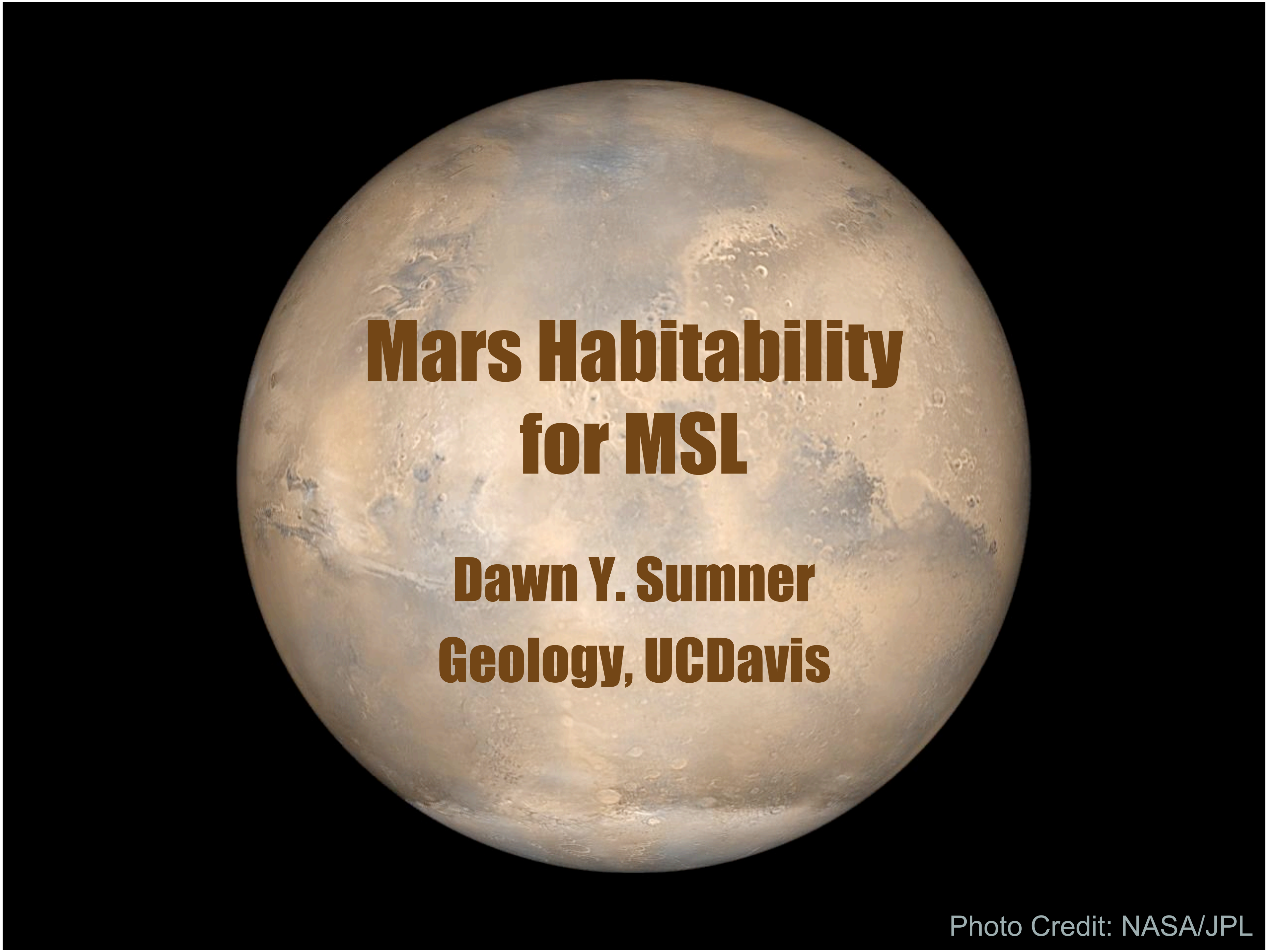

Mars Habitability
for MSL
Dawn Y. Sumner
Geology, UCDavis
Photo Credit: NASA/JPL

Looking for Life on Earth

- **Morphological Fossils**
  - **Microbial Communities**
    - Stromatolites & Microbialites
  - **Microfossils**
    - Too small for MSL to see

