BIOTIC SURVIVAL IN THE CRYOBIOSPHERE: PERSPECTIVES FOR INTERNATIONAL COLLABORATION IN ASTRO/TERRESTRIAL BIOGEOSCIENCE

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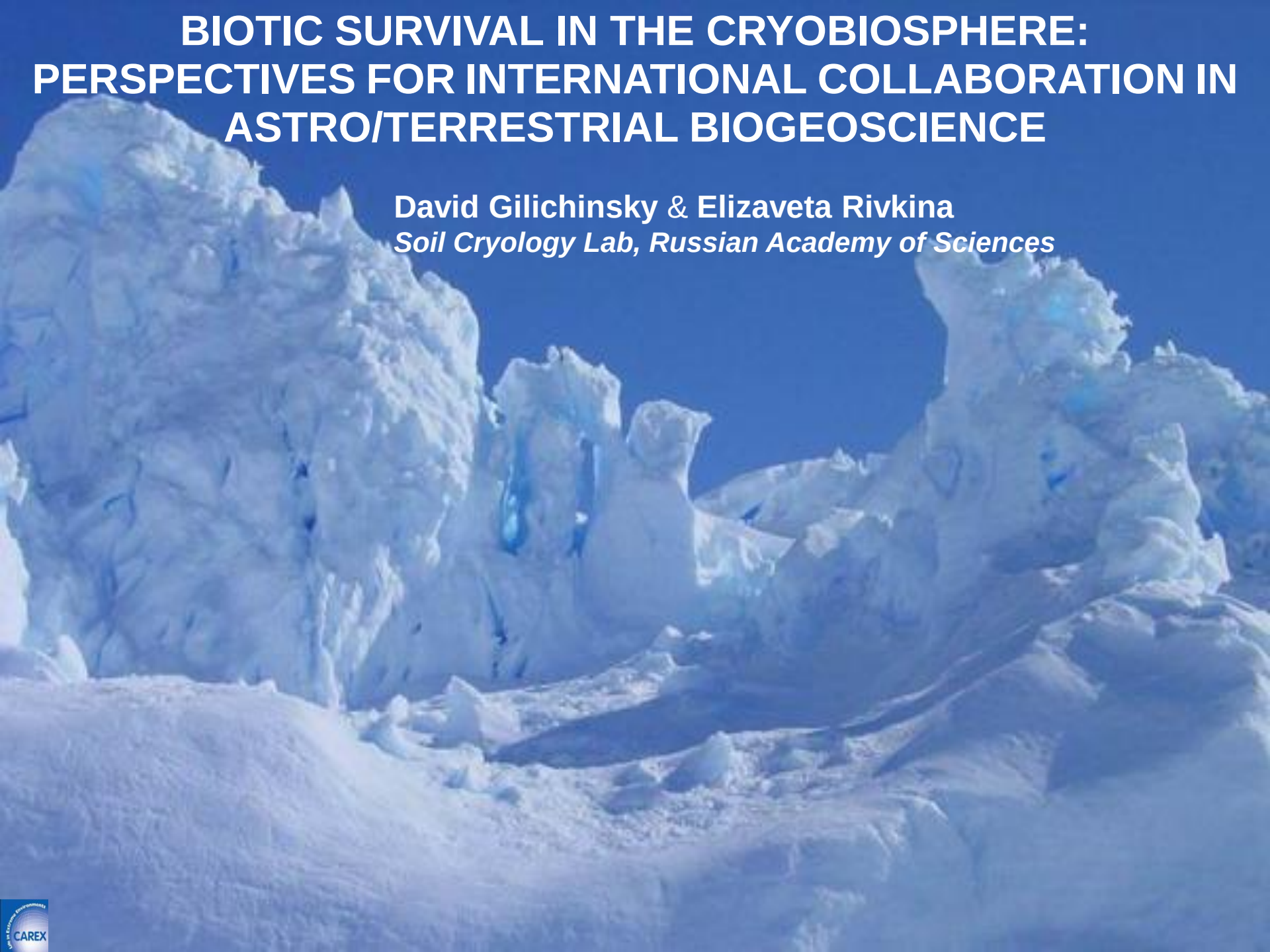
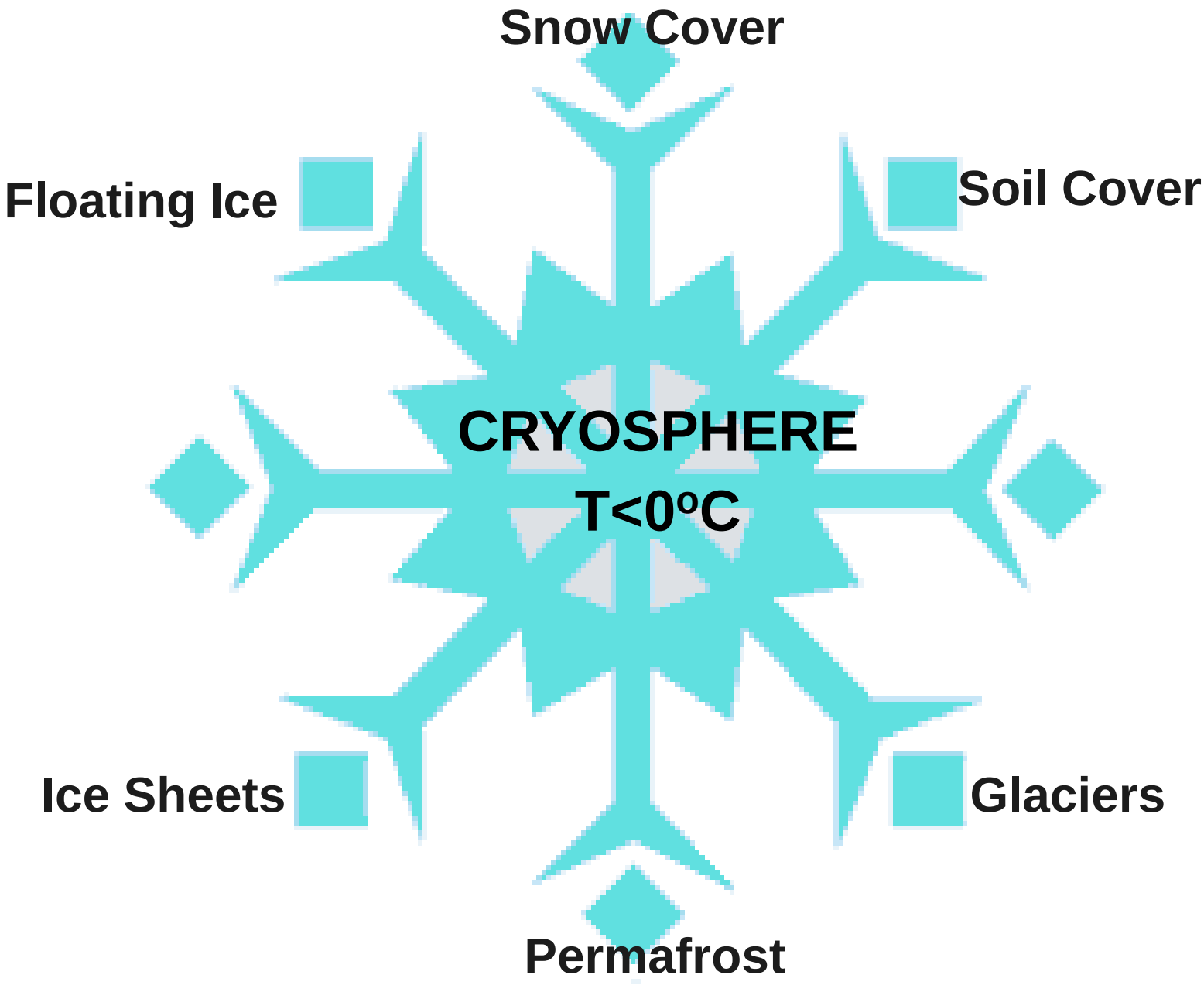
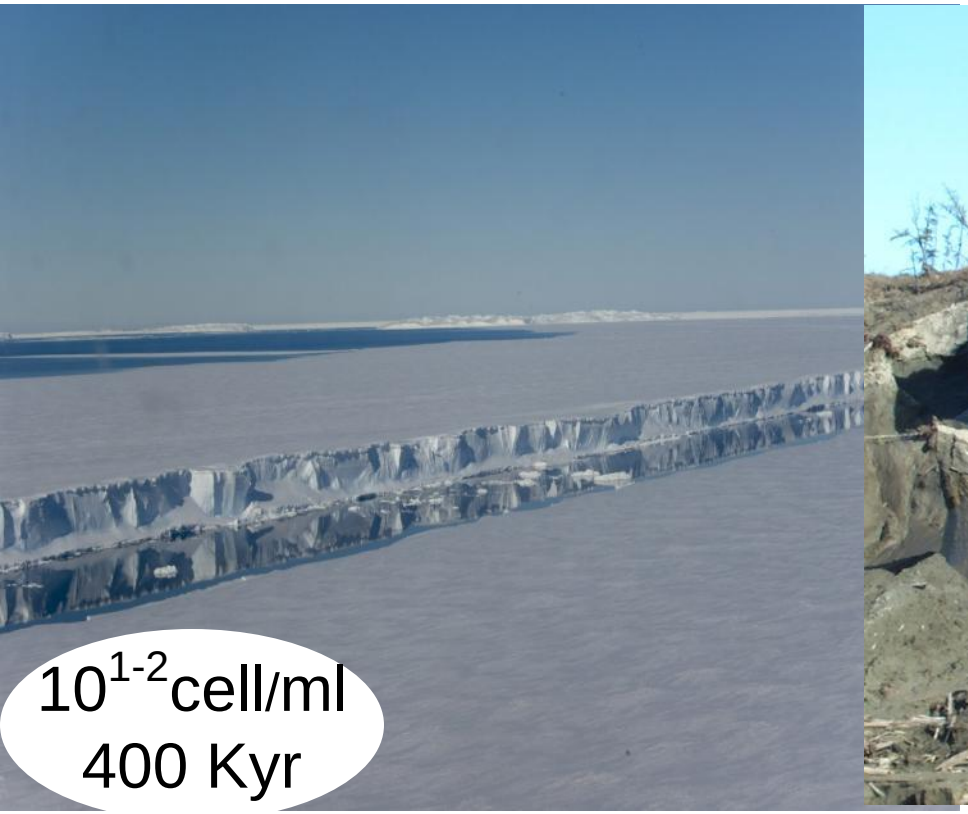
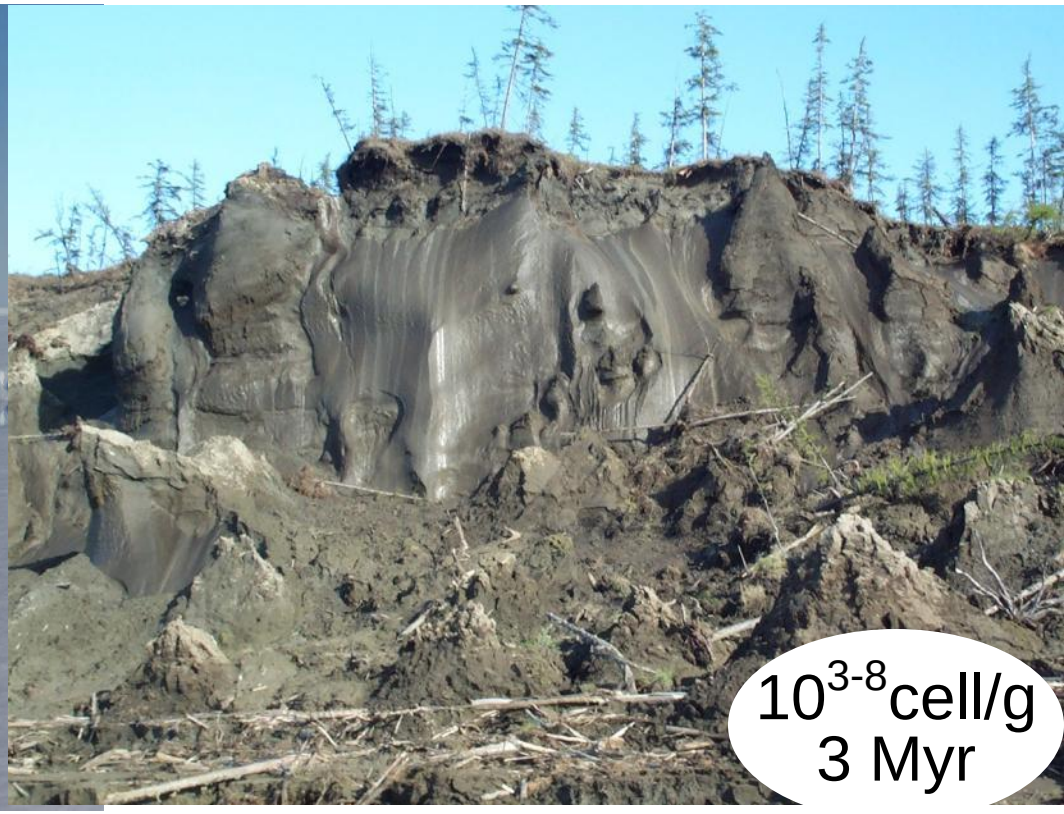



