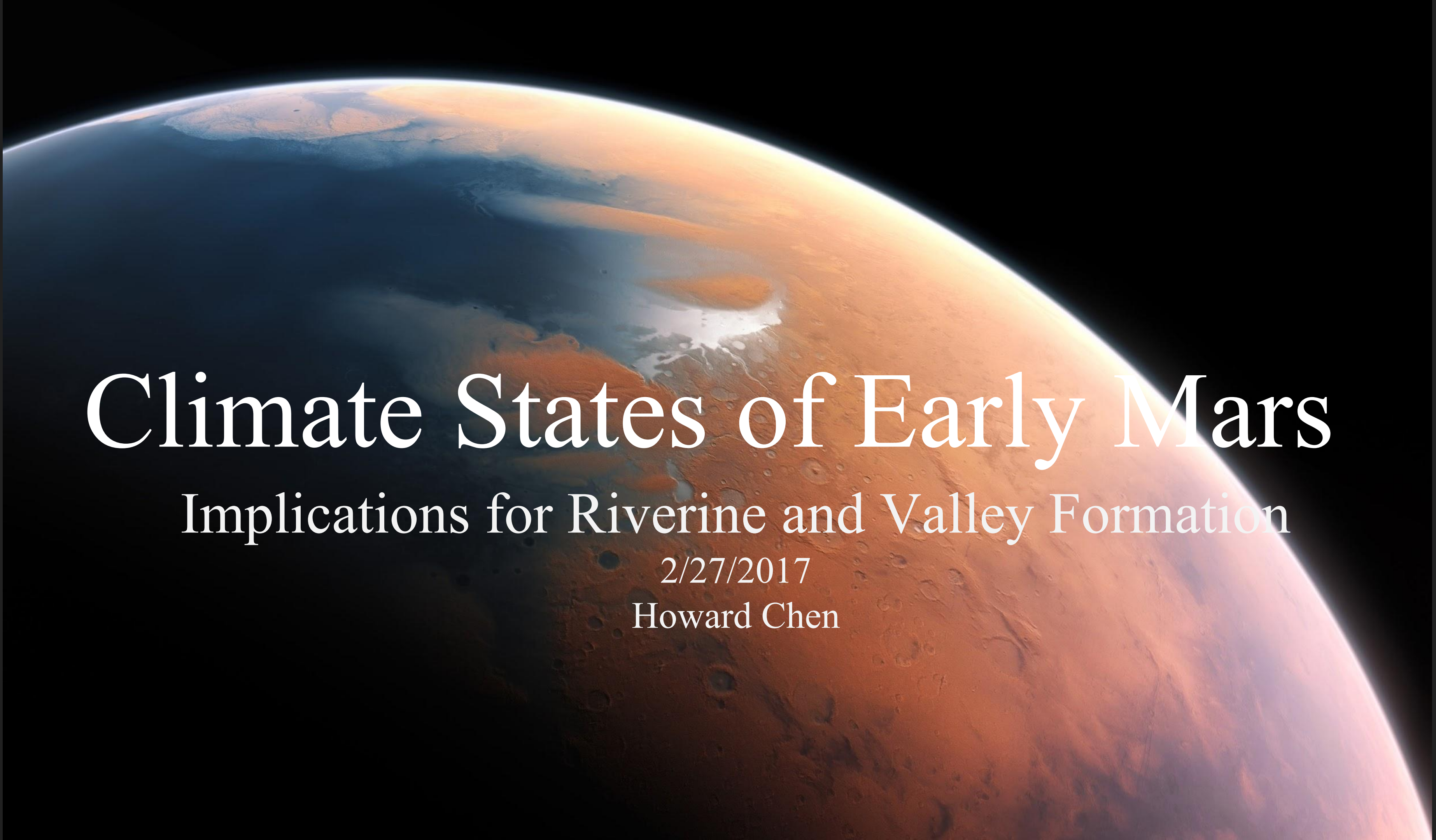


Climate States of Early Mars

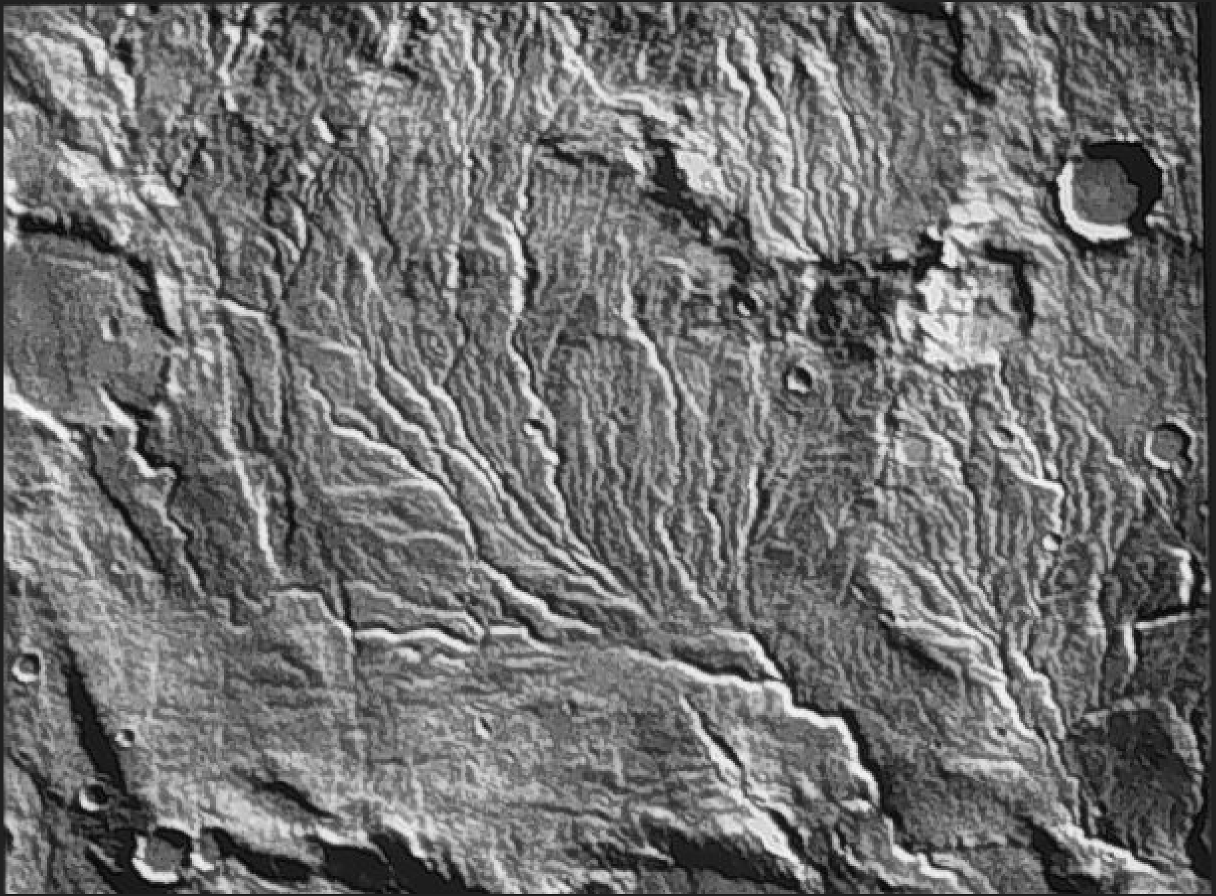
Implications for Riverine and Valley Formation

