Clay Minerals in the Mawrth Vallis Region: A proposed MSL landing site

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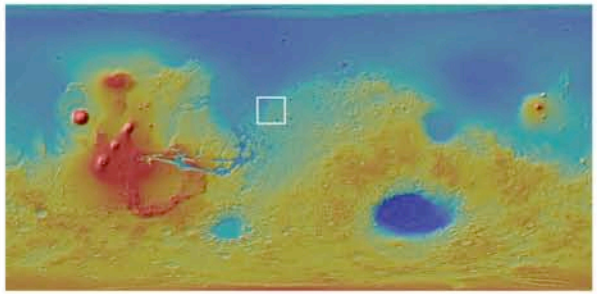
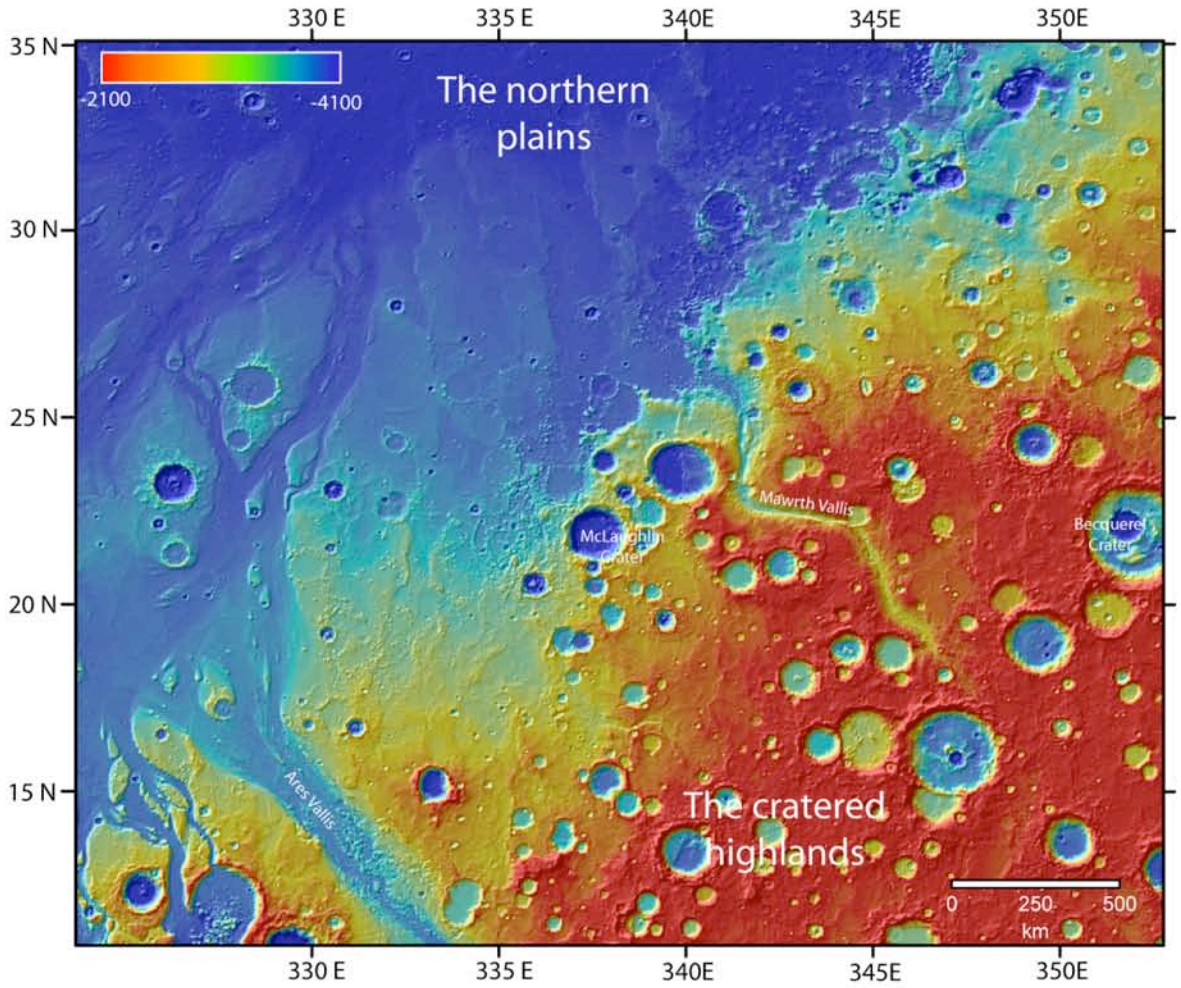
Overview

- Located near:
  - 340 E
  - 25 N





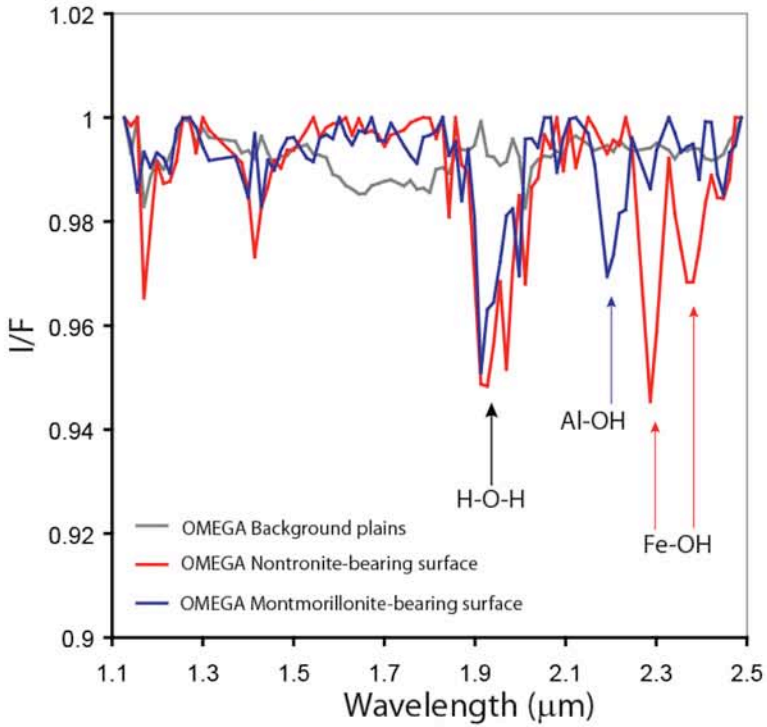
- Discovery of clay minerals
  (Poulet et al., Nature, 2005)
- Recent papers: (Loizeau et al., JGR, 2007; Michalski and Noe, Geology, 2007)

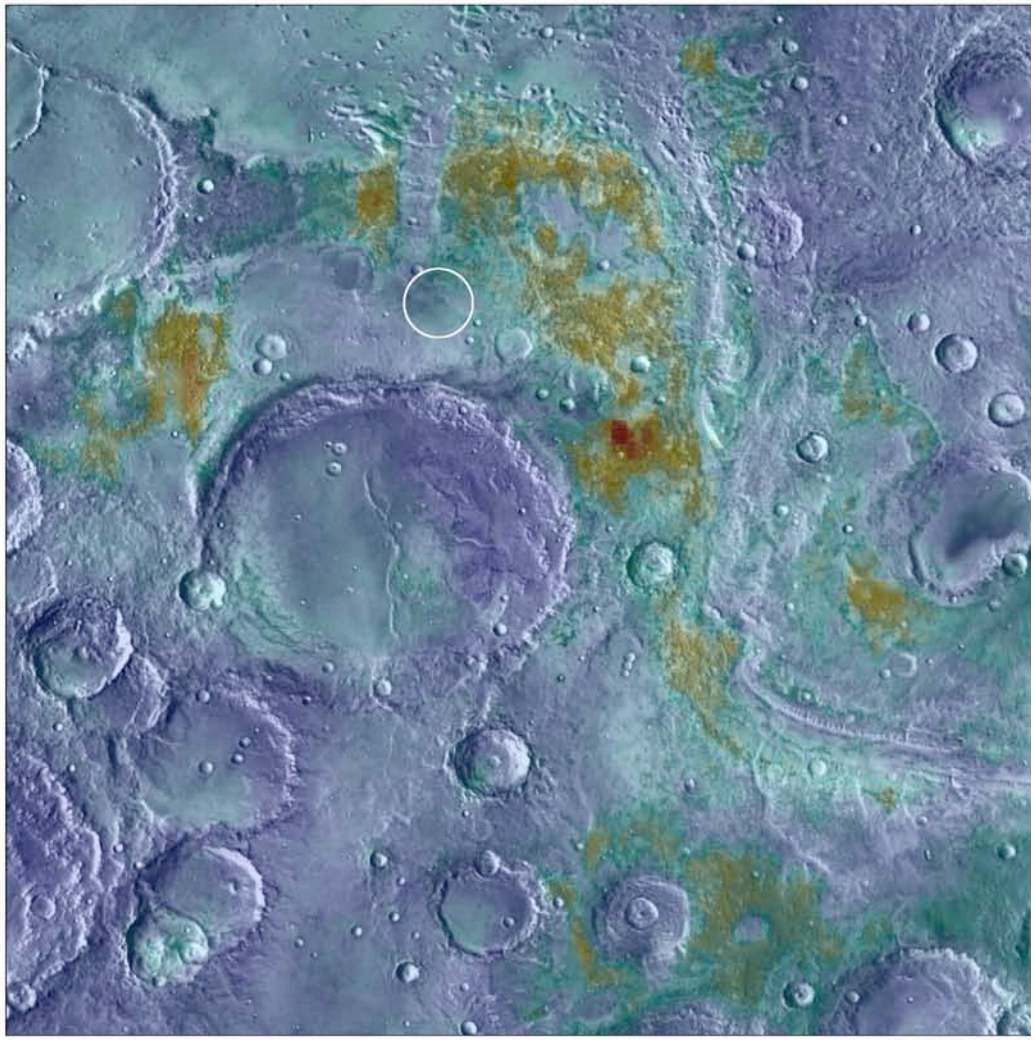
Tell n
Joseph.R.Michalski@jpl.nasa.g

Surface Mineralogy

⇒ The reason to go with MSL

- Clay minerals detected from near-infrared absorptions





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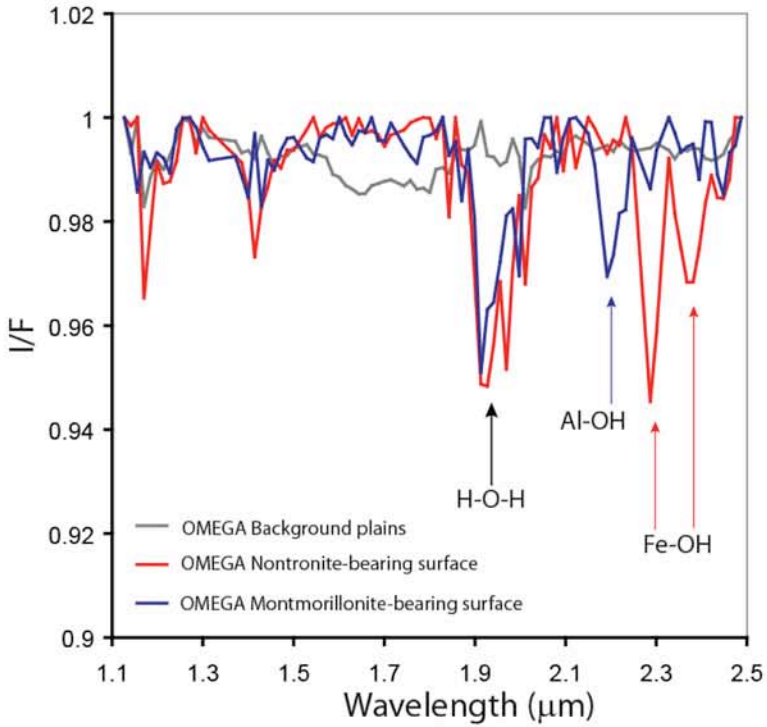

