Scientific Committee on Antarctic Research

ATCM XXXVI-CEP XVI Science Lecture

Probing the Limits of Technology: Exploration of Subglacial Aquatic Environments

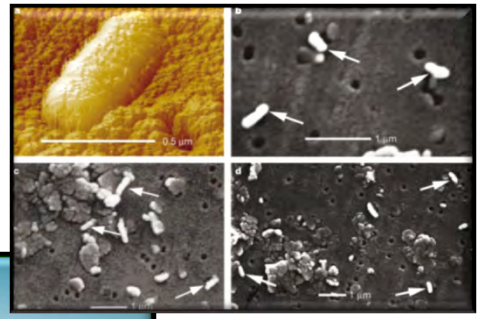
J.L. Wadham (University of Bristol, U.K.)

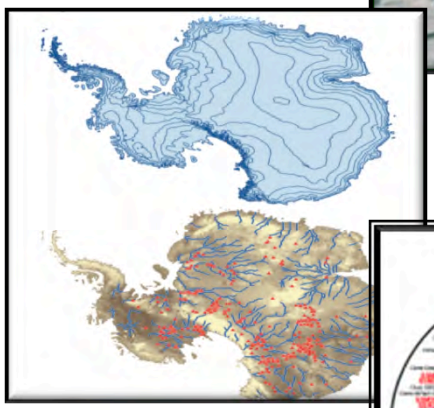
M.C. Kennicutt II (Texas A&M University, U.S.A.)

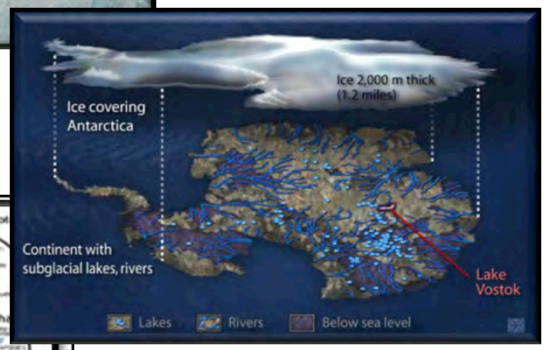
Lecture Outline

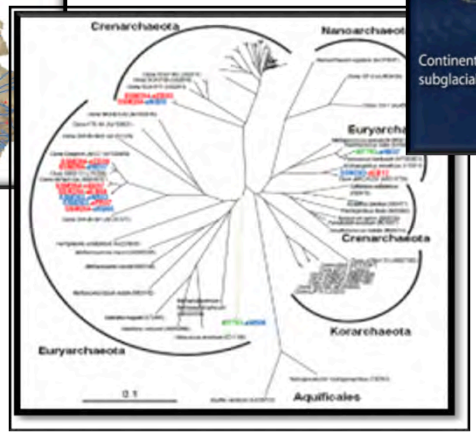
1. *Introduction*
2. *Why study Subglacial Aquatic Environments?*
3. *Environmental Stewardship*
4. *Subglacial Exploration Programs*
5. *Technological Challenges*
6. *Summary*

1. Introduction





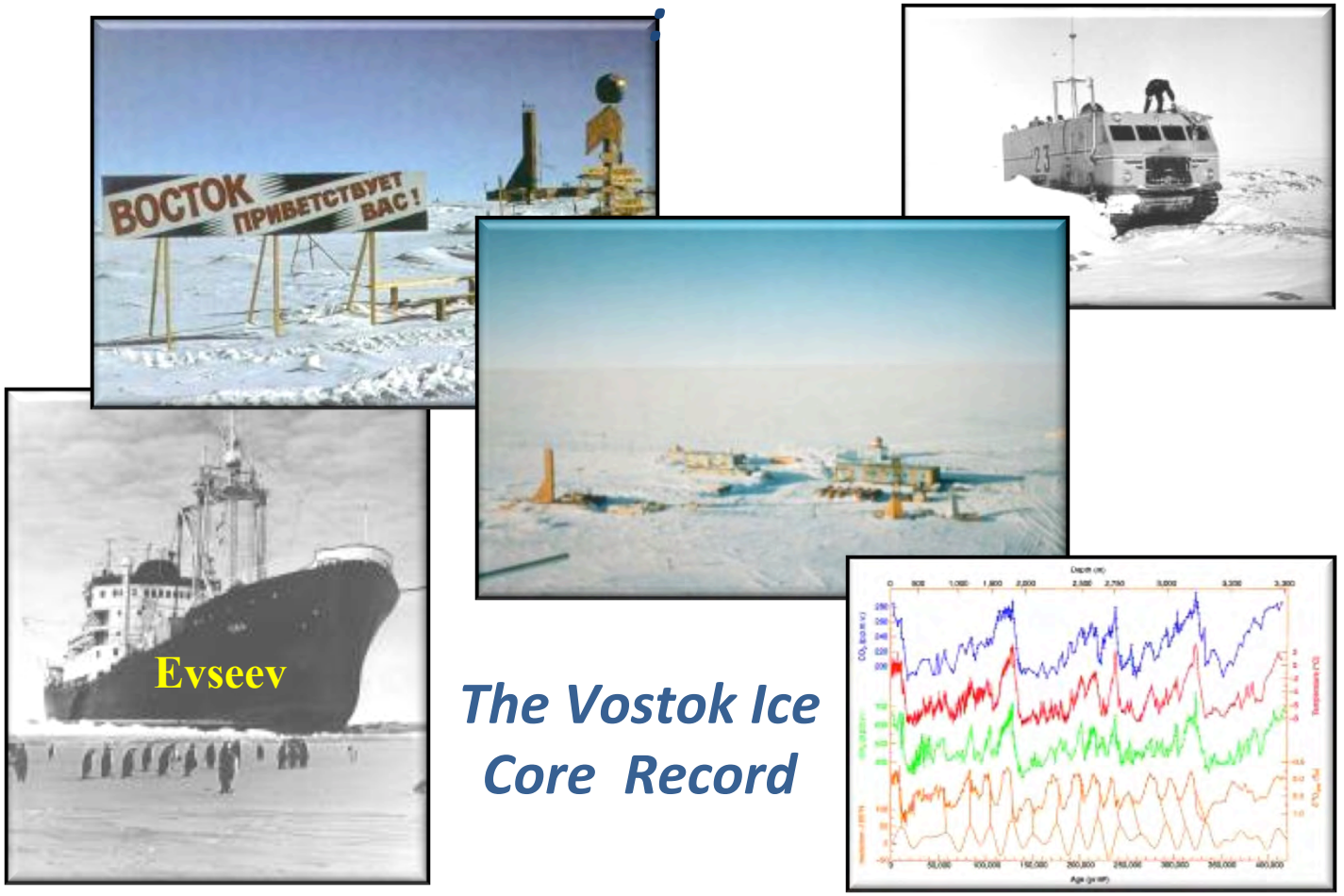




1. Introduction

The Story Begins at Станция Восток

The Russian Federation Vostok Station: Opened December 1957

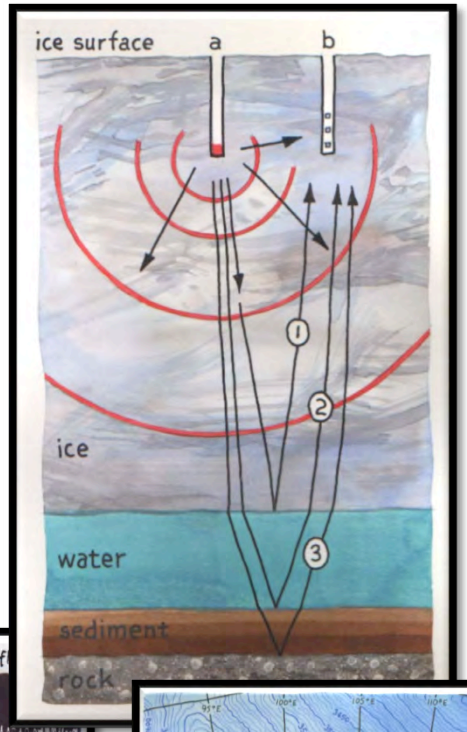


The Vostok Ice Core Record

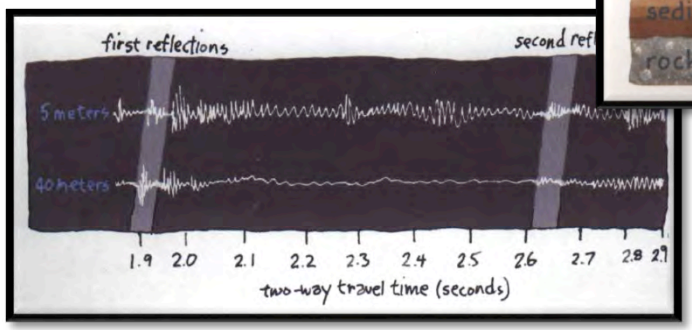
The Discovery of Lake Vostok

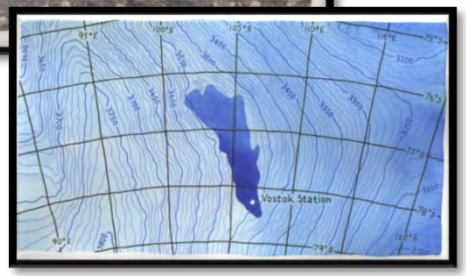
International Collaboration

International Program of Airborne Exploration in the 1970's
Danish - British -American



Original Unprocessed Seismic Recordings





1. Introduction

ATCM XXXVI

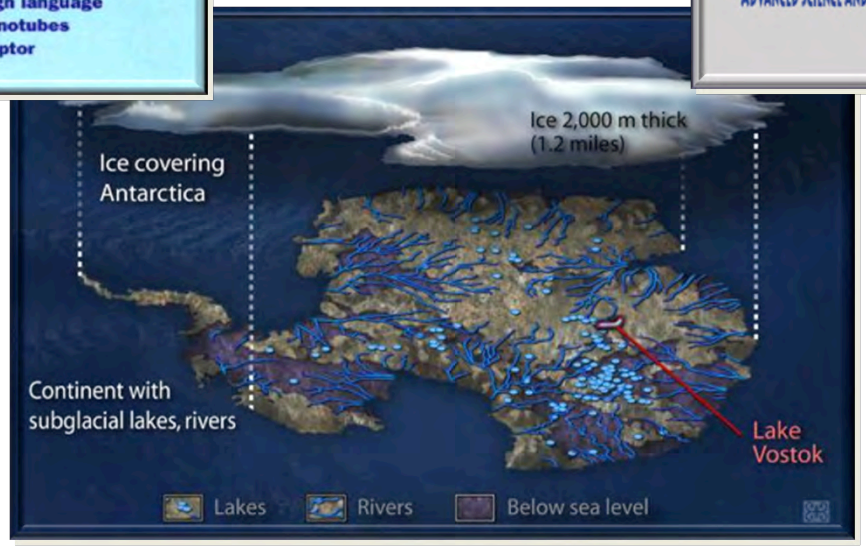
IP 82

International Cooperation

- *Subglacial Antarctic Lake Environments Group of Specialists (SALEGOS): 2000-2004*
- *Subglacial Antarctic Lake Environments. (SALE) – SCAR/IPY Scientific Program: 2004-2010*
- *Advancing Technologies and Environmental stewardship for subglacial exploration in Antarctica (ATHENA) formed 2008 - present*

http://seis.bris.ac.uk/~chgpl/Athena/home.htm

2. Why Study Subglacial Aquatic Environments?



Zina Deretsk, U.S. National Science Foundation (2007)

2. Why Study SAE?

An International Focus of Interest

1998

Washington, D.C. U.S.A.

1999

Cambridge, U.K.

2006

Grenoble, France

2. Why Study SAE?

Subglacial Lake Vostok

Subglacial Lake Vostok

18 NEWS — 22 MARCH 1998 · THE SUNDAY TIMES

JOURNEY TO THE CENTRE OF THE EARTH

How scientists hope to explore Lake Vostok in Antarctica with a robot designed to look for extraterrestrial life

Lost life hunted in buried polar lake

by Steve Connor Science Correspondent

SCIENTISTS are to reopen a lost world under the surface of Antarctica in search of new life forms. In an unprecedented expedition, researchers will drill through 2½ miles of ice to explore a vast lake which has been buried for millions of years under the South Pole.

