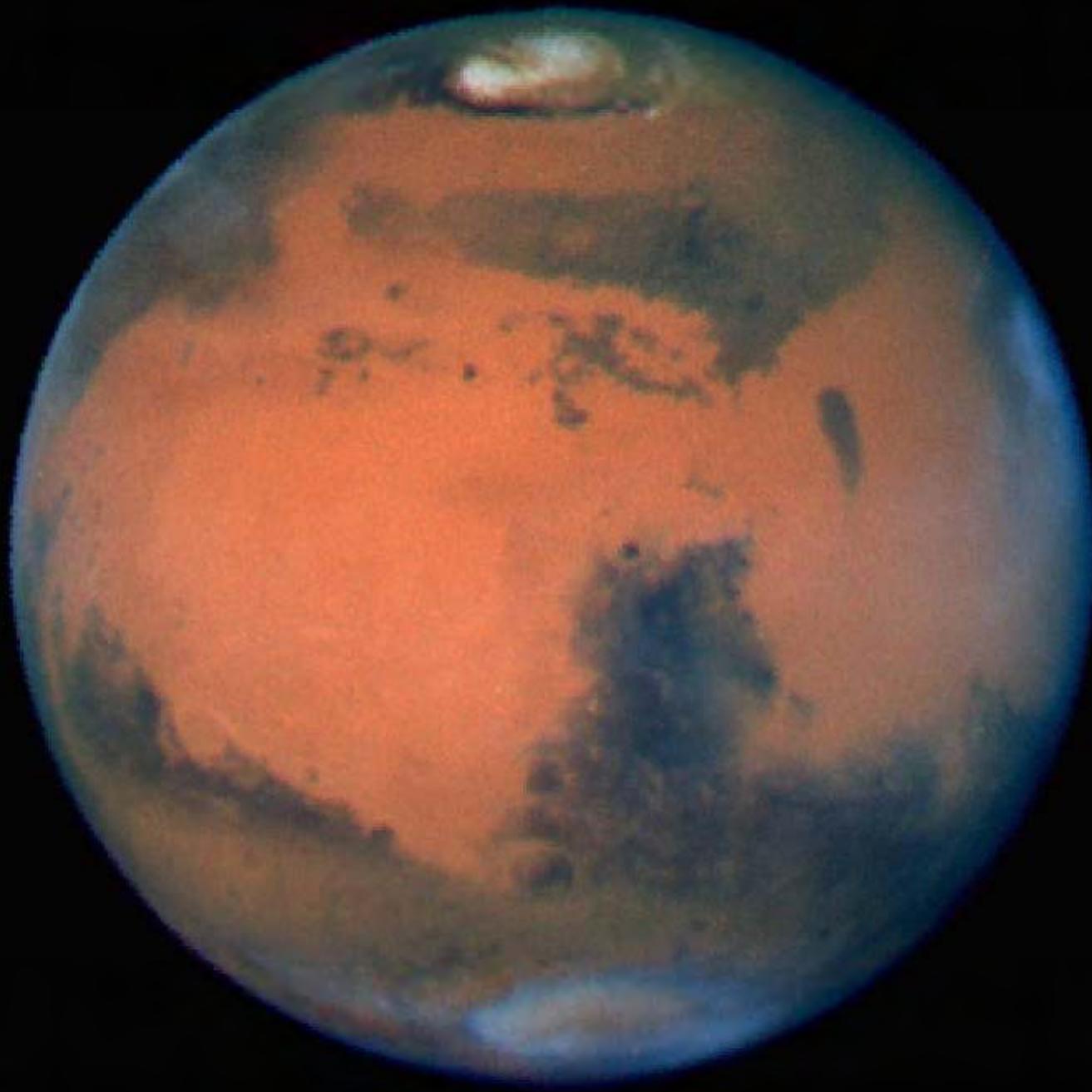


Life and Extreme Environments

Professor Brian Hynek

*Laboratory for Atmospheric and
Space Physics &*

Dept. of Geological Sciences



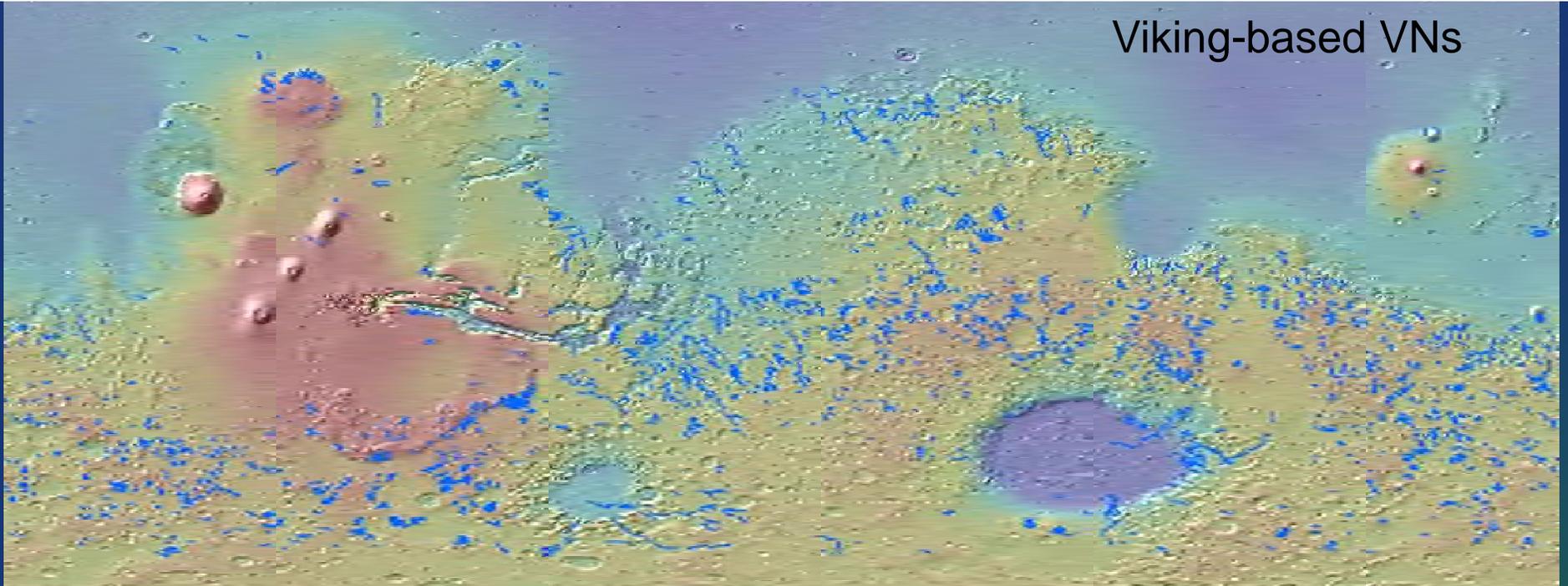
**Hubble
View of
Mars**

Evidence for Past Water

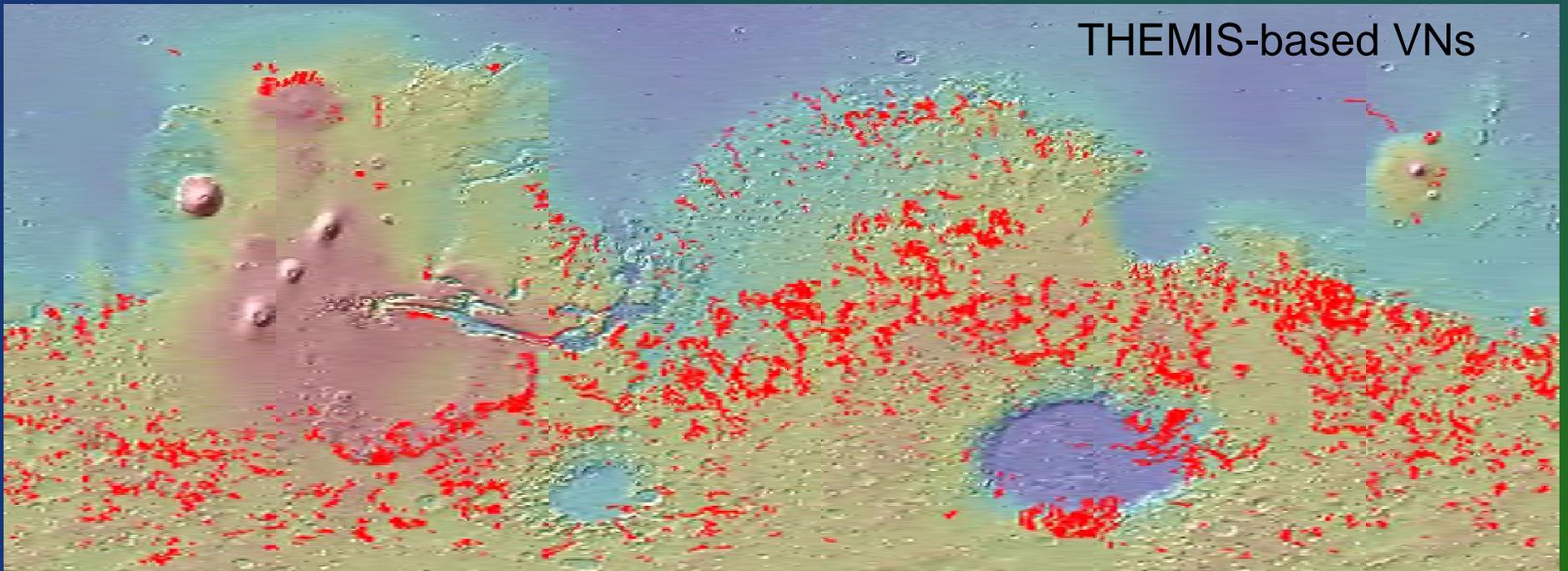
- *The current thin, cold atmosphere prohibits liquid water from being stable on the surface.*
- *However, there is ample evidence for past water; indicative of a warmer and wetter climate.*

