High, Low, Hot, and Cold Extremes and the Search for Life in the Solar System

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Sailing through the wonders of Astrobiology
Veli Lošinj, Croatia, 25-29 September 2017

Search for Life in the Solar System

- Mars,
- Ocean Worlds

Exploration

Science

Testing

Technology

Life Detection Protocols

Planetary Protection Practices

Training

Risk assm mgmt/mitig

Public engagement

Local Community Engagement

Spaceward Bound Expeditions

LIFE Yes/ No	What is the biomass distribution, variability, and timescale in extreme environments	Species and microbial ecology	Climatic and micro climatic conditions, T, RH	geology, mineralogy, chemistry, pH, water cycle and their timescales

Search for Life: why is Life on other Worlds Interesting?

- The possibility of a second genesis of life:
  $\Rightarrow$ comparative biochemistry
  $\Rightarrow$ life is common in the universe (yeah!)

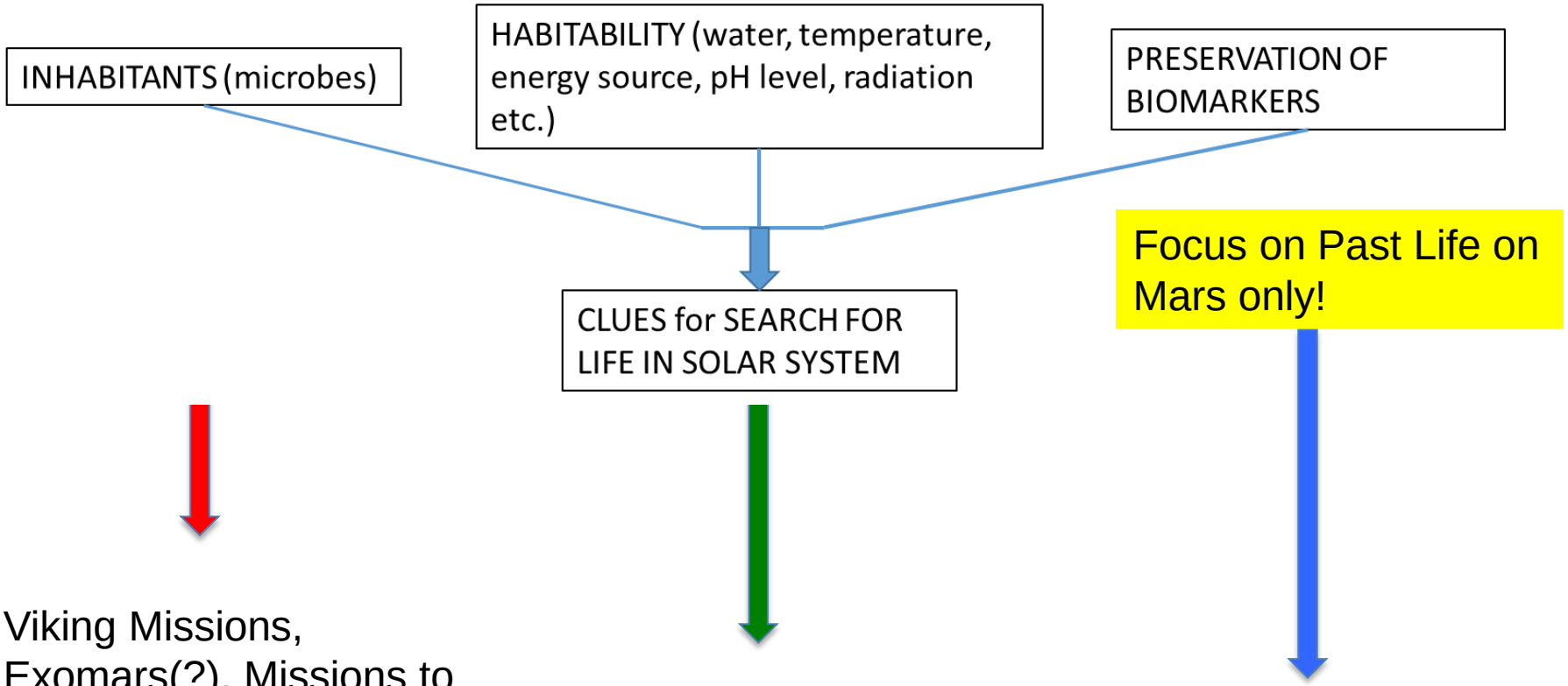
- Information about the early planetary environment
- Relevant to the origin of life on Earth

Search for Life in the Solar System (Mars) & Elsewhere

Actual Living organisms

Potential for Life aka the "ingredients for life" …but not actual life

Proxies for past & present life



Viking Missions, Exomars(?). Missions to Enceladus and Europa

Phoenix, MSL 2011; Mars 2020

MSL 2011; Mars 2020

Why Field Science Expeditions to Planetary Analogs?

- **Astrobiology-driven search for Life in the Solar System & Beyond**
- **The NASA vision for Space Exploration involves robotic missions to prepare for humans living and working on the surfaces of the Moon and Mars**

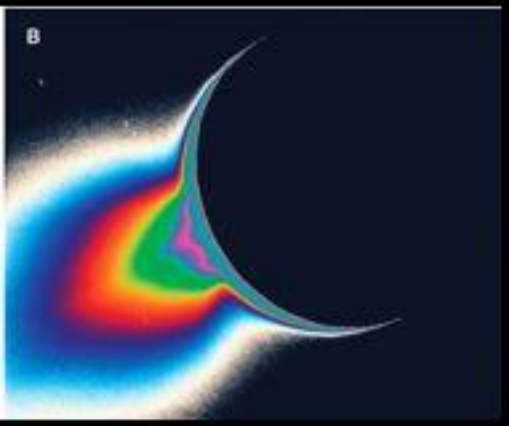
Explore to Learn – Gain scientific knowledge, a deeper understanding of the requirements definition, concept of operations

Test – Technologies, system interactions, **and analytical protocols**, Evaluate and validate the requirements, concept of operations

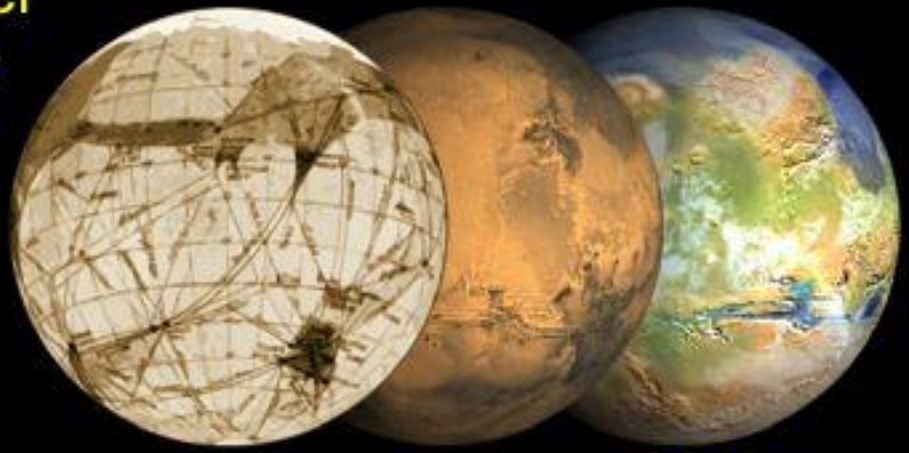
Train – teachers, educators, next generation of scientists and space explorers. Train and help select crew, ground teams, managers, and technologists

Engage – Excite and engage the public in the Exploration Vision through analog activities here on Earth

