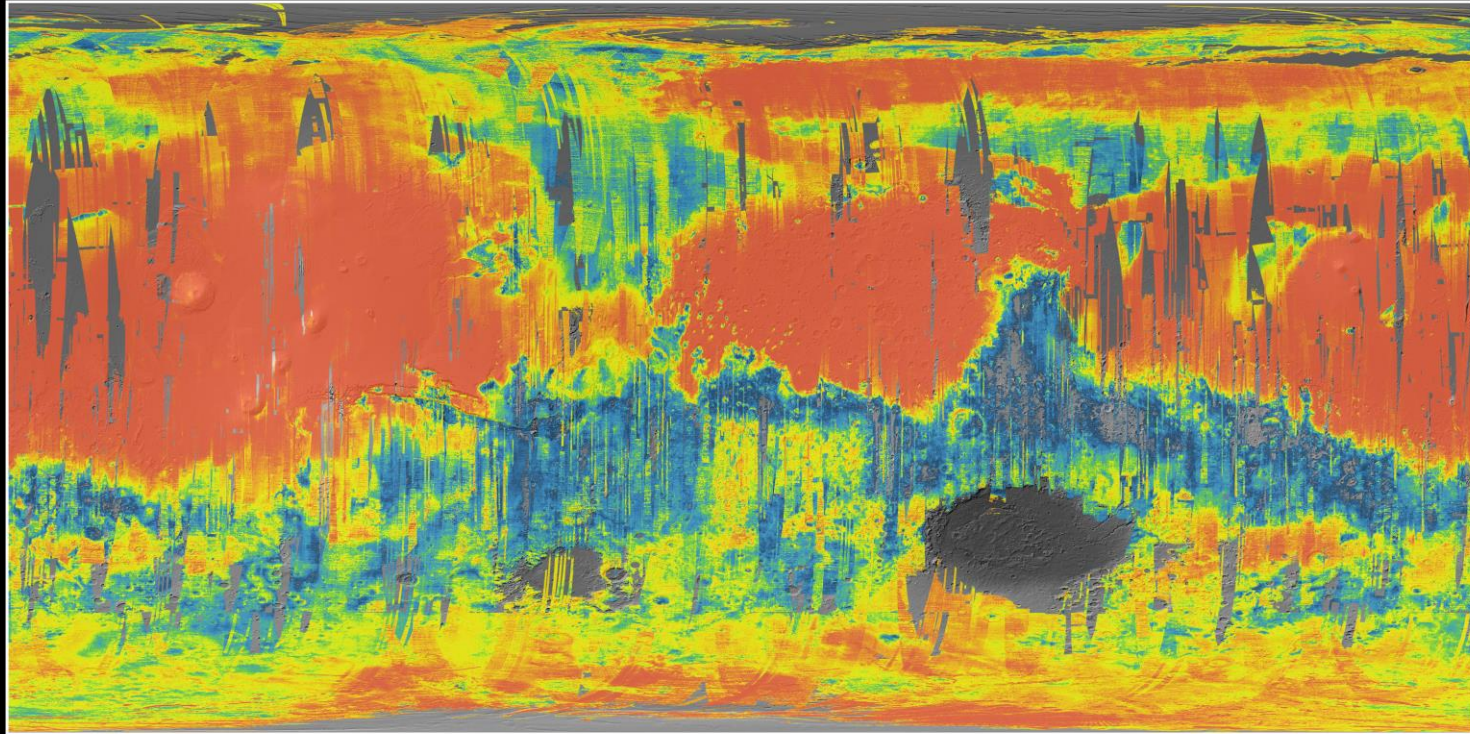


- Related to recent weathering and surface processes;
- Primary component of Martian surface soils and dust;
- Give Mars its distinctive reddish hue.