- **Most Common Where Minerals Precipitate**

2.5 Ga
South Africa

Photo Credit: Sumner

Looking for Life on Earth

- **Organic Molecules**
  - Isomers
    - Chirality
    - Diastereomers
    - Structural
  - Subunit Building Blocks
  - Patterned Distributions
  - Specific Compounds
- **Often Associated with Clay Minerals**

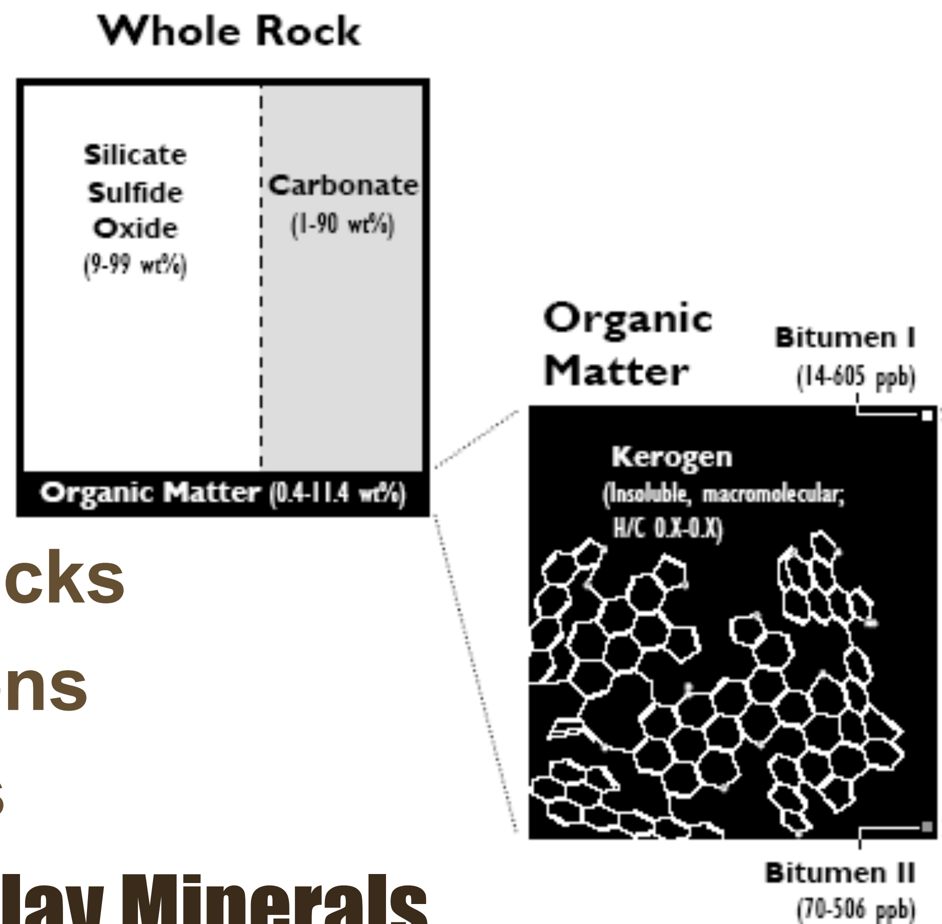


Image Credit: Waldbauer et al., in review, Precambrian Research
(NRC, 2007, An Astrobiology Strategy for the Exploration of Mars)