Analogs help us understand other worlds of interest to astrobiology

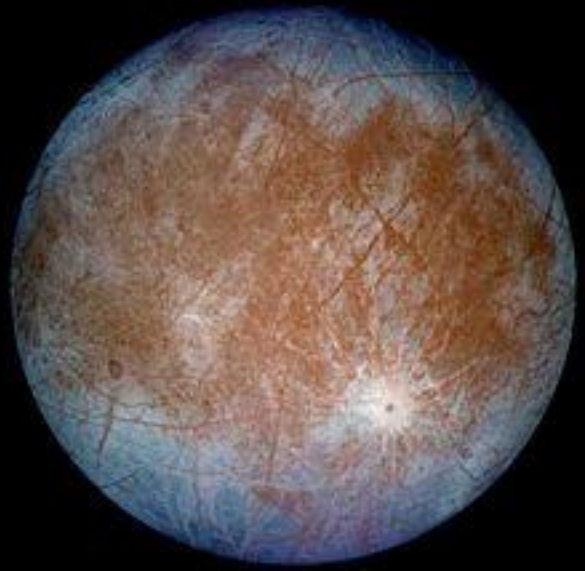


Enceladus



Mars

Europa



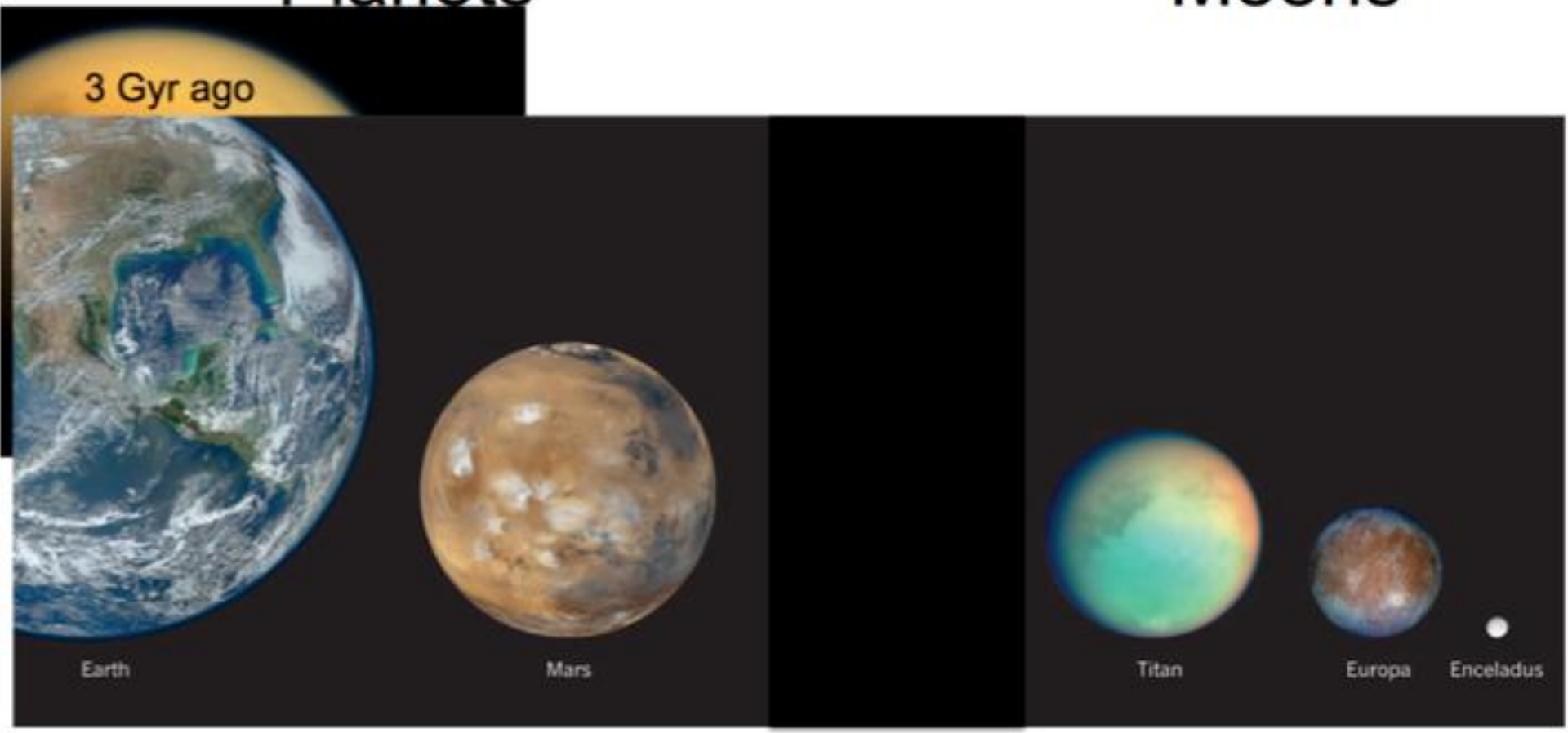
Early Earth

Extrasolar planets

Titan

Planets

Moons

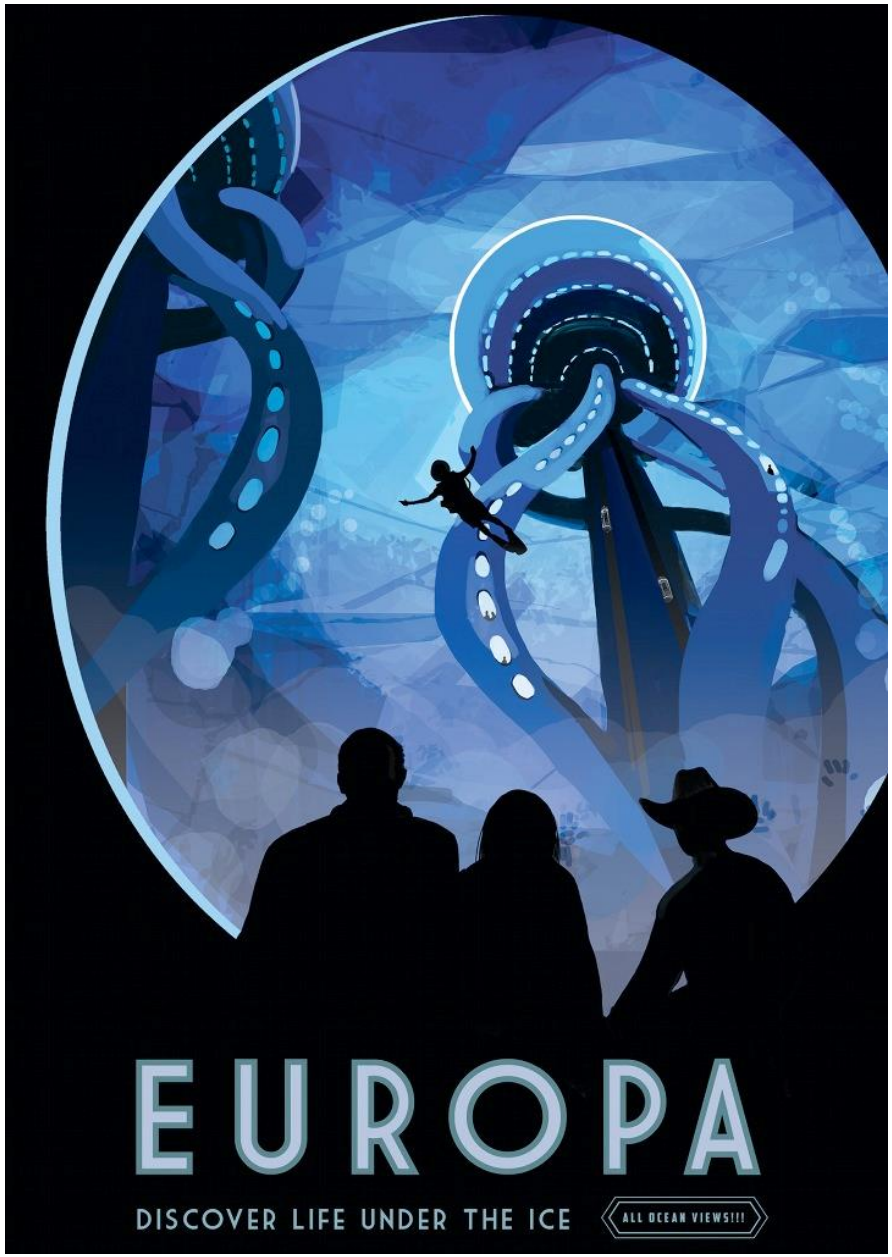


Surface water worlds

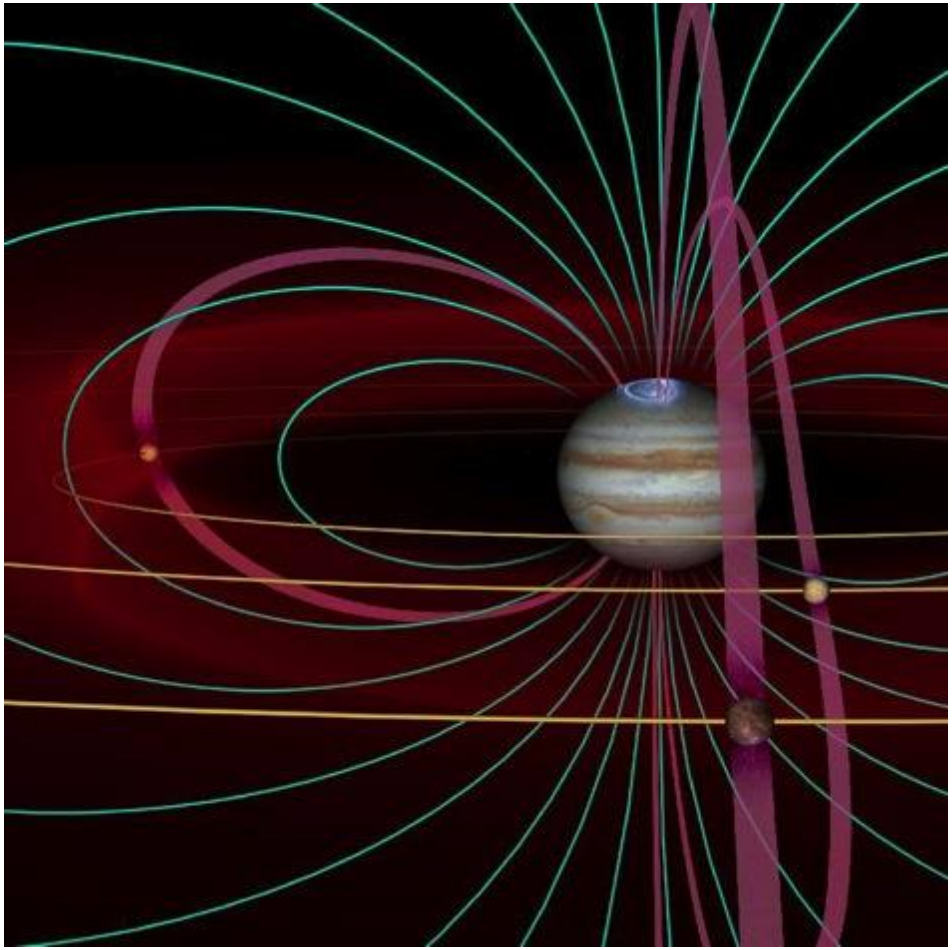
Other liquid world

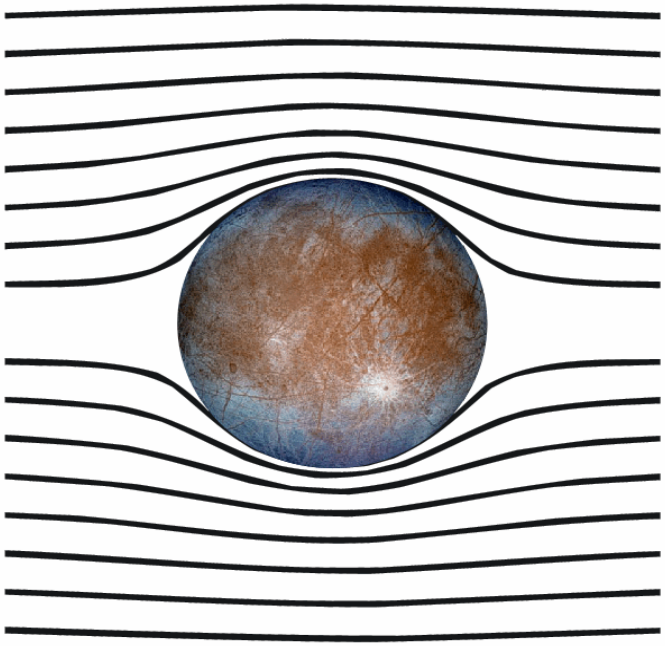
Ice covered water worlds

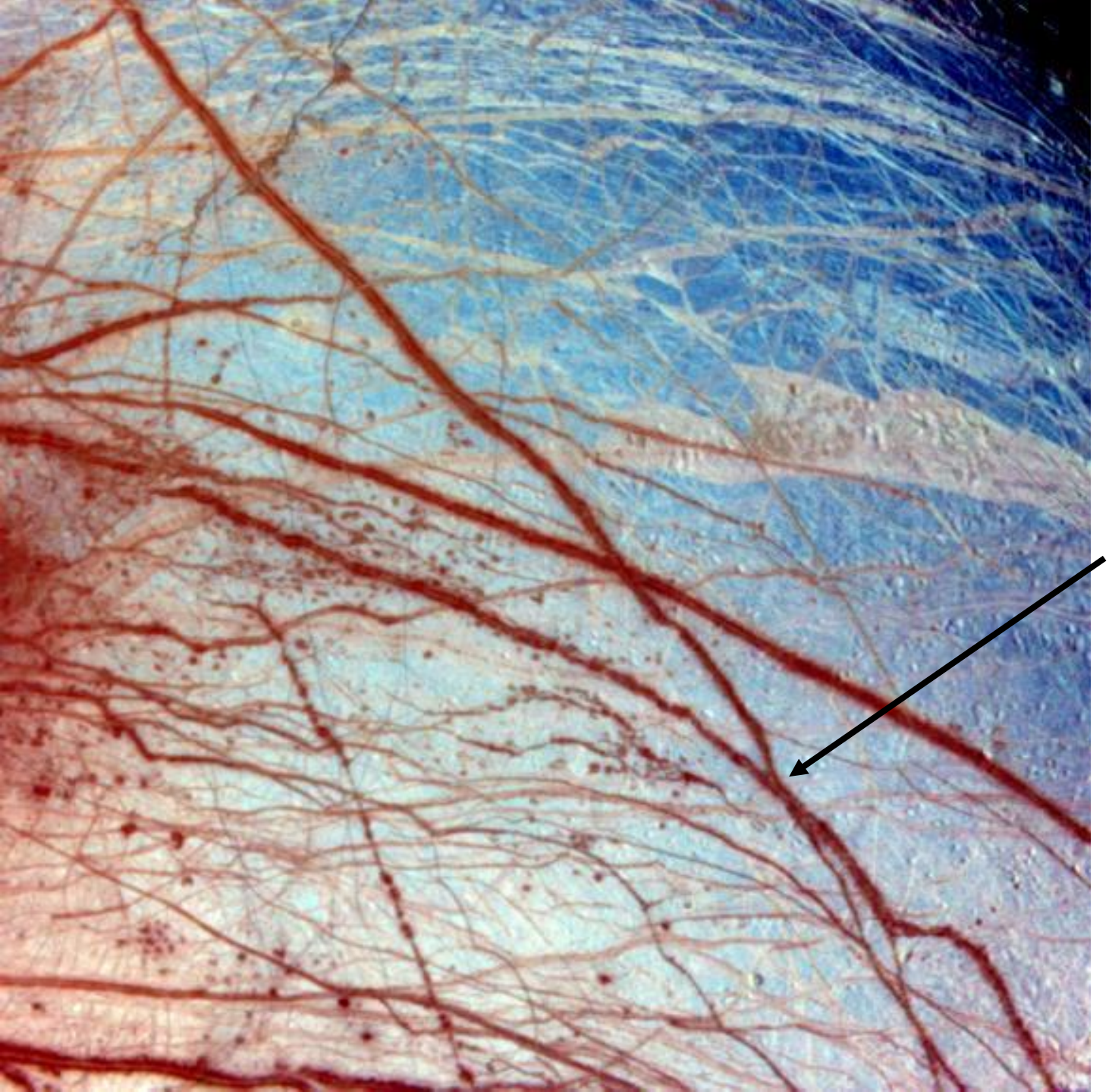
Europa!


EUROPA
DISCOVER LIFE UNDER THE ICE
ALL OCEAN VIEWS!!!

Evidence for global salty water (conductor) is the most compelling evidence for an ocean on Europa today.





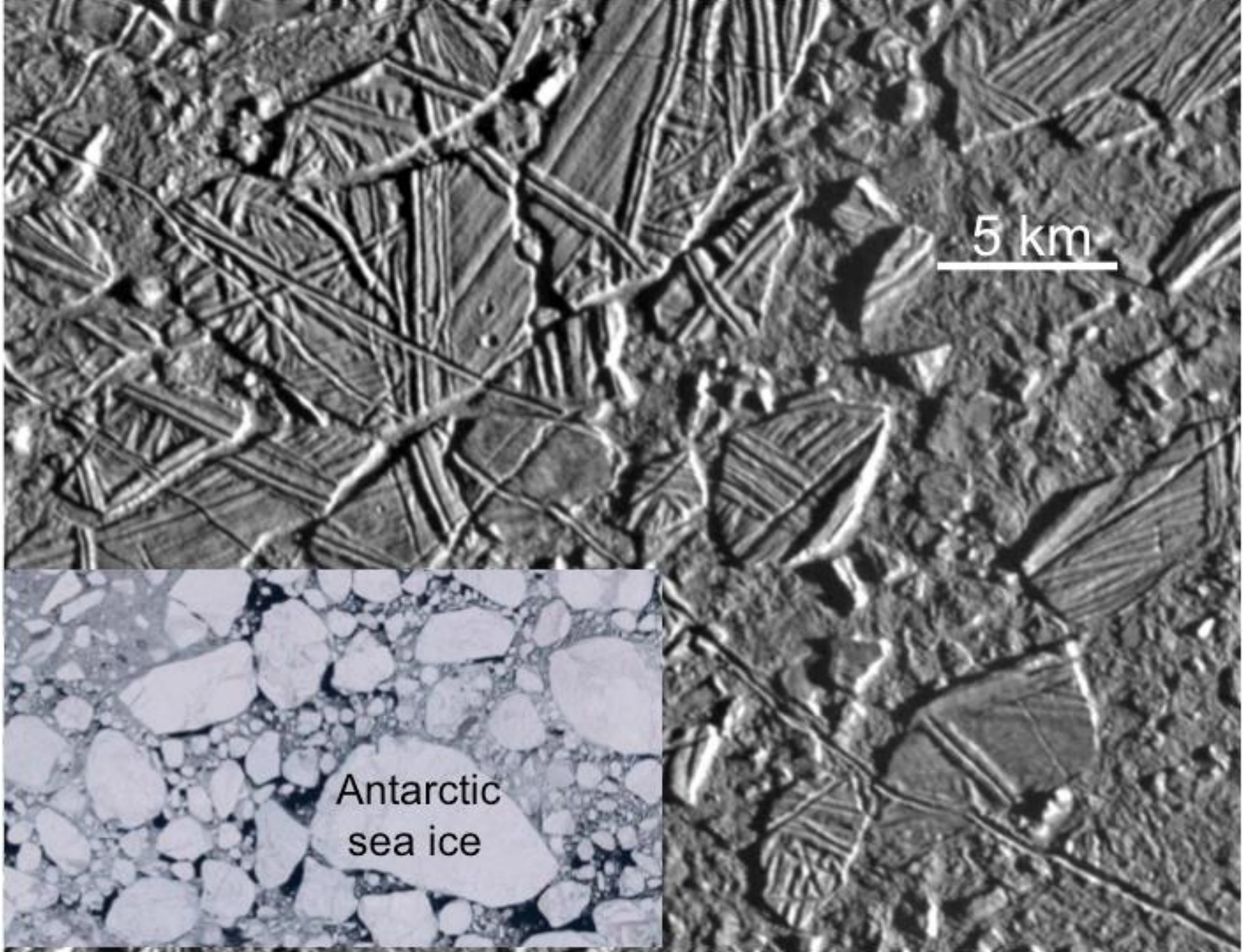


Europa's surface

If there is an ocean

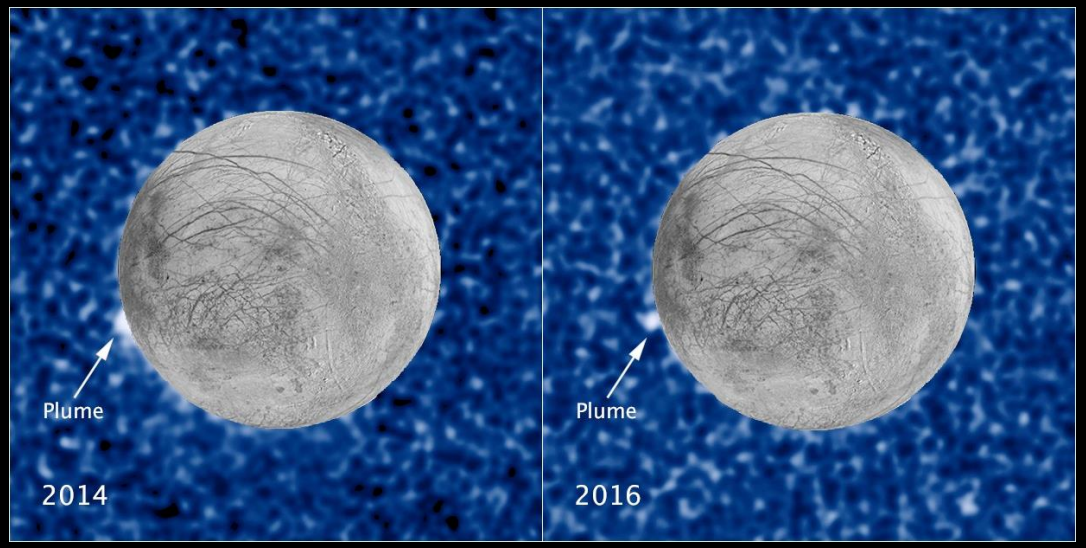
If the ocean has life

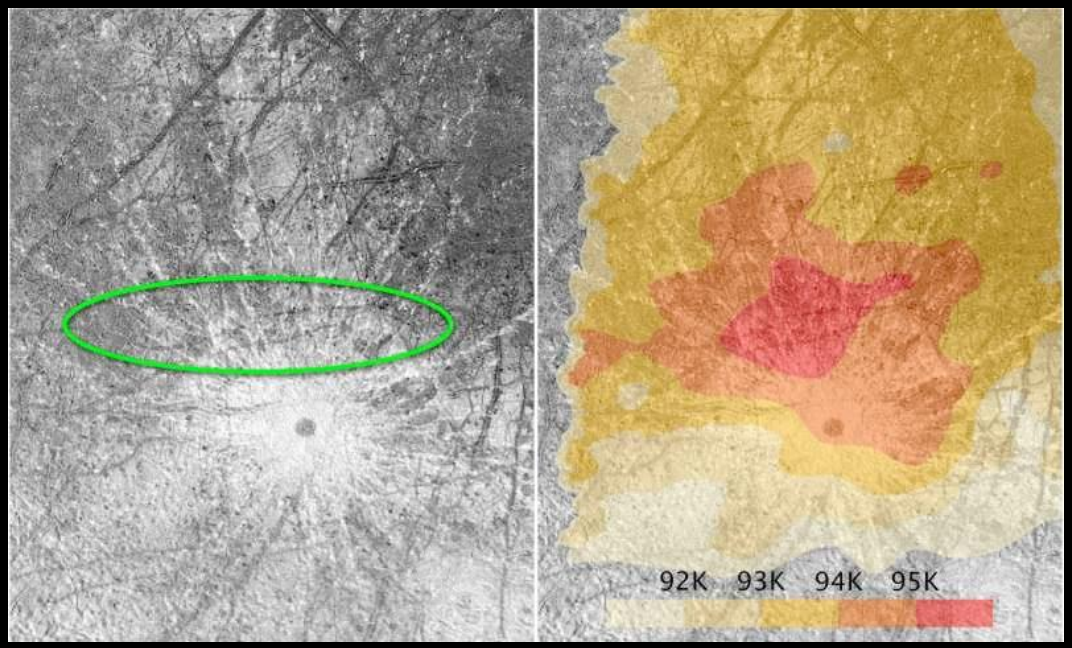
Then these surface features may contain biogenic organic material


5 km
Antarctic
sea ice

Further evidence for Europa's pelagic ocean

Possible plume from Europa's Southern hemisphere photographed in UV light by Hubble telescope.