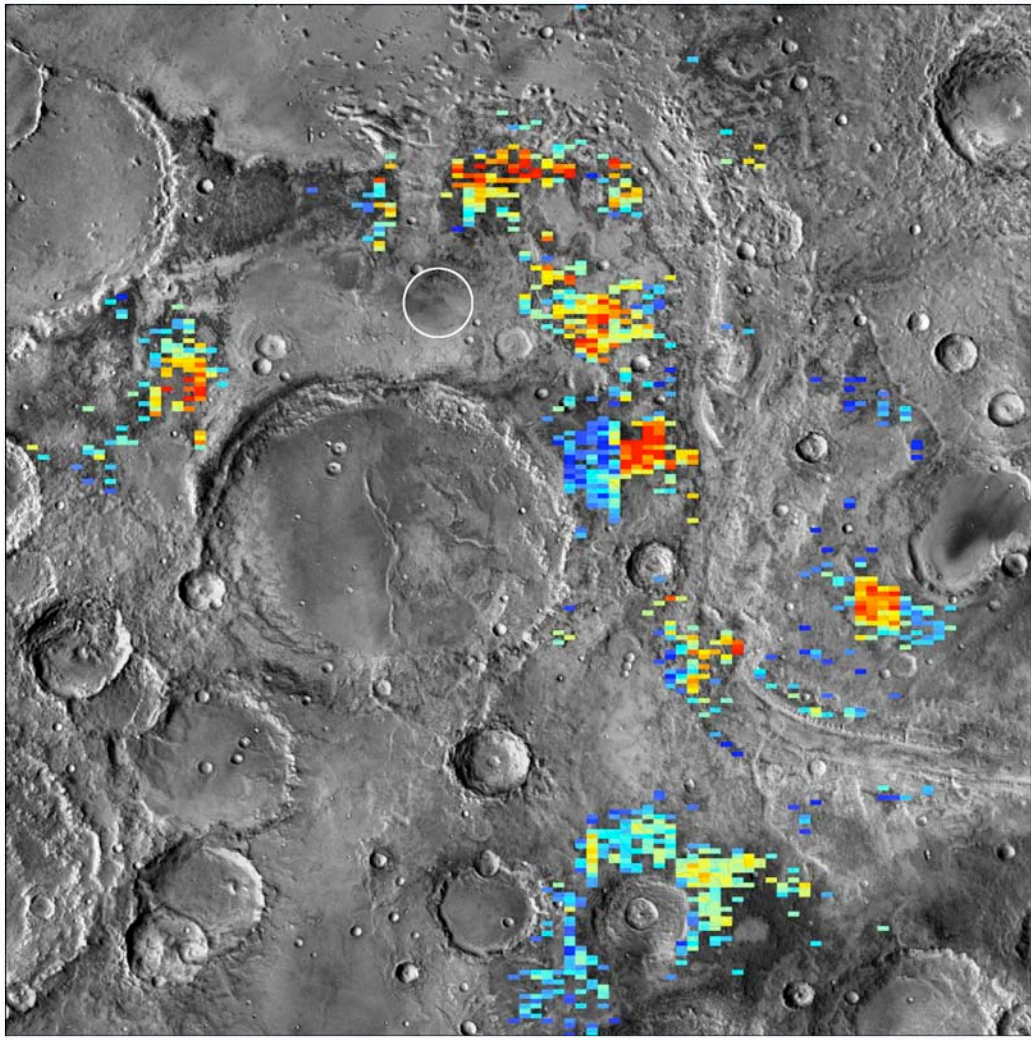

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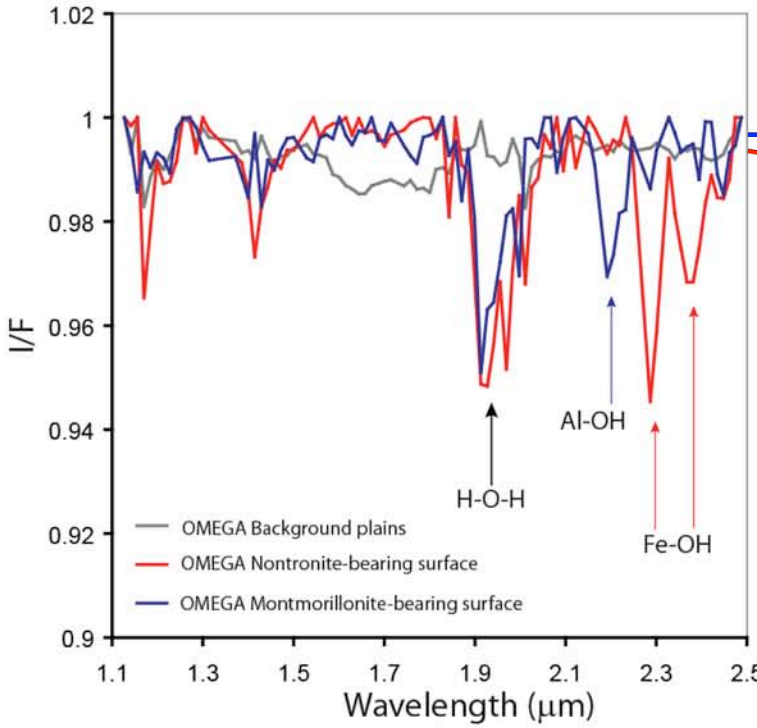
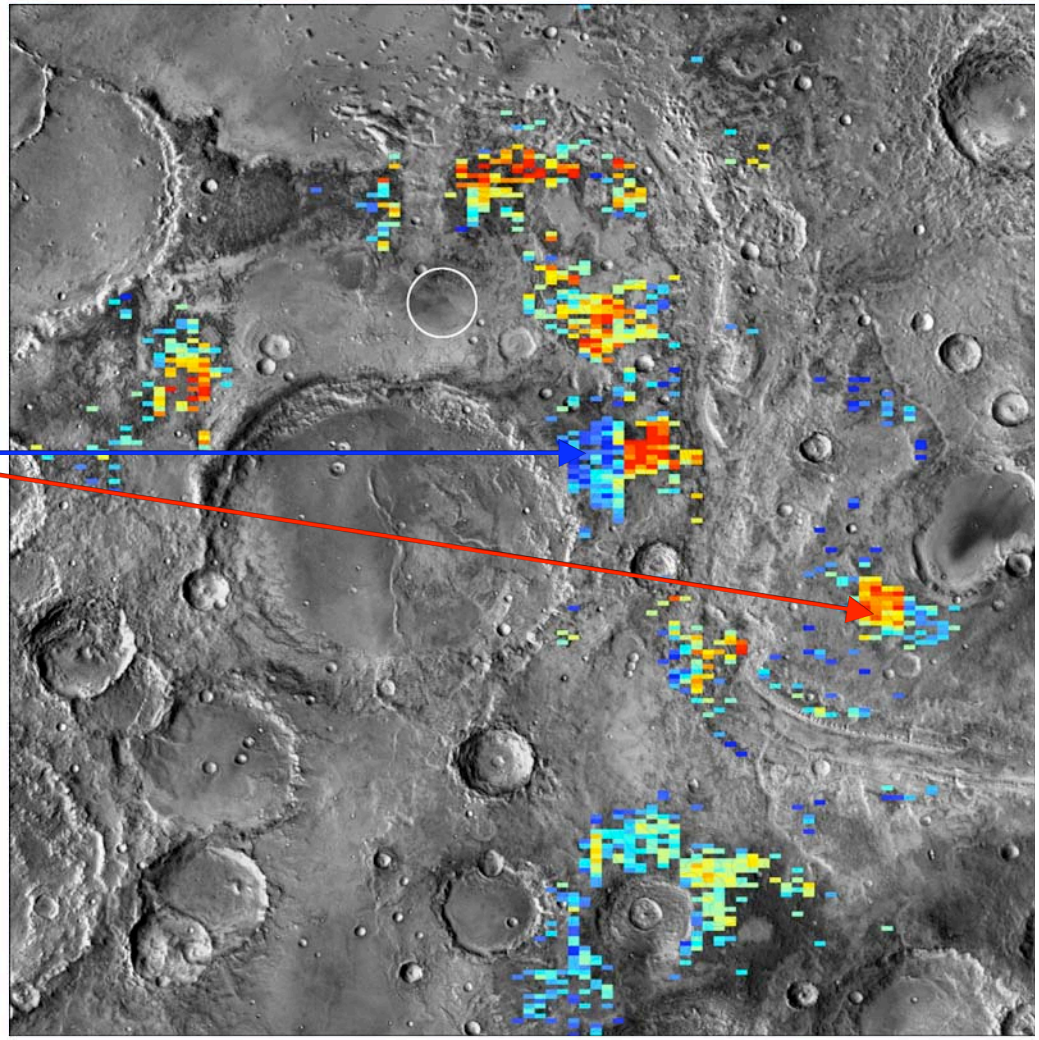
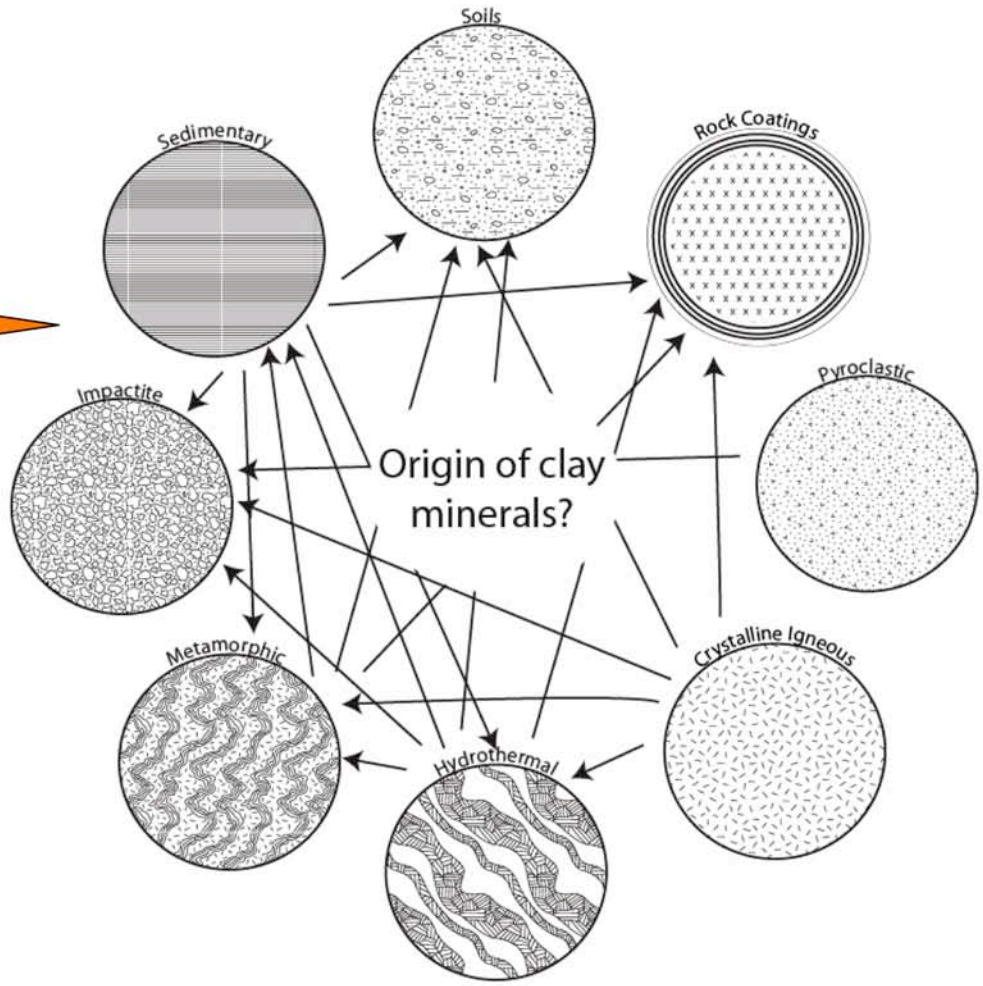


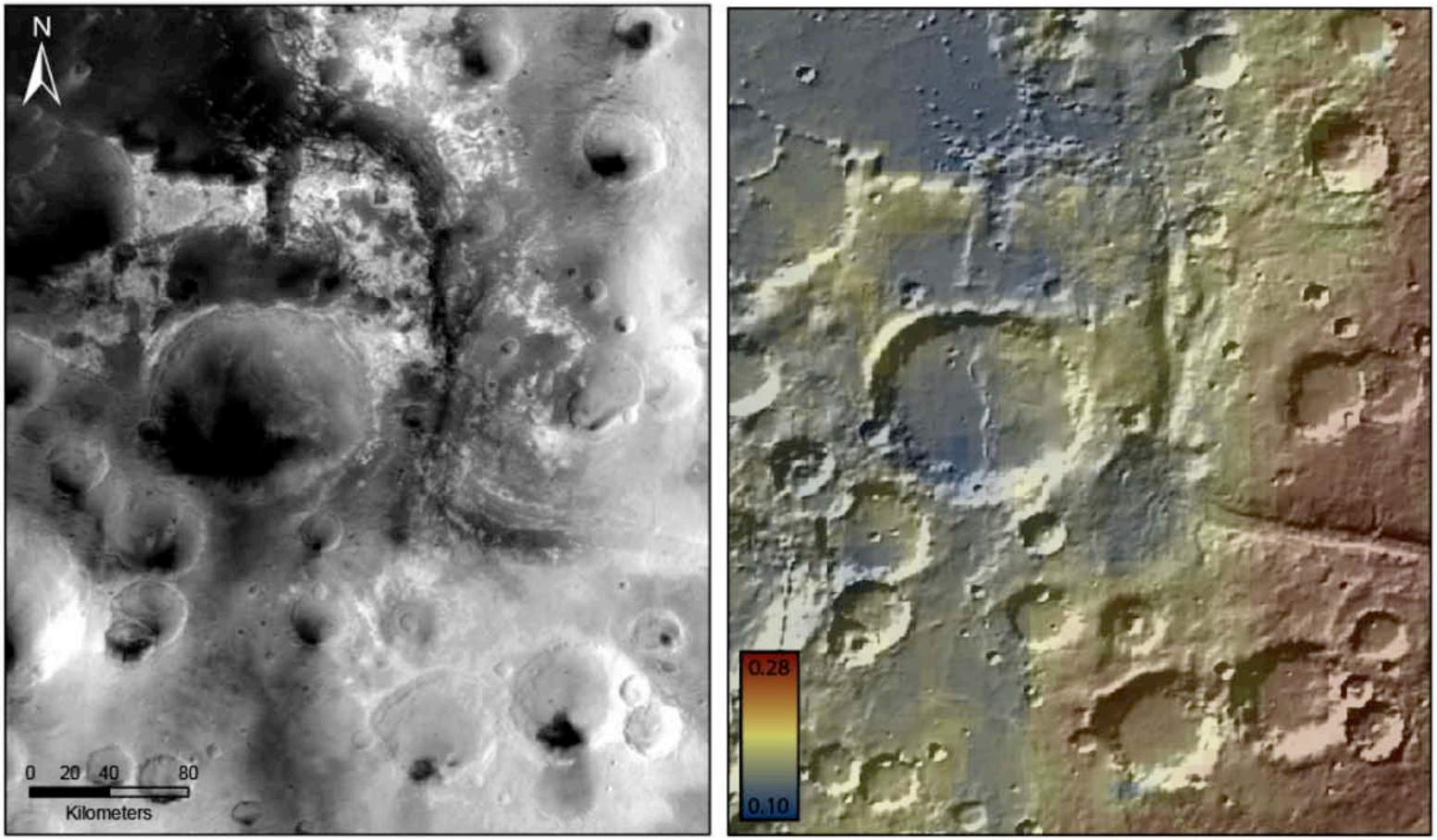


To evaluate Mawrth Vallis as a top candidate landing site, we must determine:

- Is it scientifically irresistible?
  - Lithologic context of the clays?
  - Age?
  - Stratigraphic context?
  - Likely to preserve biomarkers?
  - Understandable?
- Is it accessible?
  - Safe for landing
  - Targets reachable?

