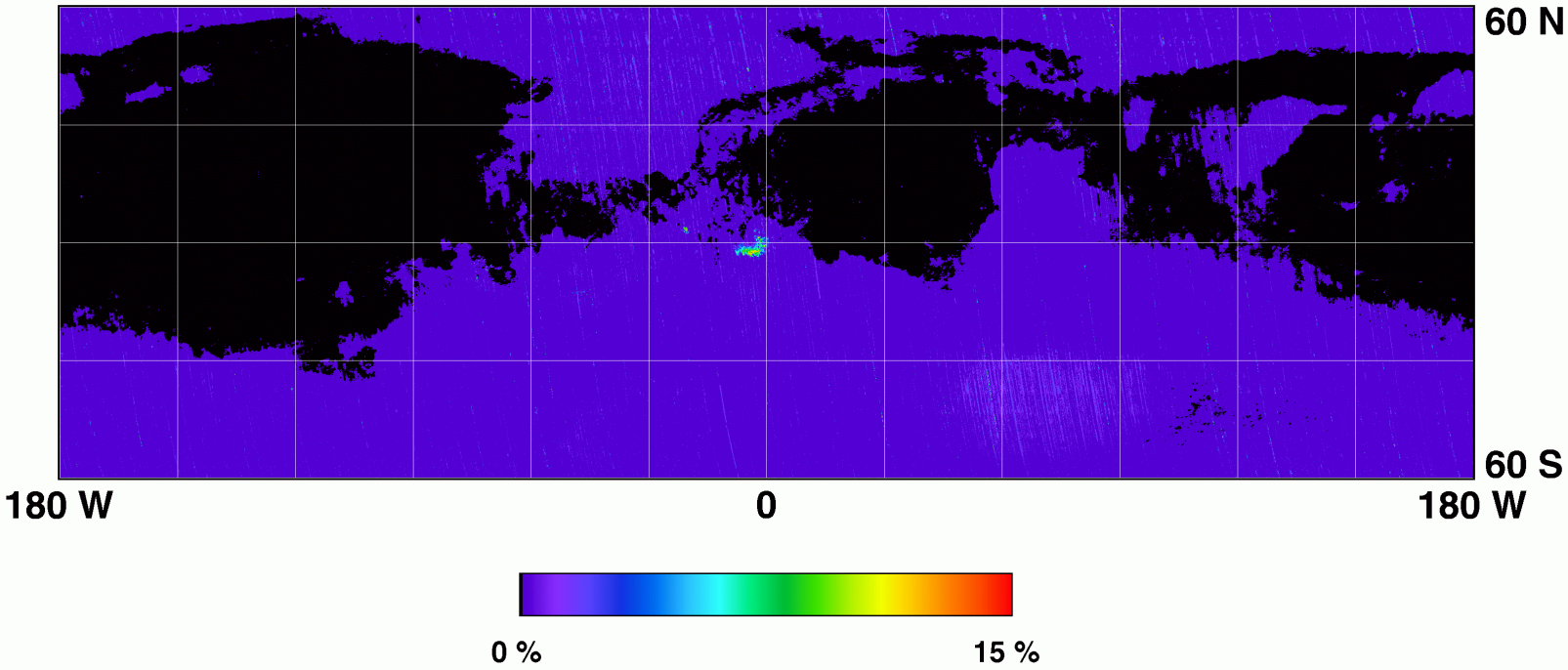
Rationale for Hematite Sites

- Mineralogy and petrology provide critical inputs to interpreting geologic processes
  - Volcanic, lacustrine, chemical precipitation, aeolian, etc
- All mineralogic data point to:
  - A Mars dominated by volcanic processes
  - Very little chemical weathering
  - No evidence for carbonates or significant clays
- Presence of crystalline hematite signature argues for unique chemical process with high probability of water