Snow Cover
Floating Ice
Soil Cover
CRYOSPHERE
T<0ºC
Ice Sheets
Glaciers
Permafrost

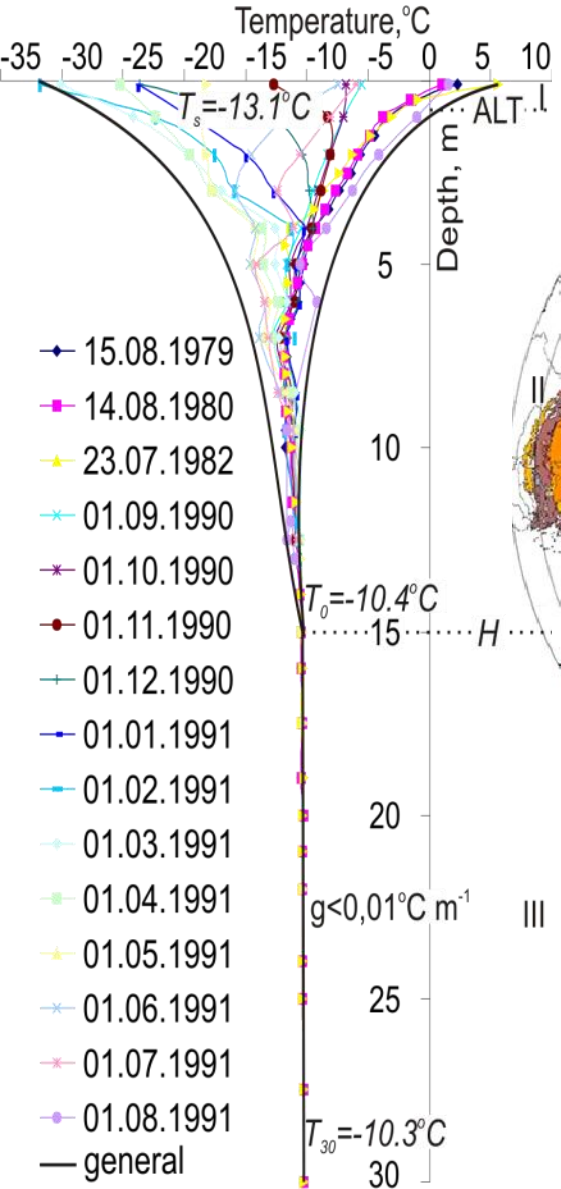
The Cryosphere is the only widespread and rich terrestrial depository of ancient organisms and represents a significant part of Biosphere, the Cryobiosphere, where life is confined over geological time

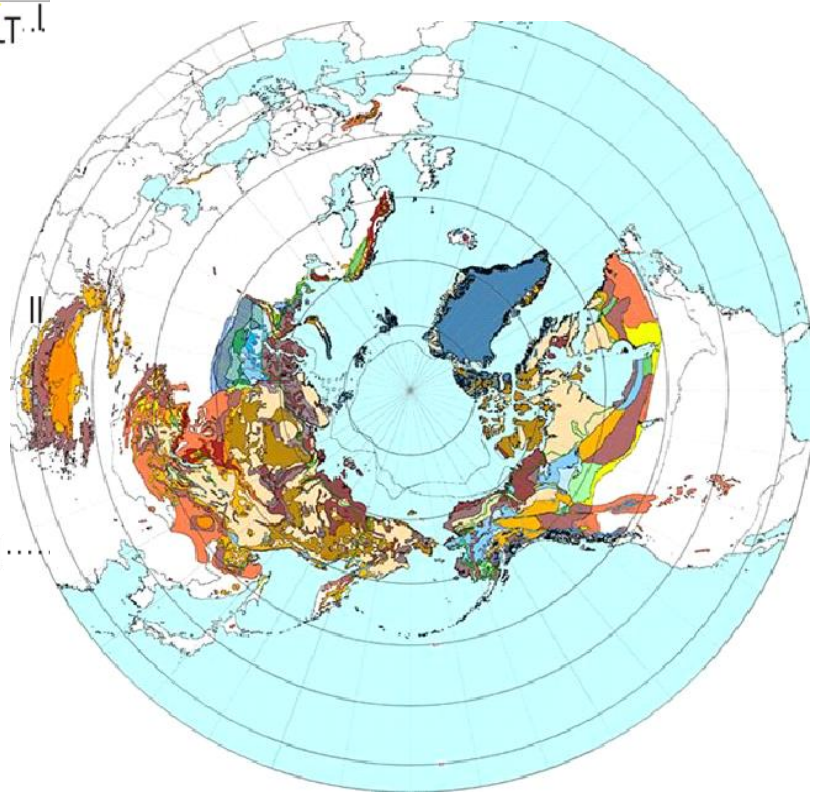


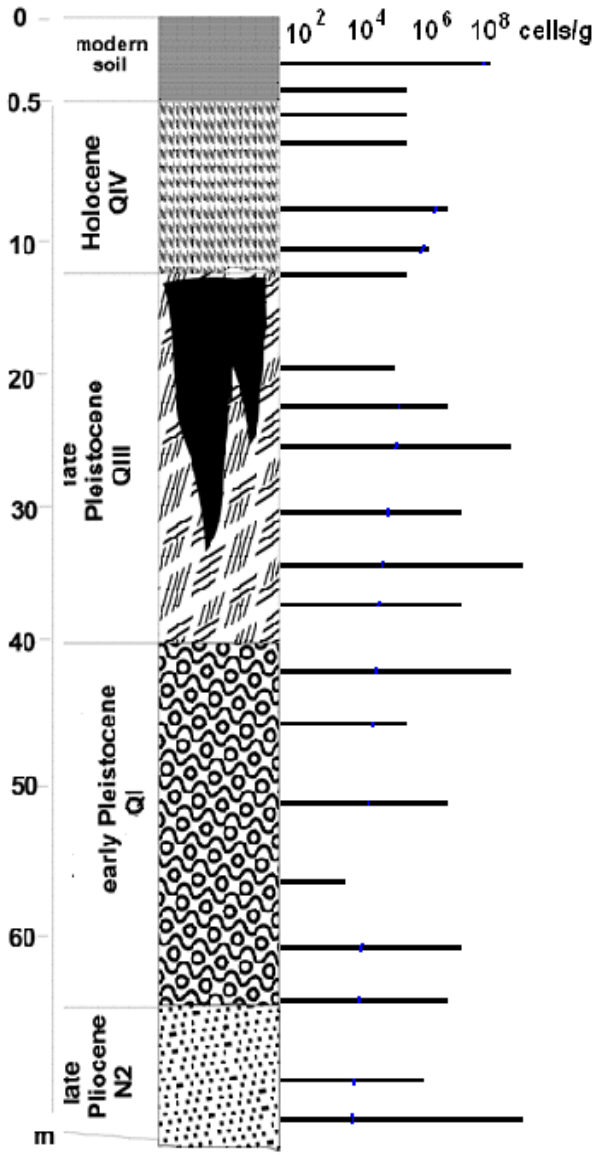


The most inhabited part of Cryobiosphere is permafrost - stable and balanced environment, which maintains life incomparably longer than any other known habitats

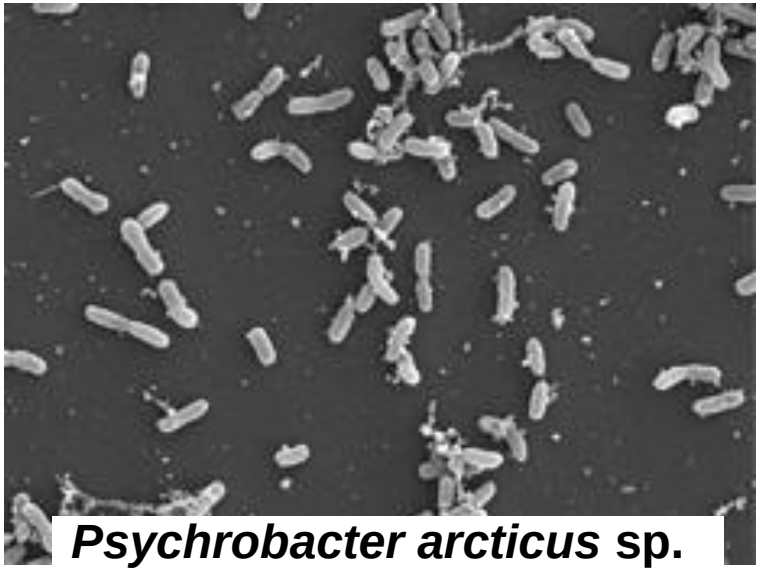
Permafrost underlies ~20% of the land surface and reaches a thickness of up to 1000 m. This huge frozen volume harbors a great mass of living matter peculiar to permafrost only





