4th MSL Landing Site Workshop - Sept., 2010

FACIES PREDICTION ON MARS

Optimizing exploration for organic biosignatures

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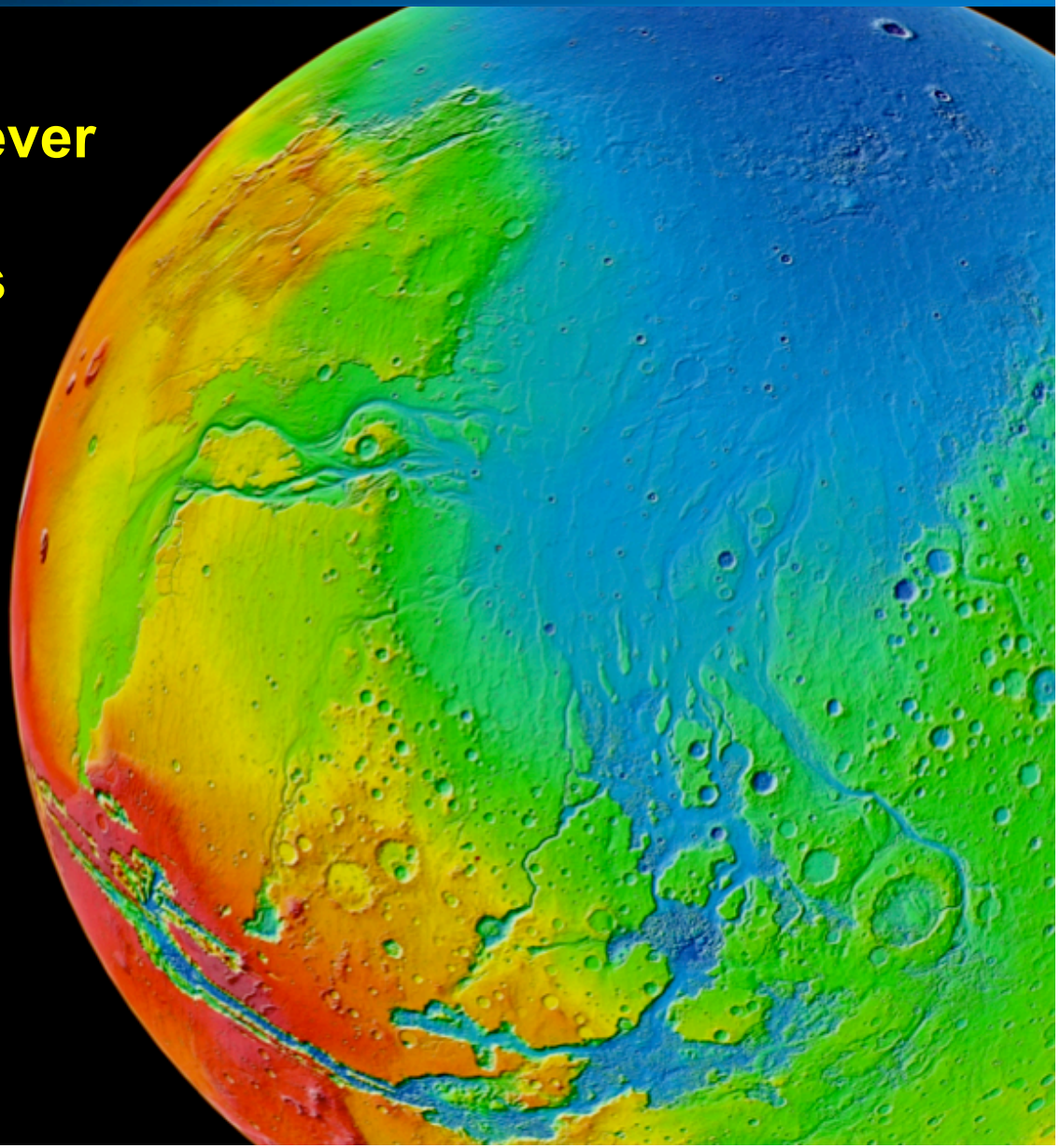
Determine if life is or ever was present on Mars

Biosignatures

Early Mars - More habitable

Early Earth - Analogs



Life on Earth & ?Mars?

Microfossils, Biomarkers, Stromatolites

Life - abundant and diversified on Earth

by at least ~ 3 Ga and likely by ~ 3.4 to 3.5 Ga

Mars

Reasonable chance that life developed similarly - in habitable

periods of Late Noachian / early Hesperian

Organic Biosignatures

"Of … biosignatures,

the most easily detected and the least ambiguous

would be

accumulations of organic matter."

(Summons *et al*., 2010. Identification of biosignature preservation windows to guide MSL landing site selection. *AbSciCon* Abs. # 5256).

Organic - Rich Shales & Mudstones

- Present on Earth > 3.2 Ga to present
- Widespread - many geologic settings
- Repositories for majority of organic carbon on Earth
- Common - even when morphological fossils not preserved

