[AV] Analogs of Earth Marbles to Mars Blueberries: Records of Groundwater History from Red Rock to Red Planet

By

Marjorie A. Chan[1], Brenda Beitler[1], William T. Parry[1], Jens Ormo[2], and Goro Komatsu[3]

Search and Discovery Article #110028 (2005)
Posted August 30, 2005

[1]University of Utah, Salt Lake City, UT (chan@earth.utah.edu)
[2]Centro de Astrobiología (INTA/CSIC), Instituto Nacional de Técnica Aeroespacial, Madrid, Spain
[3]Università d'Annunzio, Pescara, Italy

Abstract

Jurassic Navajo Sandstone coloration and concretions of southern Utah show a history of groundwater diagenesis and iron-oxide mobility. This example comprises an important Earth analog for newly discovered hematite concretions on Mars. Coloration from iron oxides (e.g., hematite, goethite) is an index to fluid pathways and compositions. These terrestrial sandstones are likely originally red early in the diagenetic history from small amounts of disseminated hematite. Bleaching by reducing solutions later mobilizes and removes iron on local to regional scales. Flow paths are controlled by host rock properties such as permeability, lithology, and sedimentology, in addition to stratigraphy and structure. When reduced waters carrying the iron meet and mix with oxygenated ground water, iron re-precipitates in concretionary forms. Concretions are typically spherical (like marbles) and develop through a self-organizing process.

This analog can help explain the remarkable hematite spherules ("blueberries") on Mars. Although other terrestrial mechanisms can generate a spherule shape, only the concretion model is consistent with the Mars observations of hematite mineralogy, variable outcrop iron-oxide distribution, common spherules with *in situ* spaced organization, weathered aprons of the resistant nodules, unusual joined doublet and triplet morphologies, and apparent fracture/joint fills. The presence of hematite concretions implies groundwater flow. The potential role of biomediation in the precipitation of some terrestrial hematite concretions could also hold important clues in the search for life on Mars. Sedimentary analogs have tremendous value in planetary geology exploration and interpretation.

ANALOGS OF UTAH MARBLES TO MARS BLUEBERRIES :

Records of Groundwater History from Red Rock to Red Planet

THE UNIVERSITY OF UTAH

Marjorie A. Chan

Brenda Beitler
Bill Parry
Jens Ormö
Goro Komatsu

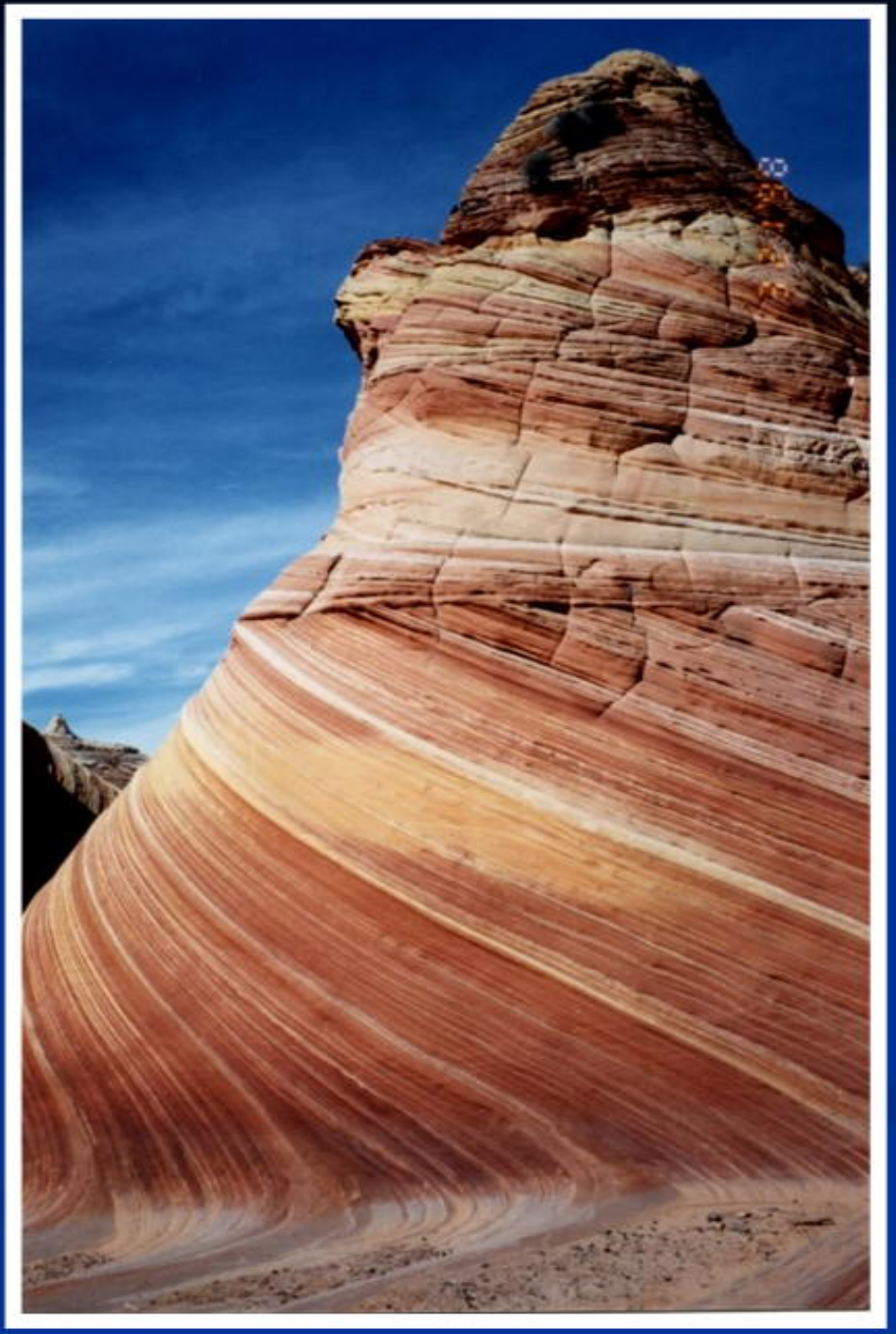
CONCEPT

- Utah rocks = color coded.
- Sandstone coloration + iron "marbles" -> groundwater fluid flow.
- Applications to reservoir sandstones and hematite on Mars.