When a sterile probe penetrates the thick ice sheet that has sealed Lake Vostok since humans evolved more than 2m years ago, the scientists expect to discover organisms that have never seen the light of day. Preliminary drilling to within a few hundred feet of the lake has uncovered microbes new to science. Some have been revived after lying in suspended animation for hundreds of thousands of years.

Scientists from Britain, Russia and America will gather in St Petersburg to plan how to drill through the ice without contaminating the lake's pristine water with microbes from the world above.

Specialists from Nasa, the American space agency, are using the project as a way of testing drilling equipment which it hopes to send to other planets in the search for alien life.

British and Russian scientists who surveyed the lake from the nearby Vostok research station, found it was about twice the size of Yorkshire and more than 1,600ft deep — by far the largest of Antarctica's 70 underground lakes. The lake lies under the coldest inhabitable place on Earth. The lowest surface temperature ever recorded — -89.6C — was monitored at the scientific base in 1983.

Scientists believe the lake formed millions of years ago under the intense pressure of the ice above, possibly helped by hot-water vents on the lake bed that have prevented the water from freezing.

'Microbes found just above the lake are too unusual to classify. One has been dubbed Eric the Enigma'

The microbes discovered in the ice just above the lake are too unusual to classify. One is nicknamed the Klingon because of its wrinkled appearance, another Mickey Mouse due to its ear-like lobes, and a third Eric the Enigma because its nature remains a mystery.

Richard Hoover, an astrophysicist at Nasa's Marshall Space Flight Center in Huntsville, Alabama, said: "We've found some really bizarre things — things we have never seen before. We're exploring a new world."

The drilling so far has been a relatively dirty technique using kerosene as a lubricant and antifreeze, which is why it has been stopped well above the lake's surface, Hoover said.

A second hole will be drilled using a heated sterile probe to release a submersible robot. This will explore the aquatic environment in search of living organisms within the lake itself.

The probe — called a hydrobot — is a prototype for equipment Nasa intends to send to Europa, one of Jupiter's moons where life is thought to exist beneath its dense, protective ice sheets.

"It is a wonderful way of testing the technology that must be employed on Europa and other ice bodies like comets and the polar caps of Mars," Hoover said. "We have to explore techniques for recognising the signatures that give clues to life."

The possibility of finding extraterrestrial life under the ice of Europa or Mars has increased with the discovery that life on Earth can exist for hundreds of thousand of years in the most isolated and inhospitable places.

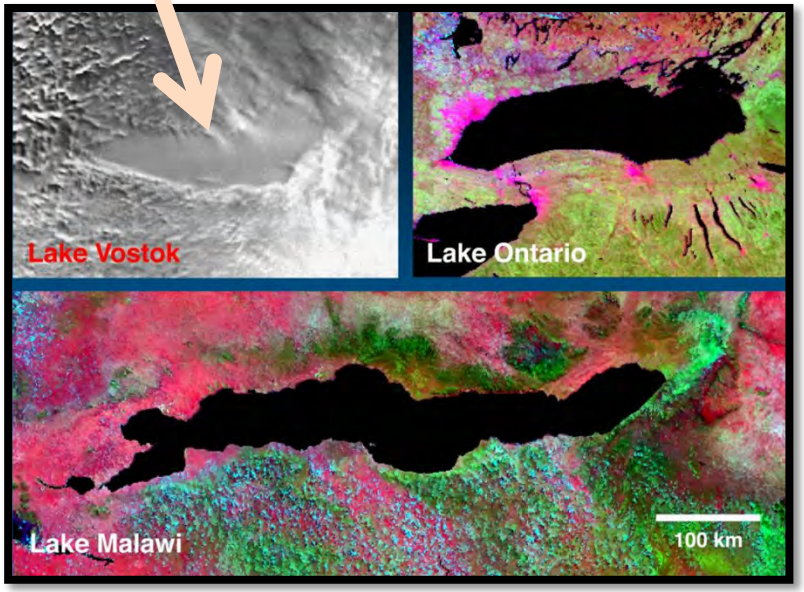
Scientists drilling deep under the oceans have discovered microbes that live off underground mineral deposits and biologists investigating subterranean caves cut off from the outside world have found thriving communities of animals that have survived for thousands of years in isolation.

Dr Cynan Ellis-Evans, head of freshwater research at the British Antarctic Survey in Cambridge, said finding organisms alive in Lake Vostok was very likely. "My gut feeling is that we will find something down there: Wherever you go looking, no matter how harsh it is, you can find microbes," he said.

The precise age of the lake is unknown but it is likely to be about 2m years, although it could be as old as 15m years. Ellis-Evans said it would provide a unique opportunity to capture life forms that have been cut off from the evolution of the rest of life on Earth.

"We are getting an opportunity to look back in time at genetic influences that we don't normally see. Our discussions in St Petersburg will focus on technologies for penetrating the ice sheet and placing equipment in the lake without compromising its pristine status," he said.

The scientists expect to penetrate Lake Vostok within two years, when they hope to start analysing the world's most isolated aquatic environment.