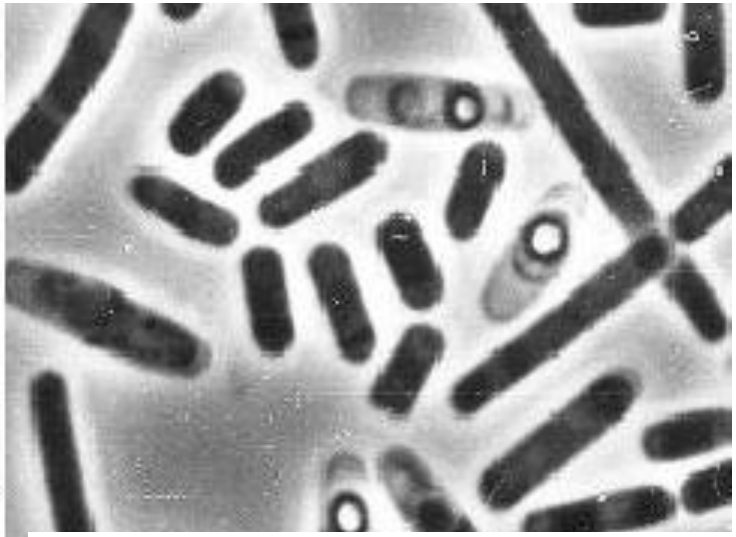


PERMAFROST BIODIVERSITY



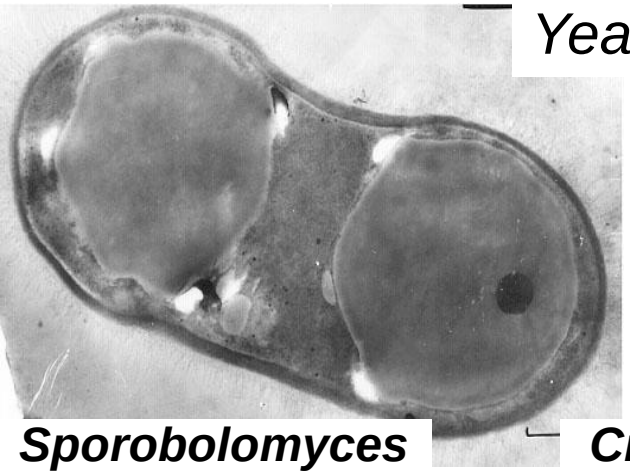
***Psychrobacter arcticus* sp.**

aerobic
&
anaerobic
bacteria

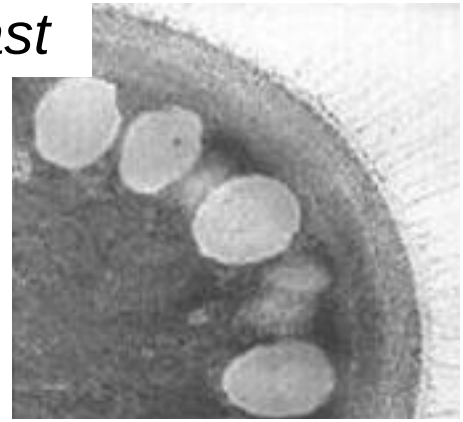


***Clostridium algoriphilum* sp.**

Yeast

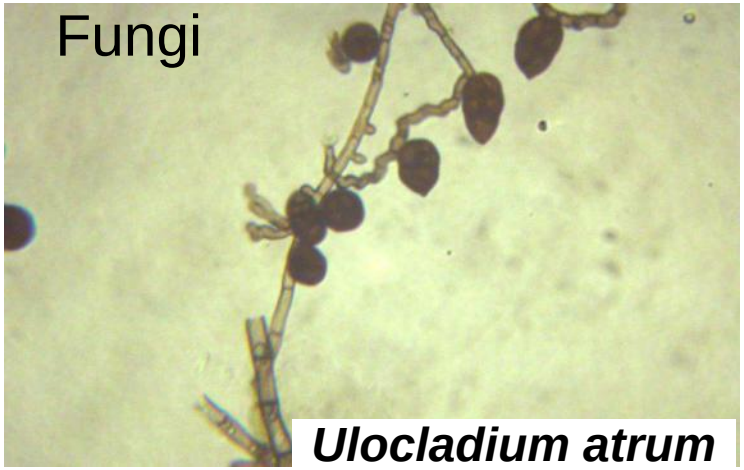


Sporobolomyces



Cryptococcus albidus

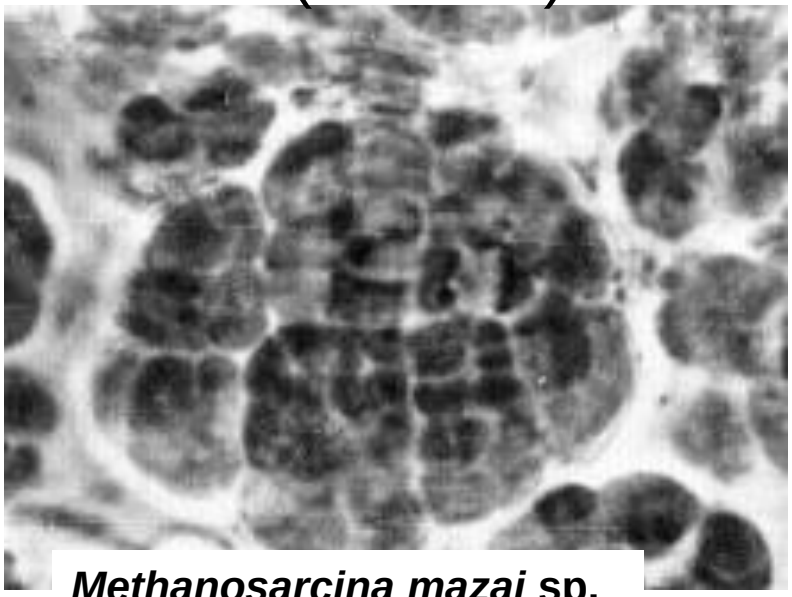
Fungi



Ulocladium atrum

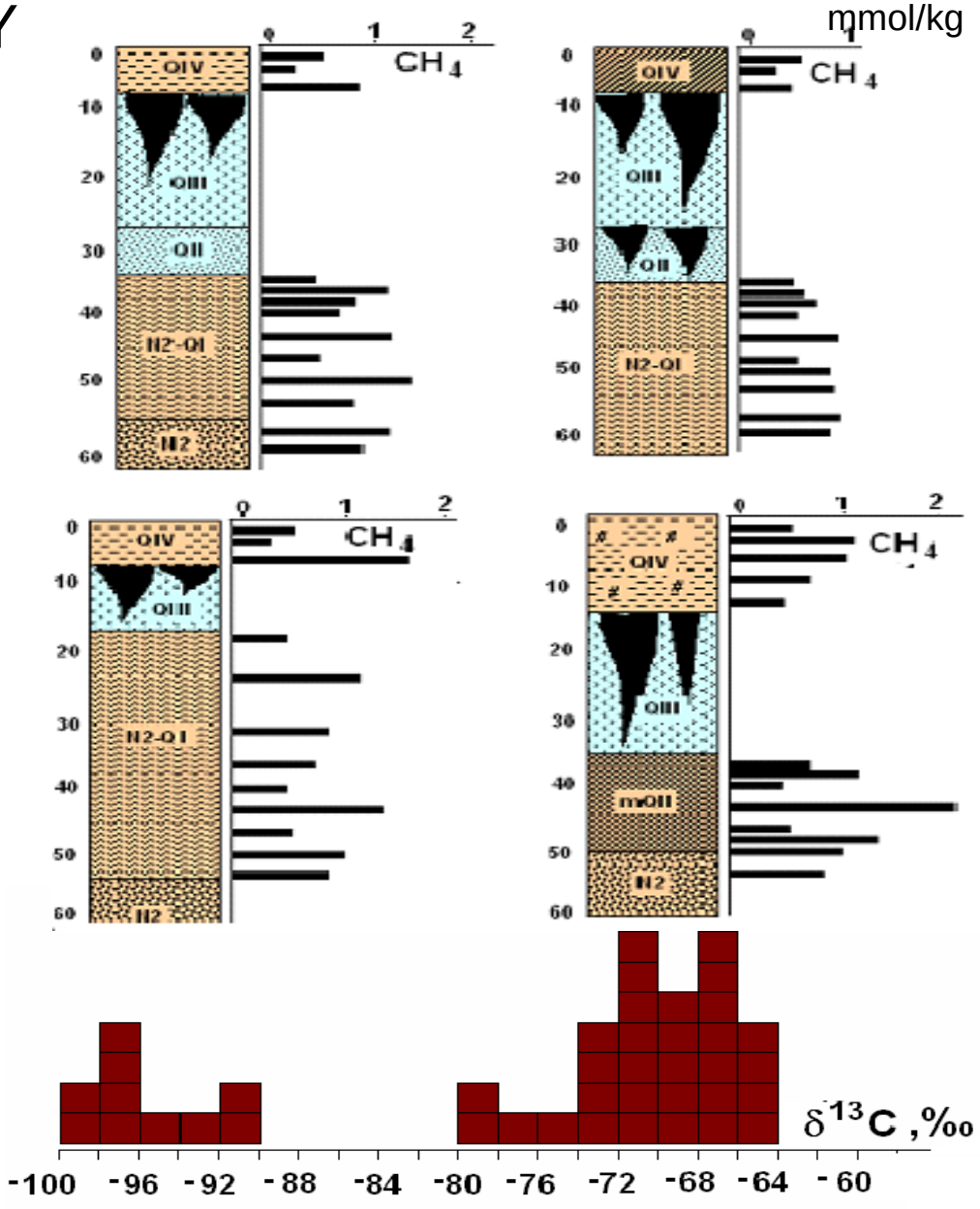
Permafrost hold potential to archive entrapped viable cells. This natural conservation makes it possible to observe what may be the oldest communities discovered on Earth

PERMAFROST BIODIVERSITY (archaea)



***Methanosarcina mazai* sp.**

***Methanobacterium veterum* sp.**



Content & isotopic composition of CH_4 in the late Cenozoic permafrost

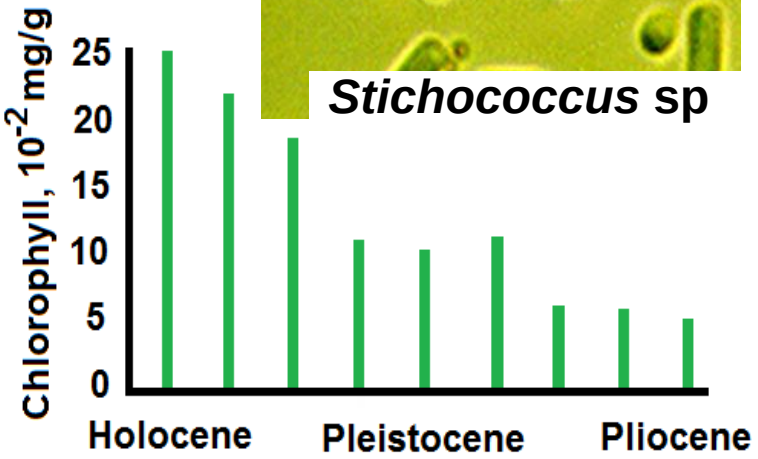
PERMAFROST BIODIVERSITY (phototrophs)

Green algae

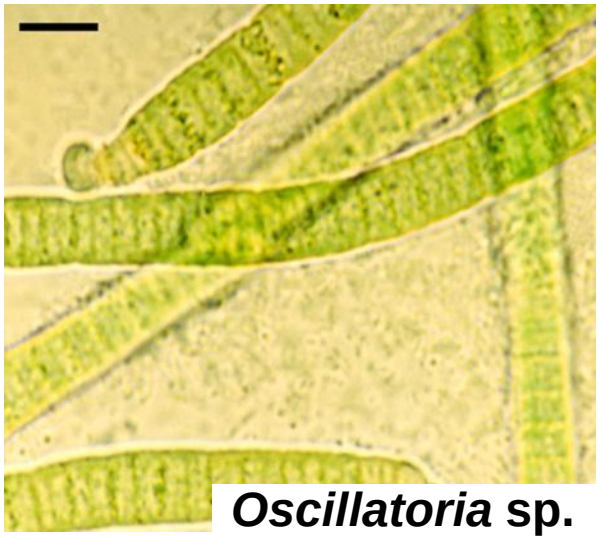
***Scotiellopsis* sp.**

***Mychonastes* sp**

***Stichococcus* sp**

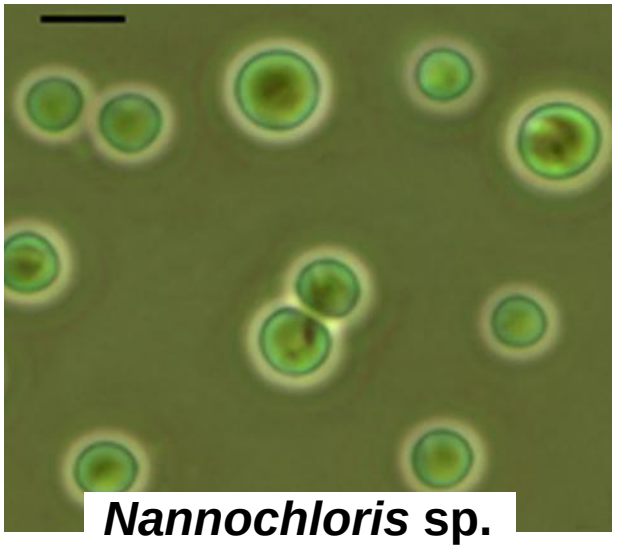


Cianobacteria



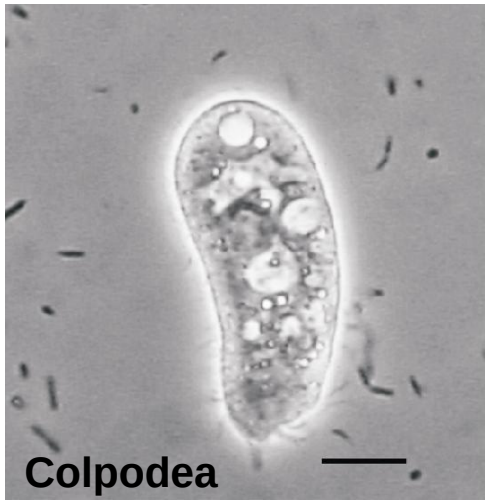
***Oscillatoria* sp.**

Gleoecapsae sp.

