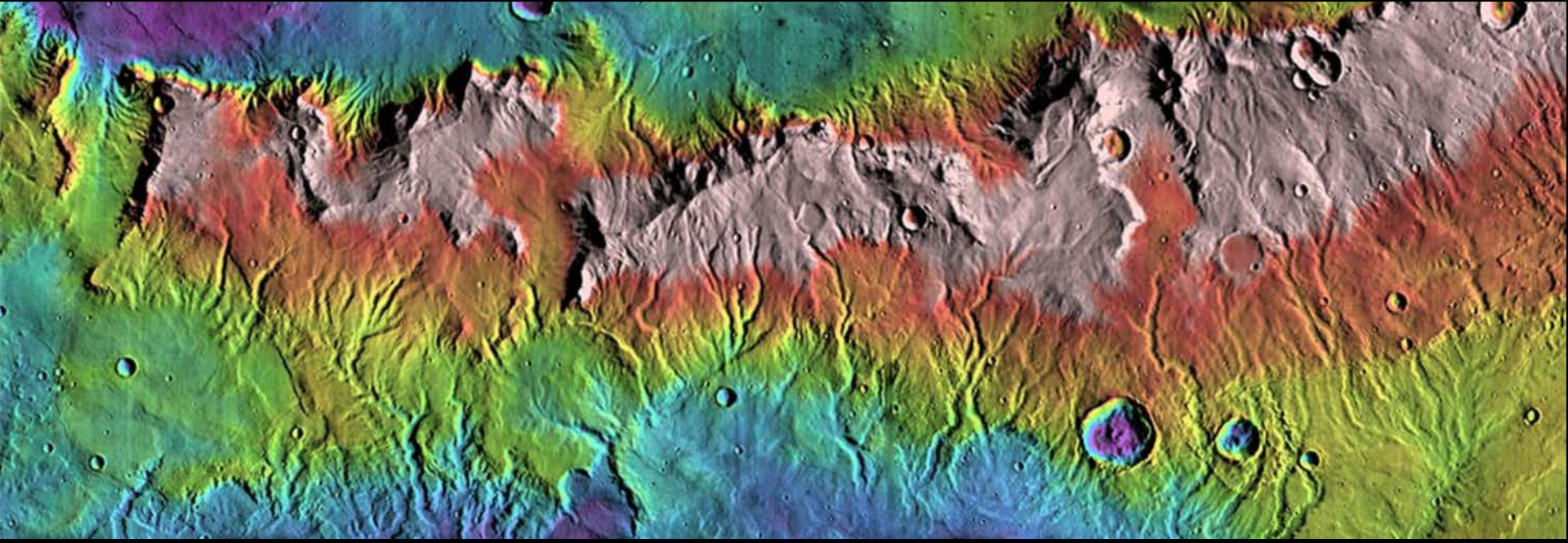

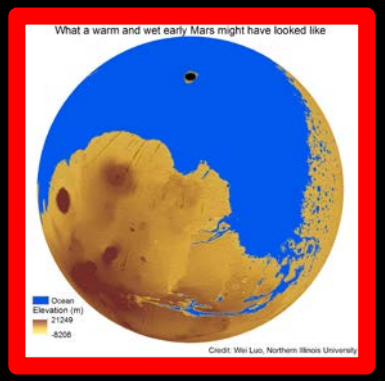

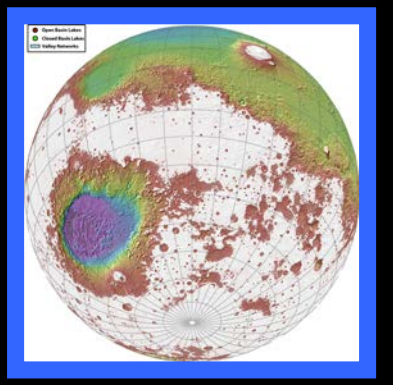

Planetary Science Decadal Survey 2022-2032 Panel on Mars Meeting No. 9; February 9, 2021

Discussion of Mars Geology: Early Mars/Paleoclimate:

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Key Geological Elements in Deciphering The Early Climate History of Mars