2/27/2017

Howard Chen

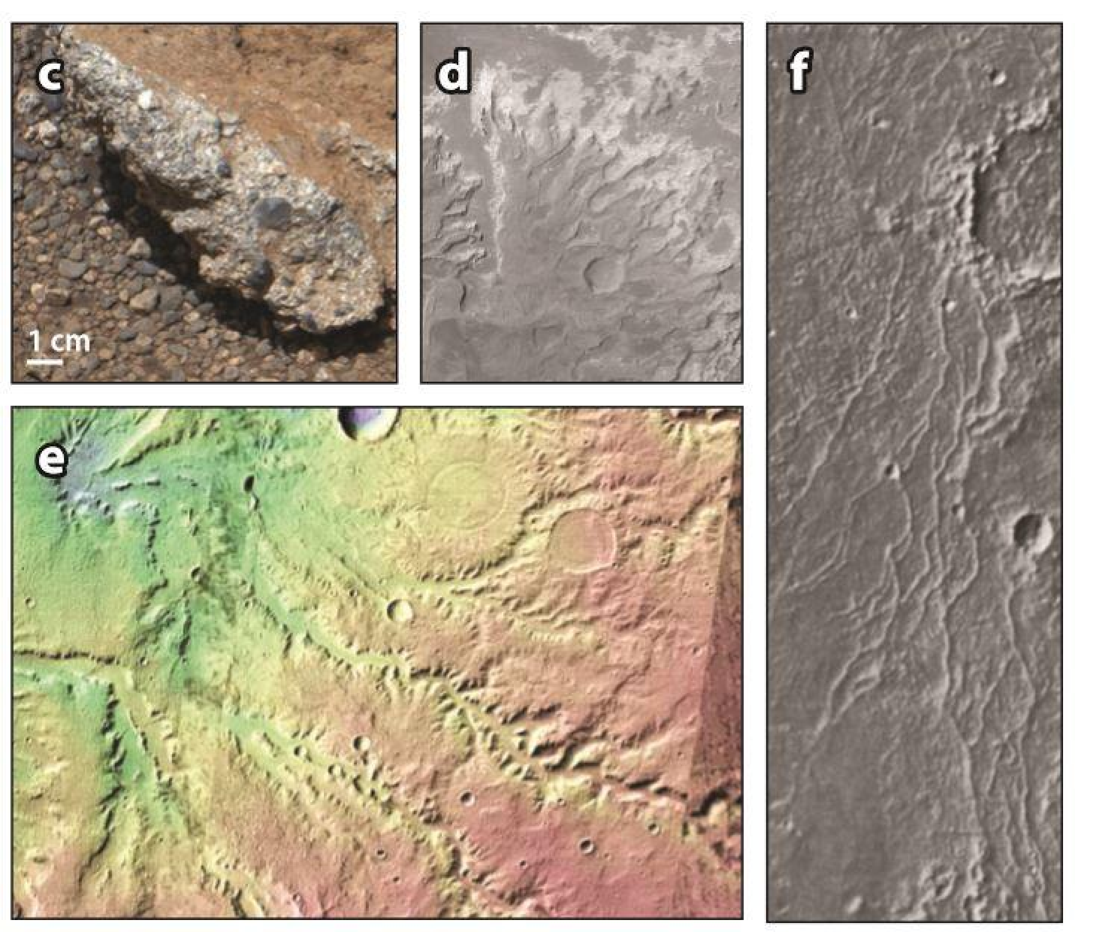
Outline

Introduction
Warm Early Martian Climate
Cold vs Warm States
Astrobiological Implications



Very first fluvial feature images captured by Mariner 9.

Many valley networks, tributaries, meandering channels, basin lakes have been imaged by subsequent spacecrafts and rovers.