Organic – Rich Shales / Mudstones

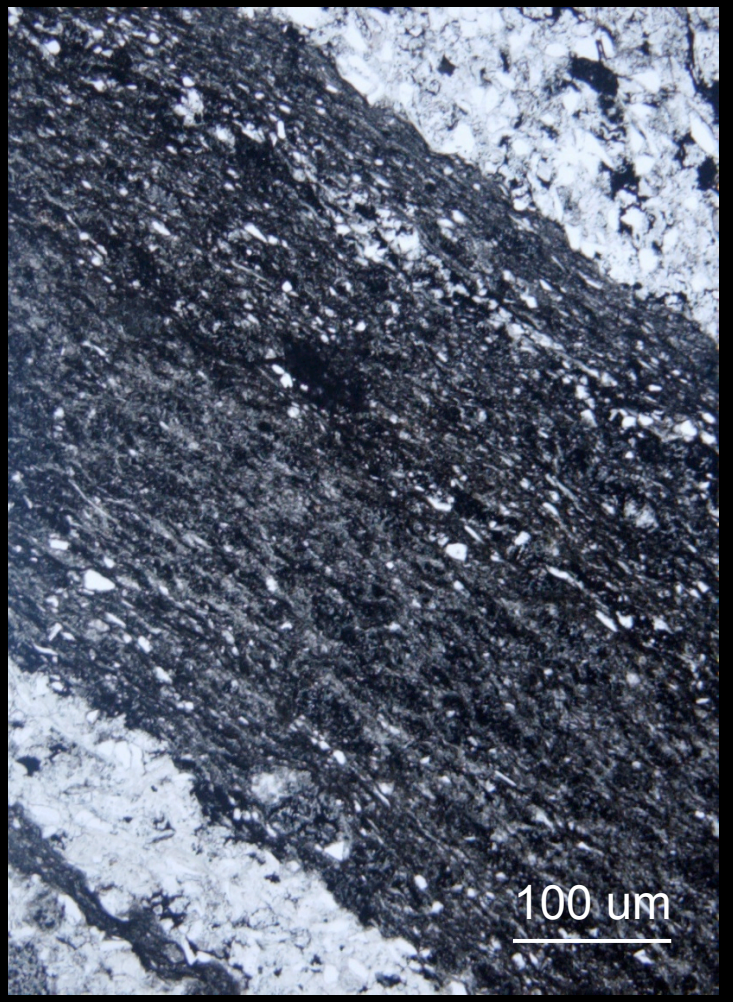
- Organic Matter

concentrated & *preserved*

- "Source Rocks" for Oil and Gas

- Decades of Experience -

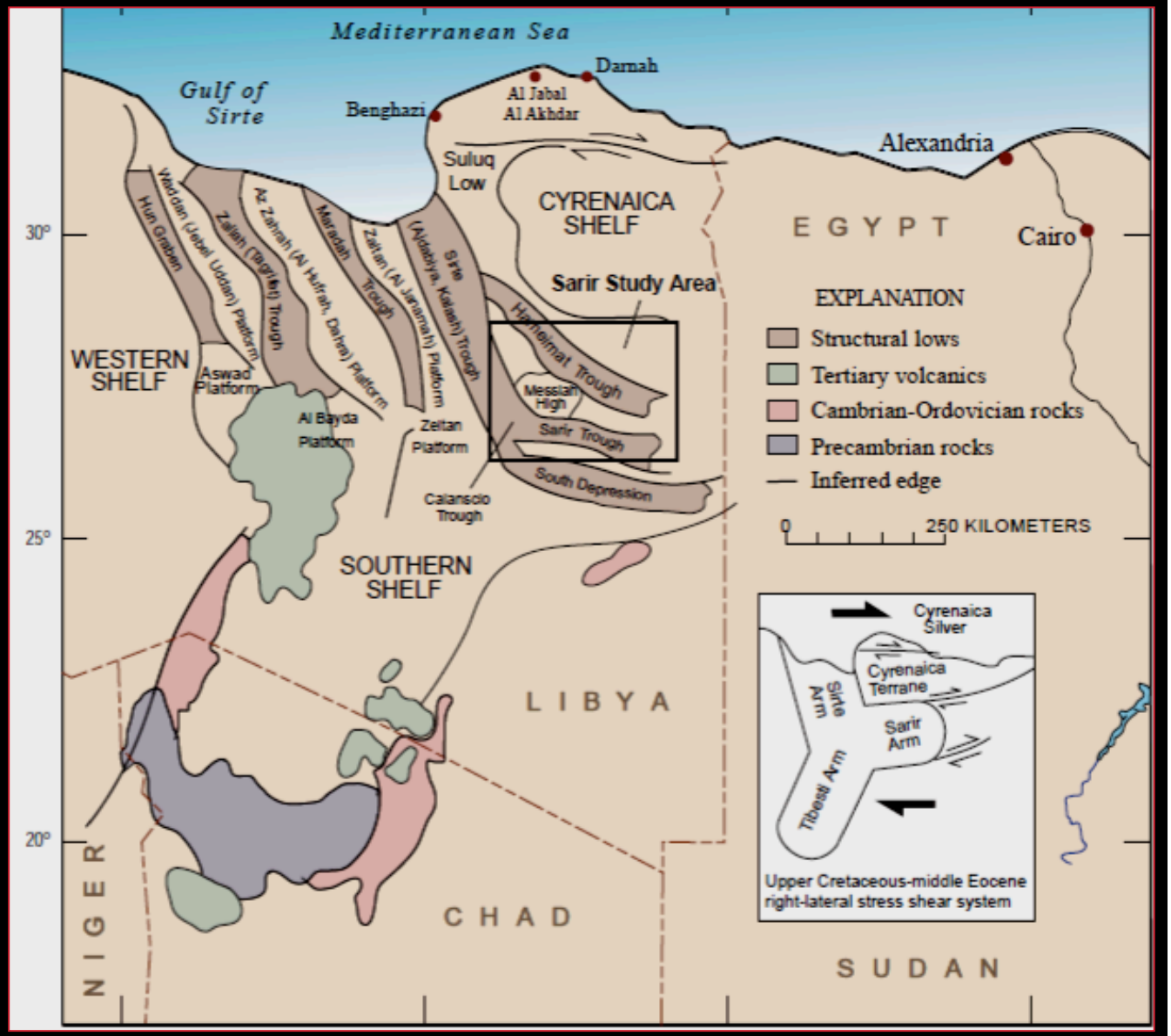
Occurrence of "Source Rocks"



~ 3.24 Ga

Source Rocks - Basins

Basins "house" the Earth's source rocks



Ahlbrandt, 2001. The Sirte Basin Province of Libya. Sirte-Zelten. Total Petroleum System. *USGS Bull. 2202F*

