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

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Surface Mineralogy

⇒ The reason to go with MSL

- Clay minerals detected from near-infrared absorptions
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- Clay minerals detected from near-infrared absorptions

![Graph showing spectral data with wavelengths and absorptions labeled as H-O-H, Al-OH, Fe-OH.](image)
Surface Mineralogy

⇒ The reason to go with MSL

- Clay minerals detected from near-infrared absorptions
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

TES Rock Abundance

TES Dust Cover Index

Nowicki and Christensen, 2007

Ruff and Christensen, 2002
Thermal IR surface properties

⇒ Dust increases to the east
Thermal IR surface properties

⇒ Dust increases to the east

⇒ Rocks are a minor issue, but we are after bedrock here...
Thermal IR properties
Thermal IR properties

⇒ Clay-bearing rocks are relatively high inertia

Putzig and Mellon, 2007
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
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⇒ 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
Hi-RISE view
Hi-RISE view
Mawrth Vallis clays: Physical properties

Daytime Temperature

Nighttime Temperature
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 $D > 1$km
  - 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
Surface roughness at CTX scales
Surface roughness at CTX scales
Surface roughness at CTX scales
Surface roughness of the light-toned unit
Surface roughness of the light-toned unit
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 beyond the edge of the "dark material" ellipse

1.33 μm brightness

Fe/Mg-clay, Al-clay, Hydr

CRISM .QUB FRT00004ECA
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.
Significance

Some of the oldest sedimentary rocks in the Solar System

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

Obvious target for future *in situ* analyses
Diversity of clay-bearing rocks