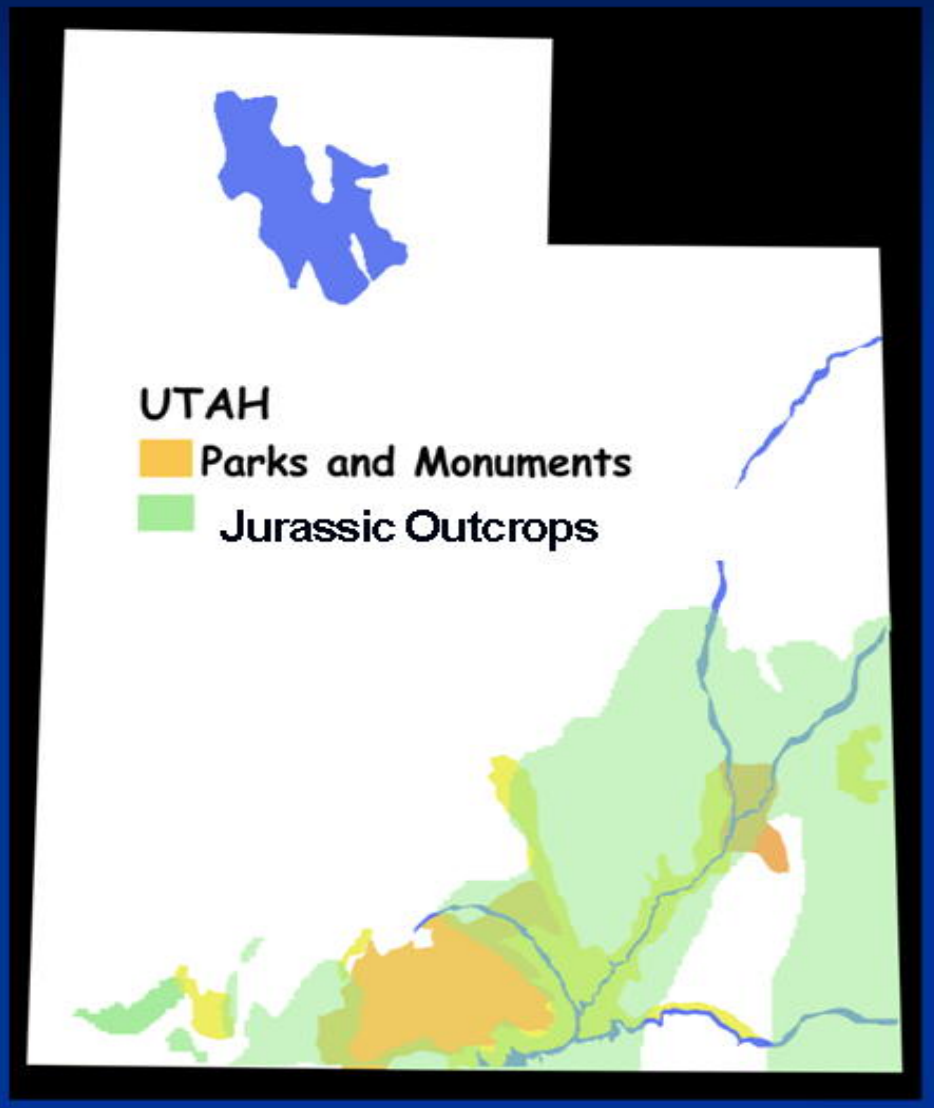
Concretion = cemented mineral mass

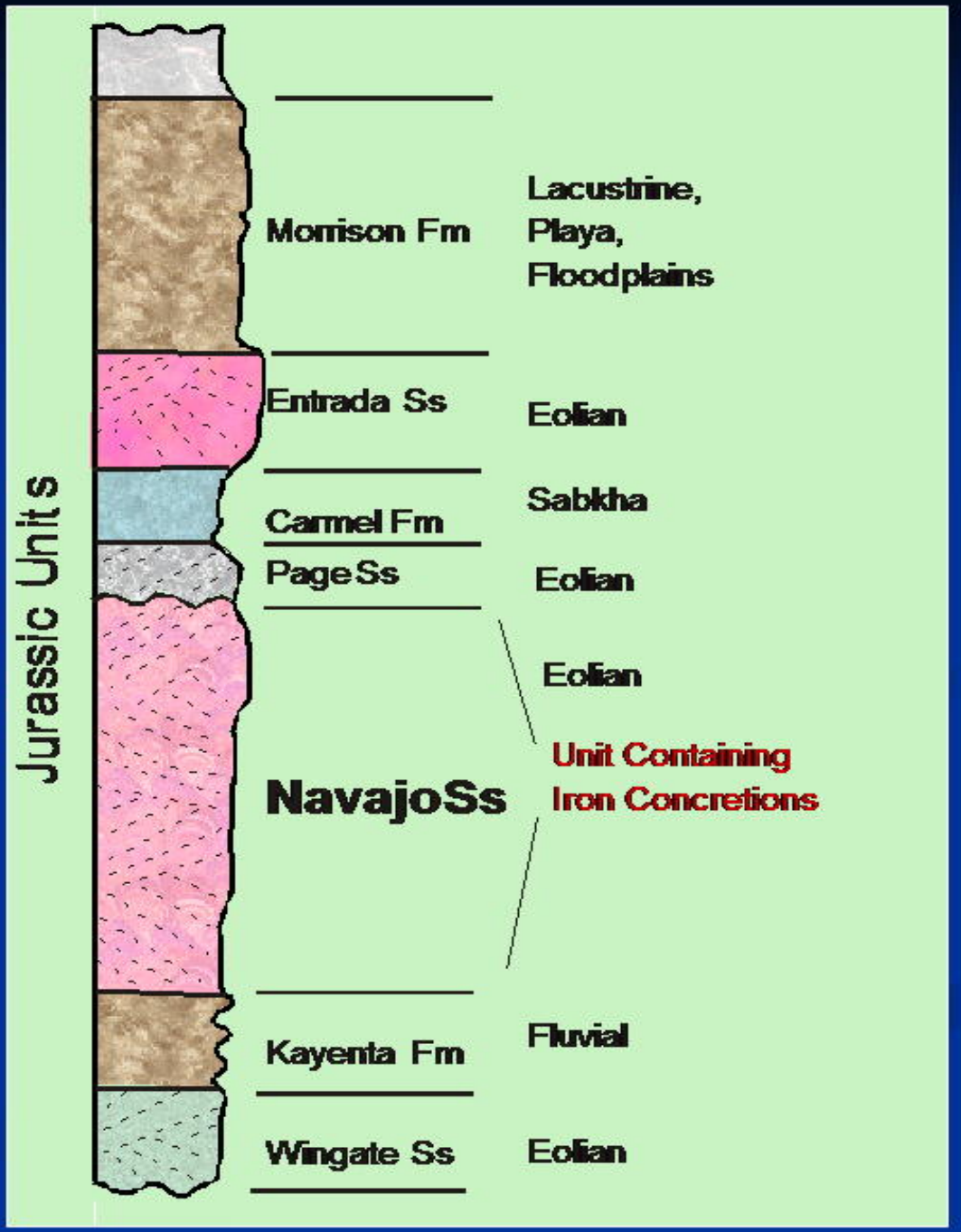
Hematite: Fe_2O_3

Goethite: FeO(OH)