# Dust Map (OMEGA)

Dust



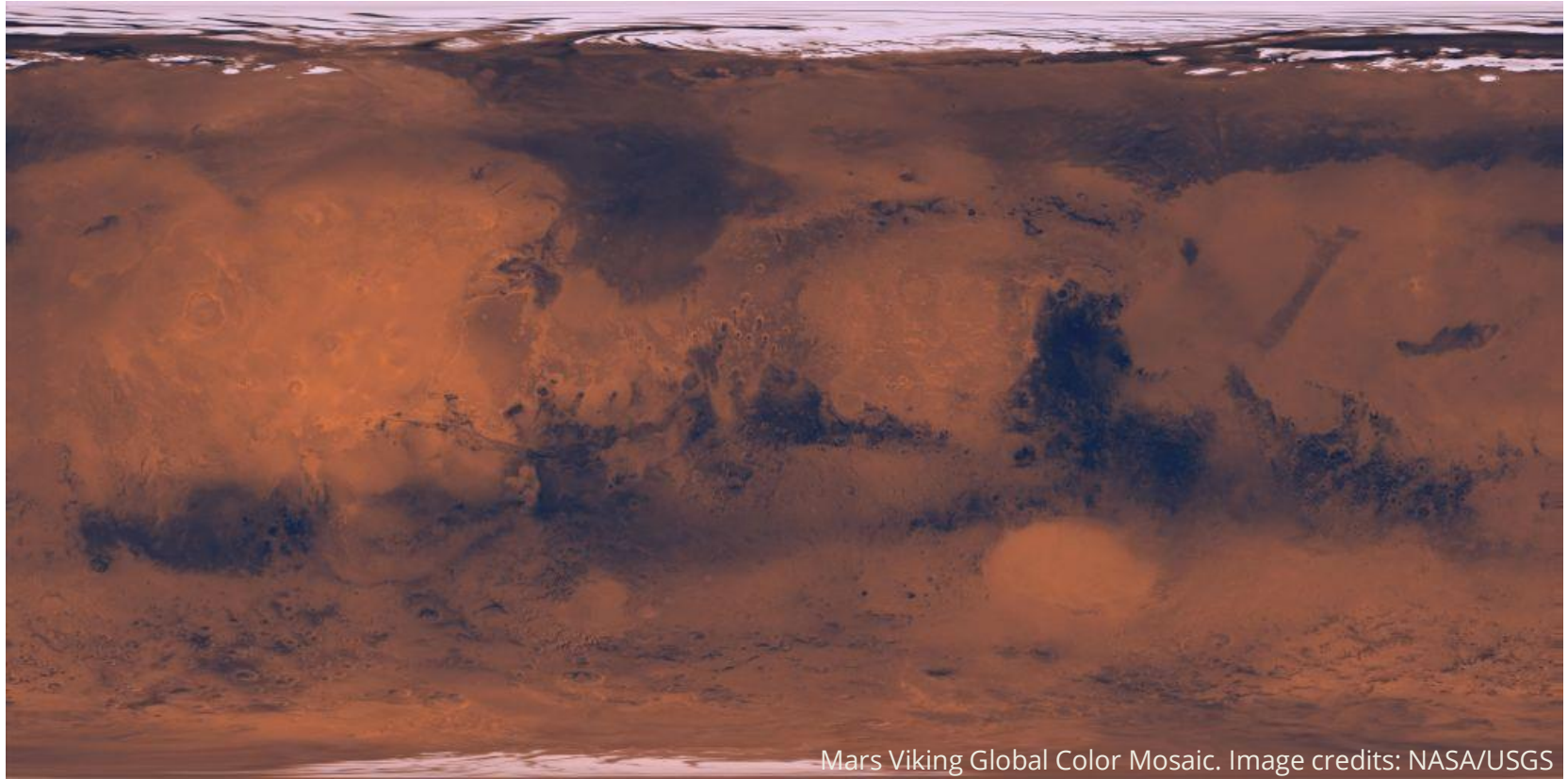
High  
abundance



Low  
abundance

Image credits: ESA

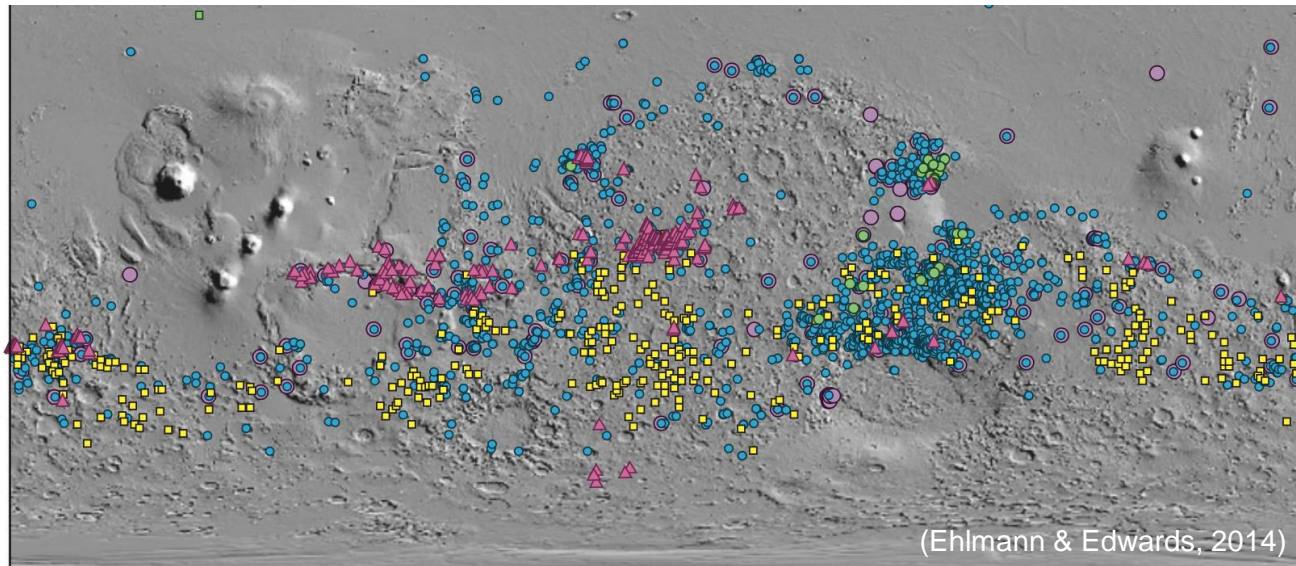
# Dust Map (OMEGA)