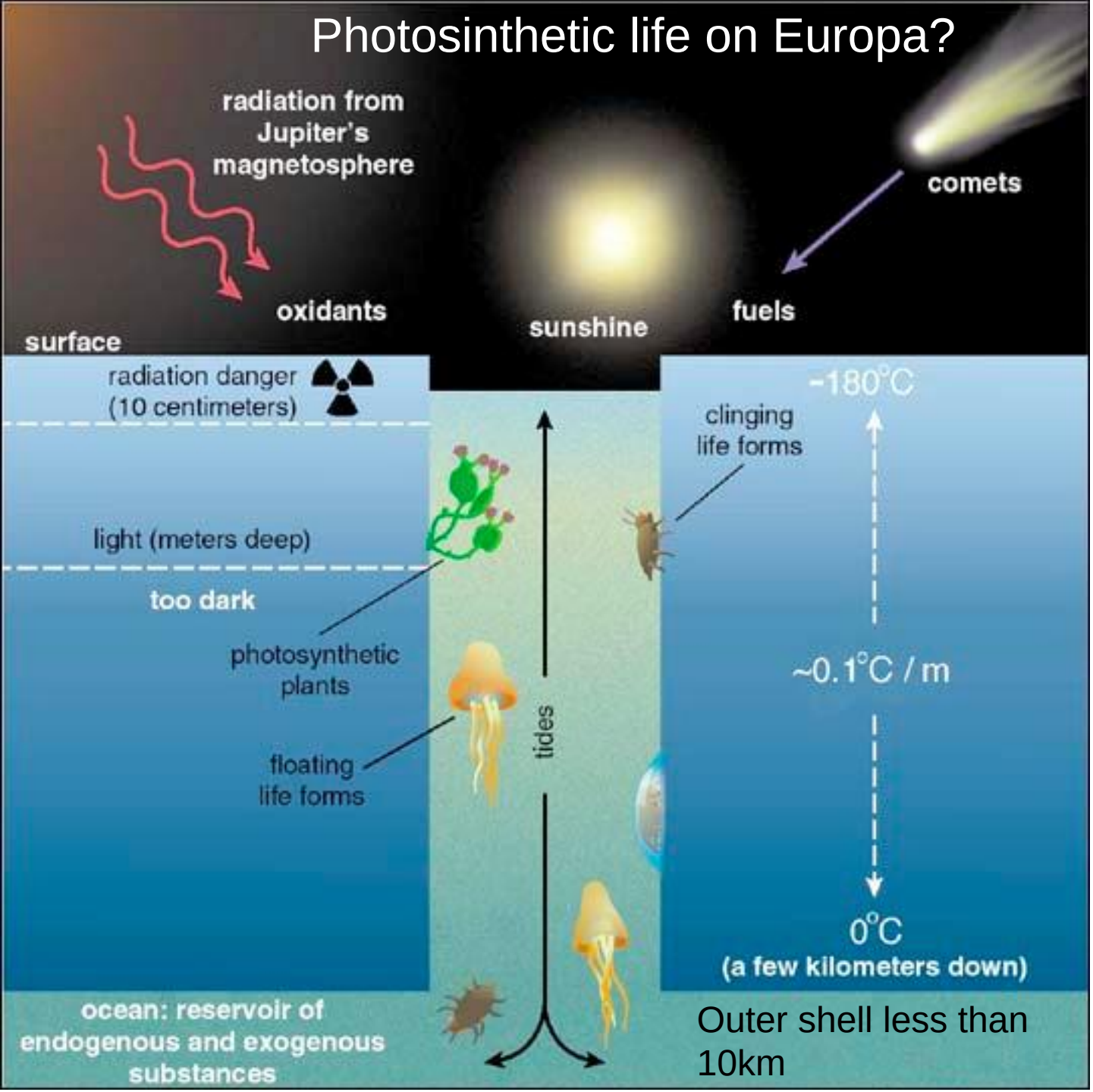


The area corresponds to a warm region on Europa's and cracks in its icy crust, seen seen by the the Galileo spacecraft in the late 1990s
Credit: NASA/ESA/STScI/USGS

Given liquid water on Europa & Enceladus is there:

- a plausible origin of life?
- a plausible ecology?

Photosinthetic life on Europa?



Europa's Icy crust may be just a few kilometres thick – perhaps thin enough to crack open under tidal stress

Greenberg's ~3km thin ice vs. Pappalardo's 25-30 km thick ice

All agree that interaction between the ice crust and ocean might support life

Outer shell less than 10km

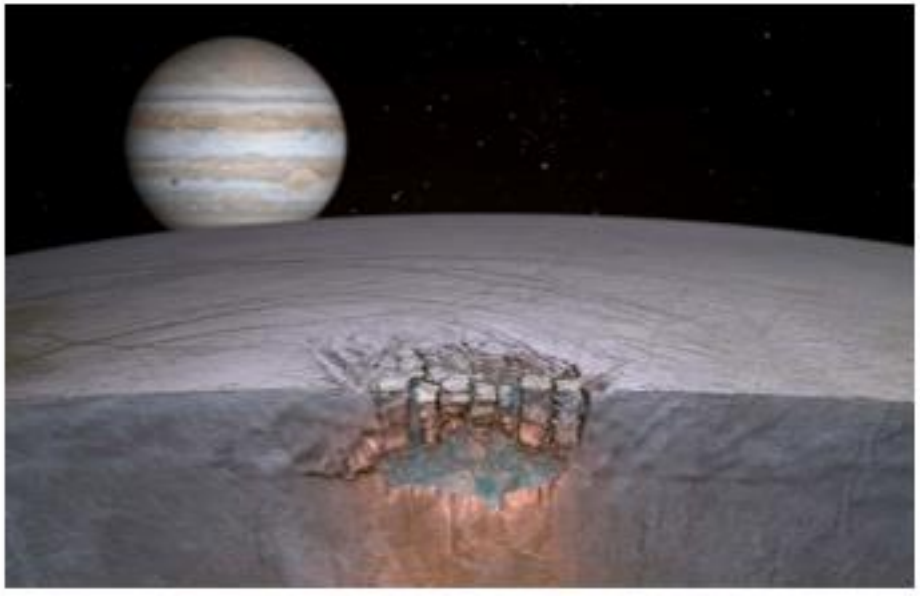
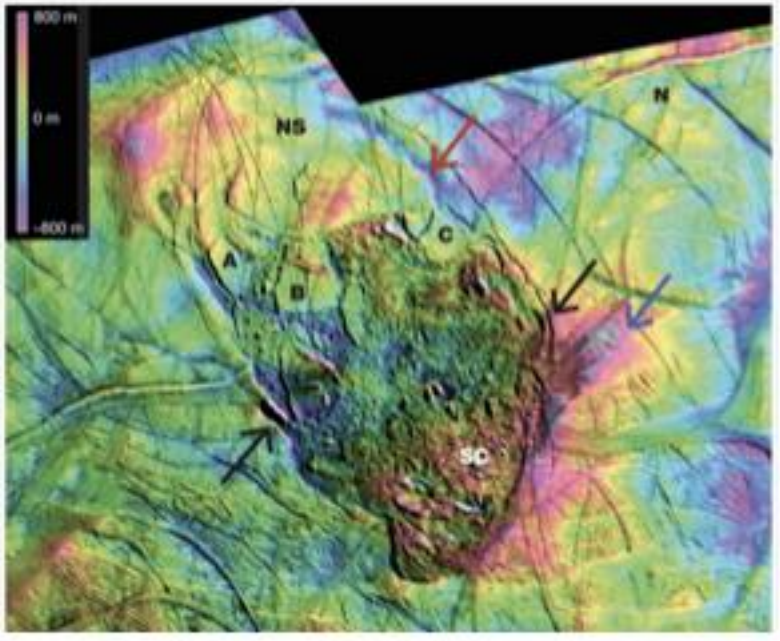
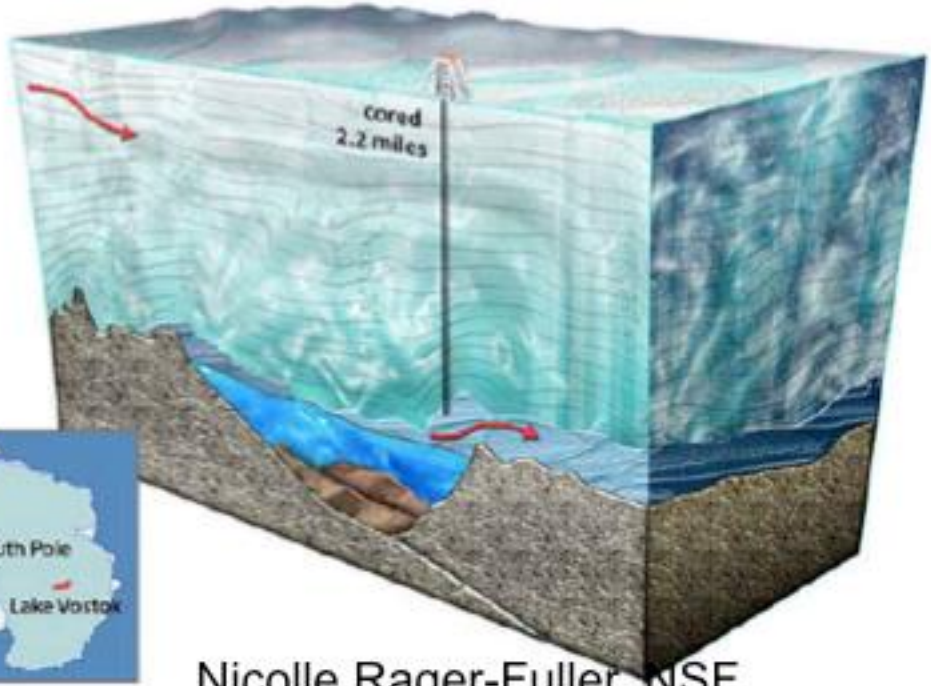


Figure 2: **Thera Macula is a region of likely active chaos production above a large liquid water lens.**

From
Active formation of 'chaos terrain' over shallow subsurface water on Europa
B. E. Schmidt, D. D. Blankenship, G. W. Patterson & P. M. Schenk
Nature 479, 502–505 (24 November 2011) | doi:10.1038/nature10608



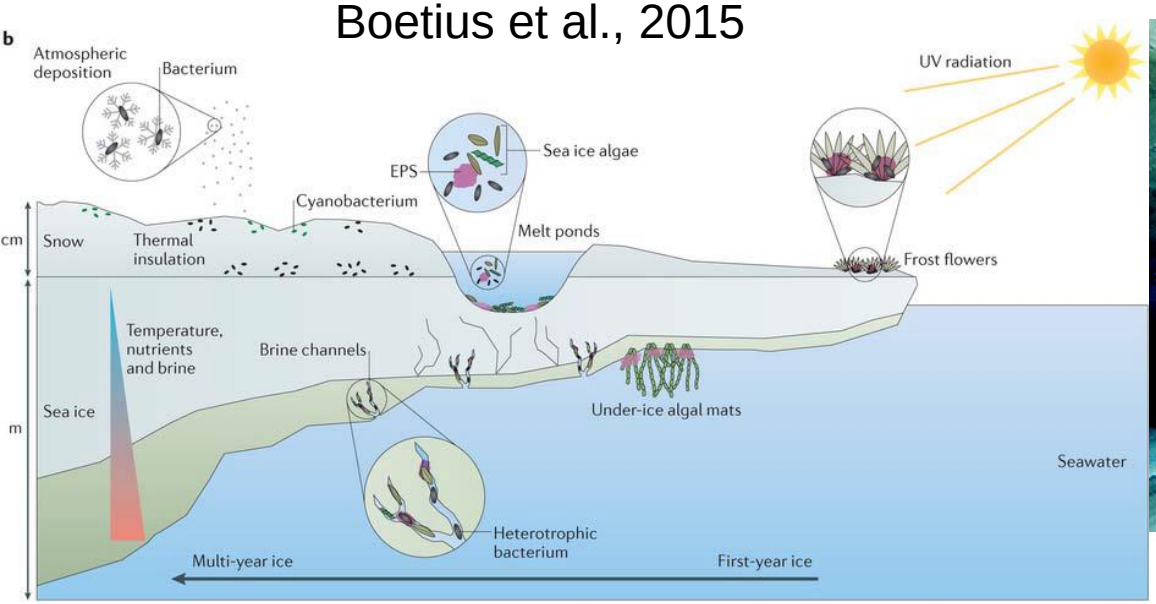


Nicolle Rager-Fuller, NSF

Closest analog environment for Europa's subglacial lakes: Lake Vostok in Antarctica

Earth Analogues for Europa ice shell and ocean

Boetius et al., 2015



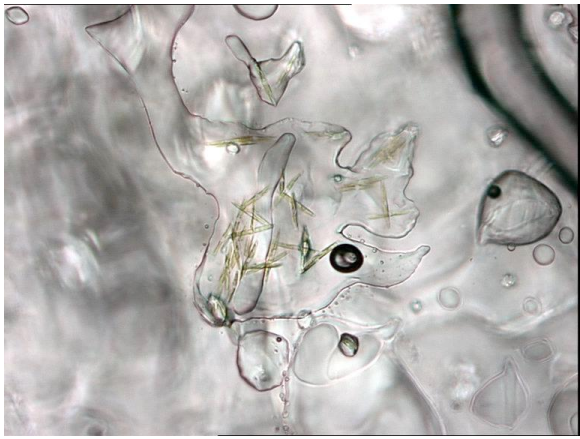


Figure 3.2. Habitable aphotic subglacial brine systems in Antarctica. **Left:** "Blood Falls" at the shear zone of Taylor Glacier is the red surface expression of iron, sulfur, and organic compounds from a deep subglacial brine (Mikucki et al., 2009). **Right:** Ice over Lake Vida in Victoria Valley hides a −13.4ºC brine in an ice-entrained aquifer in the lake ice below 16 m, which continues down into the permafrost at least 50 m below the lake surface (e.g., Dugan et al., 2015; Image: H. Dugan).