Chemical Activity of Water

- **Life needs a certain water activity to reproduce.**
  - "Based on current knowledge, terrestrial organisms are not known to be able to reproduce at an activity of water below 0.62." (These are fungi and yeast in the lab.)
- **Solutes reduce water activity.**
  - NaCl saturation: $a_w = 0.75$
  - $CaCl_2$ saturation: $a_w = 0.29$
- **Lower solute limits not characterized for bacteria or archaea.**

(MEPAG Special Regions Science Analysis Group, 2006, Astrobiology)

Chemical Activity of Water

- **Thin Film or Matrix Effects**

  a_w = 0.999 : Microbial motility ceases in porous media

  a_w = 0.97–0.95 : Lower limit for growth of *Bacillus spp.*

  a_w = 0.88 : Lower limit for growth of *Arthrobacter spp.*

  a_w = 0.93–0.86 : Microbial soil respiration ceases

- **Average Water Film Thickness and a_w:**

  500 nm : a_w=0.996

  3 nm : a_w=0.99

  <3 nm : a_w=0.97 (<10 $H_2$0 Molecules Thick)

  <1.5 nm : a_w=0.93 (< 5 $H_2$0 Molecules Thick)

  <0.9 nm : a_w=0.75 (< 3 $H_2$0 Molecules Thick)

(MEPAG Special Regions Science Analysis Group, 2006, Astrobiology)

Mars - Bad for MSL

- **Regolith & Dust**
  - Too Oxidizing for Organics
  - No Textural Preservation
- **Unaltered Igneous & Metamorphic Rocks**
  - High Temperature Origin

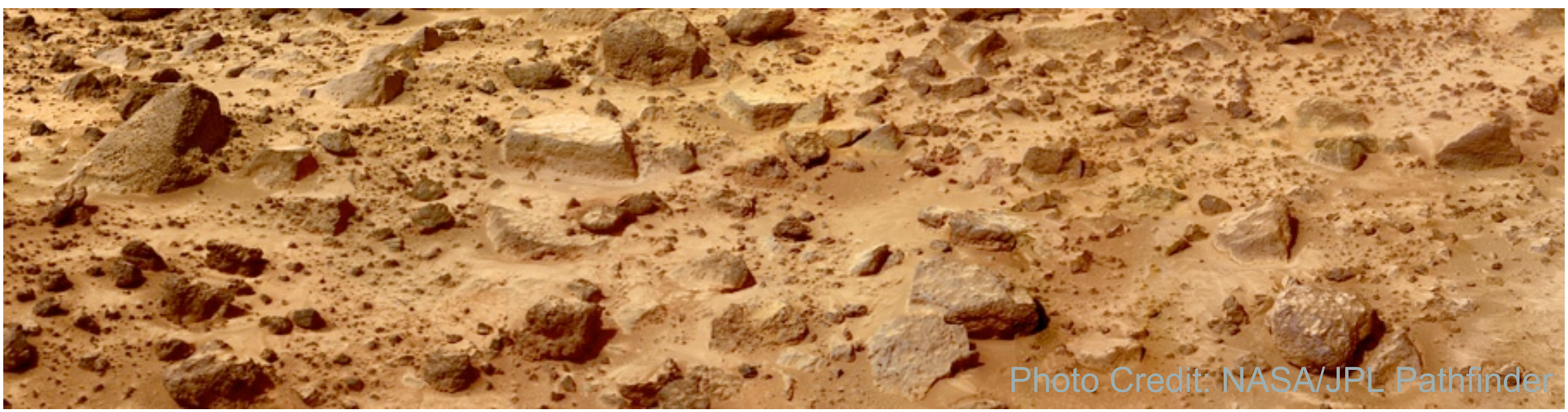


Photo Credit: NASA/JPL Pathfinder

Mars - Poor ↓ to Okay ↑ for MSL

- **Weathered Outcrops**
  - Degradational Environment (↓)
  - Long Surface Exposure Time (↓)
  - Oxidative, Dry Surface Now (↓)
  - Local Life Required (↓)
- **Hydrothermal Systems**
  - Accretionary (↑)
  - Mineral Precipitation (↑)
  - High Water Activity (↑)
  - High Temperature (↓)