TES Hematite Abundance

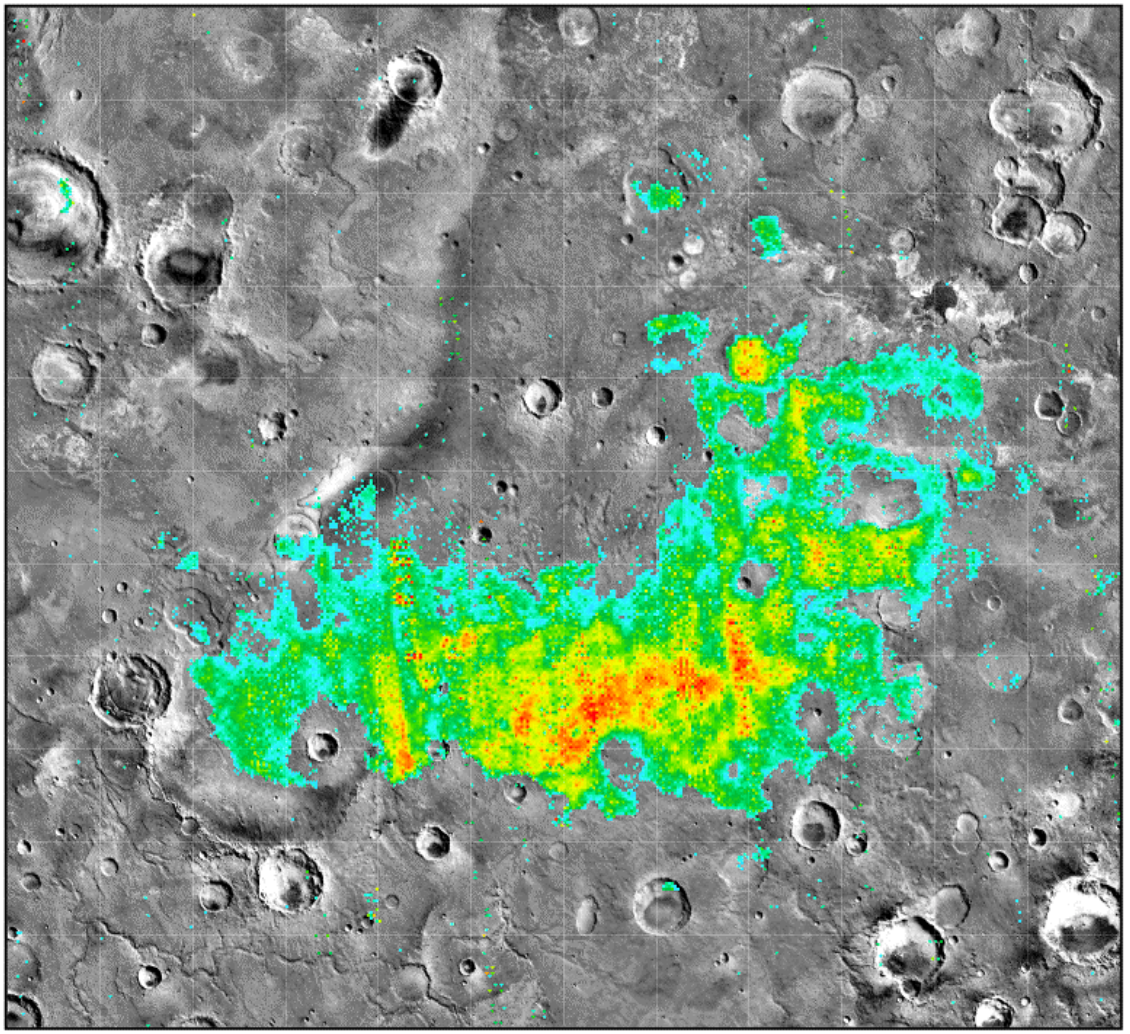


Global Mineral Mapping Summary

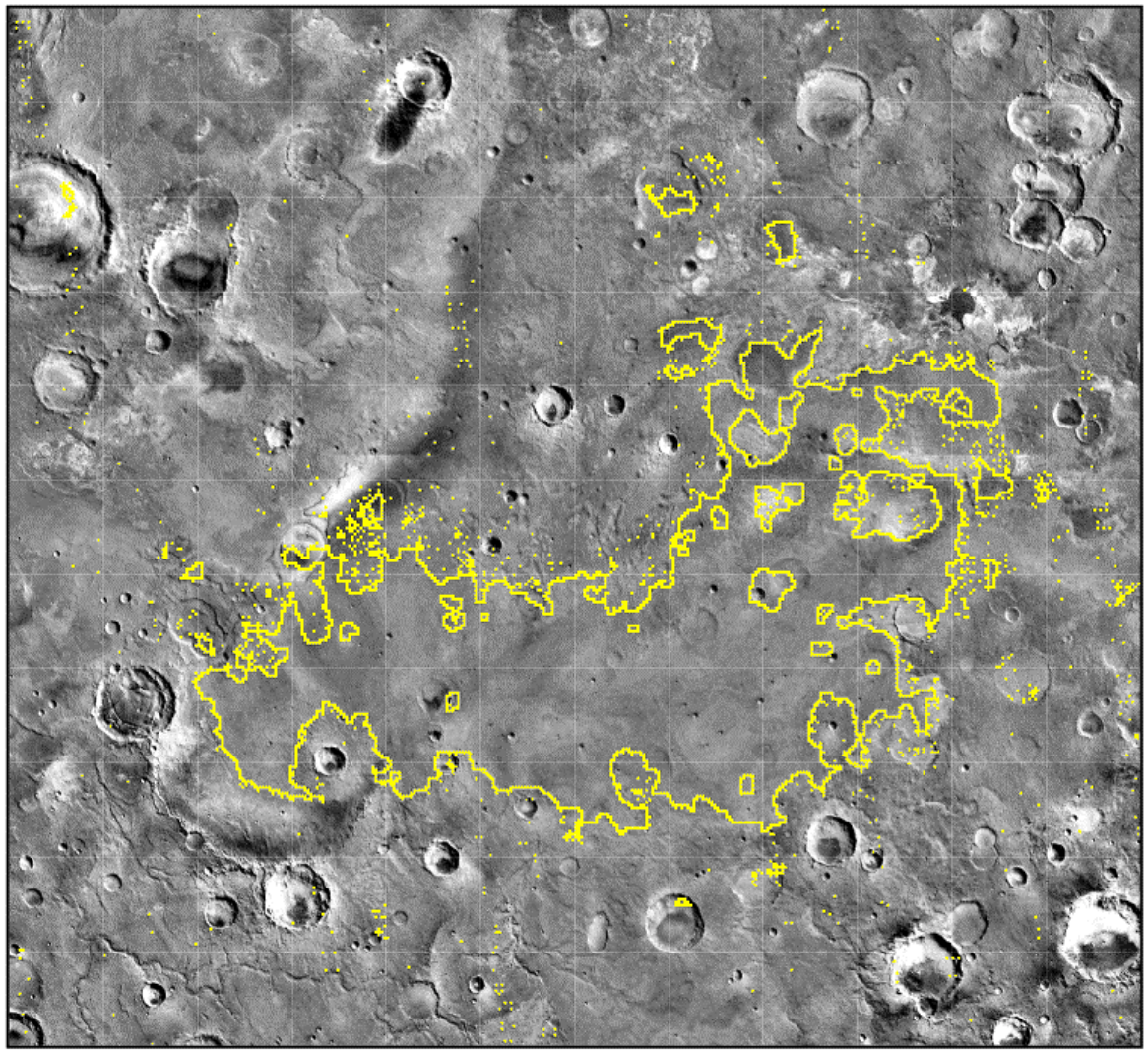
- Dust-free surfaces are volcanic materials
- Olivine detected in local regions
- No evidence for carbonates
- Unweathered to weakly weathered volcanic compositions (basalt to andesite)

- Except for hematite sites, mineralogy of other regions likely to be dominated by volcanic materials