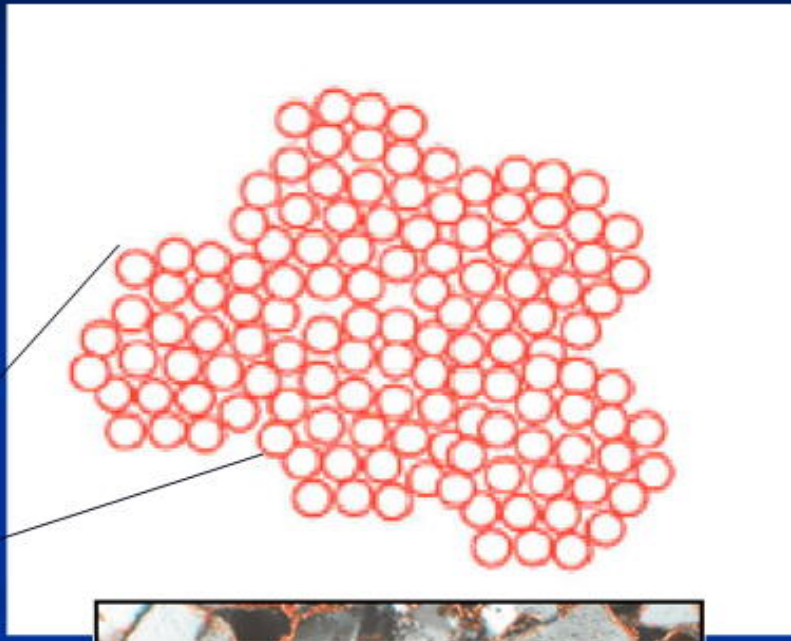


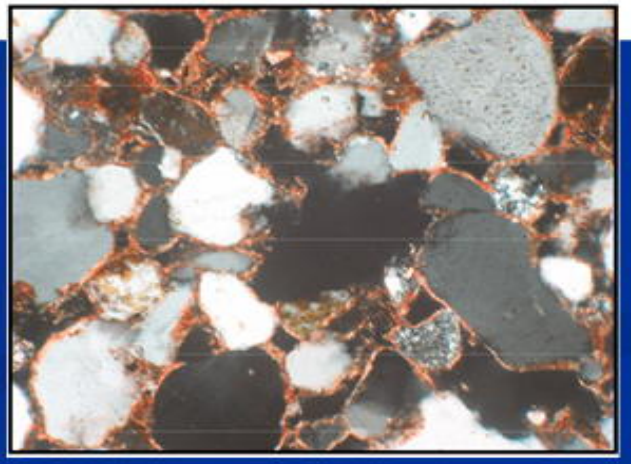
REGIONAL SETTING





1. Eolian (wind-blown) sands originally red



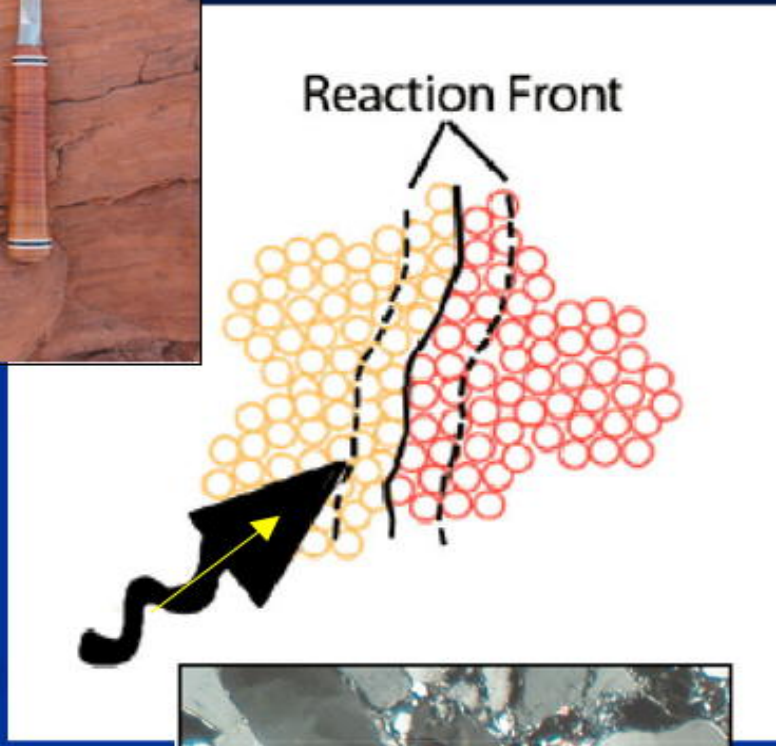


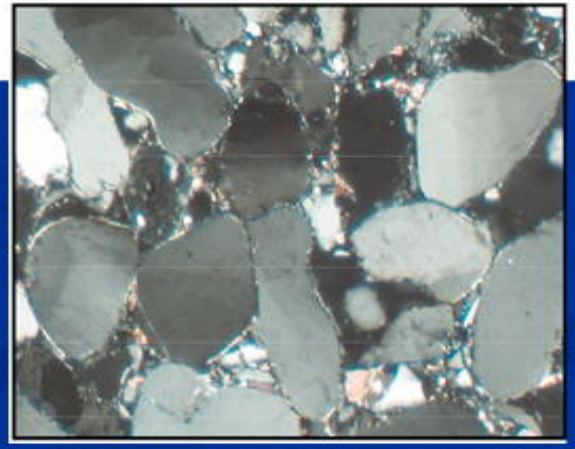
weathering of Fe-Mg silicates

Thin hematite coats

~ 1-2% iron oxide

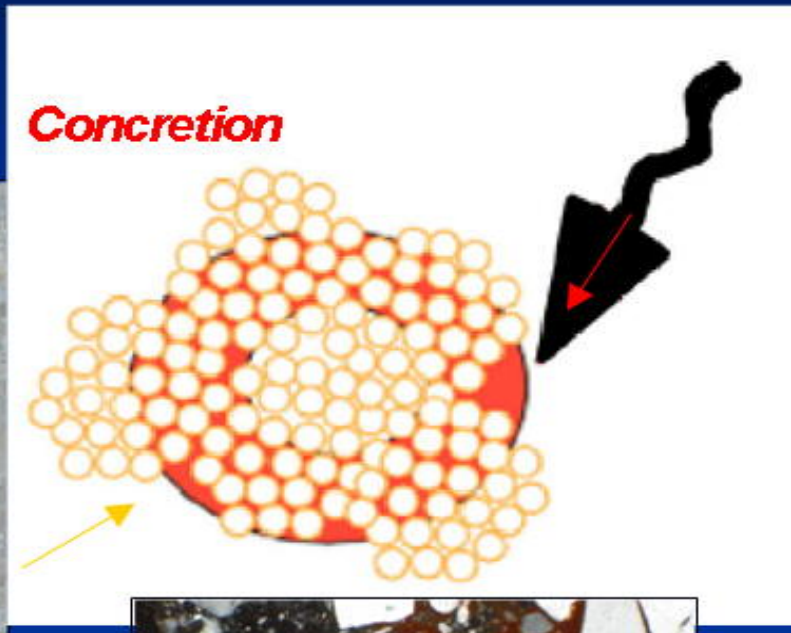
2. Reducing brines mobilize iron, bleach sandstone white

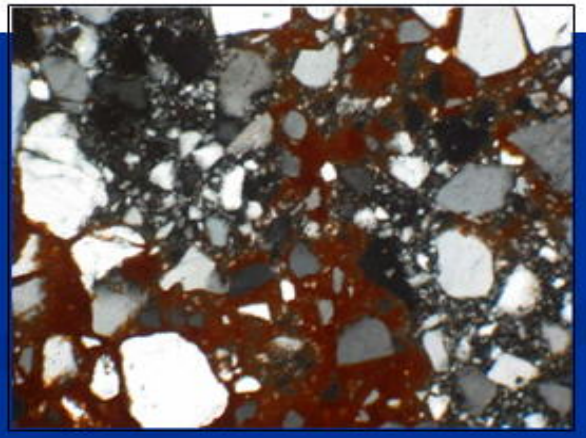




< 0.5% iron oxide

3. Reducing waters mix with oxygenated groundwater to precipitate Fe



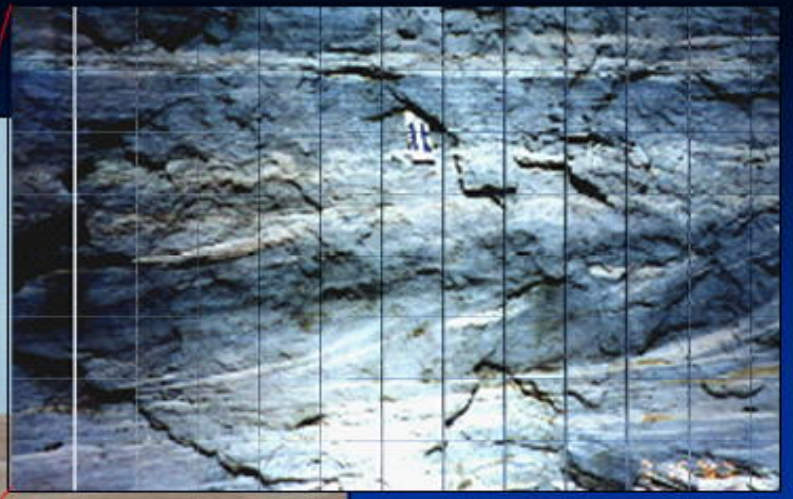


Ar-Ar age dating of related mineralization ~ 25 mya

~ 5-35% iron oxide

Examples of Reducing fluids

-Petroleum
-Methane
-Organic acids



Preferential bleaching

UTAH MODEL

1. **Numerous field sites across S. Utah**
2. **~200 samples of host rock & concretions** (petrography, whole rock, XRD, O- isotopes, GC, cone tomography)
3. **Geochemical Modeling**

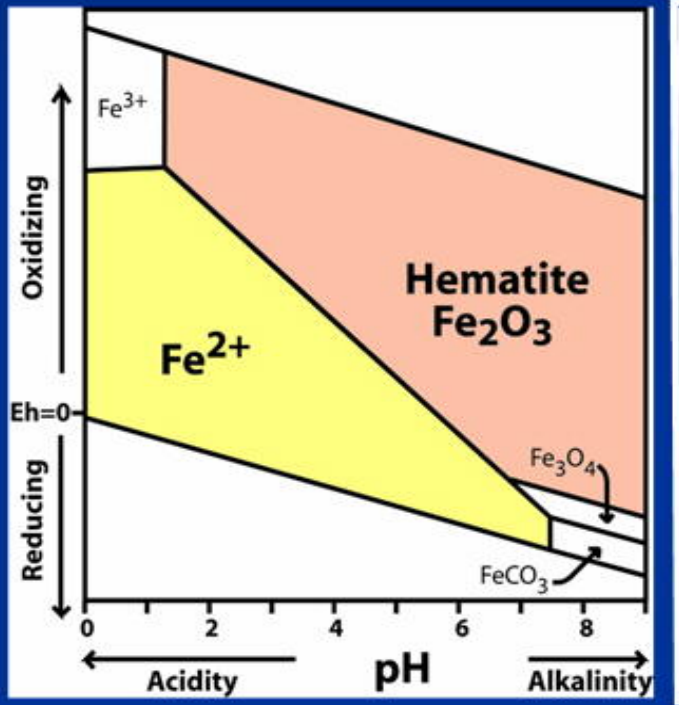
Can be complicated!

Model variants help to understand controls.

Chemistry?

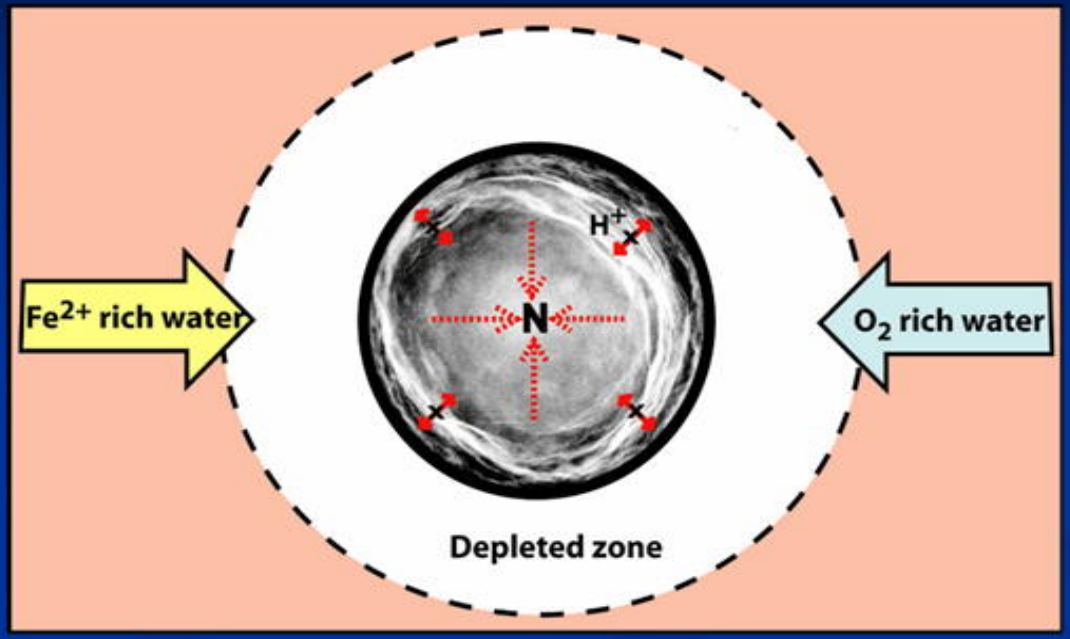
$2Fe^{2+}+{}^{1}/_{2}O_2+2H_20=Fe_2O_3+4H^+$