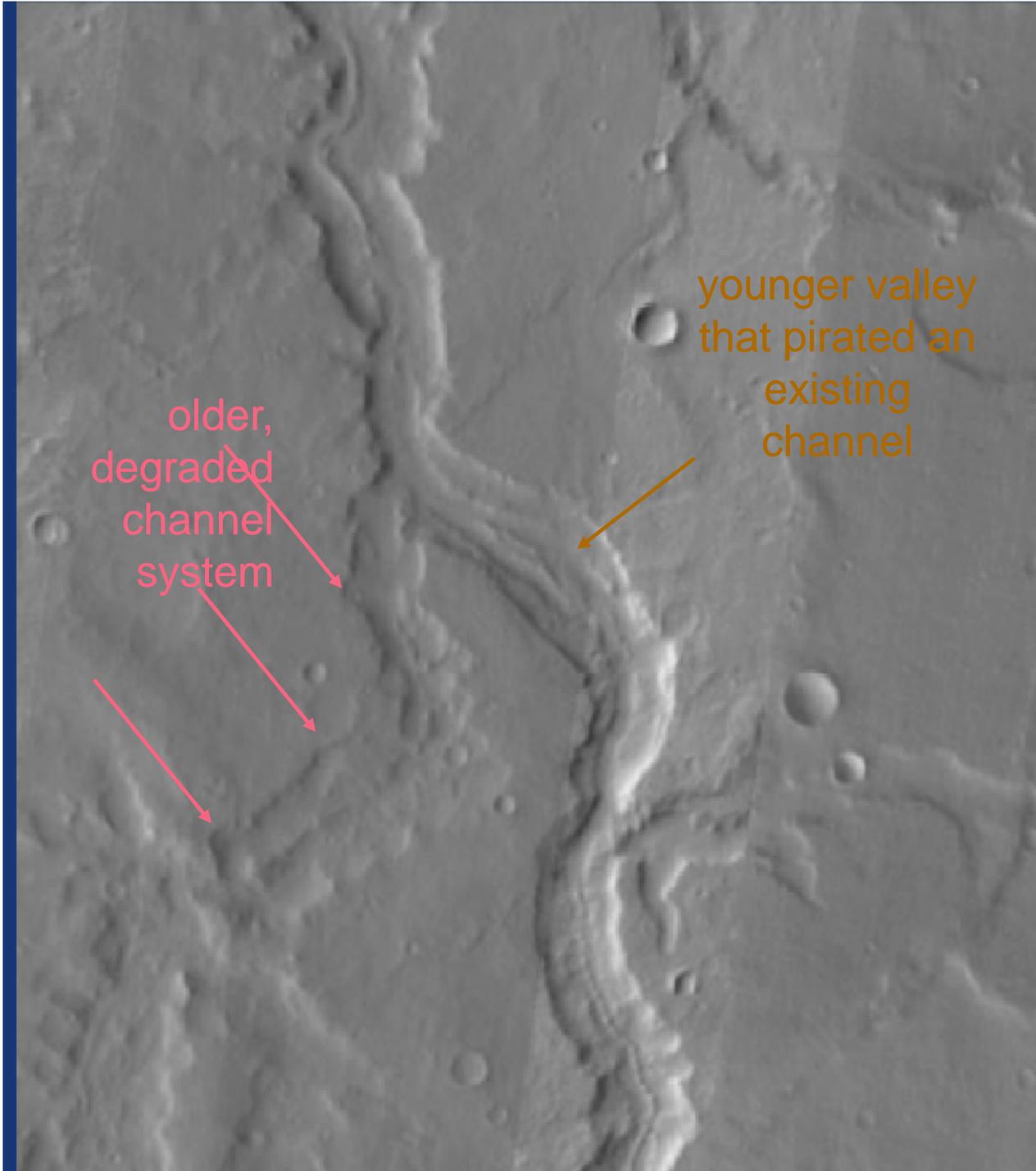


Viking-based VNs



THEMIS-based VNs





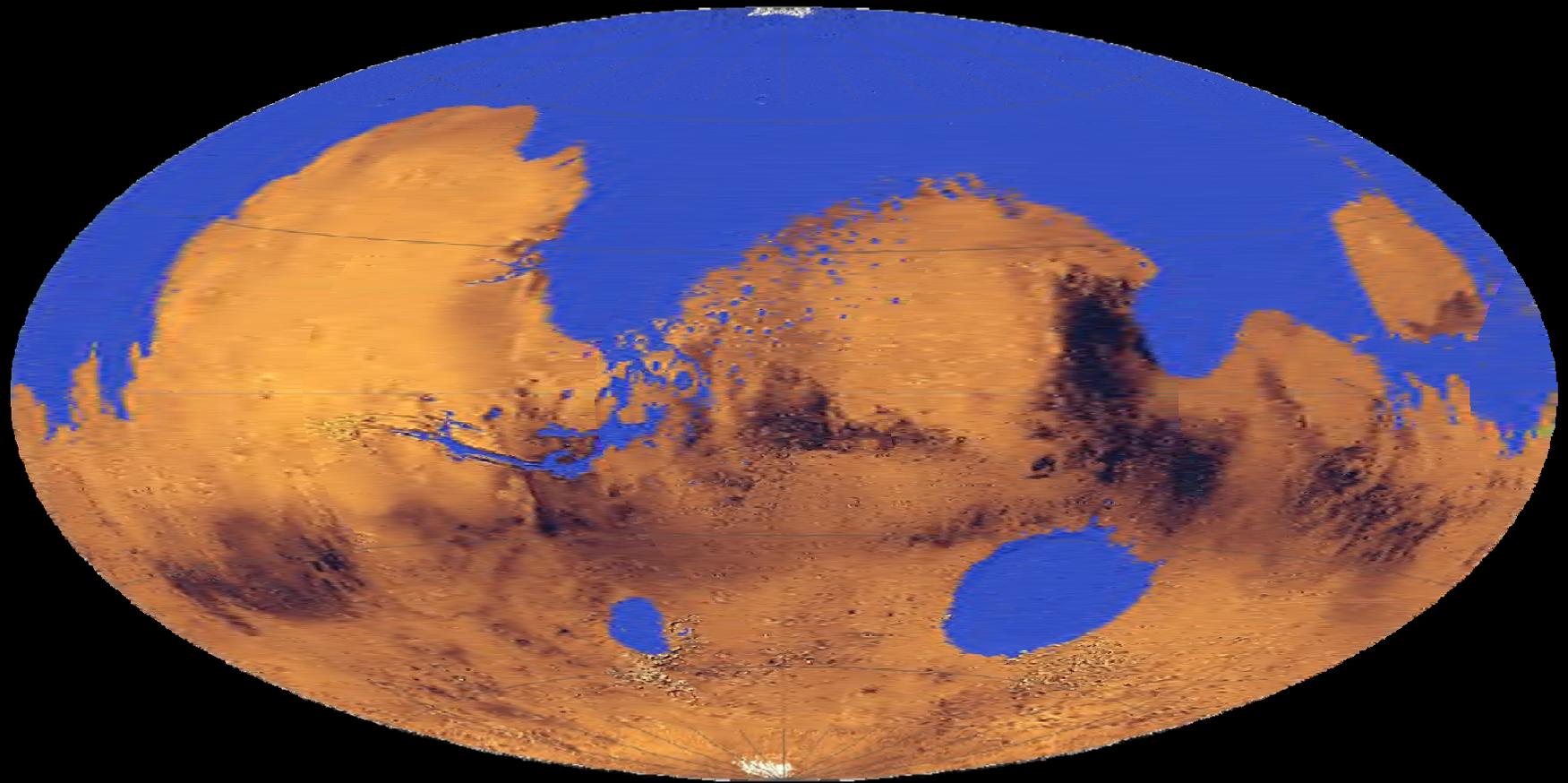
older,
degraded
channel
system

younger valley
that pirated an
existing
channel

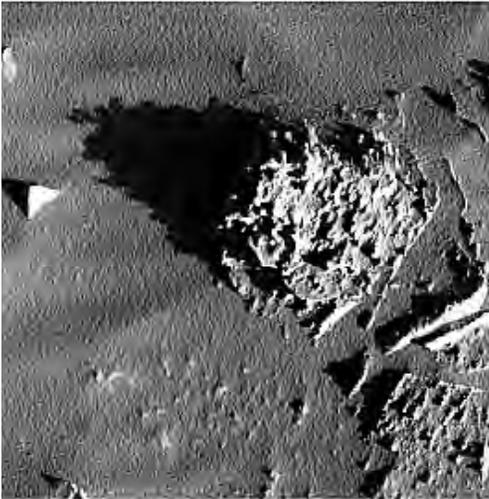
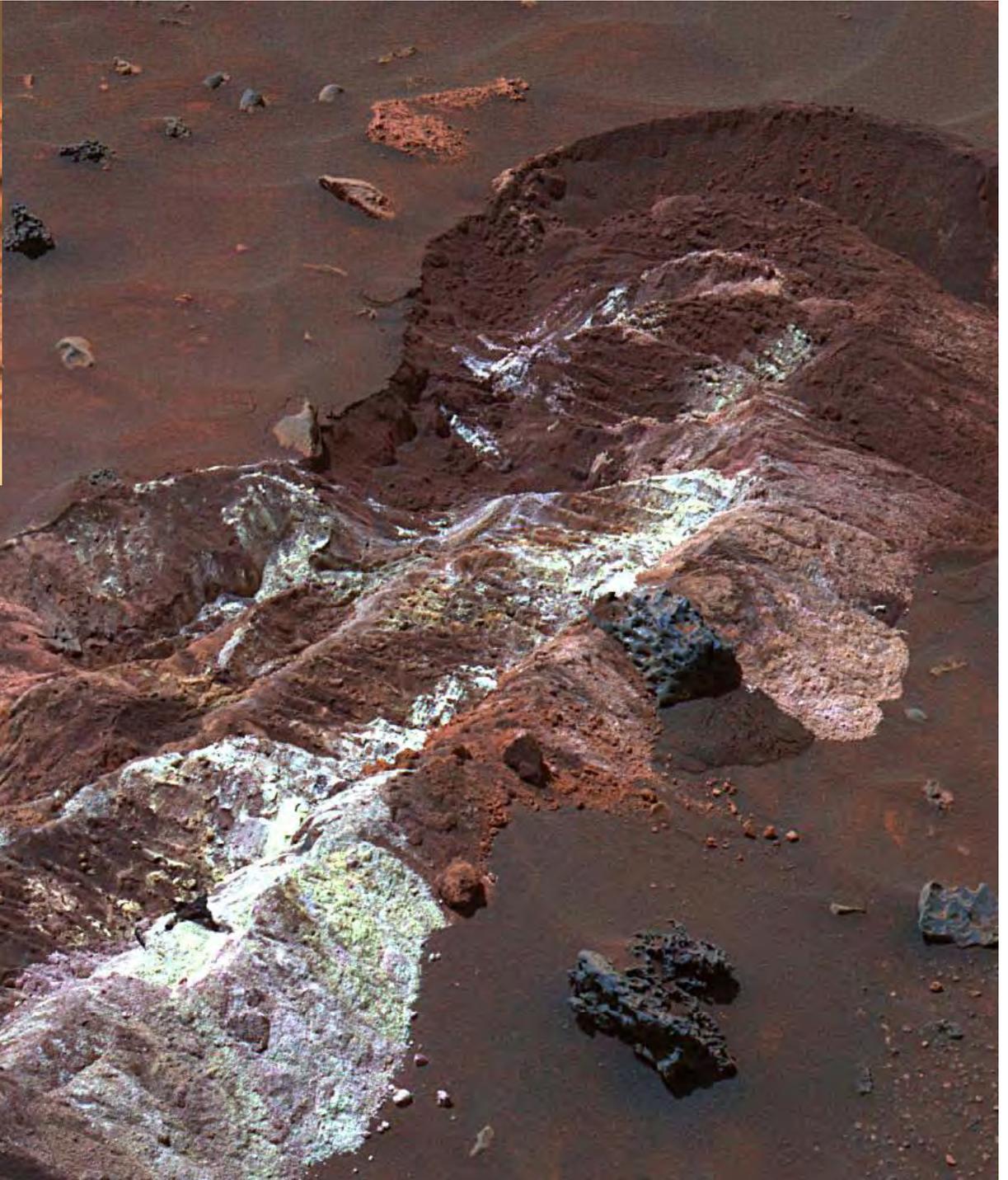
Evidence of episodic
surface runoff.