Source Rocks – Concentration - Basins

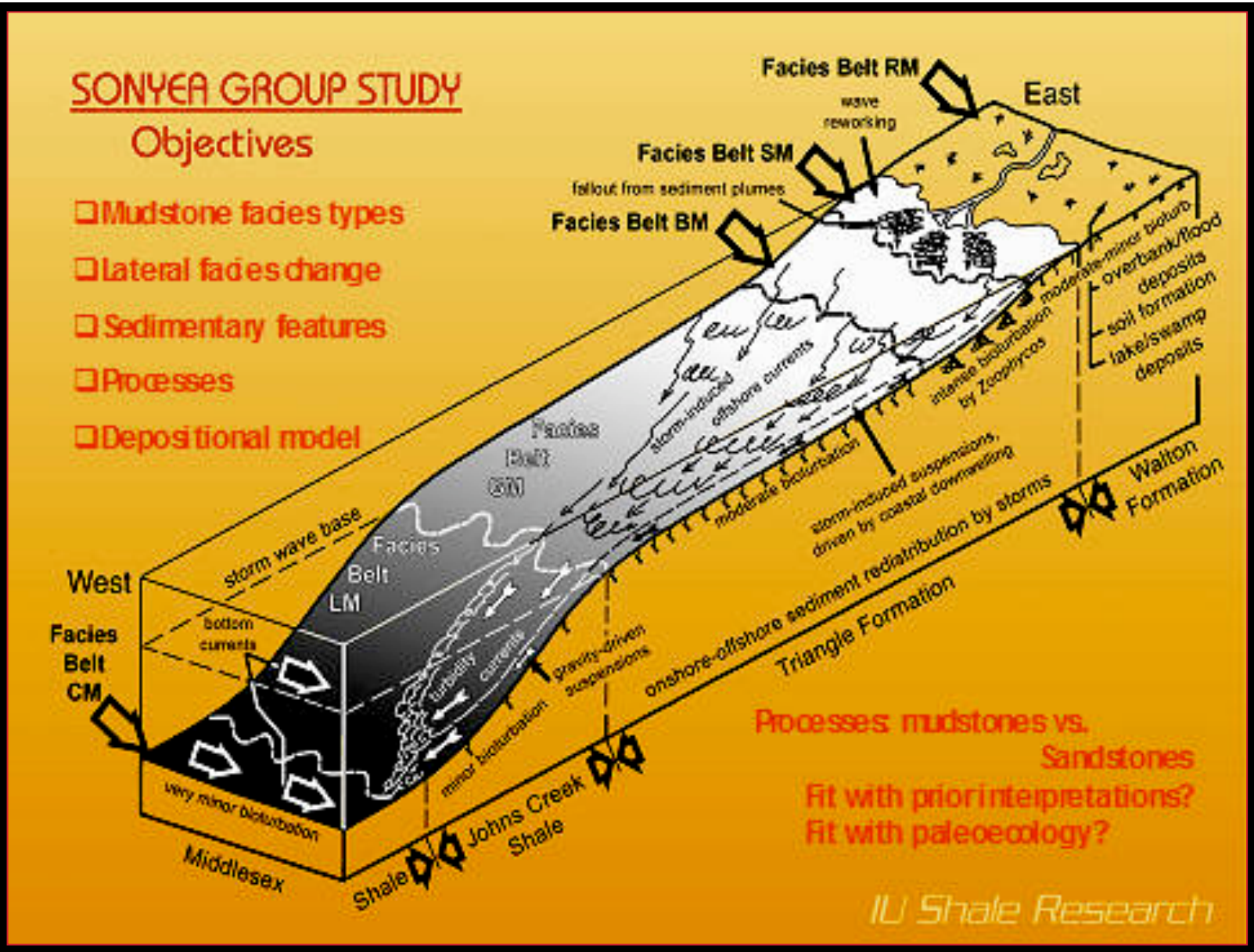
- **Basinal Settings**

(*in-situ* microbiotas - water, nutrients)

- **Distal Facies / Fine-grained sediments**

(lack of dilution by coarse sediments:

in-situ & transported organics)



Schieber, J., 1999. Distribution and deposition of mudstone facies in the Upper Devonian Sonyea Group of New York. J. Sed. Res. 69, 909-925.

Preservation - Critical

Mars - Surface Processes Destructive to Organics

- Oxidation – peroxides
- UV / Cosmic radiation
- Photocatalytic Decomposition (Iron III)

"No safe haven" because destructive radicals "small, reactive, and mobile."

(Shkrob *et al.*, *Astrobiology*, 2010)

Preservation of Organic Matter

Concentration of Organics

(geologic context & facies)

Sediment Type

(fine-grained matrix, mineralogy [clays])

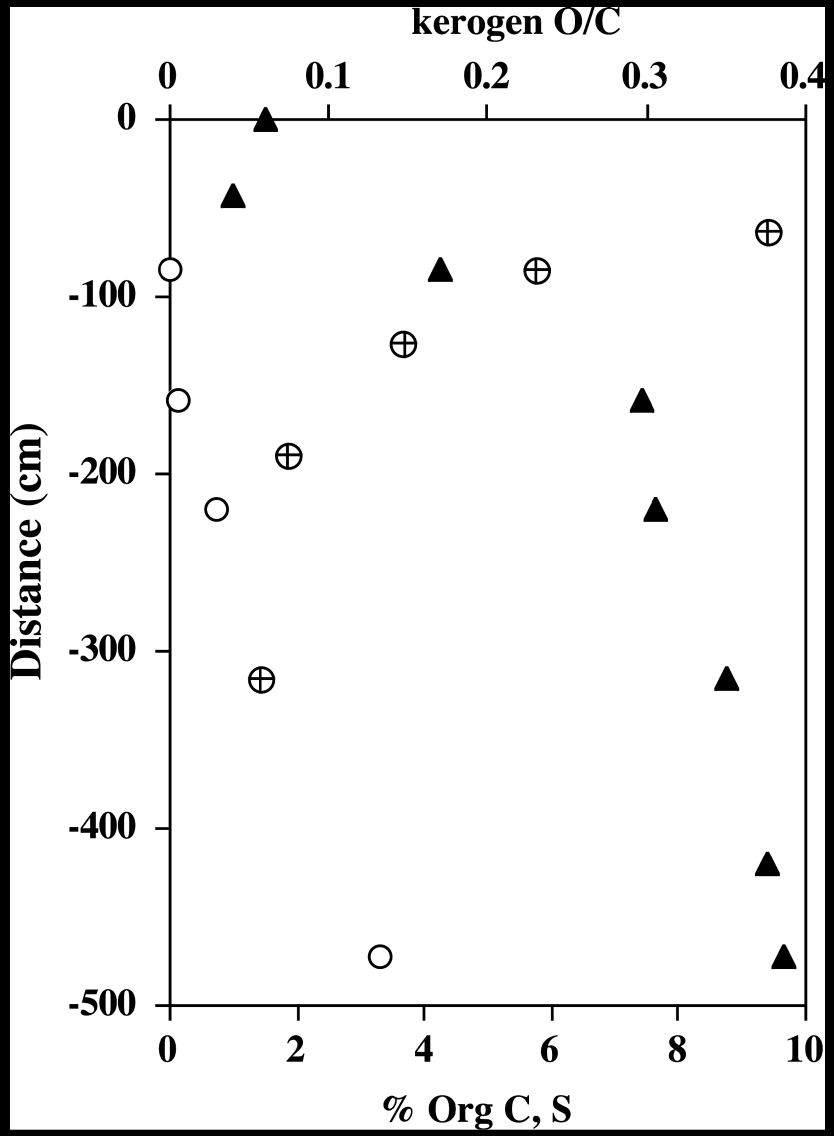
Burial

(compaction / lithification; seals for gas)