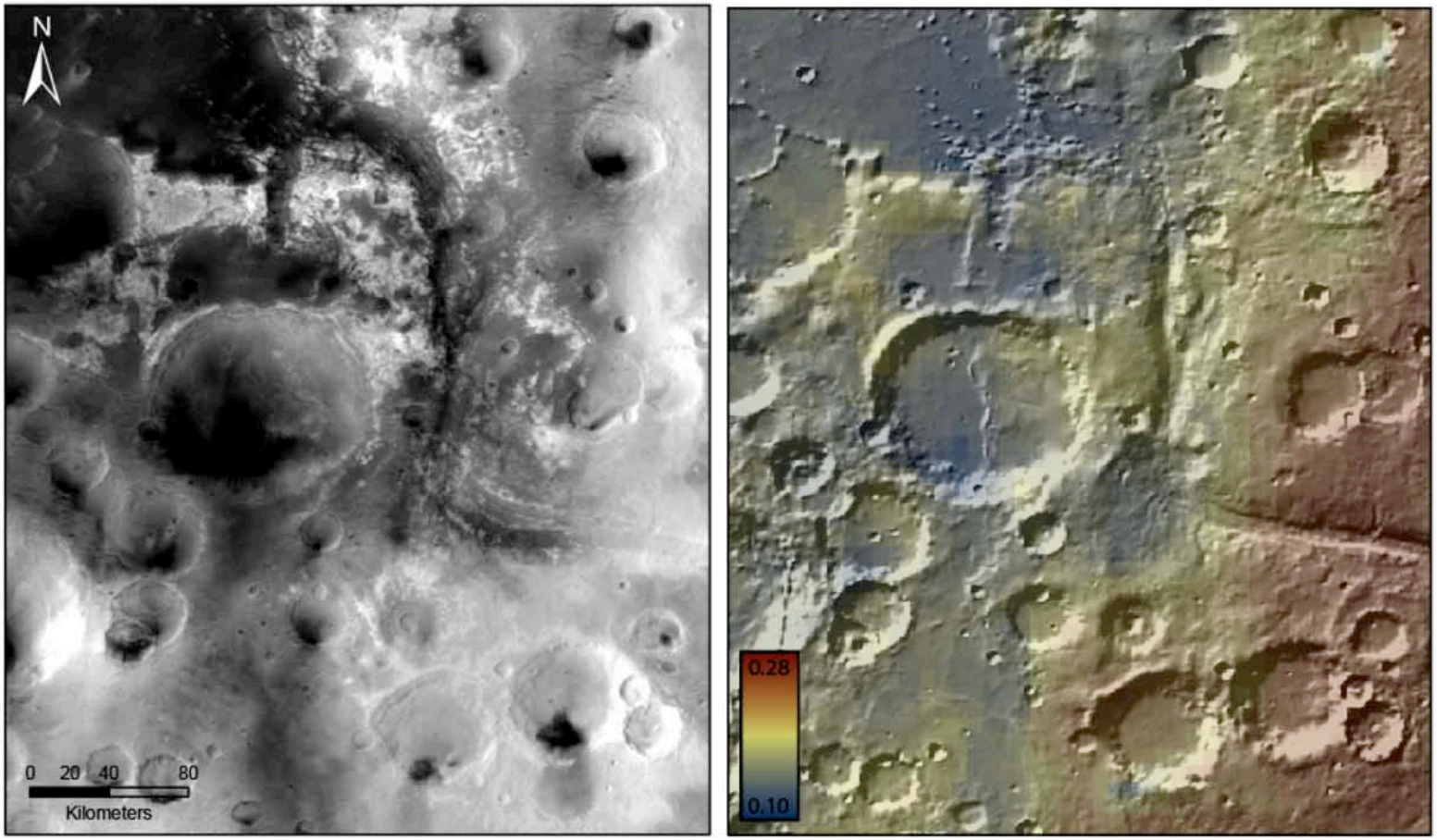


TES albedo



TES albedo

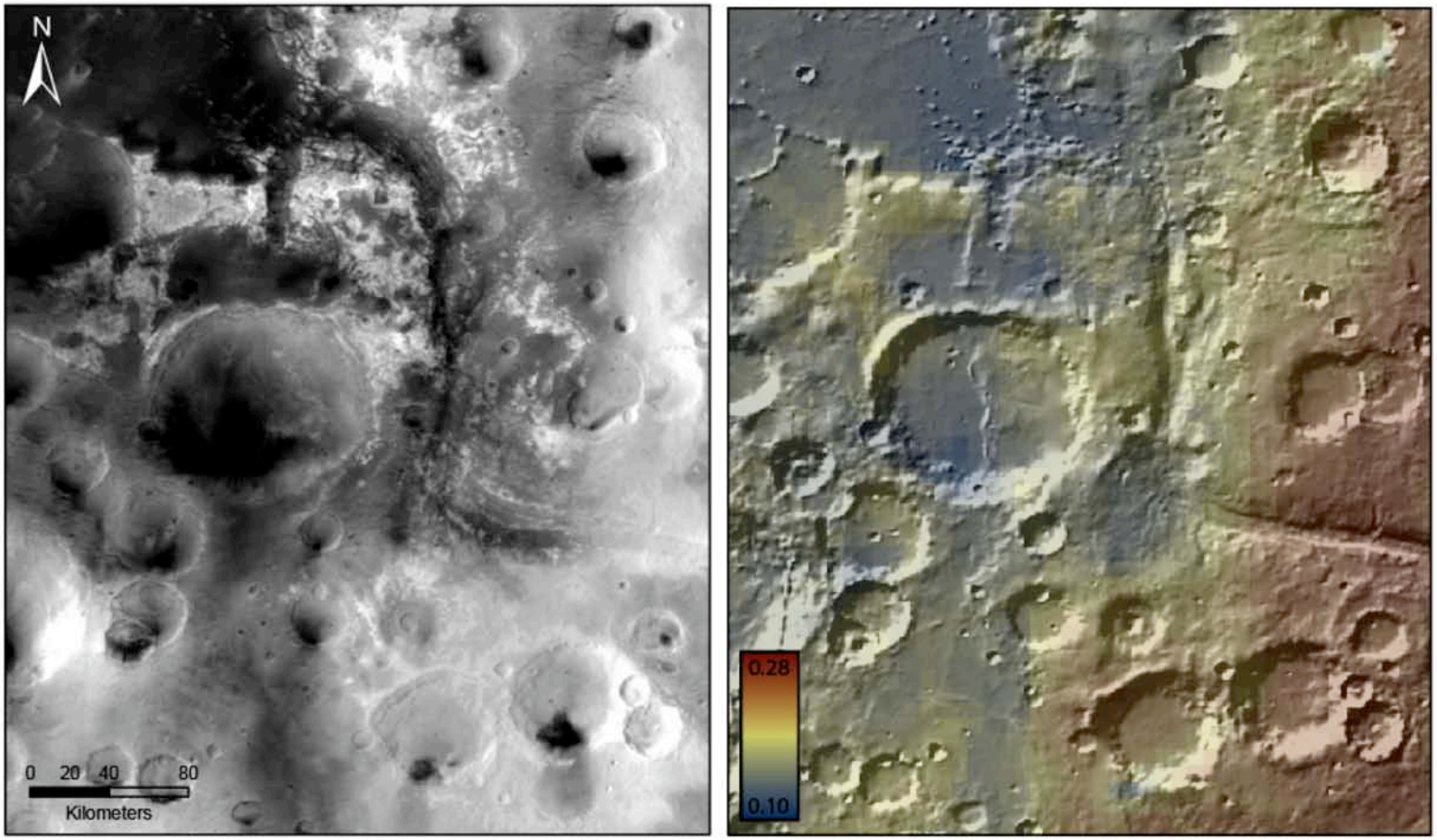
⇒ Meets albedo constrain



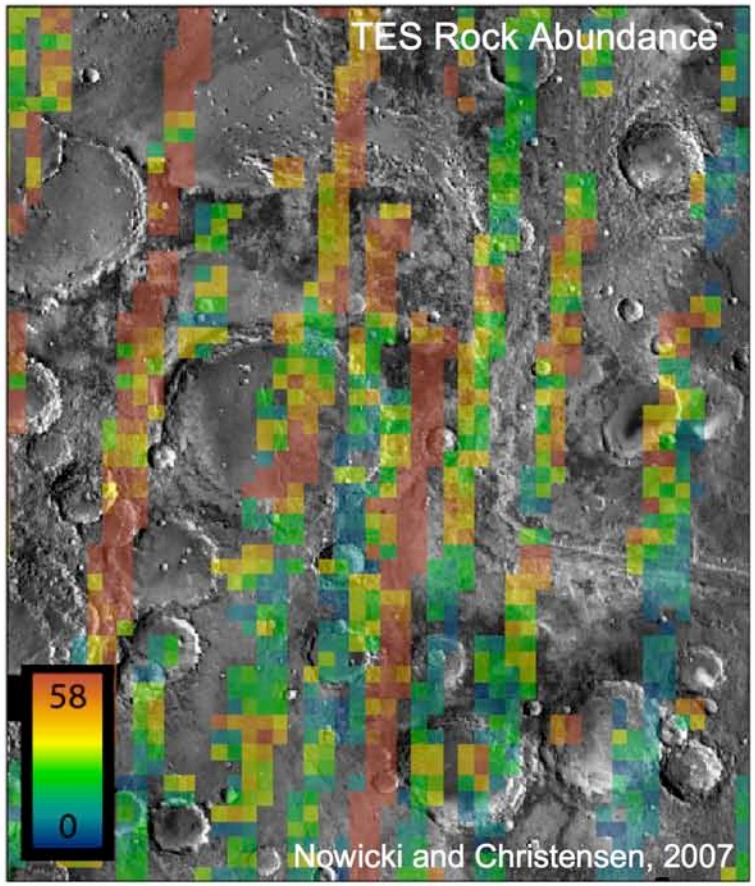
TES albedo

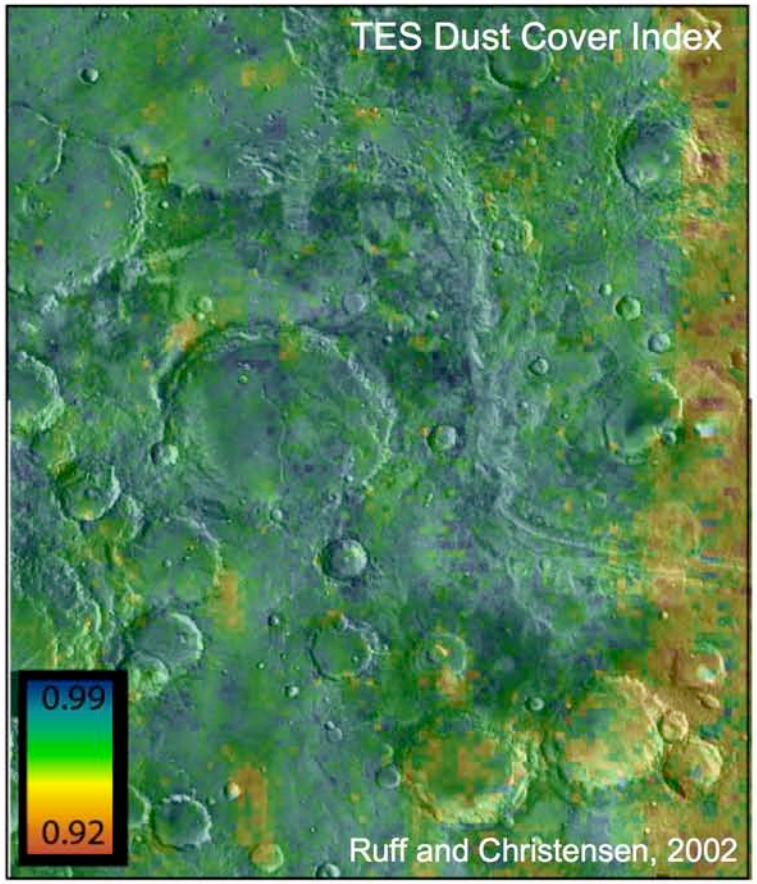
⇒ Meets albedo constrain

⇒ Dust increases to the east



Thermal IR surface properties





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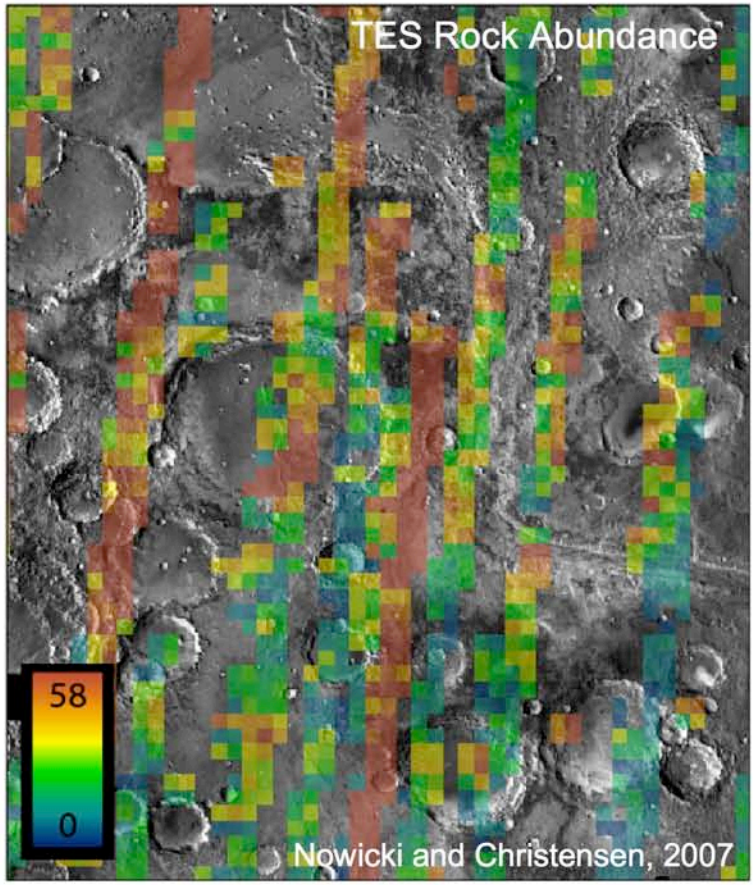
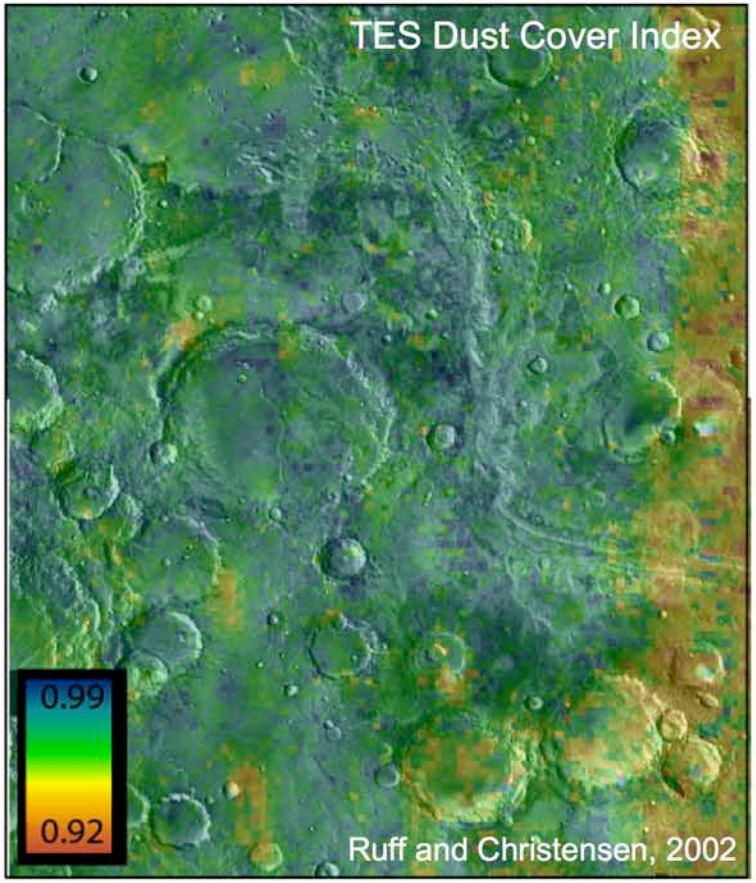
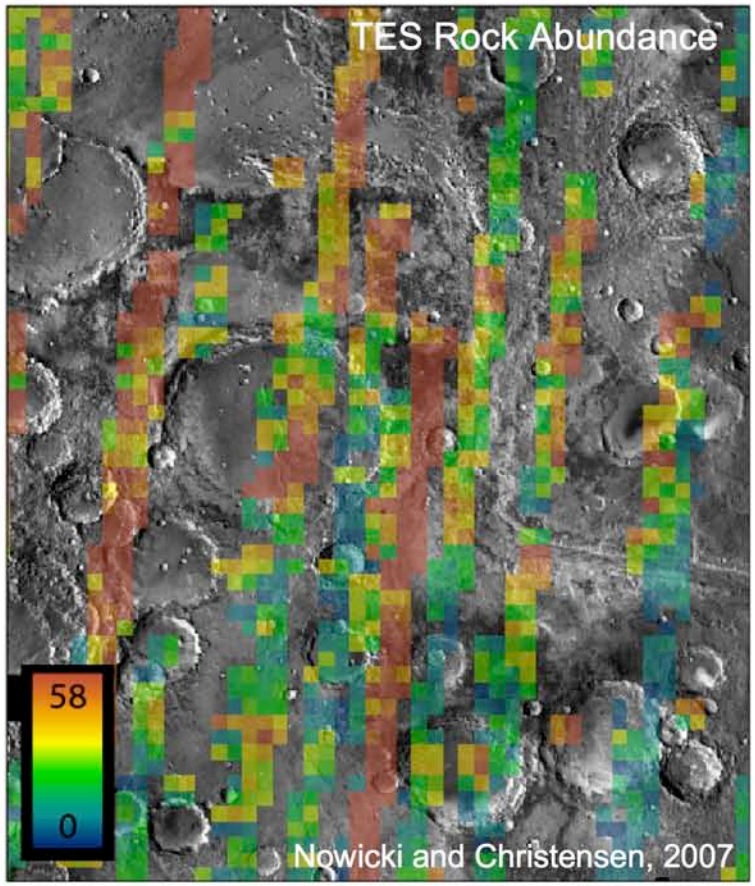


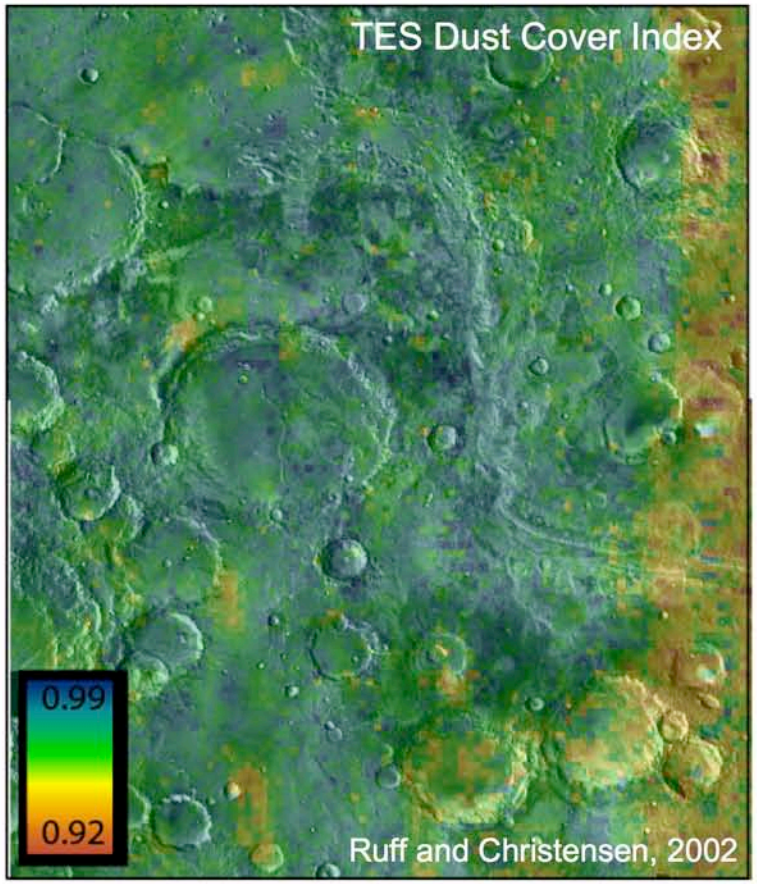


Thermal IR surface properties

⇒ Dust increases to the east

⇒ Rocks are a minor issue, but we <u>are</u> after bedrock here…





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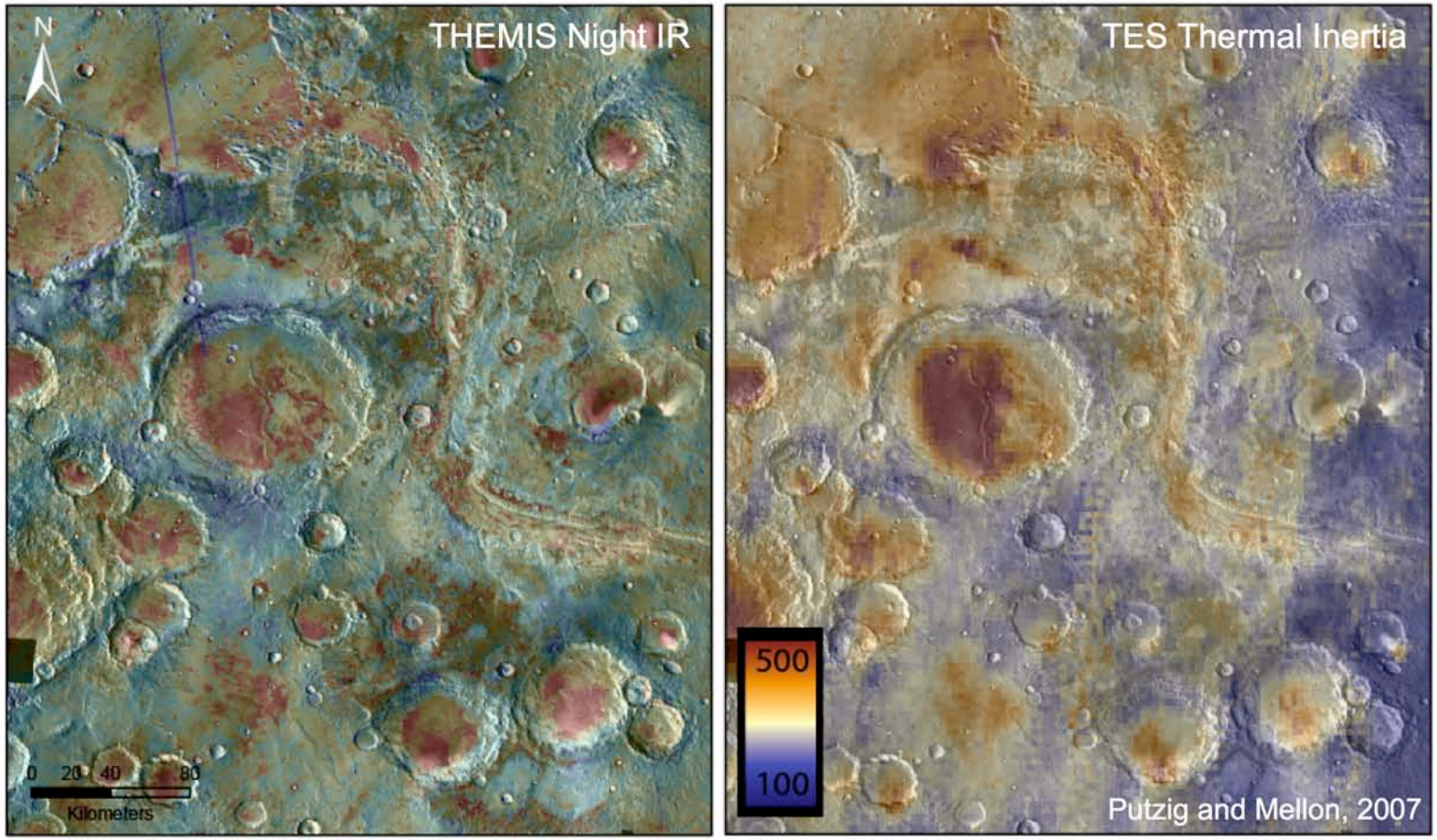
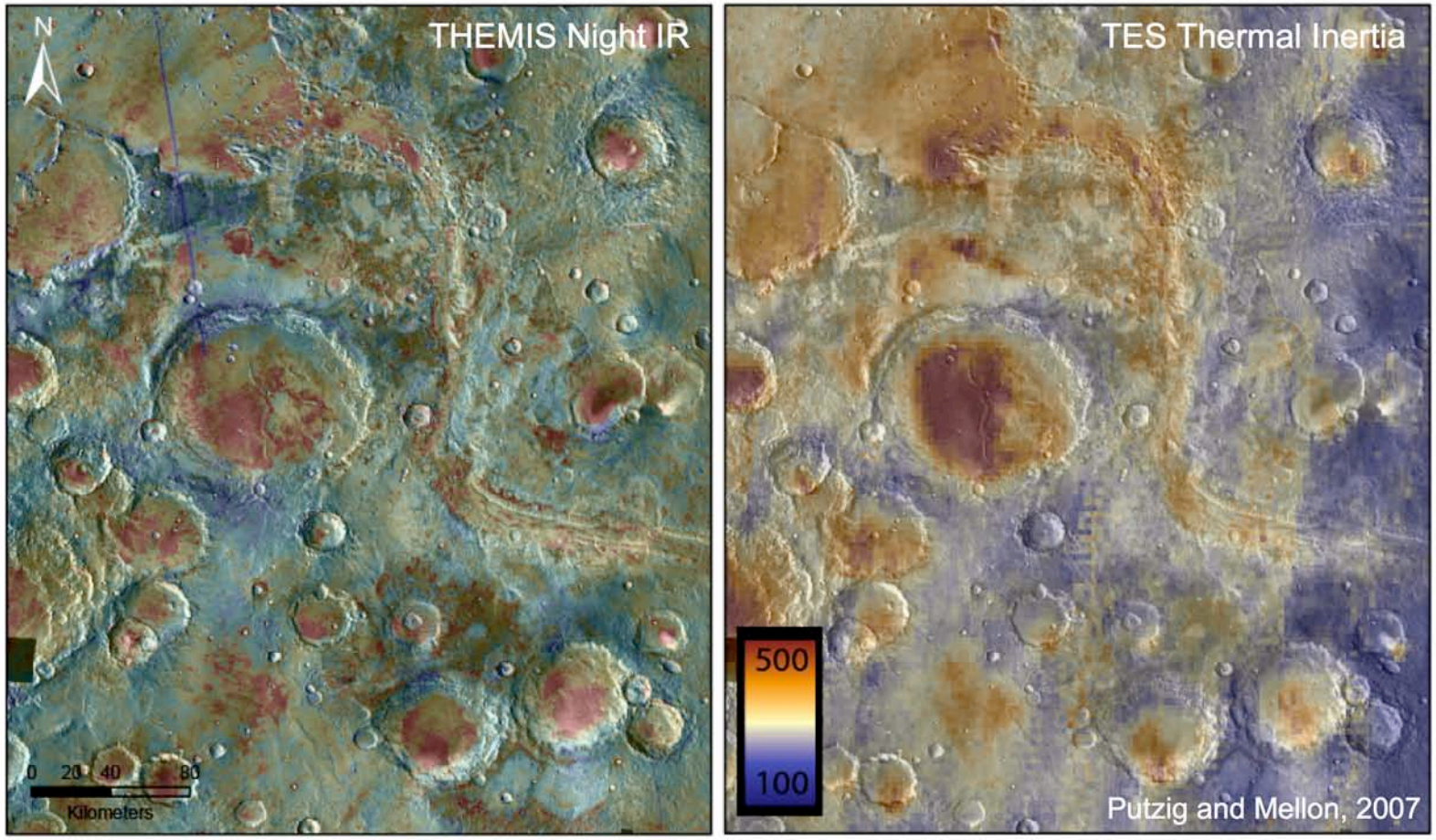