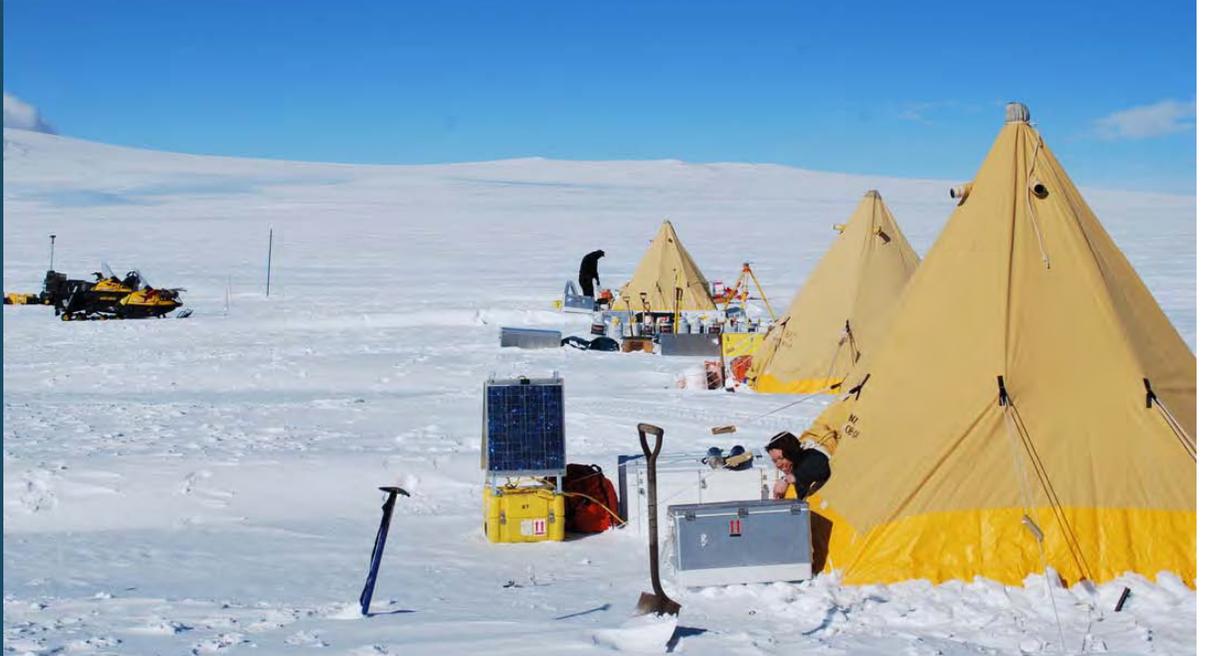
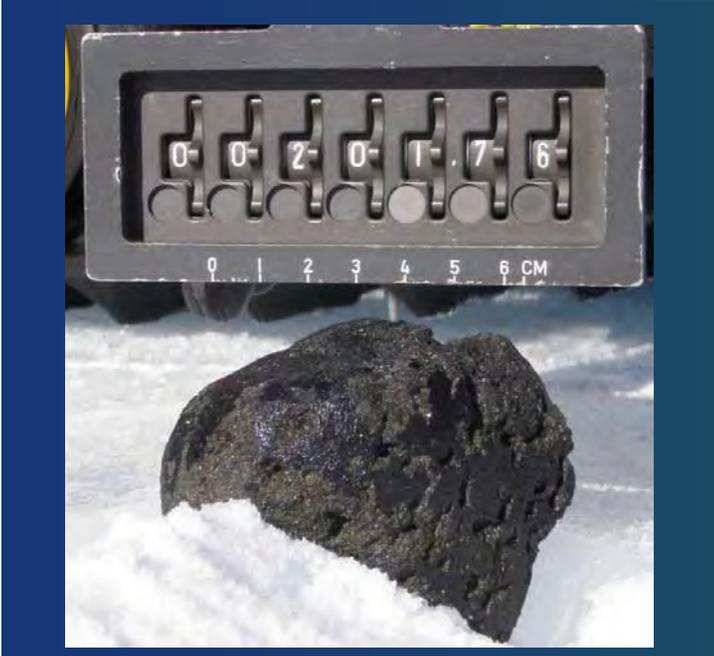
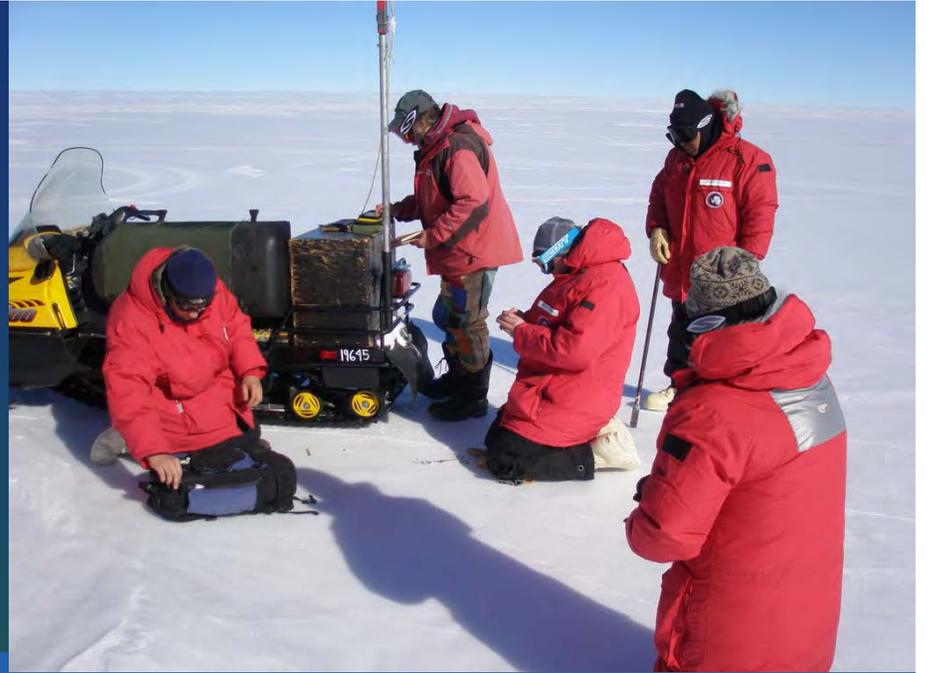
120 m.y. passed
between these two
events.

Mars 3.7 billion years ago?

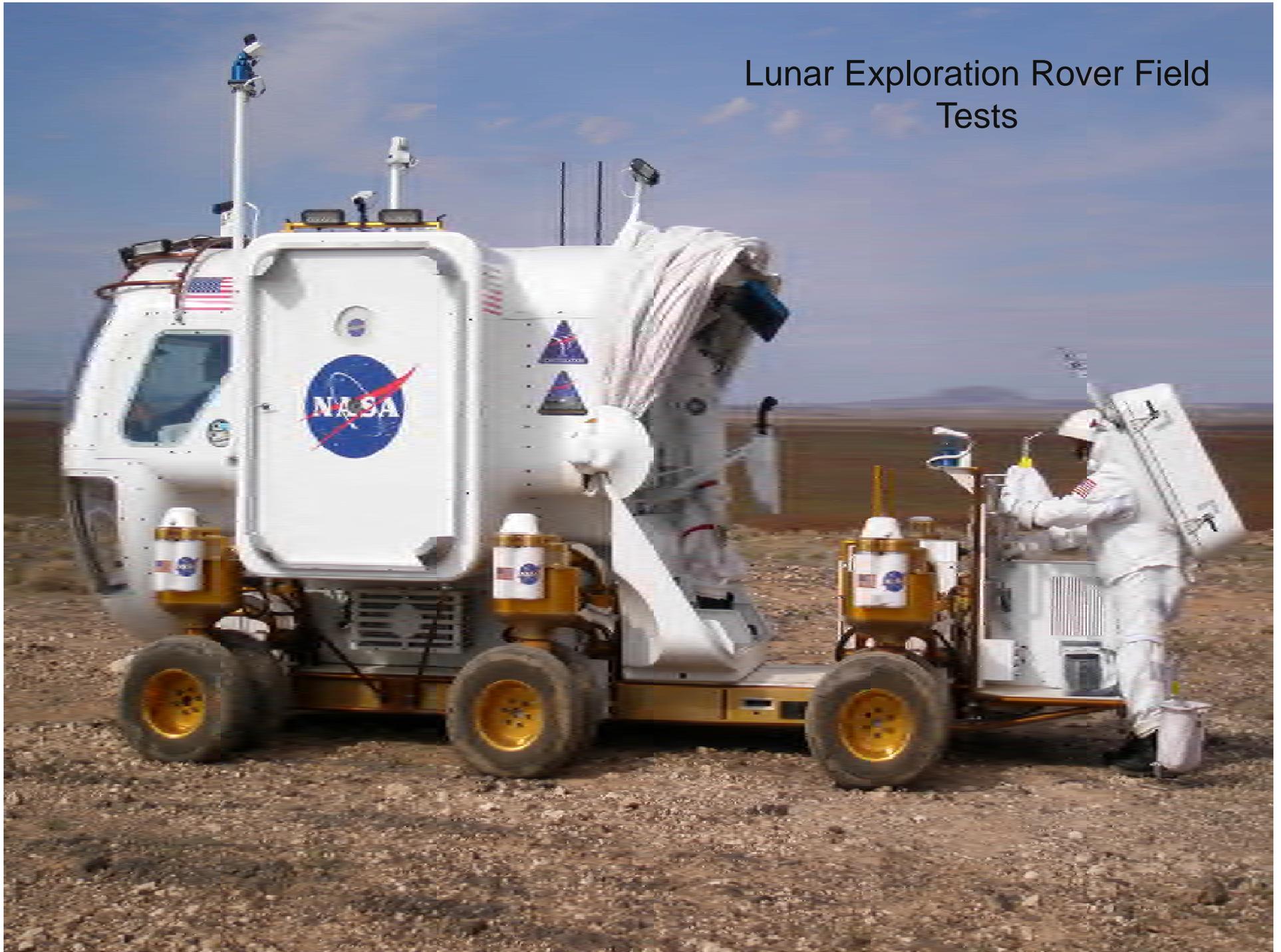


Ocean Level	Volume (km ³)	GWE (m)	Surface (km ²)	ratio
-2540	1.24 x 10 ⁸	547.88	8.11 x 10 ⁷	0.357

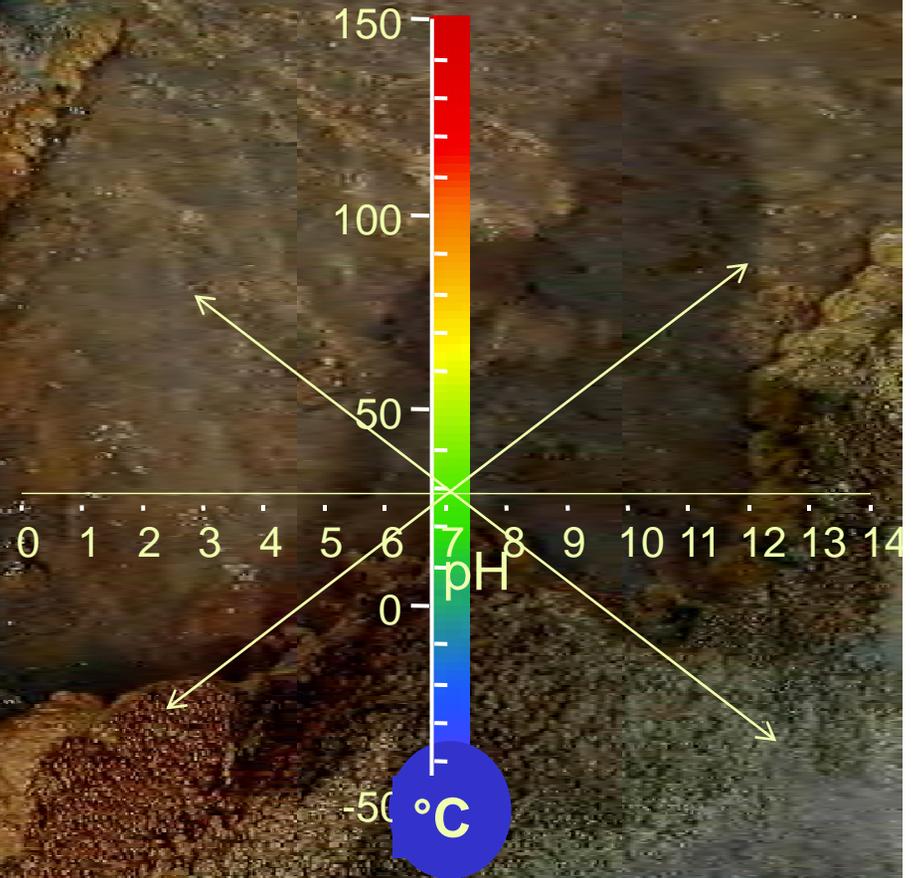




Lunar Exploration Rover Field Tests



Extremophiles and the Physical Limits of Life on Earth ...and Beyond.



Which of these can be considered an “extreme” environment?

A) An oxygen-rich atmosphere.