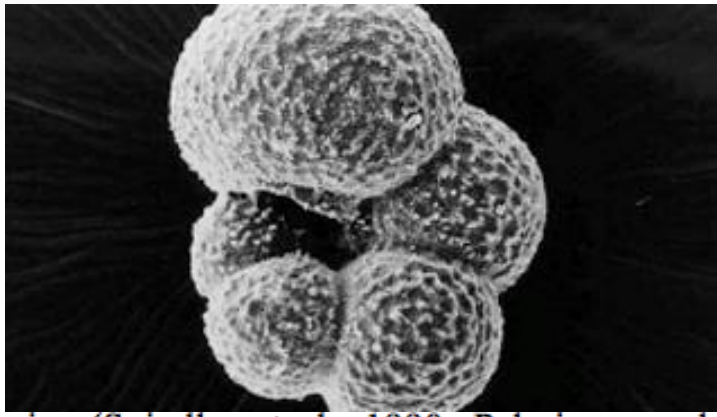
Sea Ice/Ice shelf

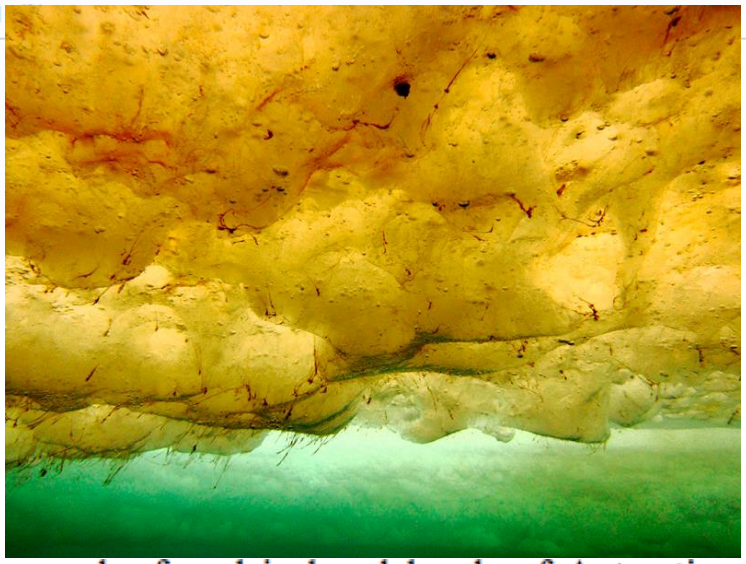
First Steps in the Origin of Life in the Universe pp 255-260 | Cite as

Persistence of Living Planktonic Foraminifera (*Neogloboquadrina pachyderma*) in Antarctic Sea-Ice Inferred from a Study of a Sediment Core (Ross Sea Continental Margin)

Authors | Authors and

R. Bonaccorsi, R. Melis

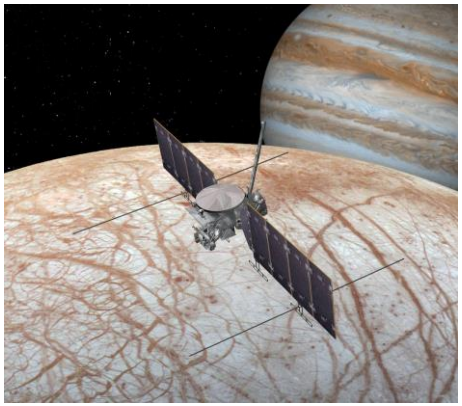




Living *N. pachyderma* can be found in basal levels of Antarctic sea-ice (Spindler et al., 1990; Palmisano and Garrison, 1993) as they are embedded during the initial dynamical stage of sea-ice growing (Lipps and Krebbs, 1974; Dieckmann, 1991). This species is also capable of surviving within granular-frazil ice and under hyper-saline and low temperature, e.g., –9.6°C, conditions (Spindler, 1996). As a result, individuals are both protected from predators and can feed on other sea-ice microbiota such as bacteria and diatoms (Stoecker et al., 1997). In a few days, during spring ice melting, *N. pachyderma* returns to the water column to resume pelagic life, feed and reproduce. At the end of its life cycle this species can become part of the sedimentary record if preserved from dissolution.

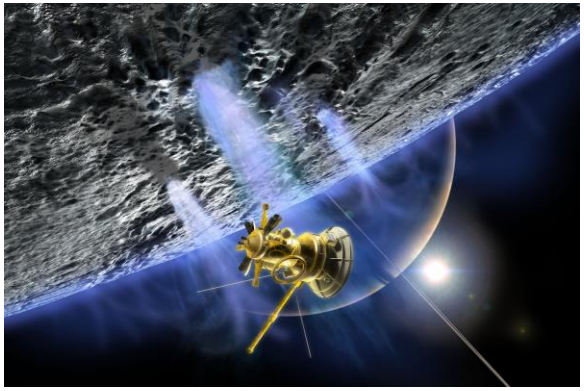

ALL THESE WORLDS
ARE YOURS EXCEPT
EUROPA
ATTEMPT NO
LANDING THERE
USE THEM TOGETHER
USE THEM IN PEACE

Planned Missions to Icy Worlds

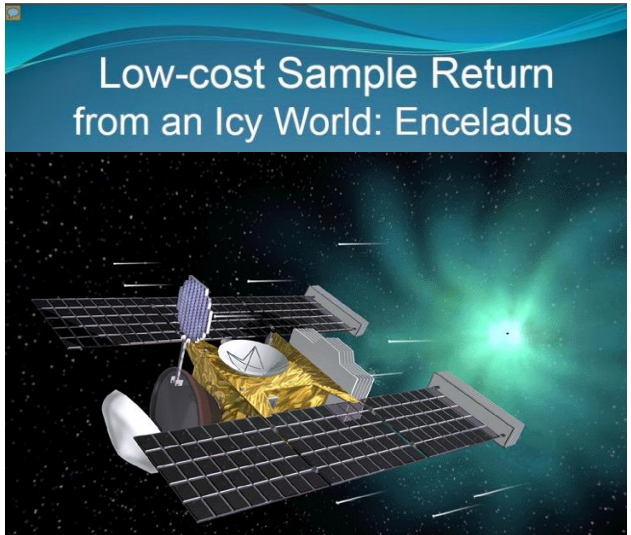


NASA's Europa Flyby Mission Design Phase. planned for launch in the 2020s

If selected, ELM separately launched in 2024



JPL Enceladus Life Finder mission vs. NASA Ames proposed in May 2017 to NASA's New Frontiers program. November 2017, PHASE A selections; then 2019 PHASE B selections with Launch in 2024

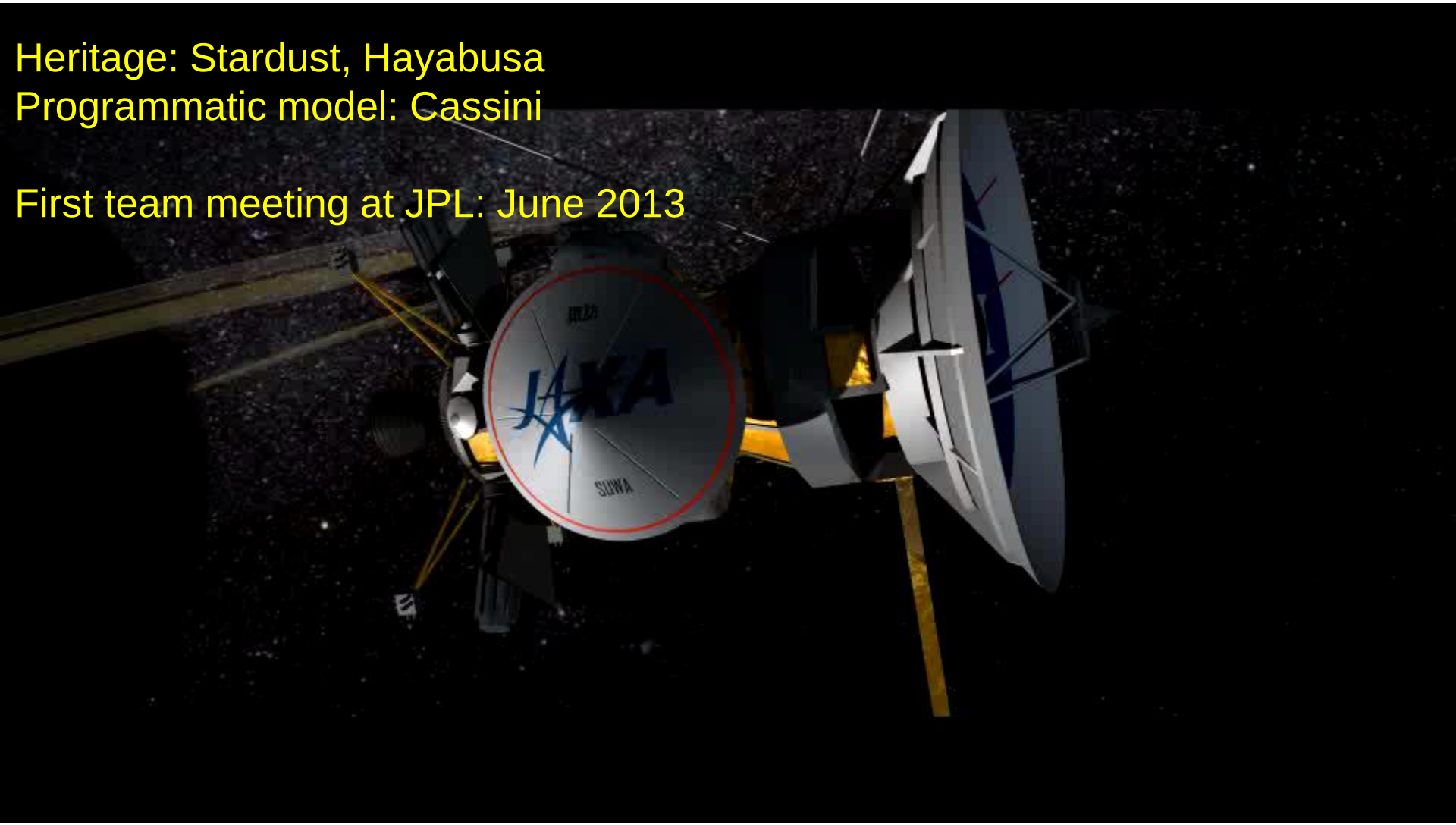


LIFE Enceladus Plume Sample Return

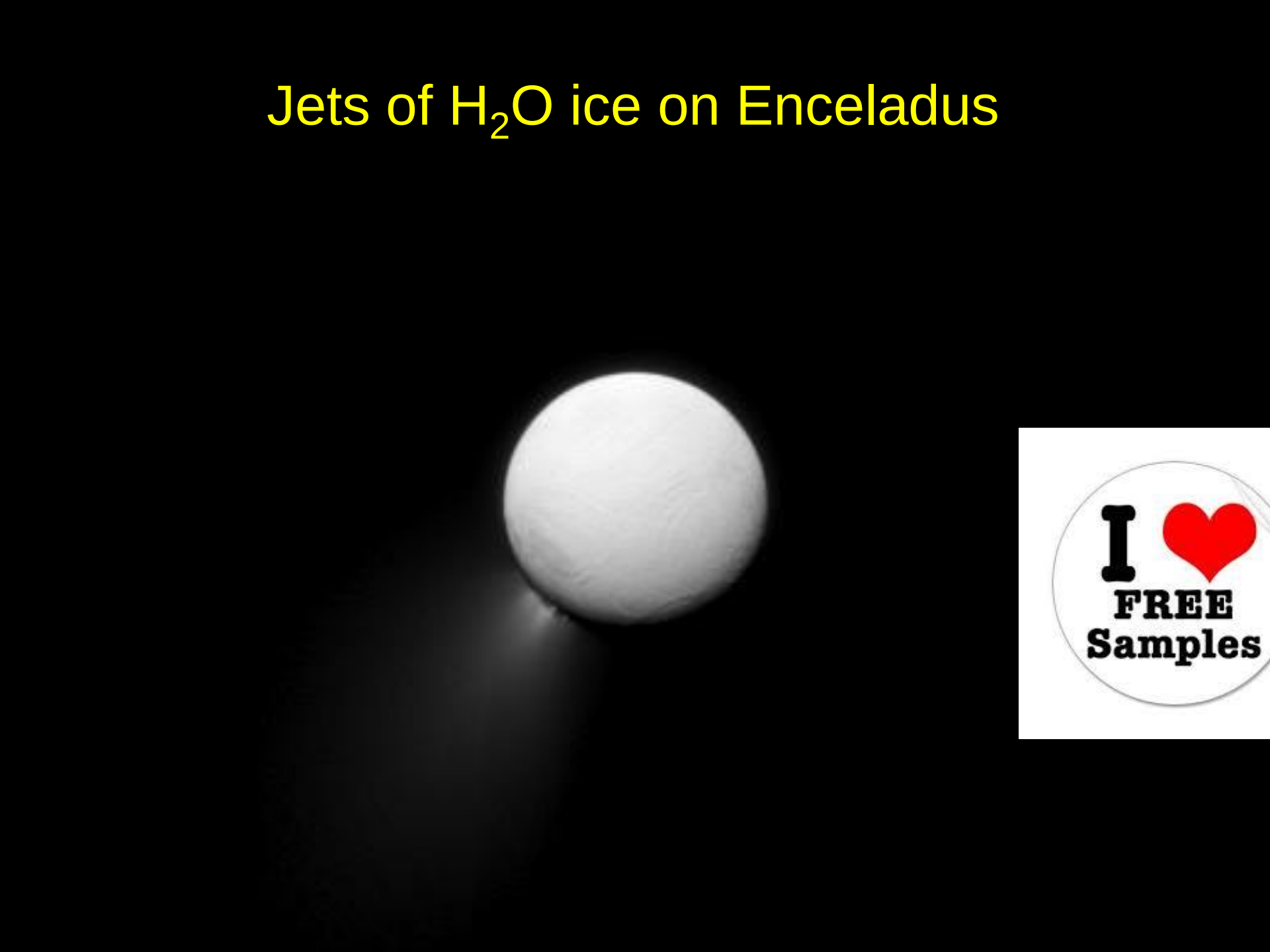
A joint US-Japan mission to study the plume of Enceladus for organics and life and return a sample to Earth.

Heritage: Stardust, Hayabusa
Programmatic model: Cassini

First team meeting at JPL: June 2013



Jets of H_2O ice on Enceladus



Why Collect Ice?

Collecting ice particles in pristine condition (at speeds < ice melt speed at impact)

- Gas Chromatograph Mass Spectrometer (GCMS) can analyze
- intact/ unaltered Large bio-molecules

Proof of life demands rigorous science including detection of:

- Amino acid distribution and chirality,
- Lipids incl. carbon chain length distributio
- Large complex bio- molecules
- Cell structures

Cassini's high speed flythroughs (7 - 15 km/sec) **measurements show Enceladus has a salty ocean and hydrothermal vents.**

- methane, water, carbon monoxide & dioxide, unidentified organics.