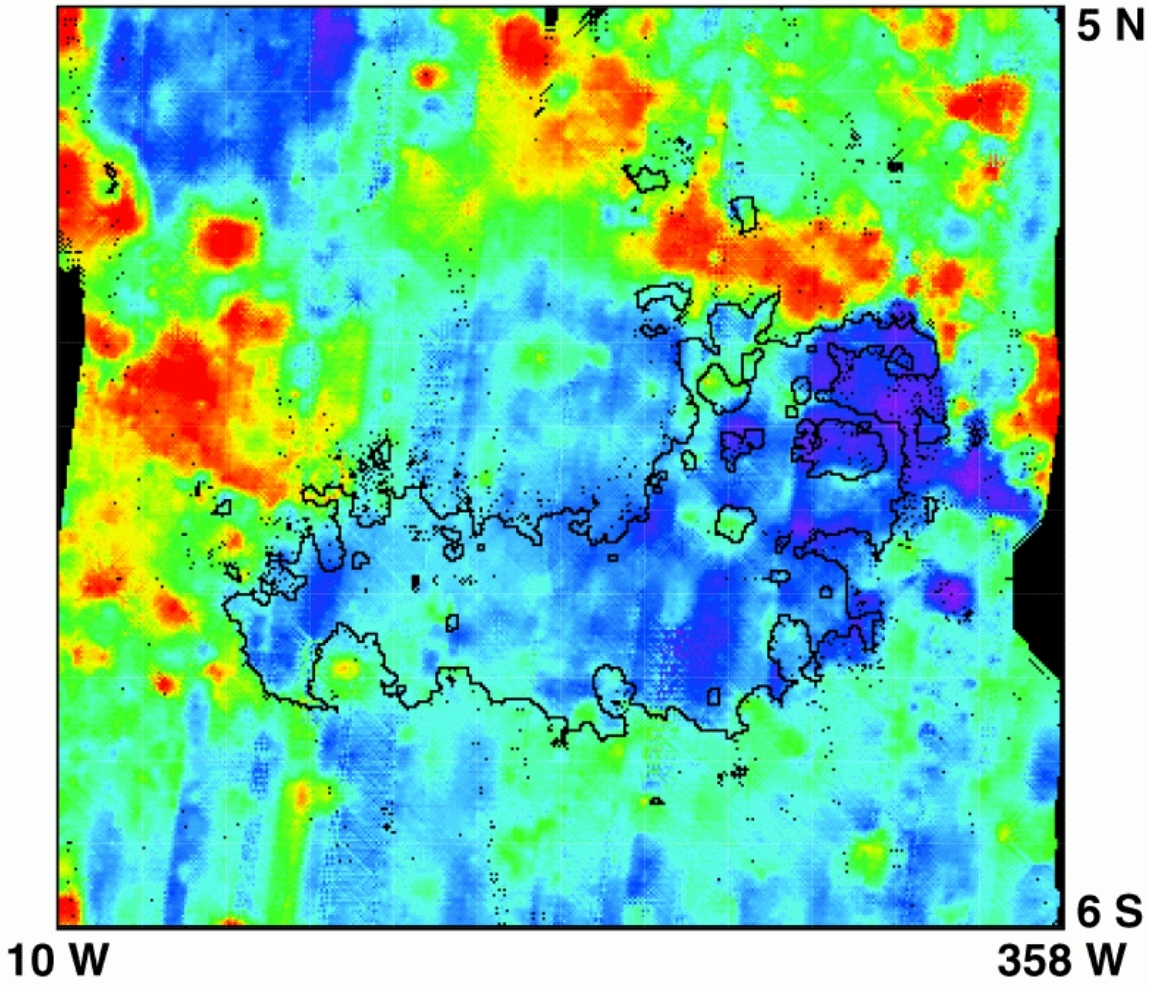
Sinus Meridiani

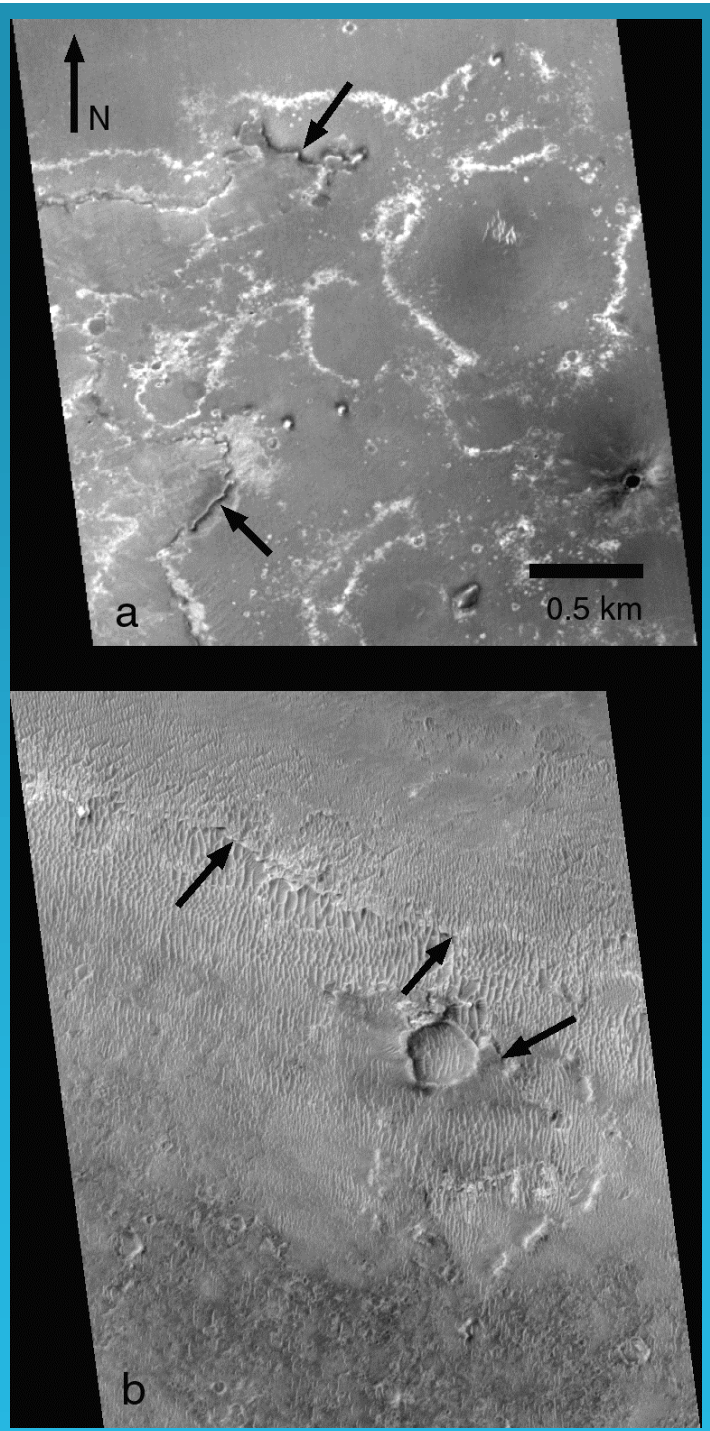


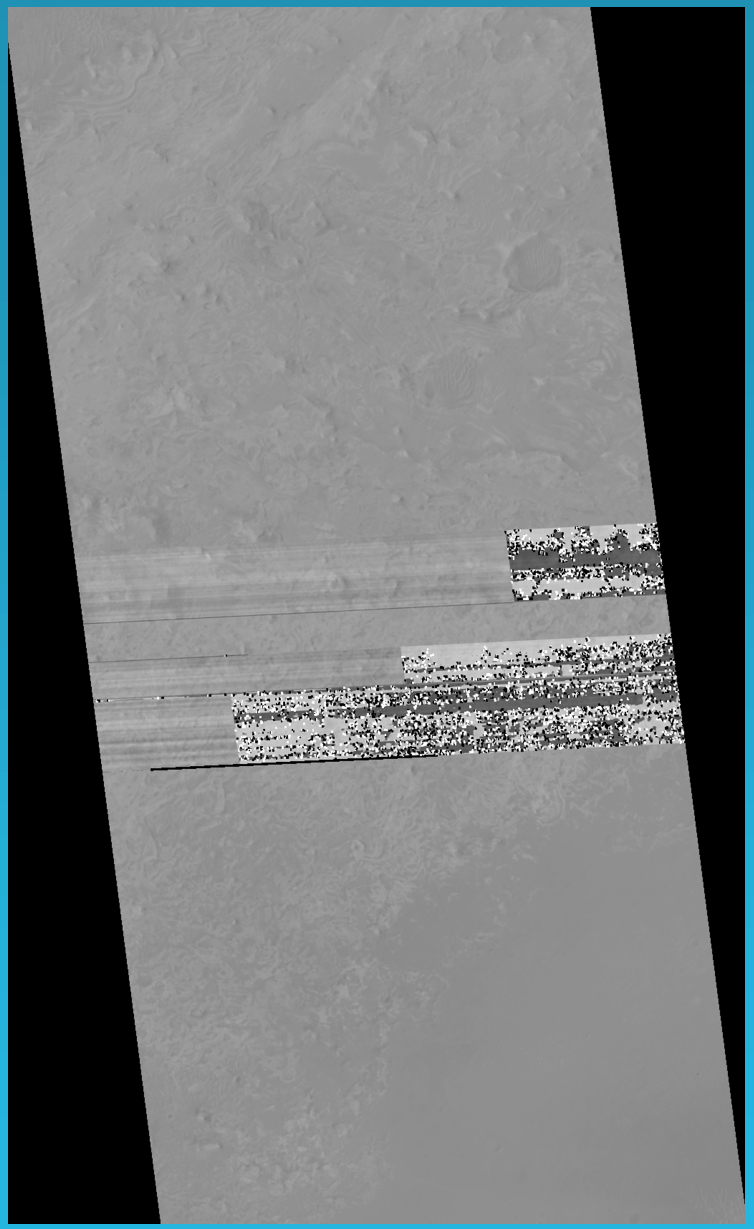
Sinus Meridiani



Thermal Inertia




N
a
0.5 km
b



Sinus Meridiani Geologic Setting

- Basaltic rock with 10-15% hematite
- Layered, friable, stripped deposits
- In-place rock unit
- Hematite-rich unit is stratigraphically above cratered highlands
- Regional tilting by Tharsis Uplift (Phillips et al.)
- Saturated population of ghost craters implies ancient surface (Hartmann and others)
- Distinct population of young craters suggests recent exhumation (Hartmann and others)

Hematite Formation Mechanisms