Mars Viking Global Color Mosaic. Image credits: NASA/USGS

# Minerals detected on Mars

Aqueous minerals  indicative of **persistent water activity**:



● Phyllosilicates      ● Silica      ■ Chlorides      ● Carbonates      ▲ Sulfates

- **Phyllosilicates** (e.g., clays),
- **Sulfates**,
- **Carbonates**,
- **Chlorides** (e.g., halite),
- Other **hydrated silica** (e.g., opal).

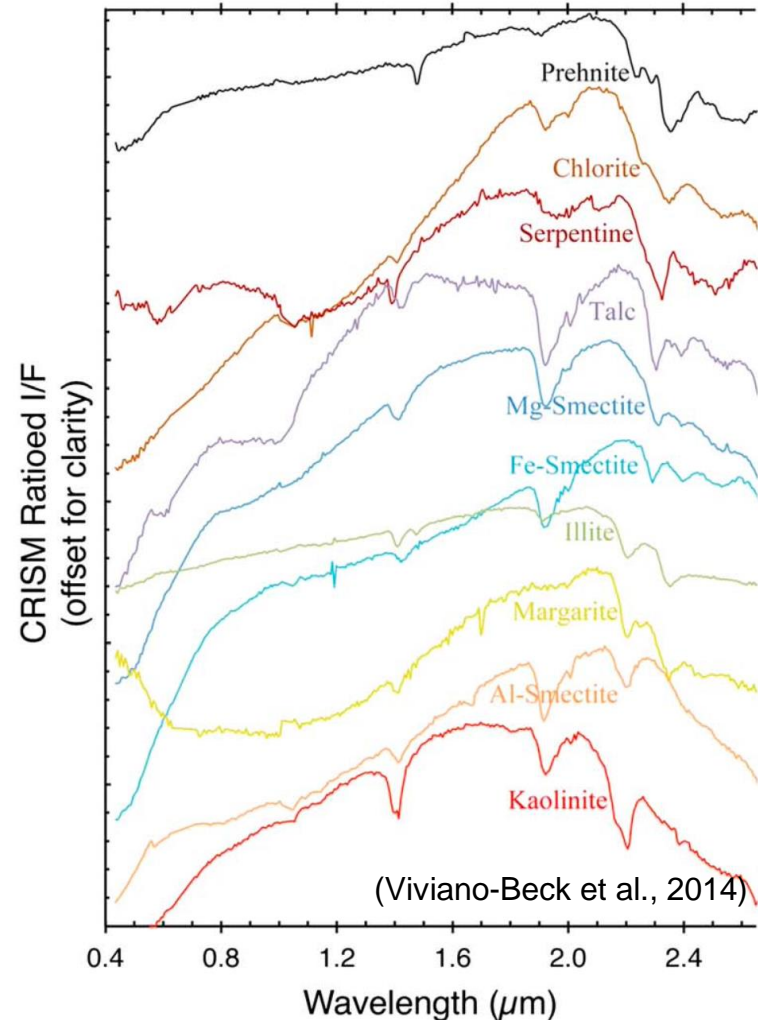
# Aqueous minerals

## Phyllosilicates

*Phyllosilicates are the most common aqueous mineral on Mars*

Possible formation mechanisms on Mars generally include water alteration at relatively low temperature and pressure

- Surface formation (e.g., pedogenesis);
- Diagenesis;
- Hydrothermal;
- Low-grade metamorphic.