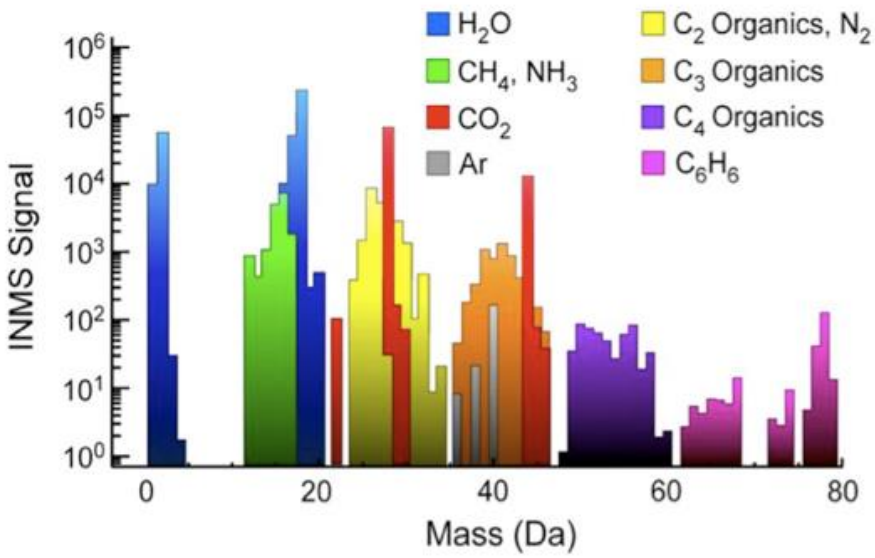
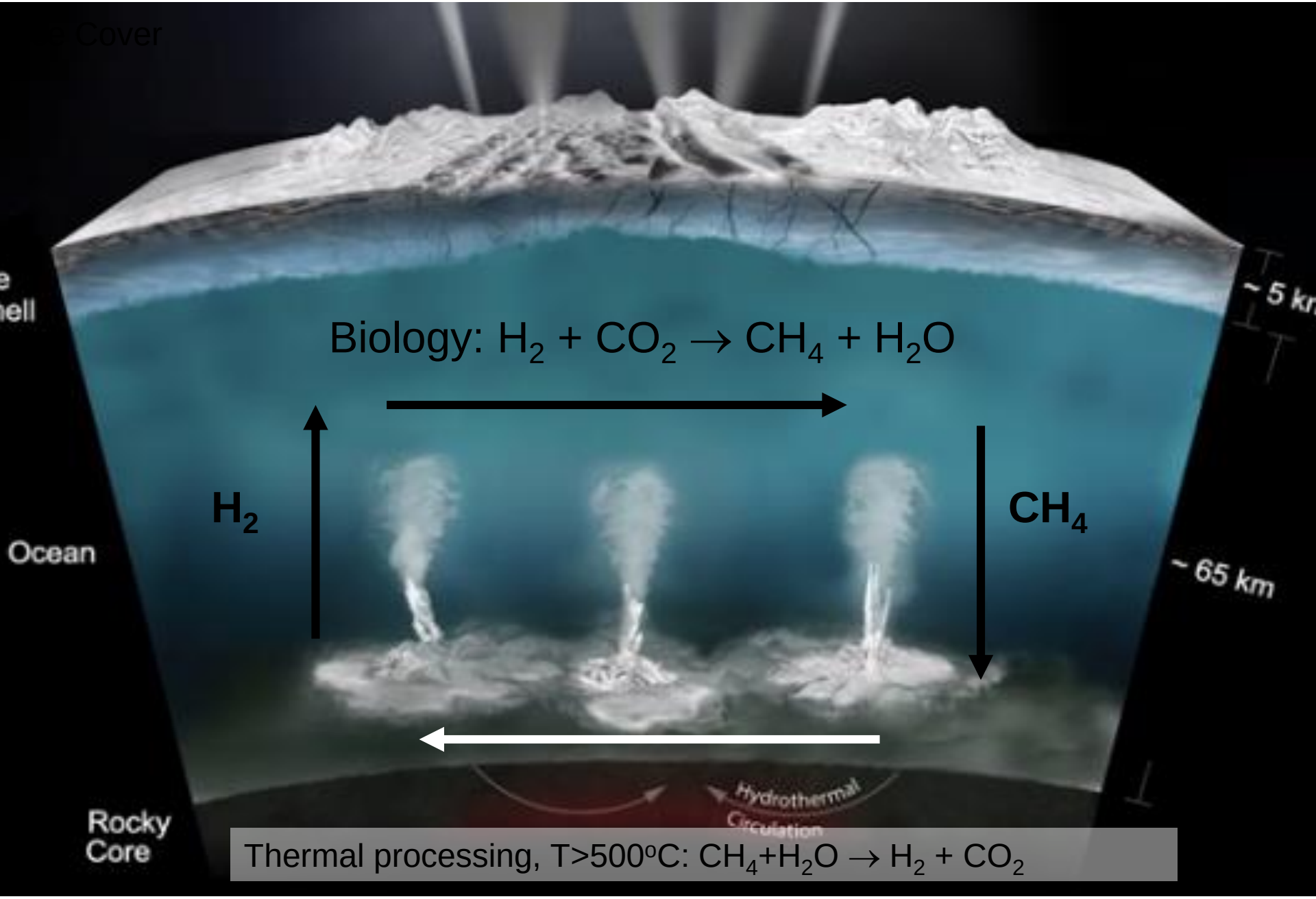


Figure 22.18 Mass spectrum of the Enceladus plume from the October 9th 2008 flyby (Waite et al. 2009). The colors show contributions from various species and their breakdown products using the composition shown in Table 22.3.


Biology: $H_2 + CO_2 \rightarrow CH_4 + H_2O$
H_2
CH_4
~ 5 km
~ 65 km
Ocean
Rocky Core
Hydrothermal Circulation
Thermal processing, T>500°C: $CH_4+H_2O \rightarrow H_2 + CO_2$

$H_2S + O_2$ is the metabolic basis of deep sea vents.

Anaerobic chemoautotrophic ecosystems may be present below the surface.

The Tools

Methods & Examples

- **Analytical protocols developed in chemico-physically different water samples**
- Analytical protocols (Dilutions, etc)
- Background contamination & bioburden mitigation protocols

===➔ High to near 0 Background

- Signal background, Negative, Positive control, spike samples for testing interferences

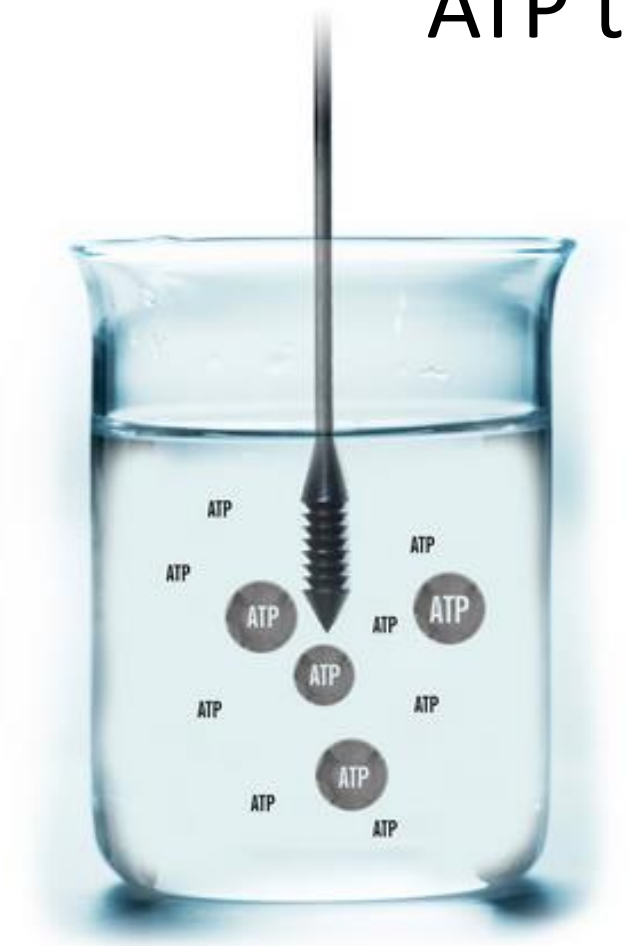
Testing Protocols for Life Detection

To test effectiveness of life detection assays we have analyzed lipopolysaccaride (LPS) Lipid A and Adenosin Triphosphate (ATP) ***biomarkers in a variety of planetary-like environments (e.g., hypersaline lakes, nanophase clay-rich, low T, freshwater alkaline hi evap ponds, ice-cemented water melt, and hydrothermal sinters).***

False negatives were yielded from most of liquid and solid samples. False negatives due to salinity, extreme PH values, and quenching effects can be mitigated by sample dilution.

Assessing and mitigating matrix-related interferences has key applications to planetary protection practices as well as future life detection missions to our Solar System Mars and Ocean Worlds icy moons Enceladus and Europa where brine-rich, extreme pH (0-13) and potential mineral rich environments will be the target.

ATP types & Assays

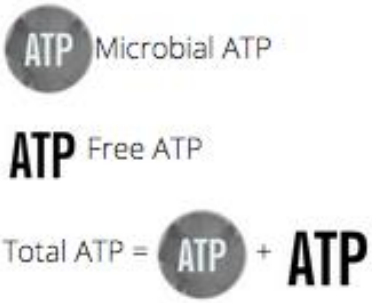


Free ATP
(extracellular)

Liquid Assays

Assays for liquids

Surface Assay

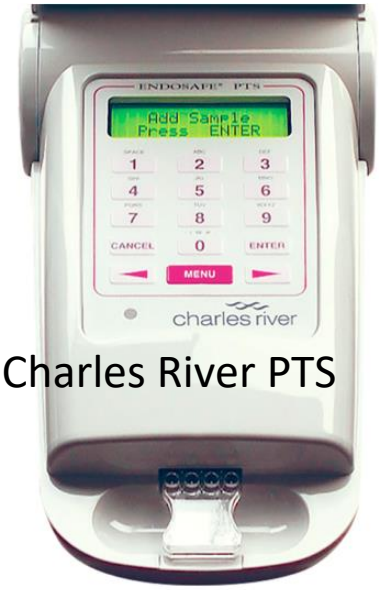


Total ATP = Free + Cellular

Cellular = Total ATP – Free

Portable system, Limulus Amebocyte Lysate (LAL) assay

In vitro test to detect presence and concentration of bacterial endotoxin Lipid A (toxic to mammals).

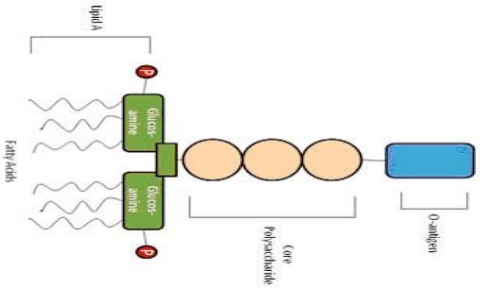


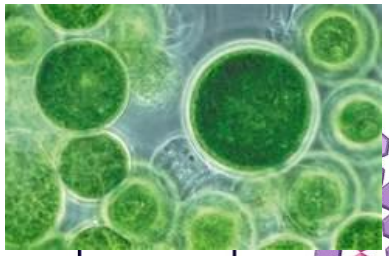
Charles River PTS

Lipid extraction, loading & detection

DL: 0.0005 EU ~1-10 cells/mL

LPS translated into microbial biomass :
(1EU/mL ~10^5 cells/ mL, *E. coli*-like cells)

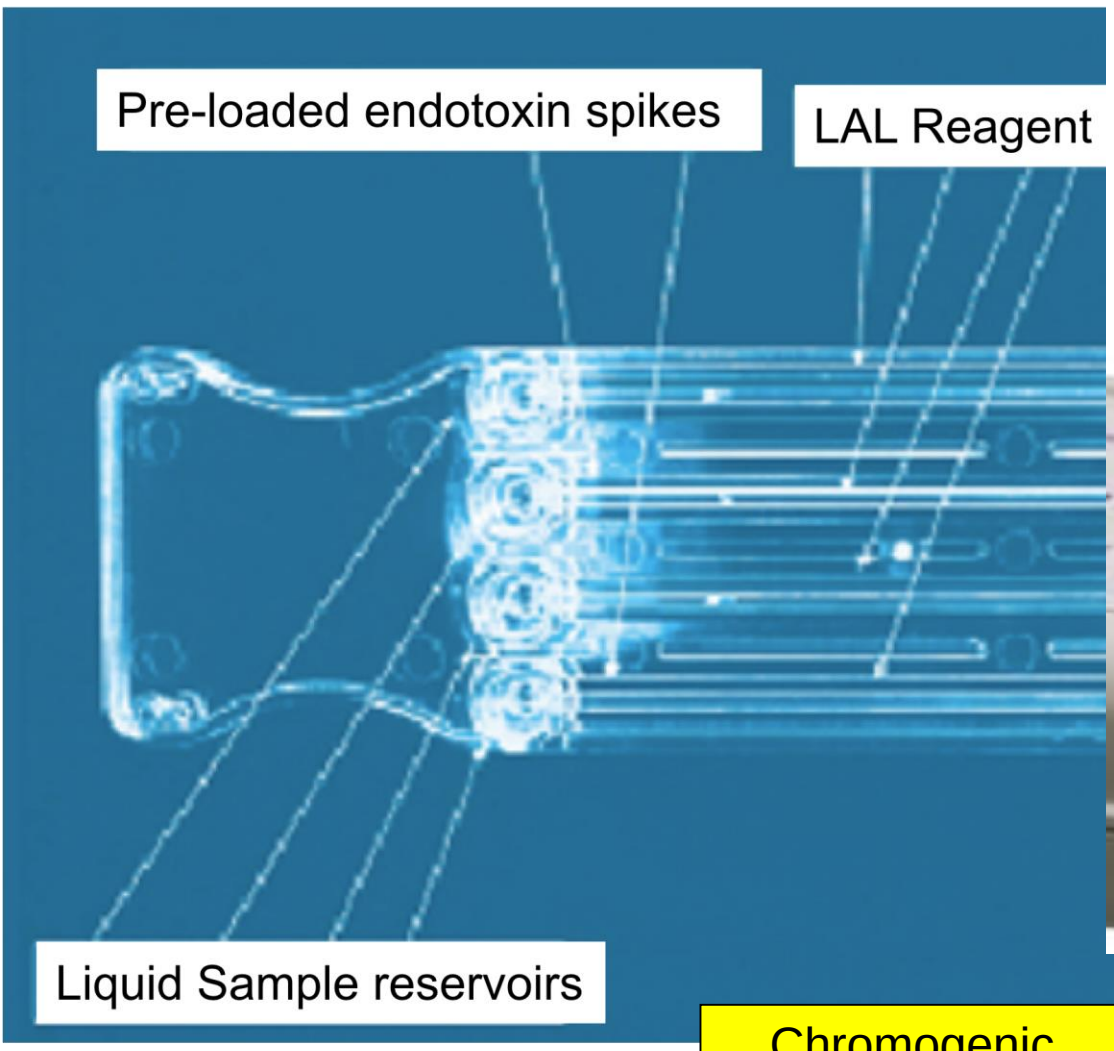




Gram negative-like biomass

The **lipopolysaccaride (LPS)** are present in the external cellular membrane of bacteria, cyanobacteria, unicellular algae, and some vascular plants.