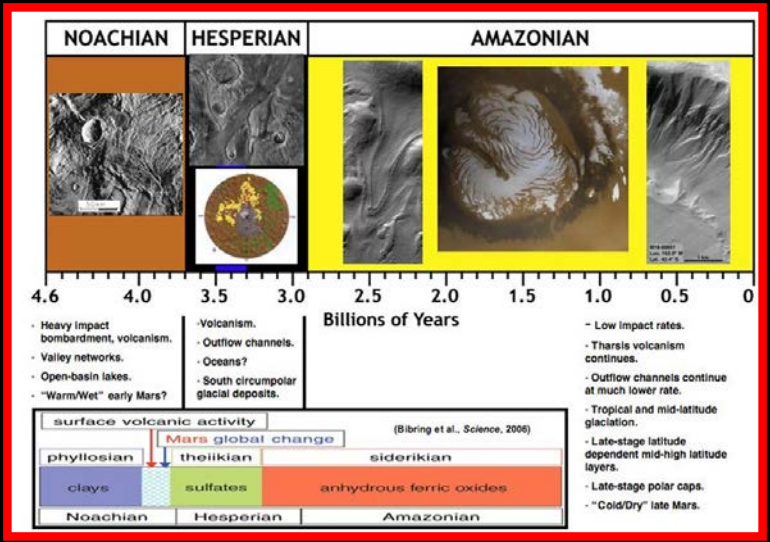
- 1) **Water:** Its historical abundance, state and distribution?
- 2) **Alteration mineralogy:** Its relation to geological/climatic environments?
- 3) **Fluvial/lacustrine and degradation features:** Their relationship to evolving climate and the atmosphere (pressure, temperature, composition, behavior and loss rates)?

Key Geological Elements in Deciphering The Early Climate History of Mars

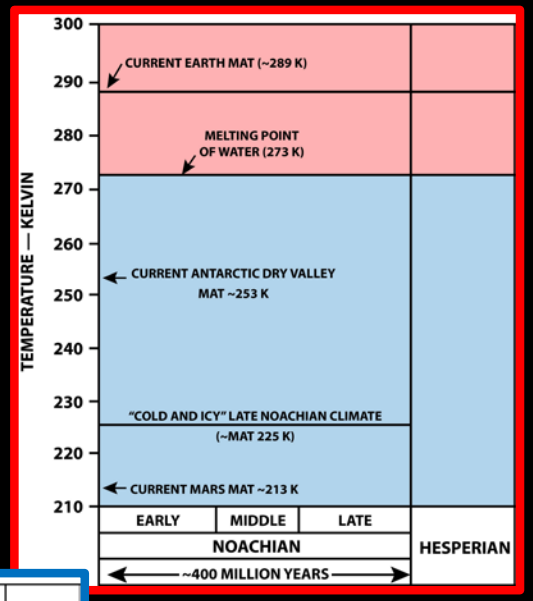
- 1) **Water:** I[illegible]istorical abundance, state and distributi[illegible]
- 2) **Alte**[illegible]**tion** to geological/c[illegible]
- 3) **Fluvial/lacustrine and** [illegible]**heir** relationship to evolving climat[illegible]**here** (pressure, temperature, compositi[illegible]**and loss** rates)?

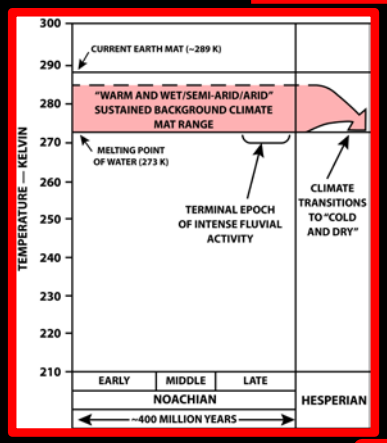
1) Geological Process Approach.
2) Stratigraphic Approach.
3) Climate Modeling Approach.