Acidity with oxidization of Fe



- Kinetics
- Nucleation
- Supersat-depletion cycles

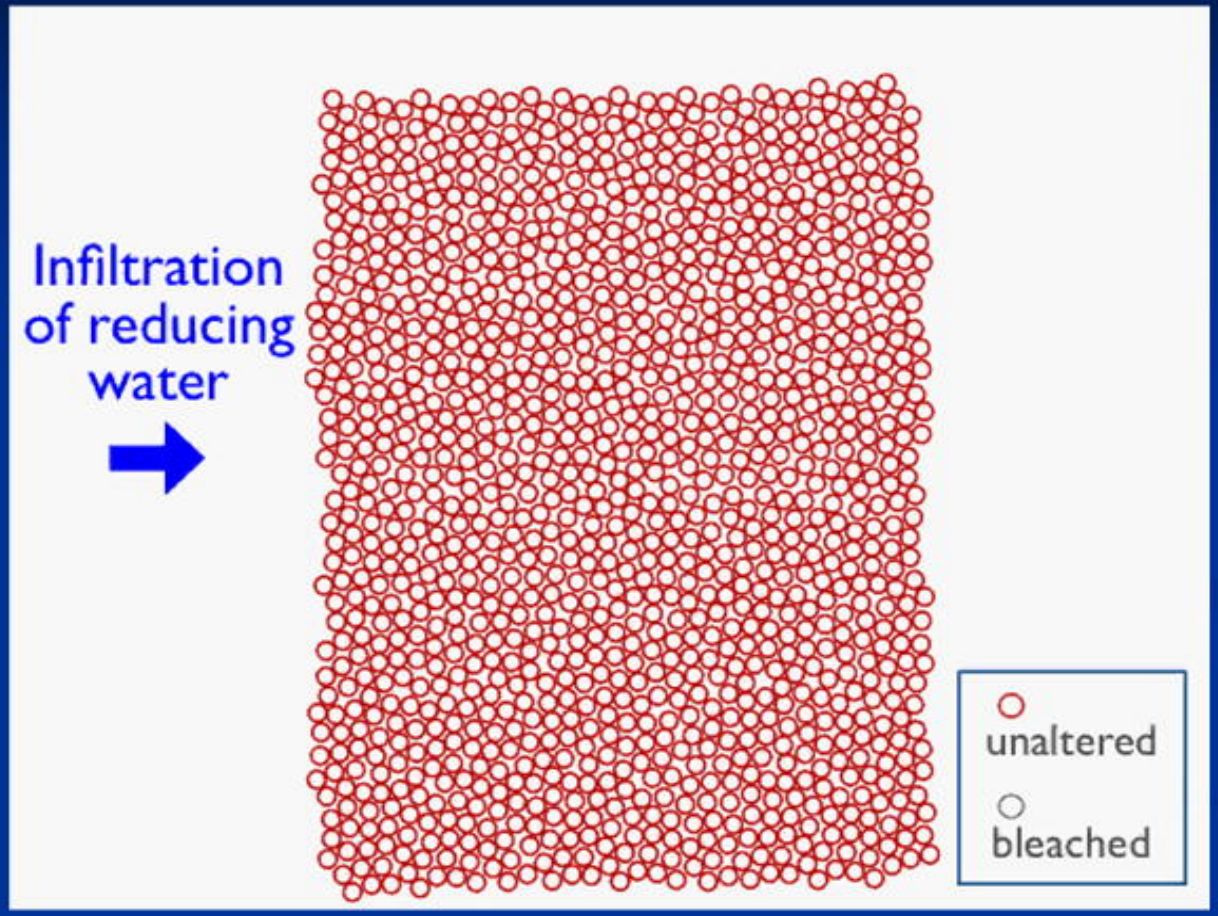
Sphere?



- No macro nucleus
- Minimum free energy shape in homogeneous host rock when diffusion transport

How do they "grow"?

1. Fe supply
2. Right chemistry
3. Advective flow
4. Diffusion, mass transfer
5. Ostwald ripening



Various Shapes, Sizes

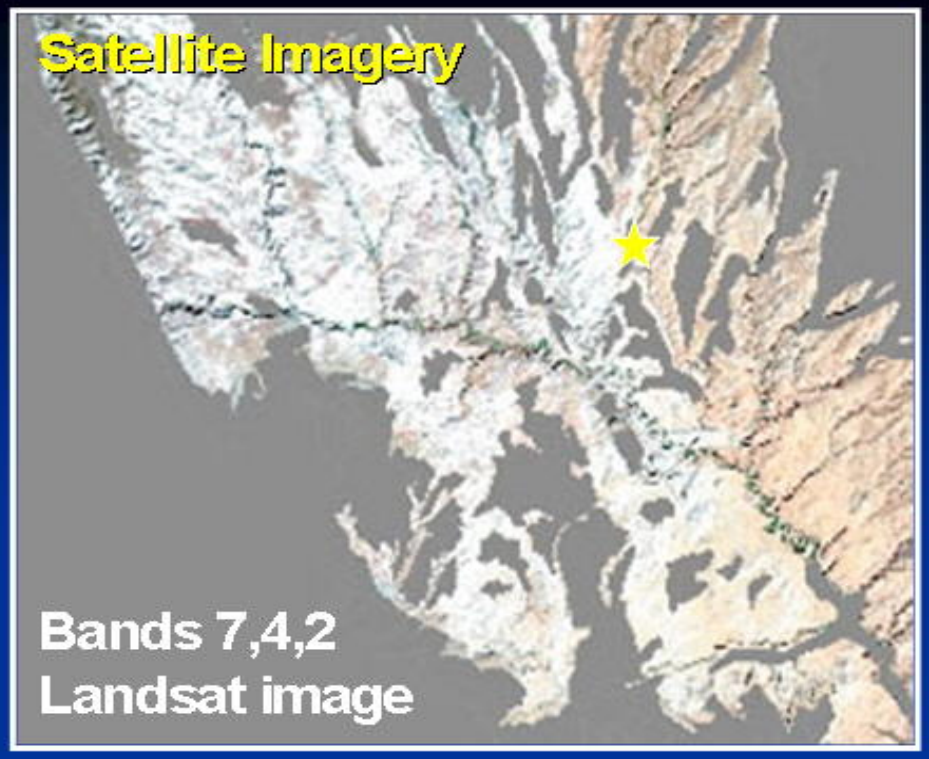
- host rock character
- nuclei, kinetics
- self-organization
- time, reactant supply
- organic influence