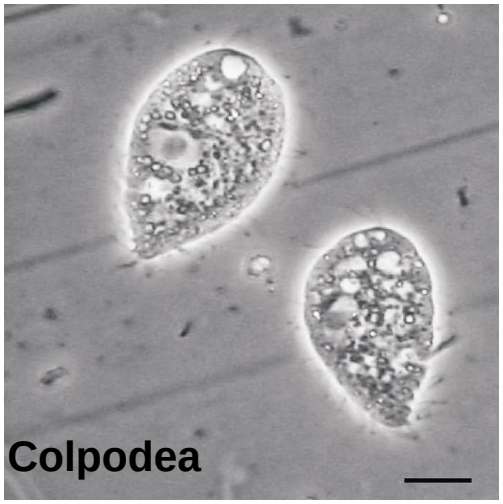


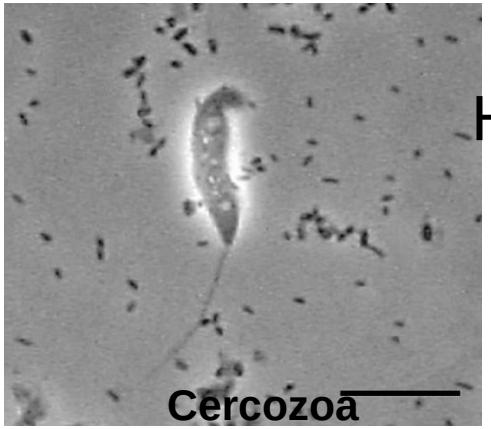
***Nannochloris* sp.**

PERMAFROST BIODIVERSITY (free-living protozoa)

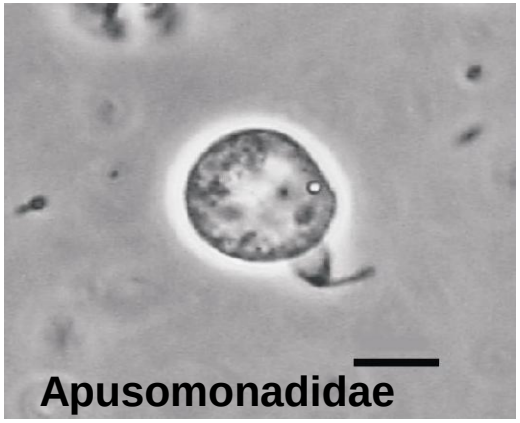


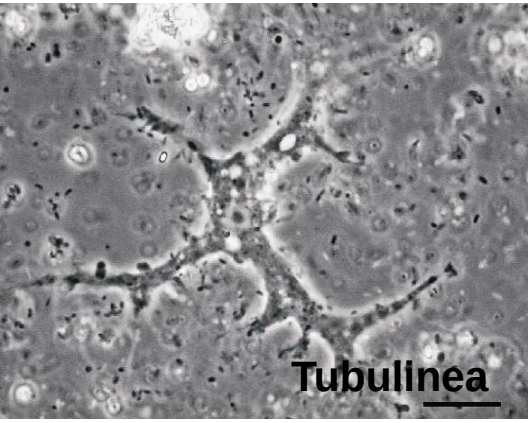
Ciliates



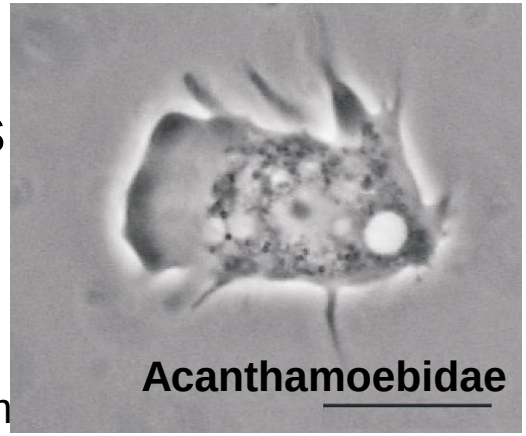


Heterotrophic flagellates





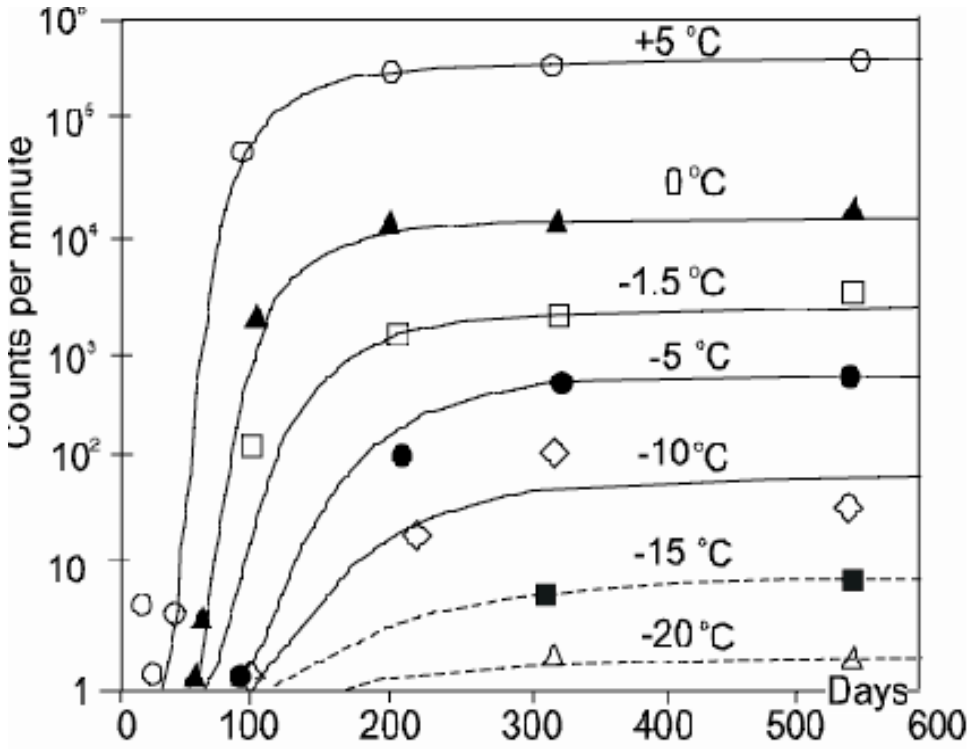
Naked amoebas



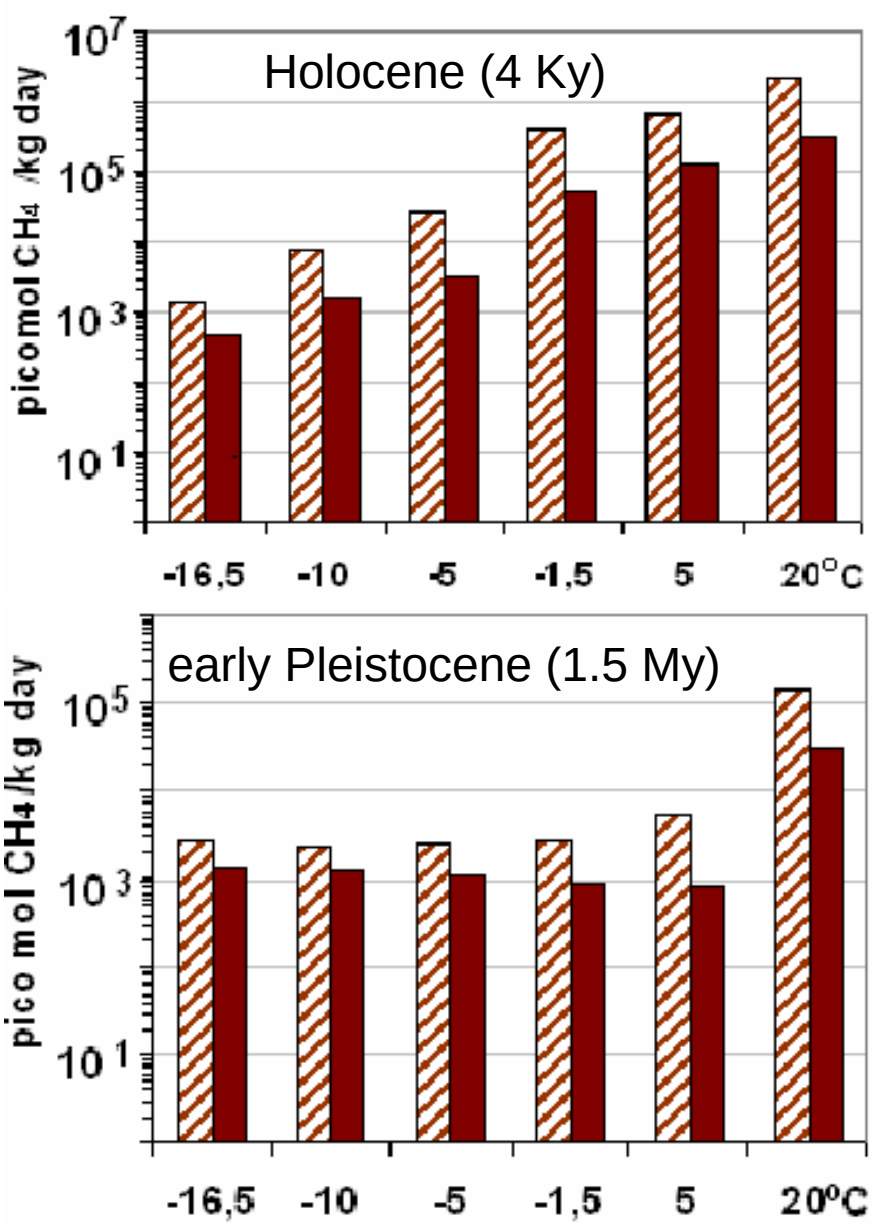
Bars = 10 µm

Paleoorganisms within permafrost are resistant to time and to environmental stresses: freezing-thawing, thermal impact & radiation

Microbial activity below freezing point *(Rivkina et al 2000, 2005)*



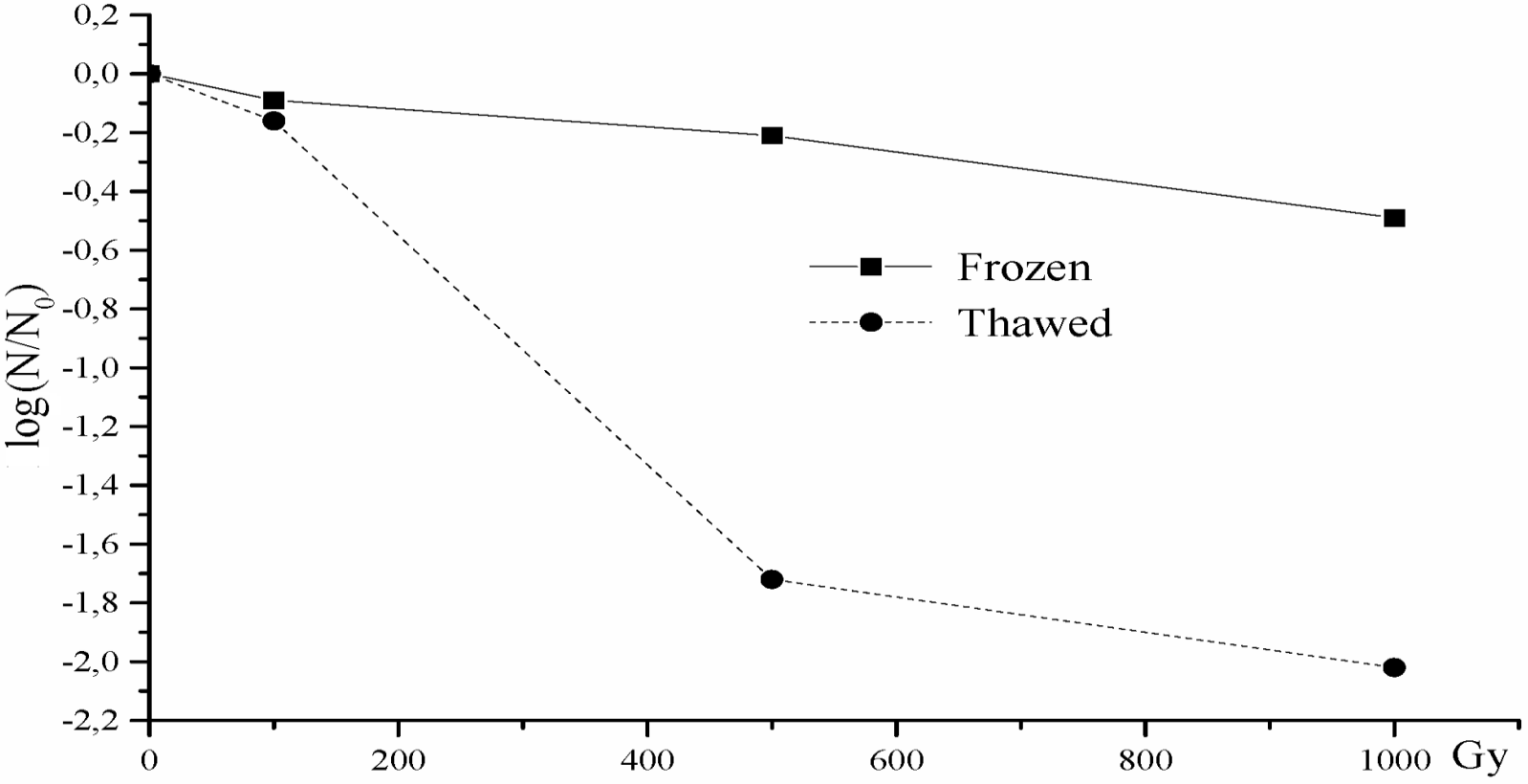
Net counts for ^{14}C-labeled acetate incorporation into lipids by the native bacterial population in permafrost