Mawrth Valles
Blue = Clays

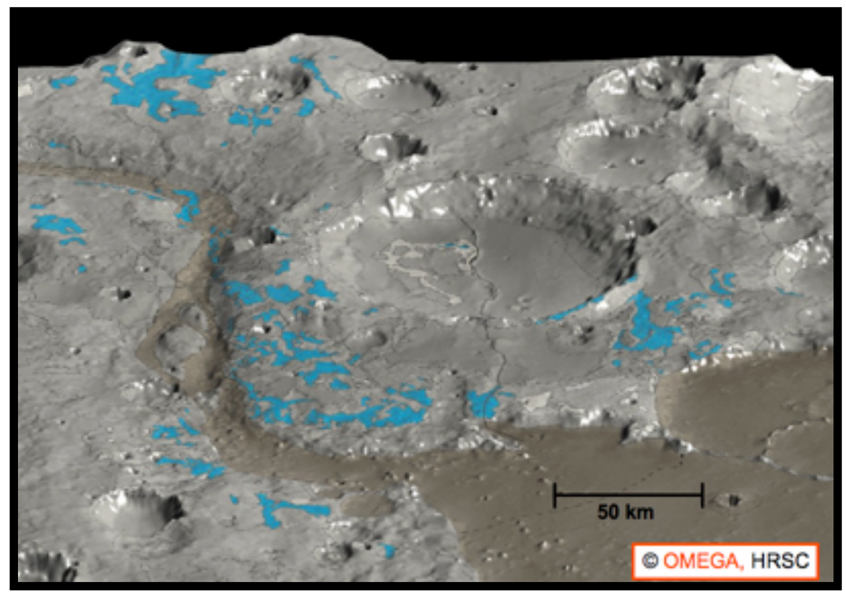
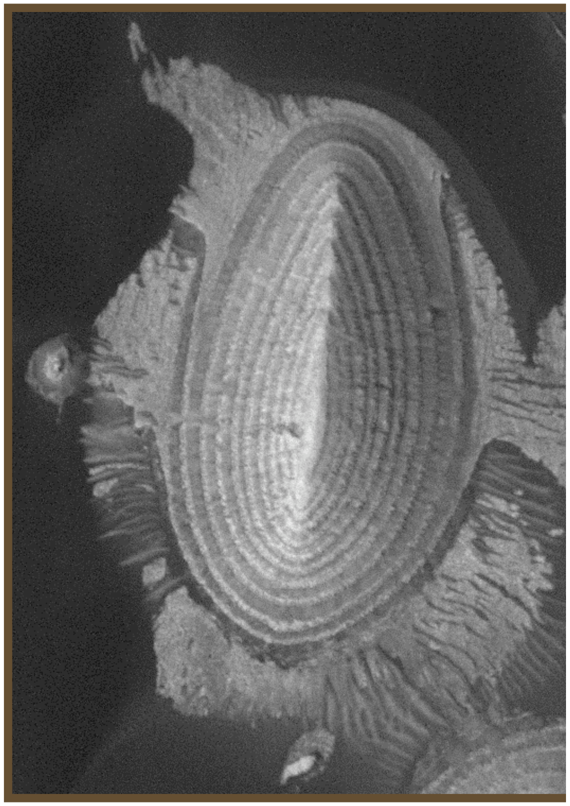


