Subglacial geomicrobiology: community input on drilling and coring

Ice Drilling Science
Community Workshop
April 2011

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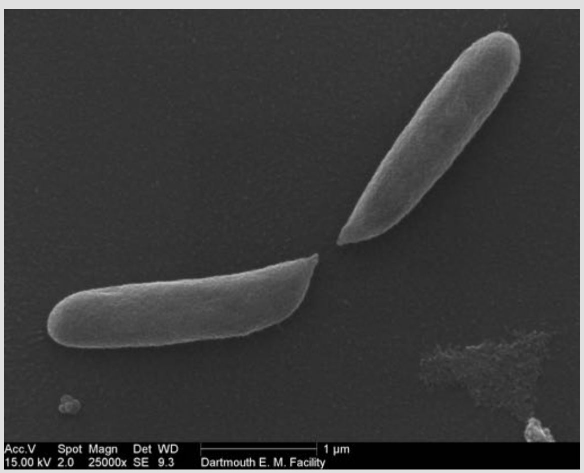
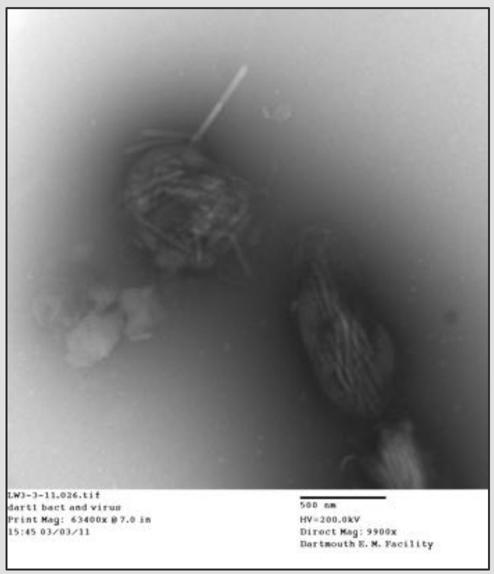
Dartmouth – Earth Sciences

Subglacial Microbiology: Science questions

- Cell abundance, diversity, ecology
- Preservation of biological material
- Viability of cells in icy environments
- Subglacial Lifestyles
  - Adaptation to and evolution in isolated environments
  - Microbial metabolism – increase weathering reactions
- Flux of metabolic products (including GHGs CO_2 and CH_4)



Wahl et al.



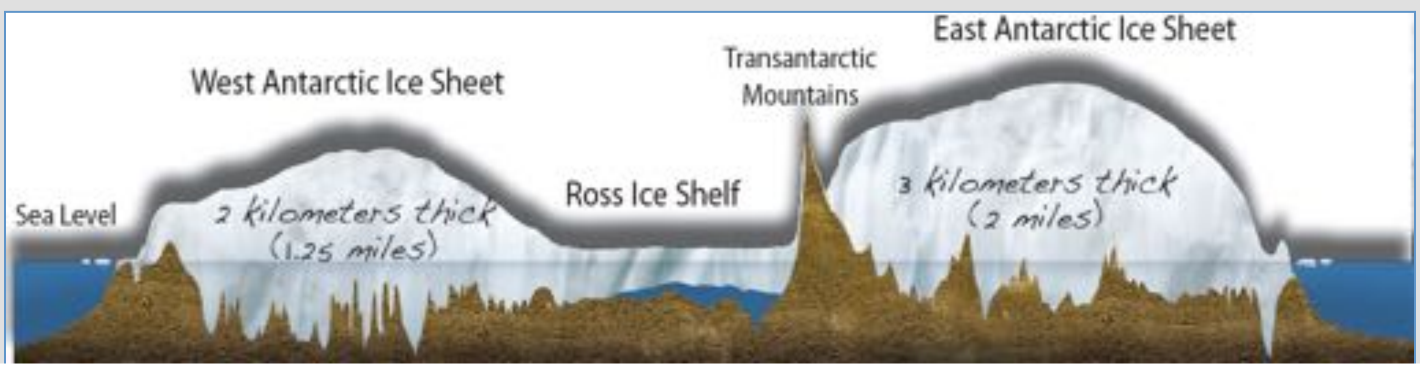
- Discovery driven
- Hypothesis driven

Emerging themes in subglacial processes:

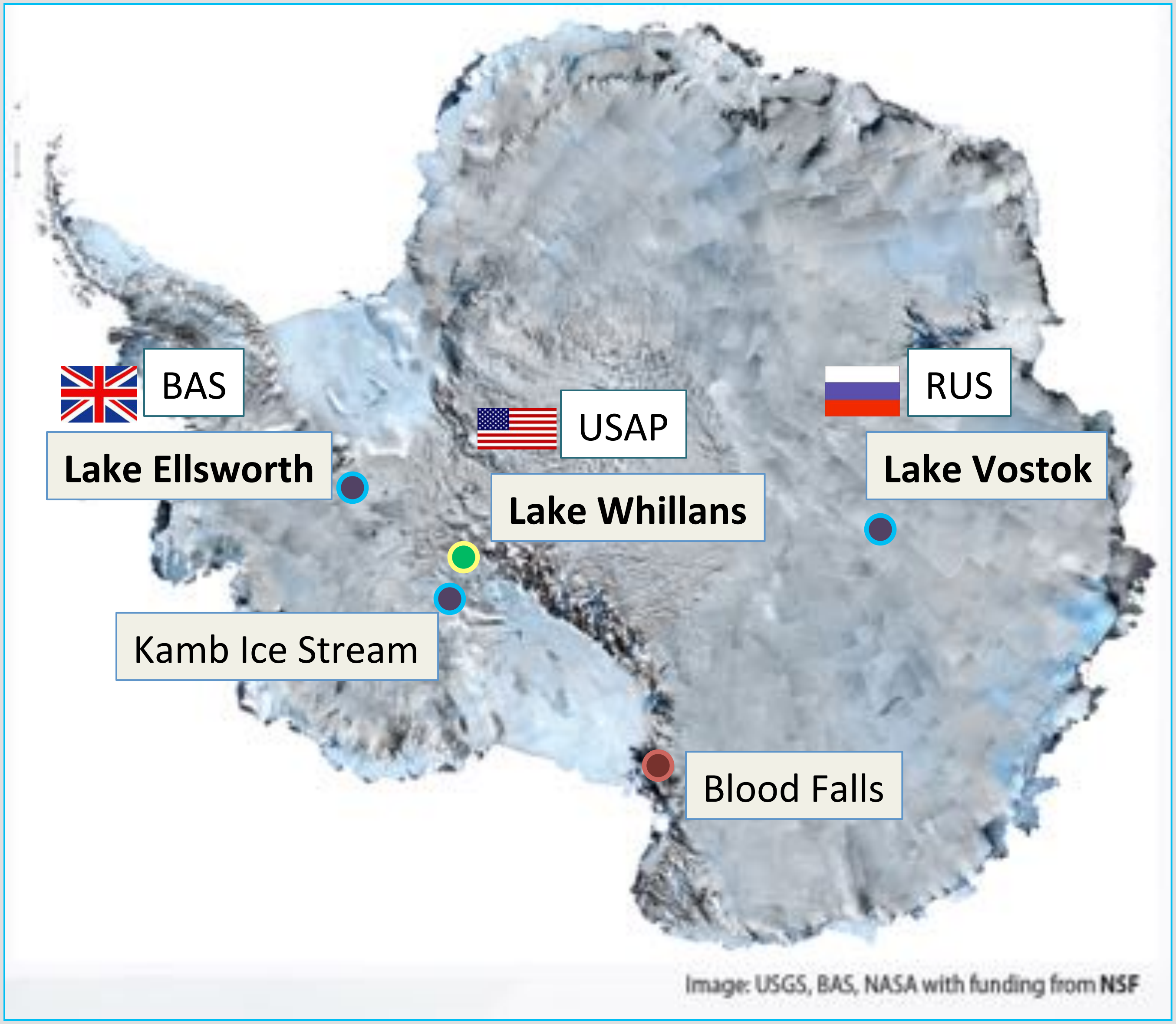
• Subglacial Environments contributes to the global carbon budget
~5 Pg C (cells + DOC) in Antarctic subglacial environments *Priscu et al. (2008)*
0.5 Pg C freshwater; 686 Pg C open ocean *Whitman et al. (1998)*