22 March 1998 Sunday Times

2. Why Study SAE?

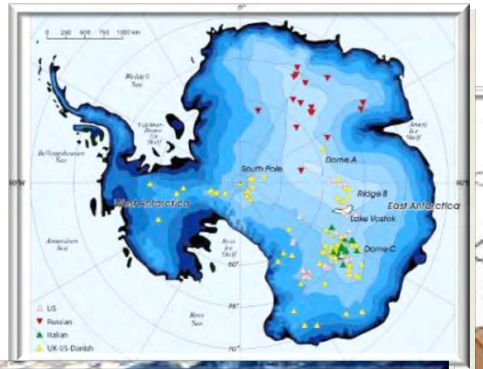
GLOBAL CLIMATE CONNECTIONS

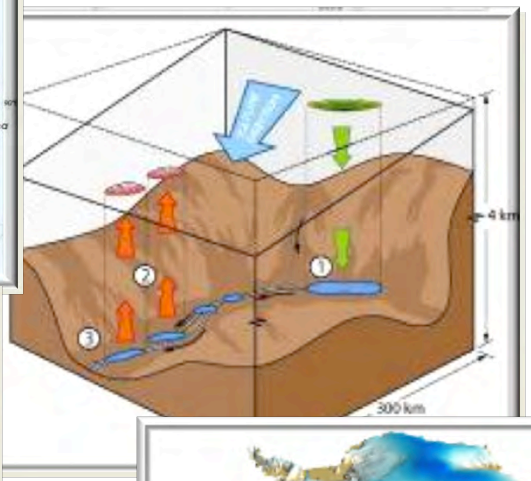
PALEOCLIMATE RECORDS

LIMNOLOGY AND BIOGEOCHEMISTRY

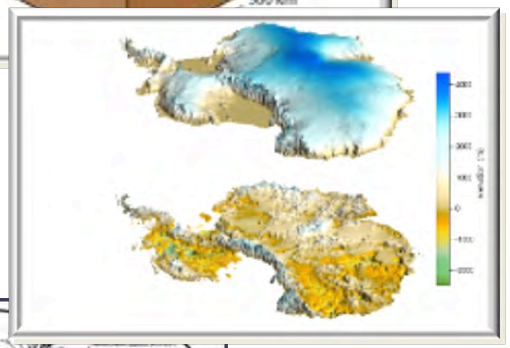
Scientific Themes

GEODYNAMICS OF LAKE EVOLUTION

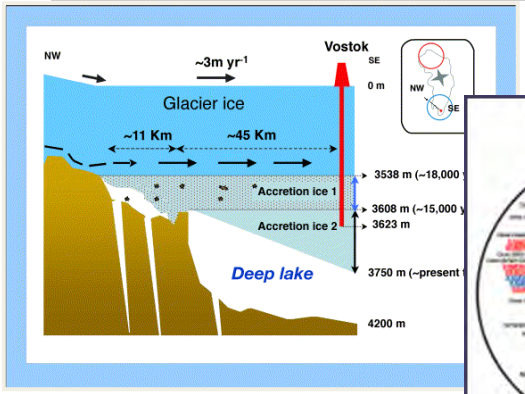


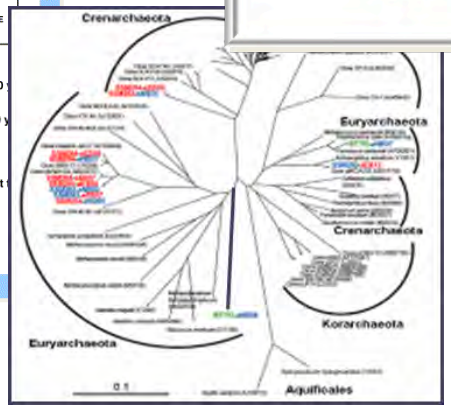


SUBGLACIAL HYDROLOGY



ICE SHEET DYNAMICS



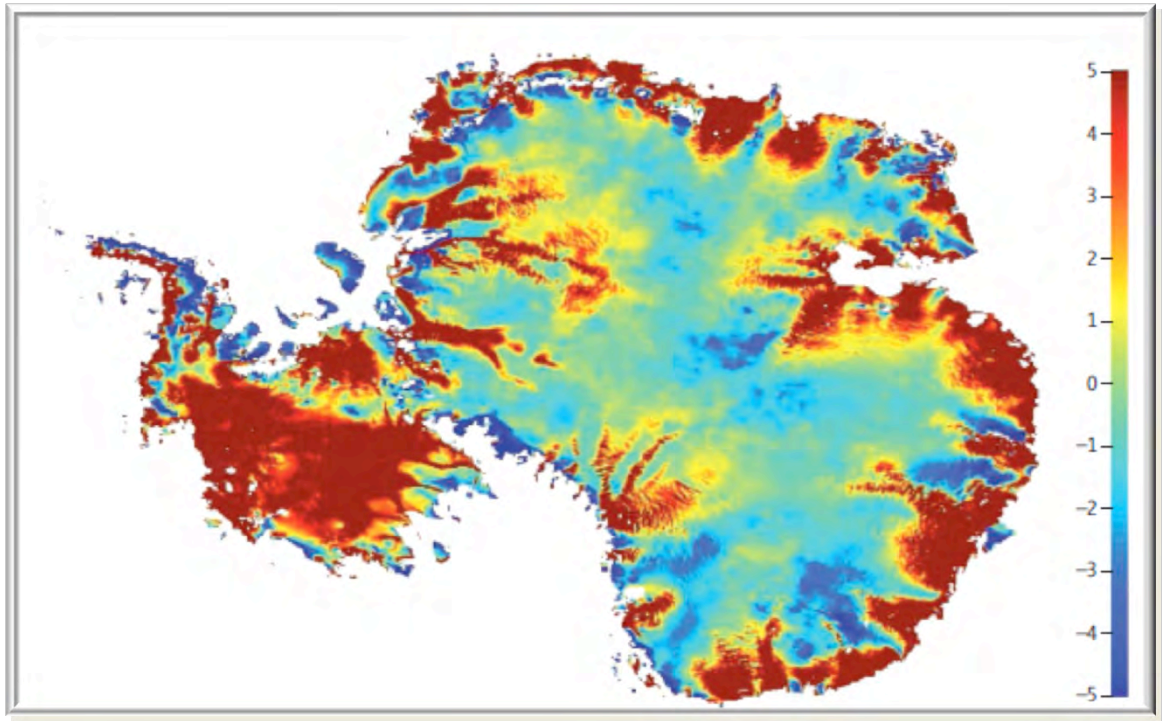


MICROBIOLOGICAL LIFE, EVOLUTION, AND ADAPTATION

Water is Abundant Beneath the Antarctic Ice Sheet

Half of the ice sheet bed is melting

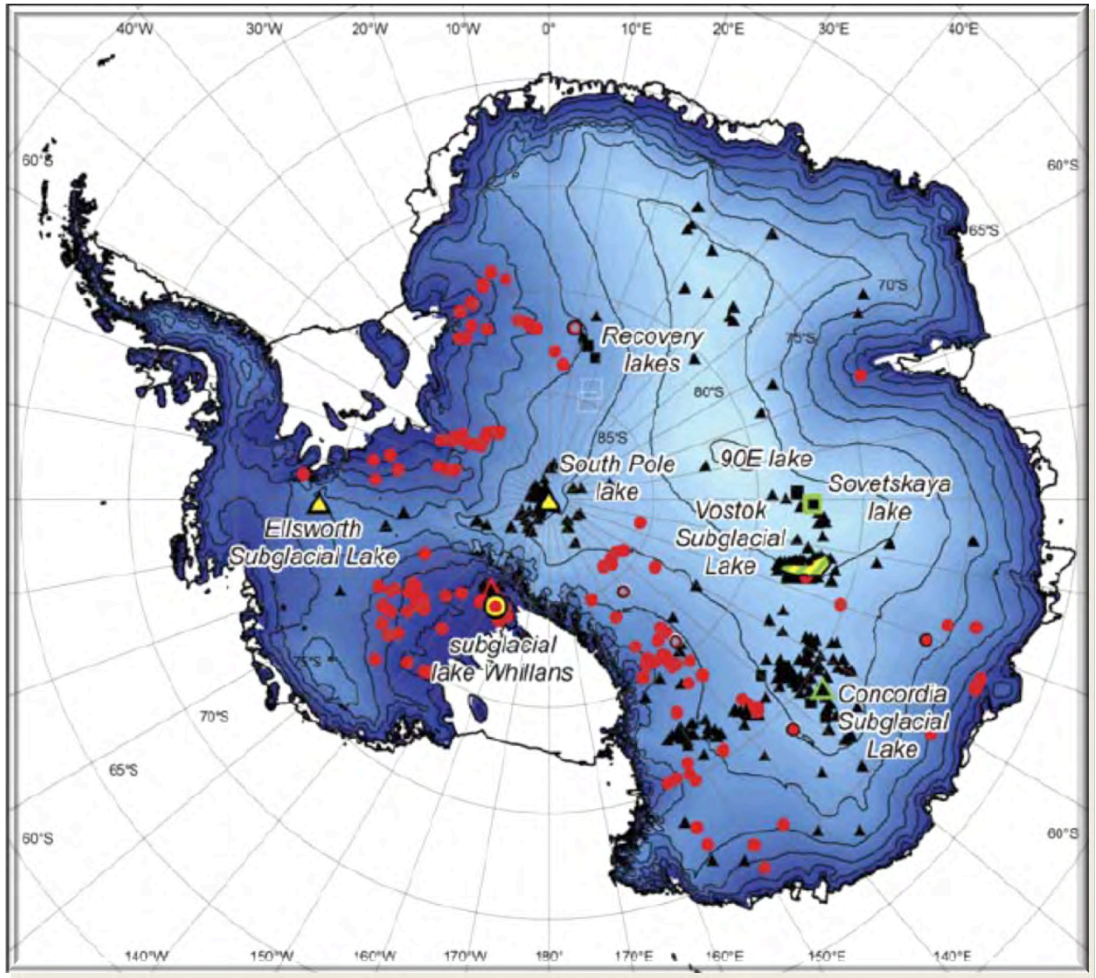
Very slow basal melt drives water fluxes towards the ice margin



Tulaczyk and Hossainzadeh (2011) Science

2. Why Study SAE?

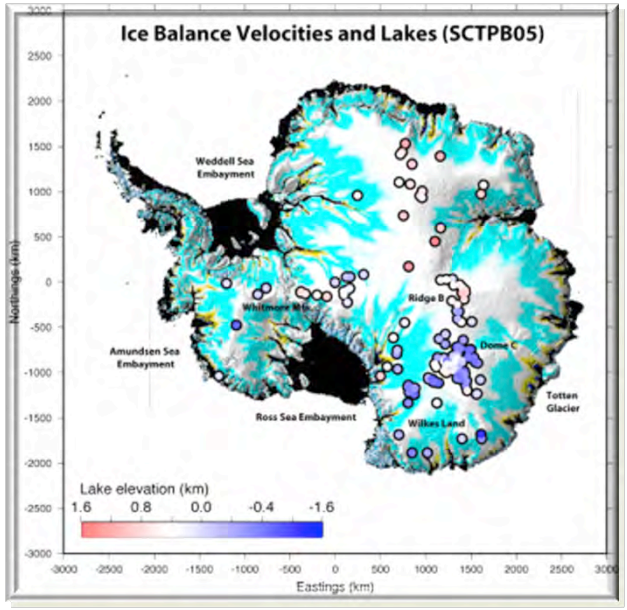
A Continent-Wide Feature

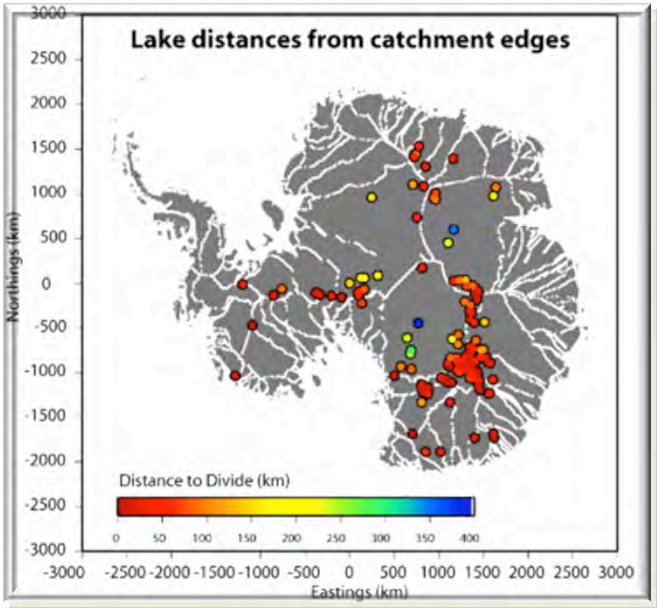


Wright and Siegert (2012) Antarctic Science

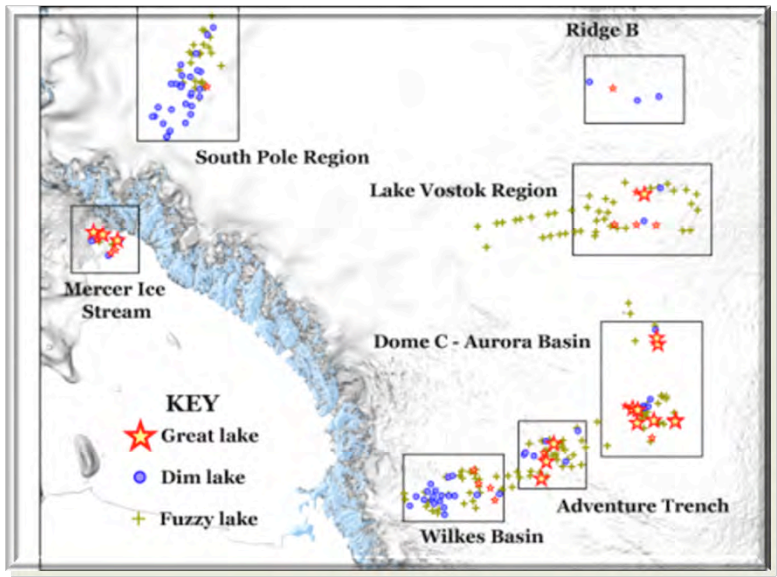
2. Why Study SAE?

Diverse Subglacial Environments



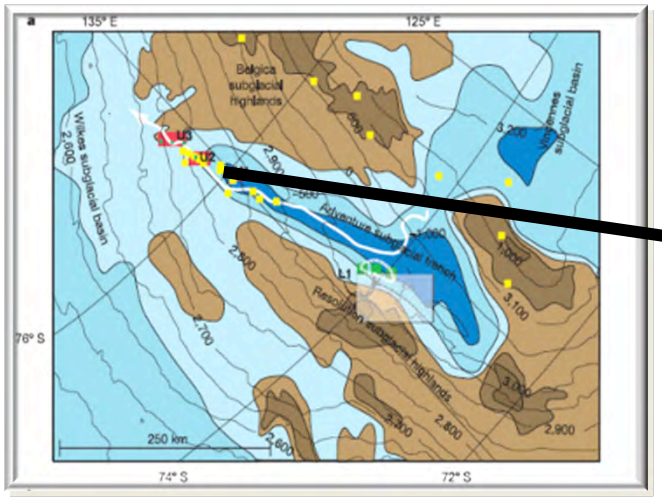


Blankenship and others

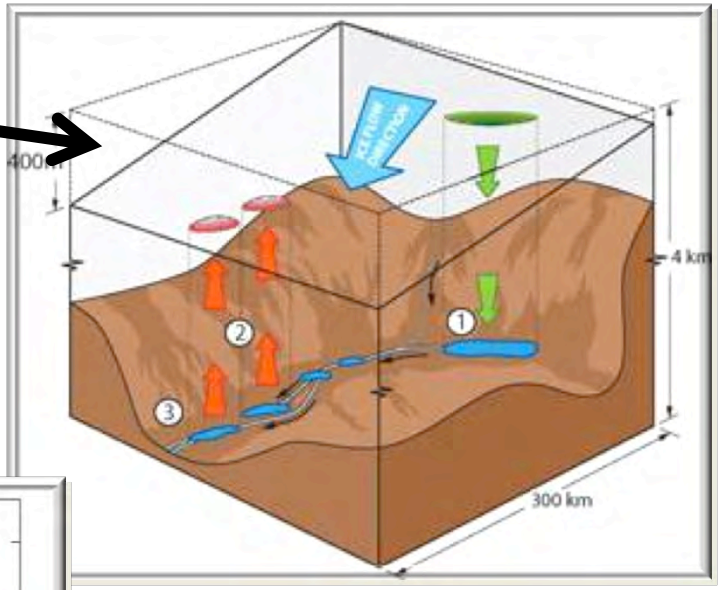


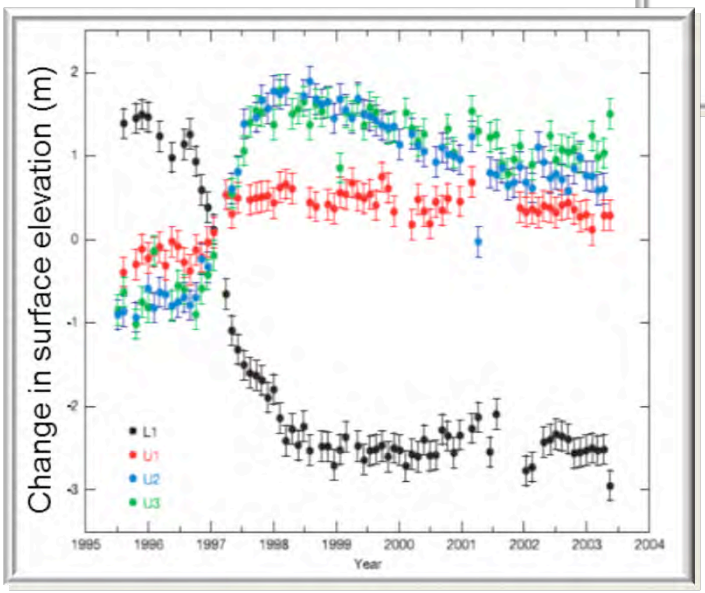
2. Why Study SAE?