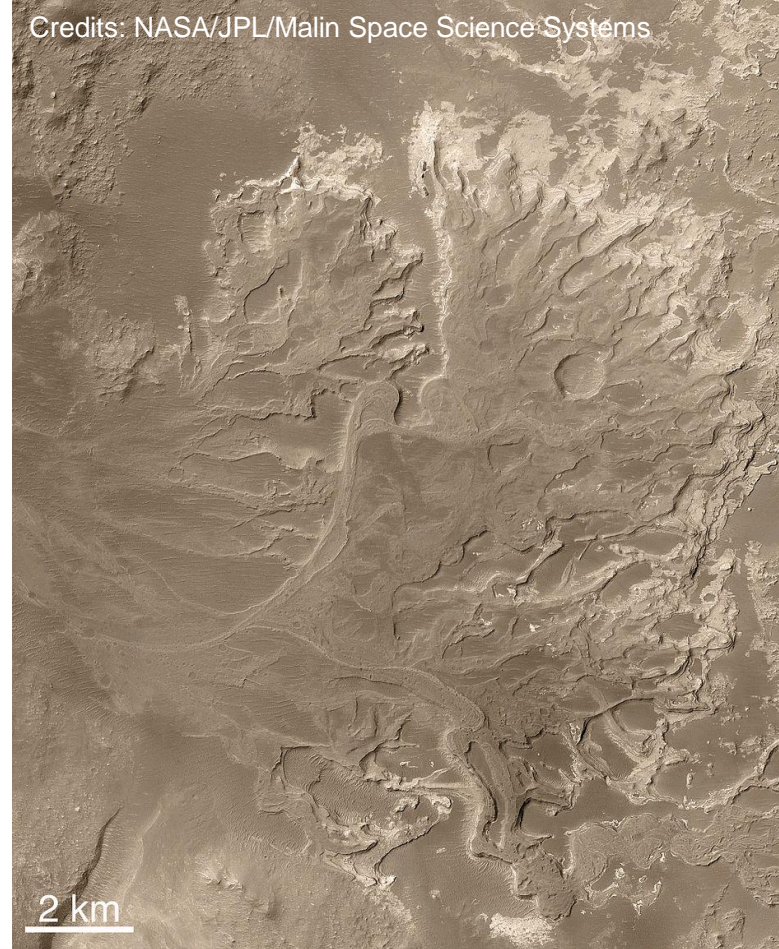
# Aqueous minerals

## Phyllosilicates

*Phyllosilicates are the most common aqueous mineral on Mars*

Common occurrences:

- Fans and deltas deposits inside craters (former crater lakes);
- Layered deposits with Al-bearing clays overlying Fe/Mg clays;
- Intercrater plains sediments;
- Outcrops on crater walls and impact ejecta.



# Aqueous minerals

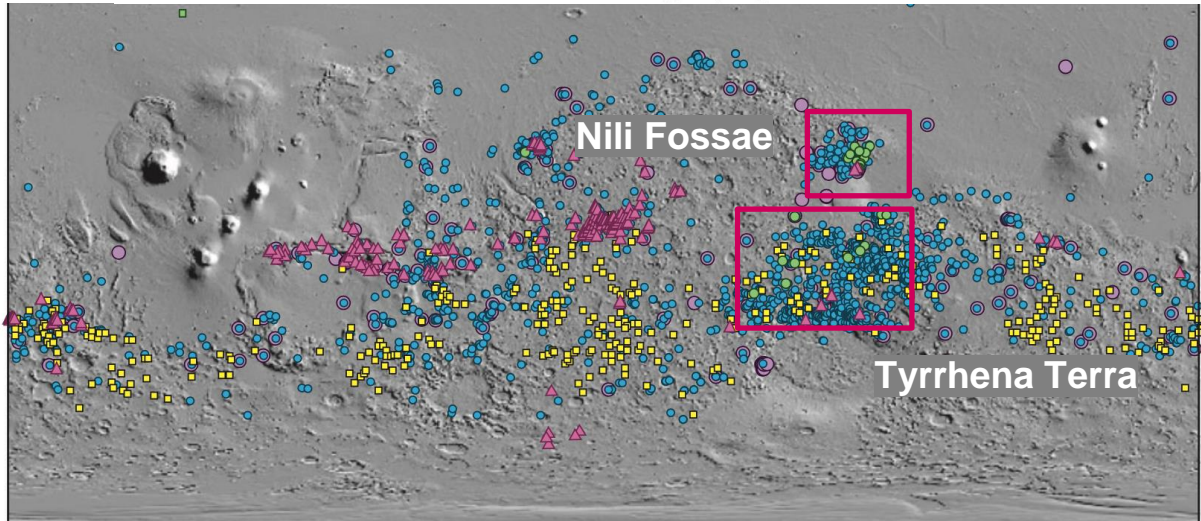
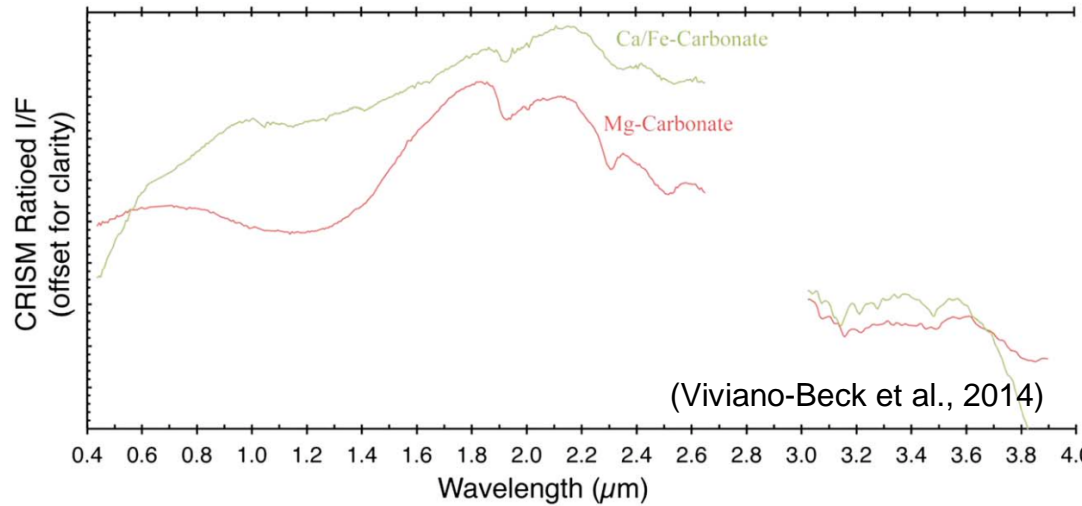
## Carbonates