Photo Credit: Mars Express/OMEGA and HRSC teams

Mars - Sedimentary Rocks

- **Better Syn-Sedimentary Properties**
  - More Water Exposure
  - Lower Oxidation State
  - Finer Grained
- **Better Post Depositional Properties**
  - Less Water Exposure
  - Deflating or Eroding Topography

western Arabia Terra



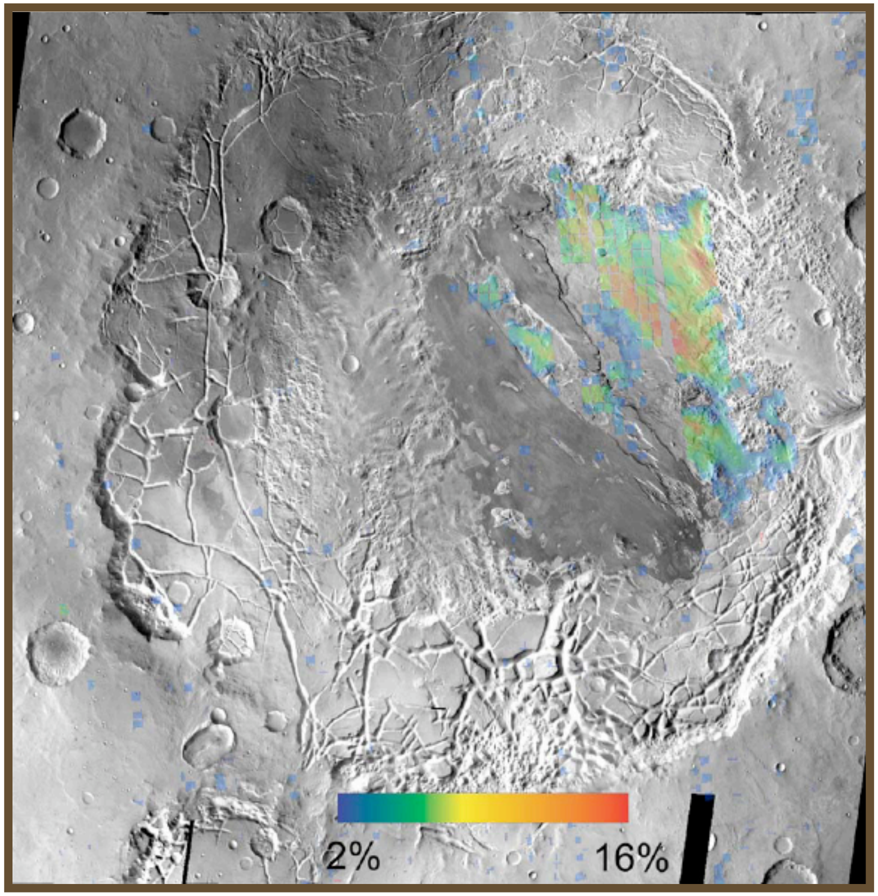
~1 km wide

Photo Credit: NASA/JPL/MSSS MOC

Mineralogy - Hematite & Fe(III)

- **In Sediments**
- **Suggests Aqueous Activity**
- **Exciting Discoveries**

But ...