Concentration of Organics

Devonian Chattanooga Shale in Outcrop - DeKalb County, Tennessee
(J. Schieber,
http://www.uta.edu/paleomap/homepage/Schieberweb/images/Flynn%20Creek/hurricane_bridge.jpg)

Oxidative Weathering of the Devonian New Albany Shale



WILDMAN, BERNER, PETSCH, BOLTON, ECKER, MOK, & EVANS.

The weathering of sedimentary organic matter as a control on atmospheric O2. I. Analysis of a black shale.

Amer. Jour. Science 304, 234–249 (2004).

Sediment Type – Coarse Grained

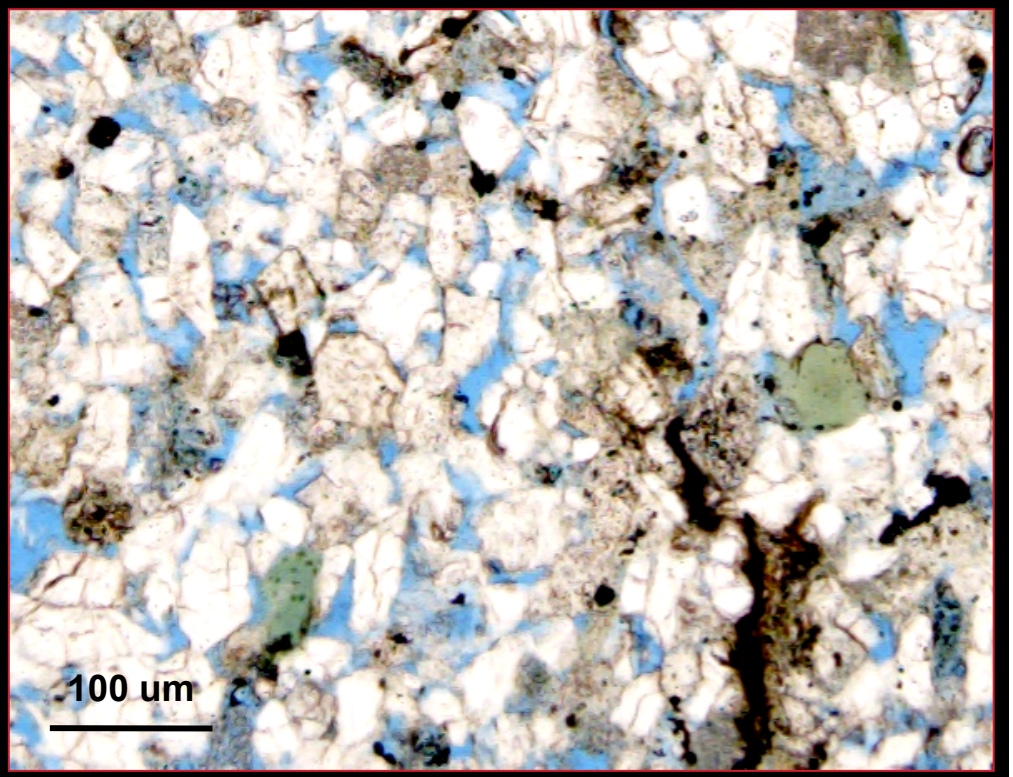
Sandstones = 0.06 mm - 2 mm

Pebble/Gravel Conglomerates = 2 - 64 mm

Porosity

Proximal Facies

(alluvial fans and pebbly braided river deposits)



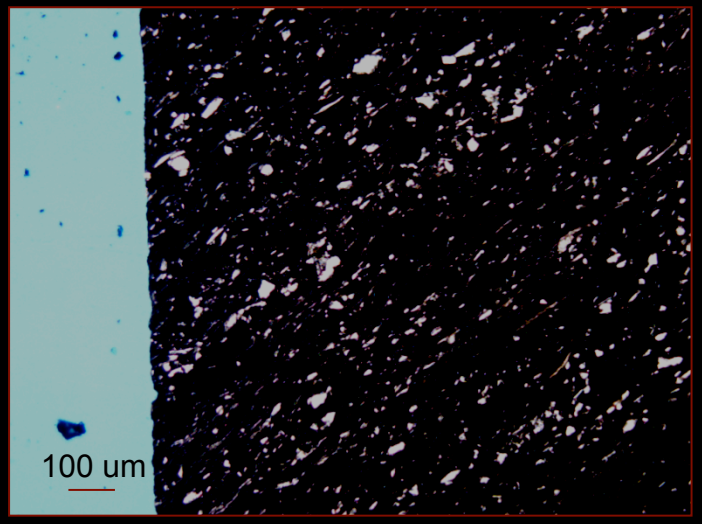
Sediment Type – Fine Grained Organic-Rich

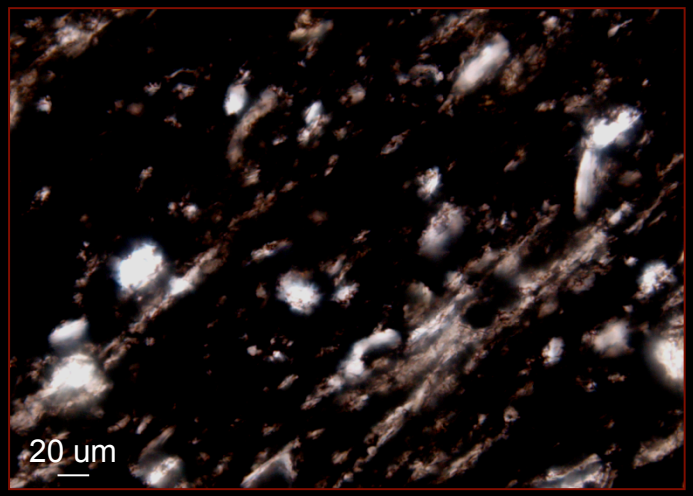
- Siltstones - 20 to 60 um;