Formation mechanisms:

- Precipitation in aqueous environments at neutral-to-alkaline conditions.

Occurrences:

- Specific locations like Nili Fossae and Tyrrhena Terra.





# Missing carbonates?

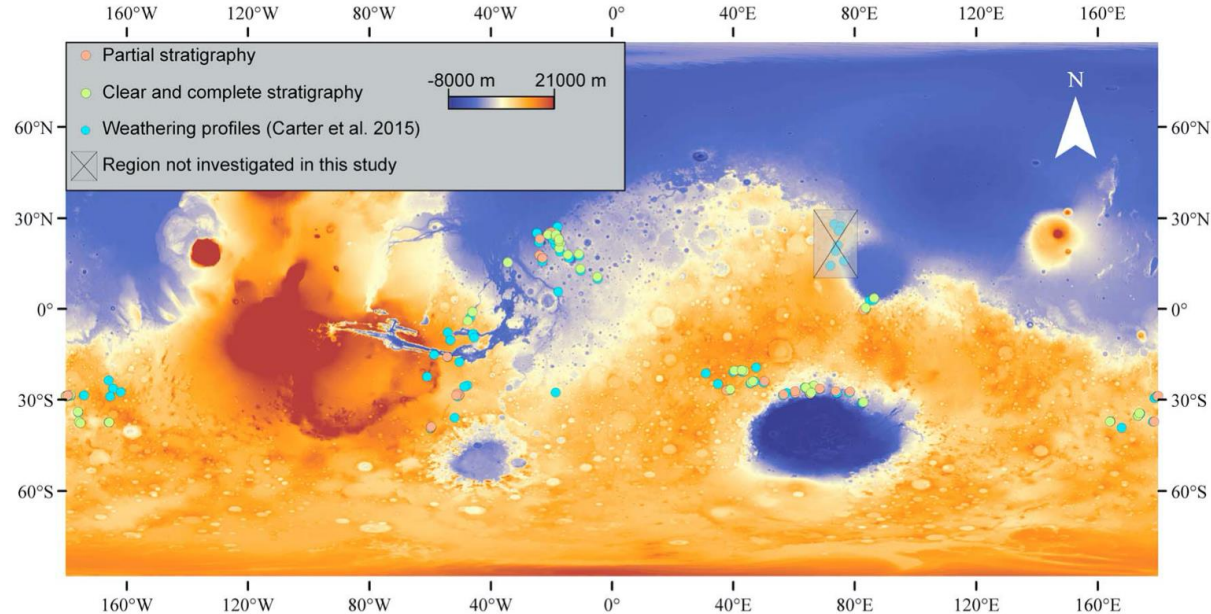
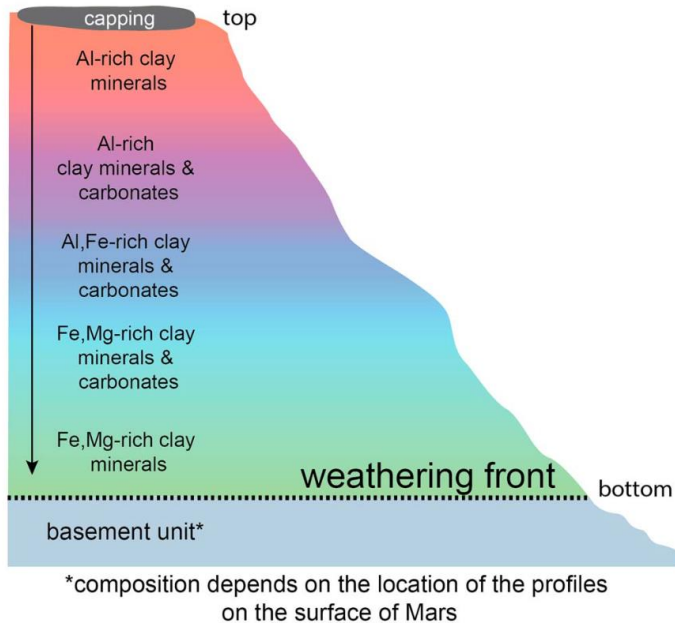
Large scale deposits of carbonates should have formed on ancient Mars (CO<sub>2</sub> rich atmosphere + abundant water at the surface)