B) Salty water

C) Basic water (i.e. high pH)

D) Outer space

E) All of the above

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Environment	Type	Definition	Examples
Temperature	Hyperthermophile	growth >80°C	<i>Pyrolobus fumarii</i> -113°, <i>Geobacter</i> -121
	Thermophile	Growth 60-80°C	<i>Synechococcus lividis</i>
	Mesophile	Growth 15-60°C	<i>humans</i>
	Psychrophile	Growth <15°C	<i>Psychrobacter</i> , <i>insects</i>
Radiation	Barophile		<i>D. Radiodurans</i>
Pressure	Piezophile	Weight loving	<i>Shewanella viable at 1600 MPa</i>
	Xerophile	Pressure loving	
Desiccation	Halophile	Cryptobiotic;	<i>Haloarcula</i> , <i>Dunaliella</i>
Salinity		Salt loving (5 M NaCl)	<i>Spirulina</i> , <i>Bacillus firmus</i>
pH	Alkaliophile	pH >9	<i>OF4</i> (10.5); 12.8??
	Acidophile	Low pH loving	<i>Cyanidium</i> , <i>Ferroplasma</i>
Oxygen tension	Anaerobe	Cannot tolerate O ₂	<i>Methanococcus jannaschii</i>
	Miroaerophil		<i>Clostridium</i> ,
	Aerophile		<i>Homo sapiens</i>
Chemical extremes		high CO ₂ , arsenic, mercury	<i>Cyanidium caldarium</i>
Vacuum Electricity			<i>tardigrades</i>

Why study extremophiles?

- Biodiversity of planet Earth. Origin of life?
- Mechanisms of survival
- Biotech potential
- Future use in space

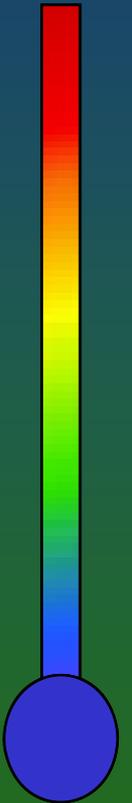


Limits for life in the universe ... for example, Mars!

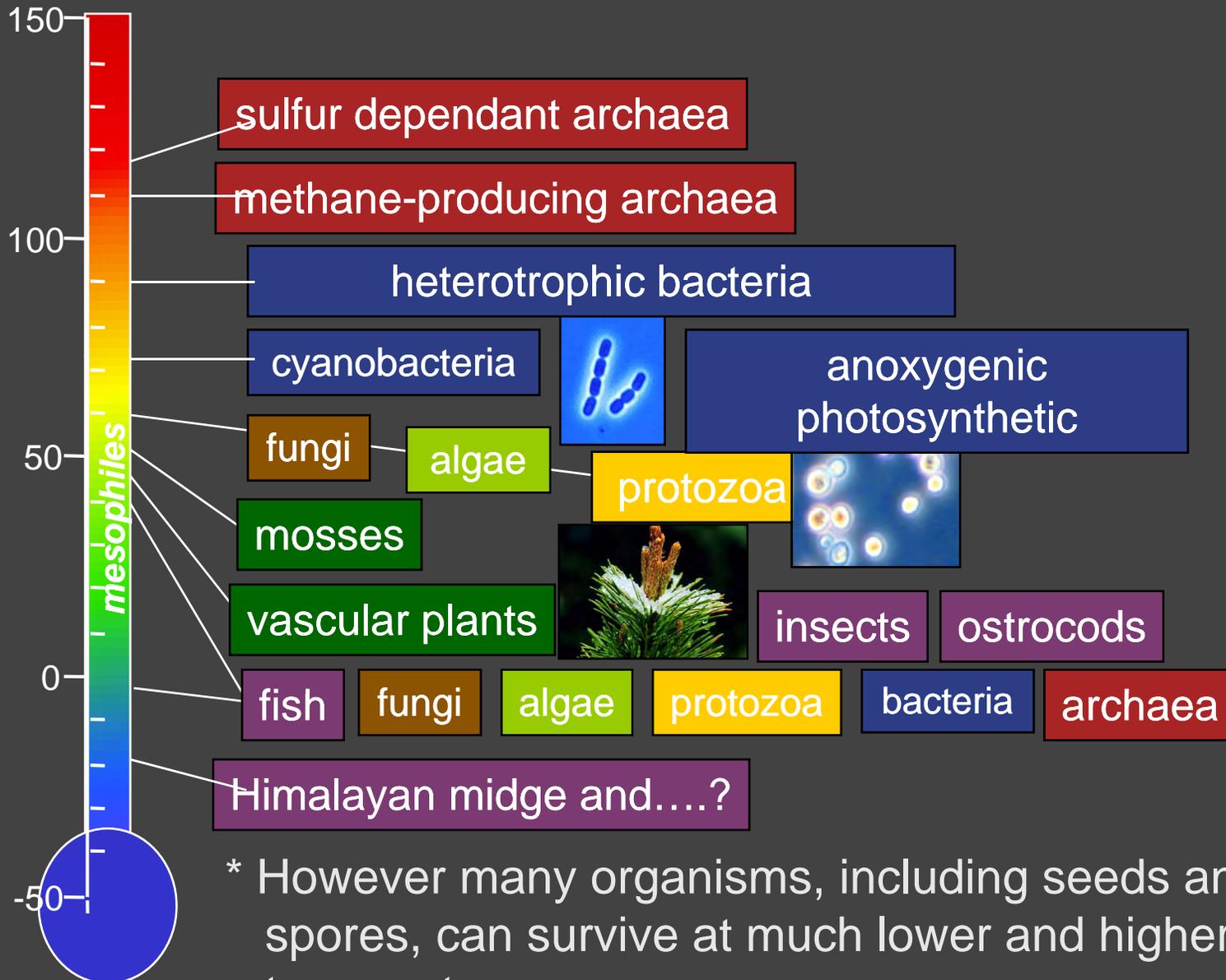
Examples of extreme parameters

Temperature: what difference does it make?

- ☞ *Solubility of gases goes down as temperature goes up.*
- ☞ *Organisms have upper temperature limits. Chlorophyll, proteins and nucleic acids denature at high temperatures.*
- ☞ *Enzymes have optimal temperatures for activity; slow down at low temperature*
- ☞ *Low temperature water freezes. Breaks membranes etc.*



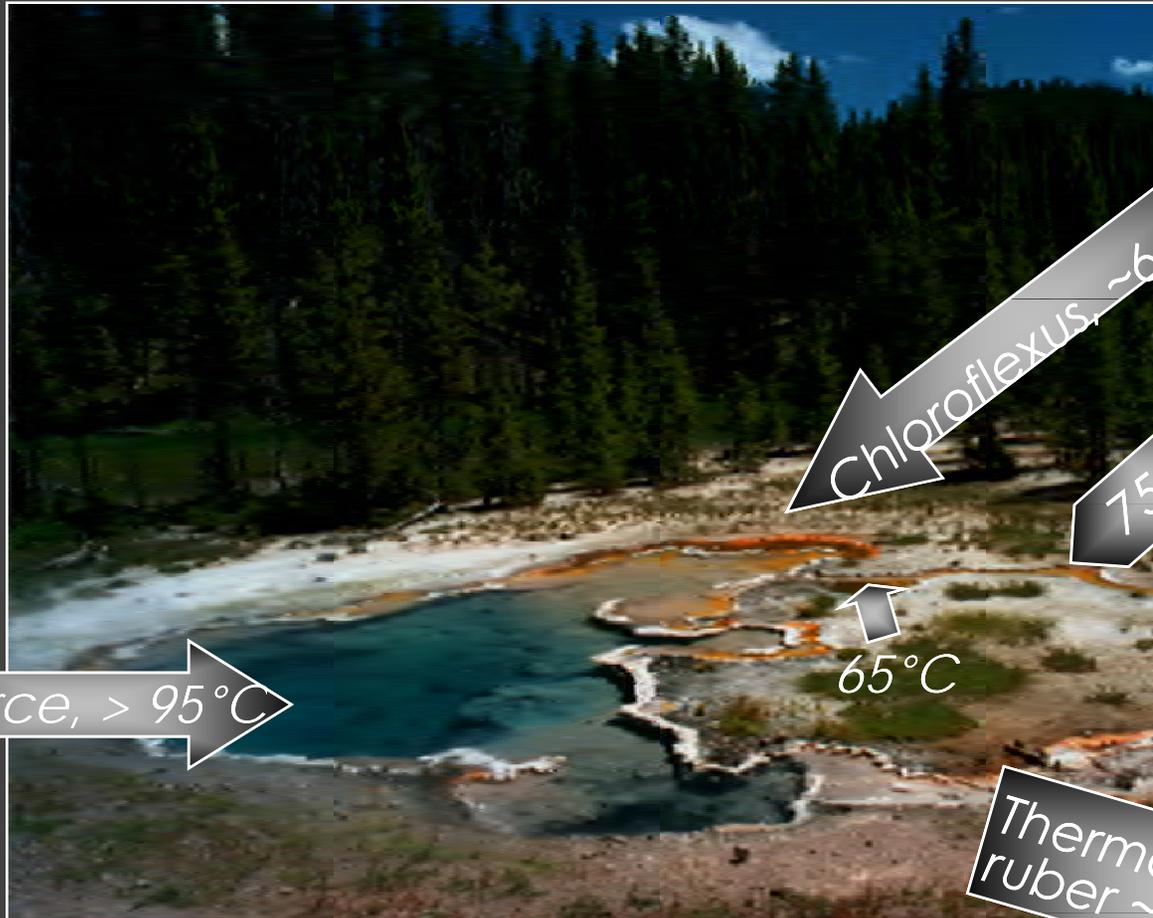
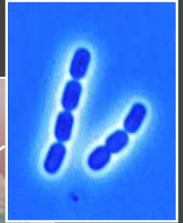
Temperature limits for life*



* However many organisms, including seeds and spores, can survive at much lower and higher temperatures.

Effect of high temp

Synechococcus



Chloroflexus, ~65°C

75°C

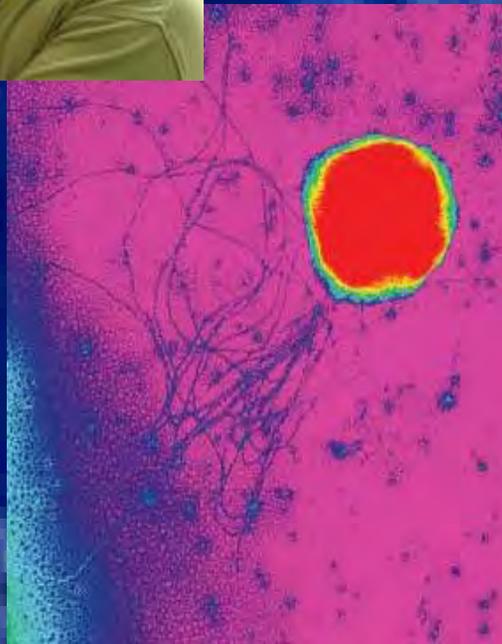
65°C

Source, > 95°C

Thermocrinis ruber ~83°C

Octopus Spring, Yellowstone National Park

The new high temp champion: *Geobacter*

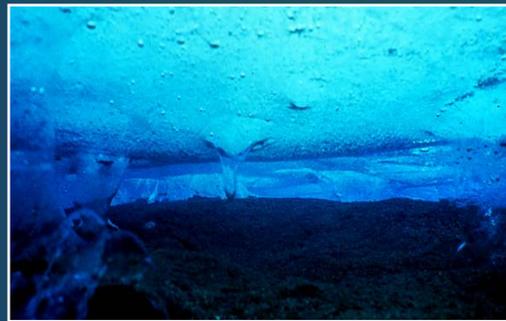


- *Stops reproducing at 121°C, remains stable to 130°C.*
- *Found in black smoker in Juan de Fuca Ridge, nearly 1.5 miles deep in the Pacific.*
- *Reduces ferric iron to ferrous iron and forms the mineral magnetite*