I) Chemical Precipitation - Extensive near-surface water

1) Precipitation from ambient, Fe-rich water (oxide iron formations)
2) Precipitation from hydrothermal fluids
3) Low-temperature dissolution and precipitation through mobile ground water leaching
4) Surface weathering and coatings

II) Thermal oxidation of magnetite-rich lava

Christensen et al. 2000

Ambient Aqueous Processes

- **Precipitation from standing water:**
  (Christensen et al. 2000)

Pro	Con
• Layered, friable units	• Goethite not hematite
• Aram and Ophir are basins	• Requires dehydration or recrystalization

Hydrothermal Processes

- Circulation of water through rock or saturated sediments:

  (Christensen et al. 2000)

Pro	Con
• Precipitation of hematite	• Lack of heat source
• Evidence of water at other sites	
• Evidence of sediments	

Igneous Processes

- **Igneous Intrusion/Ignimbrite:**

  (Noreen et al. 2000)

Pro	Con
• Layered units possibly tuffs	• Requires unique volcanic composition
• Friable deposits	
• Basalt compositoin	• Source region

Ash Induration

- **Indurated volcanic airfall:**

  (Hynek et al. 2001)

Pro	Con
• Widespread bright and dark layered deposits	• Hematite formation mechanism unclear
• Highly friable → ash	• Basalt composition
• Regional/global correlations	• Source regions?