Why don't we observe them?

- No warm and wet early Mars for long enough;
- Other greenhouse gases than CO<sub>2</sub> on early Mars;
- Some deposits destroyed by subsequent acidic aqueous activity;
- Carbonate signature is spectrally obscured by other mineral phases but in very carbonate-rich areas.

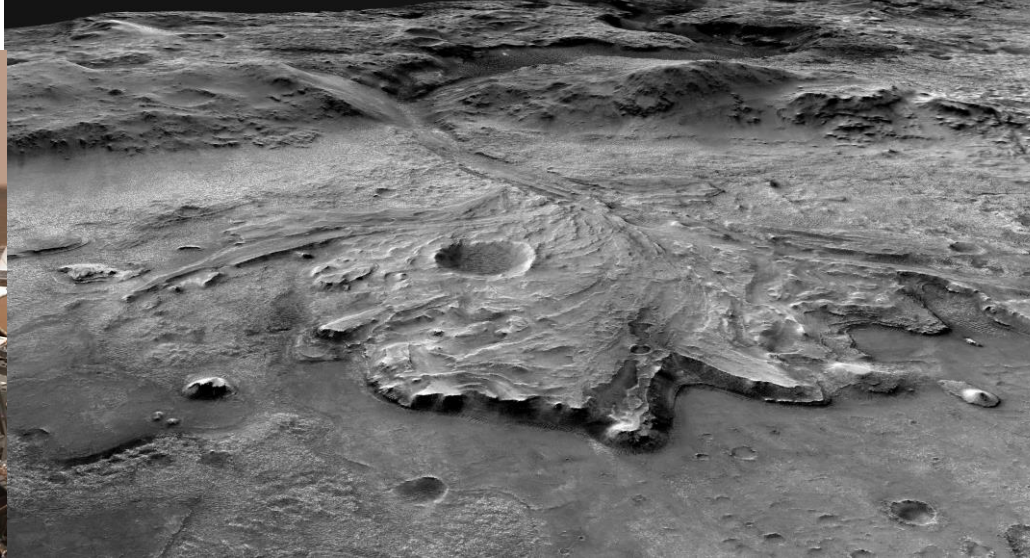
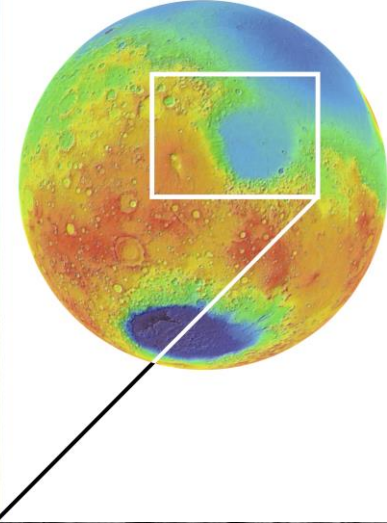
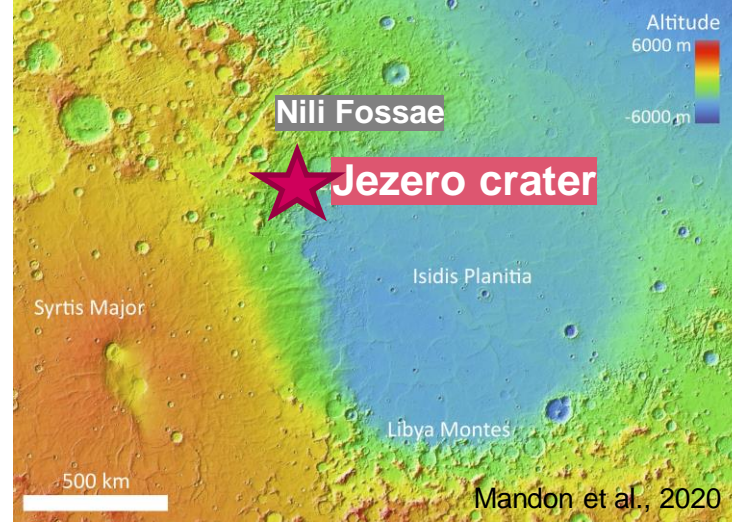
# Aqueous minerals