Thermal IR properties

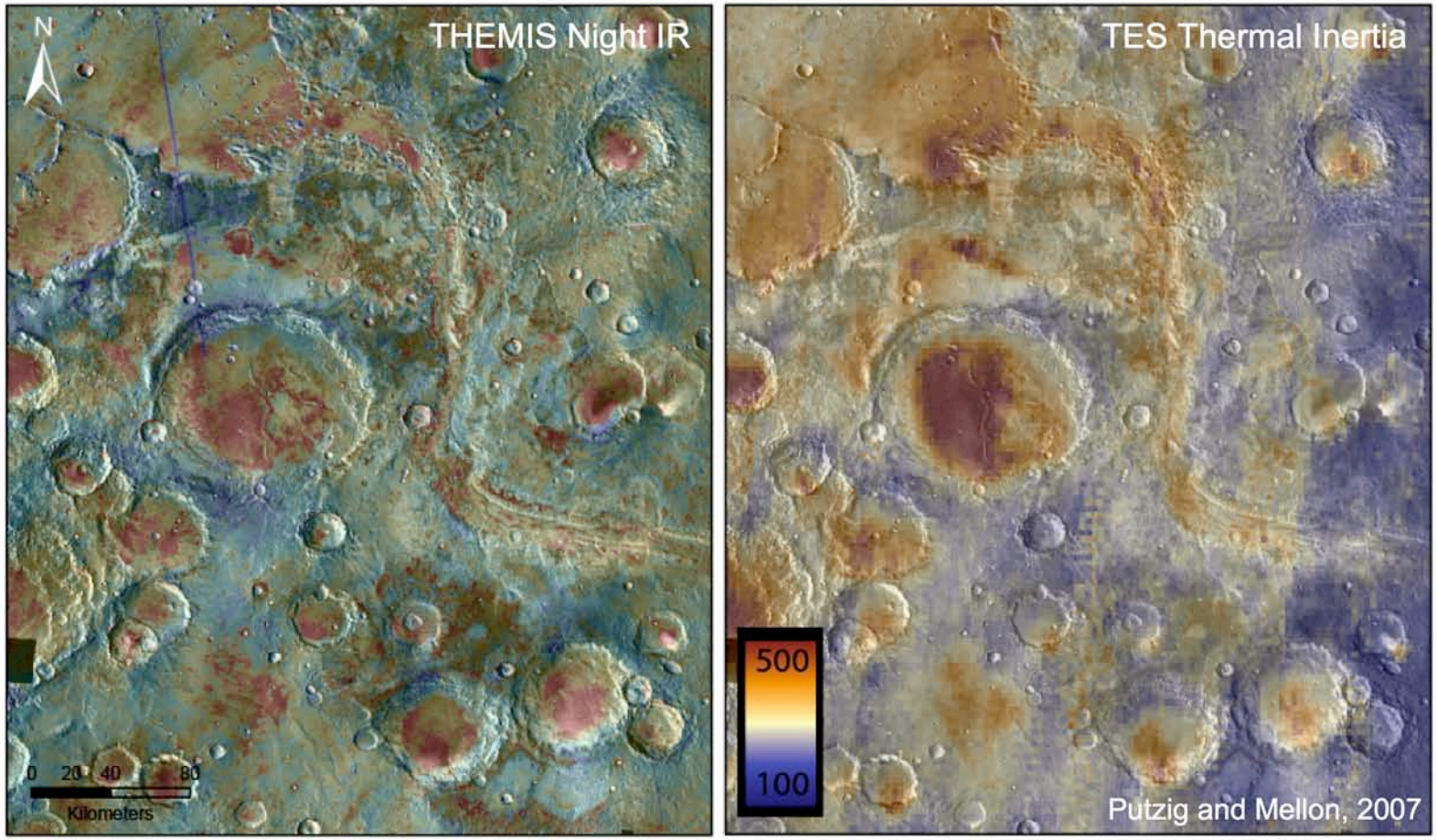
⇒ Clay-bearing rocks are relatively high inertia



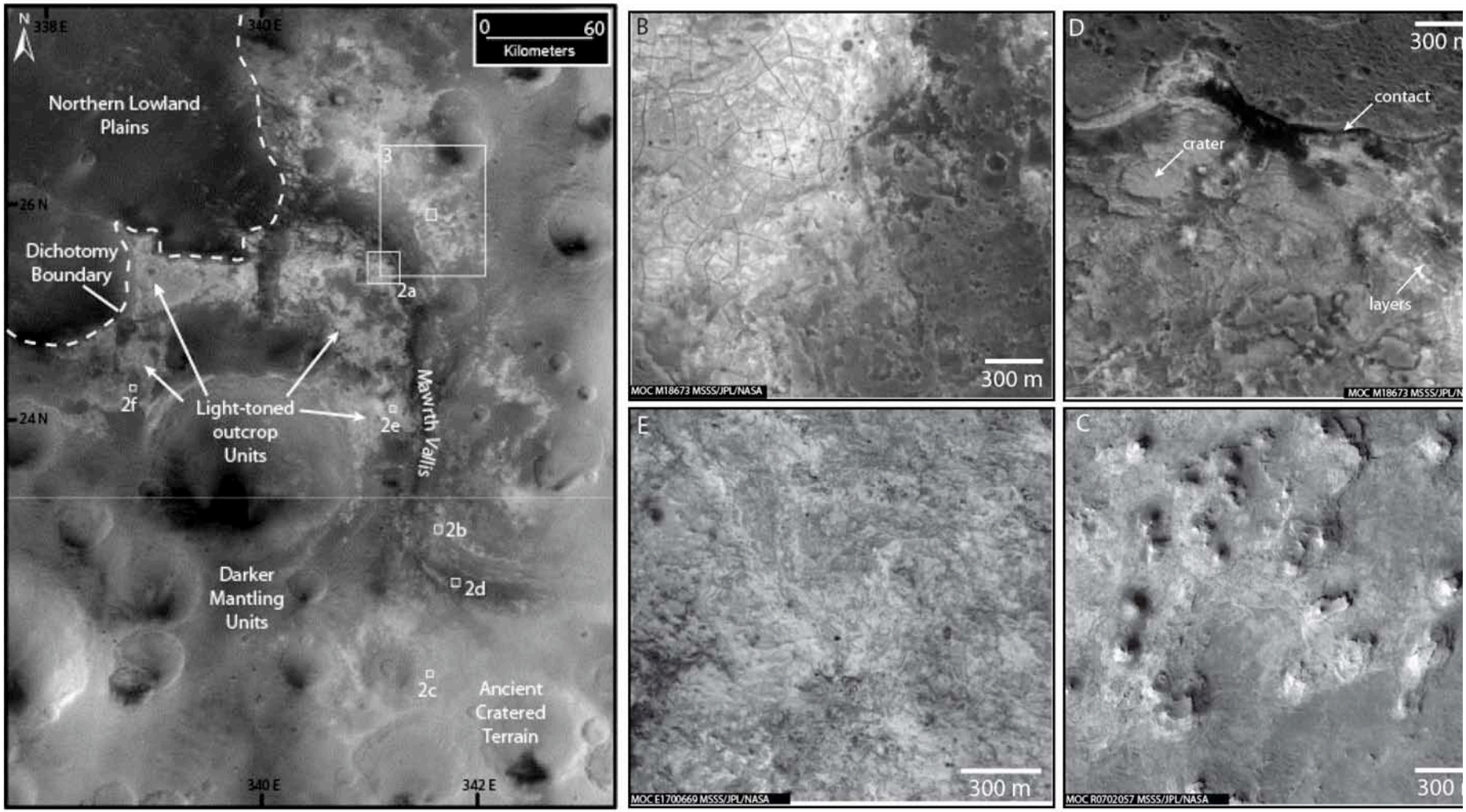
Thermal IR properties

⇒ Clay-bearing rocks are relatively high inertia

⇒ Dark materials have a range of inertia values from medium to high

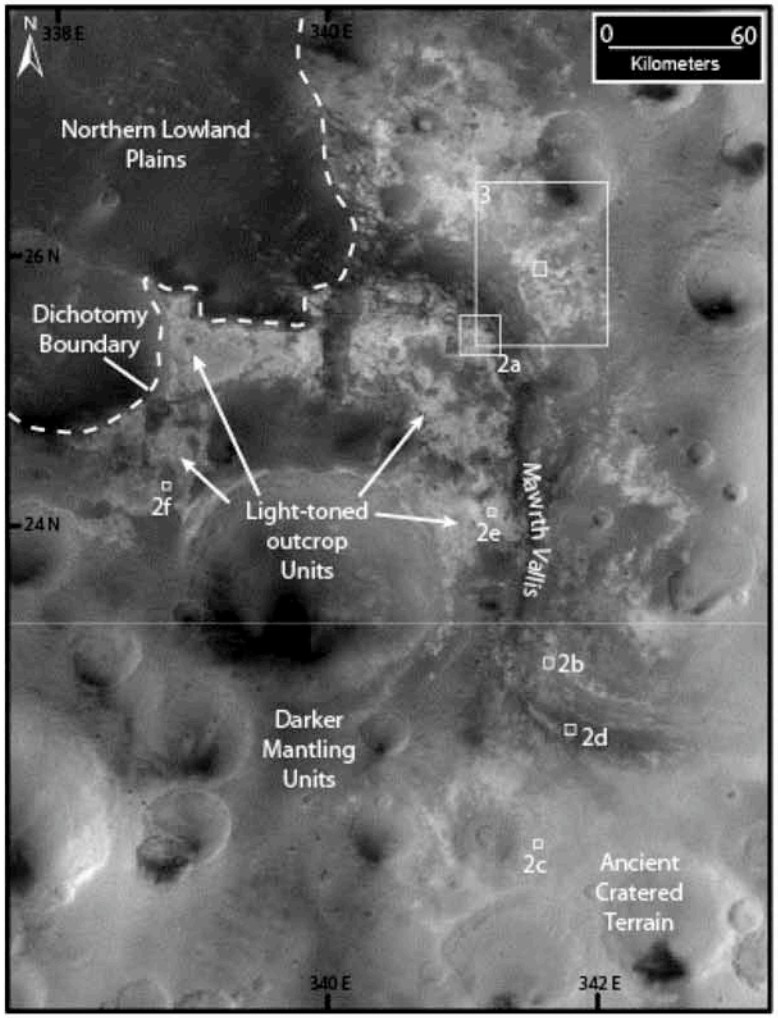


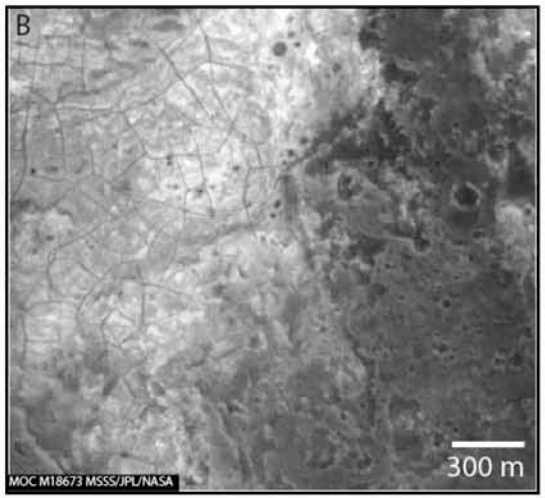
Geologic Units: Light-toned and dark-toned rocks

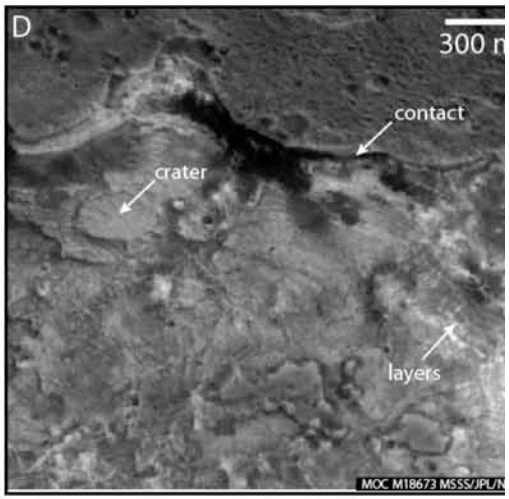


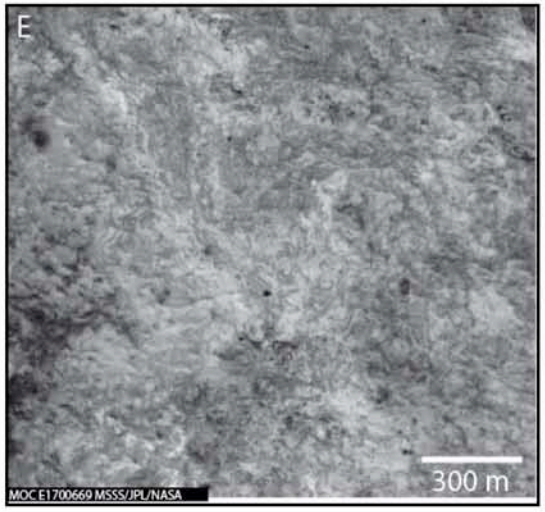
Geologic Units: Light-toned and dark-toned rocks

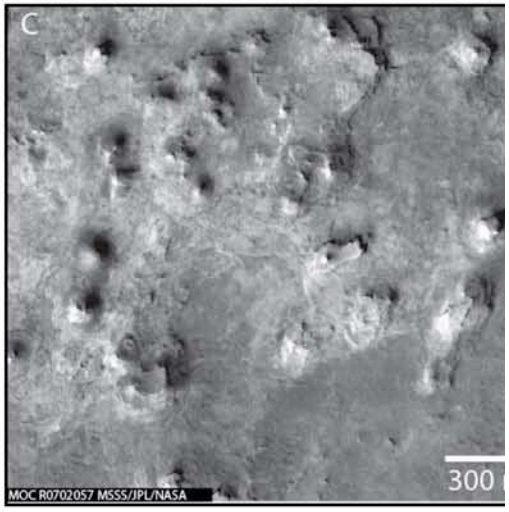
⇒ The clay-bearing, light-toned bedrock is layered, diverse, and complex







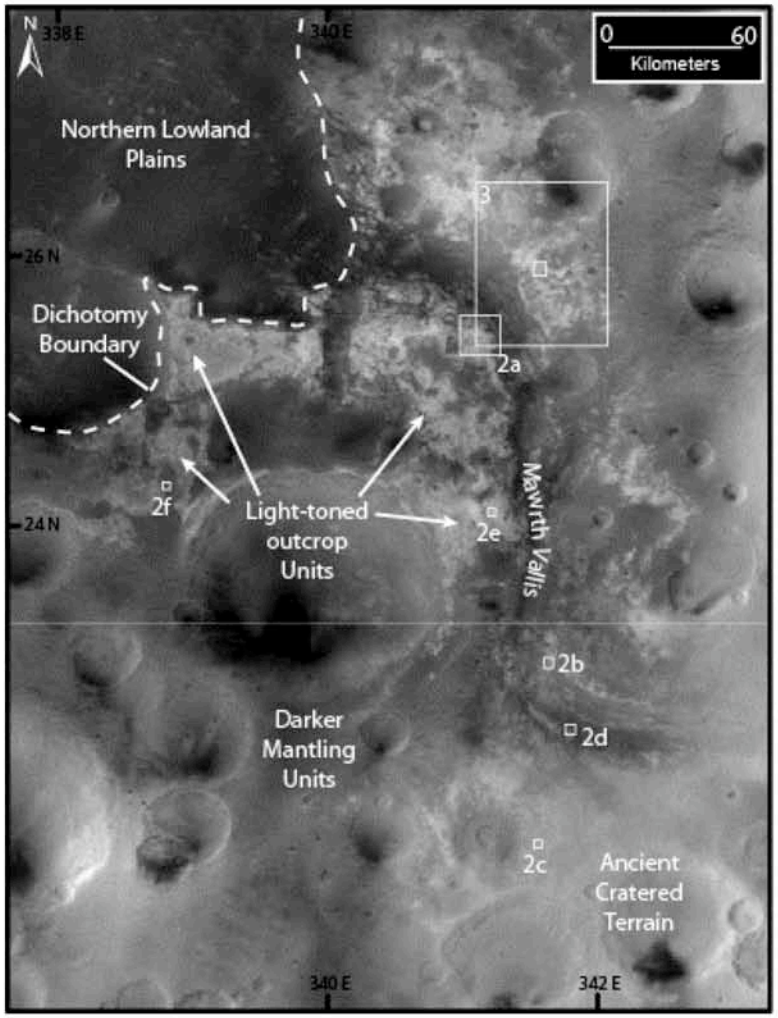


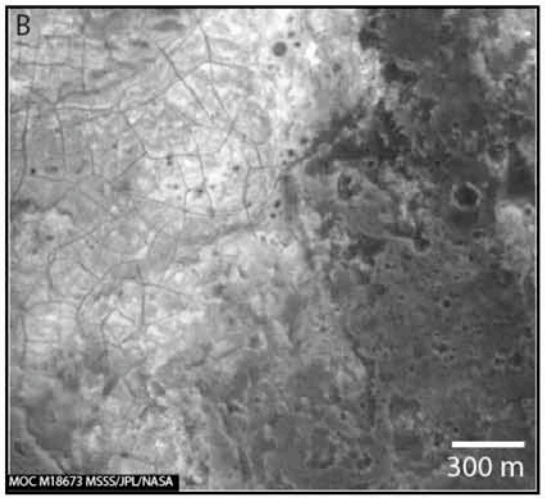


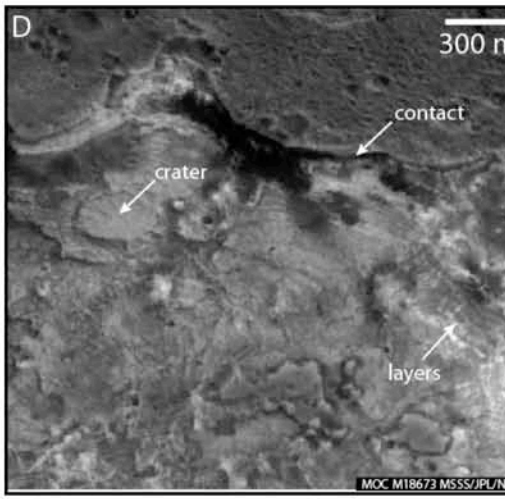
Geologic Units: Light-toned and dark-toned rocks

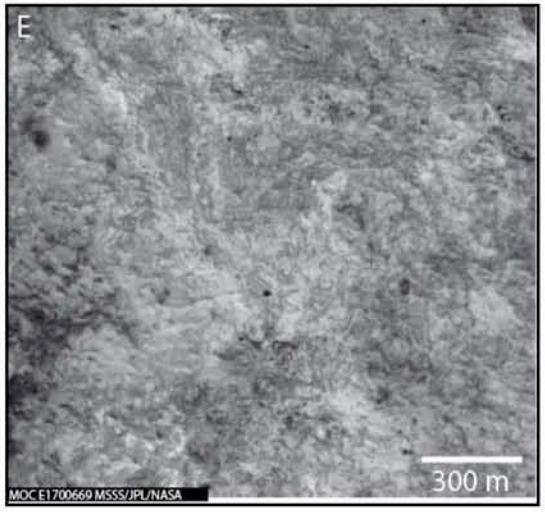
⇒ The clay-bearing, light-toned bedrock is layered, diverse, and complex

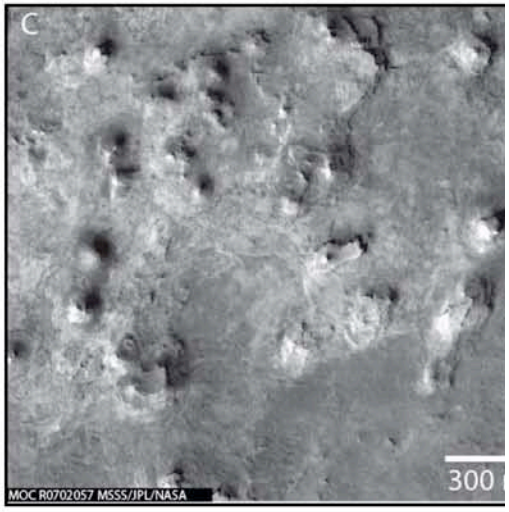
⇒ The rocks were deposited over a geologically significant duration of time