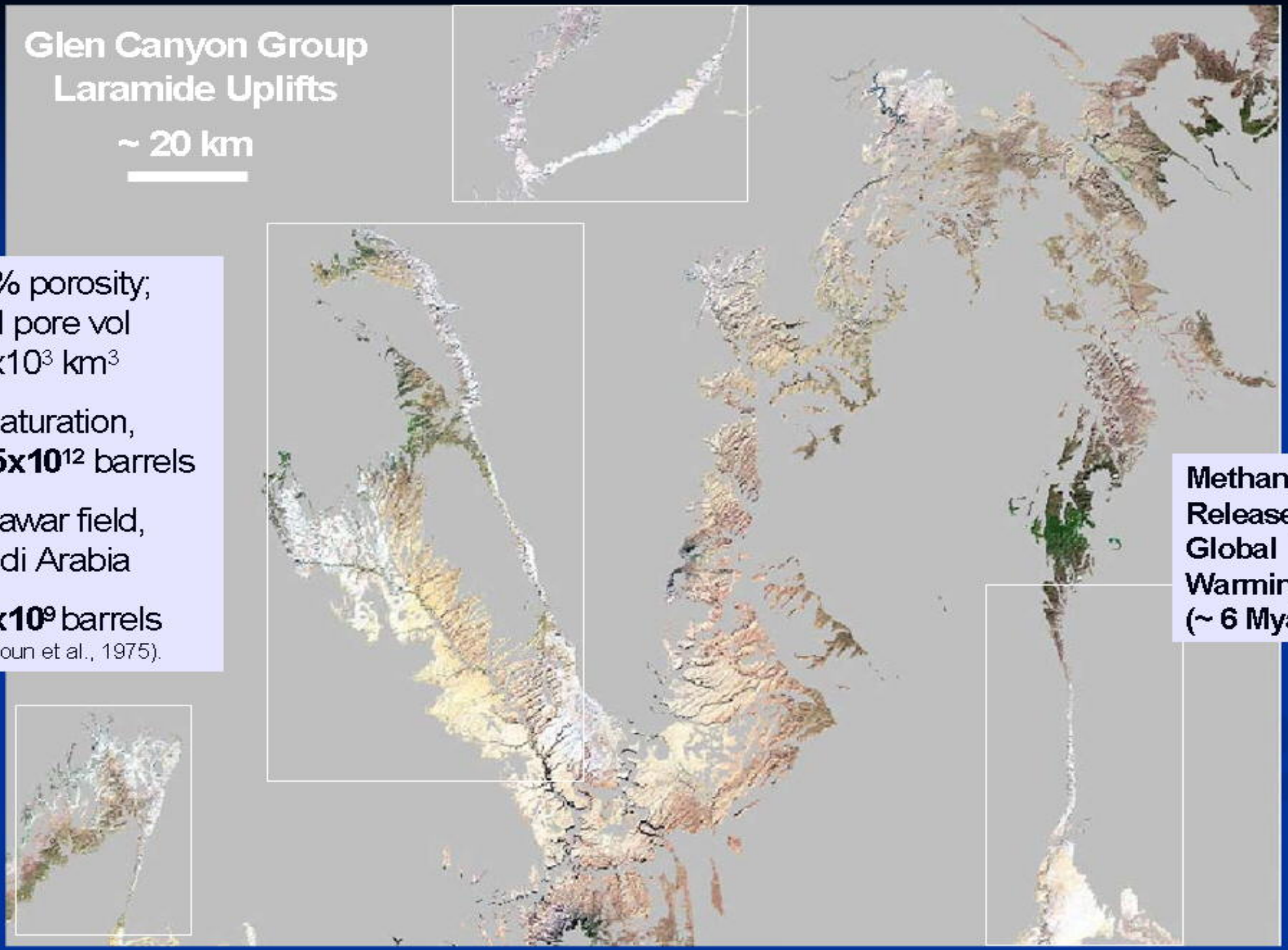
Many Varieties, Geometries

spheres

Many blueberry size

REGIONAL FLUID FLOW





- 15% porosity; total pore vol 2.2×10^3 km^3
- At saturation, **18.5×10^{12}** barrels
- Ghawar field, Saudi Arabia
- **80×10^9** barrels (Beydoun et al., 1975).

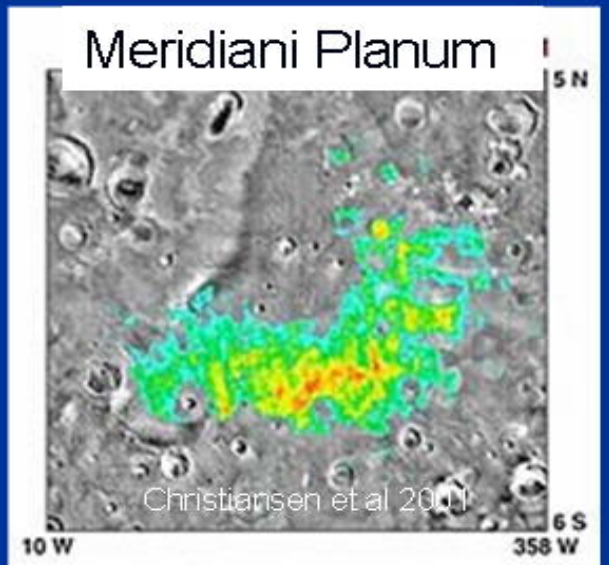
Methane Release, Global Warming? (~ 6 Mya)

Hydrocarbon Play Pays Off

April 2005

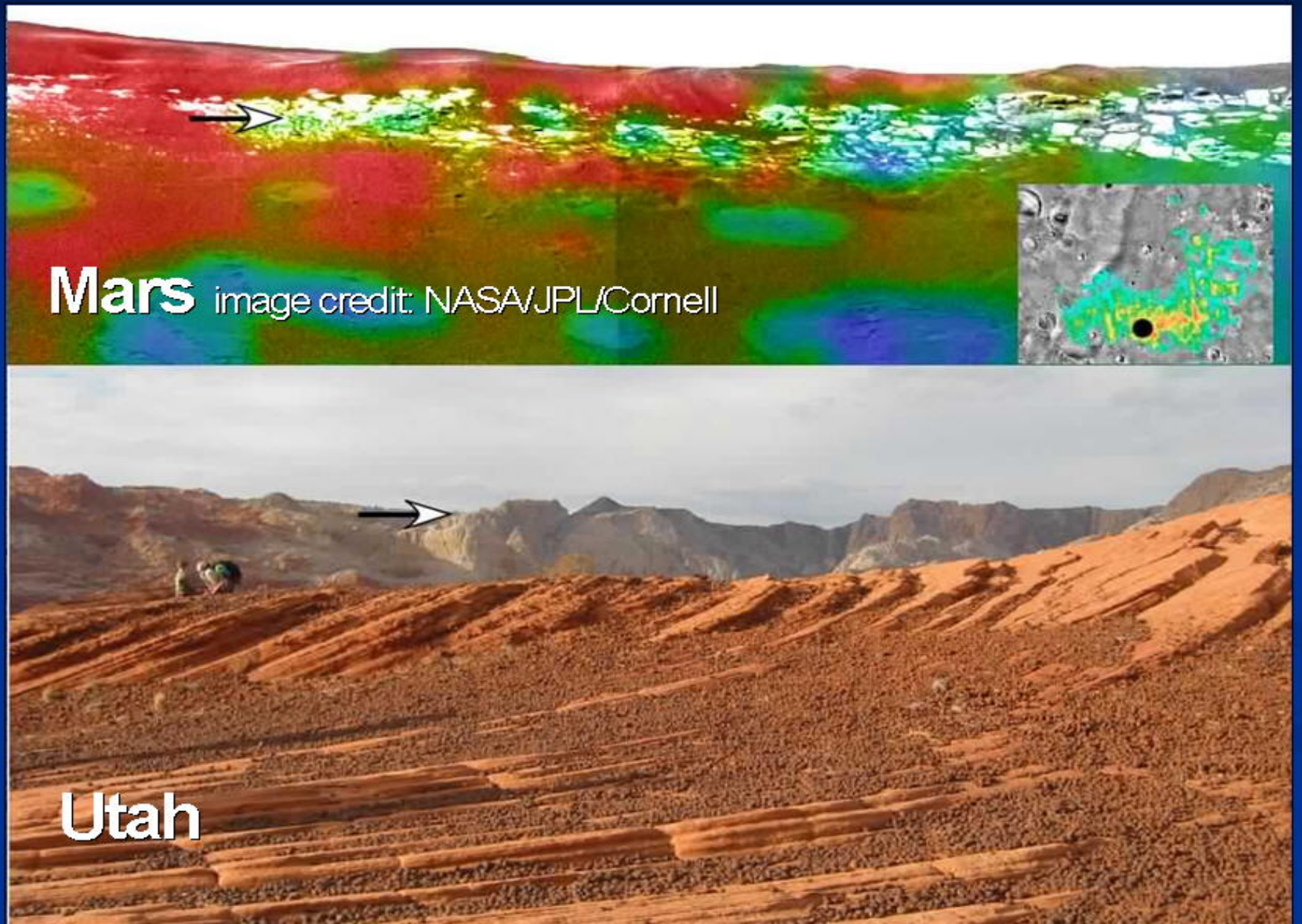
UTAH analog to MARS

- **Iron** = fluid flow indicator.
- **Implications** for water, fluid chemistry, host rock properties, & pathways.
- **Concretion** model = **Consistent** with Mars data.