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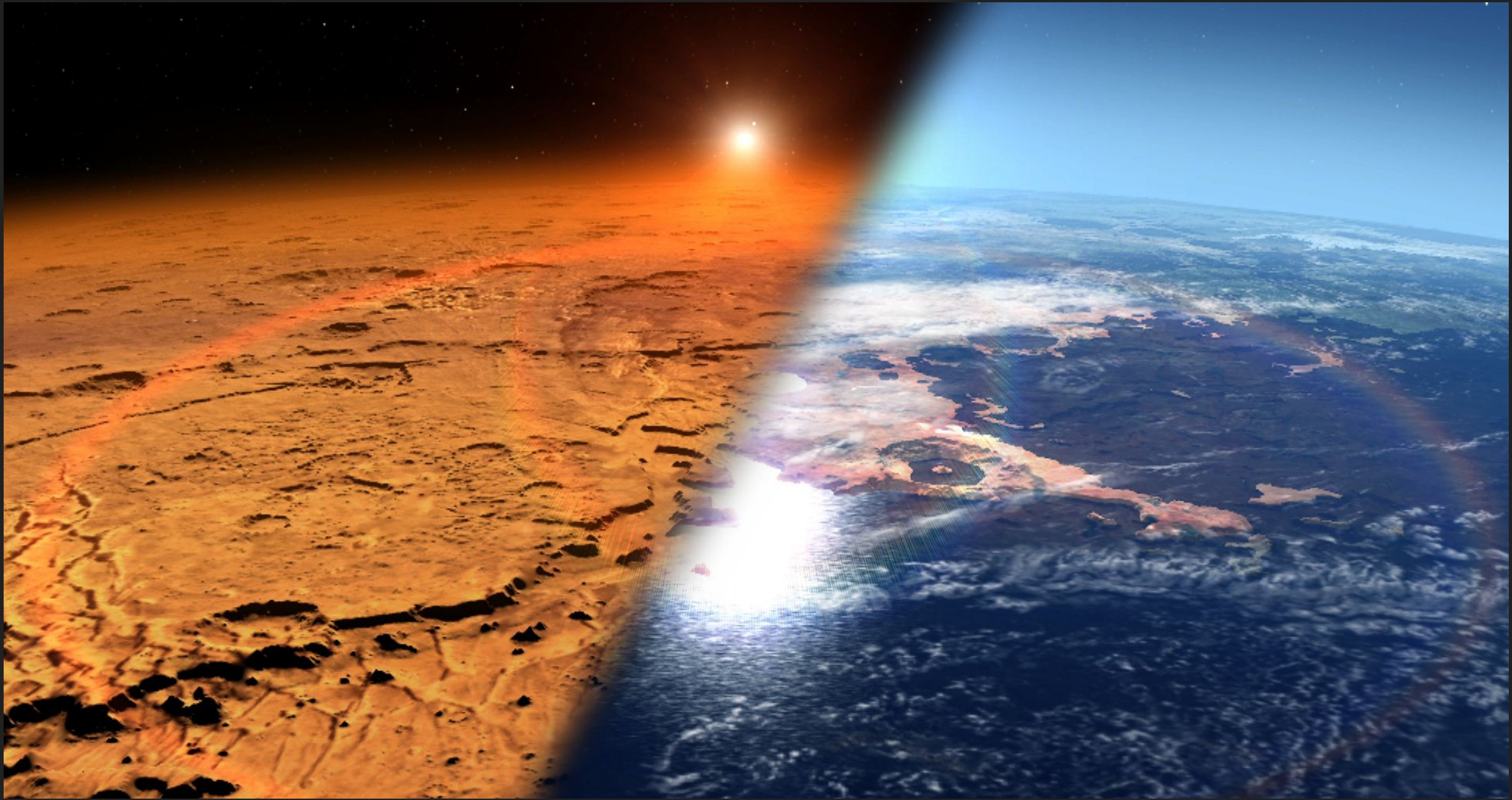
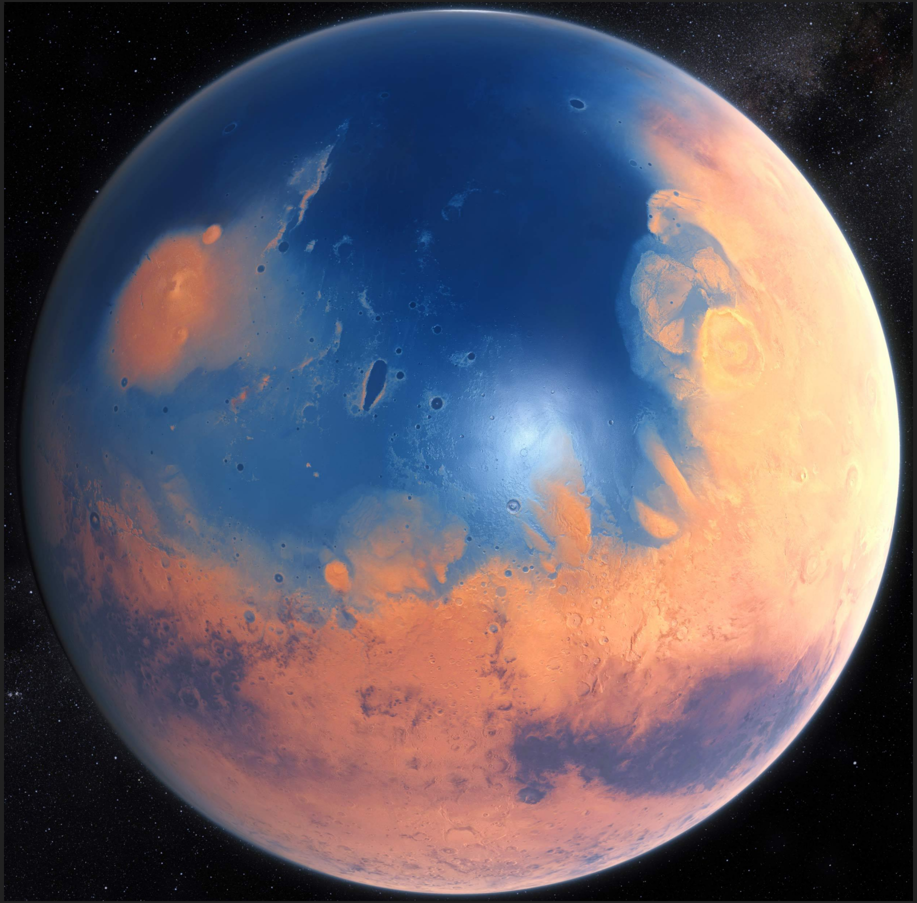
A Very Different World