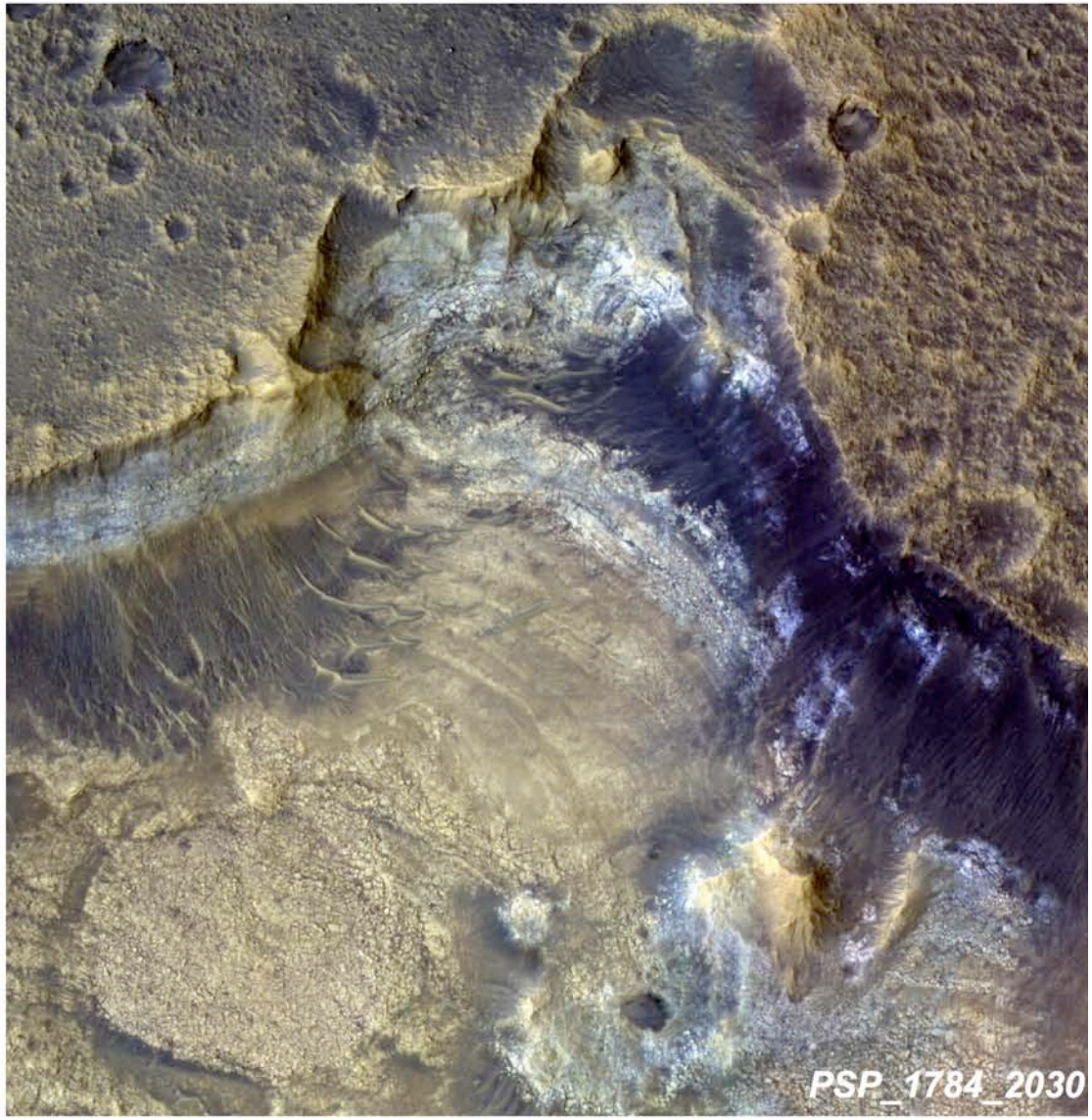








Hi-RISE view



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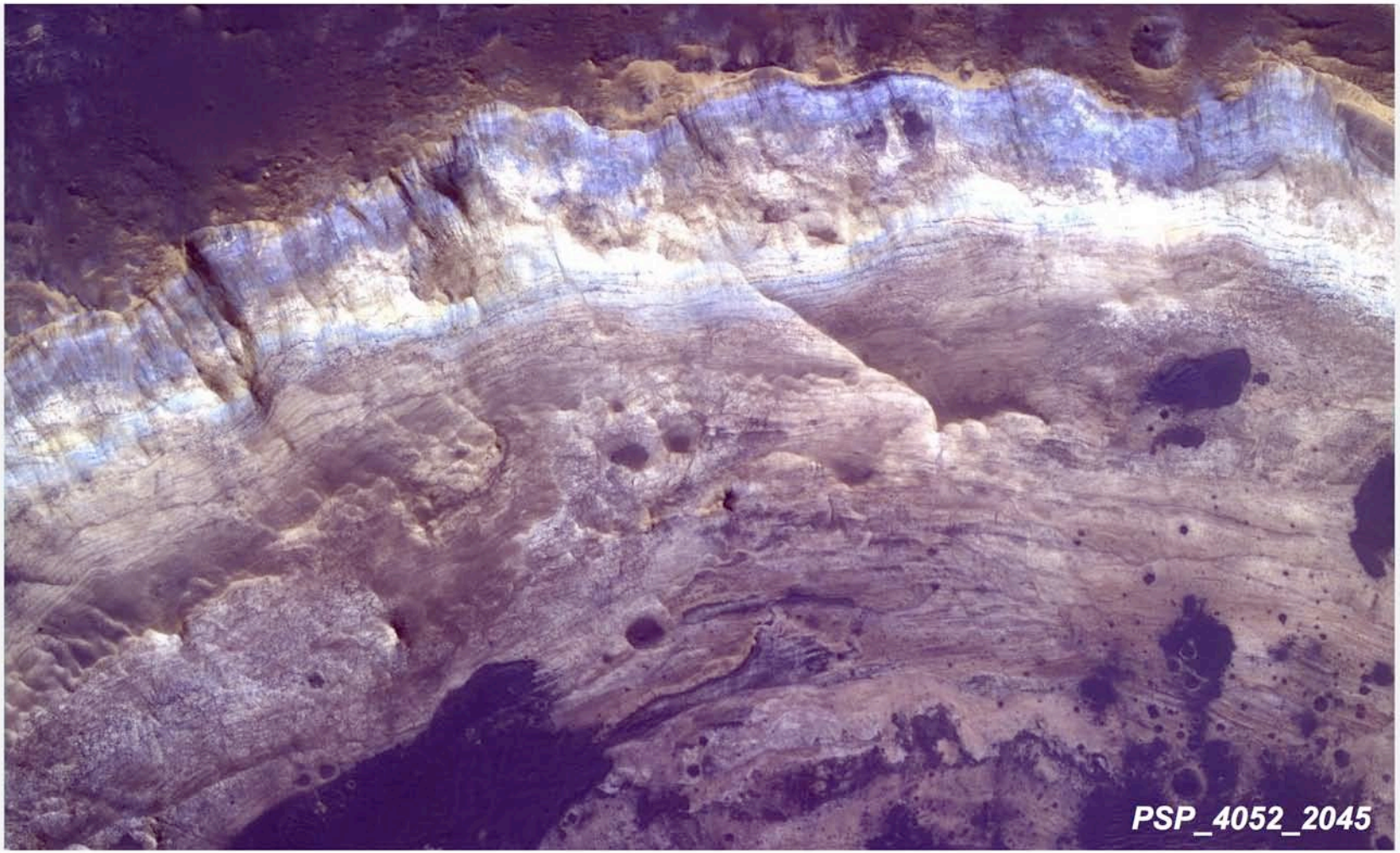
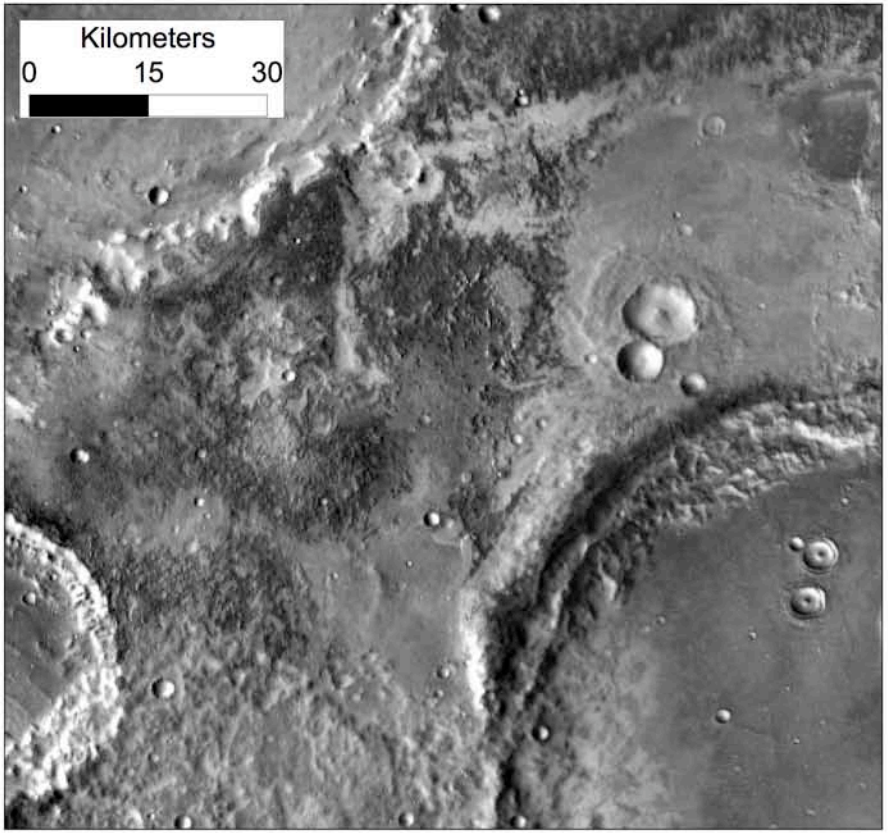


Mawrth Vallis clays: Physical properties

Daytime Temperature



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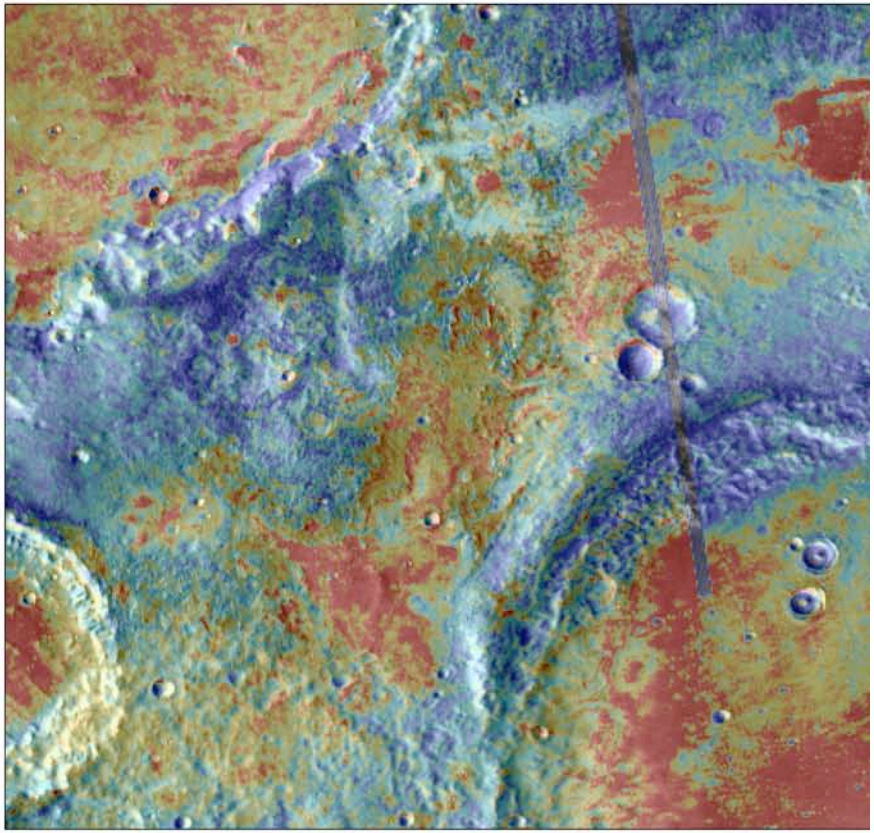
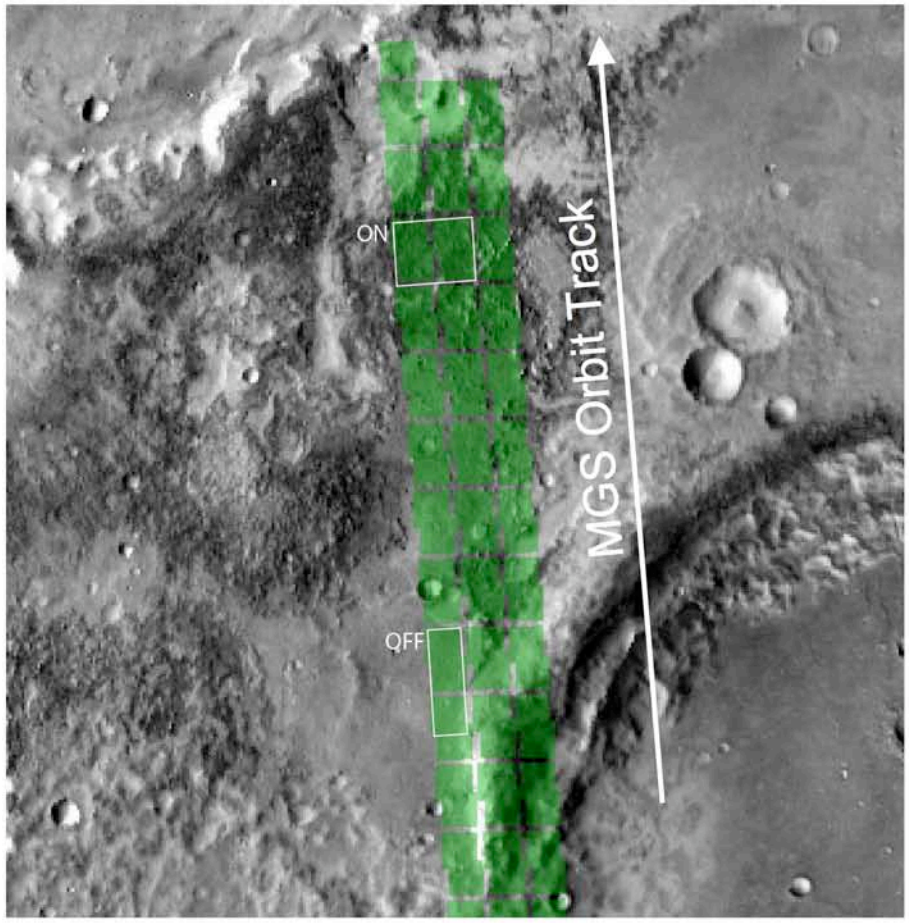
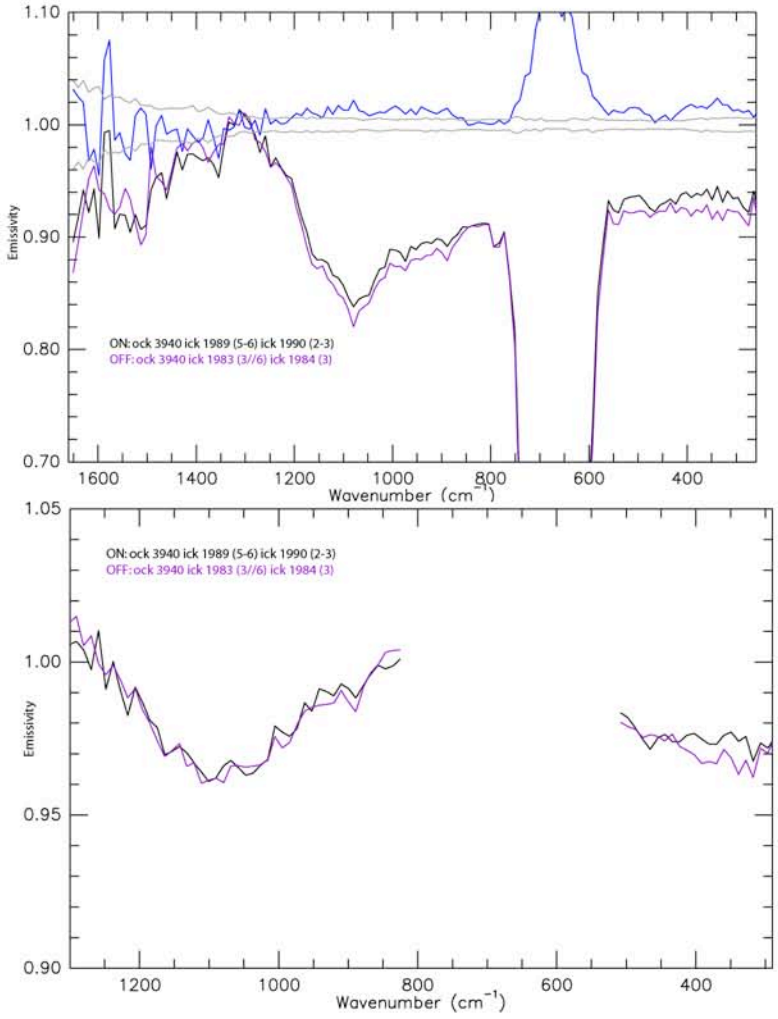