• Subglacial microbes grow using (overridden) carbon, iron and sulfur as energetic substrates

• Hydrology - an important control on microbial community structure

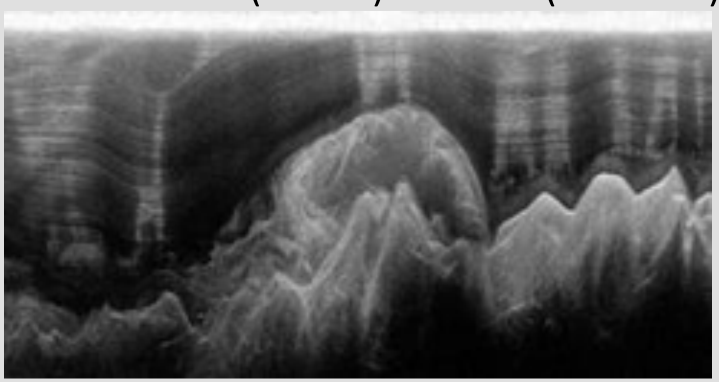


Subglacial Microbiology: Science questions



Sampling Subglacial Environments:

Pink basal ice (NGRIP) J. White (INSTAAR)



East Antarctic Ice Plumes Bell et al. (2011)

Samples of opportunity vs.
Strategic sampling for biology

•Interested in similar environments to other disciplines

•Subglacial lakes and lake sediments

•Basal ice, subglacial sediments

•Integrate with future efforts (i.e. new destinations for the DISC drill) with a dedicated biology core

•Clean collection of samples (holes with drilling fluid)

•Logistics – labs on site (to melt ice, run analyses, etc.

Subglacial Environmental Code of Conduct:

- NSF evaluates projects on an individual basis
- **Environmental Review** for any project where **subglacial water is present at the base** [ice coring or access drilling] - regardless of whether or not there is biology in the project (i.e. IEE or CEE)
- Likelihood that clean access techniques must be applied in any subglacial environment (Environmental stewardship requirements)

Borehole camera images of the basal ice layer in Kamb Ice Stream

Currently: a minimum of 10^2 cells / mL should not be exceeded
No similar requirements for Greenland

Subglacial Environmental Code of Conduct:

Clean Access for drilling Subglacial Lake Whillans

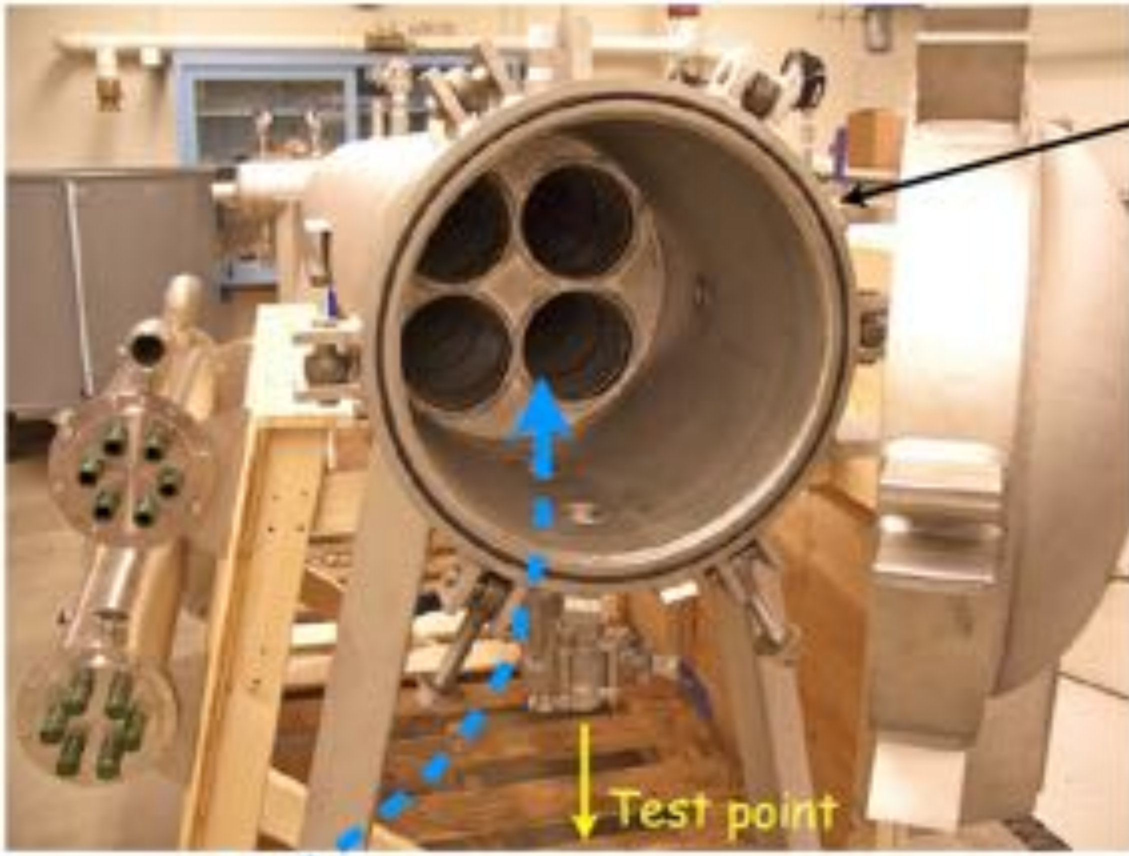
- Instrument cleaning protocol
  - 3% Hydrogen peroxide and pressure washing
  - UV treatment for cables and hoses