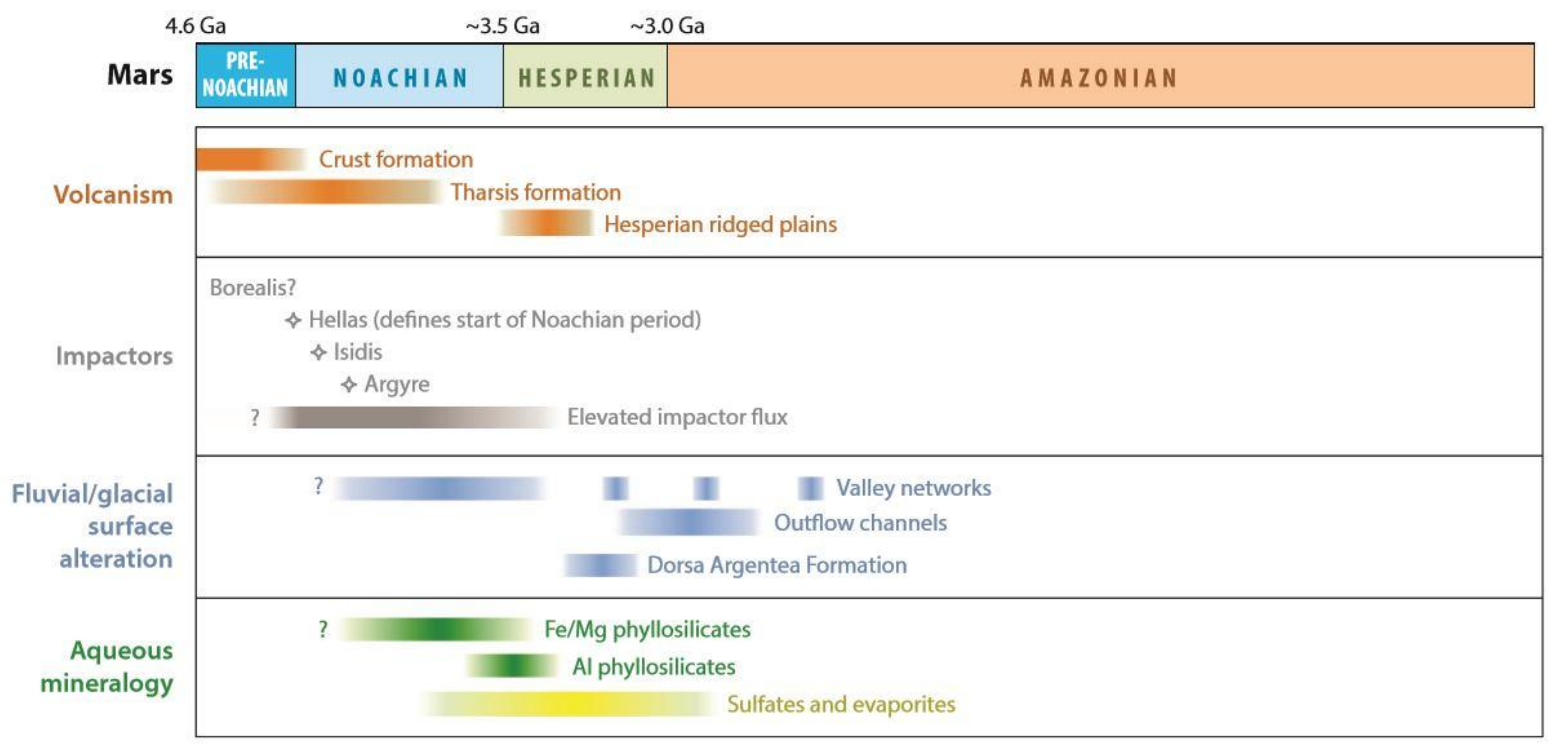
A Very Different World

Sagan & Mullen (1972), Pollack et al. (1987), Kasting et al. (1988) have suggested that the early atmosphere of Mars was warm and wet.

Global mean Ts > 273 K. To allow groundwater to be mobile near the face and recharge the aquifers.



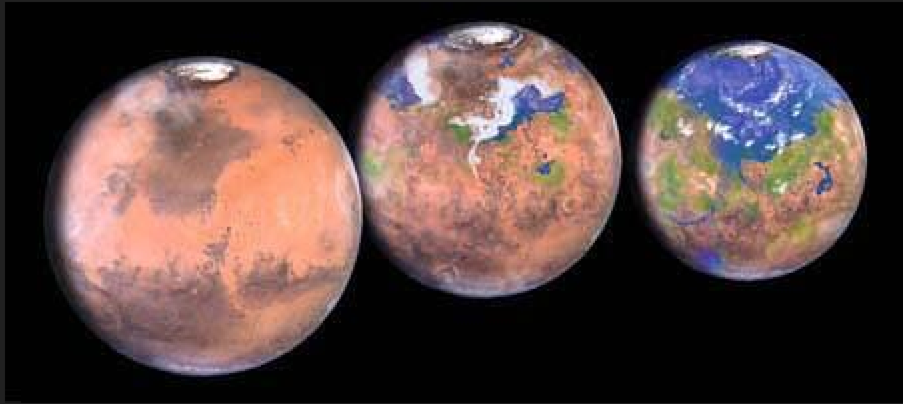
Historical Overview



The Greenhouse Gas Debate

CH4 is a strong greenhouse gas on the Earth but it absorbs incoming solar near-infrared radiation in the stratosphere (Ramirez et al. 2014).