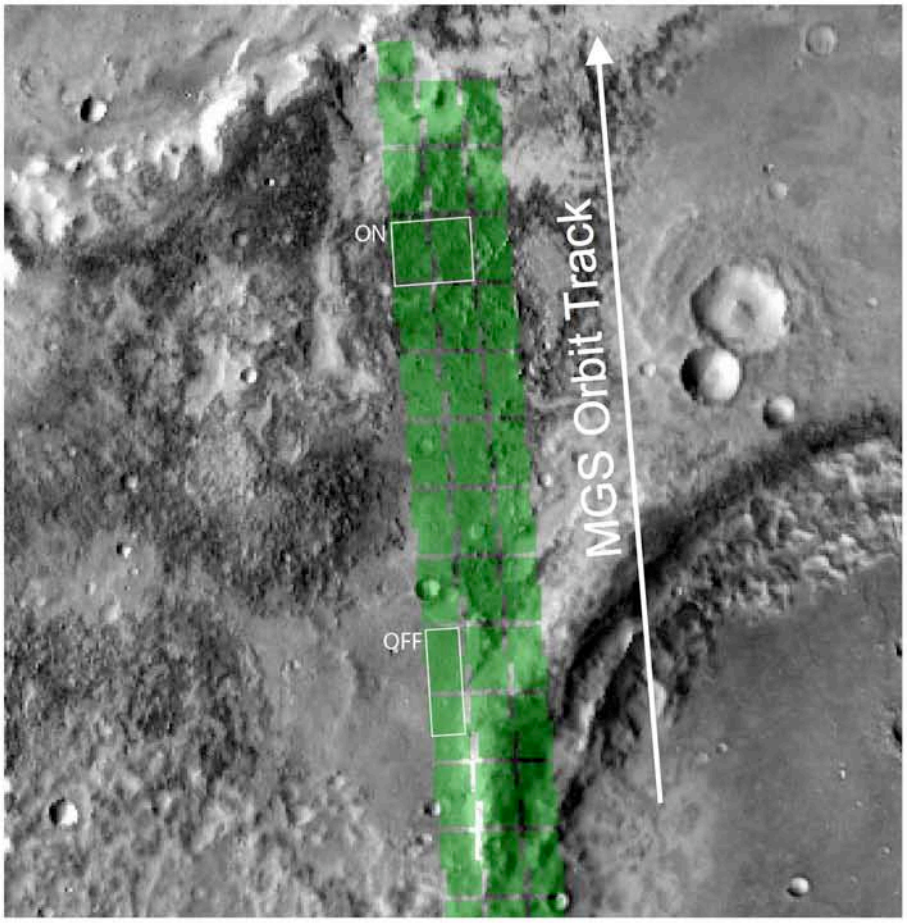
Mawrth Vallis clay minerals: Thermal IR emissivity

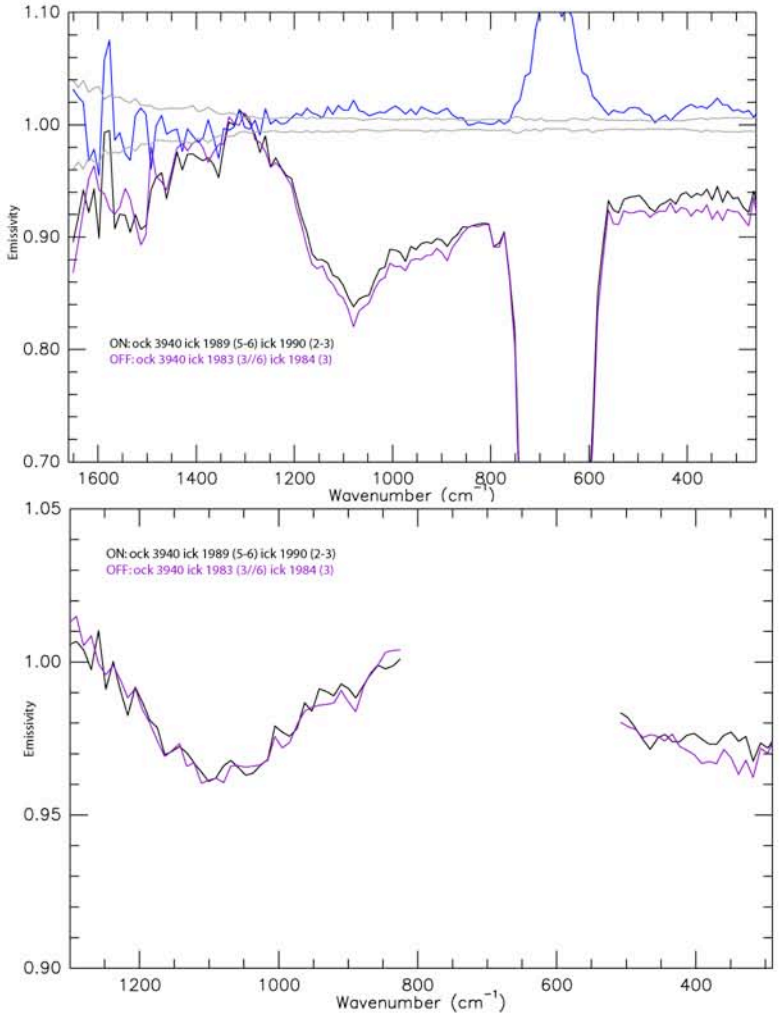




Mawrth Vallis clay minerals: Thermal IR emissivity

⇒ No obvious indication of clay minerals in these deposits, but this is not surprising if there are porous surface textures and partial eolian cover



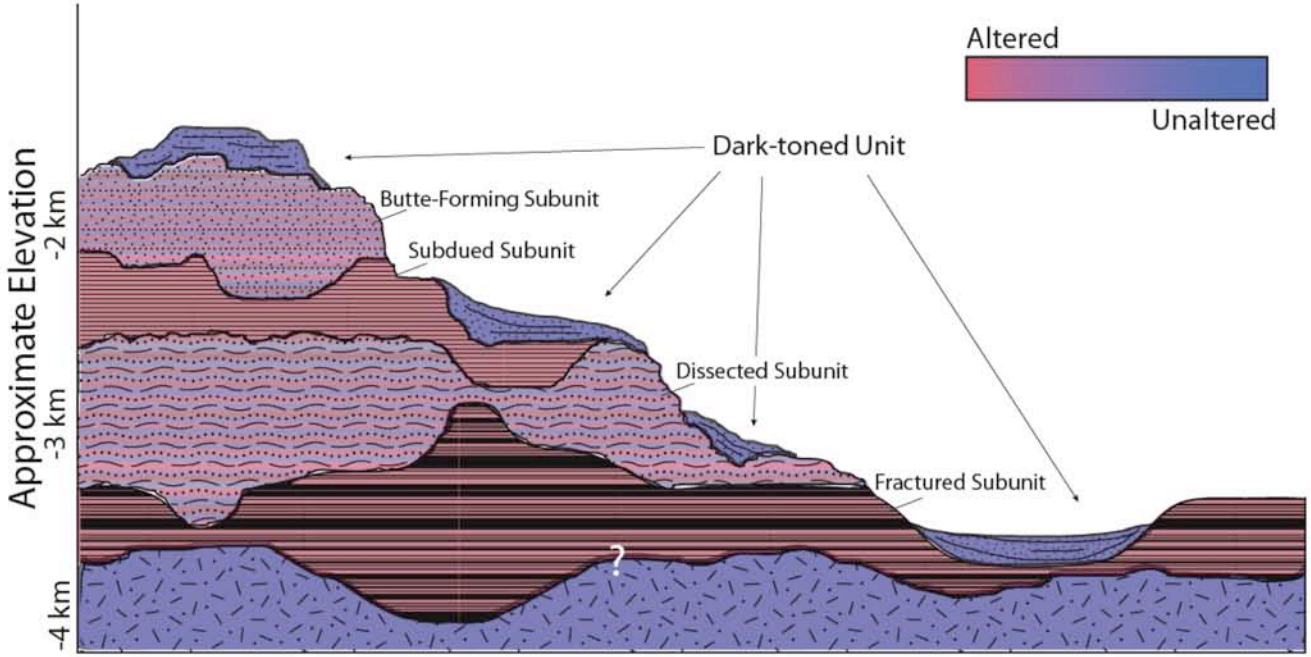


Stratigraphy

Dark toned unit unconformably overlies a light-toned unit

Light-toned unit contains several geomorphic subunits

Light-toned unit is largely altered, but contains clay mineral-bearing and clay mineral-poor layers.



Age of the light-toned rocks

⇒ The clay-bearing rocks are ancient.

- Counted all the craters in the area of D > 1km
  - Results suggest Mid-Early Noachian
    - Disputed by Howard and Moore, 2007
- Consistent with stratigraphic relations
- Older than most recent dichotomy modification event in this area

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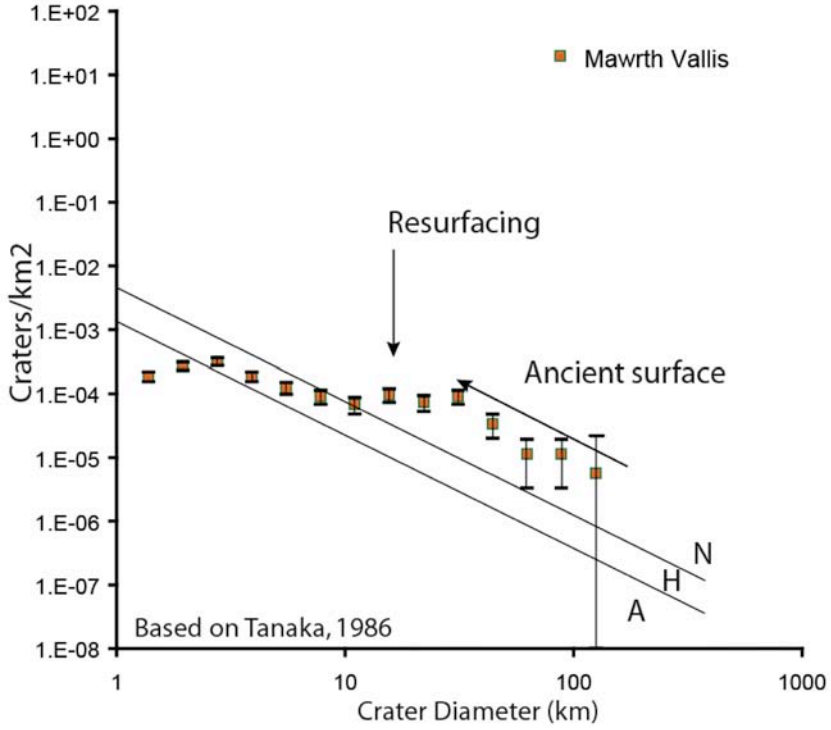


Early lithification and erosion

⇒ The clays may be diagenetic, but they are still old.

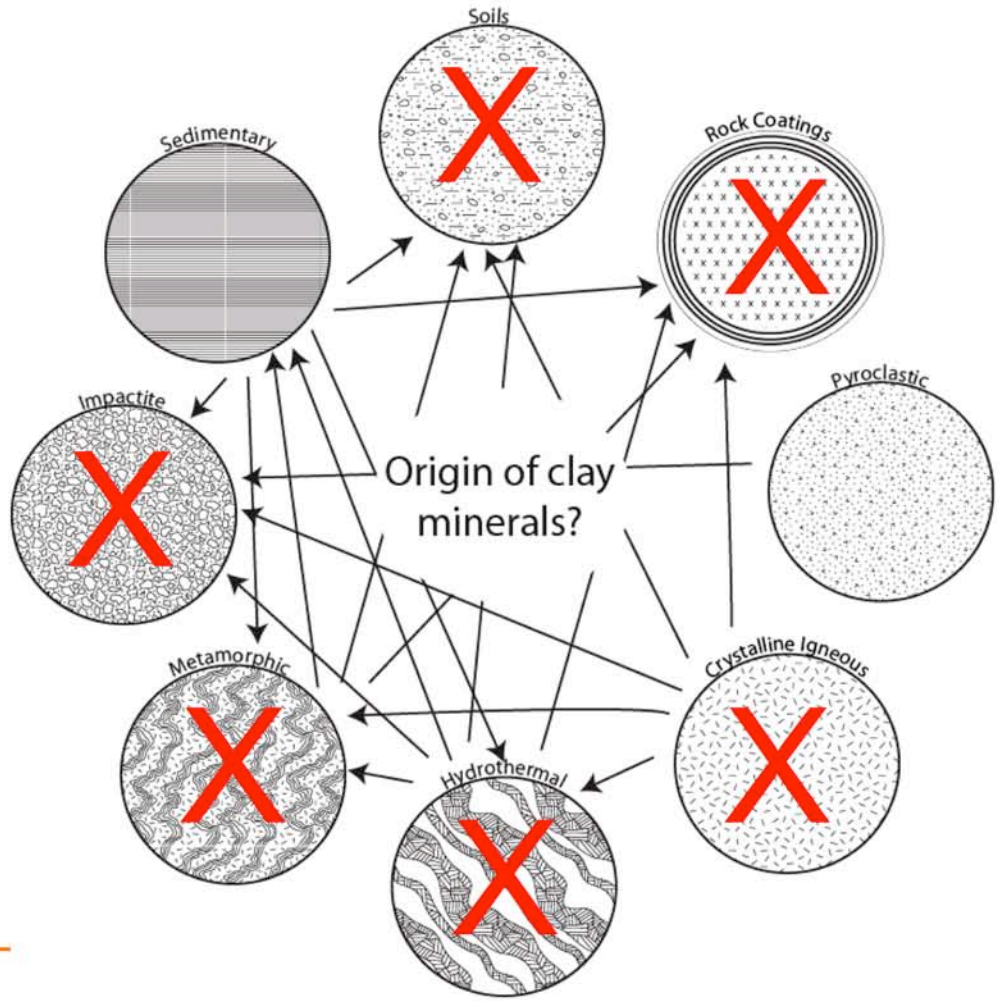
- Impact craters buried within the unit suggest it was deposited over a geologically significant period of time (i.e. not a single catastrophic event)
- Light-toned units were heavily eroded early (Possibly in the late Noachian denudation proposed by Hynek and Phillips, 2001)
- The light-toned rocks were lithified early and the clays formed early

Origin of clays in the Mawrth Vallis area

- Key point:

  Clays are demonstrably tied to a thick, flat-lying, widespread, layered, undeformed, ancient, geomorphically complex stratigraphic section of rocks that were *deposited over some duration of time*

  → *In other words, the clays seem to be sedimentary or diagenetic, indicating a much different environment on early Mars*



See papers by:

Loizeau et al., *JGR*, (2007)

Michalski et al, *Geology*, in press

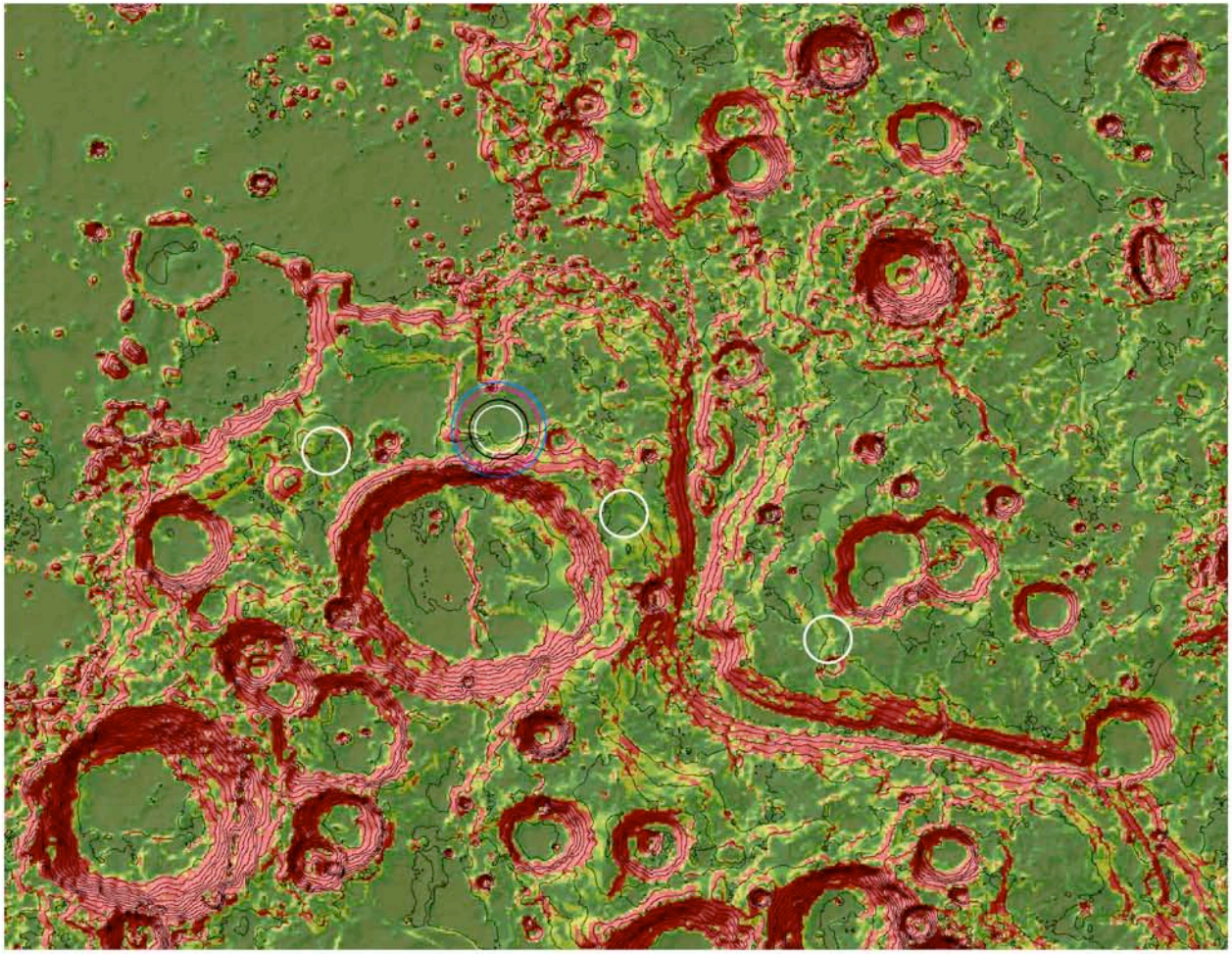
Scientific payoff

- Thick complex section gives up plenty to explore, but is intact and understandable
- Clays are as widespread, “abundant,” and diverse as anywhere on Mars
  - Chance to preserve biomarkers
  - Possible deposited in fluvial system, shallow marine environment, or shallow subsurface diagenesis
- Uncertain geologic origins, but testable:
  - XRD of clays will distinguish between 7 Å, 10.5 Å, 14 Å varieties, show zeolites if present, possibility for carbonates based on neutral pH, determine how much and what type of primary materials (glass, plag, etc)
  - Imaging will show bedding structures, grain shapes, overall rock texture
  - Bulk chemistry will show stratigraphic variation
  - SAM could show organics trapped in a variety of contexts
- Favorable atmospheric predictions, elevation, latitude, lack of dust

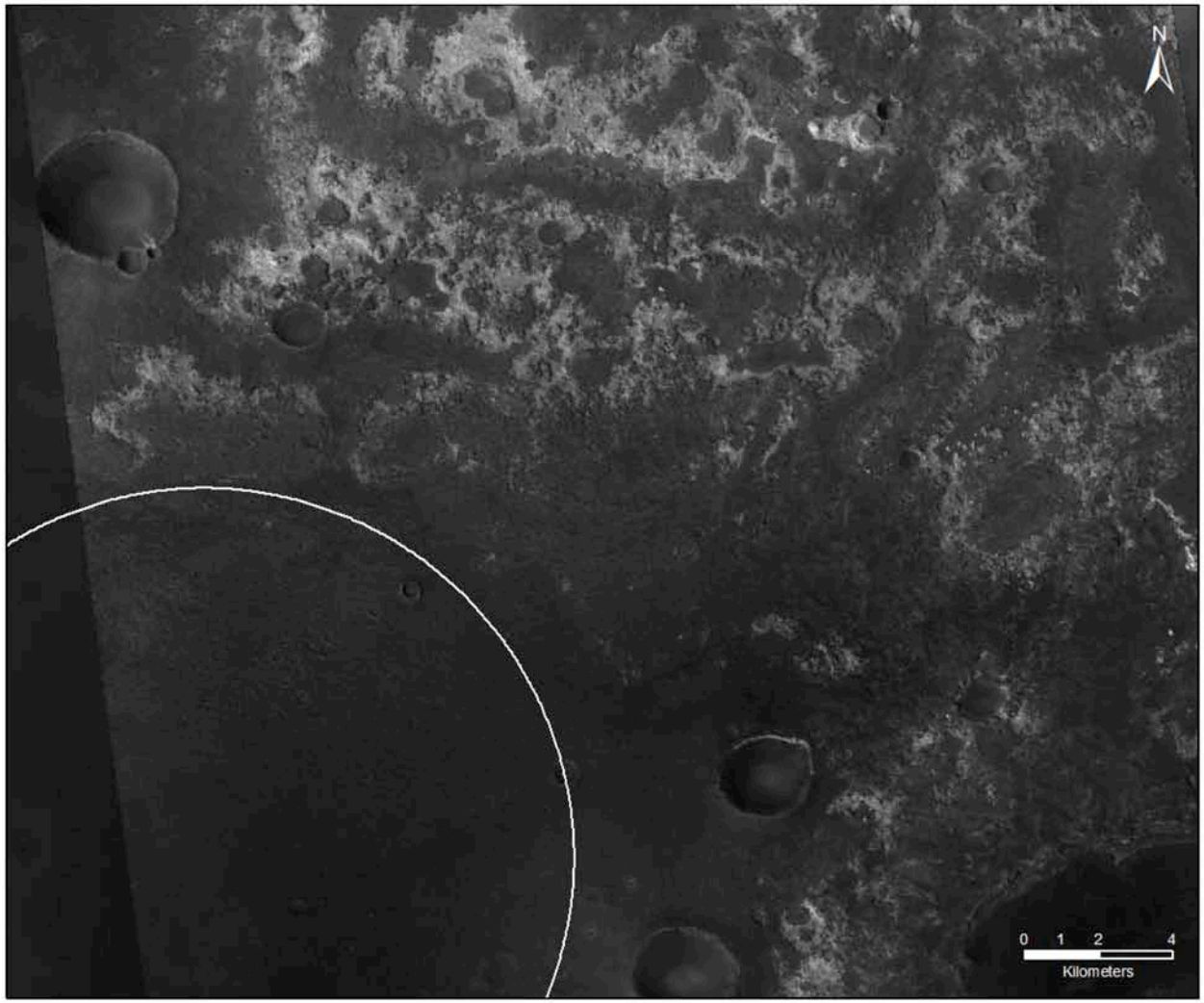
Of course we should go…
…now where to land?