CH_4-formation in permafrost from $NaH^{14}CO_3$ & $Na^{14}CH_3CO_2$

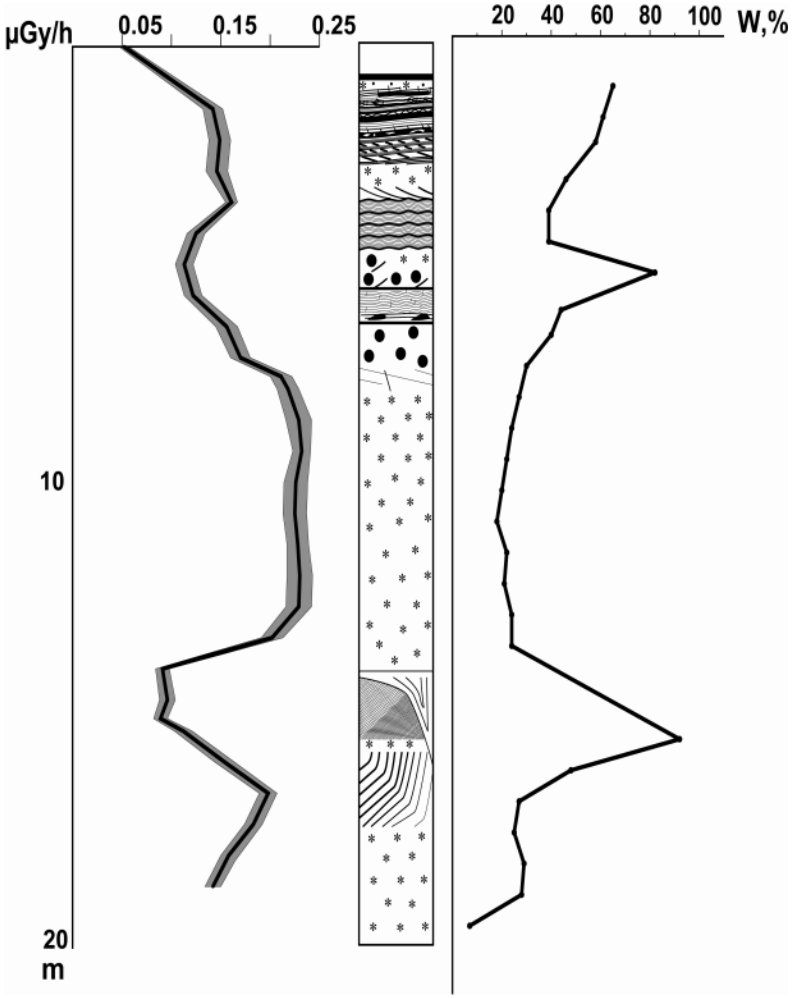
Bakermans et al 2003; Price & Sowers 2004; Ponder et al 2006; Panikov & Sizova 2007; Johnson et al 2007

At equal levels of ionizing radiation, the difference in the quantity of survived cells was ca. one order of magnitude for a dose of 1 kGy: 1 & 10% from initial number, for the thawed and frozen (-20°C) samples



simulation experiments: 22.8 Gy/min Co60 γ-source

In situ measurements in the boreholes showed that the mean radiation level provided by radio nuclides varies 0.1 to 0.3 μG/h



The dose received by cells within the Arctic permafrost with known age

μGy/h	mGy/yr	Age	Total dose
0.23	2.0	10 Kyr	0.02 kGy
		40 Kyr	0.08
		100 Kyr	0.2
		200 Kyr	0.4
		600 Kyr	1.2
		1.0 Myr	2.0
		1.8 Myr	3.6
		3 Myr	6.0

Taking into account the age of entrapped bacteria, the total dose received by cells range 0.01-0.03 kGy in 10 Kyr old sediments to 4-8 kGy in layers over 3 Myr in age

Global Change

Permafrost thawing renews aborigen's activity and exposes ancient life to modern ecosystems

THE REASONS & DIRECTIONS FOR RESEARCH

The occurrence of viable Cenozoic generation of microorganisms within the permafrost is intriguing because their features may provide a window into microbial life as it was before the human's impact

Permafrost biota represents a unique material for research on low temperature evolution and adaptation, and may possess unknown mechanisms that allow them to maintain viability over geological time

In the nearest future the genetic recourses will have the same significance as geological recourses

Microbiology | Cryobiology | Molecular Biology | Biophysics

Geocryology | Quaternary Geology | Bacterial Paleontology

Biotechnology | Reproduction of genetic resources | Ecology

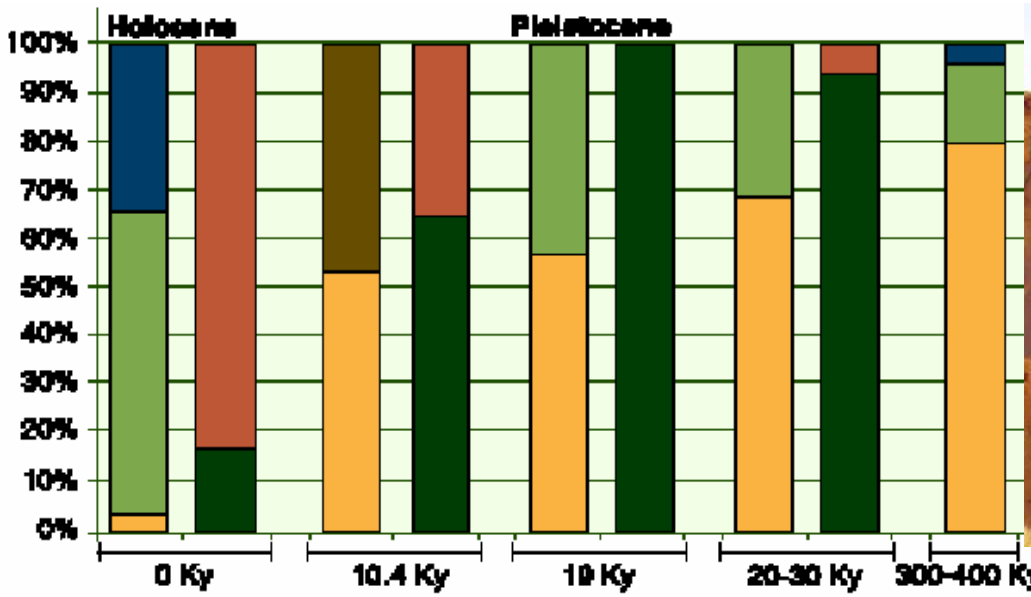
Newly emerging field of Astrobiology

Biotechnology

The only environment on the Earth, which is a depository of unaltered microbial communities is permafrost

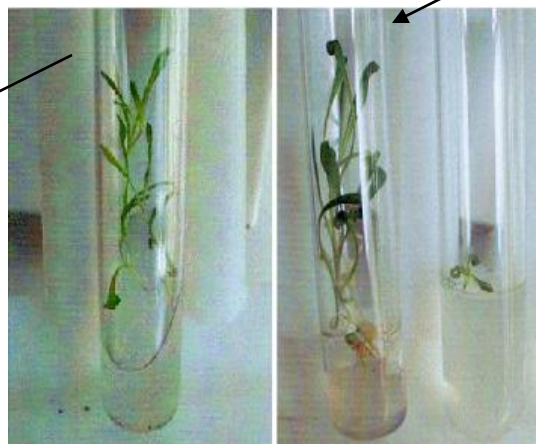
The abilities of many nonhalophilic alkaliphilic psychrotolerant strains isolated from Tibet permafrost to produce extracellular protease, amylase and cellulase suggest that they might be of potential value for biotechnological exploitation (Zhang et al 2007)

Quaternary Geology & Paleoreconstructions



***Willerslev et al* 2003**

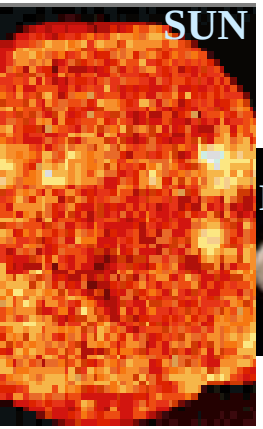
Reproduction of Genetic Resources



Silene stenophylla

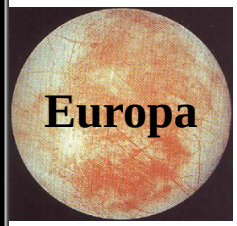
Pleistocene Park
~30Kyr

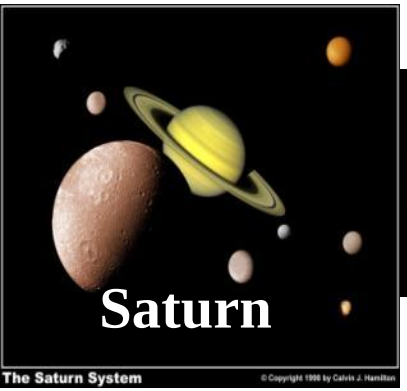
Terrestrial Models and Analogues of Extraterrestrial Habitats and Inhabitants

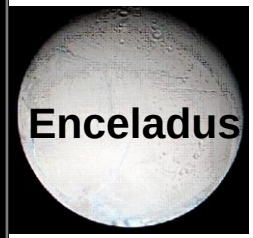


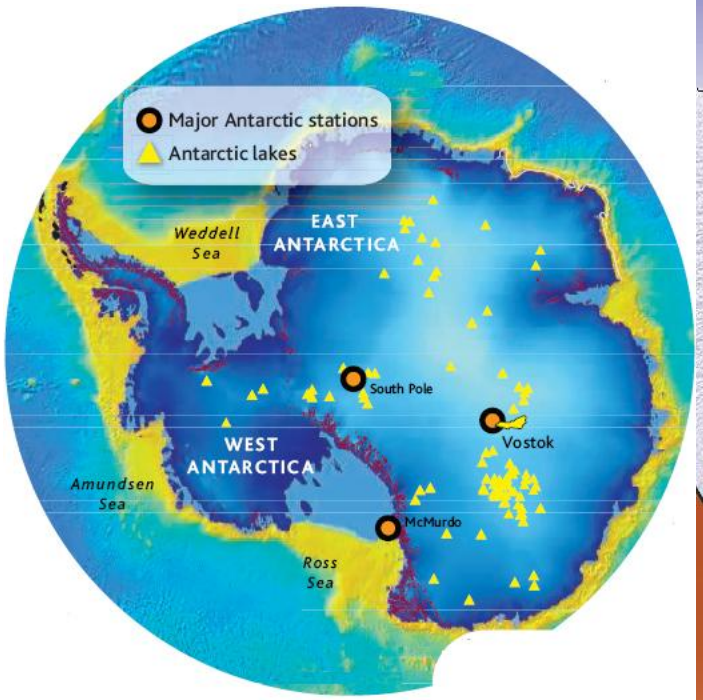
Terrestrial planets J o v i a n p l a n e t s