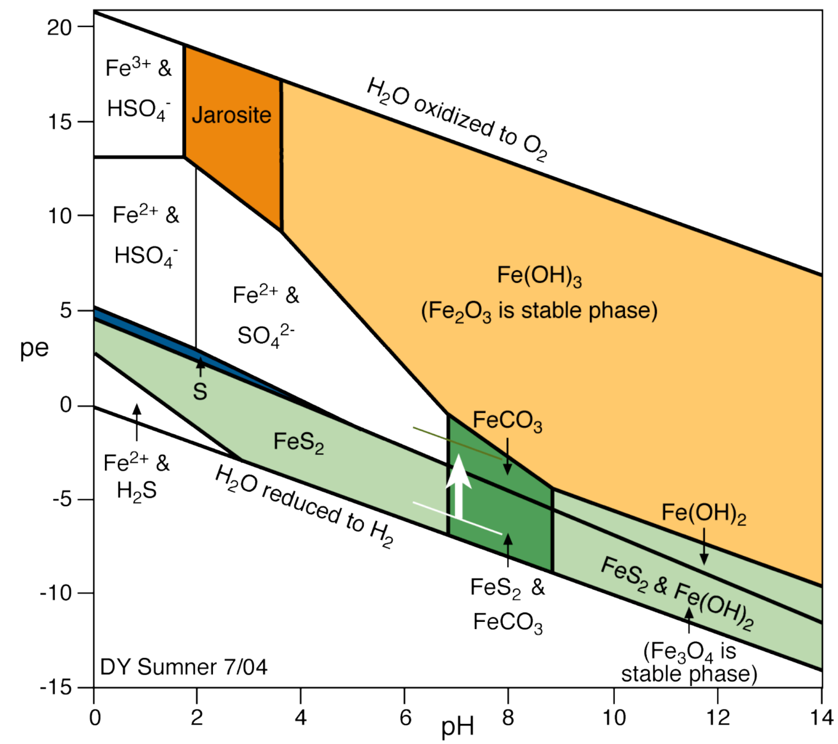


Aram Chaos
Hematite Abundance

(Glotch and Arvidson, 2007, JGR)

Mineralogy - Hematite & Fe(III)

- **Not Stable with Organics**
- **Kinetics of Fe(III) Reduction and Organic Oxidation is Rapid**
  (on geologic timescales)



Take this mineral stability diagram with a grain of salt!
(Water salinity strongly influences ion pairing in water, and thus the kinetics and mineralogy of precipitates.)

(Sumner, 2004, JGR)

Mineralogy - Hematite & Fe(III)