Subglacial Hydrology



Conceptual model of surface level fluctuations





Ice sheet surface elevation changes

Wingham et al (2006) Nature

2. Why Study SAE?

Life in Subglacial Aquatic Environments

- *Isolated*
- *Cold and Dark*
- *Limited Energy Sources*
- *Ultra-low nutrient and carbon concentrations*
- *Dilute biological solutions (low cell numbers)*

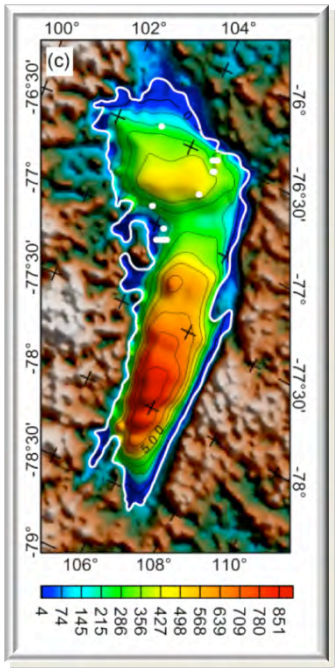


photo from A. Purcell and J. Mikucki, UTK

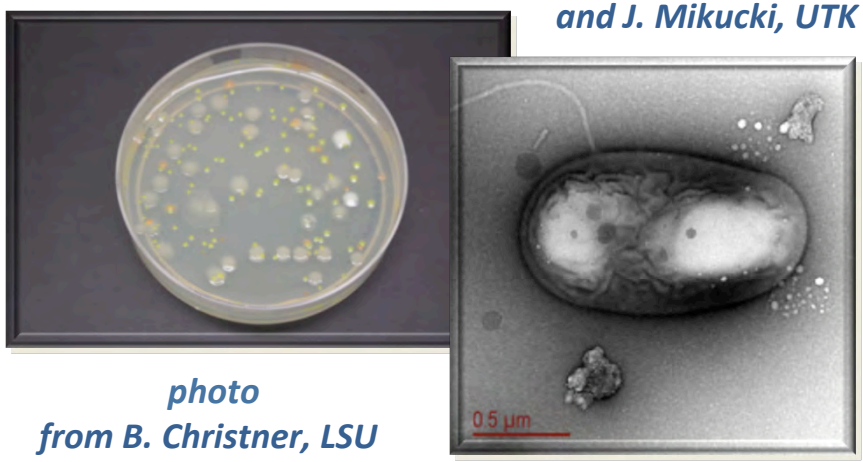


photo from B. Christner, LSU

Photo from RAE, V Lukin

(Priscu et al, 1999; Christner et al, 2006; Bulat et al 2009; D'Elia et al, 2009)

2. Why Study SAE?

Subglacial Lake Vostok: Accretion Ice

Low cell numbers
Diverse microbial metabolic strategies
Concerns about artifacts

More Than 200 Meters of Lake Ice Above Subglacial Lake Vostok, Antarctica

J. Jouzel,[1] J. R. Petit,[2] R. Souchez,[3] N. I. Barkov,[4] V. Ya. Lipenkov,[4] D. Raynaud,[2] M. Stievenard,[1] N. I. Vassiliev,[5] V. Verbeke,[3] F. Vimeux[1]

Isotope studies show that the Vostok ice core consists of ice refrozen from Lake Vostok water, from 3539 meters below the surface of the Antarctic ice sheet to its bottom at about 3750 meters. Additio gas content, crystal size, and electrical cond is a likely place for water freezing at the lake-i occurs at a higher level here than anywhere suggest that subglacial Lake Vostok is an o culation of water that was formed during p than those of the past 420,000 years. Lake i interest for preliminary investigations of lake and for the search for indigenous lake micro potential importance for the exploration of

Microorganisms in the Accreted Ice of Lake Vostok, Antarctica

D. M. Karl,[1] D. F. Bird,[2] K. Björkman,[1] T. Houlihan,[1] R. Shackelford,[1] L. Tupas[1]

Analysis of a portion of Vostok ice core number 5G, which is thought to contain frozen water derived from Lake Vostok, Antarctica (a body of liquid water located beneath about 4 kilometers of glacial ice), revealed between 2×10^2 and 3×10^2 bacterial cells per milliliter and low concentrations of potential . Lipopolysaccharide (a Gram-negative bacterial cell biomar- ected at concentrations consistent with the cell enumeration ests a predominance of Gram-negative bacteria. At least a icrobial assemblage was viable, as determined by the respi- 14–labeled acetate and glucose substrates during incubations sphere. These accreted ice data suggest that Lake Vostok may icroorganisms.

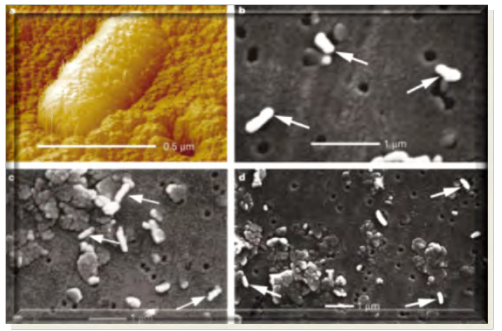
Geomicrobiology of Subglacial Ice Above Lake Vostok, Antarctica

John C. Priscu,[1*] Edward E. Adams,[2] W. Berry Lyons,[5] Mary A. Voytek,[6] David W. Mogk,[3] Robert L. Brown,[2] Christopher P. McKay,[7] Cristina D. Takacs,[1] Kathy A. Welch,[5] Craig F. Wolf,[1] Julie D. Kirshtein,[6] Recep Avci[4]

Data from ice 3590 meters below Vostok Station indicate that the ice was accreted from liquid water associated with Lake Vostok. Microbes were observed at concentrations ranging from 2.8×10^3 to 3.6×10^4 cells per milliliter; no biological incorporation of selected organic substrates or bicarbonate was detected. Bacterial 16S ribosomal DNA genes revealed low diversity in the gene population. The phylotypes were closely related to extant members of the *alpha-* and *beta-Proteobacteria* and the Actinomycetes. Extrapolation of the data from accretion ice to Lake Vostok implies that Lake Vostok may support a microbial population, despite more than 10^6 years of isolation from the atmosphere.

10 December 1999 Vol. 286 Science

Images of bacteria frozen in accretion ice

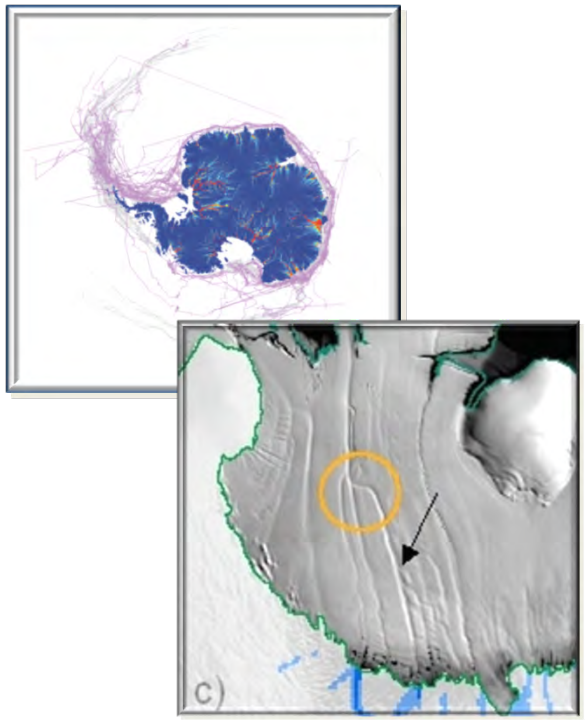


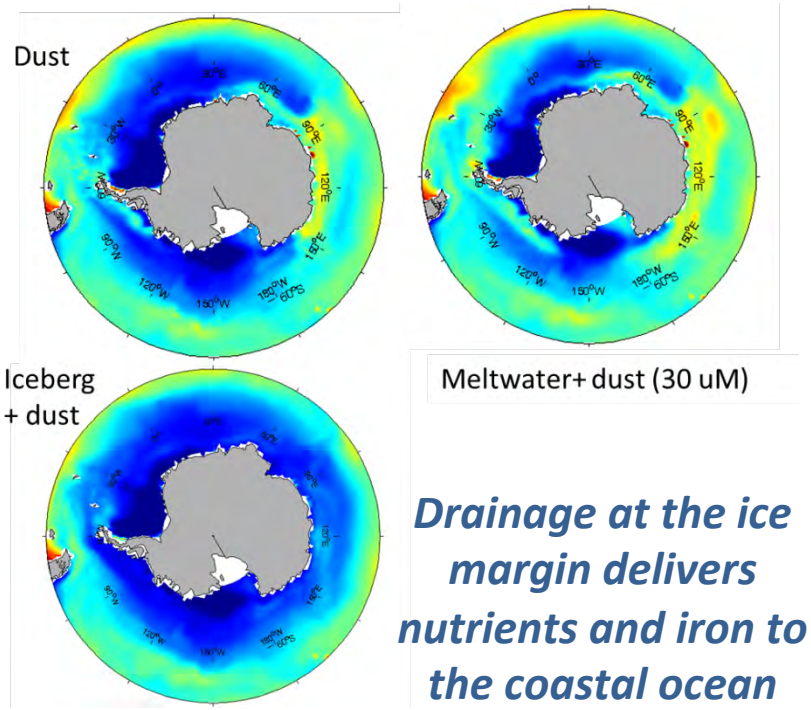
(Priscu et al, 1999; Christner et al, 2006; Bulat et al 2009; D'Elia et al, 2009)

Latest Scientific Results

Do Subglacial Water outflows at Ice Margins affect the Southern Ocean's Productivity?

Circumpolar deep water flows stimulate sub-ice melting





Drainage at the ice margin delivers nutrients and iron to the coastal ocean

Dea'th et al (in review) GRL,LeBroq et al (in review) Nature Geoscience
Gerringa et al (2012) Deep Sea Research

2. Why Study SAE?

Latest Scientific Results

Are Subglacial environments an unrecognized reservoir of greenhouse gases?

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29 August 2012 Last updated at 19:04

749 Share

Antarctic may host methane stores

Large volumes of methane - a potent greenhouse gas - could be locked beneath the ice-covered regions of Antarctica, according to a new study.

It says this methane could be released into the atmosphere as ice retreats, contributing to climate warming.

The findings indicate that ancient deposits of organic matter may have been converted to methane by microbes under the ice.

Ancient organic matter could be converted to methane by microbes

An international team reported the results in Nature journal.

Study leader Jemma Wadham, from Bristol University, said: "This is an immense amount of organic carbon, more than ten times the size of carbon stocks in northern permafrost regions.

Related Stories

Arctic melt releasing ancient gas

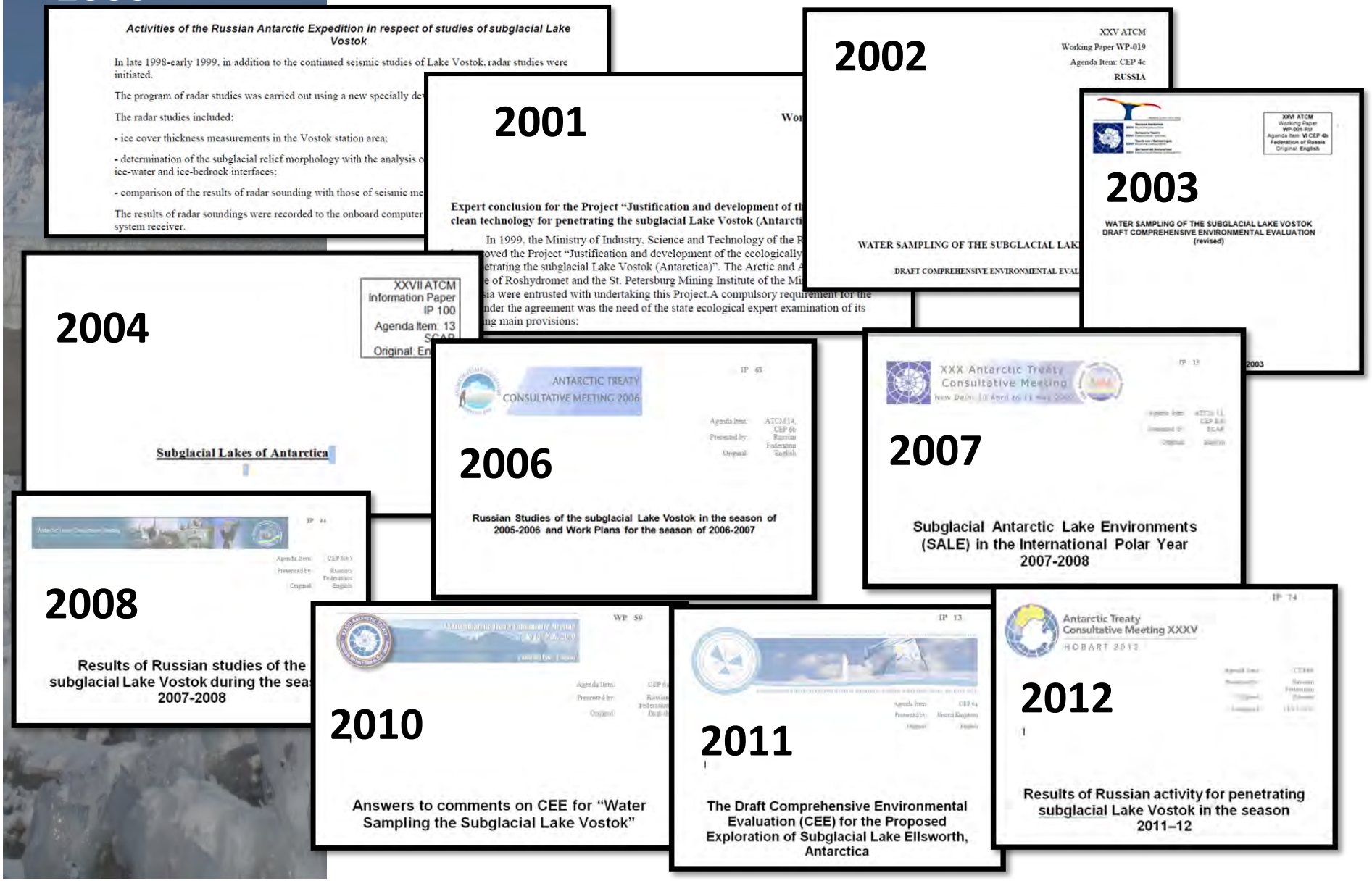
Arctic climate 'tech

- *Subglacial sedimentary basins are likely anoxic*
- *Methanogenesis is active in subglacial systems*
- *Methane hydrate is stable in subglacial sedimentary basins*