- Hot water drilling
  - Water filtration
  - 'Pasteurization'
  - UV treatment

- Monitoring of Bioload

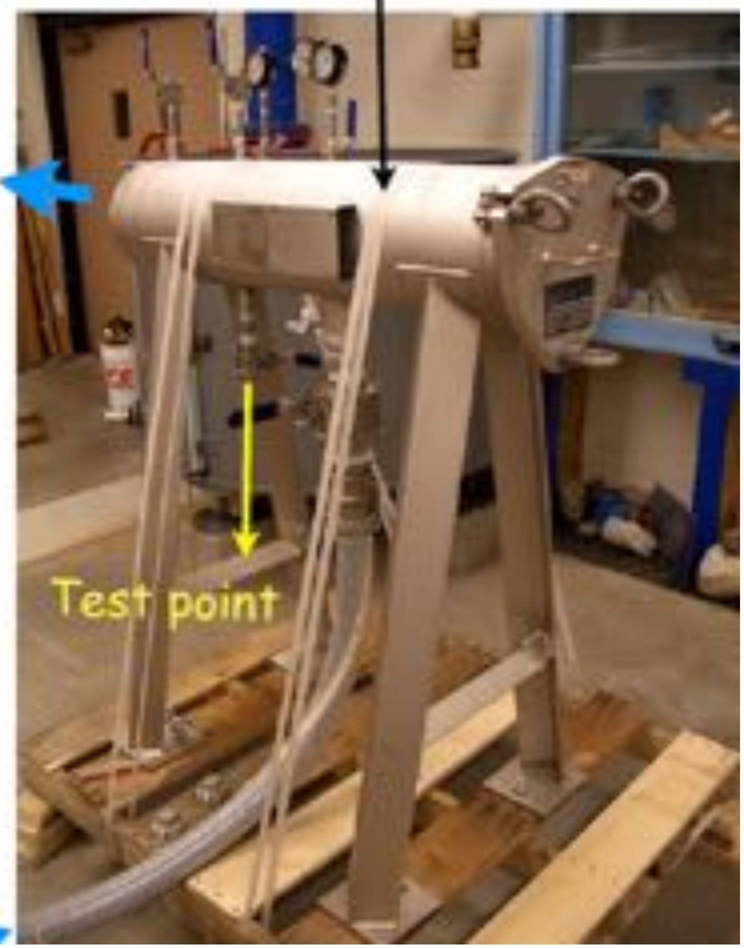
WISSARD water filtration test setup

2um filter (150 gallons)