Shales / Mudstones < 20 um

- Limited Porosity & Permeability
- Seals for Oil and Gas
- Distal Facies

(shales, mudstones, marls, evaporites)





Shales / Mudstones - Burial

Lithified - due to burial & compaction

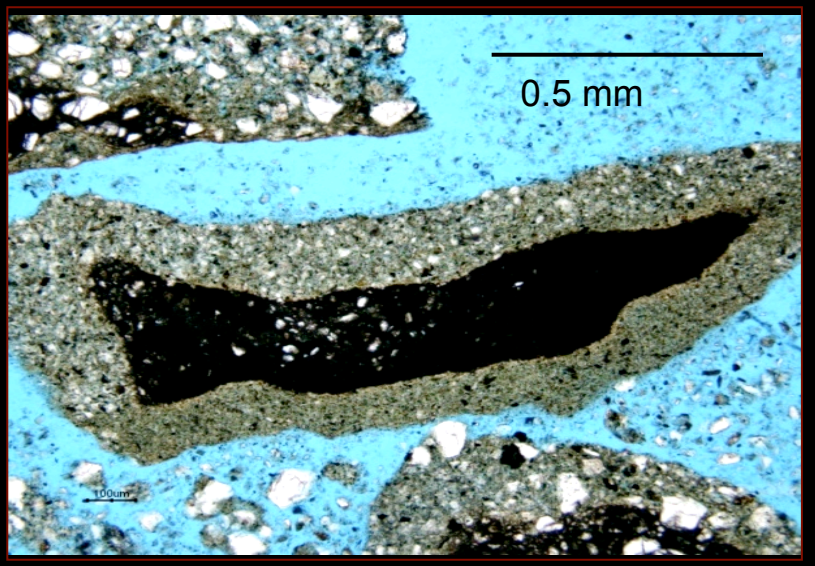
Lithification - porosity & permeability reduced

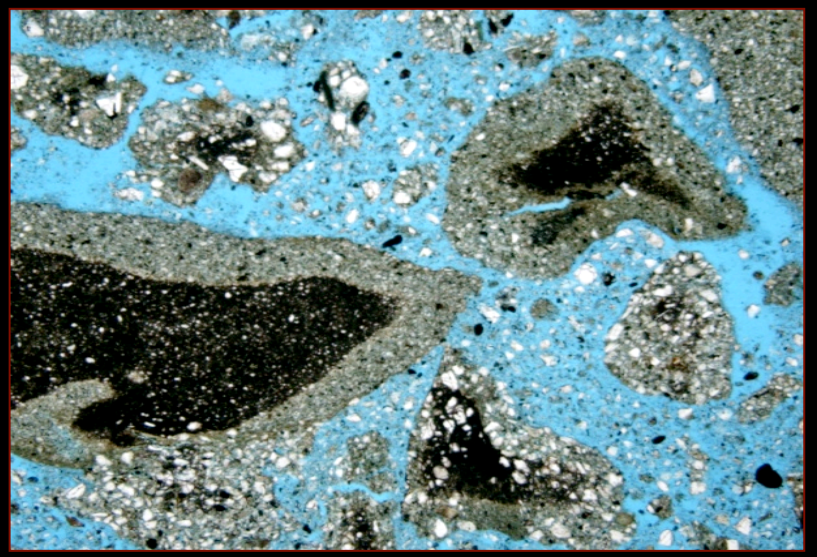
Alteration rinds

but

internal core appears unaltered

Time Factor ??





Identifying & Highgrading Basins for Source Rocks

- Topography - Basin Architecture
- Drainage - Sediment & Fluid input
- Depositional History - Timing
- Organic Concentration - Facies
- Preservation - Facies, Mineralogy, Burial, Post-depositional processes

Best Basins for Source Rocks

Many things must come together

(from, Frontier & Underexplored Basins of the World, *Petroleum Economist Energy Map Series No. 24)*