Figure 4-35a Brock Biology of Microorganisms 11/e



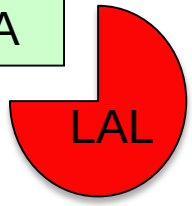
Lab-on-a-chip assay

Environ mental Sample

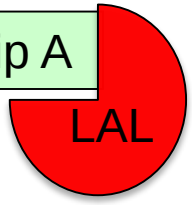
Water extraction of Lip A

Chromogenic assay

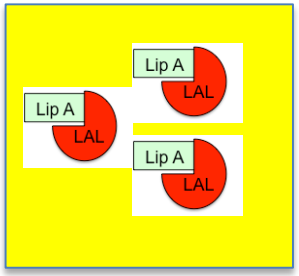
Lipid A



Lip A



Detection with PTS Spectrophotometer 405 nm



Environments

Evaporitic, freshwaters to brackish, briny & hypersaline water

Methodology

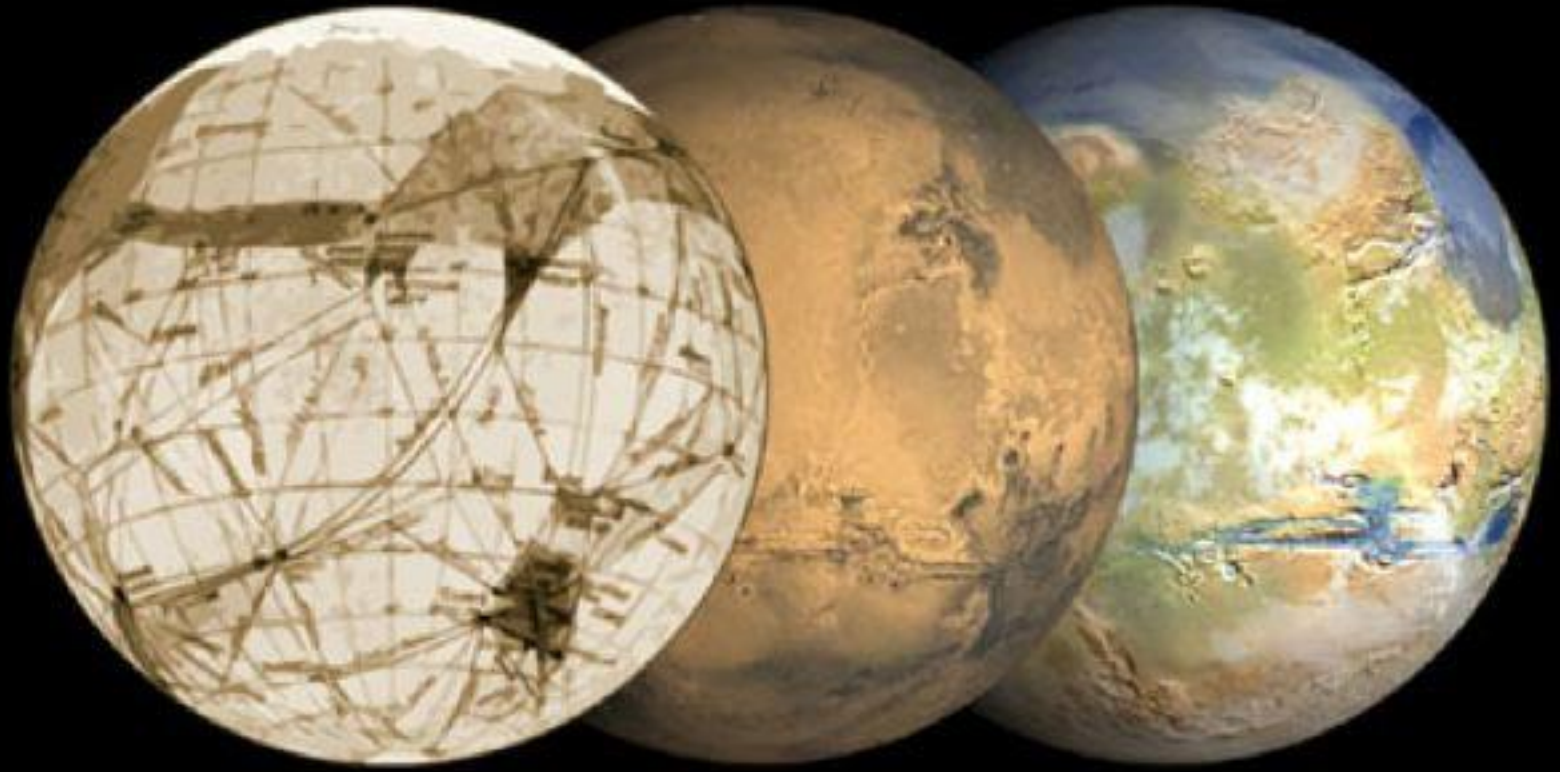
- Analytical protocols (Dilutions, etc)
- **Background contamination & bioburden mitigation protocols**

===➔ High to near 0 Background

- *Signal background, Negative, Positive control, Procedural blanks, spiked samples for ID matrix related interferences*
- Analytical protocols developed in chemico-physically different water samples

Mars!

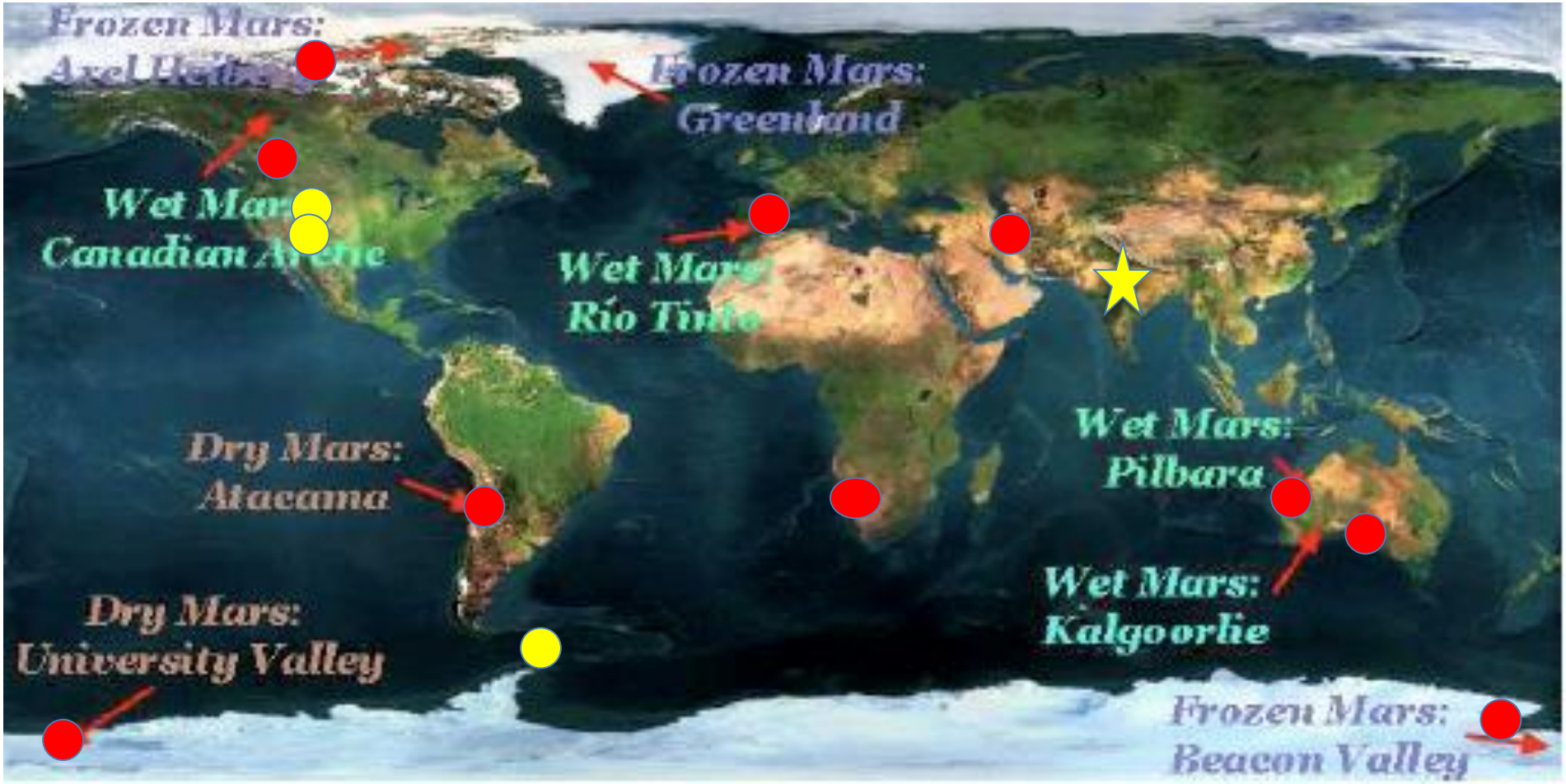
Why Mars?



Evidence for past liquid water
Presence of an atmosphere with CO_2 & N_2
Potential for preservation of evidence of life

Expeditions to analogue environments for the past ages of Mars

(after Fairen et al., 2010)



Planetary Analogs?

Mars-Like Geology –

- Terrain

- Rocks

- Sediments

- Minerals

Climate – Oceans to ponds & their timescales

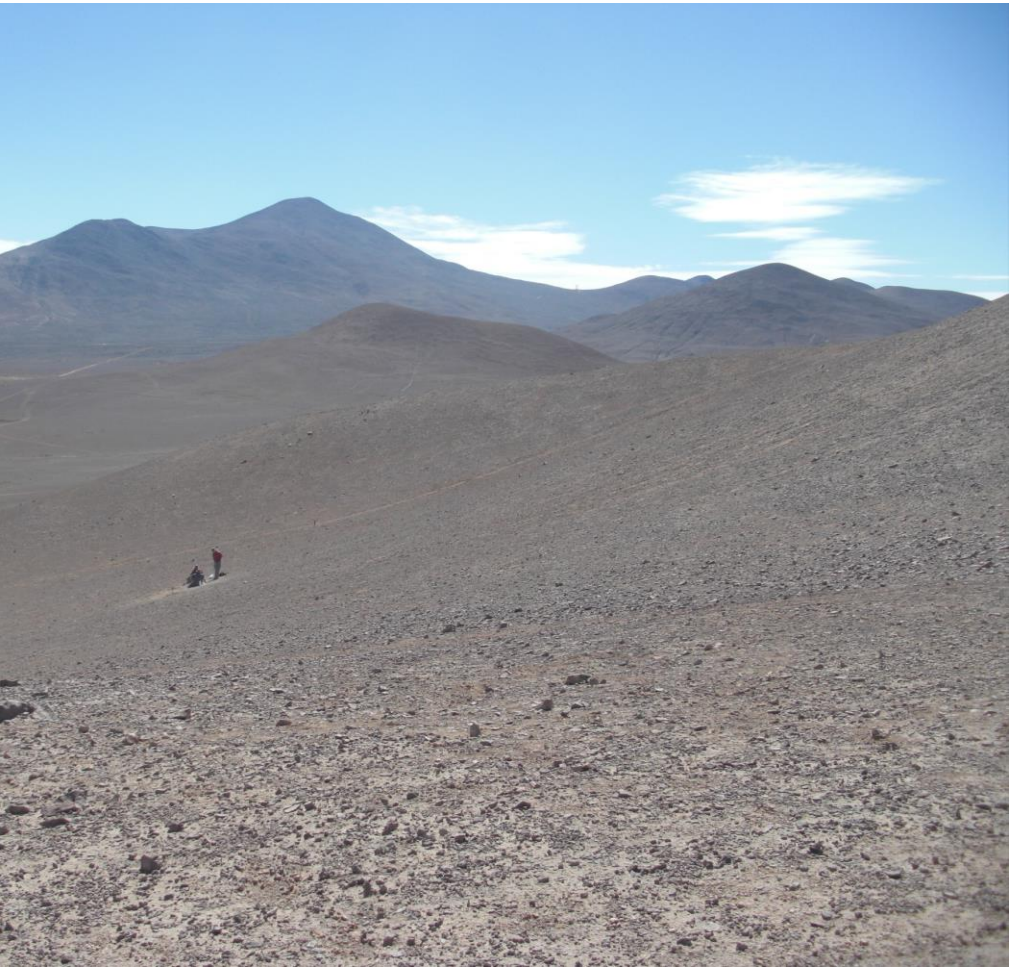
Extremes for life

Yellowknife Bay, Mars

Follow the water …The ingredient for Life



100.0µm



Astrobiology Field Expeditions

NASA Spaceward Bound expeditions!

http://quest.nasa.gov/projects/spacewardbound/field.html

Spaceward bound is an educational program developed at *NASA Ames.*

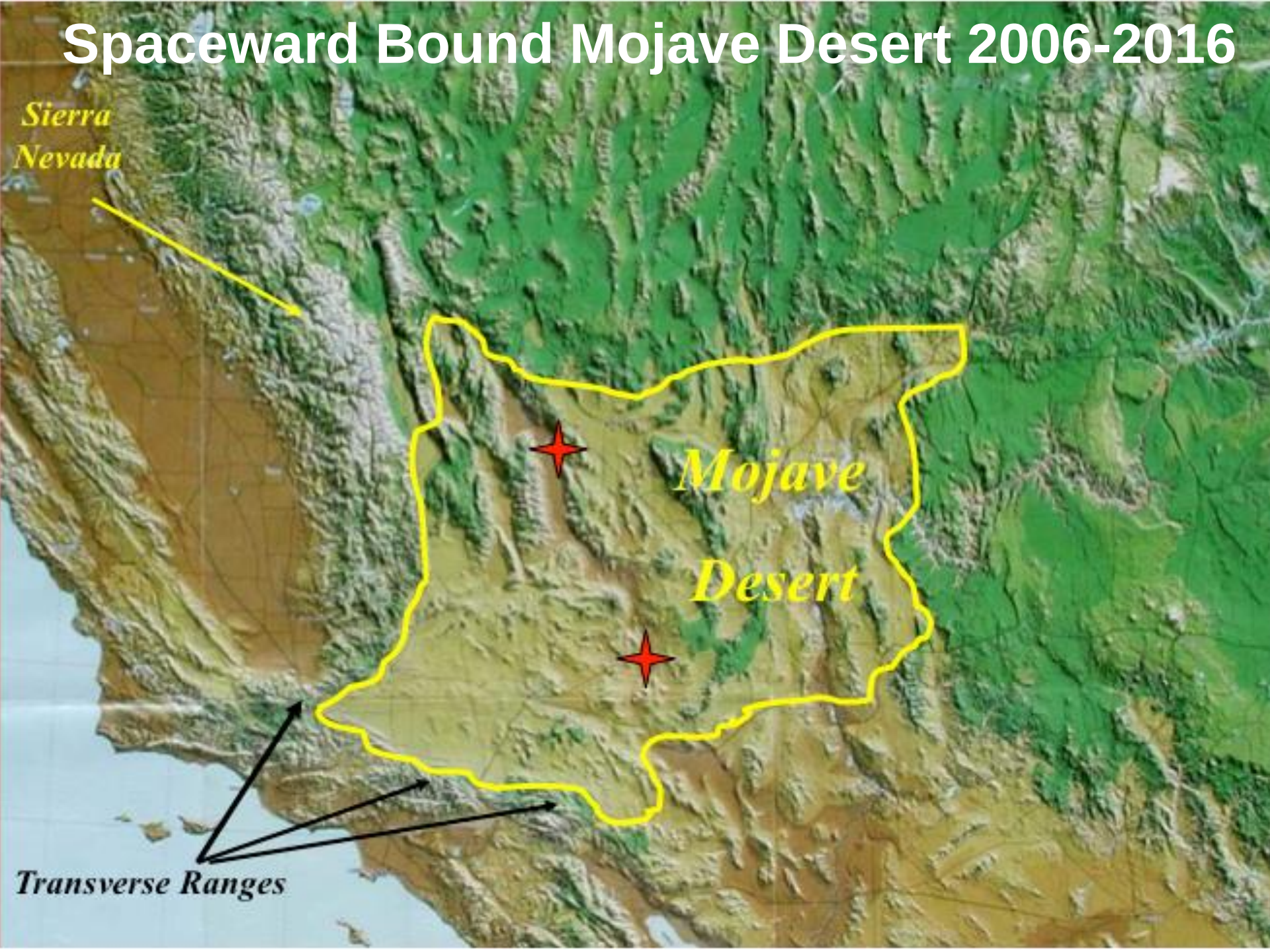
The mission of Spaceward Bound is to train the next generation of space explorers
by having students and teachers participate in the exploration of scientifically interesting
but remote and extreme environments on Earth as analogs for human exploration of the Moon and Mars.

NEW: Spaceward Bound at Ubehebe Crater",
reflection by Stephanie Kyriazis, Education Specialist, Death Valley National Park.

See 2011 Expeditions
See Past Expeditions Archive
See what our alumni are doing now!

HOT & DRY

Spaceward Bound Mojave Desert 2006-2016



Max5 Rover test in the Mojave Desert Lava flow

First ever Spaceward Bound 2006 Expedition to the Atacama Desert!!