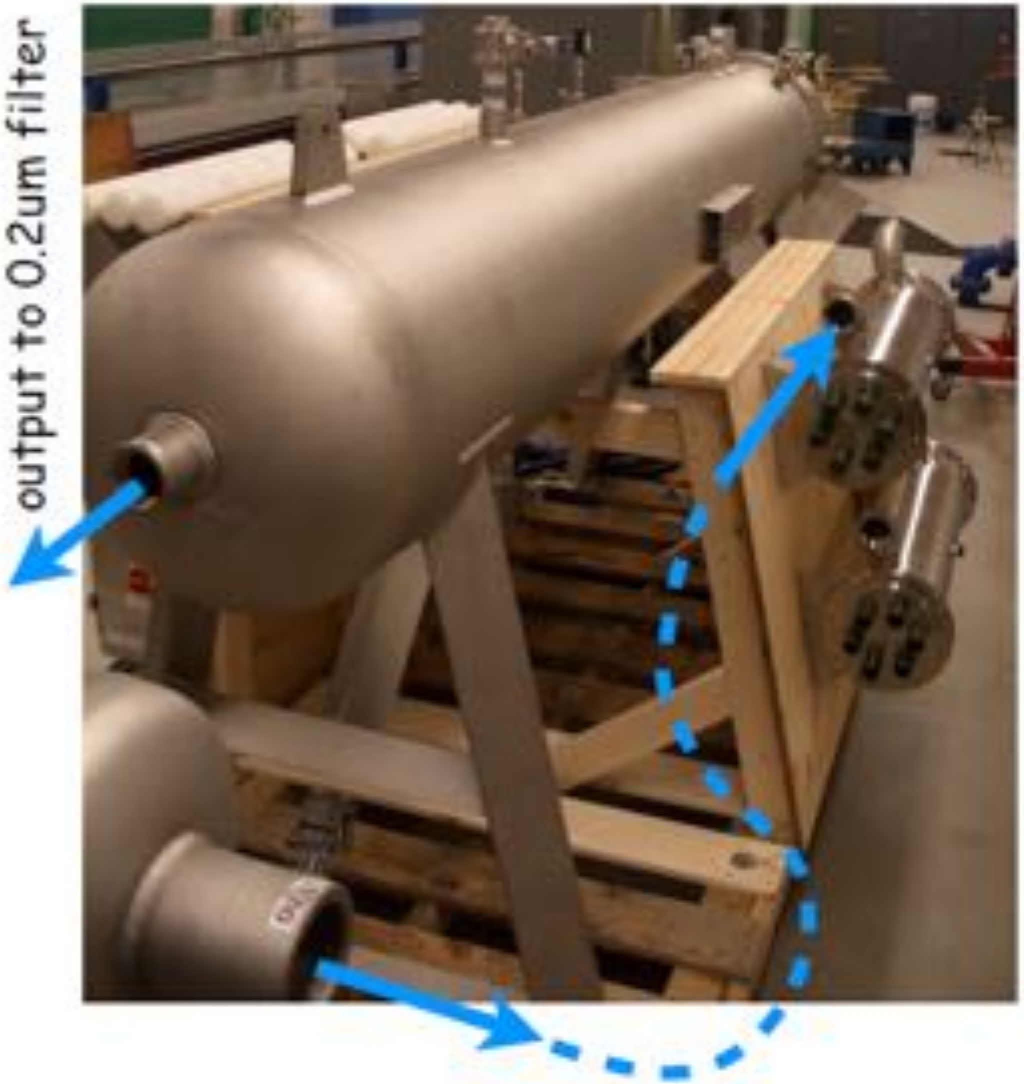


Input from 15hp pump

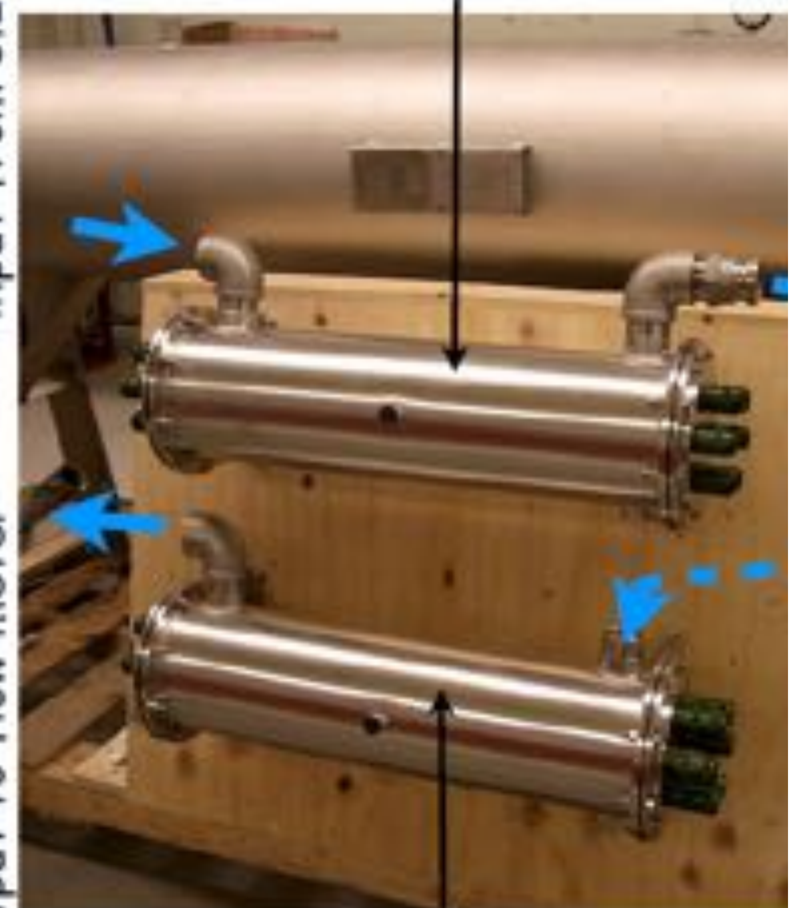
0.2um filter



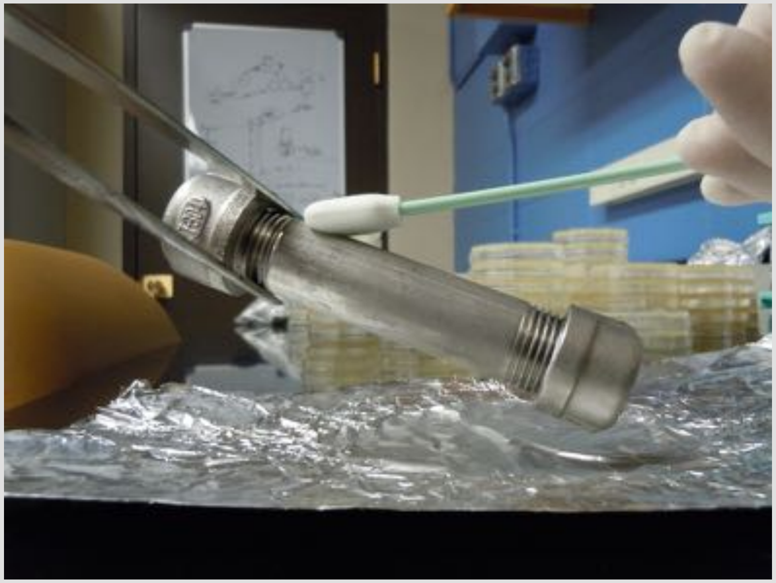
WISSARD water filtration test setup



Destruction of organics and germicida



Monitoring Clean Techniques

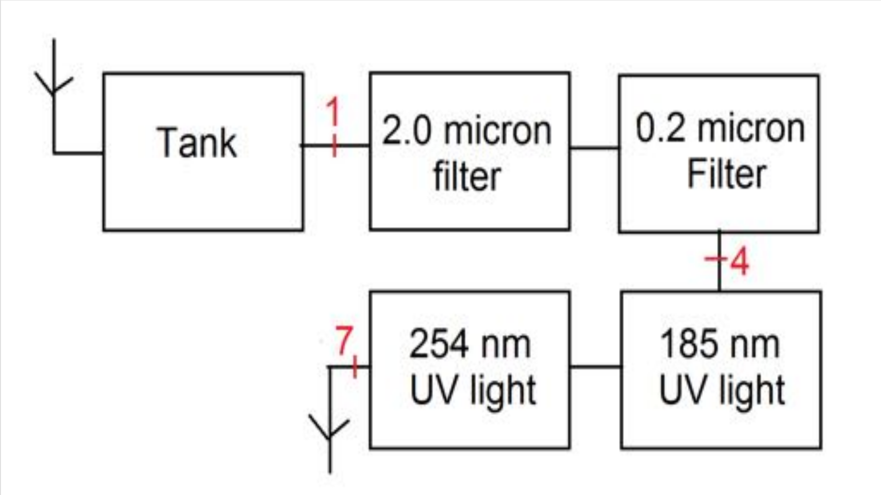


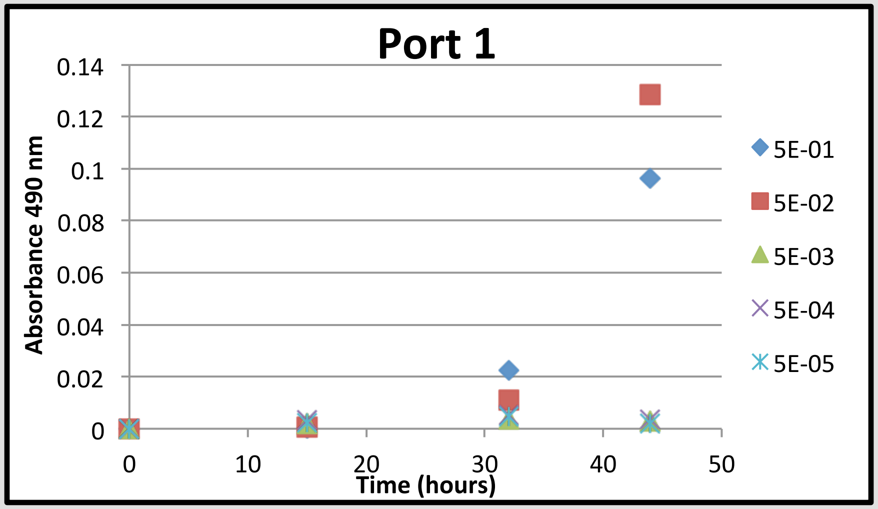
- Bioload
- Cell viability
- Establishing baseline for nutrients, trace elements, etc.