(Boyd et al (2010) Environmental Microbiology Reports; Wadham et al (2012), Nature)

3. Environmental Stewardship

3. Environmental Stewardship



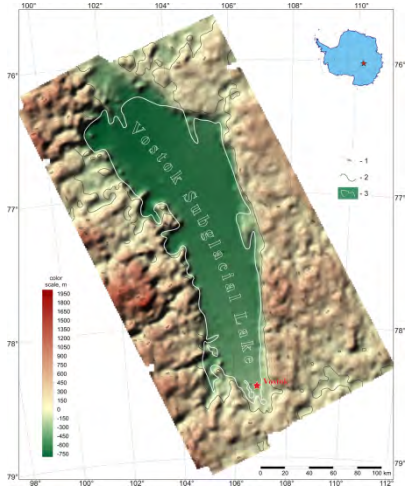
3. Environmental Stewardship

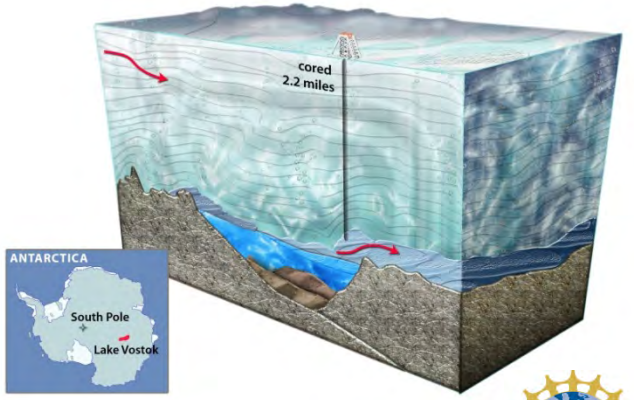
ATPs/ATCM/CEP

Subglacial Aquatic Environments have been on the ATCM/CEP agenda for more than a decade (2000-present).

- ***Seven (7) Working Papers***
- ***Twenty (19) Information Papers***
- ***Authored by the Russian Federation (18), SCAR (4), the U.S.A. (2), U.K. (1) and the Netherlands (1)***

Source:
Russian Antarctic Expedition



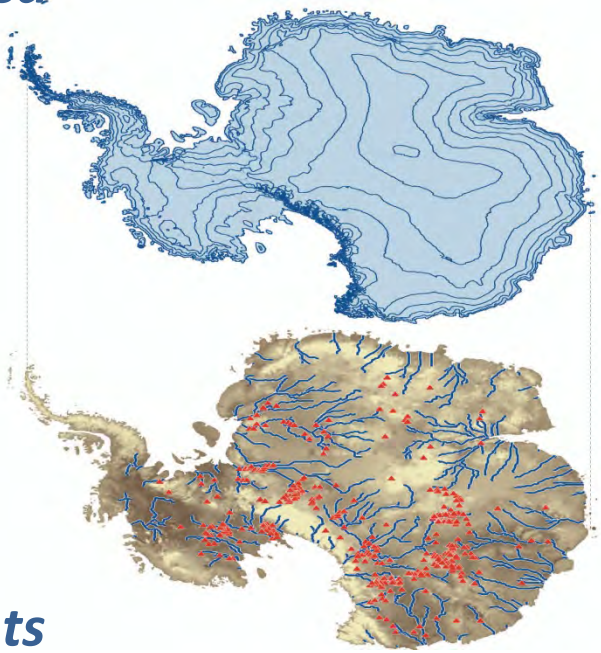


Source: U.S National Science Foundation

3. Environmental Stewardship

SCAR's Contributions to the CEP Agenda

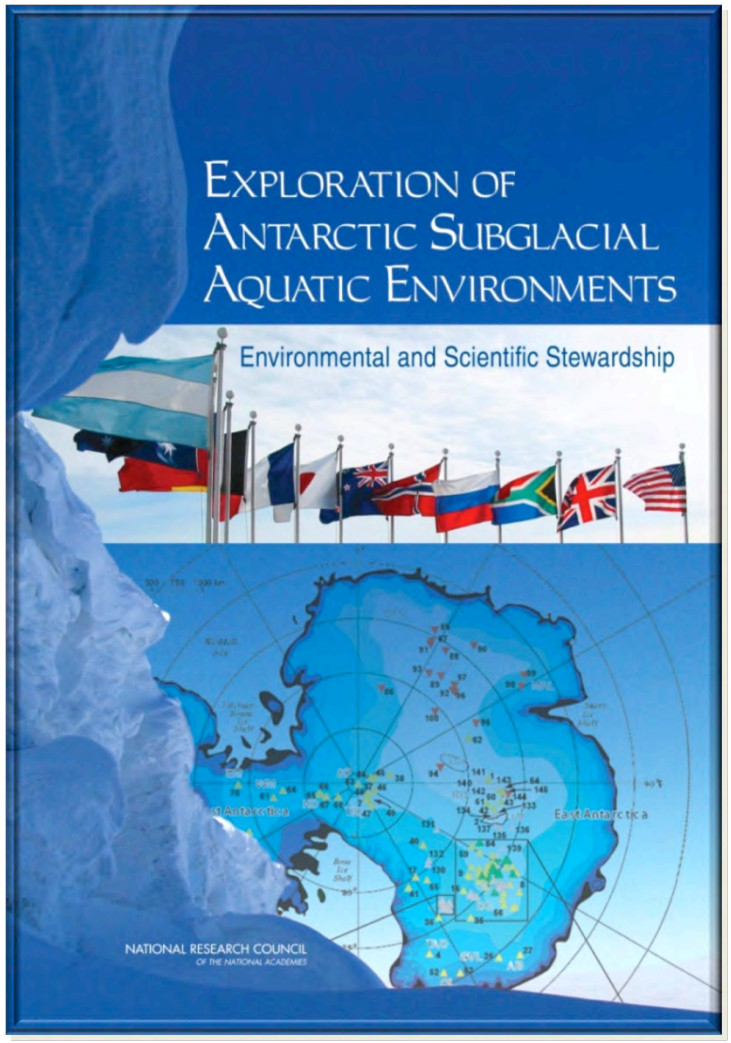
- ***2003 ATCM XXVI IP 94 - Comment on the Draft Comprehensive Environmental Evaluation: Water Sampling of the Subglacial Lake Vostok***
- ***2004 ATCM XXVII IP 100 - SCAR Science Lecture - Subglacial Lakes of Antarctica***
- ***2007 ATCM XXX IP 15 - Subglacial Antarctic Lake Environments (SALE) in the International Polar Year 2007-2008***
- ***2010 ATCM XXXIII IP 33 SCAR - SCAR's code of conduct for the exploration and research of subglacial aquatic environments***

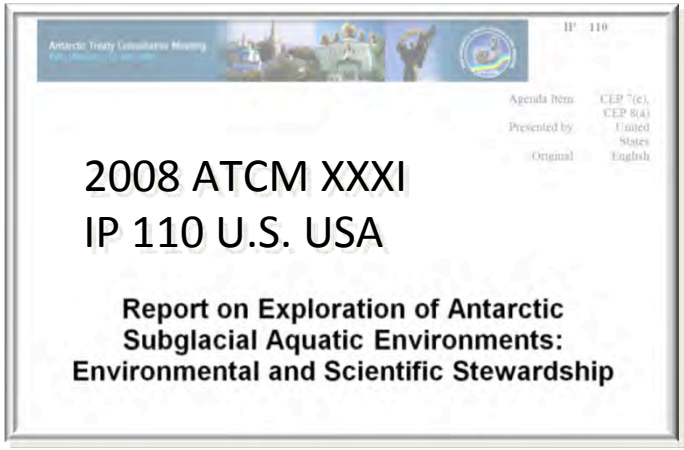


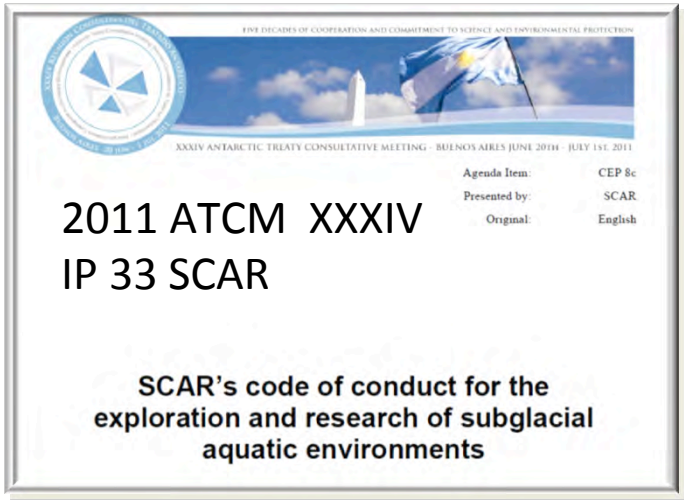
Siegert and Kennicutt, 2010

3. Environmental Stewardship

Guiding Environmental Principles







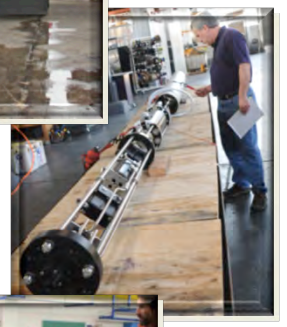
3. Environmental Stewardship

Program Design and Environmental Protection

Do no harm!

Multi-faceted Approach

- *Drilling fluid: filtered, UV irradiated and pasteurized*
- *Hoses and cables: high pressure water/air cleaning and UV irradiated*
- *Science Instruments: disinfection with hydrogen peroxide*