View of Atacama From Shuttle with Hubble Telescope In the Foreground

Yungay

View of Northern Chile (NASA Spa

ESO PR Photo 24b/99 (8 June 1999)

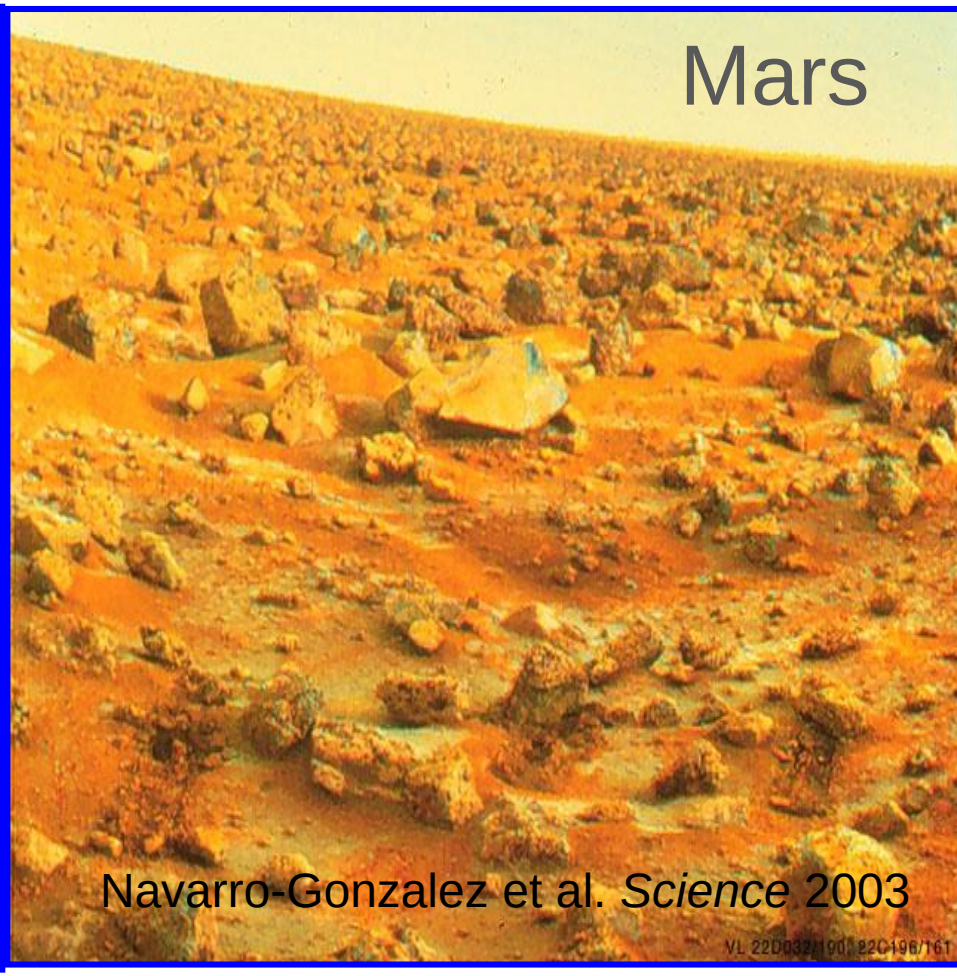
Nights & mornings are cold

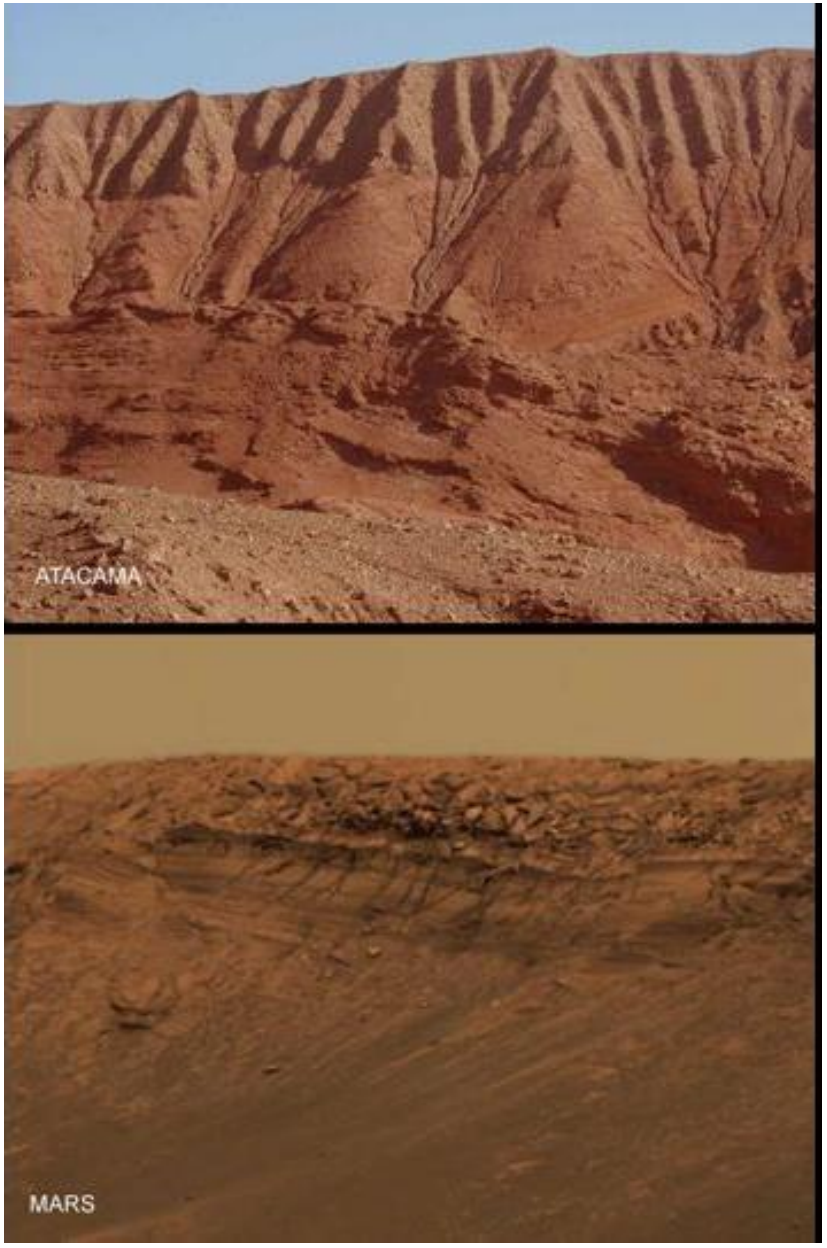
Troy Hudson deploys a water sensor for dew.

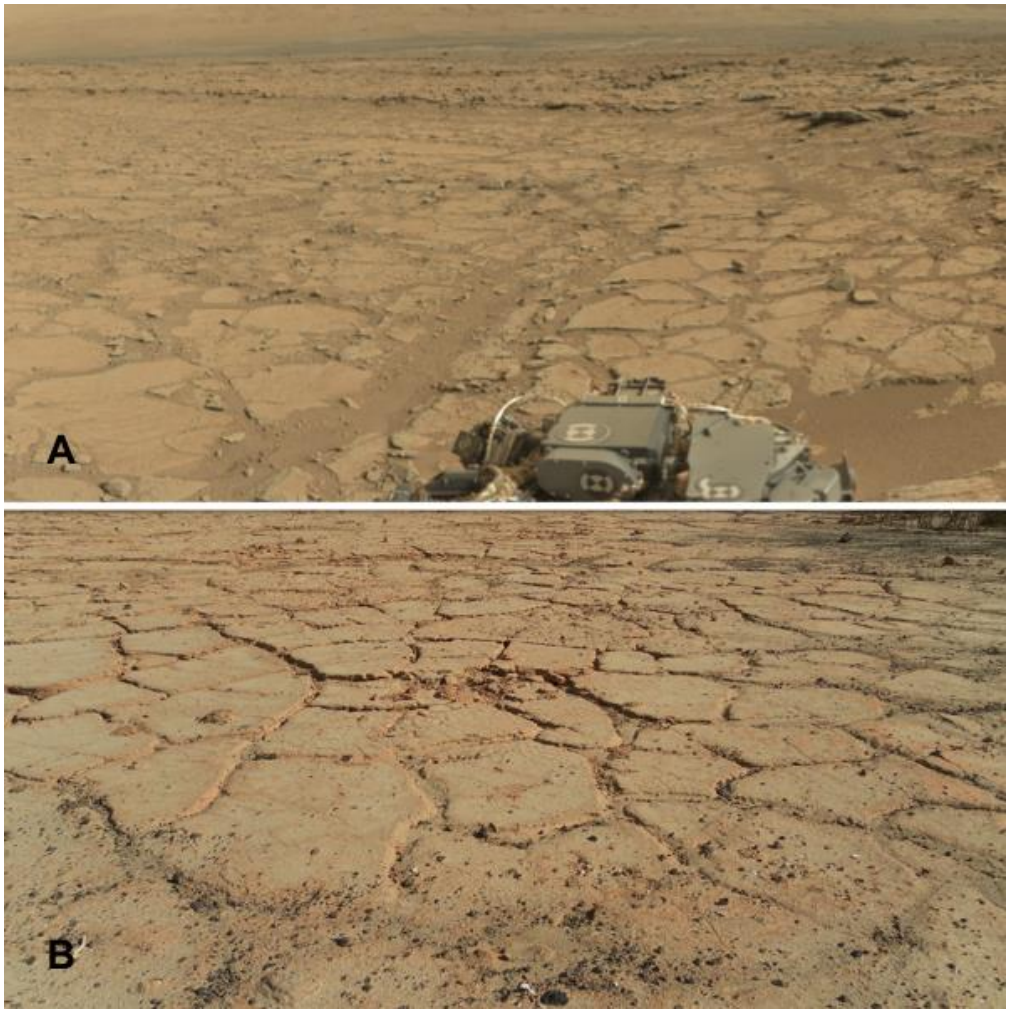
Afternoons are hot

Aaron Gronstal downloads a data logger.

Mars-like Soils: The Atacama Desert in Chile is an organic and microbiological analog of Mars