Antarctica



preparing to dive under ice-covered lakes



under the ice-covered lake

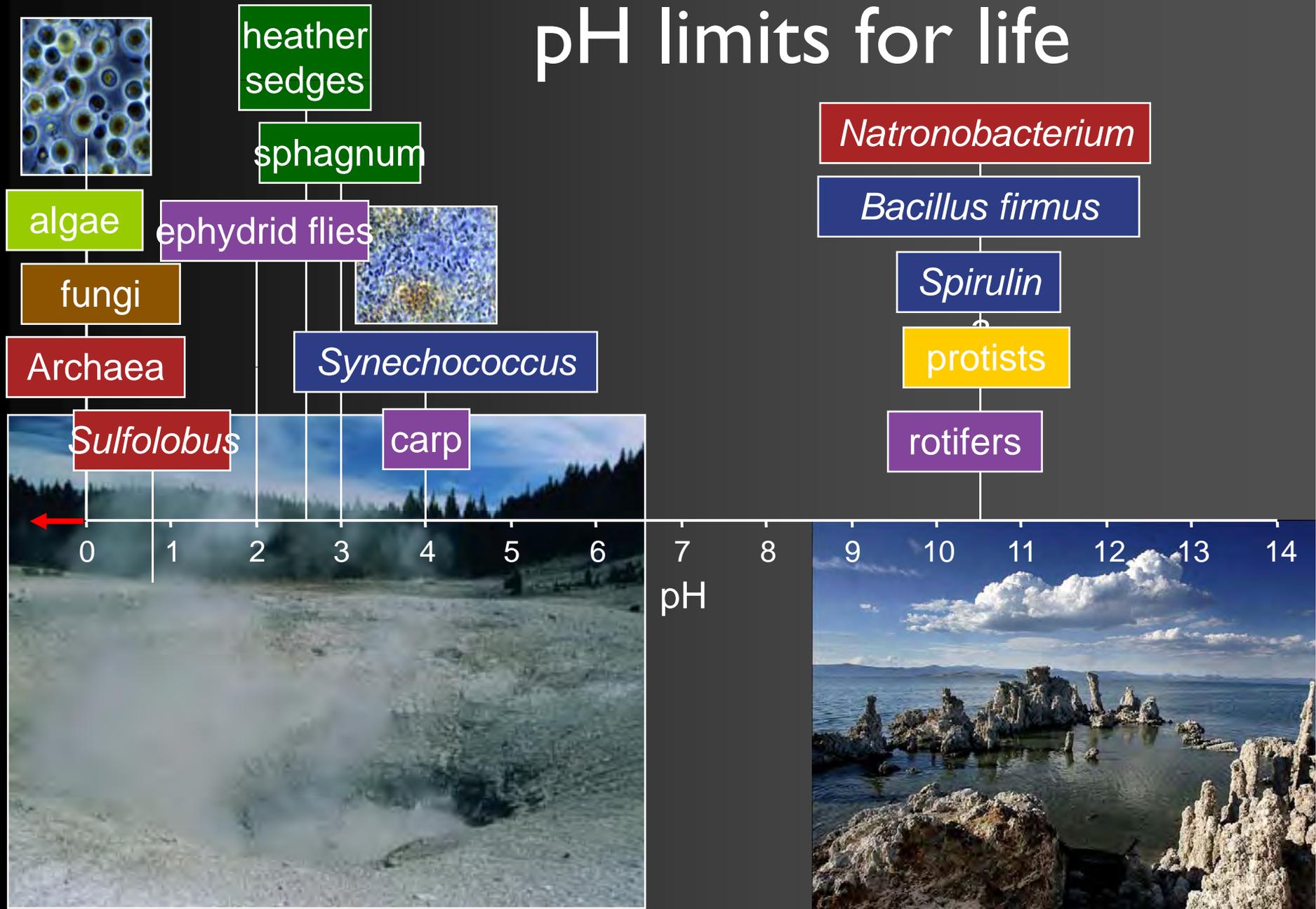


lift-off microbial mat



mat layers

pH limits for life



Salinity



- *Halophiles: 2-5 M salt*
- *Dunaliella salina is used in biotech industry. Produces glycerol and b-carotene.*
- *The bacterial halophiles have been flown in space.*

Desiccation (drying up)

- *Can be correlated with salinity tolerance.*
- *Possibly a few organisms, e.g. lichens in some deserts, can survive on water vapor rather than liquid water.*
- *Don't repair cell damage during desiccation, so must be good at repair upon rehydration.*

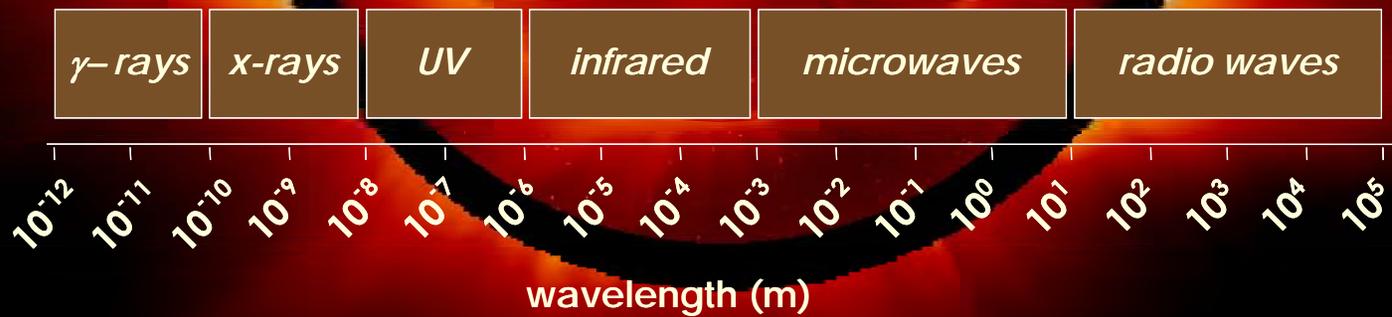


*Evaporite, Baja
California Sur*

Radiation

- *Some forms of radiation have been a constant for organisms over geological time, whereas others vary seasonally and diurnally. Exposure may depend on ecology.*
- *Some radiation is blocked by the Earth's atmosphere, and thus is newly relevant with respect to interplanetary travel or to an potential extraterrestrial biota.*

The Solar Spectrum



Deinococcus radiodurans (Conan the Bacterium)

- *An example of survival in extreme radiation environment*
- *Can withstand 1,500,000 “rads”*
- *500 rads kill humans!*



High oxygen

- *Oxygen is the one environmental extreme that we consider “**NORMAL**”*
- *This is one of the **WORST** environmental extremes.*
- *Conclusion: **WE** are extremophiles too.*

What is oxidative damage?

✓ *Oxidative damage is caused by reactive oxygen species and cause damage to DNA, enzymes and lipids.*

✓ *Can be formed by UV sunlight.*



✓ *Oxygen and the OH[•] radical directly modify DNA* _____ ↙
including causing strand breakage.

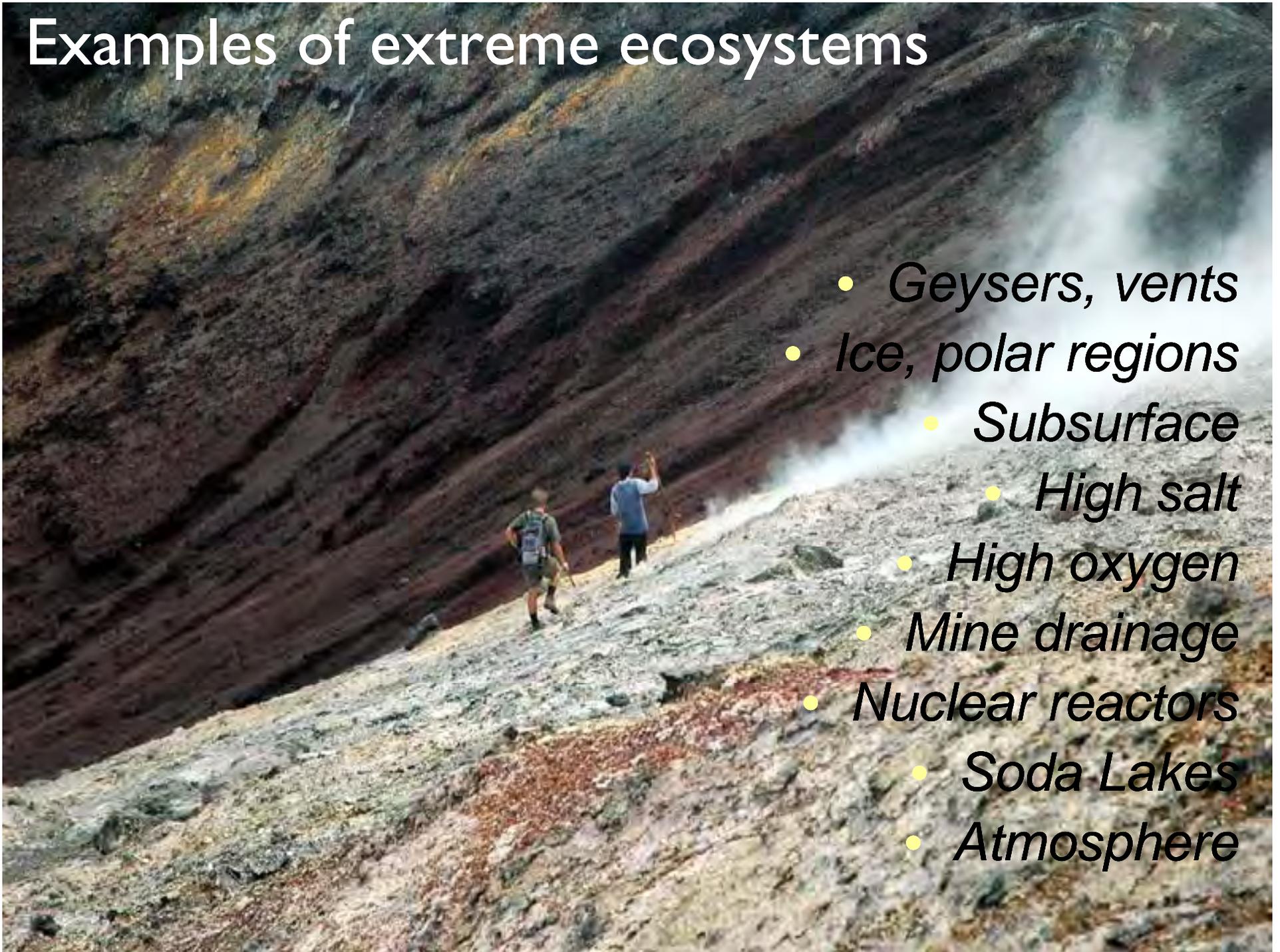
✓ *Oxidative damage may cause many diseases.*



✓ *Protection includes antioxidants and enzymes*

Examples of extreme ecosystems

- *Geysers, vents*
- *Ice, polar regions*
- *Subsurface*
- *High salt*
- *High oxygen*
- *Mine drainage*
- *Nuclear reactors*
- *Soda Lakes*
- *Atmosphere*