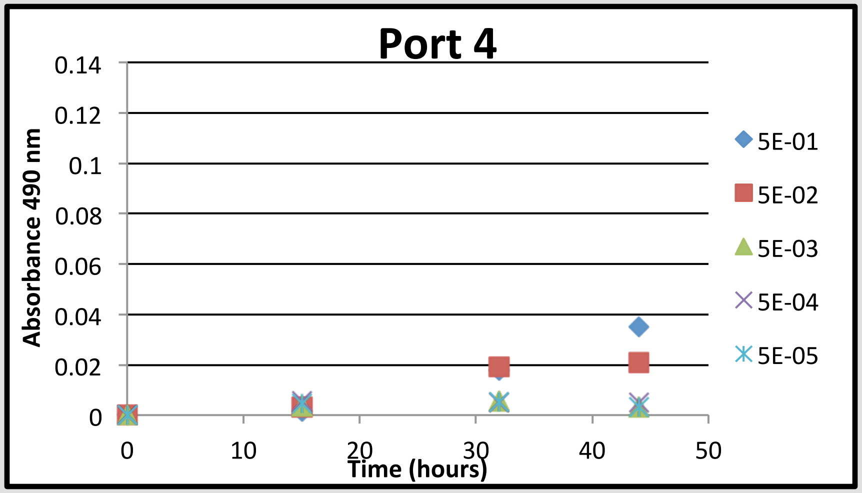
- Contaminants (bacterial cultures) do not adhere consistently to stainless steel.
- 3% H_2O_2 reduces contamination to below detection (<300 cells ml^{-1}).

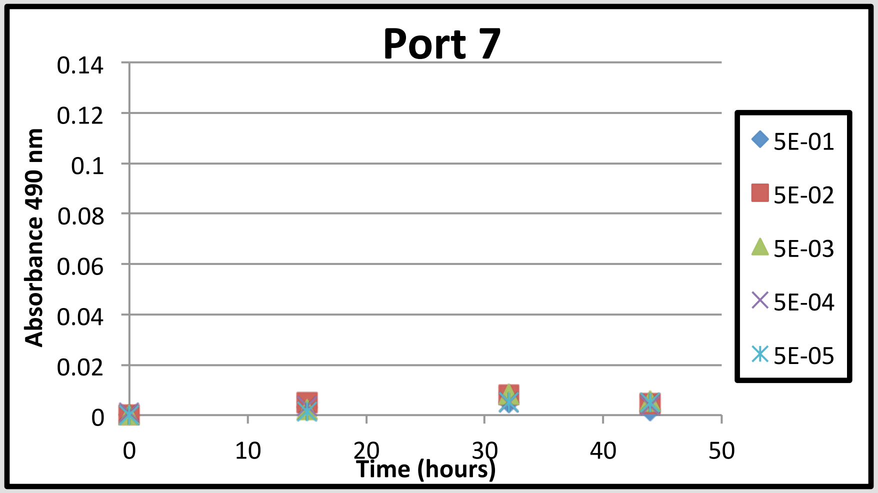
Vick and Michaud (Graduate students in the Priscu Lab)

Cell Viability Assay









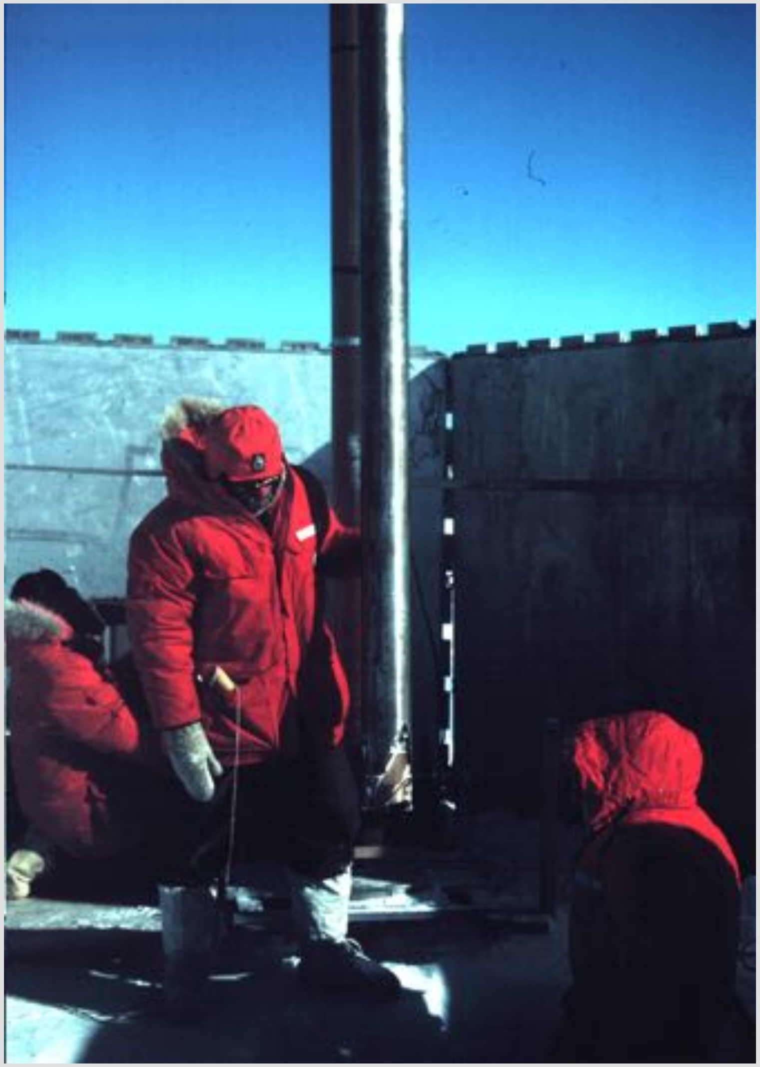
Christner et al.