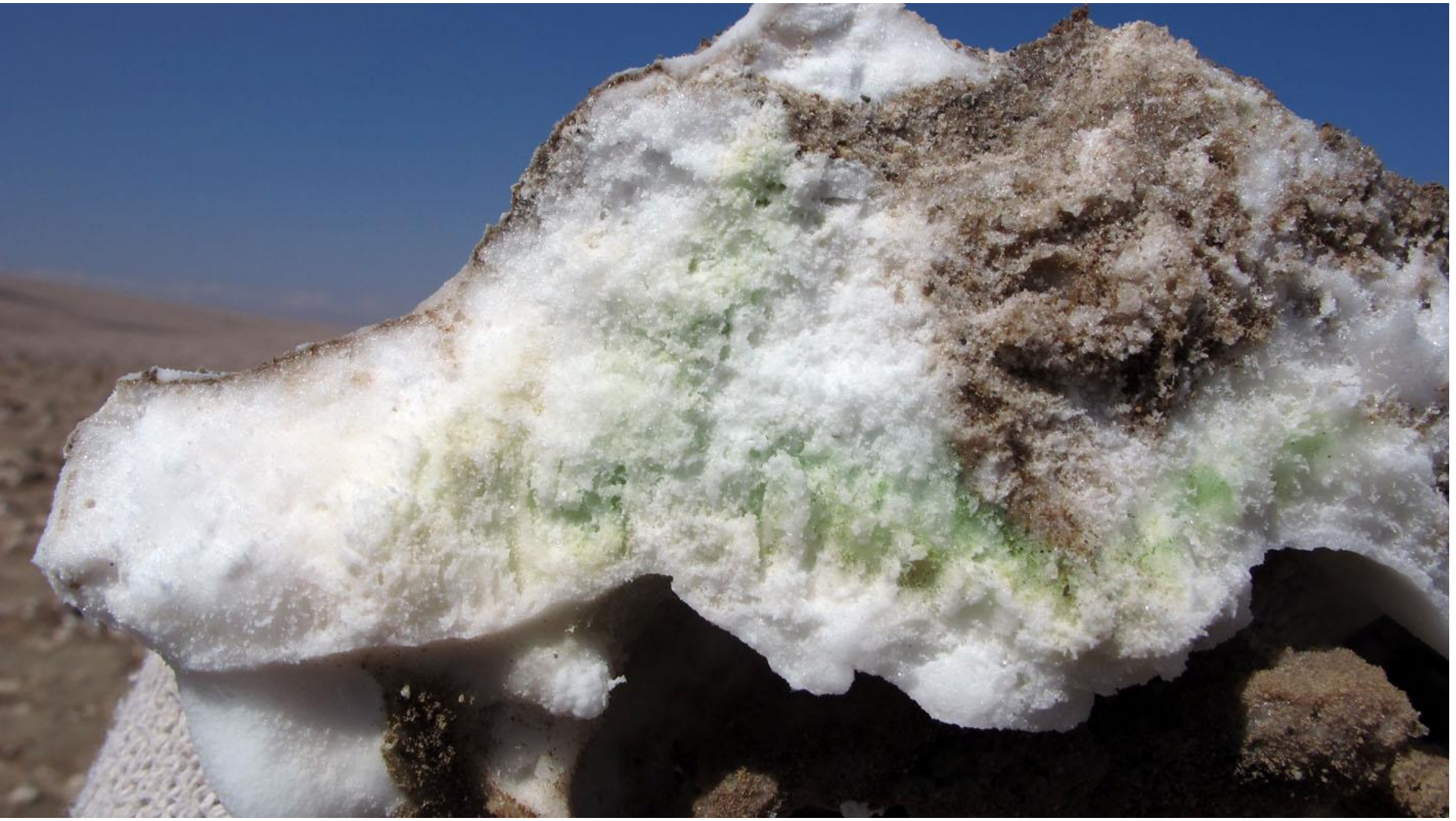



ATACAMA
MARS

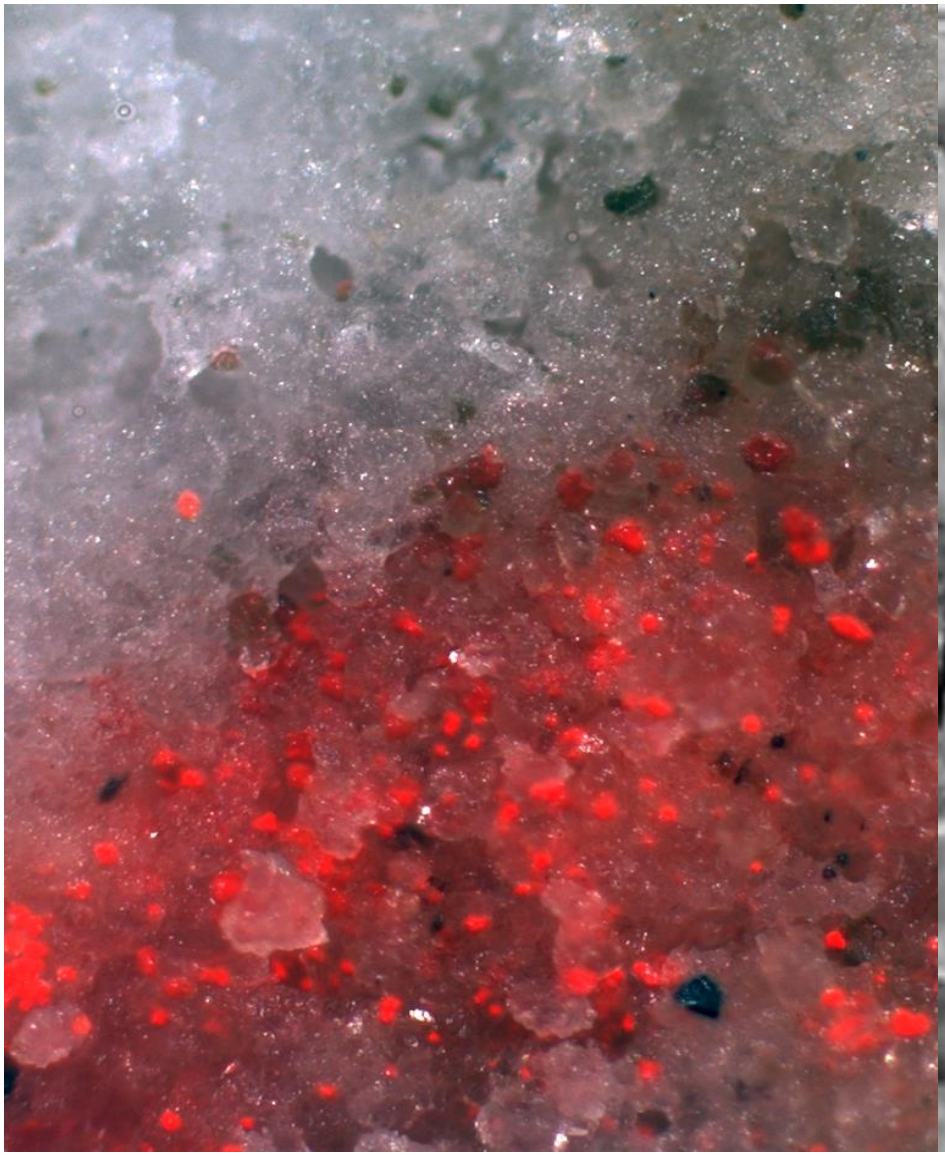

A
B

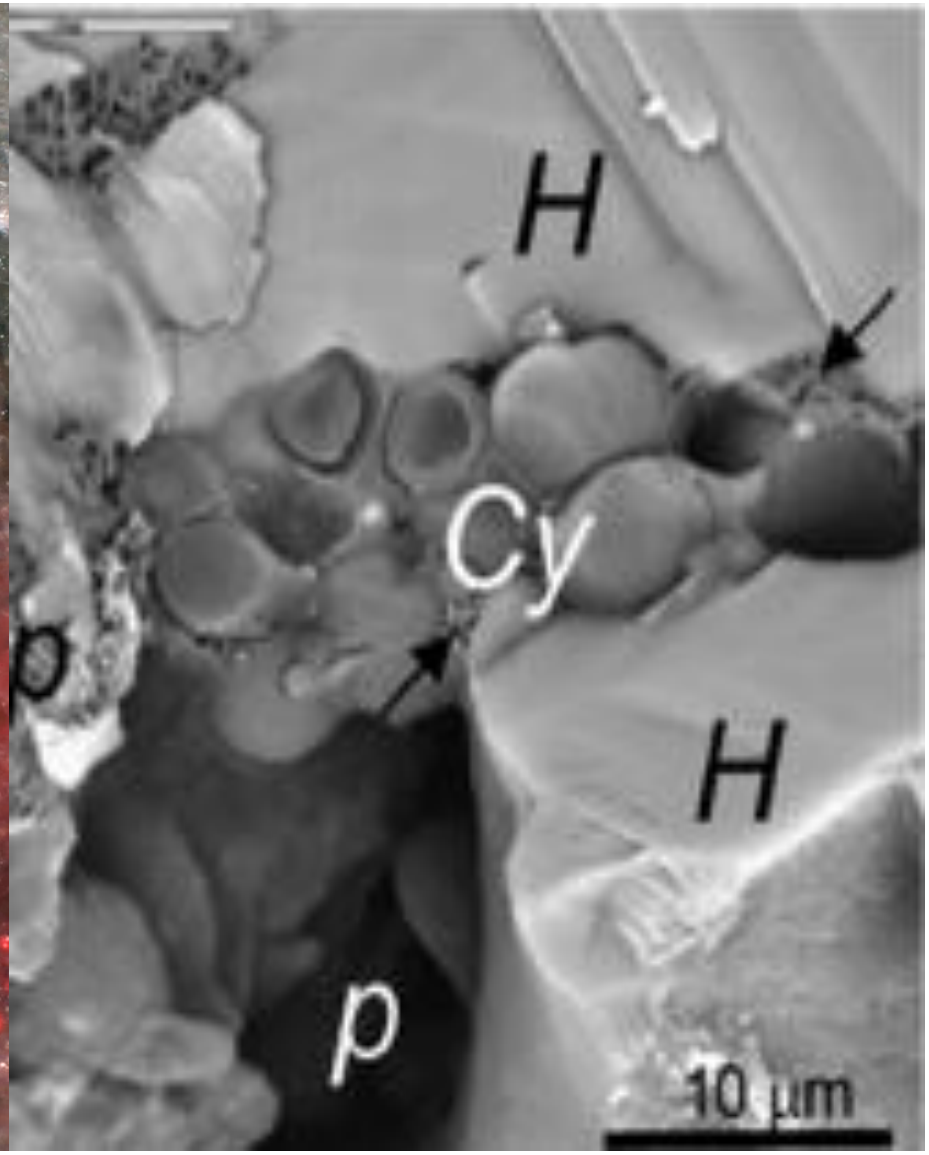
Credit: Alfonso Davila
(SETI Institute)

The last outpost for Life



The last outpost for Life





Spaceward Bound 2011
Expedition West Australia

MSA
Mars Society Australia

NDX-1 Space Suit Trials

The Children of Nullagine

Police arresting man in space suit harassing innocent stromatolites

Photo credit: David Willson

Field Laboratory set up in Arkaroola's motel room!

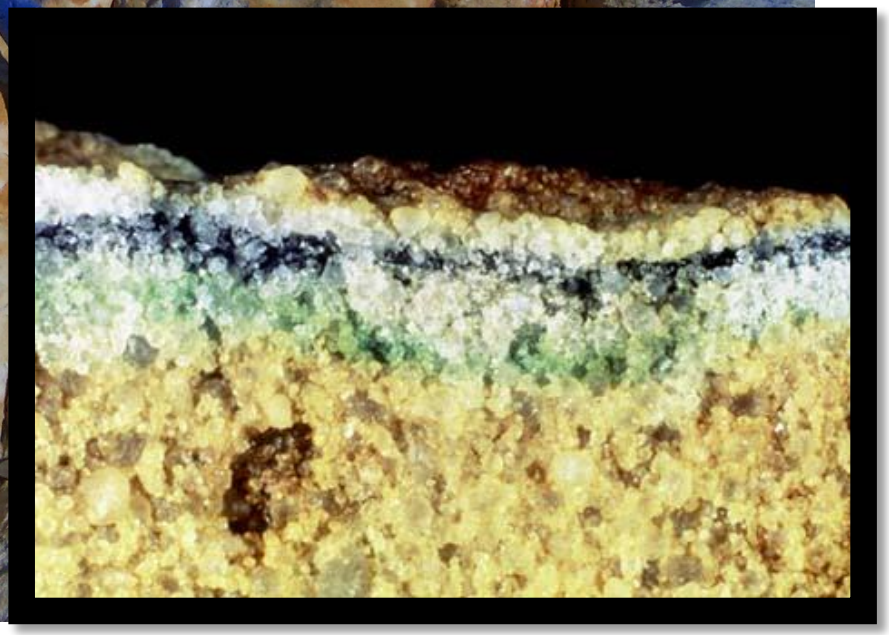
Dr. Penny Boston (AZ Uni) inspiring teachers

Spaceward Bound 2010 Expedition Namibian Desert

COLD & DRY

Dry Valleys of Antarctica

Credit: Chris McKay
(NASA Ames)



EDUCATION, RESEARCH, SPACE, SPACEWARD BOUND

SPACEWARD BOUND NEW ZEALAND 2015

SEPTEMBER 12, 2014

Expedition dates: 16-21 January 2015

Ever wished you worked with a NASA scientist? For one week only, Spaceward Bound is making that happen right here in our 'back yard' in New Zealand! Come along for an extraordinary event where you can walk the walk and talk the talk with top local researchers and NASA astrobiologists.

Daily Activities

Day 0 – Waka Hourua in Auckland

Day 1 – Arrival at Marae, powhiri and visit to Kuirau Park

Day 2 – Waimangu Volcanic Valley

Day 3 – Tongariro and Sulphur Point Rover Competition

Day 4 – Paraki Stream

Day 5 – Marae Open Day

Day 6 – Closing talks, wrap up and closing

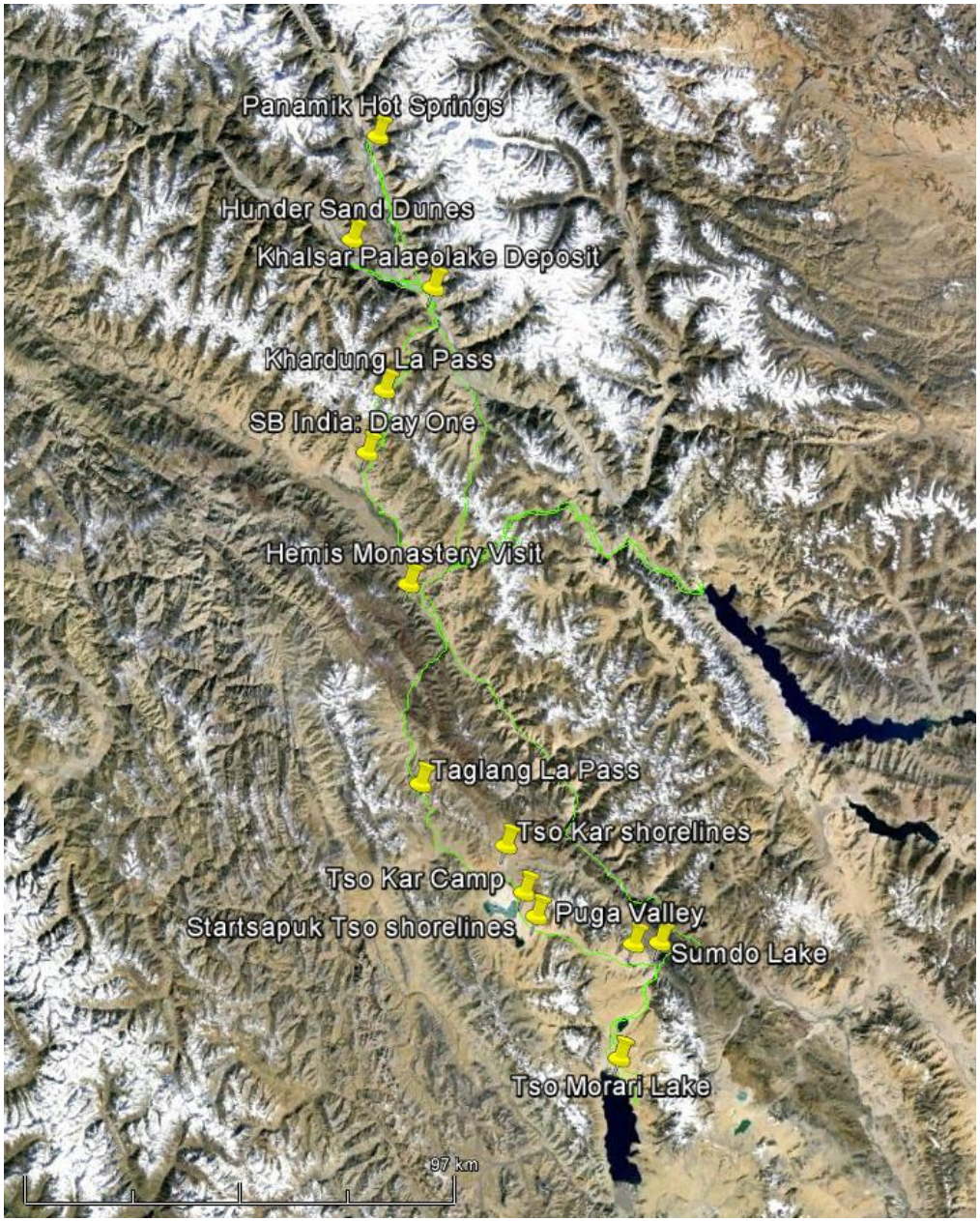
Day 7 – Whakatane and Tauranga

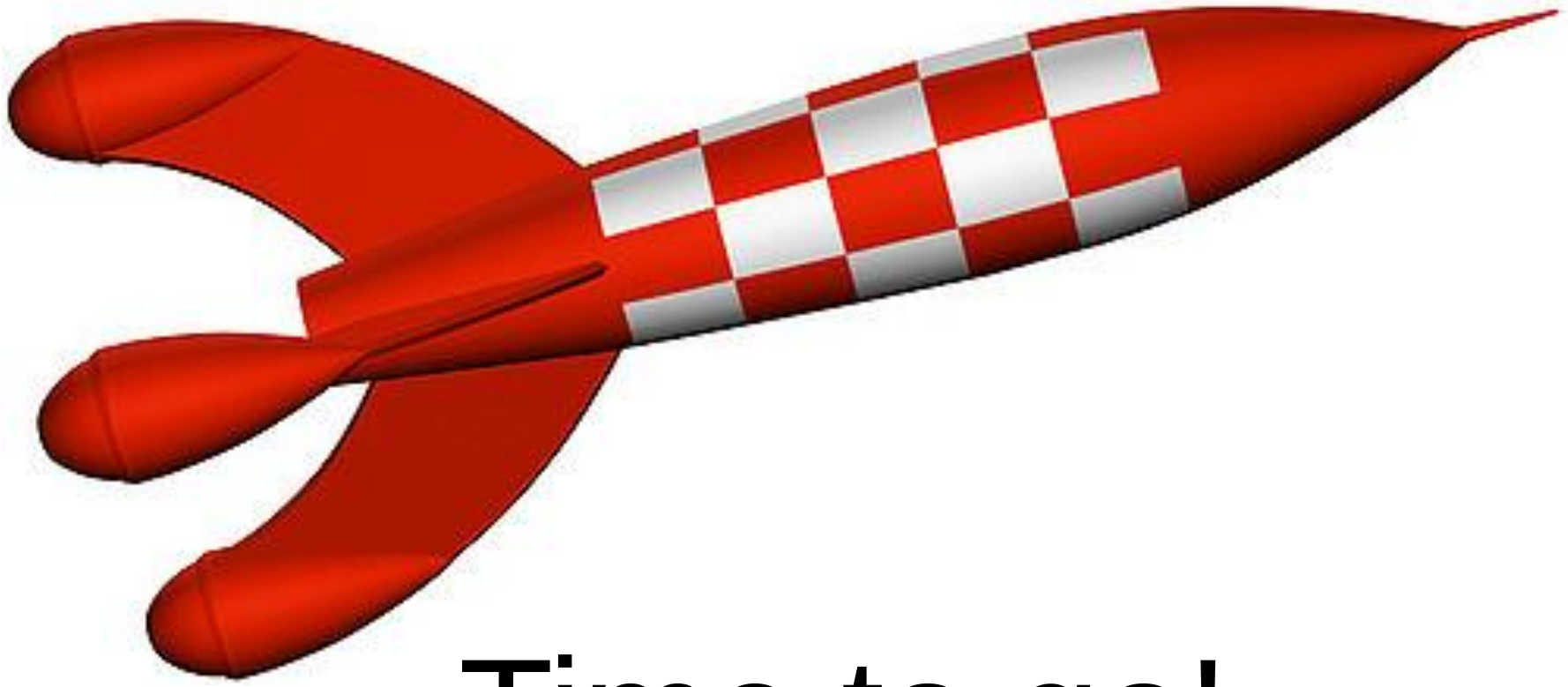
High & Dry

Spaceward Bound India 2016

Map of visited sites:

- ✓ Khardung-La Pass
- ✓ Panamik Hotsprings,
- ✓ Hunder sand dunes,
- ✓ Chumathang Hotsprings,
- ✓ Sumdo's Lake,
- ✓ Puga Hotsprings,
- ✓ Tso-Kar Lake
- ✓ Tso-Kar permafrost
- ✓ Tang-La Pass





Time to go!

THANK YOU!!