Space: a new
category of
extreme
environment



Extremophiles beyond Earth

Multiple Mars possibilities

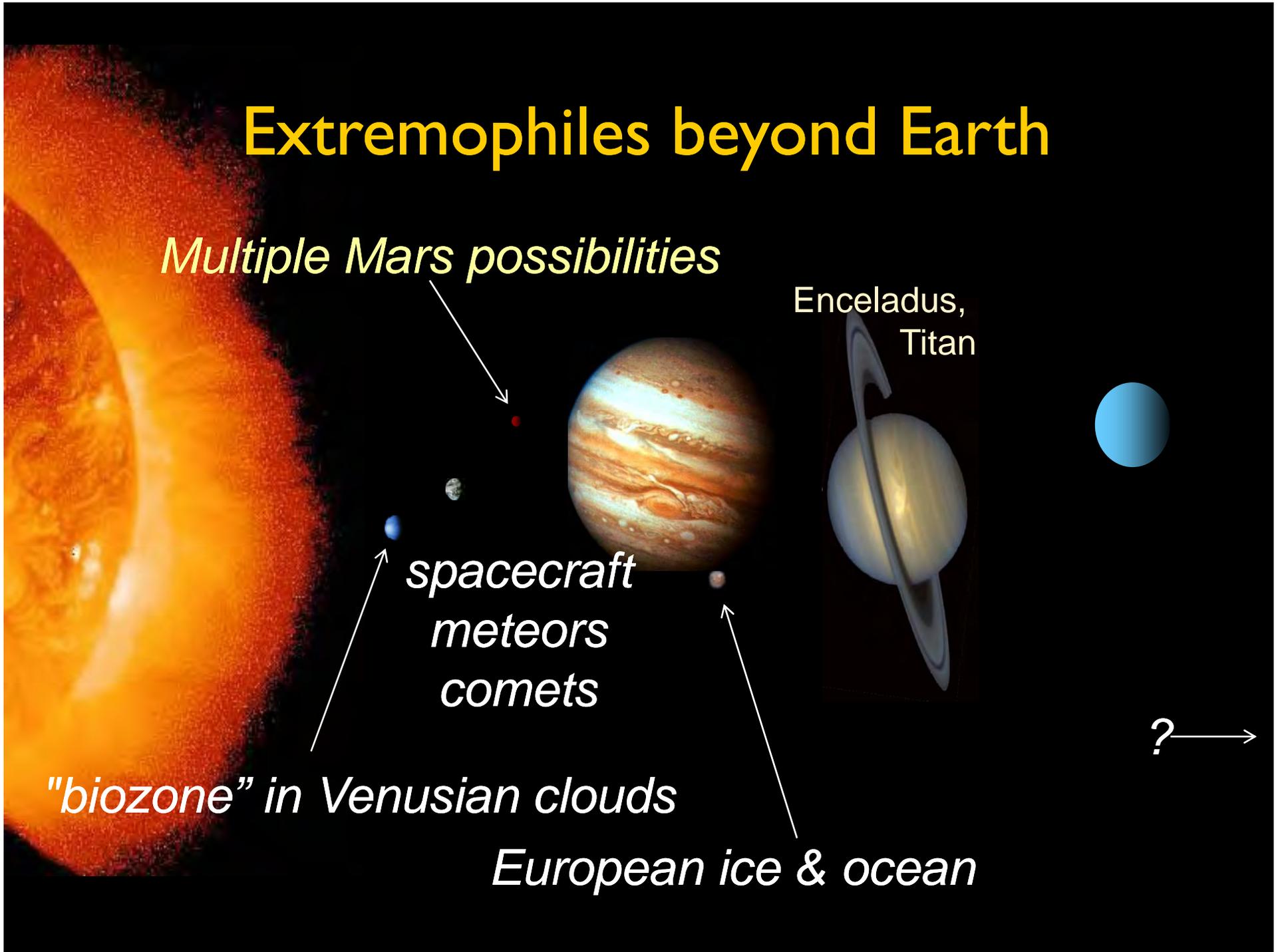
Enceladus,
Titan

*spacecraft
meteors
comets*

"biozone" in Venusian clouds

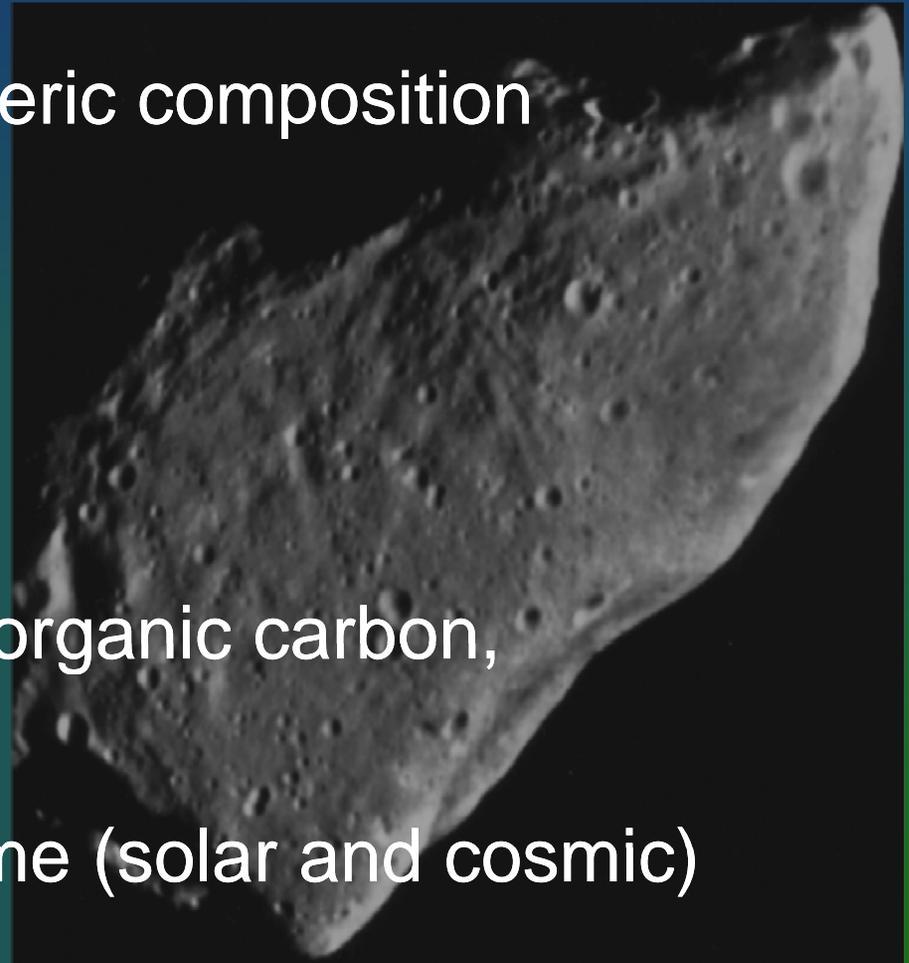
European ice & ocean

? →



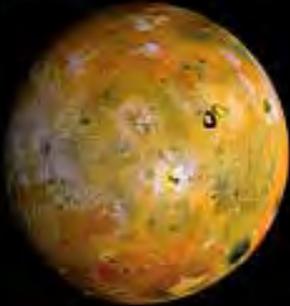
Why is life beyond earth difficult?

- Differences in atmospheric composition
- Altered gravity
- Space vacuum
- Temperature extremes
- Nutrient sources (e.g., organic carbon, nitrogen)
- Different radiation regime (solar and cosmic)



Jupiter's Moons

Io



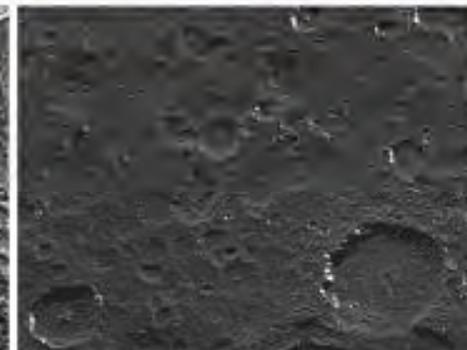
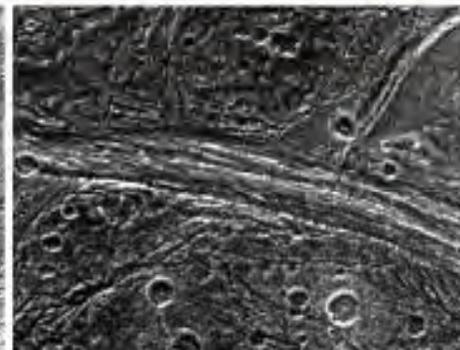
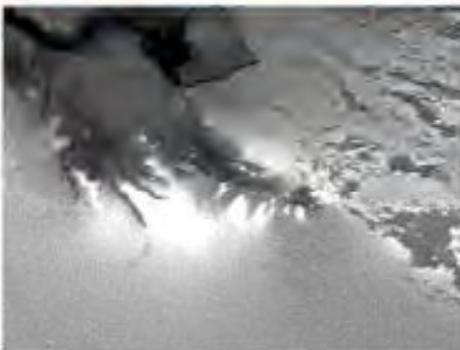
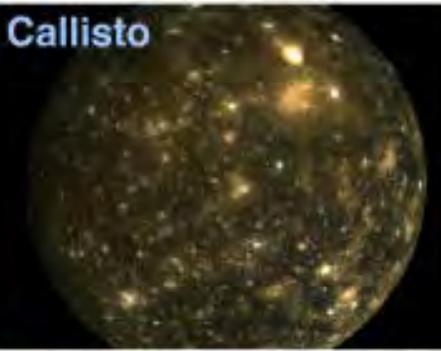
Europa



Ganymede

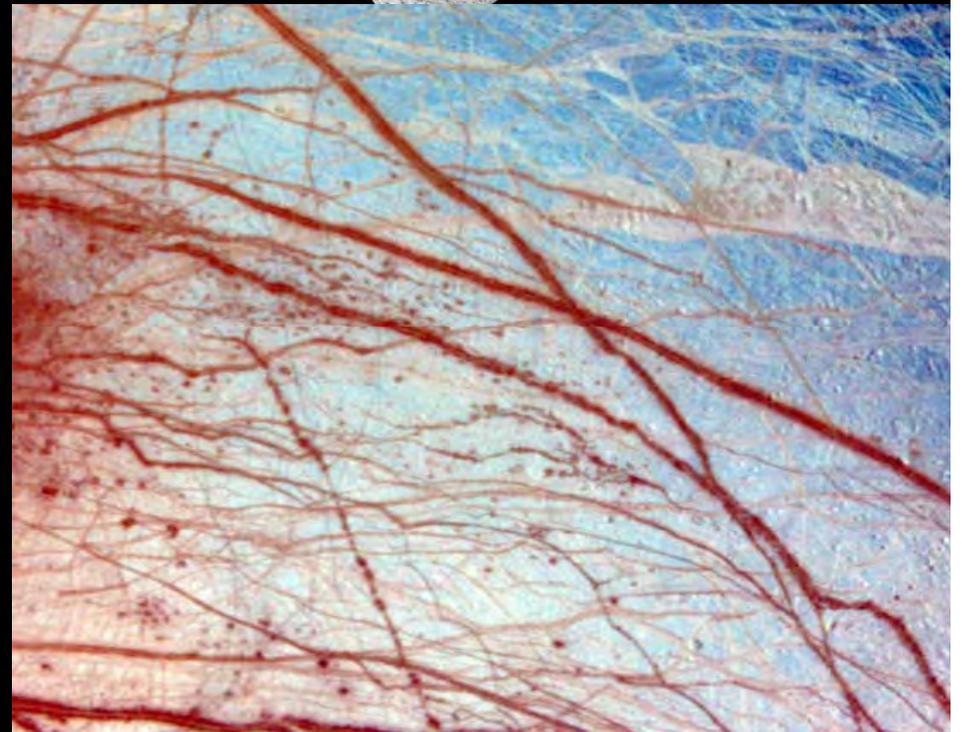
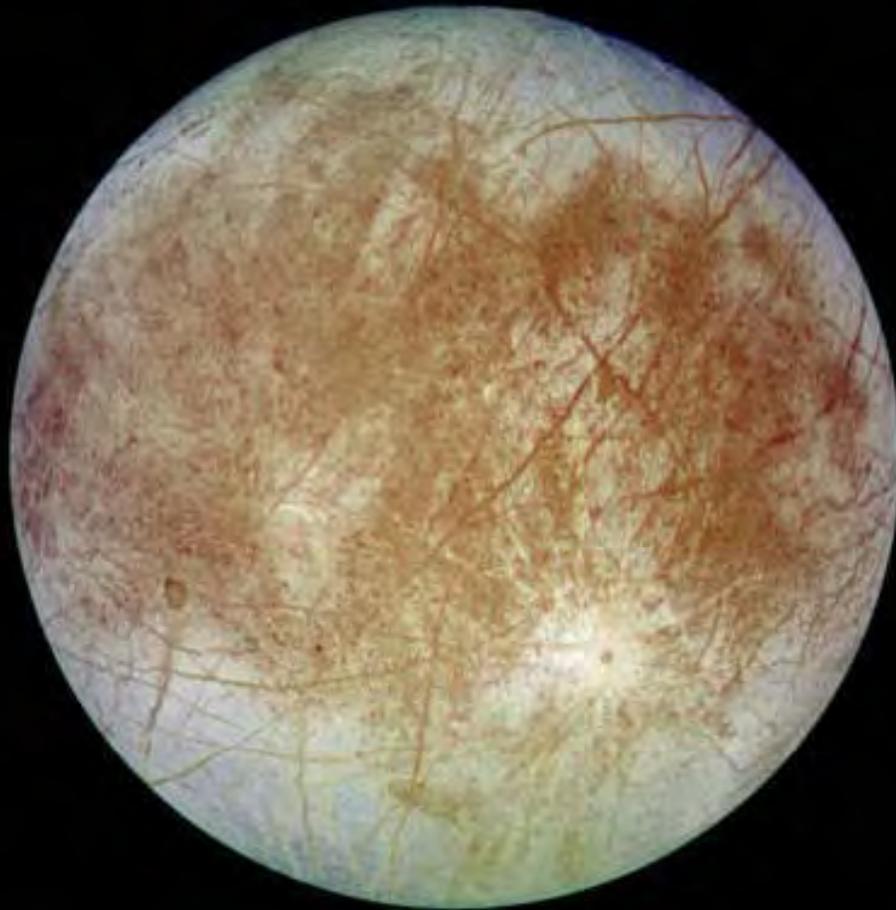
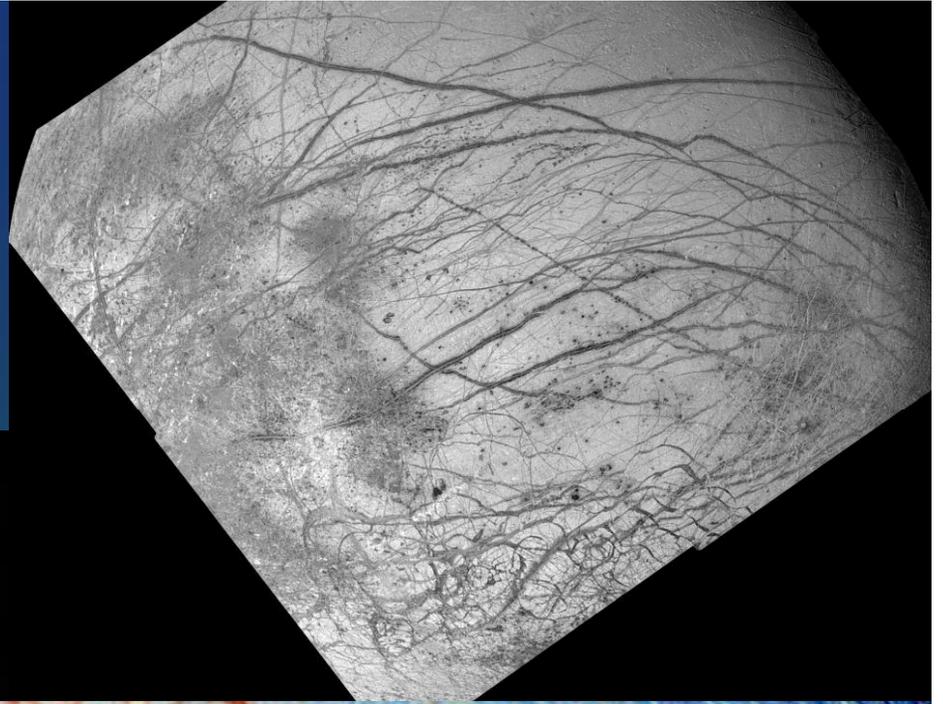