Recently, carbonates were found mixed with clays in weathering profiles at Oxia Planum, Valles Marineris, Hellas (Bultel et al., 2019).



# Jezero crater

Jezero crater is the only known location where clear orbital detection of **carbonates + fluvio-lacustrine features** are present

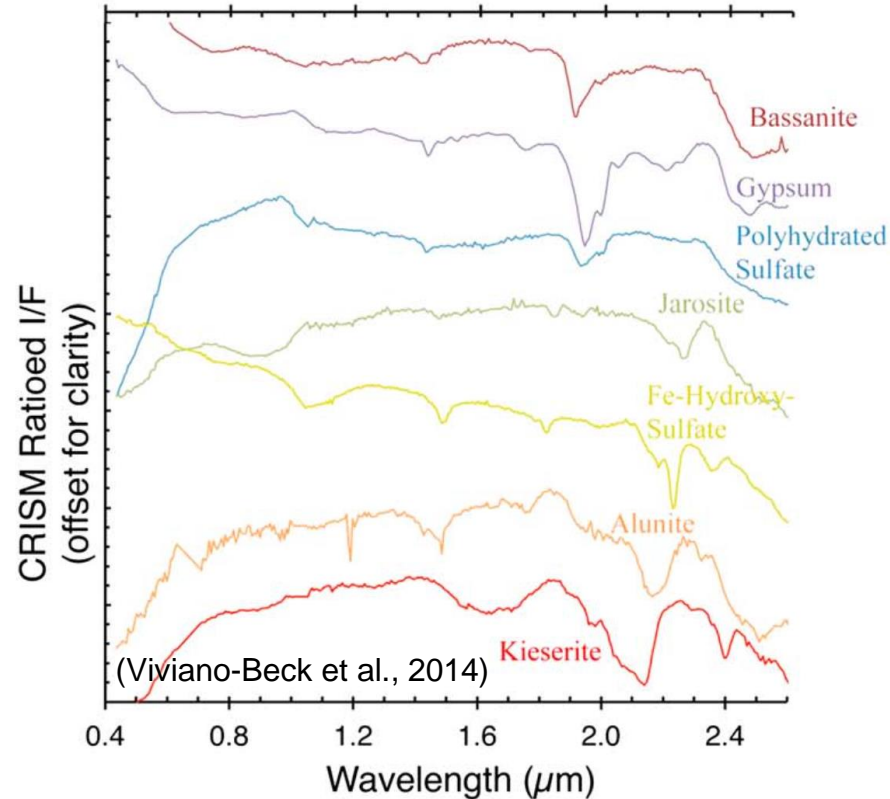


# Aqueous minerals

## Sulfates

Sulfates could have formed in the following **settings**:

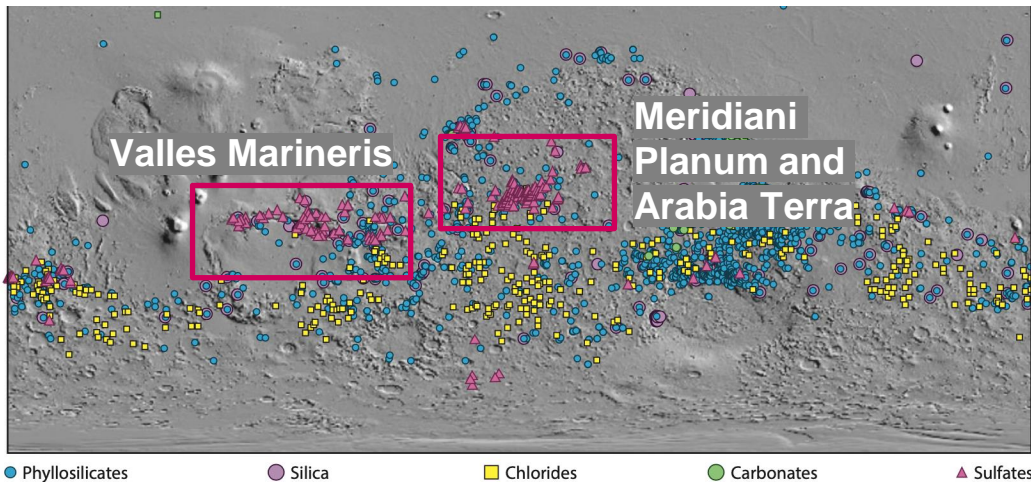
- Alteration of the crust through acidic groundwater (subsurface) or rain/frost (surface);
- Evaporation of standing water bodies/brines.



# Aqueous minerals

Common **sulfate** occurrences:

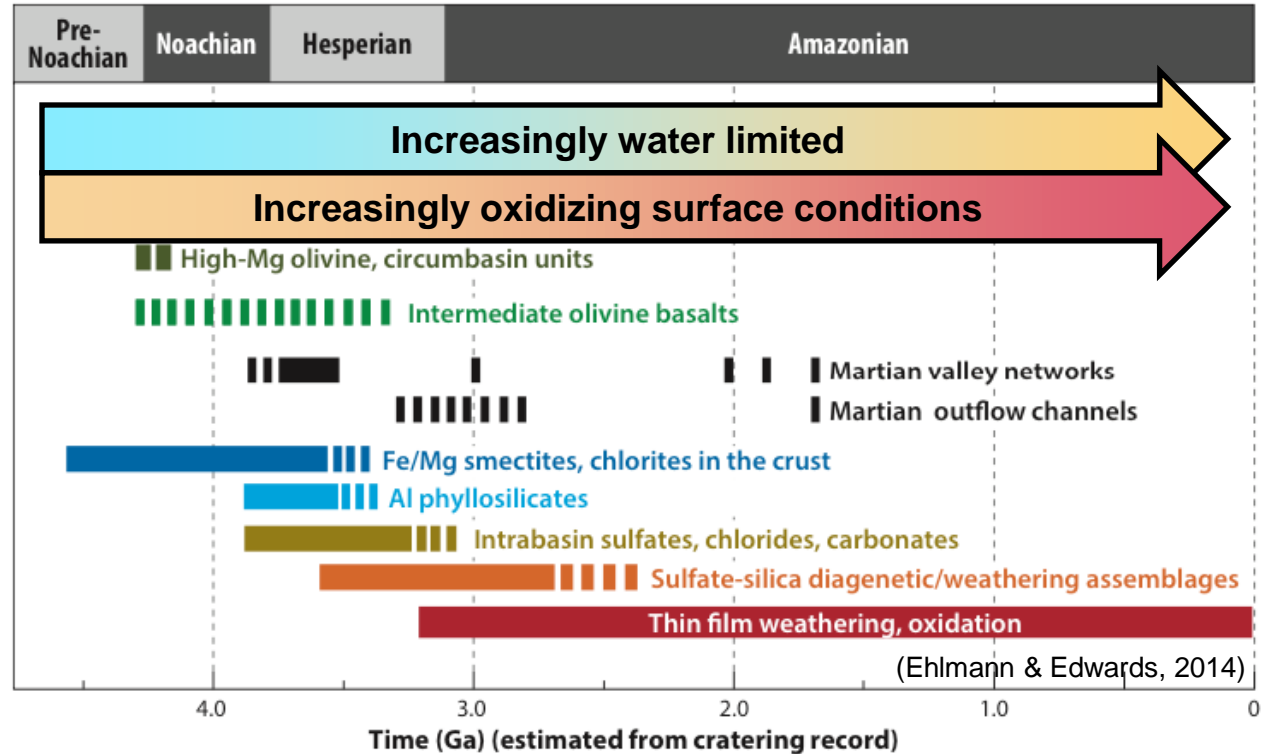
- Valles Marineris, chaotic regions, Meridiani Planum and Arabia Terra, dunes surrounding the northern polar cap (gypsum).



# Timeline of large-scale compositional units

Different aqueous mineralogy means:

- Different environmental and chemical conditions;
- Different epochs (although with some overlapping).





Geology & Planetary Mapping  
**Winter School**

# Thank you!



# References

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Minerals Identified through CRISM Analysis – The MICA Files: <http://crism.jhuapl.edu/data/mica/>