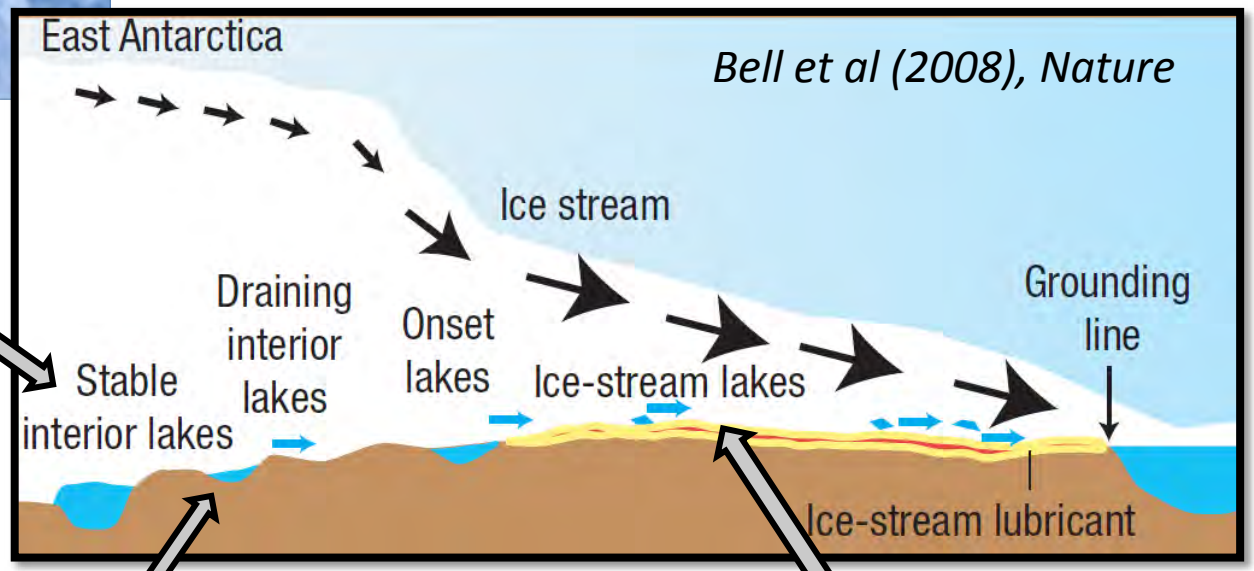


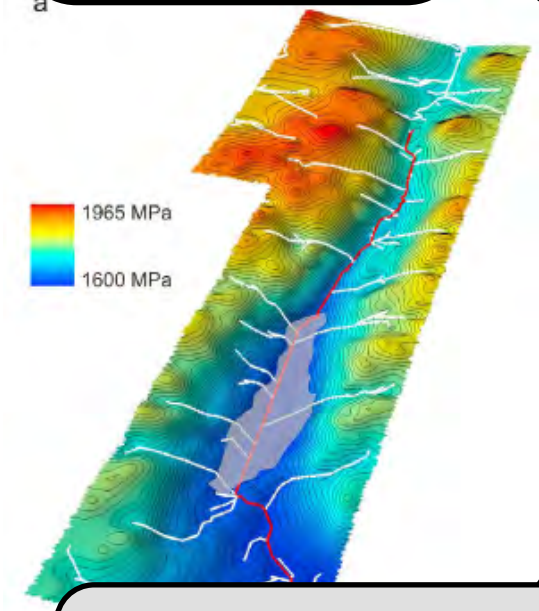
NSF

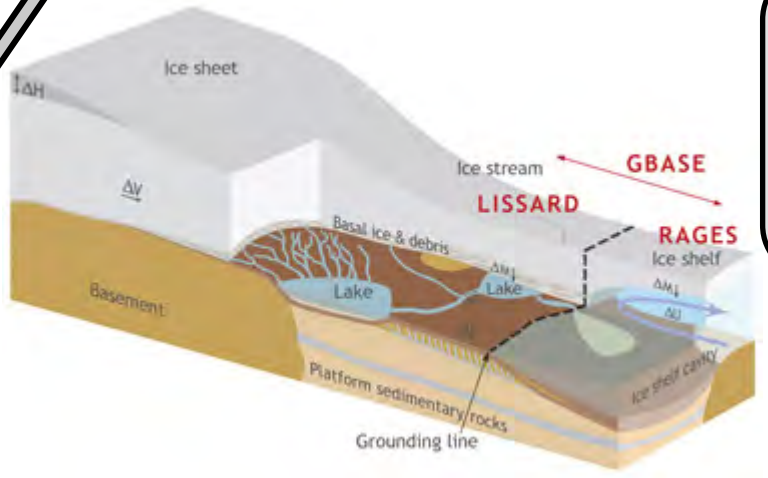
wissard

4. Subglacial Exploration Programs

Lake Vostok:
large stable lake in interior, closed system?





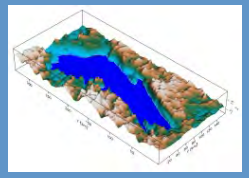
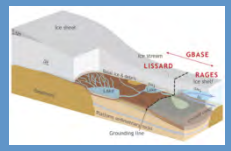
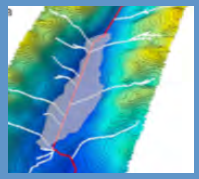


WISSARD:
dynamic, ice stream/lake near grounding line

Lake Ellsworth:
small mountainous lake in headwaters

4. SAE Programs

A Continent-wide Network of Study Sites

Location *Variables*	*Lake Vostok* 	*WISSARD* *Whillans Ice Stream* 	*Subglacial Lake Ellsworth* 
Setting	**Large stable lake**	**Dynamic Ice Stream**	**Small Mountainous Lake**
Ice Thickness	**4 km**	**0.8km**	**3.4 km**
Lake Area (dimensions)	**15,690 km^2** (250 x 50 km)	**60 km^2**	**29 km^2** (12 x3 km long)
Sediment (water depth)	**Yes** (Mean 344 km)	**Yes** (2 m)	**Yes** (150 m)
Drilling Approach	**Mechanical**	**Hot water**	**Hot water**
Entry	**2012-13**	**2012-13**	**2015-16?**

4. SAE Programs

The First Challenge: Getting There

None of this can be accomplished without the scientific and logistical support of National Antarctic Programs.

Scientific Stations

Traverses

Air Transport

Support Personnel

Field Camps

4. SAE Programs

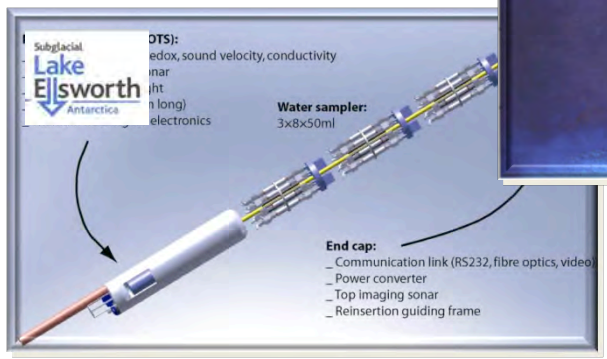
The Next Challenge: Access and Sampling

None of this can be accomplished without the scientific and logistical support of National Antarctic Programs.

Ice Drills

Sediment Corers

Clean Field Laboratories



Sensor Packages

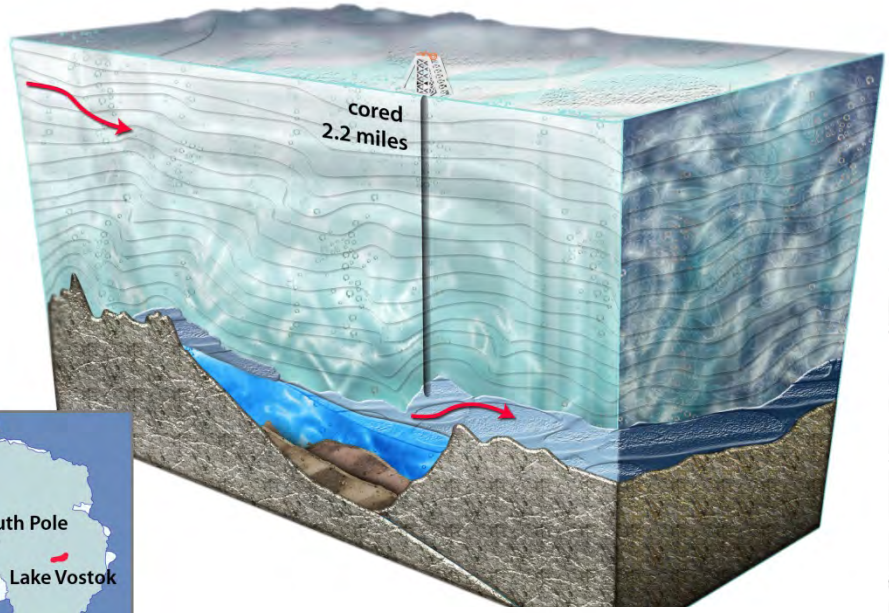
4. SAE Programs

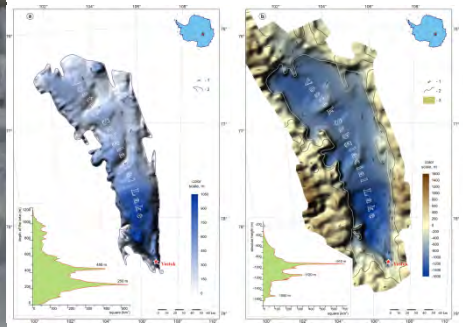
ATCM XXXVI

WP 24

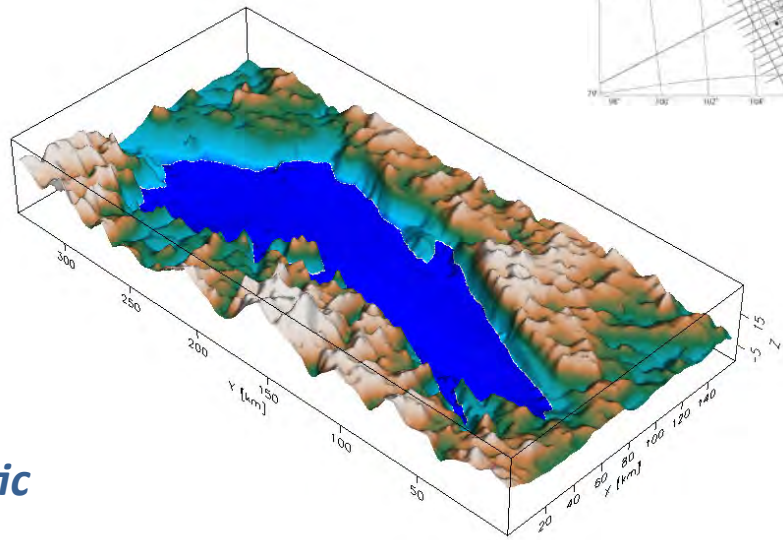
Subglacial Lake Vostok

Source: U.S. National Science Foundation





Source: Russian Antarctic Expedition



Source: Russian Antarctic Expedition

Source: M Studinger, NASA

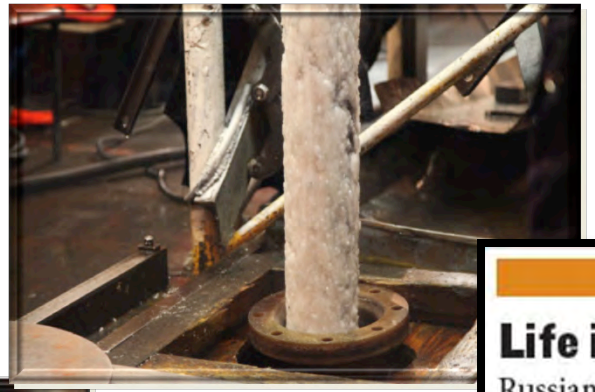
4. SAE Programs

ATCM XXXVI

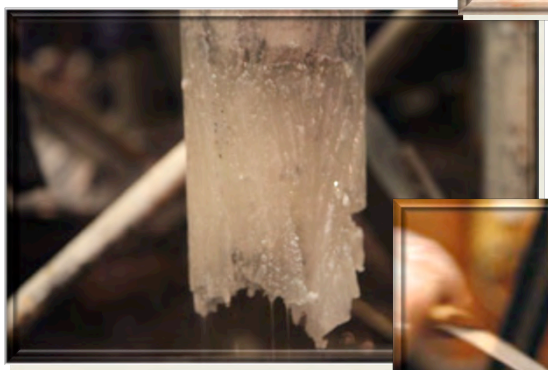
IP 42

Subglacial Lake Vostok

In Situ Samples



ATCM XXXVI
IP 42



Photos from:
V Lukin, RAE and
S Bulat, NPI

RESEARCH

Life in Lake Vostok

Russian scientists say that they have found a hitherto-unknown type of bacterium in Antarctica's largest subglacial lake. Samples retrieved last year from Lake Vostok contain an "unclassified" bacterium whose DNA is less than 86% similar to known bacteria, Sergey Bulat of the Petersburg Nuclear Physics Institute in Gatchina announced at a meeting last week in Moscow. More tests and cleaner samples are needed to establish the physiology and biochemistry of the microbe, says Bulat. See go.nature.com/ydcmw4 for more.