Callisto



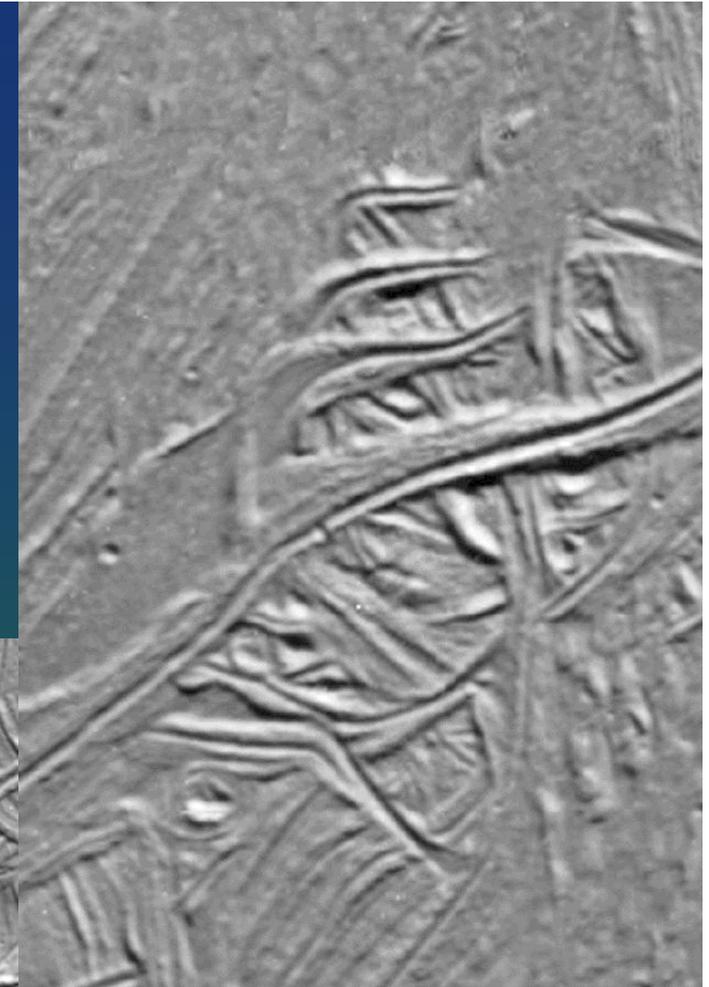
Europa

Dark Material Seeping Through Cracks



*Zooming in
on Cracks
and Flows*

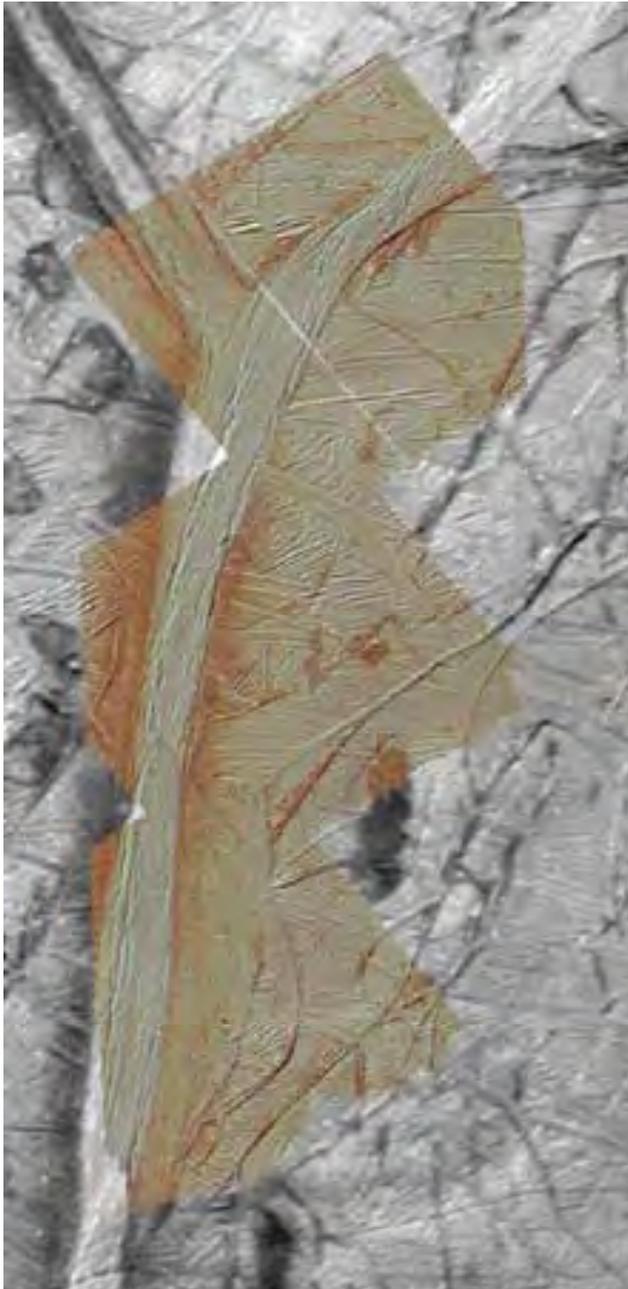
10 km



5 km

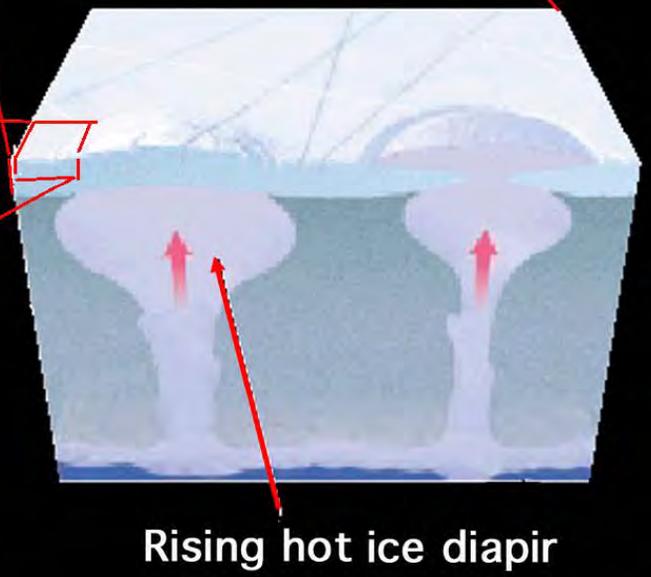
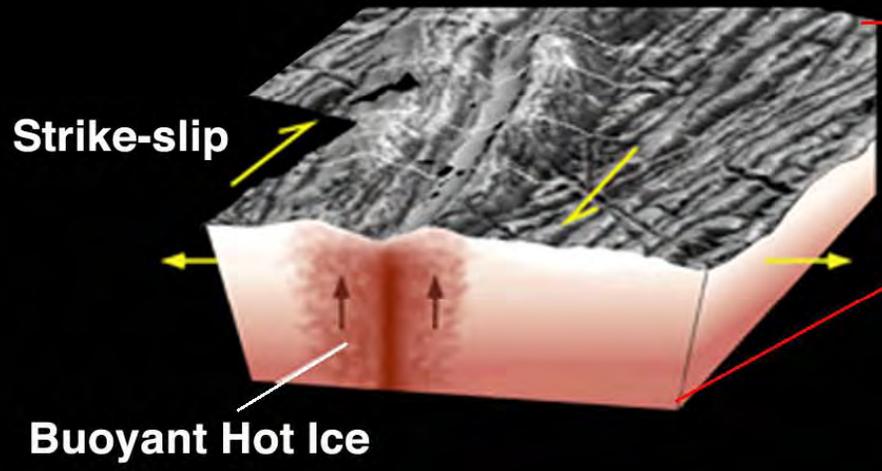
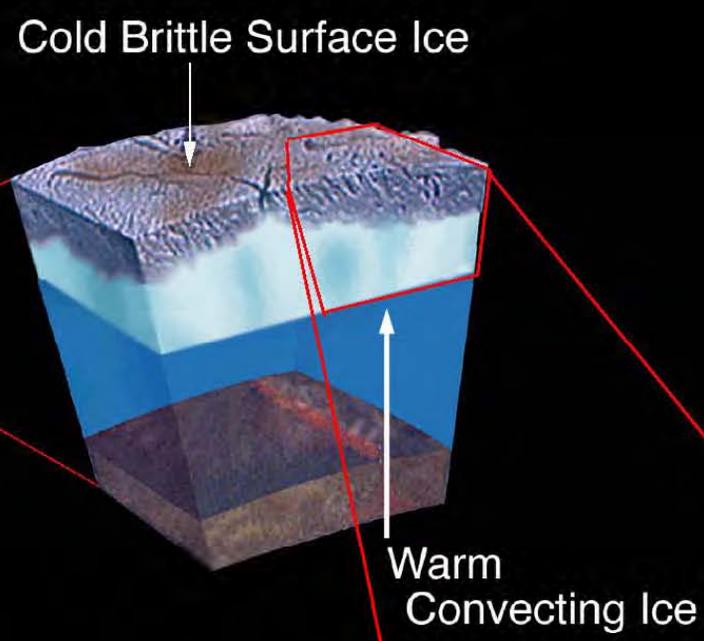
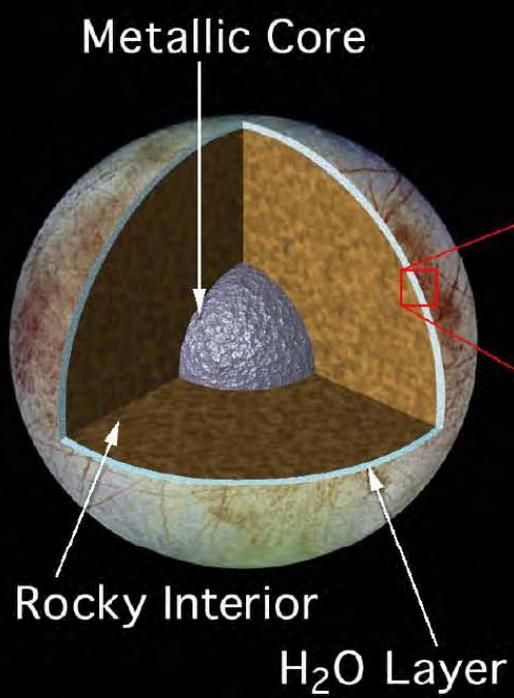