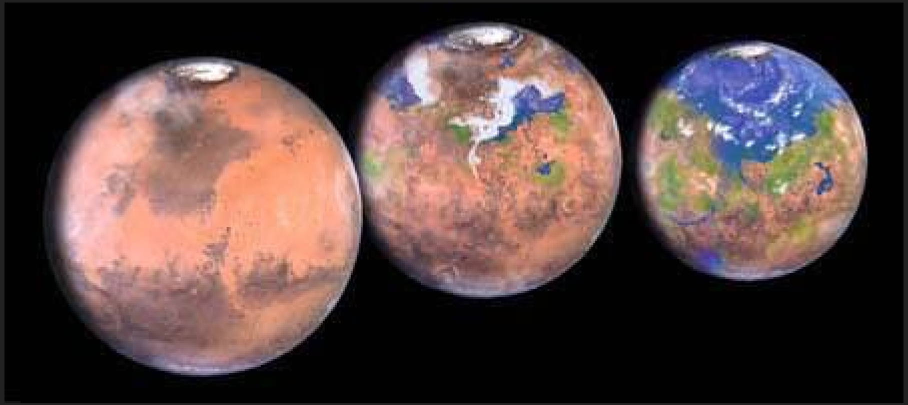
A range of climate models (Pollack 1979, Cess et al. 1989) indicate that CO2 partial pressures merely of a few bars (3-5) could raise Ts to allow for liquid water.



The Greenhouse Gas Debate

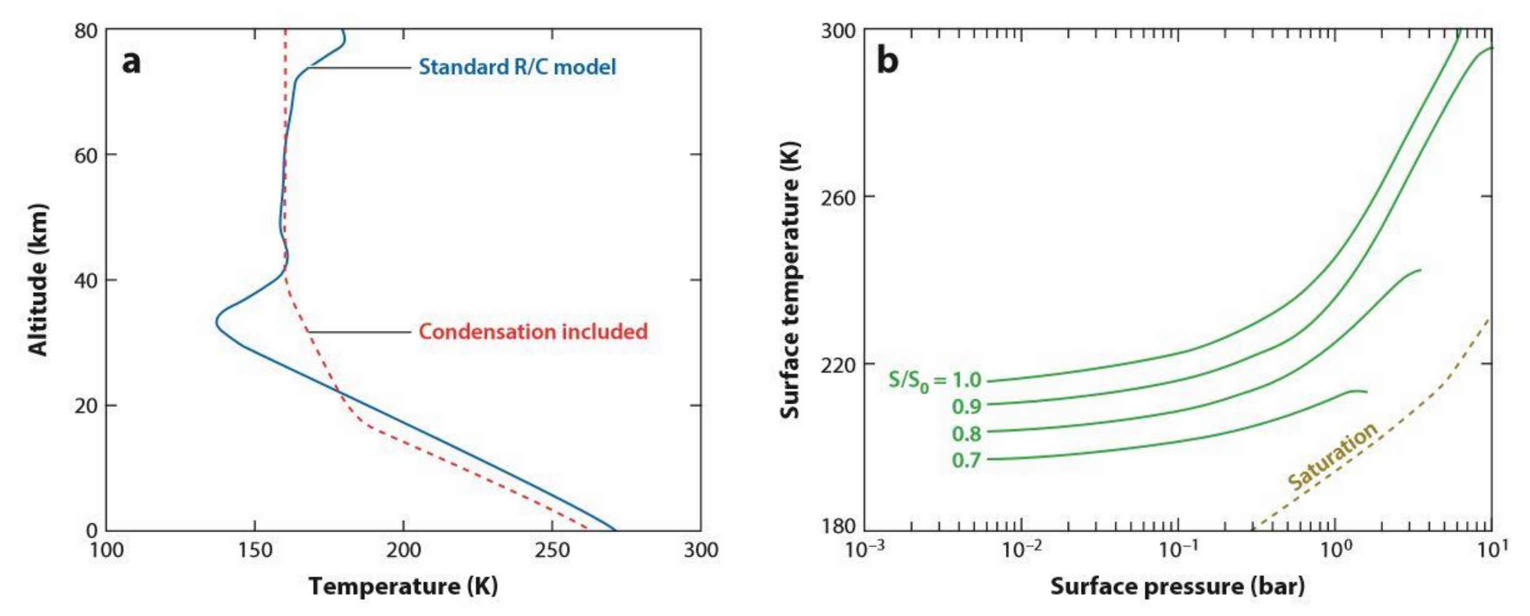
Sagan and Mullen have suggested ammonia as the important GHG. However, NH3 readily photodissociates to N2+ and H+.

SO2 may work but it rains out easily or photolyzes to sulfate aerosols (Tian et al. 2010).



The Problem of CO2 Condensation

In the seminal paper, Kasting (1991) demonstrated that CO2 alone could not have warmed early Mars.



The Problem of CO2 Condensation cont.

Outstanding problems with CO2 warming mechanism:

CO2 and water clouds have different optical properties; water is much better at absorbing infrared than condense CO2 (Warren 1986).

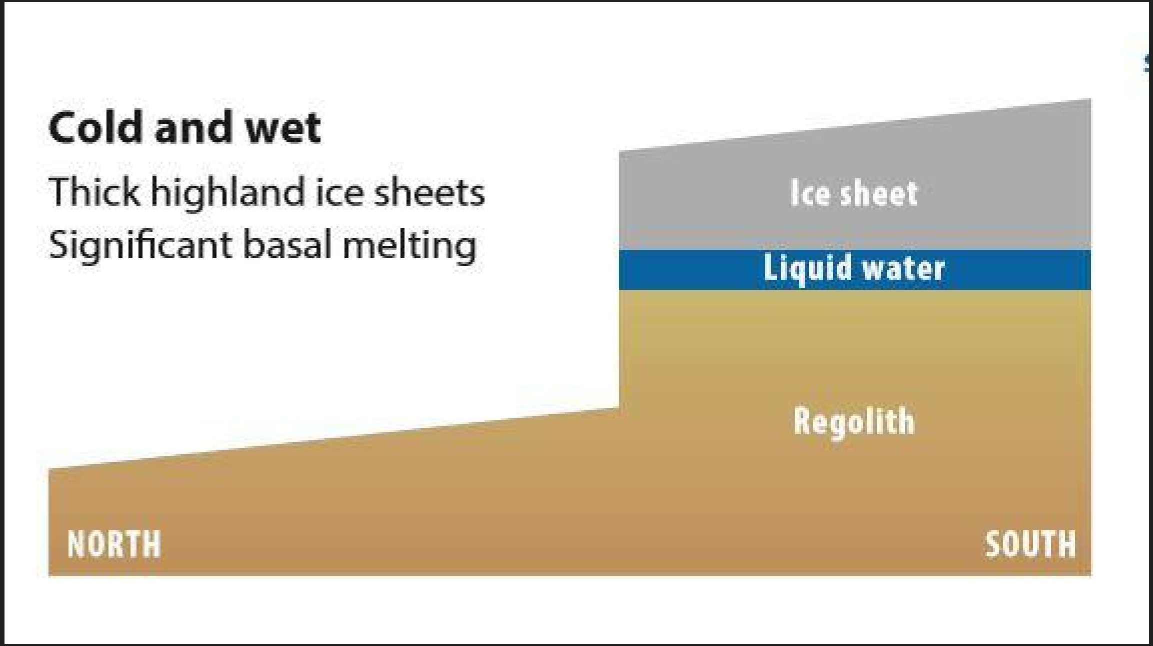
On the other hand, CO2 is an efficient Rayleigh scatterer, which may raise the planetary albedo.