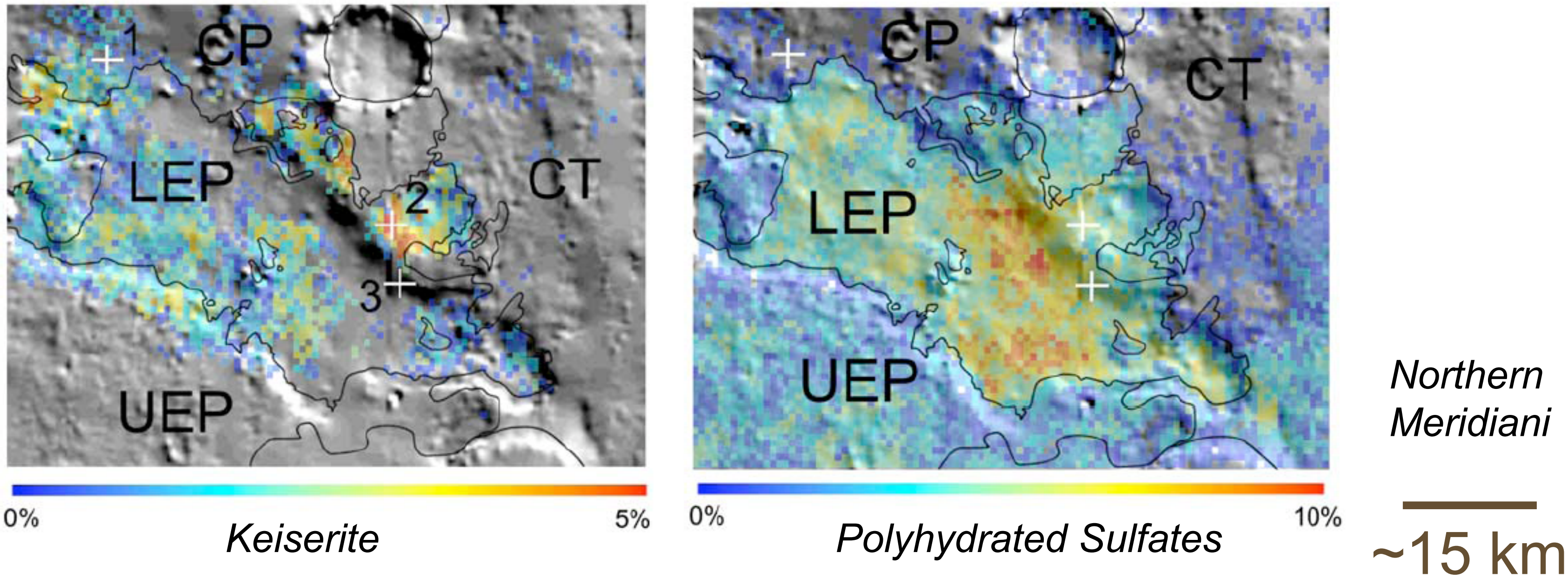
5 cm diameter core

- **Only Studies I Know from Earth:**
  - **2 Ma Rio Tinto terrace**
    - Goethite and Recalcitrant Organics Only (Fernandez Remolar and Knoll, in review)
  - **Jurassic Navajo Sandstone**
    - Hematite Concretions Lack Organics (Souza-Egipsy et al., 2006)
  - **1.88 Ga Gunflint Iron Formation**
    - Hematite and Graphite Inclusions in Chert (Tazaki et al., 1992)
    - Pressure may stabilize graphite

Photo Credit: Sumner

Mineralogy - Sulfates

- **Require Substantial Water-Rock Interaction**
- **Precipitation can Encapsulate Organics**



(Griffes, et al., 2007, JGR)

Mineralogy - Sulfates

- **Not Stable with Organics**
- **Kinetics of S(VI) Reduction to S[-II] and Organic Oxidation can be Very Slow**

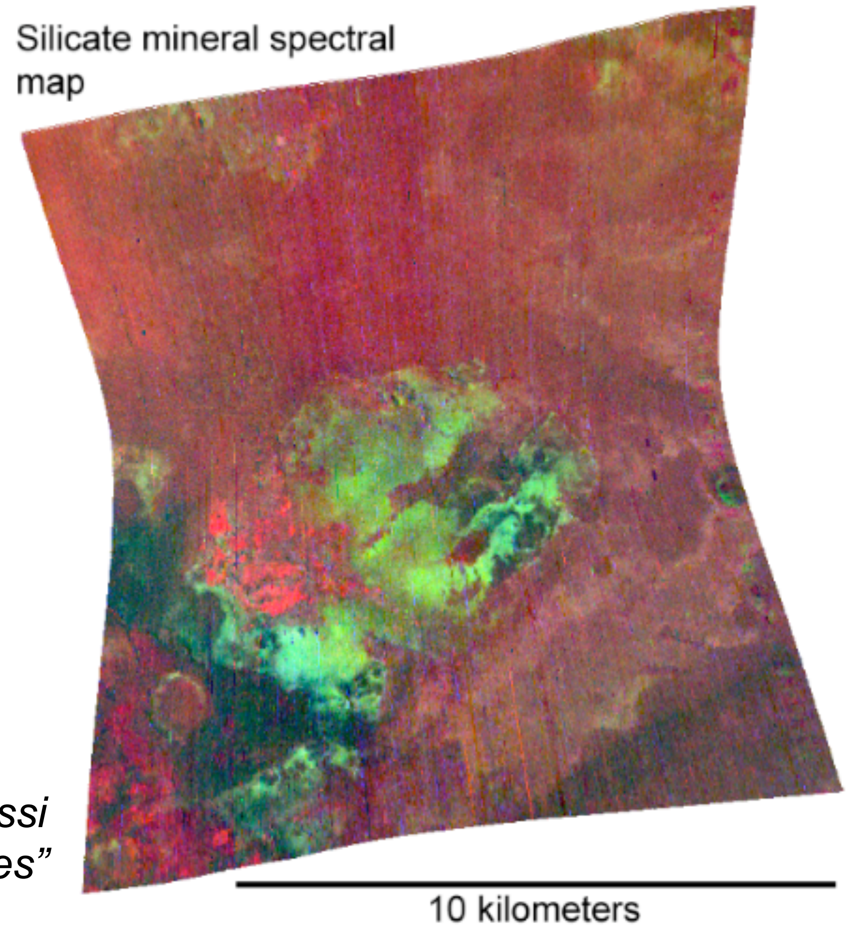
  SO_4^{2-} Metastable for 1-10 billion years at pH 4-7