*Ice - sometimes it
suddenly cracks,
sometimes it slowly
flows*

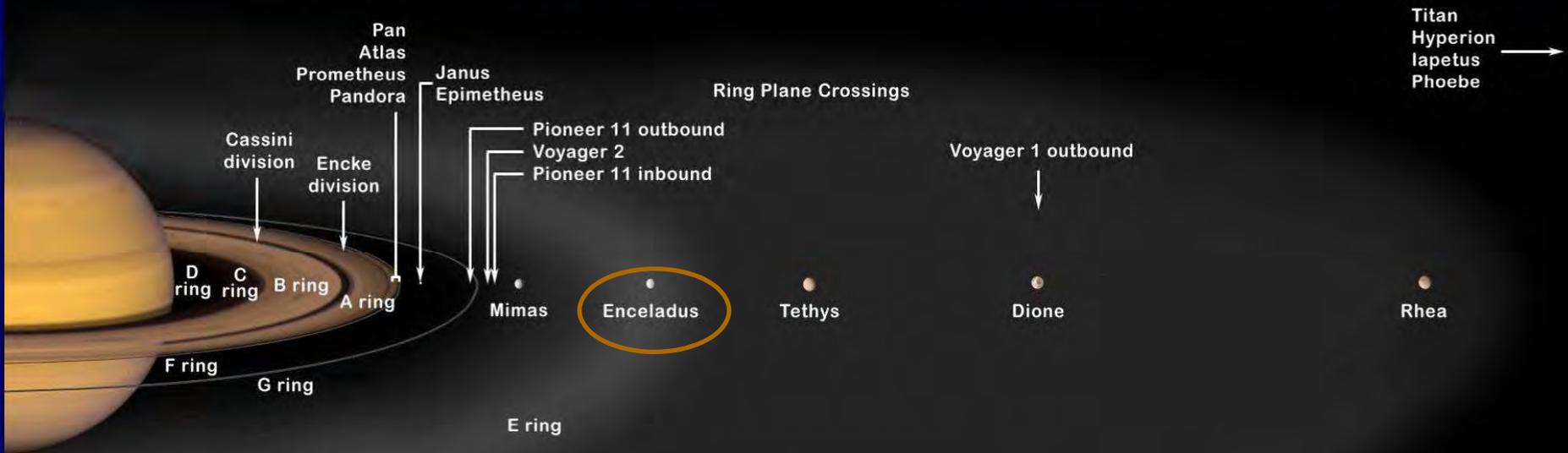


50 km

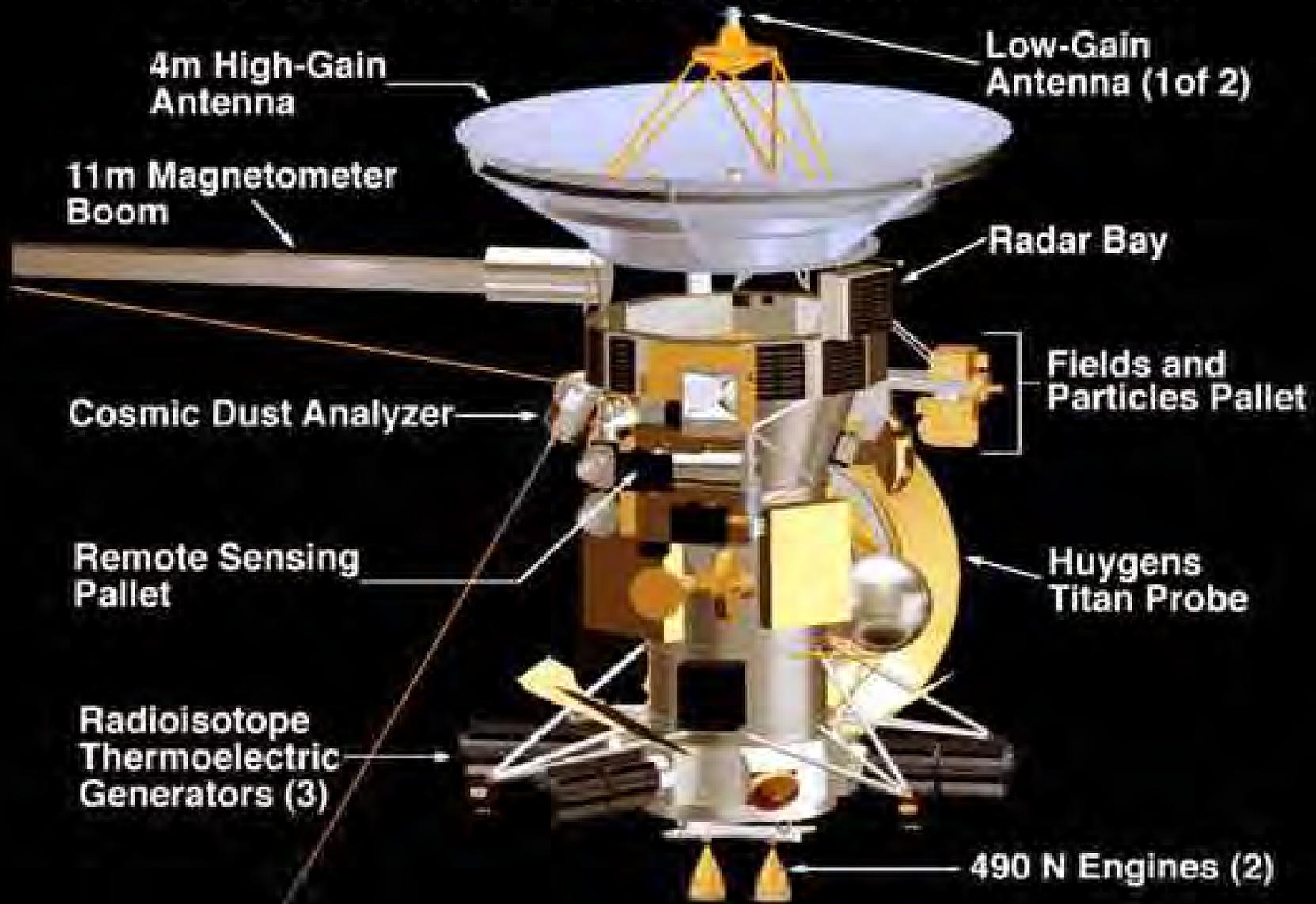




Saturn's Satellites and Ring Structure

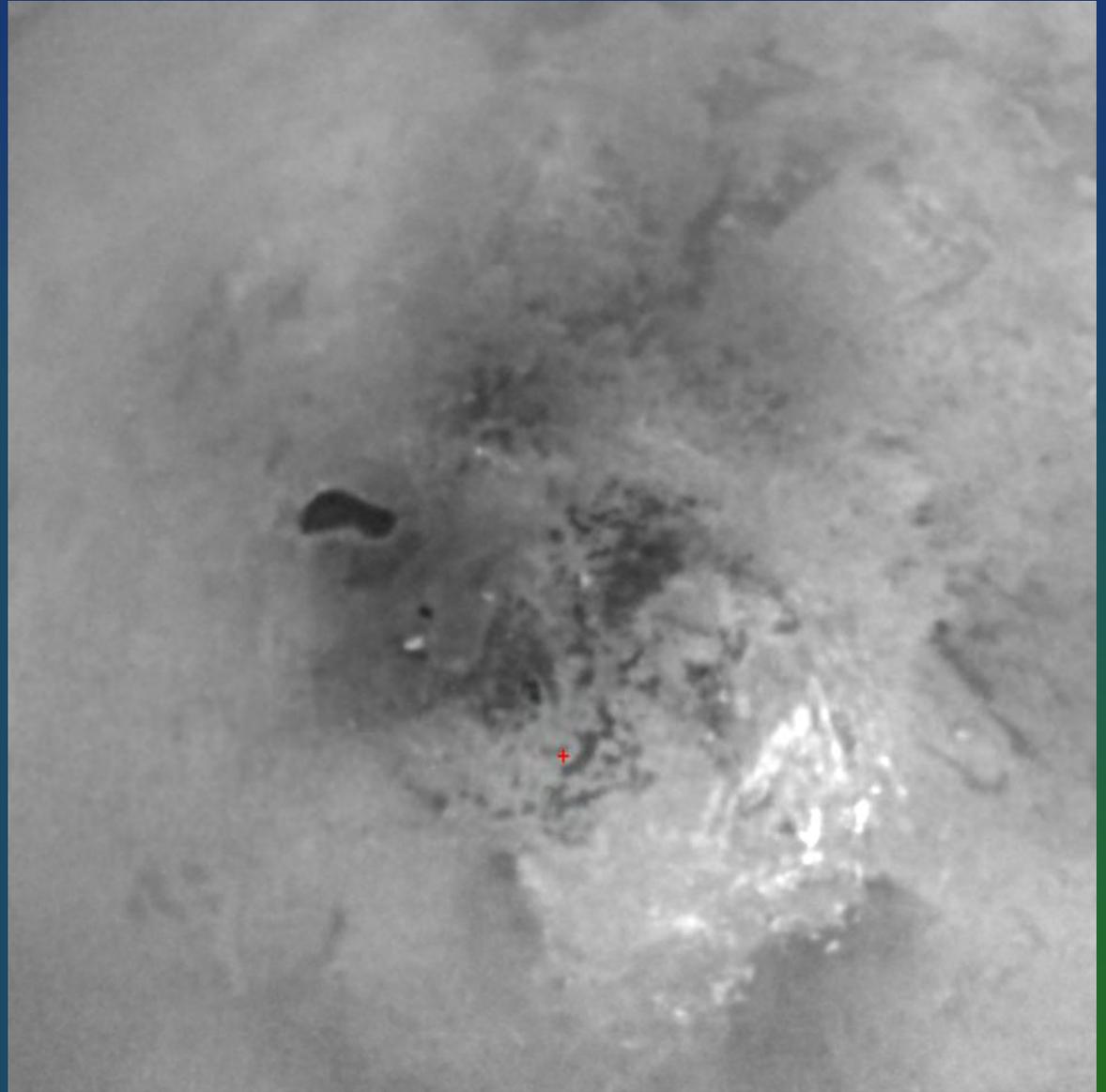


CASSINI CRUISE CONFIGURATION



Titan: Land o' lakes?

- *This image of the south pole shows white clouds and an intriguing dark feature with a sharp boundary.*
- *This is likely a lake of hydrocarbons.*



River to the shore?

- *This composite of three images shows what looks like a branching river draining to a shoreline.*
- *Rainfall on Titan would presumably be liquid methane.*