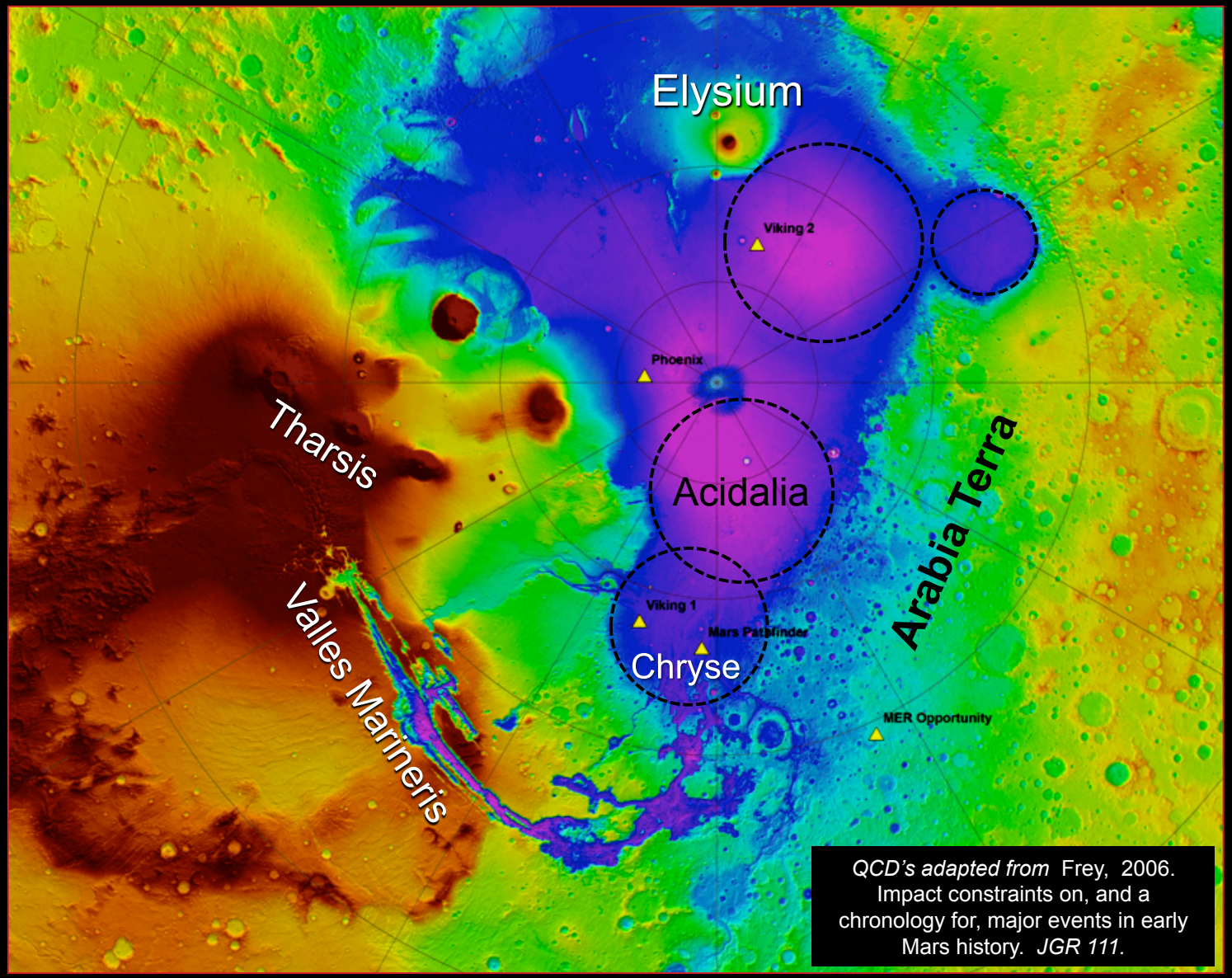
Orbital Data – Sediment Prediction

- MOLA -- Topography - Basin Architecture

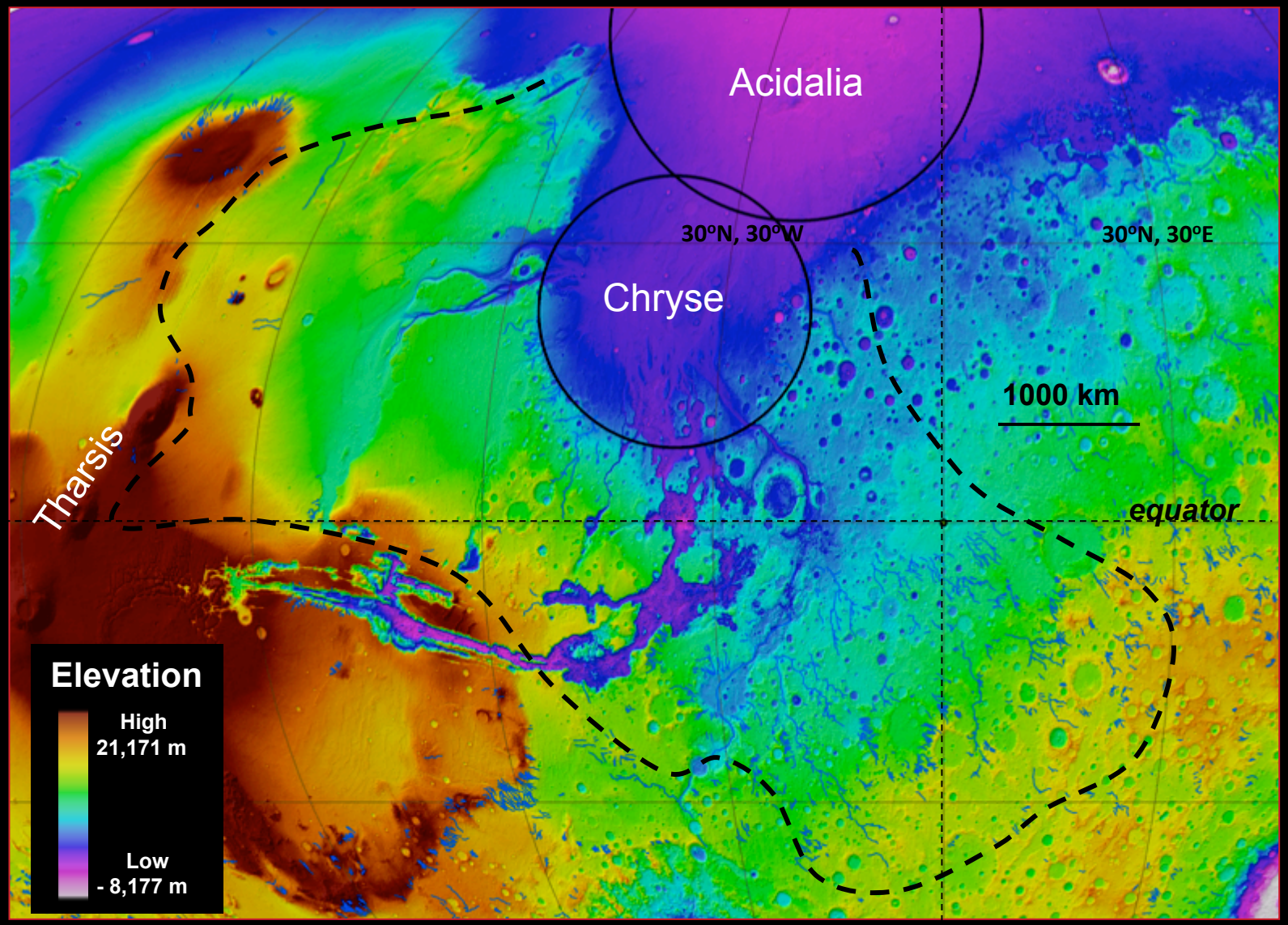
- MOLA, THEMIS IR & VIS, CTX, HRSC --
  Drainage - Sediment Input, Character, Deposition, Burial

- MOLA, THEMIS IR & VIS, CTX, HRSC, MOC, HiRISE, CRISM / OMEGA --
  Facies, Mineralogy, Post-depositional Processes