Oolitic
Pedogenic
Fe-Mn nodules
Impact spherules
Accretionary lapilli

COMPARABLE IRON VARIATIONS



COMPARABLE ACCUMULATIONS

Mars

Utah

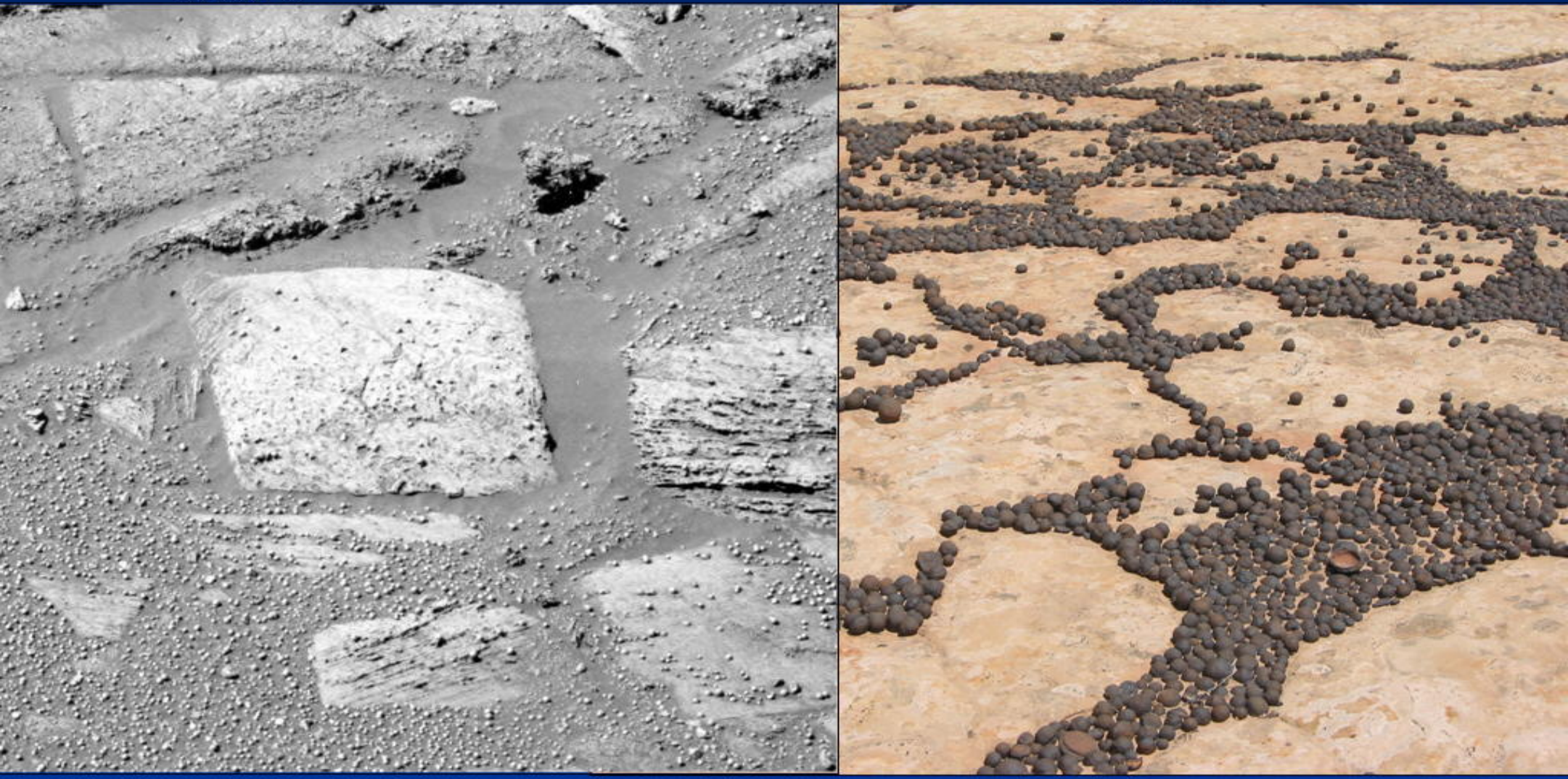
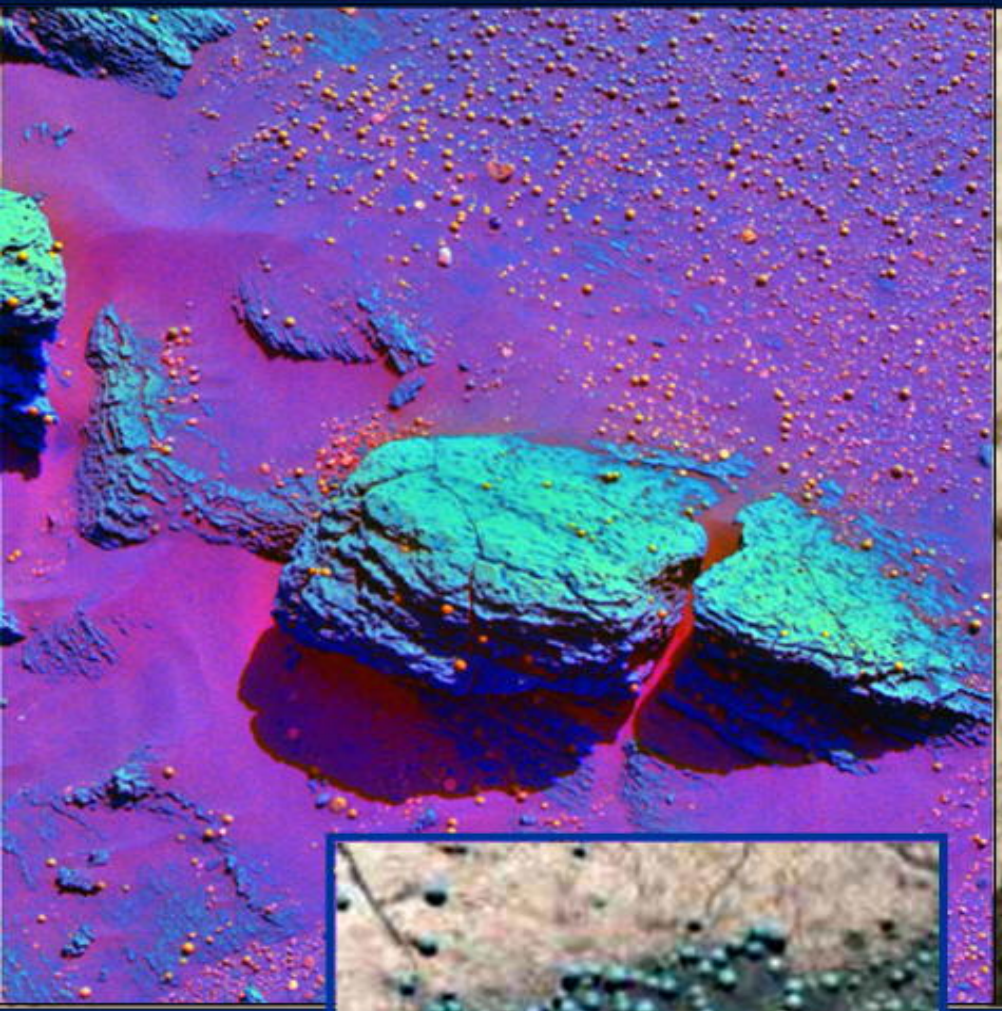