4. SAE Programs

ATCM XXXVI

IP 49

Subglacial Lake Vostok

2012-2013 Field Season at Lake Vostok: Deep Drilling Operations

Objective: coring lake water frozen in hole 5G-1 and continuation of drilling towards Lake Vostok

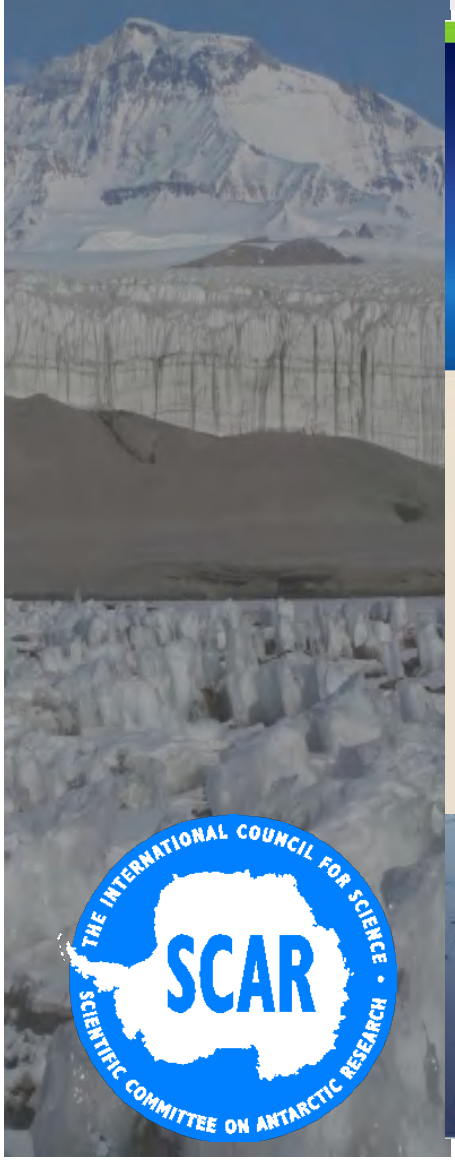
Hydrate core from depth 3419 m

ATCM XXXVI IP 49

Glacial ice and the refrozen lake water from 3445 m

Bulat et al., 2013
Bulat & Lukin, 2013
Lipenkov et al., 2013

4. SAE Programs



WISSARD

Whillans Ice Stream Subglacial Access Research Drilling

Image of the Day

Planning Begins in Earnest for the 2013-2014 Season

Logistics for the upcoming WISSARD season are being discussed this week, when an all PI meeting convenes at the Antarctic Support Contract offices in Denver, Colorado on **April 10th, 2013**. Detailed field planning will take place. In the meanwhile, water and sediment samples continue to arrive and are being processed at institutions across the country. The WISSARD Education and Outreach team are working on creating WISSARD scientists of the future, and are presenting some WISSARD science at NSTA, the National Science Teachers Association National Conference, Friday, April 12th, in San Antonio Texas.

In the News

See all News articles

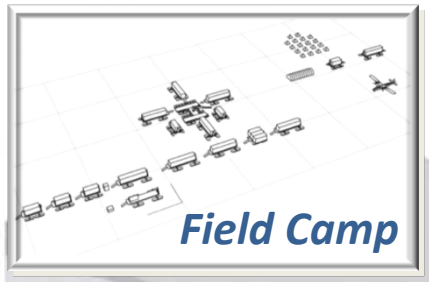
What Lies Beneath: NASA Antarctic Sub Goes Subglacial
Read the full article...

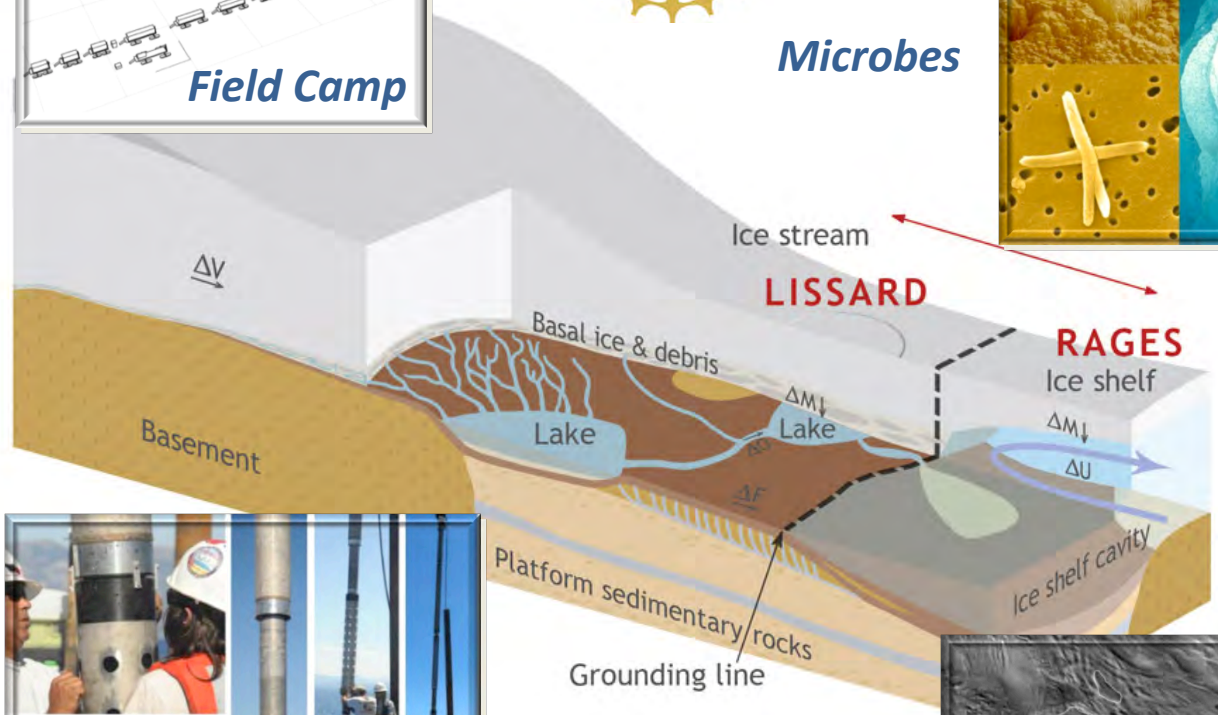
Scientists collect first intact samples from an Antarctic subglacial lake
Read the full article...

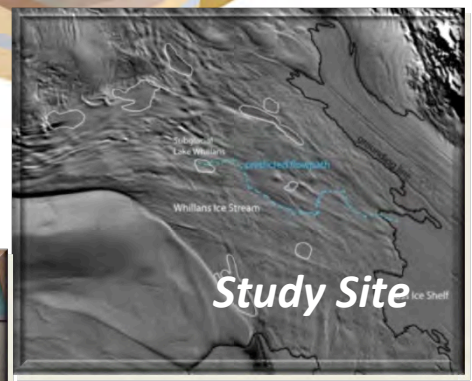
Life Under the Lake Ice
Read the full article...

4. SAE Programs

WISSARD: An Update



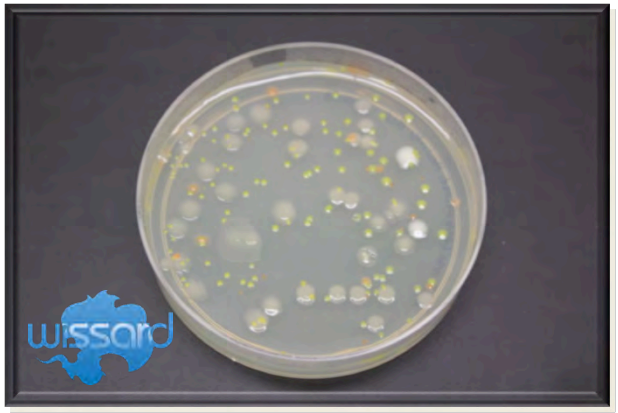




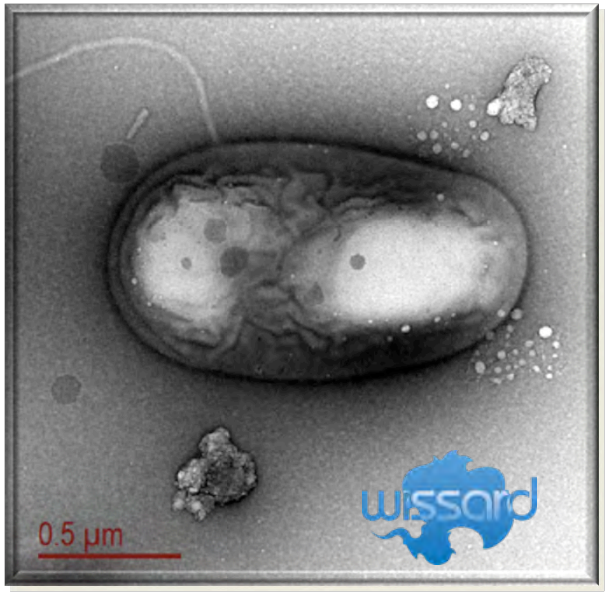
http://www.wissard.org/

Subglacial Lake Whillans In *situ* Samples

Subglacial Lake Whillans



Bacterial Colonies from Subglacial Lake Whillans water samples
(photo from B. Christner at Louisiana State University)



Microscopy image of a cell from Subglacial Lake Whillans
(photo from A. Purcell and J. Mikucki, University of Tennessee Knoxville)

4. SAE Programs

Subglacial Lake Ellsworth Antarctica

Search

exploring the unknown

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Mission called off for 2012

In the early hours of Christmas Day (Tuesday 25 December 2012) Professor Martin Siegert, Principal Investigator of the Subglacial Lake Ellsworth experiment, confirmed that the mission to drill through 3 km of solid ice into a buried lake to search for life forms in the water and clues to past climate in the lake-bed sediments was called off for this field season. read more

To find out how the 2012 field season went read our blog

Discover the amazing technology and engineering challenge .... read more

Follow one of the most exciting journeys in the world .... read more

Find out why exploring sub glacial Lake Ellsworth matters ..... read more

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- SCAR Expert group
- Environmental Evaluation
- WISSARD

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British Antarctic Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

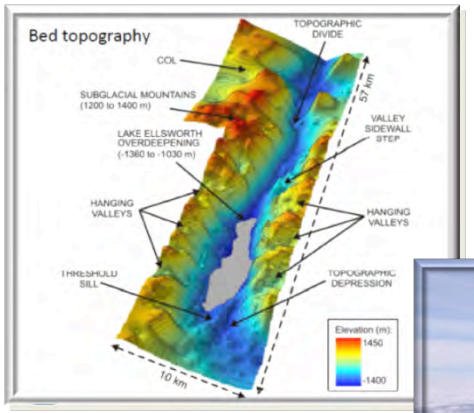
THE UNIVERSITY OF EDINBURGH

UNIVERSITY OF ABERDEEN

Durham University

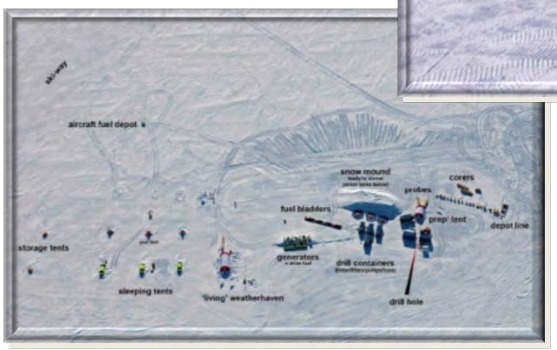
Subglacial Lake Ellsworth: An Update

- *Observe and sample life at the extremes*
- *Unlock palaeo-climate secrets in the subglacial sediments*



http://www.ellsworth.org.uk/

NATURAL ENVIRONMENT RESEARCH COUNCIL



Subglacial Lake Ellsworth Antarctica

THE INTERNATIONAL COUNCIL FOR SCIENCE · SCIENTIFIC COMMITTEE ON ANTARCTIC RESEARCH · SCAR

5. Technological Challenges

Drilling/ access

Samplers (sediment, water)

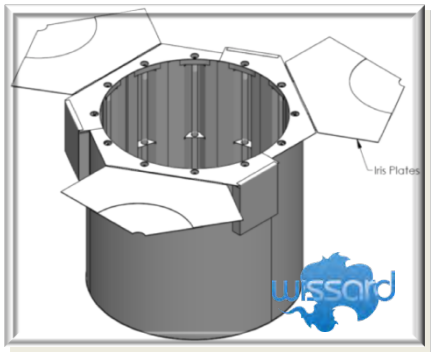
In situ sensing

5. Technological Challenges

Technology is central to subglacial exploration and technological advances are essential for realizing the promise on research beneath Antarctica's ice sheet.

Technology development is driven by scientific necessity and environmental stewardship concerns.