CO2 condenses into clouds of dry ice at low temperatures. As surface pressure increases, this leads to a shallower lapse rate, reducing the GHG effect.

Does Early Mars have to be Consistently Warm?

Cold vs Warm States

The cold and wet states leads to large highland wet-based glacial ice-sheets, in conflict with geological record.

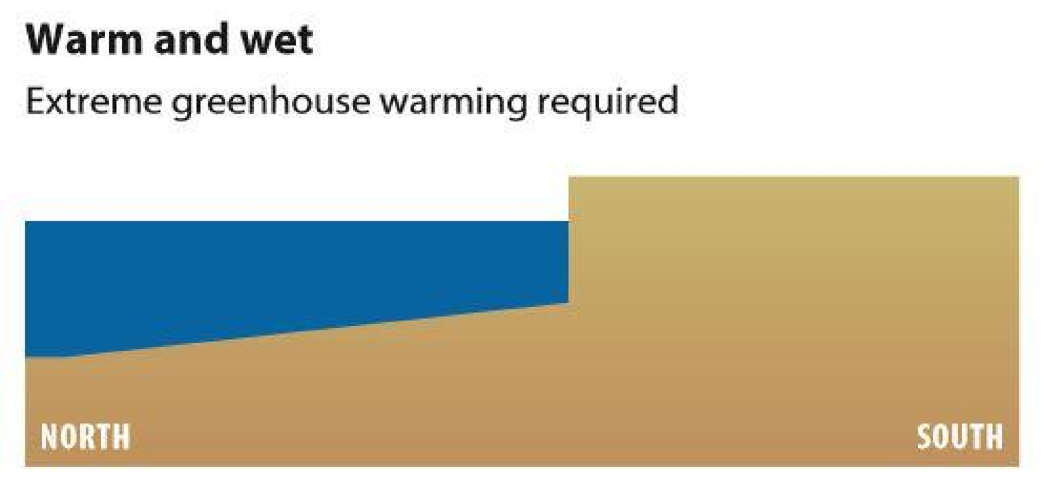


Figures from Wordsworth (2016)

Cold vs Warm States cont.

The warm and wet state requires rapidly transitions to the cold and wet state with decreasing surface temperatures.

Requires unrealistic GHG warming.



Cold vs Warm States cont.

Warm and dry states may lead to less precipitation in the highlands, which is inconsistent with the position and location of channels/valleys.

Repeated Warming Events

Favored scenario: Relatively cold and dry states punctuated by warming periods.

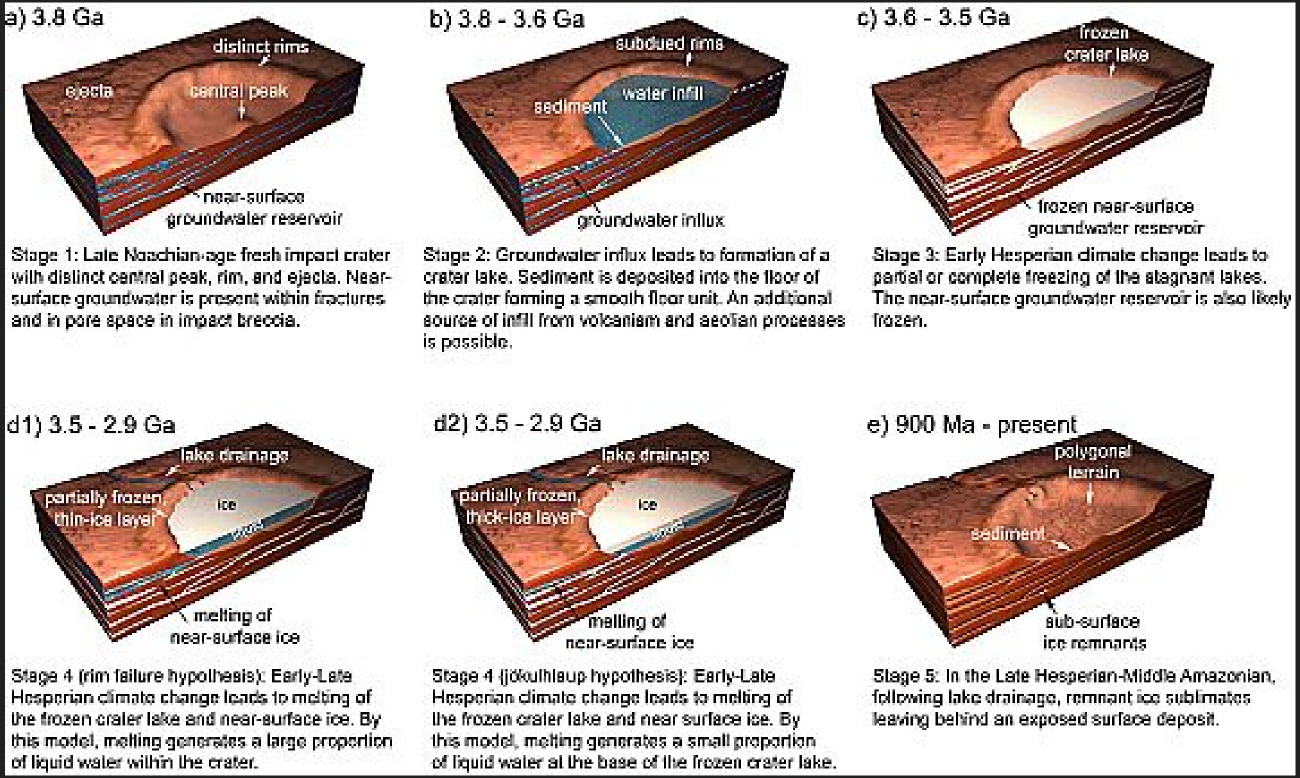
Caused ice and snowpacks in the Noachian highlands to melt, carving valley networks etc.