Other Mechanisms

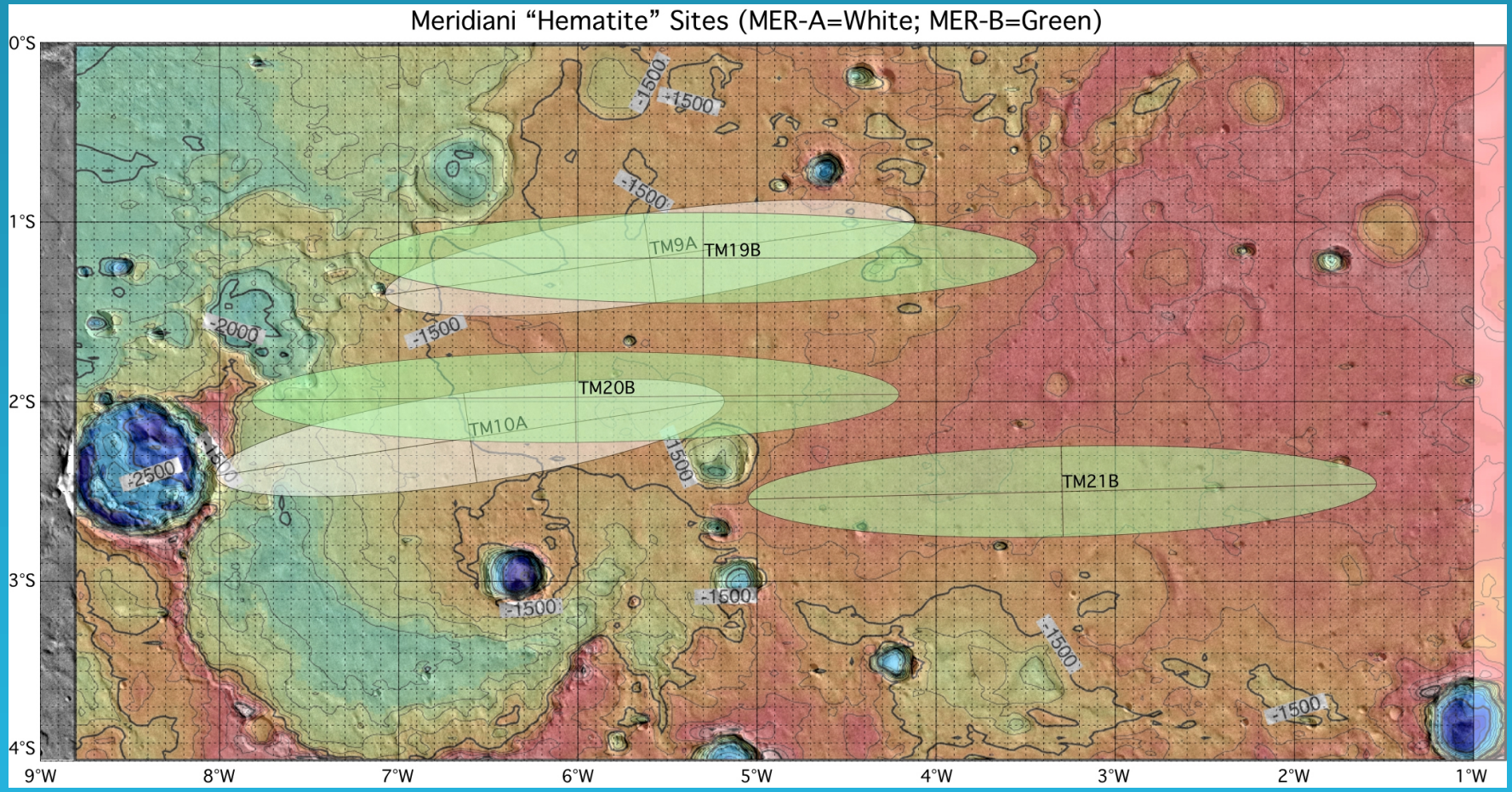
- Low-temperature dissolution and precipitation through mobile ground water leaching
  - Requires extensive surface water - no other morphologic evidence
- Surface weathering and coatings
  - Appears unlikely due to excellent correlation with geologic units
  - Typically produces red, not gray, hematite

Testable Hypotheses: What Will MER Payload Do?

- Lacustrine
  - Sedimentary structures, sorting, bedding, grain size
    - Pancam, Microscopic Imager
  - Major and minor component mineralogy
    - Mini-TES, APXS, Mossbauer, Pancam
- Hydrothermal
  - Mineralogy, alteration
    - Pancam, Microscopic Imager
  - Precipitation, veins, cements
    - Pancam, Microscopic Imager

Testable Hypotheses: What Will MER Payload Do?

- Igneous
  - Large- and small-scale volcanic structures
    - Pancam, Microscopic Imager
  - Mineralogy
    - Mini-TES, APXS, Mossbauer, Pancam
- Indurated airfall
  - Grain size, rounding, sorting, bedding
    - Pancam, Microscopic Imager
  - Glass and ash vs. basaltic grains
    - Mini-TES
  - Minor mineralogy
    - APXS, Mossbauer


Meridiani “Hematite” Sites (MER-A=White; MER-B=Green)
0°S
1°S
2°S
3°S
4°S
9°W
8°W
7°W
6°W
5°W
4°W
3°W
2°W
1°W
TM9A
TM19B
TM20B
TM10A
TM21B
-1500
-2000
-2500

Summary

- Presence of unique hematite mineralogy has led to formulation of multiple testable hypotheses
- Most hypotheses involve significant amounts of liquid water
  - Mineralization requires long-term stability of liquid water near surface
  - Time is critical to origin and survival of life
- Hematite sites are only locations on Mars with proven occurrence of a possible water-related mineralogy
- Layered friable deposits occur in all hematite sites
  - Suggests sedimentary origin
  - More likely to preserve products and record of early abiotic or biotic environments than volcanic, impact, metamorphic, or erosional environments