  SO_4^{2-} Metastable for 5,000 years at pH 2

  (Ohmoto and Lasaga, 1982)
- **I know of no studies on Earth showing organics in ancient sulfates**
  - Microbial sulfate reduction may oxidize organics

Mineralogy - Clay Minerals

- **Not all Phyllosilicates are Clay Minerals**
  - Smectites good
  - Micas irrelevant
- **When in Deposited Layers:**
  - Regional Signatures Integrated
  - Good Preservation Potential



Nilli Fossi
Greener = “Phyllosilicates”

Mineralogy - Clay Minerals

- Bind Organics in Interlayers
- Low Redox Potential
- Low Post-Depositional Permeability

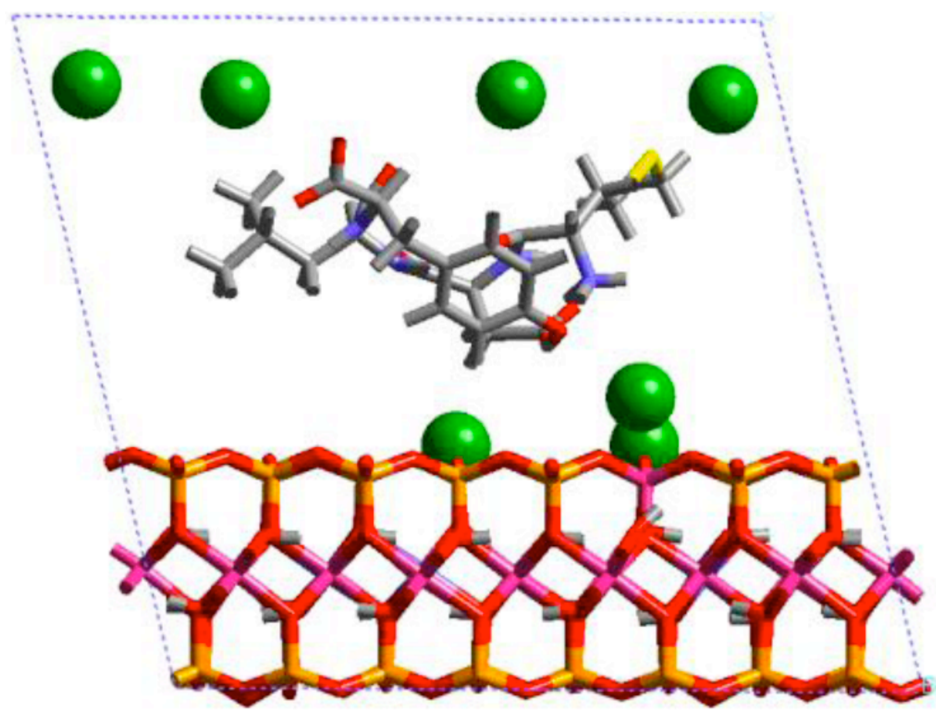


Image Credit: RT Cygan http://www.sandia.gov/geobio/randy_files/image018.jpg

MSL Landing Sites

- **Mineral Summary**
  - Hematite - Bad for Organics, Good for Morphology
  - Sulfates - Okay for Organics, Okay for Morphology
  - Clay Minerals - Good for Organics, Bad for Morphology

MSL Landing Sites

- **Good Syn-Depositional Parameters**
  - High Water Activity
  - Accreting Environment
  - Mineral Precipitation
  - Low Oxidation State
- **Good Post-Depositional Parameters**
  - Low Water Activity, Low Permeability
  - Low Temperatures
  - Low Oxidation State
  - Deflating or Eroding Topography