WISSARD Monitoring Conclusions

- Measurements in this test demonstrate that the filtration system is successful in removing viable cells
- Coupled with pasteurization, occurring in the boiler of the hot water drilling system, there is expected to be a further decrease in the number of viable cells
- Water analyzed in this test contained 3 orders of magnitude more cells than expected in Antarctic water sample

Christner et al.

Sampling Subglacial Environments: strategies/concerns



- Clean Access
- **Time in borehole**
- Large volumes needed for molecular biology
  - *In situ* filtering of 100s of liters (time)
- Instrumentation of boreholes for biogeochemistry
- *In situ* sample collection(time)

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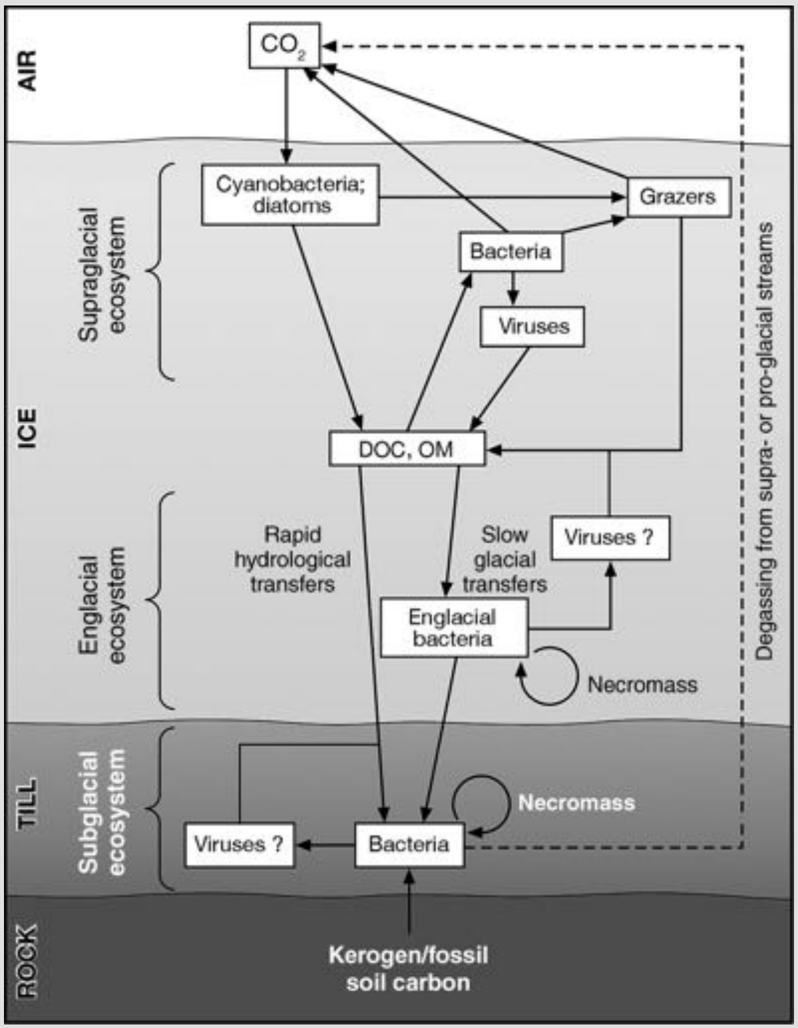
Recent Science Highlights: an ecosystem perspective

The Glacial Ecosystem



Hodgson et al. 2008

CH_4

Glacial Environments are Players in Earth's Biogeochemical Cycles

•Evidence for a spectrum of thermodynamically favorable REDOX reactions (Skidmore -Review in press)

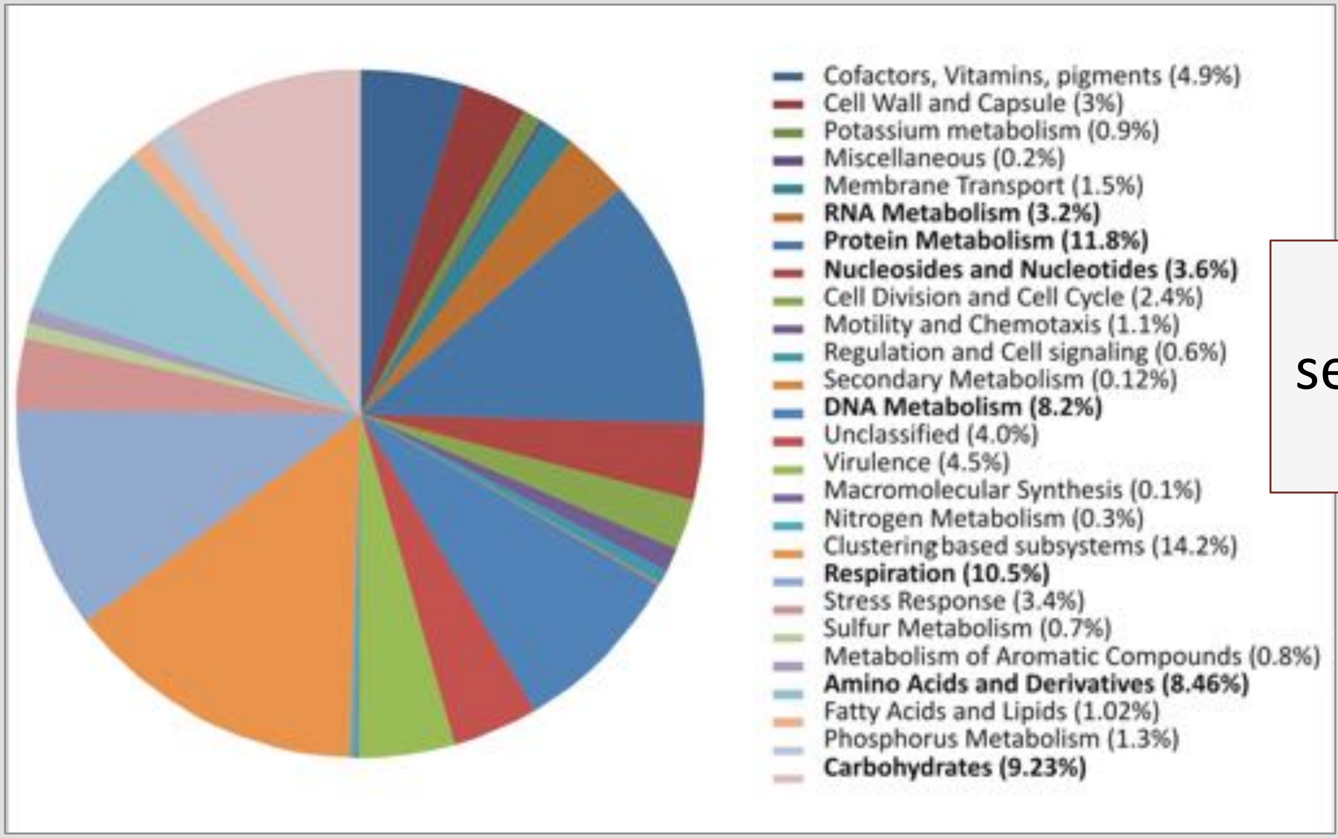
•Aerobic and Anaerobic transformation of organic carbon overridden by ice (Wadham et al. 2008)