Transient Warming: Driving Mechanism?

One theory suggests that impacts during the LHB created thick steam atmospheres that rained out (Segura et al. 2012).

Another group argues for sporadic volcanic outgassing of SO2 as the warming mechanism (Head et al. 2015)..

Transient Warming: Driving Mechanism?



Stage 1: Late Noachian-age fresh impact crater with distinct central peak, rim, and ejecta. Near-surface groundwater is present within fractures and in pore space in impact breccia.

Stage 2: Groundwater influx leads to formation of a crater lake. Sediment is deposited into the floor of the crater forming a smooth floor unit. An additional source of infill from volcanism and aeolian processes is possible.

Stage 3: Early Hesperian climate change leads to partial or complete freezing of the stagnant lakes. The near-surface groundwater reservoir is also likely frozen.

Stage 4 (rim failure hypothesis): Early-Late Hesperian climate change leads to melting of the frozen crater lake and near-surface ice. By this model, melting generates a large proportion of liquid water within the crater.

Stage 4 (jökulhlaup hypothesis): Early-Late Hesperian climate change leads to melting of the frozen crater lake and near surface ice. By this model, melting generates a small proportion of liquid water at the base of the frozen crater lake.

Stage 5: In the Late Hesperian-Middle Amazonian, following lake drainage, remnant ice sublimates leaving behind an exposed surface deposit.

Kasting et al. (2001)

Climate Cycles & Episodic Warming

A Penn State group recently proposed climate cycles caused by carbonate-silicate cycles as the primary driver.

Glaciated state: CO2 consumption by silicate weathering cannot keep pace with CO2 outgassing from volcanoes, planet gets warm

Ice-free, deglaciated state: CO2 outgassing cannot keep pace with consumption by weathering, planet gets hot