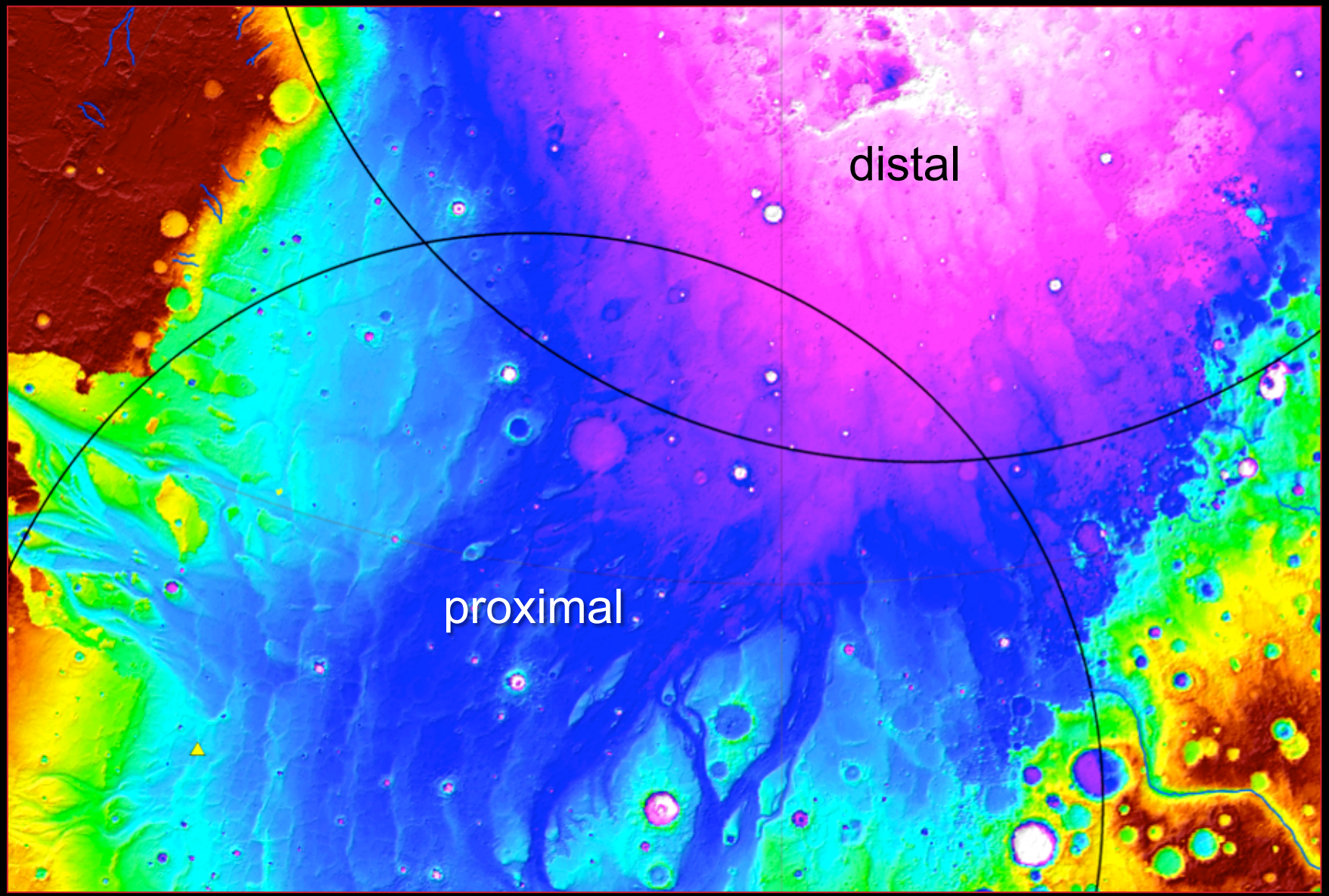
Regional Setting



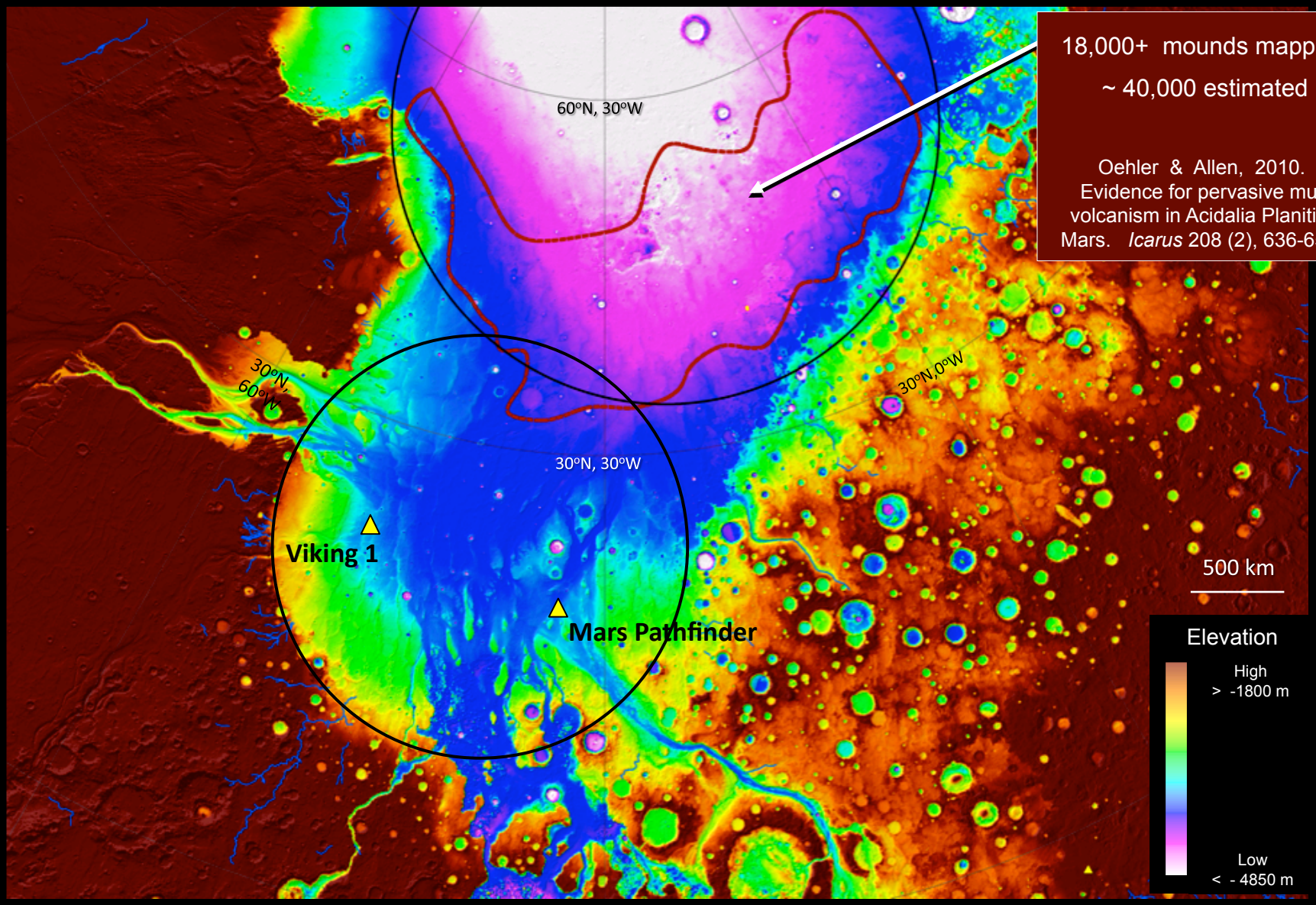
Drainage


Acidalia
30°N, 30°W
Chryse
30°N, 30°E
1000 km
Tharsis
equator
Elevation
High
21,171 m
Low
- 8,177 m

Stretched MOLA - Facies



Mud Volcanism in Acidalia



Optimizing the Chances of Finding Organic Biosignatures

Regional Geological Context

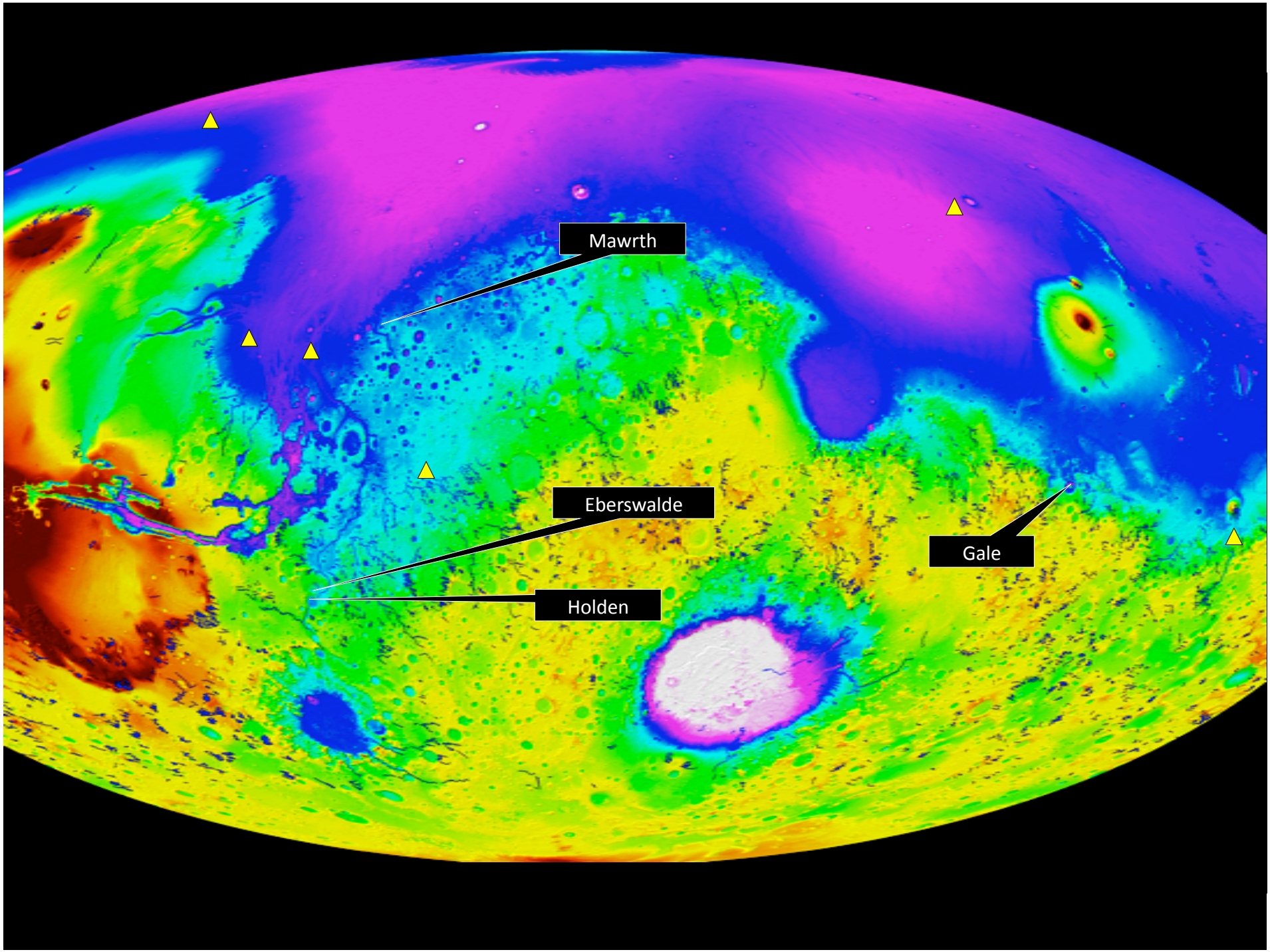
- Where are basins (containers)
- Where would water have accumulated & have been long-lived
- What type of sediments would have flowed into basin

Facies

- Where would distal facies / condensed sections occur

Burial / Mineralogy / Post-depositional Processes

- What is the likely history of burial / compaction
- Clays, sulfates, silica
- Length of time of exposure to surface
- Where would burial, facies, & mineralogy provide best Isolation from surface destruction of organics


Mawrth
Eberswalde
Holden
Gale