•Lithotrophic lifestyles: Iron and Sulfur REDOX metabolism

Fe

Subglacial Metagenome Analysis

Total no. of sequences	40,285 (contigs)
Total sequence size	11,783,762 (basepairs)
Shortest sequence length	31
Longest sequence length	714
Average sequence length	292.51



Representative sequences from most cellular processes

Year-Long Study of Microbial Processes at the Juan de Fuca Ridge Using Biological Osmotic Samplers (BOSS)

Evidence for Seismicity Influencing Deep Sea Primary Productivity

Peter R Girguis

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Harvard University
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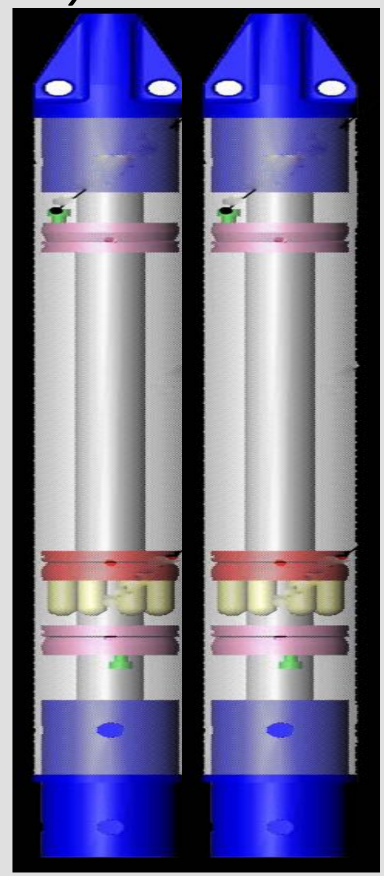
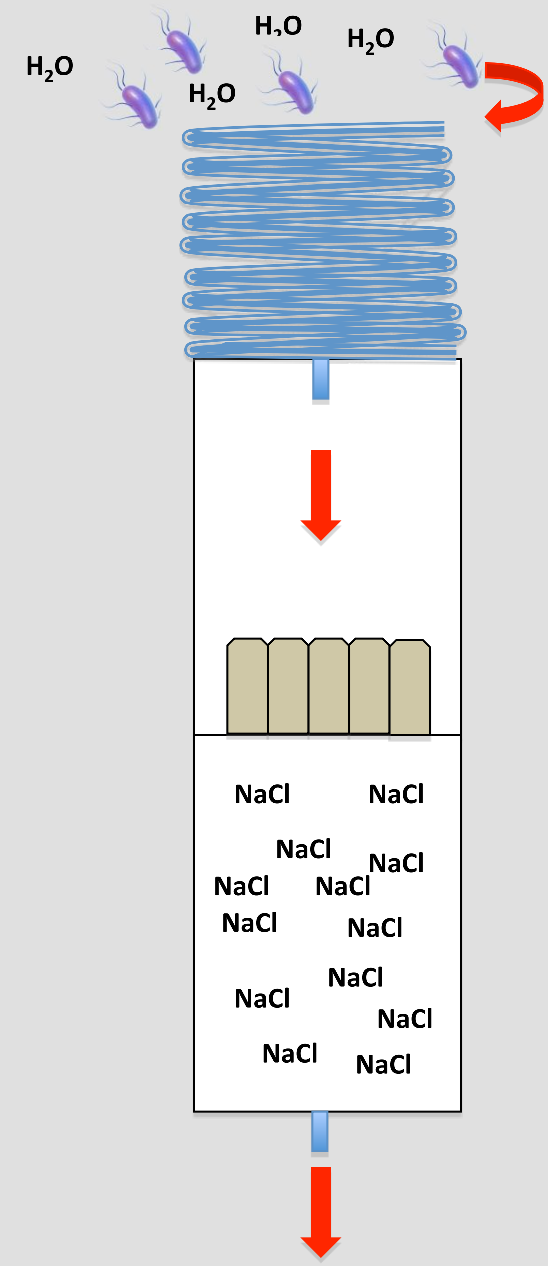
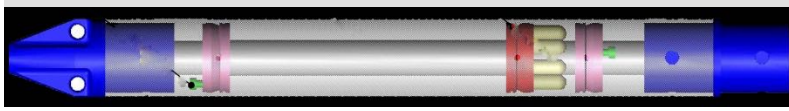


The Goal = Develop a sampling system for *in situ* microbiological studies

The Biological Osmotic Sampling System (BOSS)

- Preservation of microbiological and geochemical samples over time
  - DNA, RNA, proteins, dissolved ions, volatiles
- Scalable in size /performance
  - Can sample from µL to mL per day (Jannasch et al 2004)
  - Can be deployed in IODP boreholes (CORKS)
- Proven record in sampling microbes and chemistry over time
  - (Wheat et al 2000, 2003, 2008; Robidart et al, in review)
- Requires little to no electrical power

