Aqueous Sedimentary Depositional Environments, Meridiani Planum, Mars

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on behalf of
MER Athena Science Team
MARS SCIENCE STRATEGY: Follow the Water!

Common Thread

- Determine if Life Ever Arose on Mars
- Characterize the Climate
- Characterize the Geology
- When? Where? Form? Amount?
- Prepare for Human Exploration
The Rovers

Remote Sensing Package
- Pancam Mast Assembly (PMA)
- Pancam
- Mini-TES

In-Situ Package
- Instrument Deployment Device (IDD)
- Microscopic Imager
- Alpha Particle X-Ray Spectrometer
- Mössbauer Spectrometer
- Rock Abrasion Tool
Opportunity at Meridiani Planum
Hematite: Mineralogic Beacon

HEMATITE DISTRIBUTION MAP FROM TES DATA

(Figure based on Christensen et al., (2001) JGR, v. 106(E10), Plate 2, p. 23,877.)
Geological Traverse
El Capitan
Mössbauer Spectrum of El Capitan: Meridiani Planum
Jarosite: $(\text{K, Na, X}^{+1})\text{Fe}_3(\text{SO}_4)(\text{OH})_6$
Bromine vs. Chlorine

Graph showing the comparison between bromine (Br) and chlorine (Cl) concentrations in various samples. The graph plots Br ppm on the x-axis and Cl ppm on the y-axis. The data points include Martian Meteorites, Chondritic CI/Br ratio, Dead Sea Salt, Seawater, and other types of samples such as Flat rock, Trench floor, and Trench wall. The graph also highlights the chondritic Cl/Br ratio.
APXS Results: High S in Rocks

Fe$_2$O$_3$ (wt.%) vs. SO$_3$ (wt.%, total S as SO$_3$)

END MEMBERS (SCHEMATIC)

HEMATITE-RICH
SULFATES

B. Jolliff
If subtract 60% of dust or basalt component from average RAT'd rock composition, Al$_2$O$_3$ and Cr$_2$O$_3$ go to zero at ~50% SO$_3$. 
Rio Tinto, Spain
Mini-TES: Hematite Distribution
Soil Granules (Spherules)
Pancam on Stone Mountain
Microimager: Spherules in Outcrop
Concretions
Spherules Not Concentrated Along Bedding
Distribution of Concretions
The “Berry Bowl”
Mössbauer on the Berry Bowl

Mössbauer spectra of the BlueBerry bowl and bare outcrop at Meridiani Planum

"Empty" (Berry-free) Sol 46
"MössBerry" Sol 48

Hematite sextet

Mapping and GIS Laboratory, OSU
Initial evaporite assemblage

Infiltrating fluid

Fluid-mineral equilibrium

Resulting mineral assemblage (porosity = 0.30):
- Bilinite
- K-Jarosite
- FeSO₄•nH₂O
- Gypsum
- Epsomite
- Goethite

N. Tosca
Concretions: Two Types?
Sulfate Minerals: Gypsum?
Evaporite-Filled Crystal Molds on Earth
The Rocks are “Sandstones”

- Laminae Defined by Variable Grain Size
- Medium Grain size
- Well Rounded

[Image of sandstone texture with measurements 0.3 mm and 0.8 mm]
Bedforms in Flowing Water

Southard and Bouchwal, 1990
Current Ripples in Water

6 hours of ripple migration

Image is 60x40 cm

Flume experiments by Dave Rubin and Jon Nelson, USGS
Current Ripples in Cross Section

Simulation by Dave Rubin, USGS
Ripple Cross-Bedding on Mars
Ripple Cross-Bedding
Modern Mars Analog: Umm a Samin

- Dunes
- Braid Plain
- Modern Playa
Network of Interdune Depressions
Interdune Depression
Modern Interdune Depression: Namib Desert
Endurance Chemostratigraphy
A Trail of 11 RAT Holes

- Tennessee
- Virginia
- Kentucky
- Ontario
- Manitoba 1
- Manitoba 2
- Millstone
- Alex Heiberg
- Inuvik
- MacKenzie
- Diamond Jenness
Ratio to surface rock average

Selected Elements in Endurance Crater Rocks

- Tennessee
- Kentucky
- Virginia
- Ontario
- Manitoba 1
- Manitoba 2
- Millstone
- Diamond Jenness 1
- Diamond Jenness 2
- MacKenzie
- Inuvik
- Axel Heiberg

- Magnesium
- Sulfur
- Chlorine

Depth in crater

A. Haldemann
Changes Down Section: Texture

Ontario

Diamond Jenness
Stage 1. Syndepositional - Early Burial: Pore-filling cements

Evaporation

Playa Facies

Dune Facies

S. McLennan, N. Tosca
Stage 2. *Burial (Near isotropic phreatic recharge)*: Hematite concretions

- Dune Facies
- Playa Facies

Hematite concretions

S. McLennan, N. Tosca
Stage 3. *Burial (May be same recharge event as Stage 2):* Moldic porosity (vugs), overgrowths, recrystallization

![Diagram showing geological features including Dune Facies and Playa Facies with symbols for hematite concretions, overgrowths, recrystallization, and moldic porosity.]

Hematite concretions
Overgrowths
Recrystallization
Moldic porosity

S. McLennan, N. Tosca
Other Evidence for Liquid Water on Mars

Modern

Ancient
What about (astro)biology?

- Rover reveals Mars was once wet enough for life (MsNBC)
- Red planet may have been hospitable to life (CNN)
- Mars could once support life, scientists now say, but did it? (NY Times)
• Meridiani environment appears to have been acidic, hypersaline, and only intermittently wet.
• Life exists at such extremes on Earth.
• But Meridiani data suggest potential challenges to origin as well as persistence of life.
Could Life Begin in Acidic Waters?

- Several key reactions do not proceed at acidic pH: e.g. Strecker synthesis (generates amino acids)
- Proteins and DNA both readily hydrolyzed in acidic waters
- Experimental growth of nucleotides yields triple helix in acidic waters
- The oxidizing surface of Mars would make things worse. We need to understand when Meridiani-like conditions were established on Mars.

- Was there ever a surface environment that was more conducive to prebiotic chemistry?
The Good News

- Evidence of any life that might have existed might well be preserved in chemical sediments and concretions.
- Chemical and textural details of Meridiani salts and iron oxides likely to reveal much about environmental history.

- All this favors Meridiani Planum as a target for sample return.