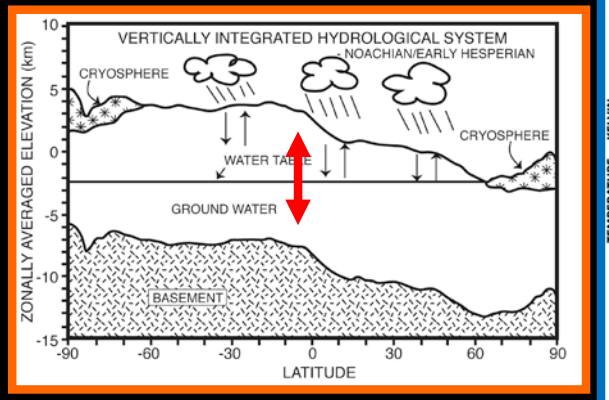
Geological Record

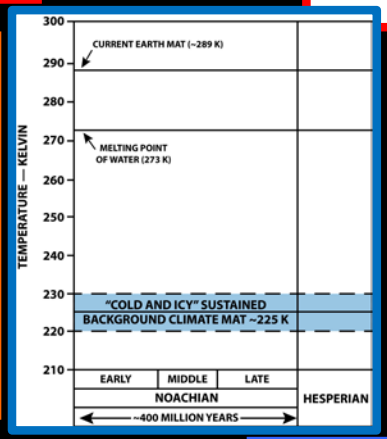


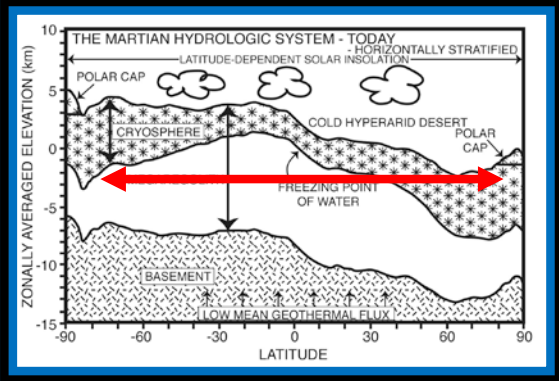
Ambient Climate



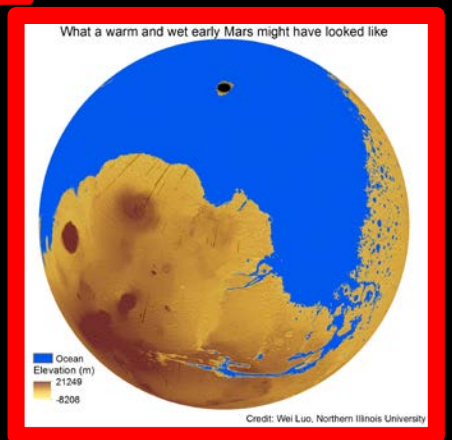




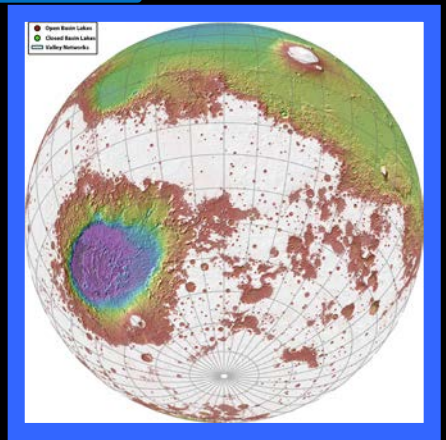




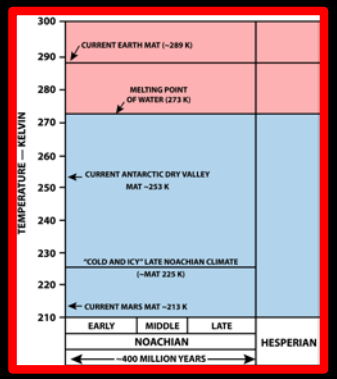
Warm and Wet?



Cold and Icy?

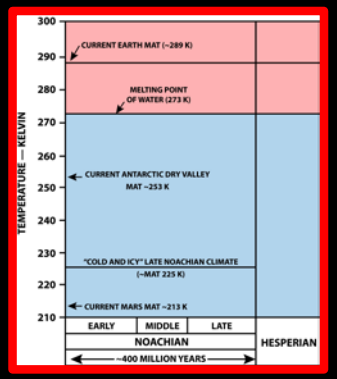


Mars Geology: Early Mars/Paleoclimate (Top 10 Questions):



- 1. Primary and secondary atmospheres: What was their nature, and the transition?
- 2. Nature of the Noachian ambient climate ("warm and wet" or "cold and icy").
- 3. Characteristics and magnitudes of transient climate events (cratering, volcanism, solar).
- 4. What is the planetary water inventory (initial, surface, subsurface, loss to space)?
- 5. Nature of the hydrological system (horizontally stratified, vertically integrated, or both).

Mars Geology: Early Mars/Paleoclimate (Top 10 Questions):



- 6. What is the source of water for valley networks, closed/open-basin lakes: rain, snow?
- 7. Outflow channels: Number, timing, source of water, magnitude, duration, fate of water?
- 8. Oceans: How many, how large, source of water, duration, fate?
- 9. What is the relationship between the magmatic and atmospheric evolution of Mars?
- 10. Life: Do these questions alter our exploration strategy?

Future key measurements, modeling, analyses?