Climate Cycles & Episodic Warming

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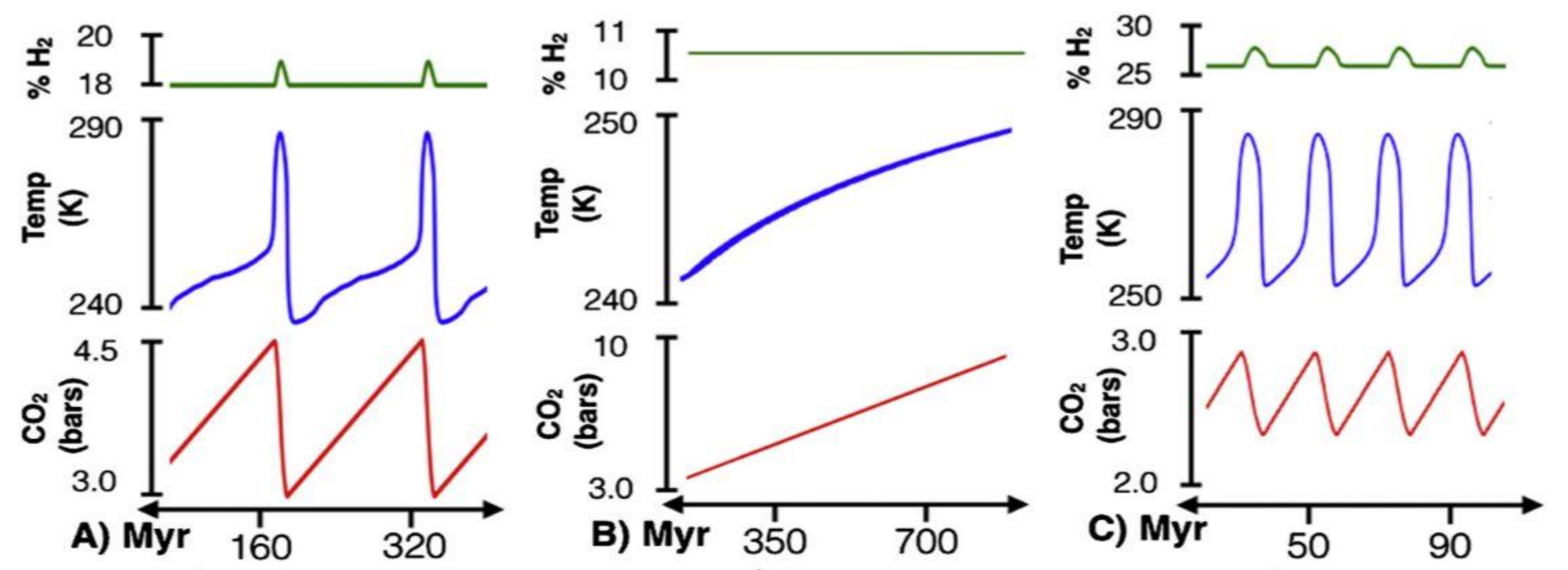
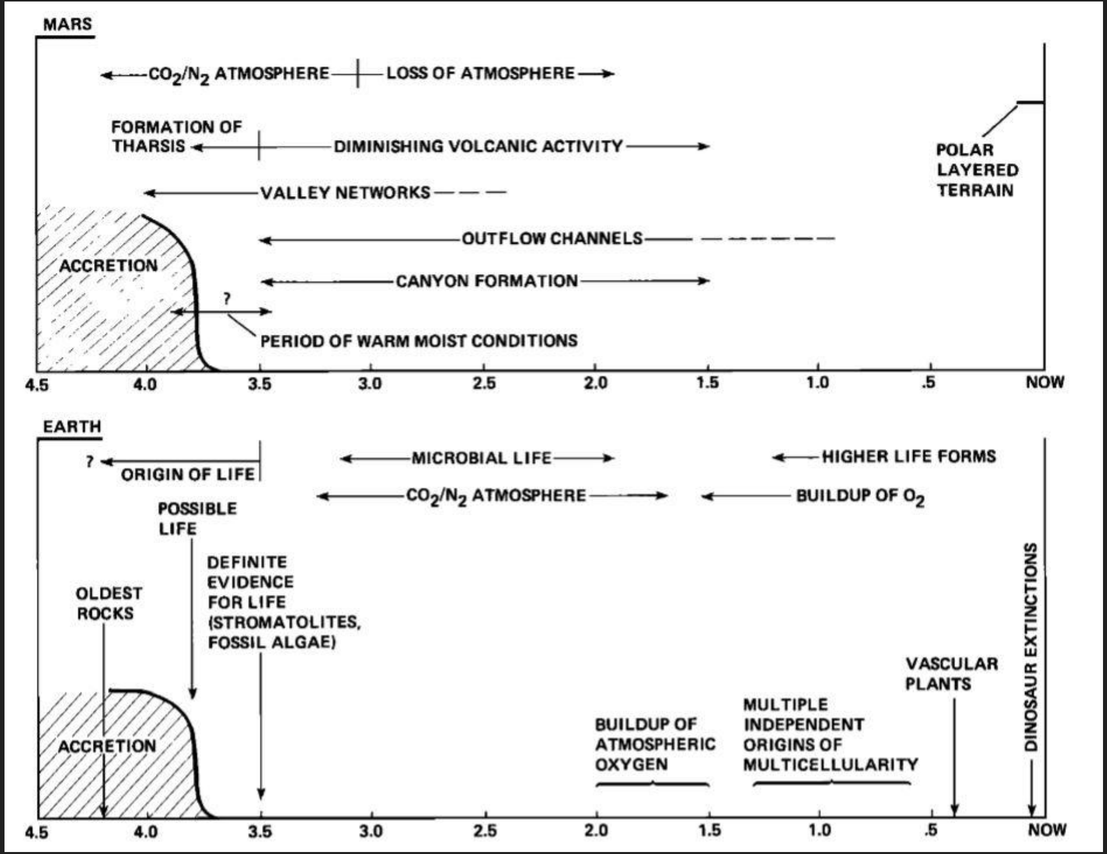
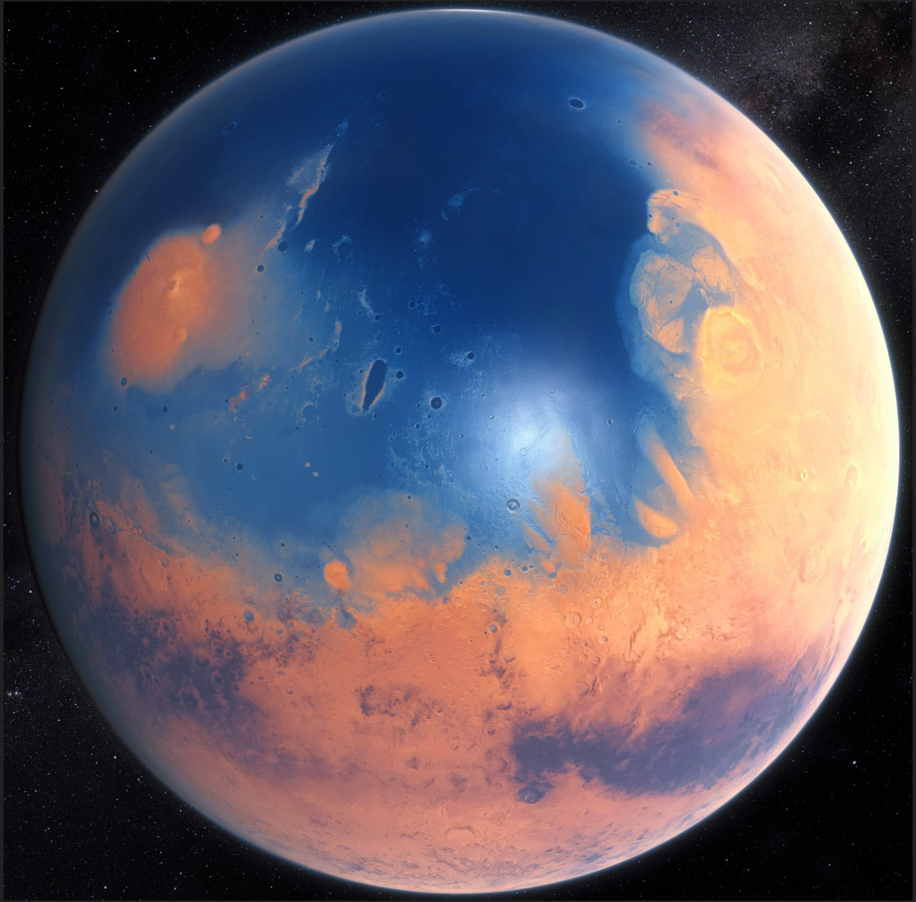


Astrobiological Implications

Potential for Astrobiology



Periods of moist conditions on Mars may have corresponded to the time during which life originated on Earth (Mckay & Stoker 1991).



Terraforming Mars

Early Mars warming ideas spawned ideas to terraform Mars.

For instance, deploying GHG generating plankton or algae