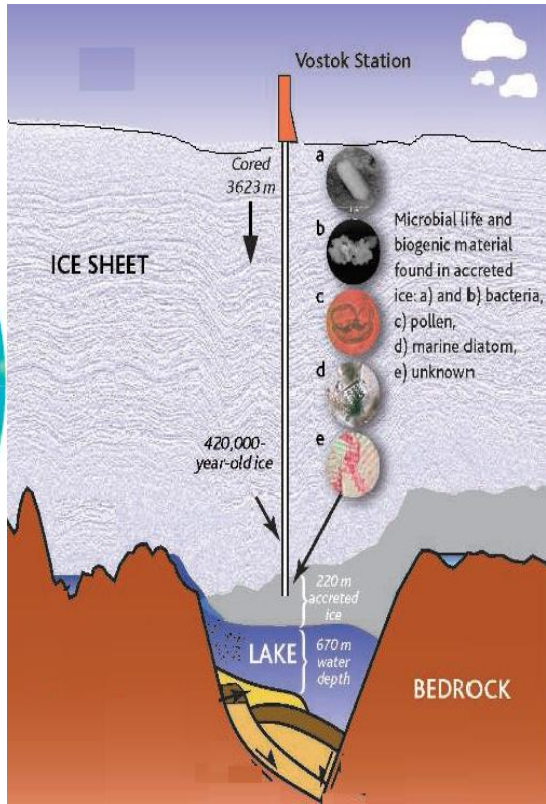
← PLANETS OF CRYOGENIC TYPE →



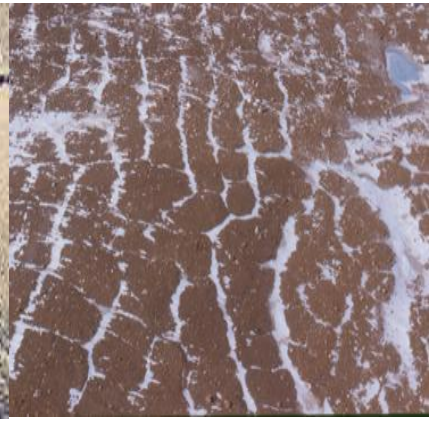
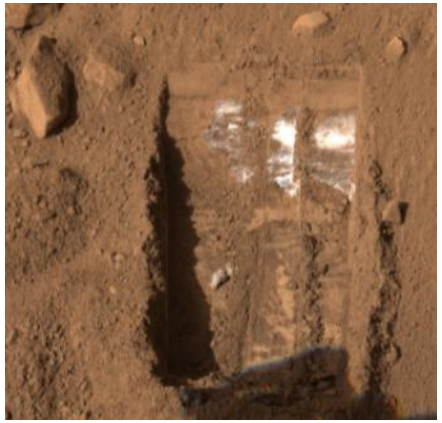
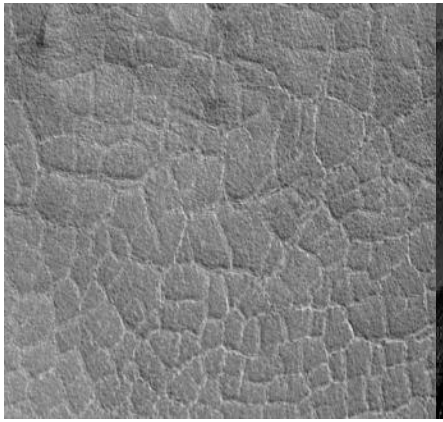








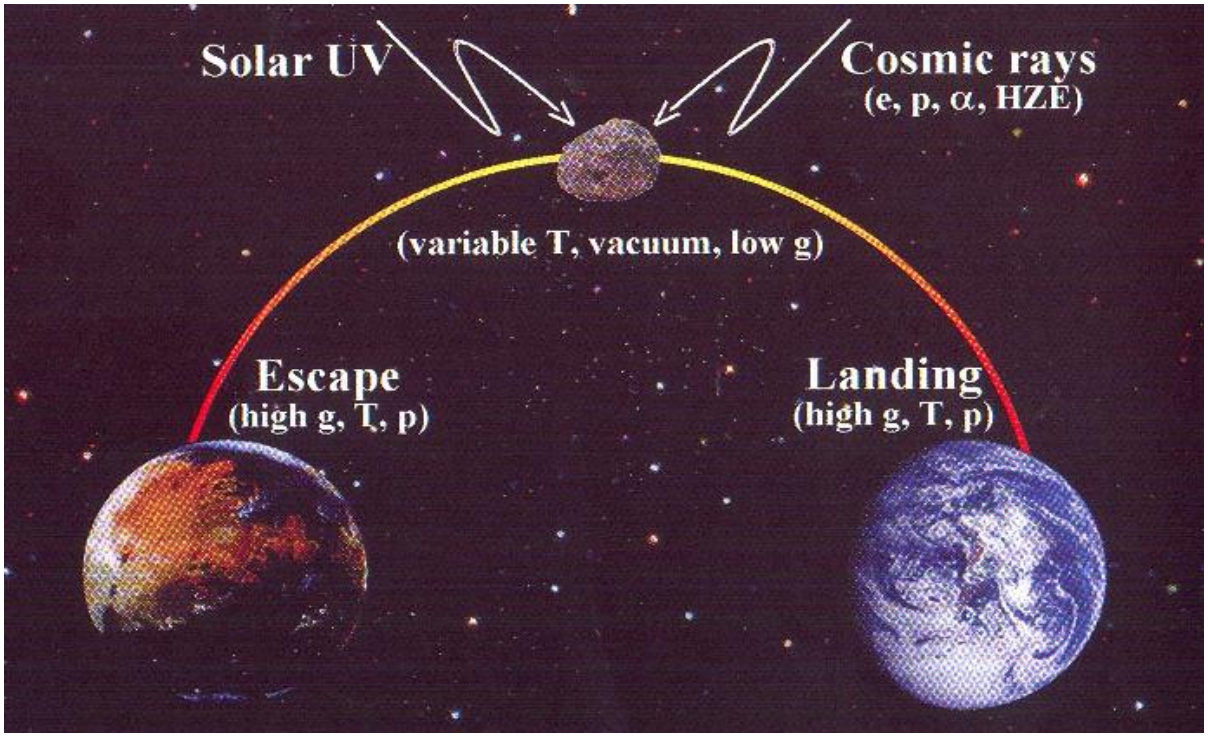
If life ever existed on Mars during the early stages of development, then its traces might have been preserved at the cell's level and could be found at depths within the permafrost


Probably the Martian permafrost contains the genetic resources of existed life, vanished on the surface due the catastrophic events on the planet

The obtained longevity of life preservation assert that during few million years required for Mars to reach the Earth cells could preserve their viability

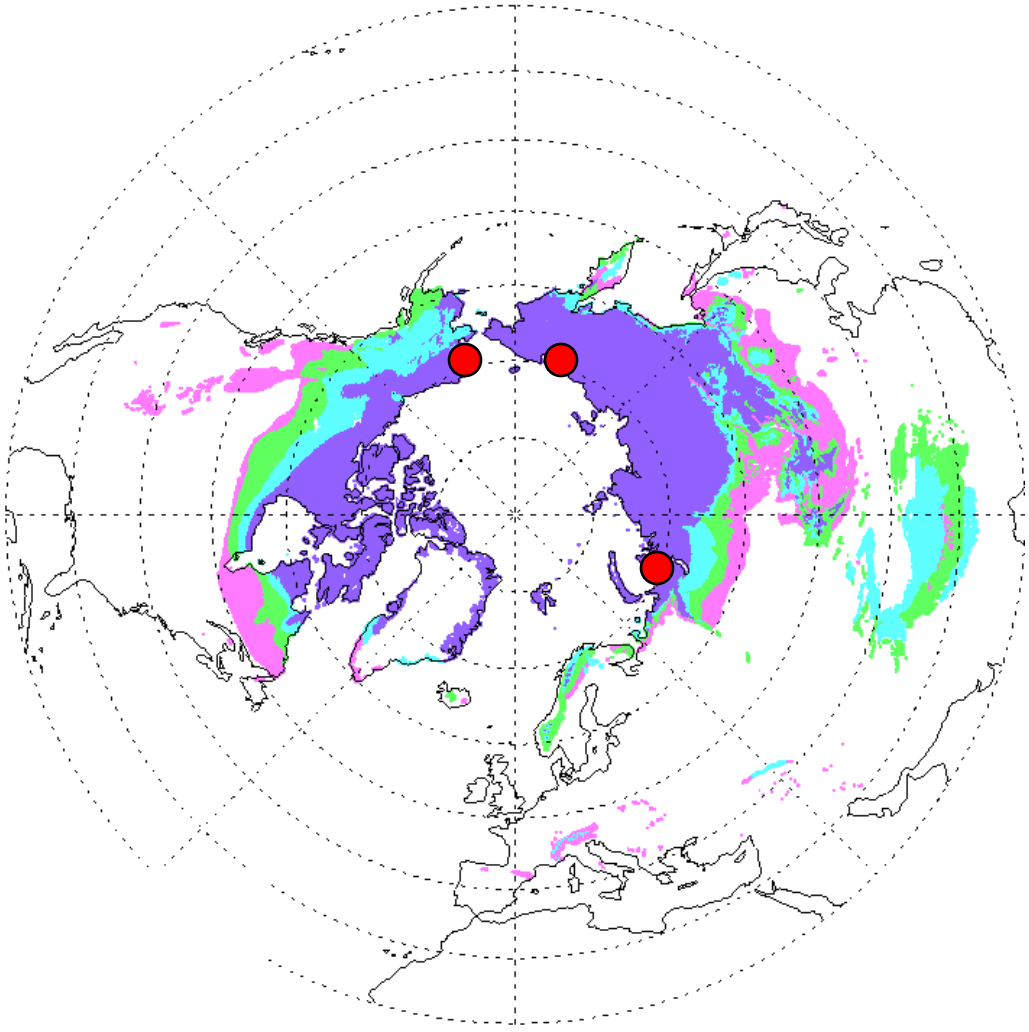
This phenomenon confirms panspermia - the possibility to transport the organisms within the cryogenic meteorites to the Earth