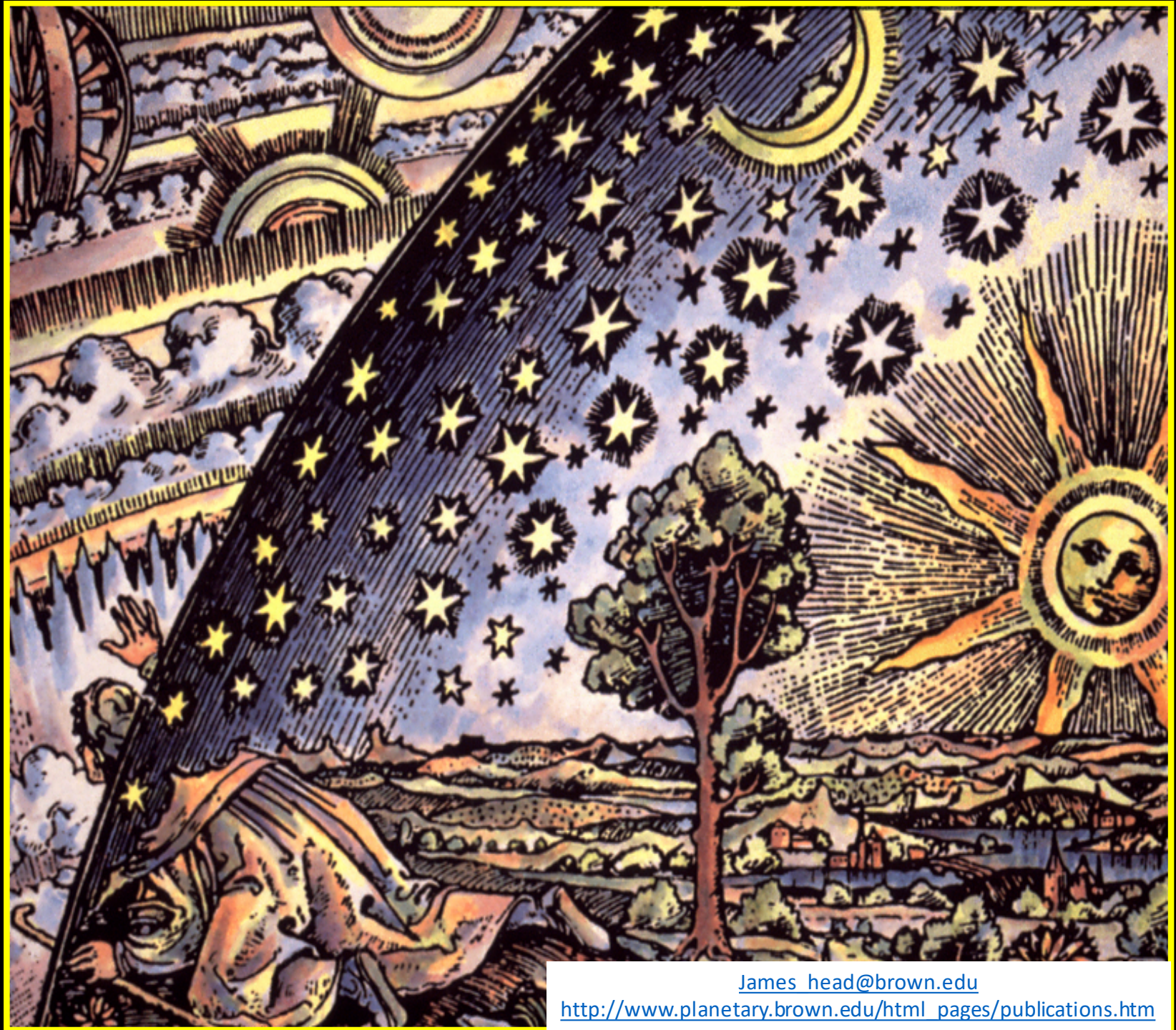
- Ionosphere+:
  - -Early solar behavior: radiance, temporal variability, extreme events.
  - -Refined atmospheric loss rates; species.
- Atmosphere:
  - -Clouds: Microphysics, improved altitude/latitude/time sensitivity.
  - -Benchmarking different models: Links to geological environments.
  - -Mesoscale models: Link atmosphere and regional environments.
  - -Primary -> secondary atmosphere transition.
  - -Role of extreme events: Impact basins and craters, volcanic eruptions.
  - -Influence of transient volatile species release (volcanism, clathrates).
- Atmosphere/Surface:
  - -Alteration minerals: Provenance?
  - -Alteration minerals: More rigorous T, t, pH parameter-space definition.
  - -Refined link to remote sensing, improved spectral and spatial resolution.
  - -Returned samples from a range of known environments.

Future key measurements, modeling, analyses?

- Surface:
  - -Absolute chronology:
  - -Oceans? How many, how large, source of water, duration, fate?
  - -Improved temporal surface water inventory.
  - -Origin of sulfates.
  - -Process timescales: Alteration, fluvial, lacustrine, volcanism.
- Subsurface:
  - -Hydrological system: Horizontally stratified, vertically integrated, or both?
  - -Improved temporal subsurface water inventory.

Future key measurements, modeling, analyses?

- **Interior:**
  - -Petrogenetic evolution.
  - -Crustal thickness and variability.
  - -Lithospheric thickness and variability.
  - -Mantle structure, fO_2, convection paradigm
  - -Duration of the magnetic field?
- **Life:**
  - -Are we asking the right questions?
  - -Is the answer in the deeper subsurface?
  - -Could it be an RNA world?



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http://www.planetary.brown.edu/html_pages/publications.htm