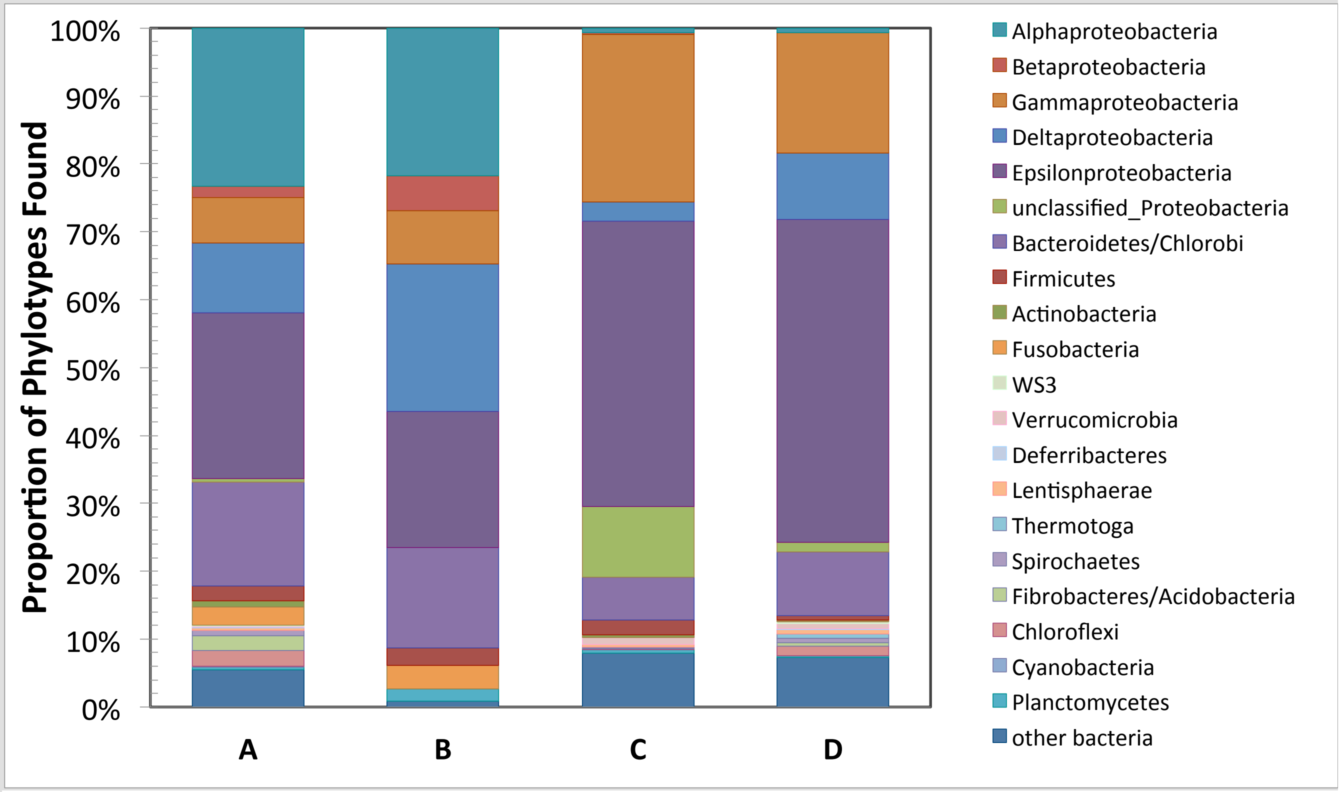


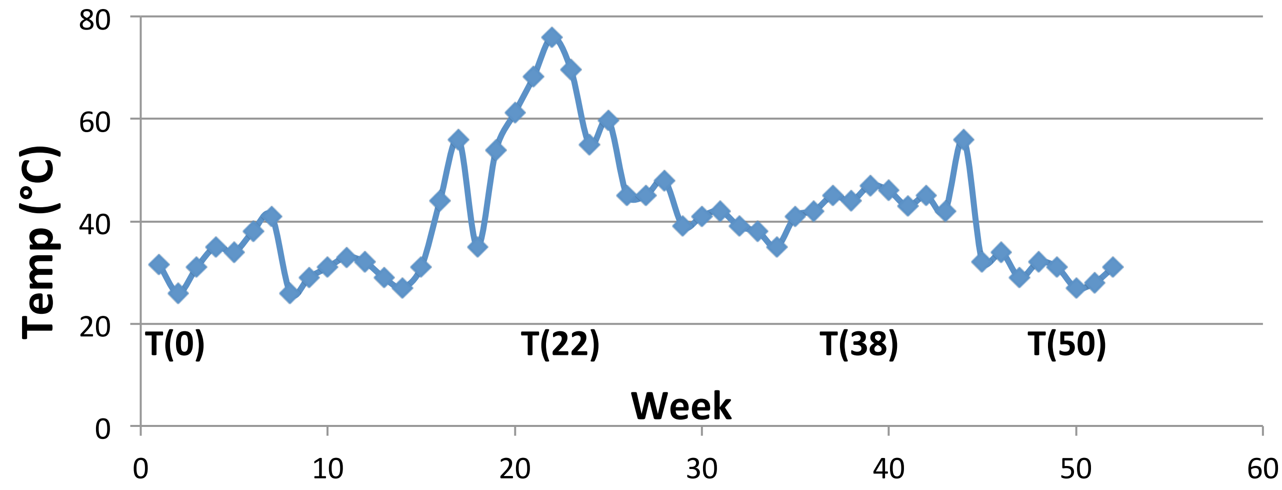


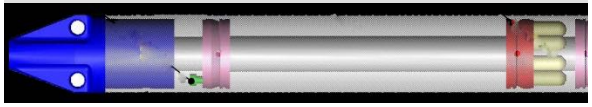
BOSS: Coupling microbiology and geochemistry in the deep subsurface.

BOSS: mapping temporal changes in bacterial diversity over one year

- BOSS samples were collected over a year; coincident with seismic events at Juan de Fuca (3/30/08–4/9/08)
- Seismic events known to change vent fluid chemistry
- Changes in microbial composition and <u>protein expression</u> after seismic events







Conclusions

- Clean access still needs optimization and development

- The WISSARD test season – important step forward in clean access protocols

- ‘Agile’ filtration units, compatible materials and clean drills for a diversity of borehole projects and clean access needs

- Dedicated biology cores and basal material

- Only the beginning of subglacial geomicrobiological exploration