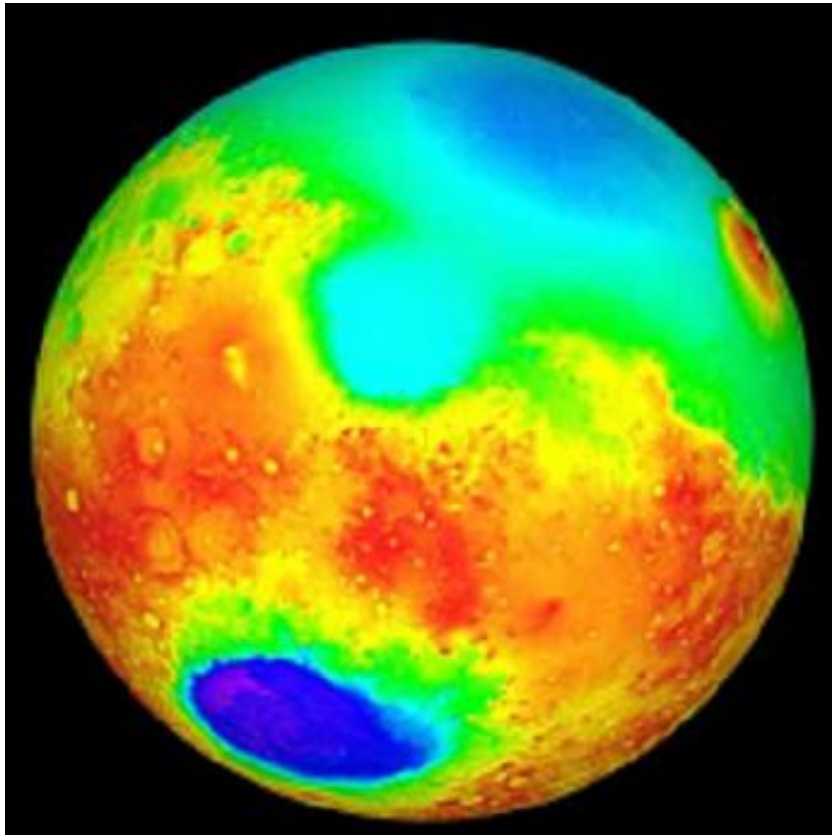


If the Space travel is fatal for microorganisms within the frozen ground

CRYOPEGS

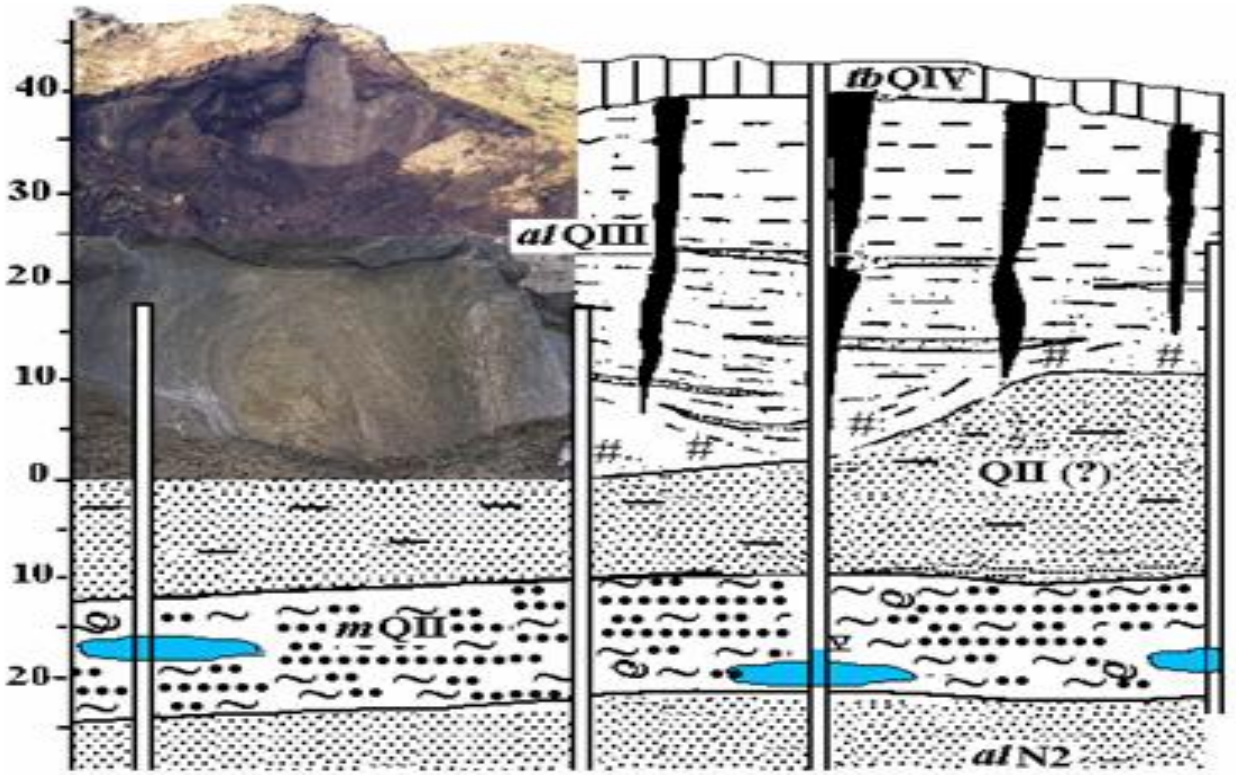
From the astrobiological perspective, lenses of overcooled brines provide the only opportunity for free water within the permafrost, formed when Mars became dry & cold





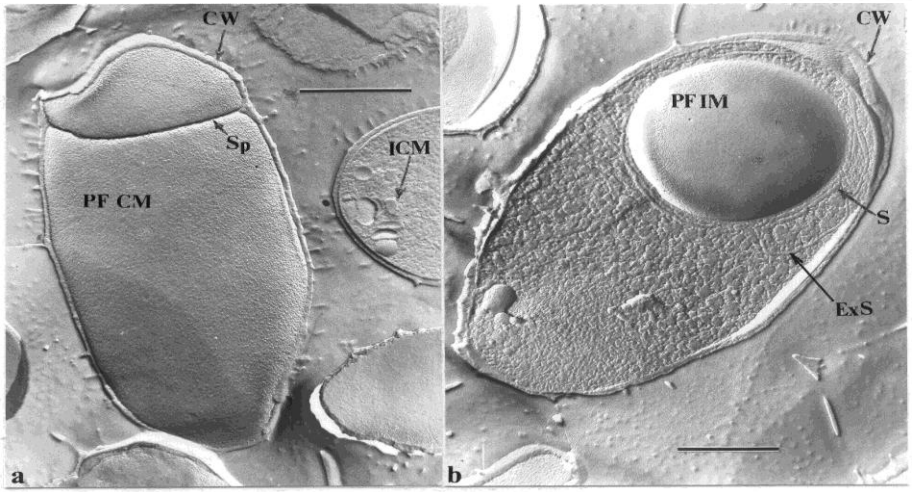
CRYOPEG BIODIVERSITY

T -10°C
free water 100%,
salinity 170-300‰



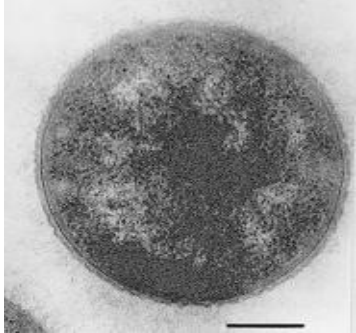
Anaerobic bacteria

Clostridium algidum



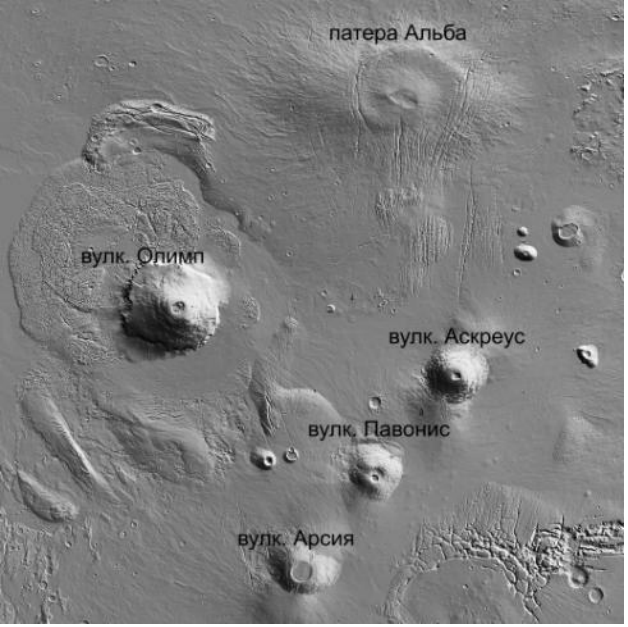
Aerobic bacteria

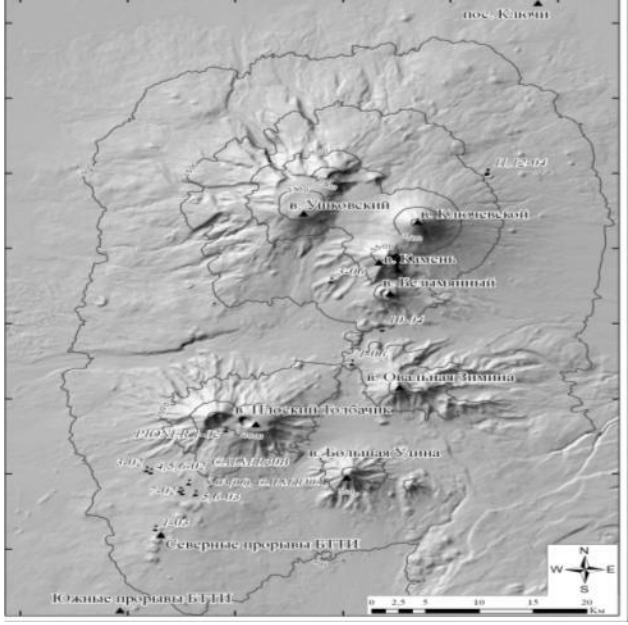
Psychrobacter cryopegella - *halotolerant psiychropilic bacterium* remains active at -20°C



Sulfate reducers detected in cryopegs are halophilic and psychrophilic at the same time

VOLCANOES


патера Альба
вулк. Олимп
вулк. Аскреус
вулк. Павонис
вулк. Арсия


пос. Ключи
г. Ушковский
г. Ключевской
г. Камень
г. Безымянный
г. Овальная Сопка
г. Плоский Толбачик
г. Большая Удина
Северные прорывы БТТИ
Южные прорывы БТТИ
N
W
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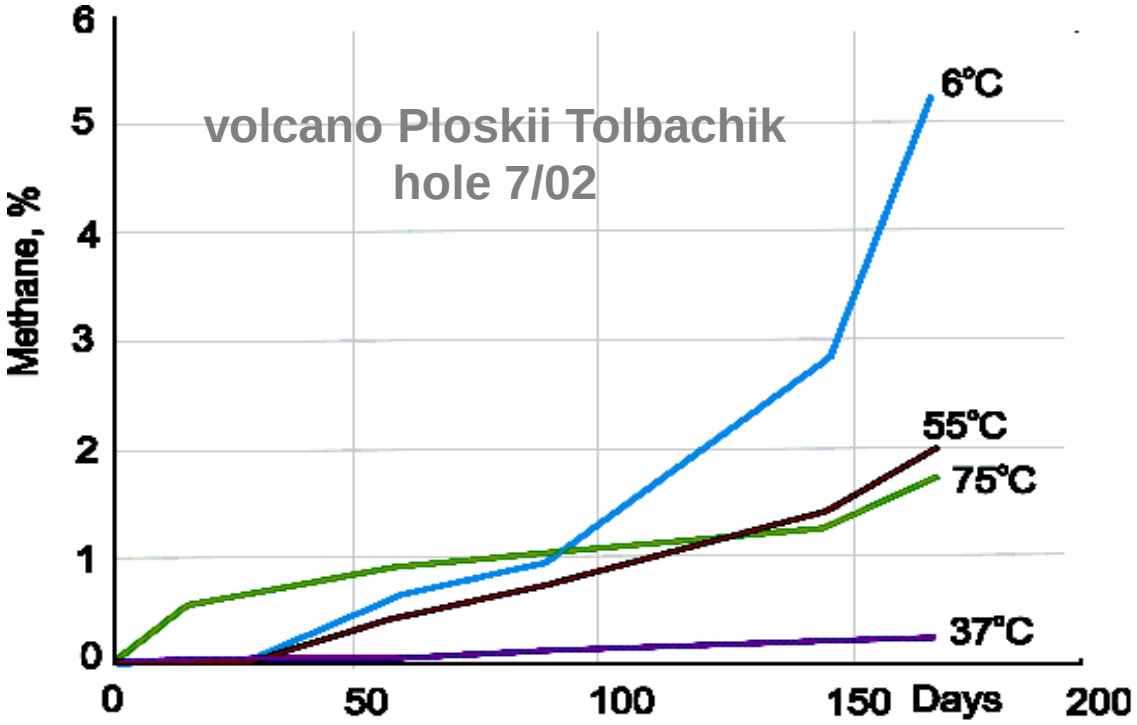
S