image credit: NASA/JPL/Cornell

COMPARABLE *IN SITU* DISTRIBUTION

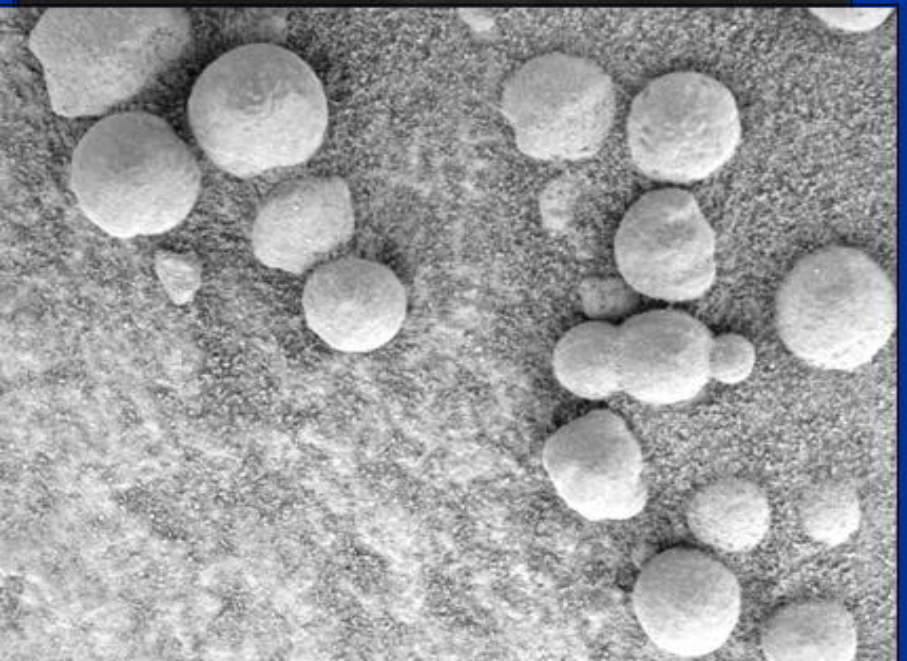


Mars

Utah

image credit: NASA/JPL/Cornell

COMPARABLE MORPHOLOGY



Utah

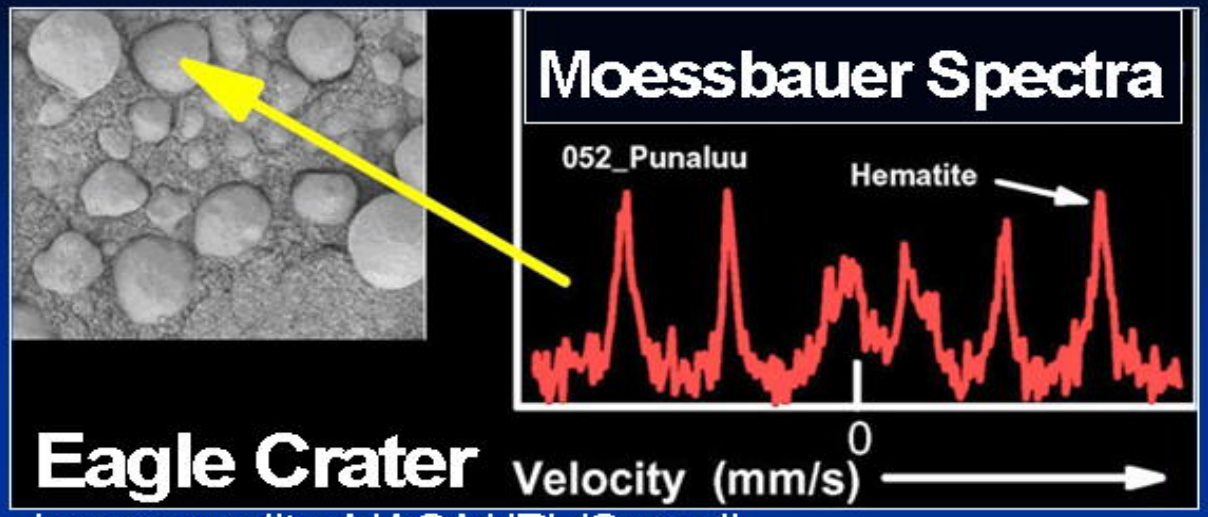
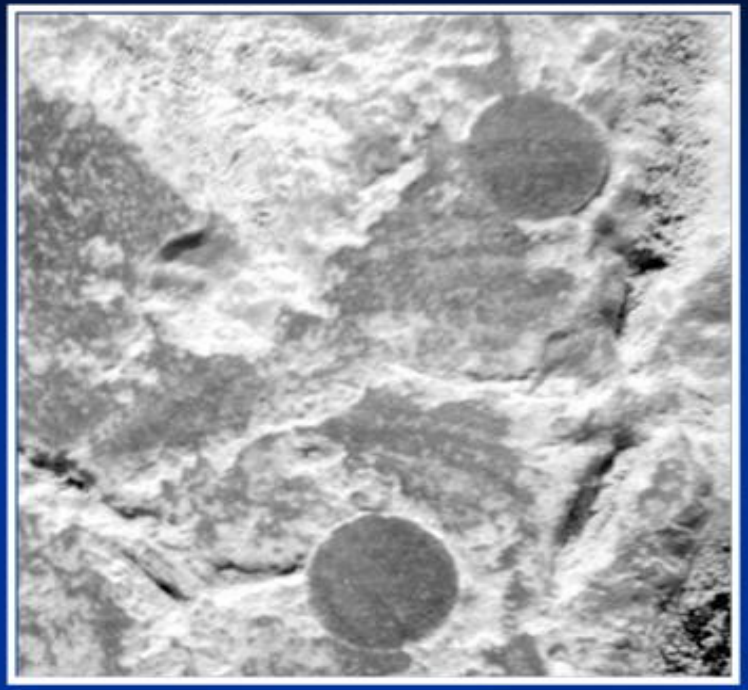
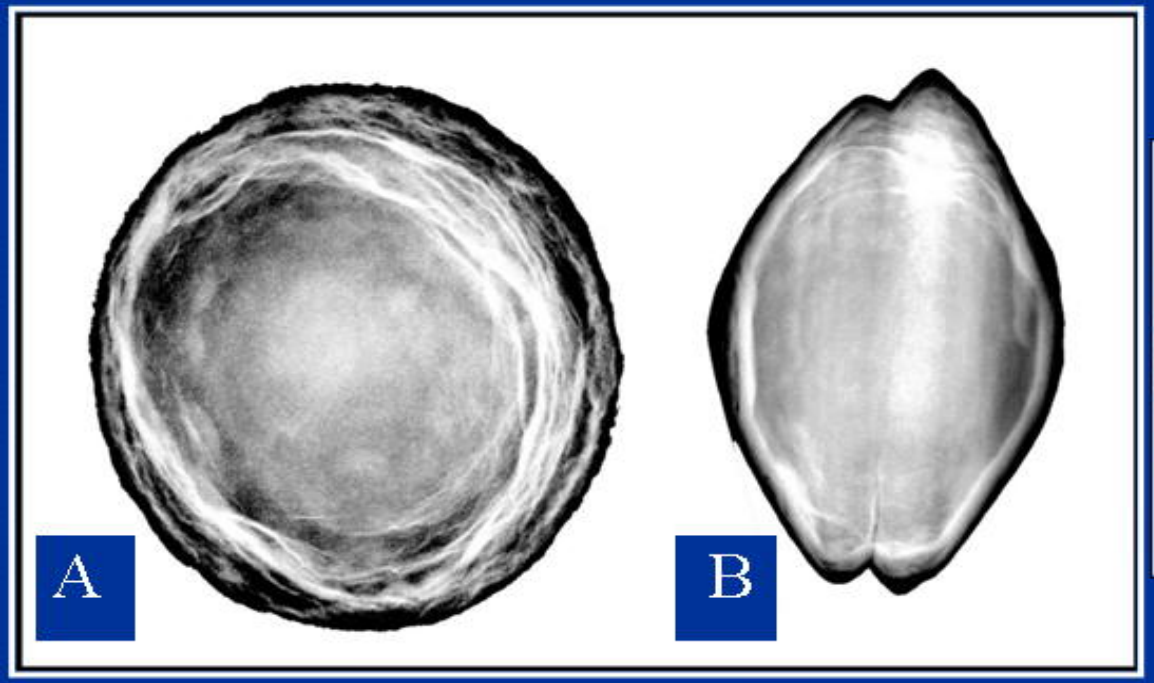