Slopes at the 926 meter scale

Red = ☹



Surface roughness at CTX scales



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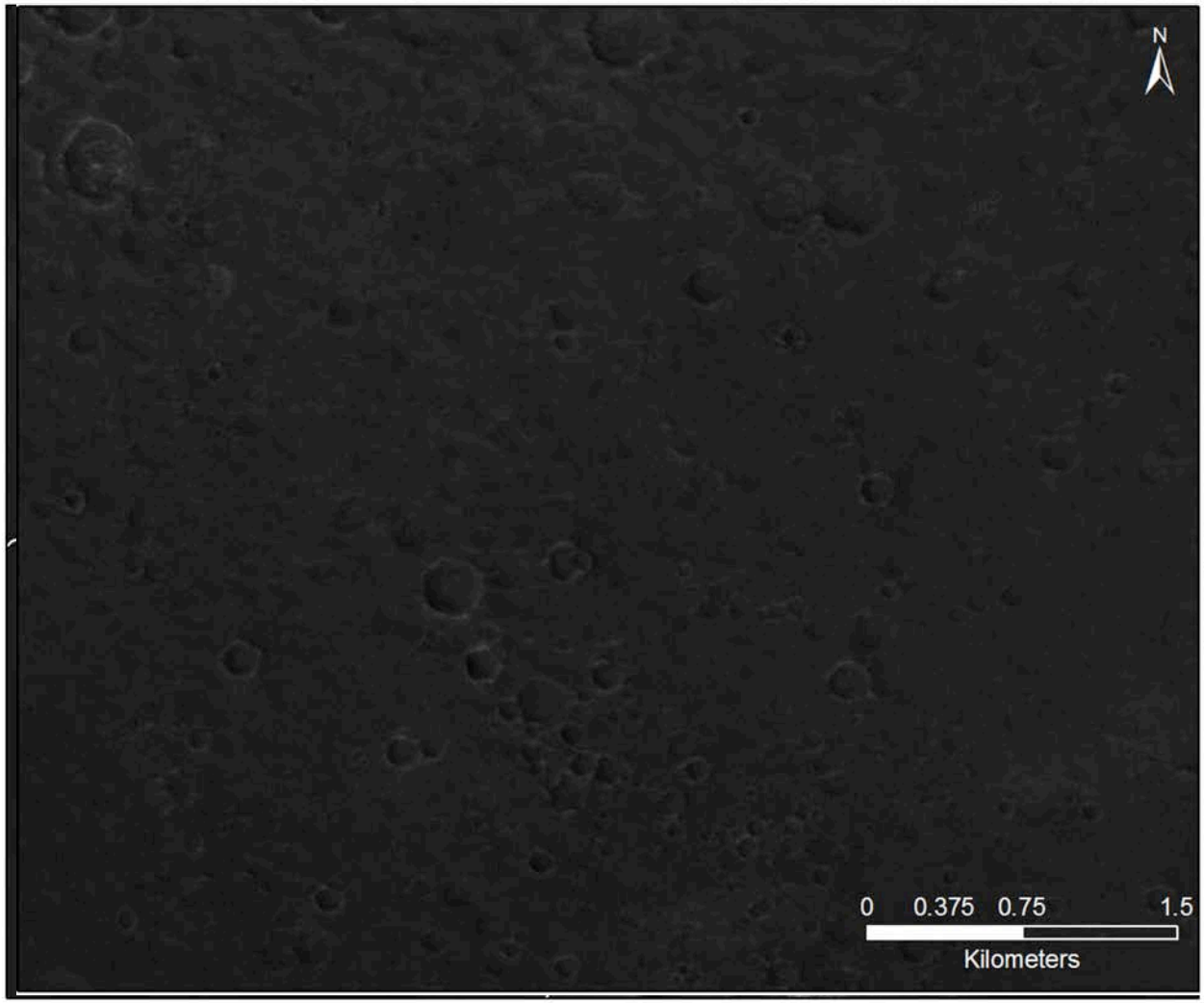

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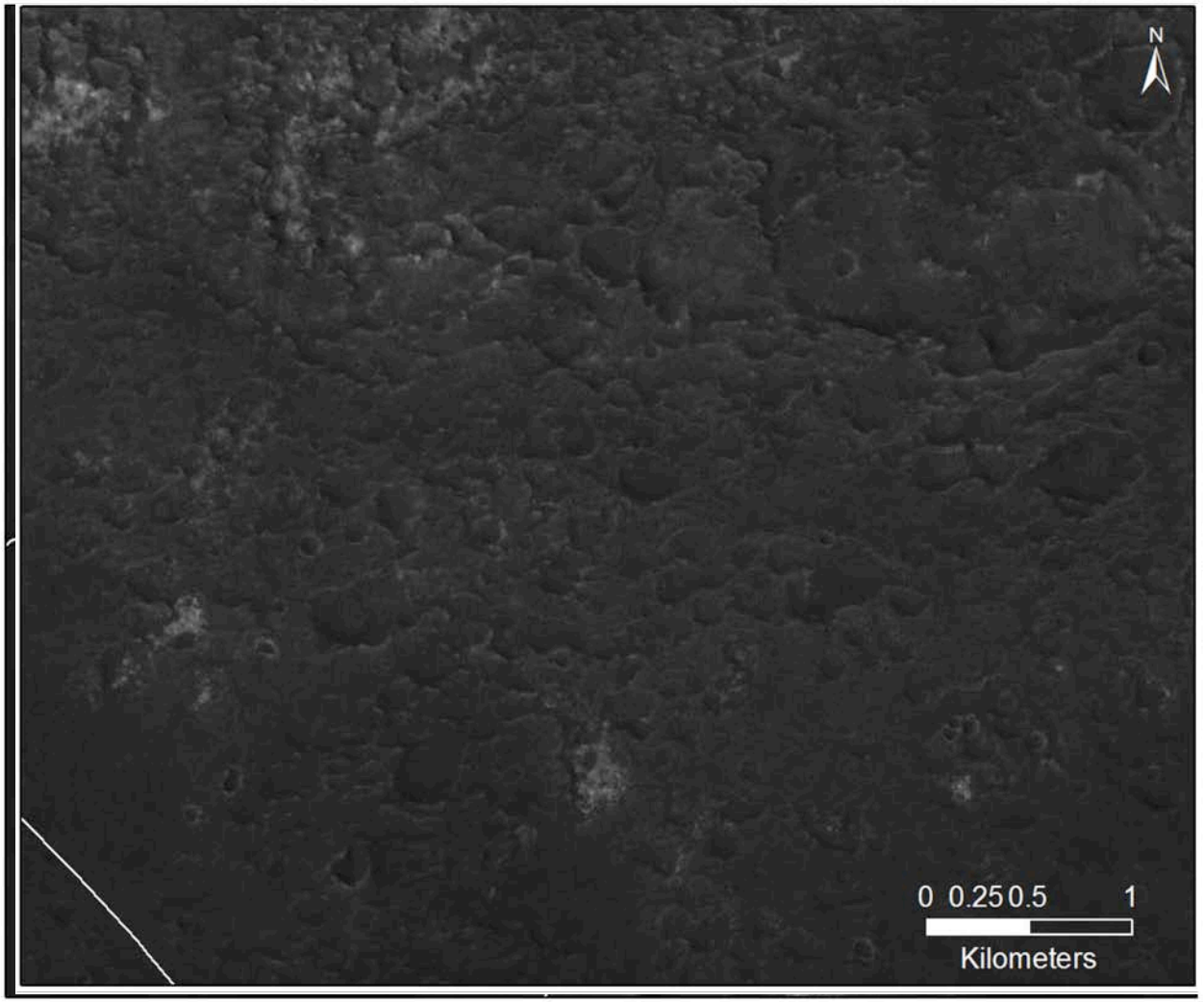

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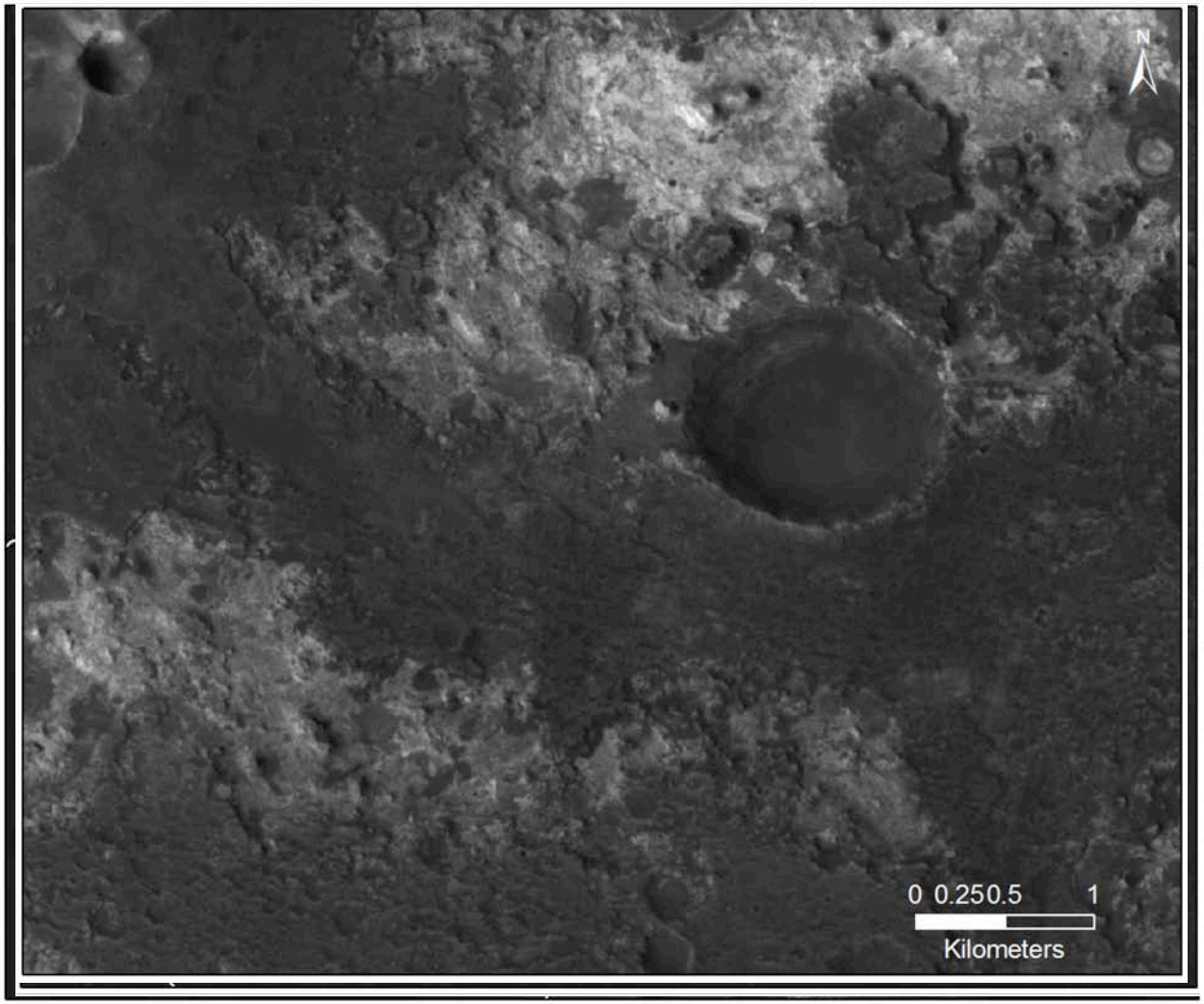
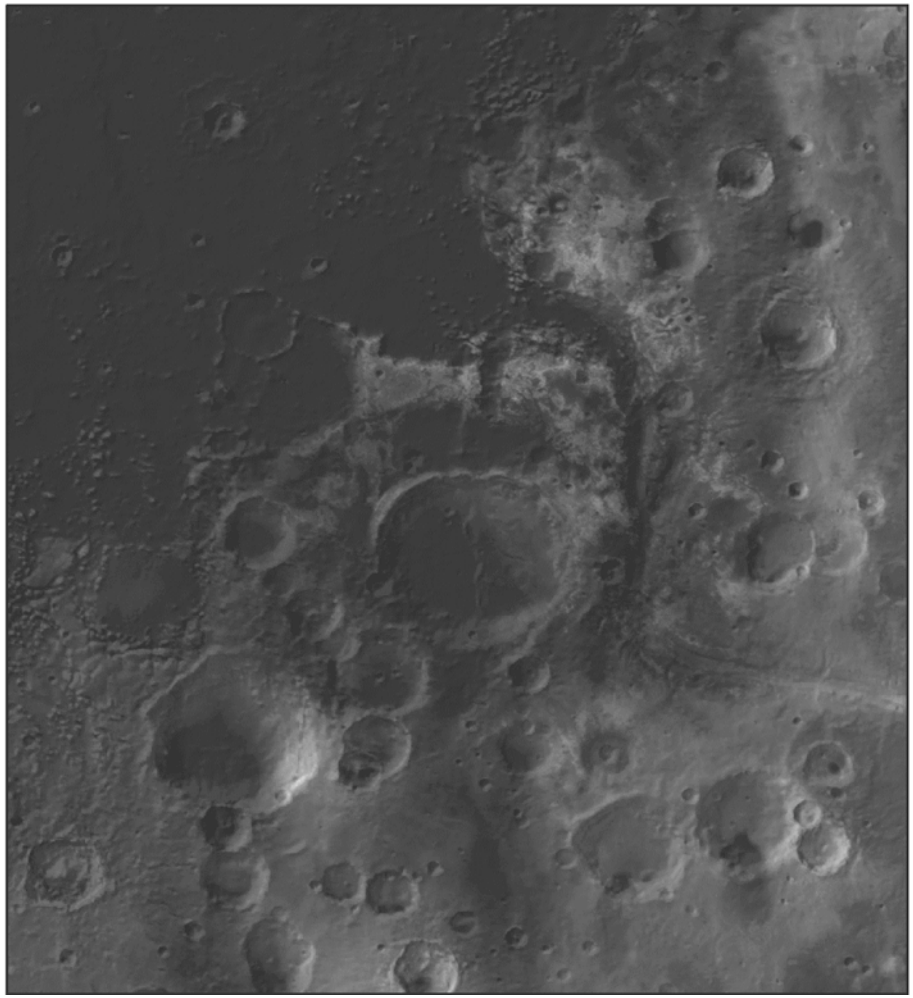