Number of volcano permafrost anaerobic microorganisms growing on CO_2+H_2

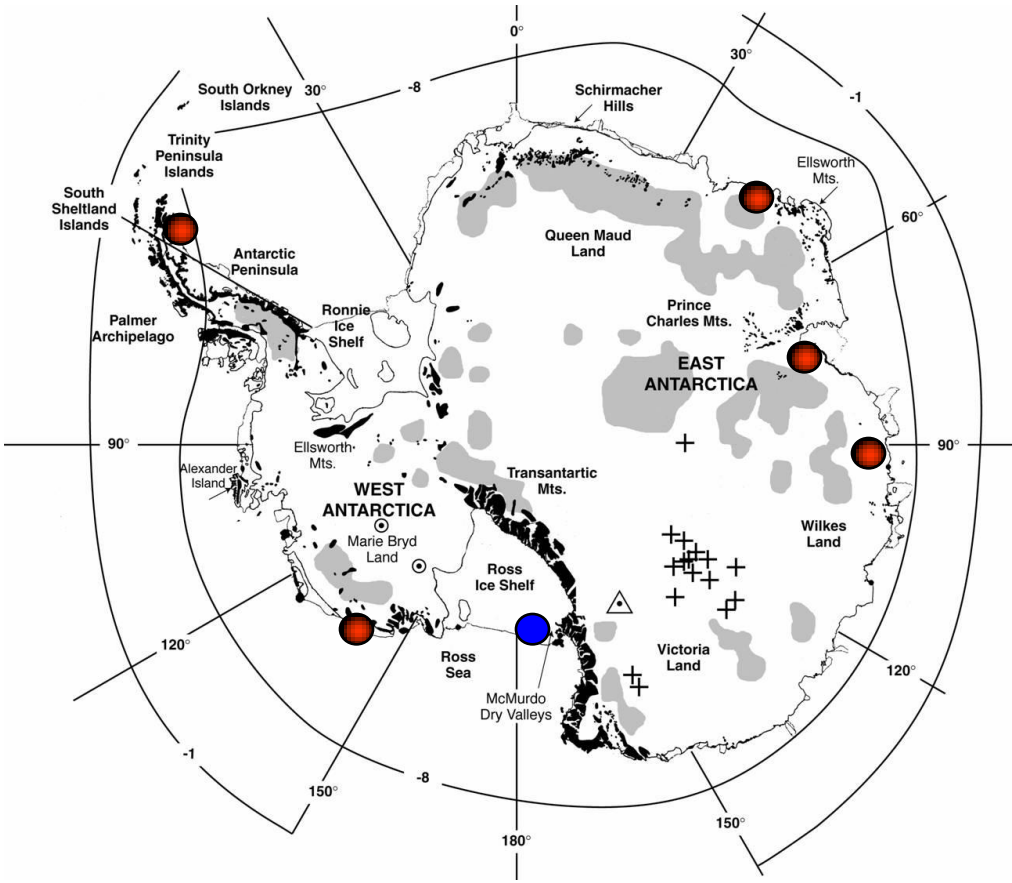
m	methanogens	acetogens	sulphate redusers	methanogens	acetogens	sulphate redusers
	+75°C (cells/g)			+6°C (cells/g)		
5.5	12	0	0	16	0	0
6.5	14	0	0	311	0	0
7.5	0	142	13	150	0	10
8.5	0	145	1205	19	0	0
9.3	0	110	10	12	0	0
10.5	0	13	100	14	0	14
11.0	0	0	13	15	0	0
12.0	20	0	125	293	0	20

Methane production from CO_2+H_2 by enrichment culture of methanogens



ANTPAGE - Antarctic Permafrost Age – Implications to the Earth and Planetary Geo/Bio Sciences

The climate and geological history of Antarctica were favorable for the formation and persistence of pre-Pliocene permafrost more than 30 Myr

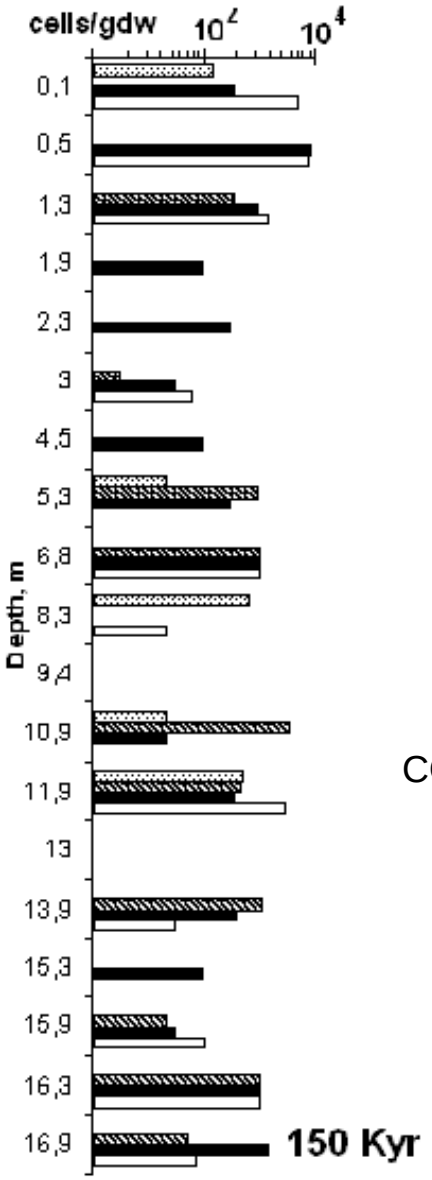


Permafrost age:
Arctic ~3 Myr
Mars ~3 Byr

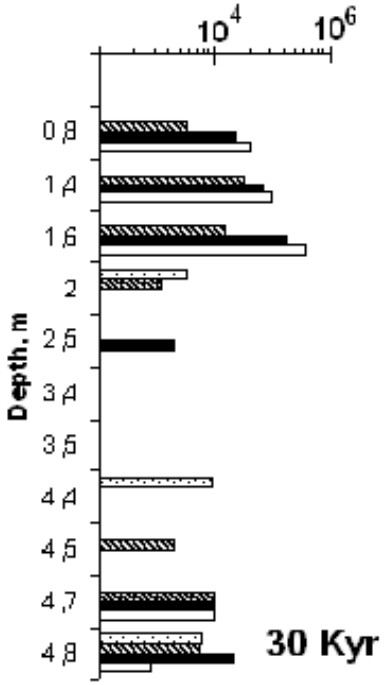
The main goal of ANTPAGE project is to find the oldest permafrost, to date these sections and test for the presence of viable microorganisms & DNA

VIABLE BACTERIA in ANTARCTIC PERMAFROST: HOW OLD ARE THEY & HOW OLD MIGHT THEY BE?

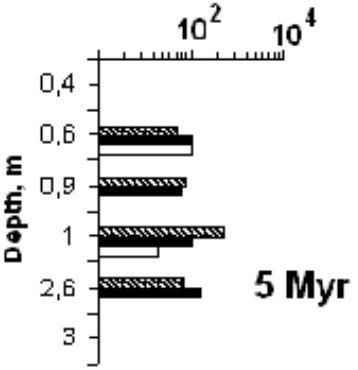
COMRAC 3, Taylor Valley



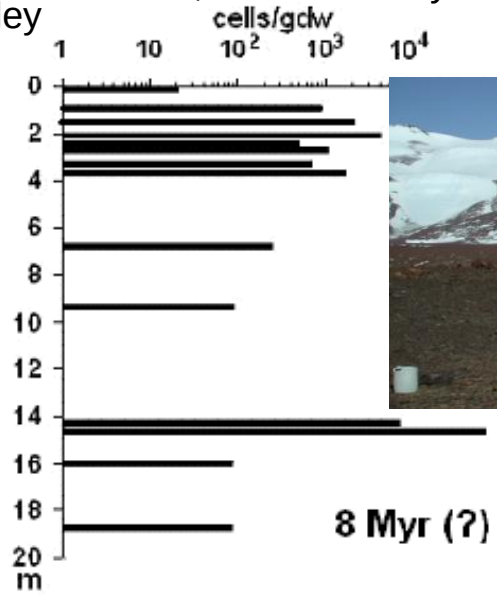
COMRAC 4, Miers Valley



COMRAC 8, Mt. Feather

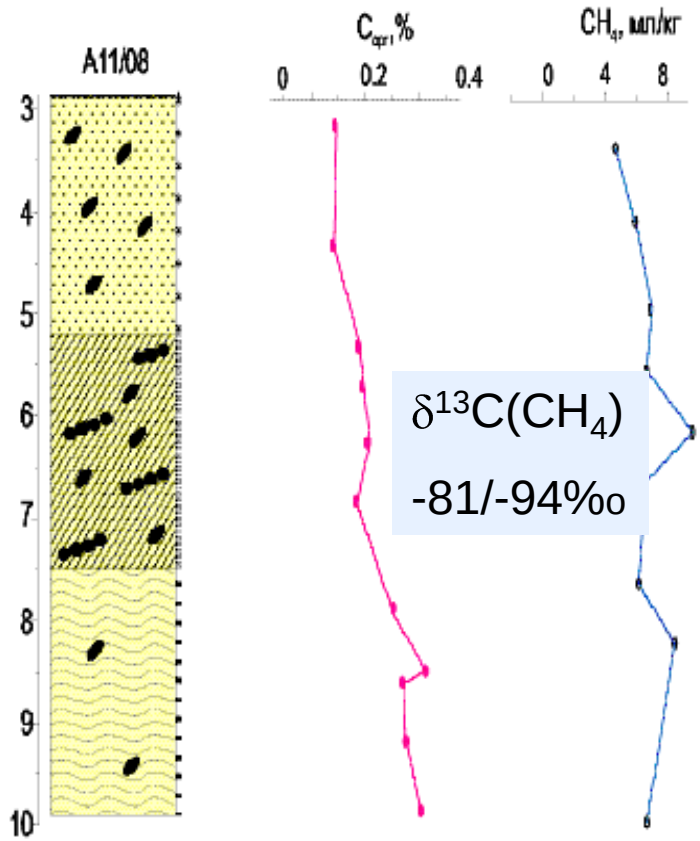


1/99, Beacon Valley



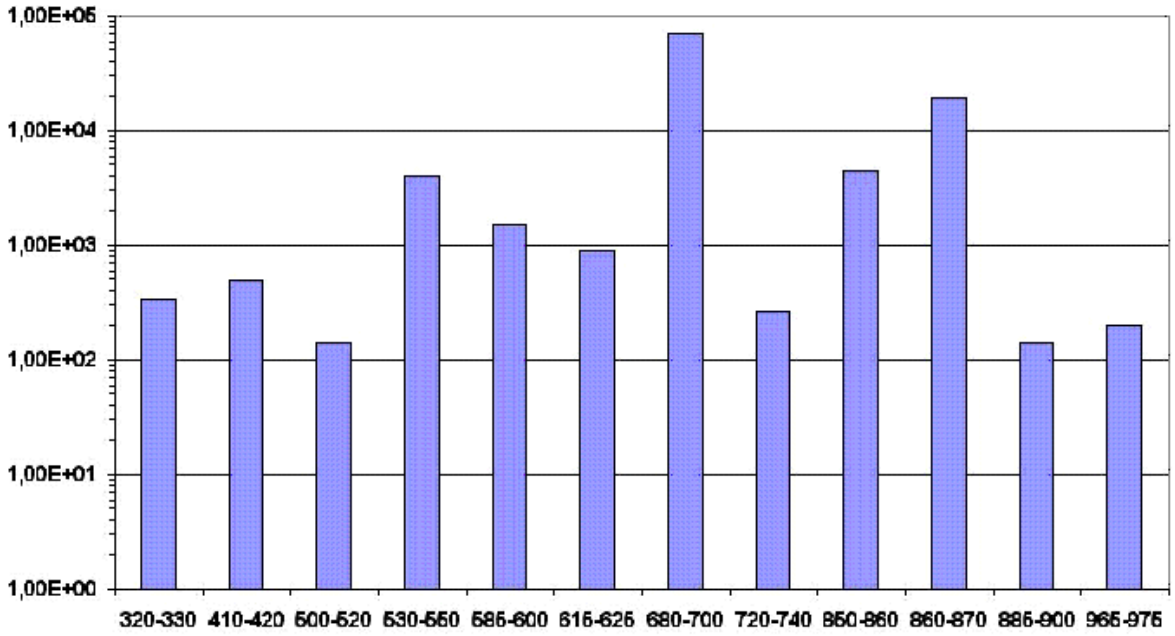
If the ages suggested in Beacon Valley (8.1 Myr) and Mt Feather (5 Myr) are correct, then the microbial communities retrieved from those cores are also as old as the permafrost and, to date, are the oldest viable microorganisms discovered in permafrost on Earth

Gilichinsky et al *2007/ASTROBIOLOGY*



$\delta^{13}C(CH_4)$

-81/-94‰



CONCLUSION

"**Permafrost ecosystem**" could be a multidisciplinary bipolar astro/terrestrial bio/geo collaborative project, focused on the following fundamental and applied problems:

- How long can life be preserved in frozen environment ?
- Is life below the freezing point active or dormant ?
- What life forms are present ?
- Is there a threat to humans, animals, plants from pathogens?
- Is there lateral gene transfer from ancient to contemporary bacteria?
- Are there any new gene products that can be extracted from ancient microbes (anticancer, antibiotic, industrially useful products)?
- Can we directly measure microbial mutation rates over long periods of time?
- Can the models and methods developed for detection of microbial life in frozen substrates in situ be directly applied to astrobiology research

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Terrestrial permafrost models of extraterrestrial (Martian) habitats & inhabitants

THANK YOU FOR ATTENTION !

This hope prototype of Martian inhabitants was installed in 2008-Christmas night on South Polar Cycle: Bunger oasis, Antarctica, 66°36’S, 100°45’E

Due the artistic and scientific features the monument is protected from melting by all States - members of Antarctic Treaty