image credits: NASA/JPL/Cornell

Mars





Utah

1 cm

Mars "Popcorn" Utah

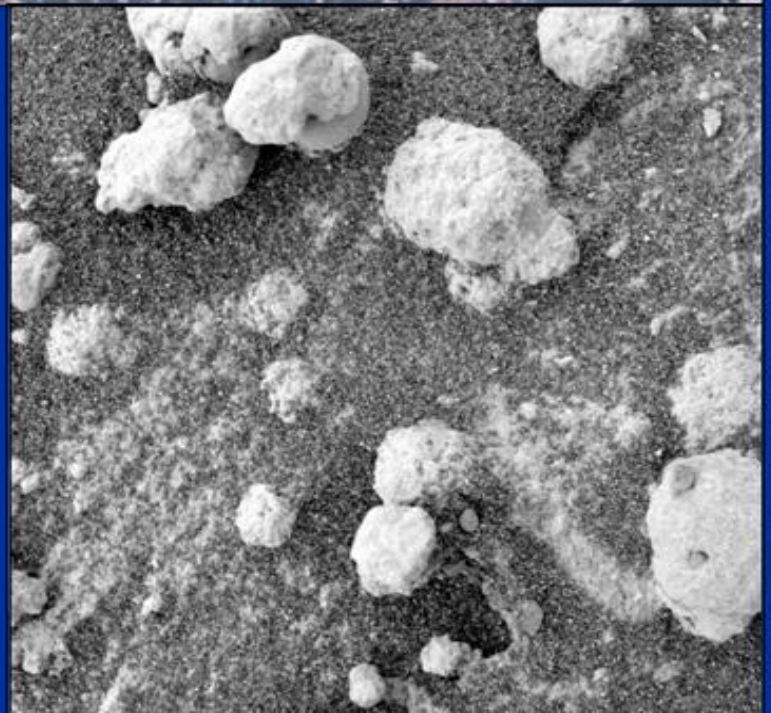


image credits: NASA/JPL/ Cornell

Preferential cementation along fractures, joints

Mars

Utah

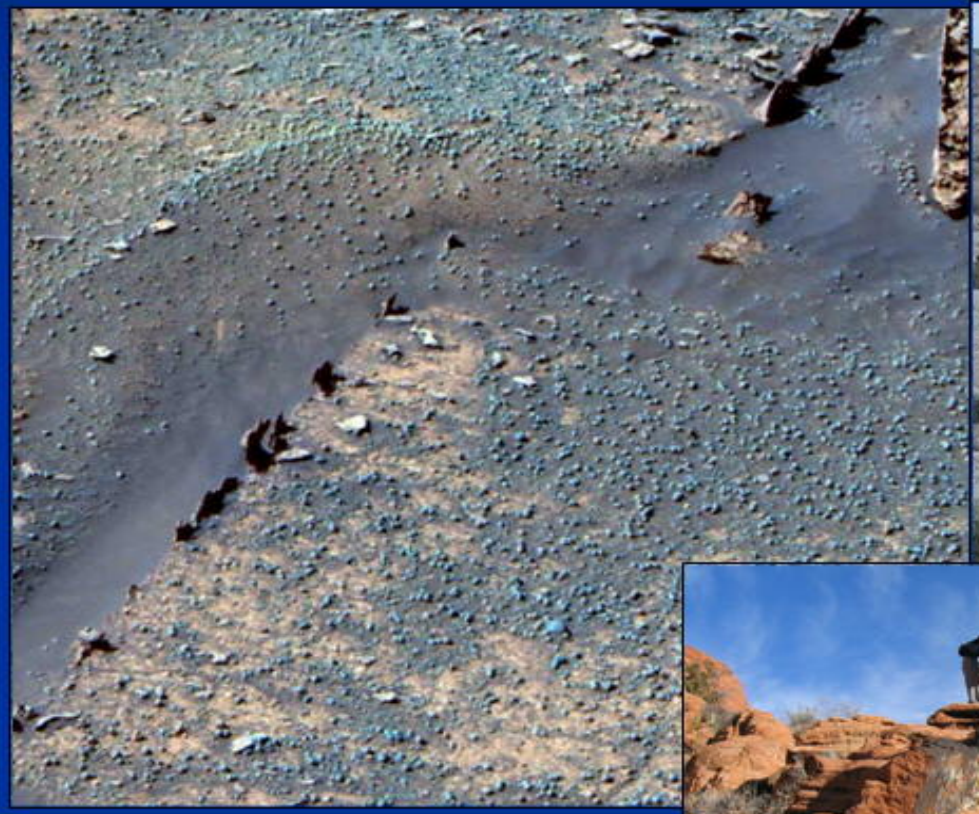


image credit: NASA/JPL/Cornell

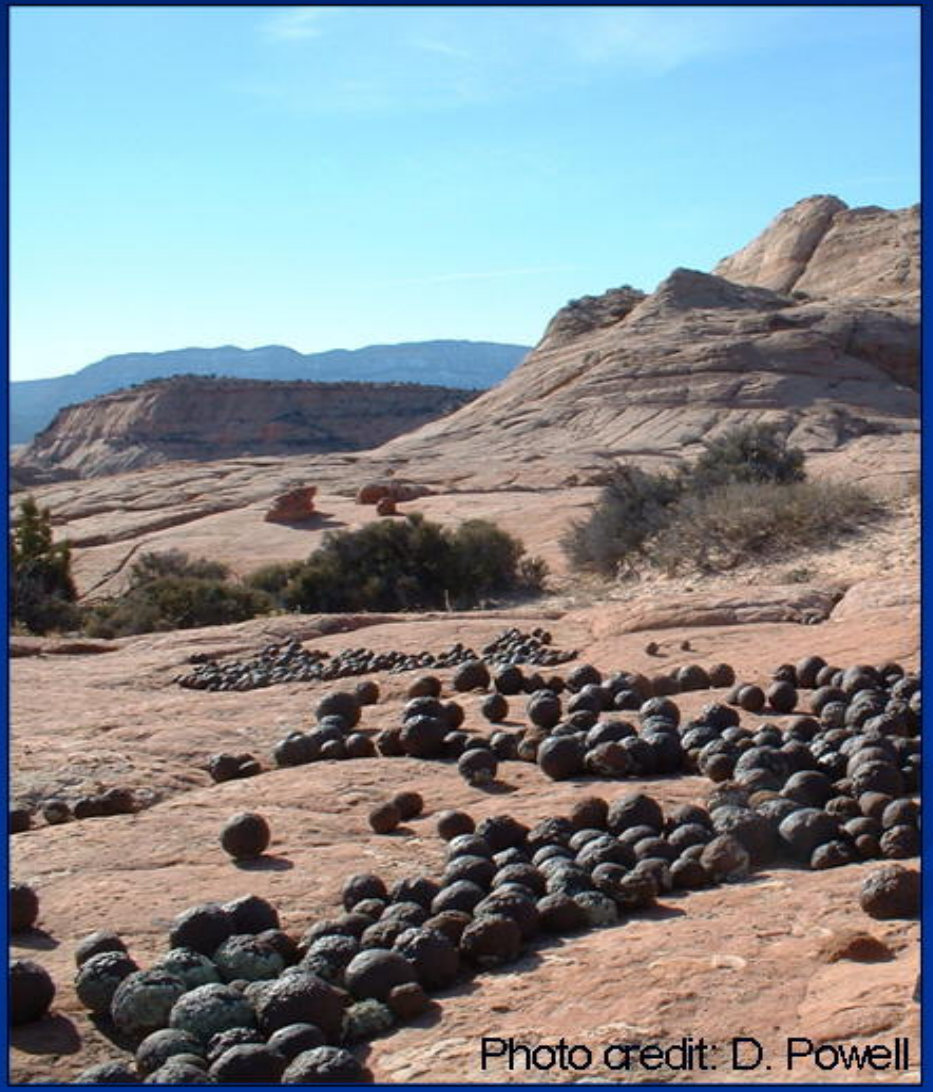
COMPARISONS

	UTAH	MARS
Host	Quartz sandstone	Fine-grain sed +sulfates?
Source	Grain coats	Basalt? jarosite?
Fe moving fluids	Reducing	Acid brine
Precip. fluids	O_2 groundwater	O_2 groundwater
Concretion	Insitu, within beds	Insitu, within beds
Cement	Hematite, goethite	Hematite
Geometries	Spherules + variety	Spherules + more
Accumulations	Surface + topo lows	Surface + lows
Crystals	Cement, $\pm$ crystalline	Pure, crystalline

Why more variety in Utah analog?

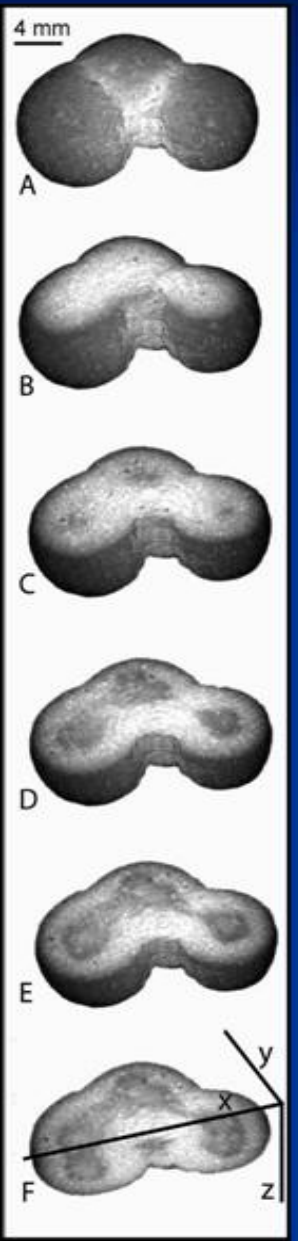
- Area 10s km^2
- More porous host
- Multiple waters + events
- Active plate tectonic regime
- More fluid paths

Not perfect, but variability helps us better understand processes!



Life on Mars?

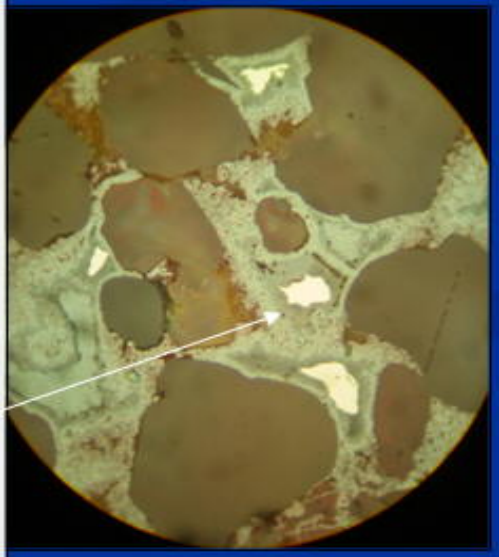
- Biosignatures



Current Work

- Concretion geometry
- Mineralogy
- Spectral character
- Chemical modeling
- Fe Isotopes
- Fluids (inclusions, GC)
- Variations

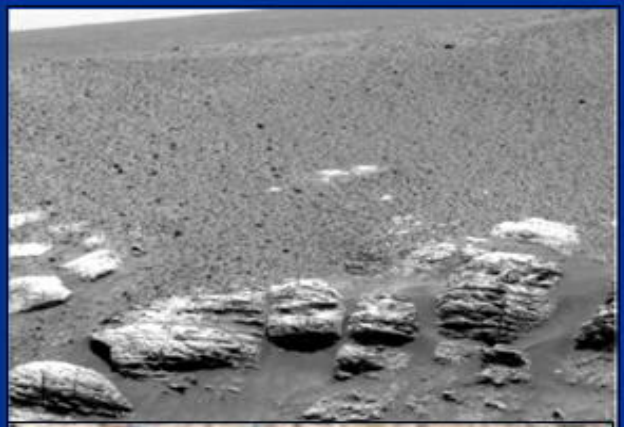
0.015 mm



0.015 mm

SUMMARY

- **RED ROCK**
  - Iron → fluid flow
  - Colors:
    - Red (original)
    - White (bleached)
    - Dark (concretions)
  - **Field + satellite mapping** show fluid paths
    - up to reservoir scales
- **RED PLANET**
  - Analog → Fe mobility
  - Concretions preserve diagenetic history
  - Saturated fluid flow
  - Watery history, ET life?
  - Sample return mission - 2013?



ACKNOWLEDGEMENTS

NASA - MER team (NASA web page + Science Dec. 3, 2004)

Funding: American Chemical Soc., Grand Staircase-Escalante Nat. Mon.

Modeling: Tony Park, Sienna Geodynamics & Consulting Inc.