Surface roughness of the light-toned unit



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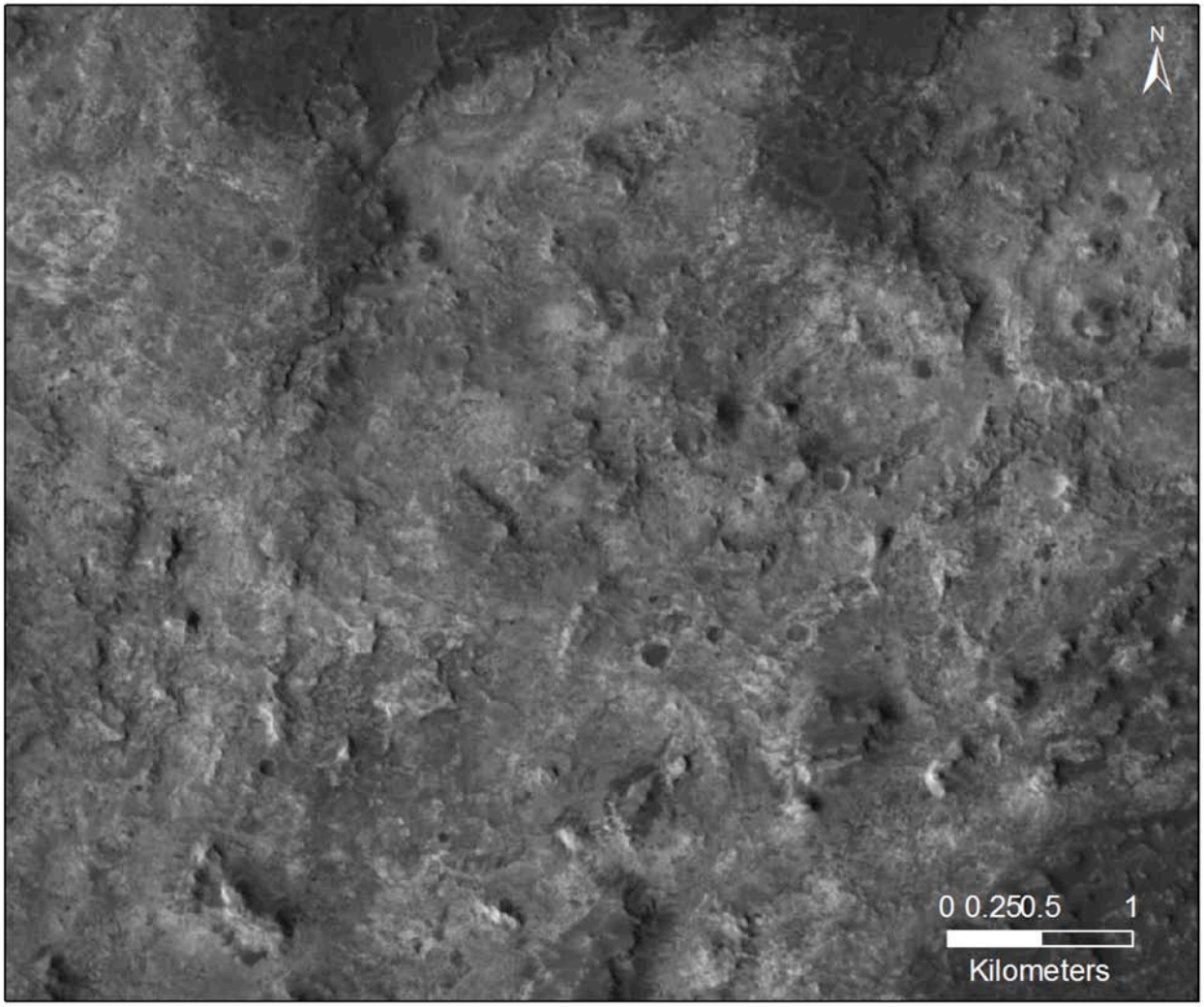
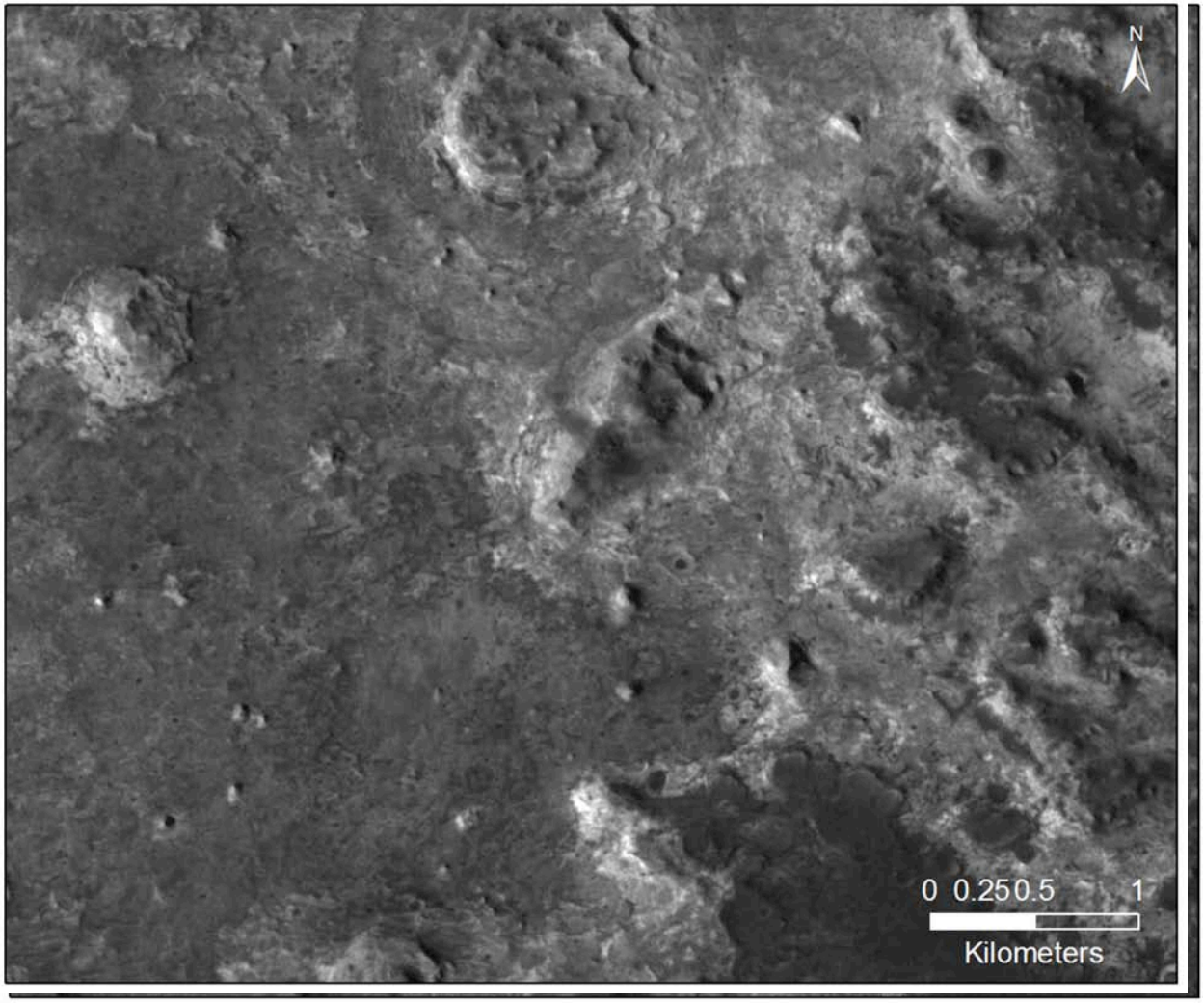
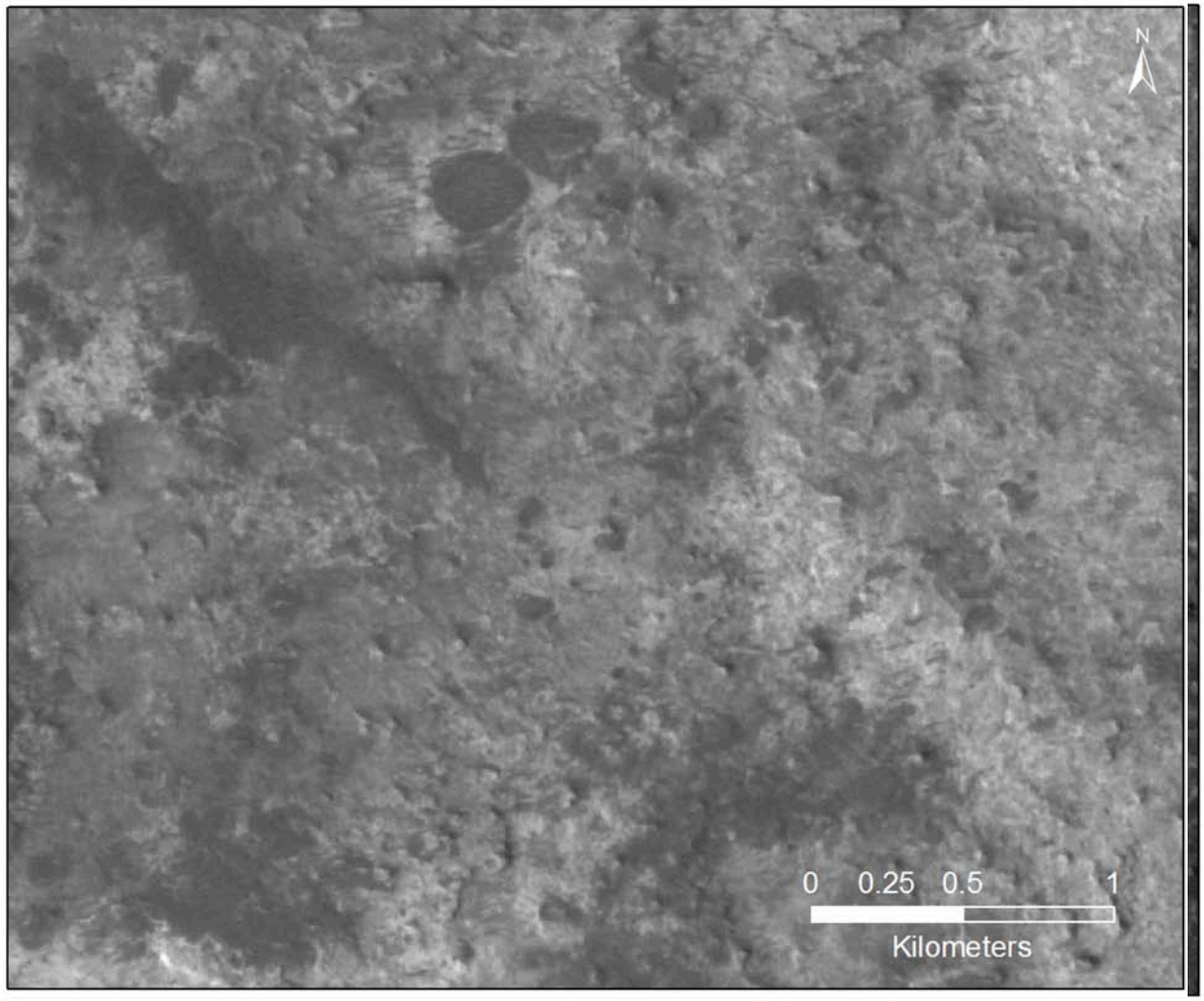


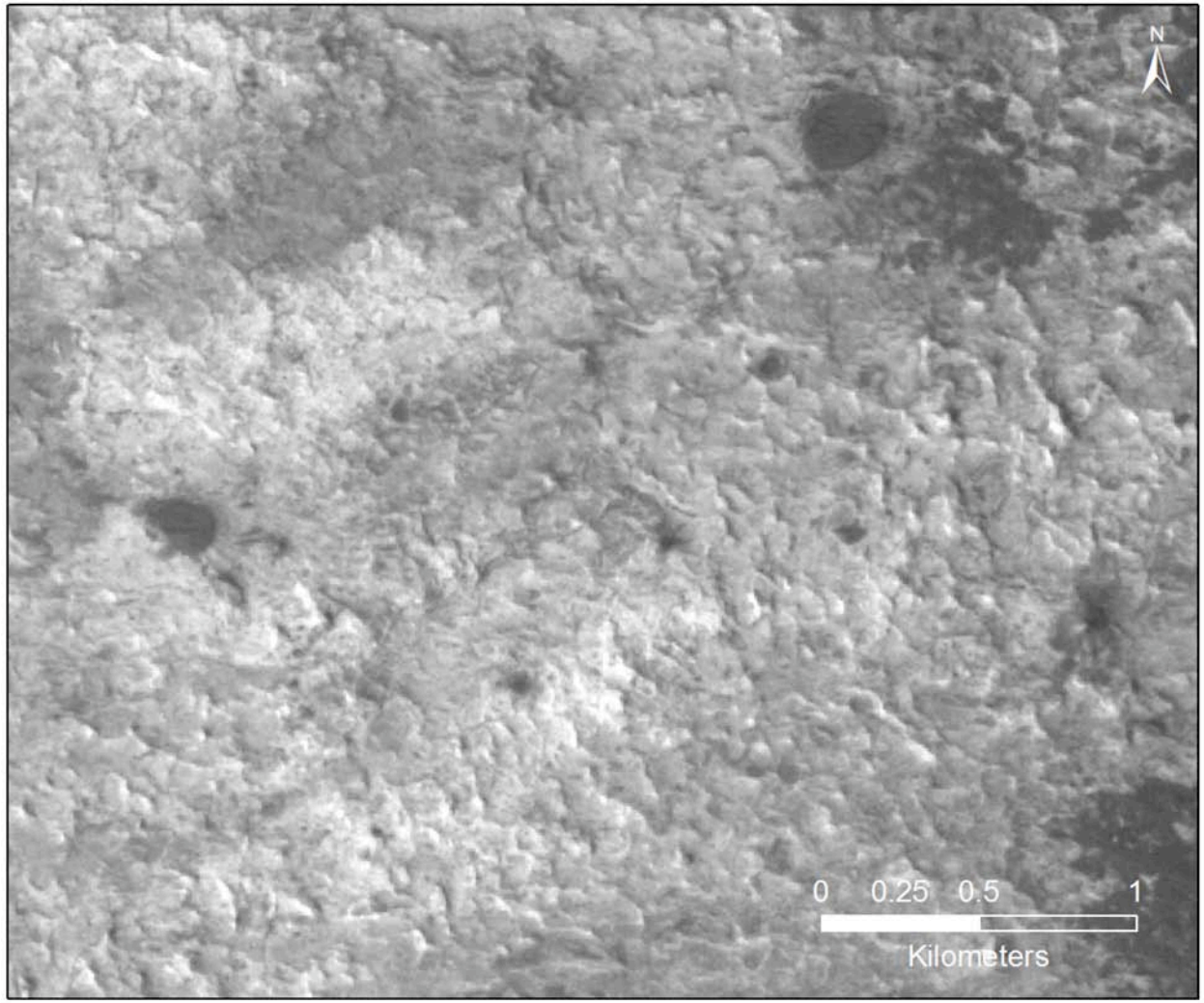
Surface roughness of the light-toned unit



Surface roughness of the light-toned unit



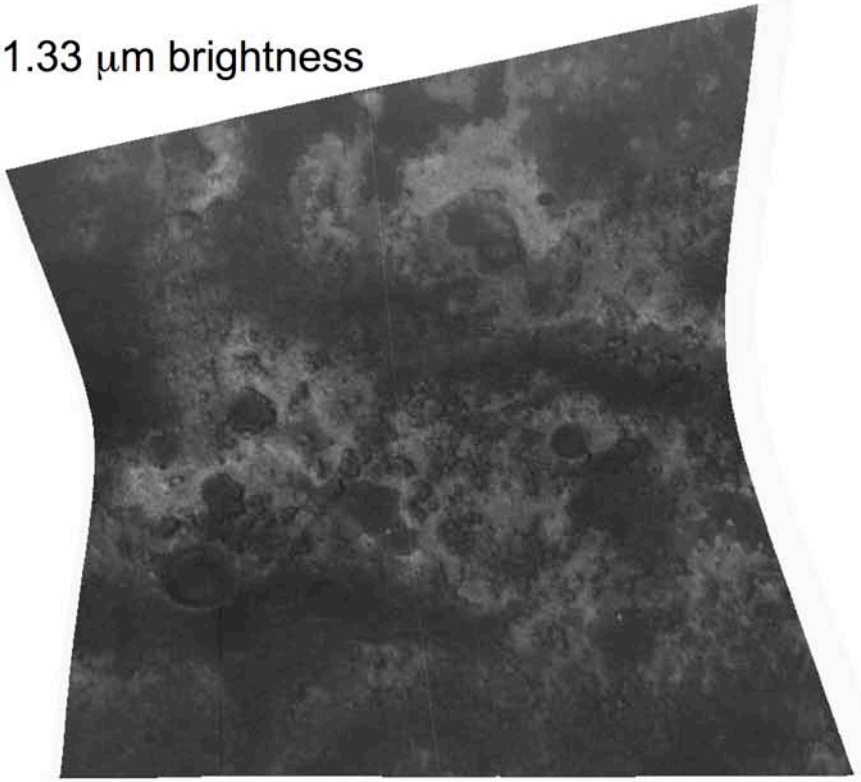
Surface roughness of the light-toned unit



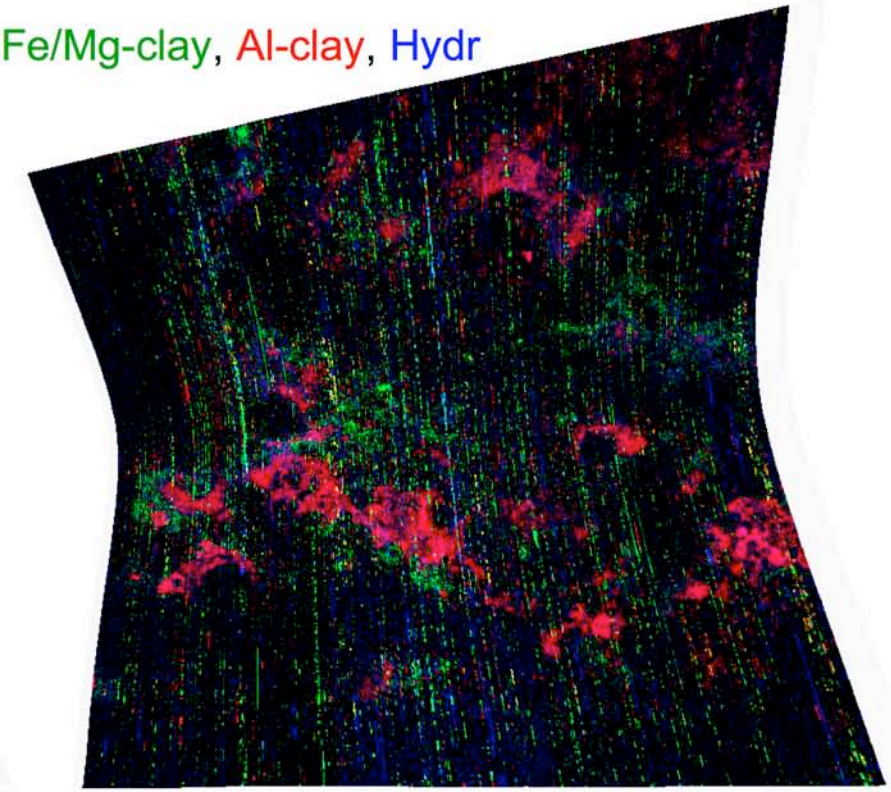
CRISM

- Interesting targets are just beyone the edge of the “dark material” ellipse

1.33 μm brightness



Fe/Mg-clay, Al-clay, Hydr



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Origin of MV clay minerals

- **Key point:**

  Clays are demonstrably tied to a thick, flat-lying, widespread, layered, undeformed, ancient, geomorphically complex stratigraphic section of rocks that were *deposited over some duration of time*

  - Not consistent with:

    Impact origin – expect instantaneous event, less complex section of rocks

    Recent subaerial weathering – expect diffuse pattern of surface composition

    Hydrothermal alteration associated with intrusion – expect localization, ties to structure/permeability conduits

    Amygdules or low T hydrothermal overprint on lavas – not consistent with volcanic structures, lavas

    Regional metamorphism – requires deep burial and re-exposure, expect to see deformation, metamorphic fabrics, different geologic context

    Deep marine environment – difficult to reconcile with repeated subeareal exposure, dynamic section

  - Favored interpretation:

    Sedimentary origin at/near the surface – clays deposited as clasts or cements within clastic (or volcanoclastic) rocks associated with a sustained, but dynamic surface environment (fluvial plain/lacustrine/marine)

    Diagenetic processes, including brine metasomatism, should not be ruled out, but in even if the clays are diagenetic, they are still old.

Contact: Joseph.R.Michalski@jpl.nasa.

Significance

Some of the oldest sedimentary rocks in the Solar System

Neutral pH environment implied by smectitic clay expands our realm of Mars experienc

Obvious target for future *in situ* analyses

Diversity of clay-bearing rocks