Sergey Bulat, NPI



5. Technological Challenges

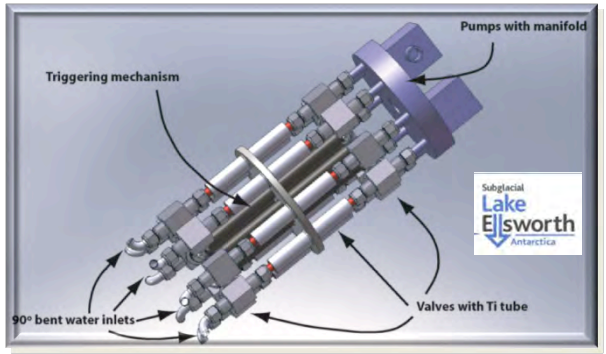
Drilling/ access

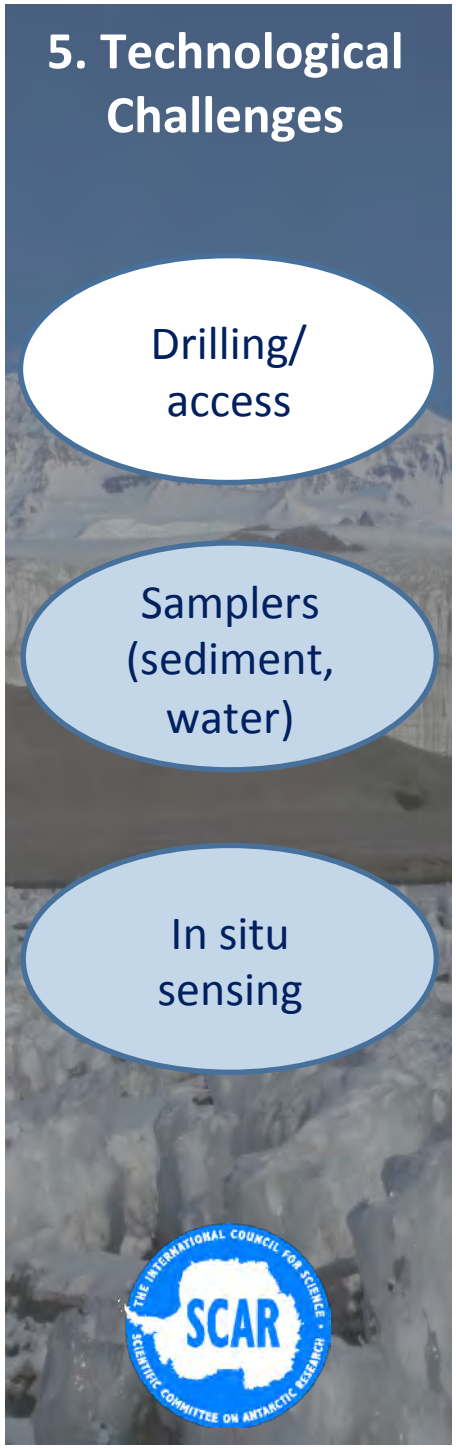
Samplers (sediment, water)

In situ sensing

Unique Technological Requirements

- *Ultra- dilute solutions*
- *Low and variable temperature exposures*
- *High pressures*
- *Remote locations and hostile weather*
- *Miniaturization*





Drilling and Access

- ***Thermo-mechanical and hot water drilling have been successfully utilized at ice streams.***
- ***Drilling through glacial ice, liquid water and into deep lake sedimentary basins has NOT been accomplished.***
- ***Coupling of hot water drilling and sediment coring capabilities*.**

Use of drill fluids, disturbances during sediment coring and retrieval, and collection of samples at* in situ *conditions are challenges.

5. Technological Challenges

Drilling/ access

Samplers (sediment, water)

In situ sensing

Water and Sediment Sampling

- ***Sample collection and return is an essential element – water, sediments, and microorganisms.***
- ***Collection at* in situ *conditions preserves samples' original states.***
- ***On-site processing of samples and/or preservation require clean conditions.***
- ***Retrieval of sediment cores through the lake water column can cause disturbances.***

WISSARD sediment corer

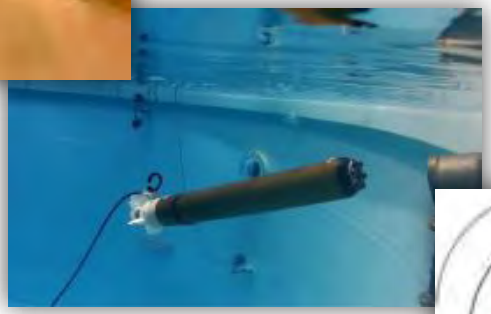
Subglacial Lake Ellsworth probe

5. Technological Challenges

- Drilling/ access
- Samplers (sediment, water)
- In situ sensing

In situ Sensing

In situ *sensors*



Remotely operated probes/vehicles

Autonomous probes and vehicle

New technologies will facilitate deployment of sensors and observatories. Challenges include:

- ***Data transmission (including thro-ice)***
- ***Autonomous/remote operation/ruggedization***
- ***Environmental stewardship issues***

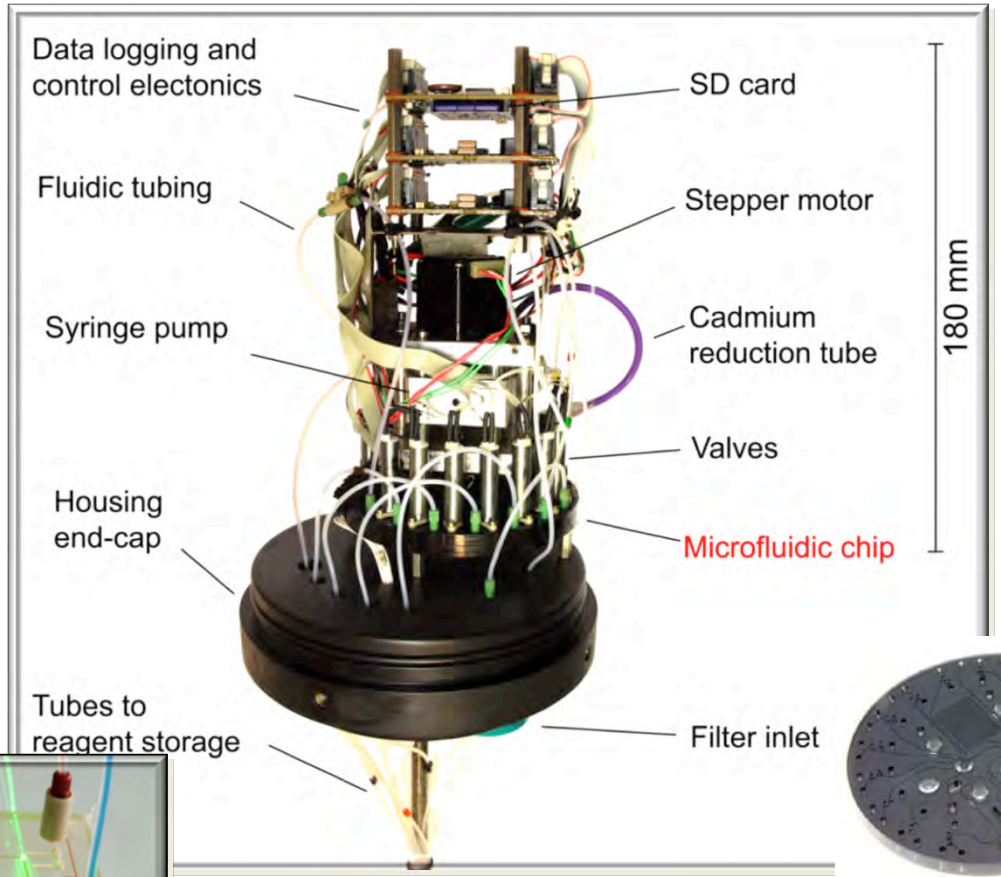
5. Technological Challenges

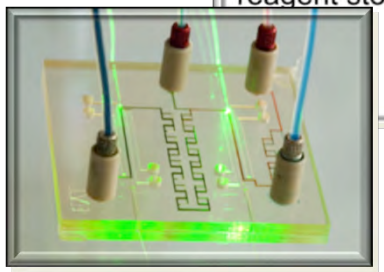
- Drilling/ access
- Samplers (sediment, water)
- In situ sensing

Adapting Technologies from Others

Lab-on-a-Chip Nitrate Sensor

Analytes: nitrate, nitrite, dissolved iron and manganese, phosphate, and ammonium





University of BRISTOL

National Oceanography Centre

5. Technological Challenges

Drilling/ access

Samplers (sediment, water)

In situ sensing

Probes and Observatories

Probes

- *Micro submersible Lake Exploration Device (MSLED)*

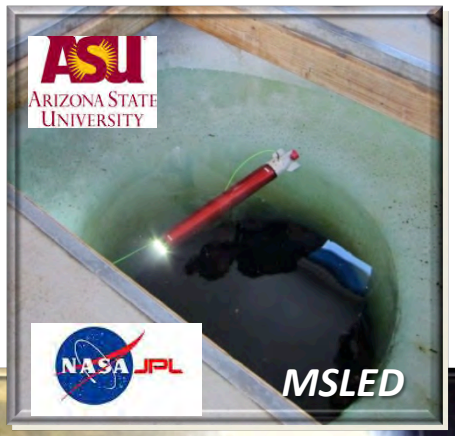
Autonomous Vehicles

- *IceMole*
- *VALKYRIE*

Melting probes

- *Environmentally Non-Disturbing Under-ice Robotic Antarctic Explorer (ENDURANCE)*
- *Cryo-egg*

Subsurface Icecraft



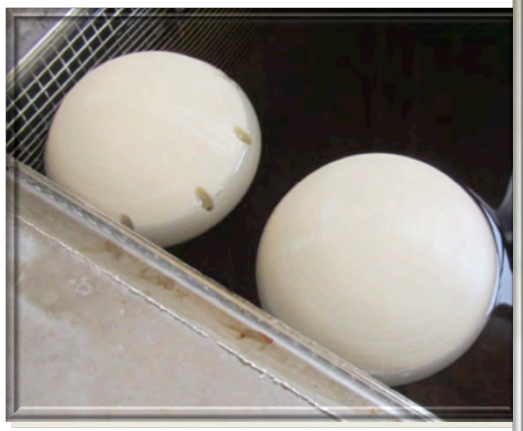
5. Technological Challenges

- Drilling/ access
- Samplers (sediment, water)
- In situ sensing

Autonomous Vehicles

Cryo-Egg

- *Miniaturised/autonomous*
- *Through-ice communications*
- *Passive transport*
- *Integrate with chemical sensors*



NATURAL ENVIRONMENT RESEARCH COUNCIL

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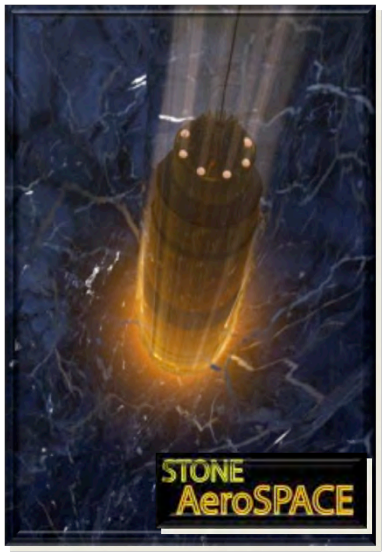
VALKYRIE

- *Self-contained melting probe*
- *Power via fiber optic line laser power*
- *Astrobiology sensors*



6. The Future

- *Subglacial exploration strategies will increasingly depend on sensors, probes, and observatories.*
- *Sensors, probes and observatories have distinct environmental issues.*
- *Other fields of science and technologies developed by subglacial exploration programs will reap great scientific benefits.*
- *Future successes will build on the lessons of past programs.*

6. The Future

- *Interdisciplinary in scope and international in participation.*
- *A continent-wide network of study sites.*
- *Environmental stewardship is a guiding principle.*
- *The SCAR facilitates international partnerships and provides scientific advice.*
- *ATPs and the CEP ensure the highest environmental standards.*

A Special Thanks To:

- SCAR – *S Chown*
- *COMNAP*
- SCAR-ATHENA
- SCAR-SALE
- National Oceanography Centre, UK
- NASA-JPL – *A. Behar*
- The DELVE project (NERC)
- The WISSARD Program – *J Priscu, S Tulaczyk, R Powell and S Smith*
- Lake Vostok Program – *V Lukin, S Bulat, I Alekhina, V Lipenkov*
- The Lake Ellsworth Exploration Program – *M Siegert and Team*
- The Natural Environment Research Council, UK
- The National Science Foundation, USA – *P Penhale, A Dahood*
- Anne LeBrocq (UK)
- Bernd Dachwald (Germany)

Thank you for your attention and are there any questions?