

# Astrobiology Initiatives in Canada:



## Canadian Astrobiology Network



## Canadian Astrobiology Training Program

<http://create-astrobiology.mcgill.ca/>



# Overview:

- Three primary multidisciplinary initiatives in Astrobiology
  - Canadian Astrobiology Network
  - Canadian Astrobiology Training Program
  - Canadian Institute for Advanced Research (CIFAR) workshops
- Institutional Initiatives
  - Canadian Space Agency
    - CARN and Analogue Missions programs
  - McMaster Origins Institute
  - McGill, Western Ontario
- Specific examples of research activities

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# Canadian Astrobiology Researchers

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Neil Banerjee	U. Western Ontario	Ancient Life, Mars habitats
Andrey Becker	U of Manitoba	Early Earth
Ed Cloutis	U. Winnipeg	Planetary Spectroscopy
Mike Daley	York University	Instrument development
Rene Doyen	U. de Montreal	Exoplanet imaging
Alex Ellery	U of Ottawa	Instrumentation
Chris Herd	University of Alberta	Astromaterials
Victoria Hipkin	Canadian Space Agency	Phoenix mission
Graham James	Dunlap Institute	Exoplanet detection
Ray Jayawardhana	University of Toronto	Exoplanet detection
Richard Leveille	Canadian Space Agency	Biosignatures
Christian Marois	Herzberg Institute	Exoplanet imaging
Penny Morrill	Memorial University	Biosignatures
Jay Nadeau	McGill University	Instrumentation
Gordon Osinski	U. Western Ontario	Planetary Science, Mars Habitats
Wayne Pollard	McGill University	Cryogeomorphology
Ralph Pudritz	McMaster University	Astrophysics, Exoplanets
Barbara Sherwood Lollar	U. Toronto	Methane Biosignatures
Greg Slater	McMaster University	Biosignatures, Extremophiles
Gordon Southam	U. Western Ontario	Geomicrobiology
Curtis Suttle	U. British Columbia	Virology and Microbiology
Peter Unrau	Simon Fraser U	RNA world
Hojatollah Vali	McGill University	Biosignatures
Warwick Vincent	Laval U.	Cryomicrobiology
Boswell Wing	McGill University	Biogeochemistry, S isotopes

**And more... and increasing....**

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# Canadian Astrobiology Network

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Recently accepted as an International Affiliate of the  
NASA Astrobiology Institute

Chair: Dr. Neil Banerjee                      neil.banerjee@uwo.ca  
U. of Western Ontario

Vice-Chair: Dr. Lyle Whyte,                lyle.whyte@mcgill.ca  
McGill University

Goal:

To provide a focal point for Canadian Astrobiology Researchers and  
facilitate participation of Canadian Astrobiology researchers in the NAI

Building many collaborations between Canadian and US researchers

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# Canadian Astrobiology Network

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## 1. Understanding the nature and distribution of habitable environments in the universe:

McMaster University (Pudritz): modeling of planetary system formation. Toronto (Jaywardhana), Dunlap (Graham), Montreal (Doyen), Herzberg (Marois): Exoplanet imaging and detection

2. Exploring for habitable environments and life in our own Solar System. University of Winnipeg (Cloutis): geological mapping of Mars and search for water-bearing minerals. University of Alberta (Herd): nature of organic materials in primitive meteorites. McGill University (Nadeau, Whyte) and Carleton University (Ellery): development of astrobiology analytical tools. University of Western Ontario (Osinski, Banerjee): geological mapping of Martian impact craters and host hydrothermal minerals.

3. Understanding the emergence of life. McMaster University (Pudritz) and University of Alberta (Herd): origin and evolution of biomolecules. McMaster University (Slater) and McGill University (Wing): geochemical and isotopic analysis of biomarkers, Earth's early atmosphere, and ancient crustal materials. University of Western Ontario (Banerjee): geochemical fingerprints of Earth's earliest life forms. Simon Fraser University (Unrau) RNA world

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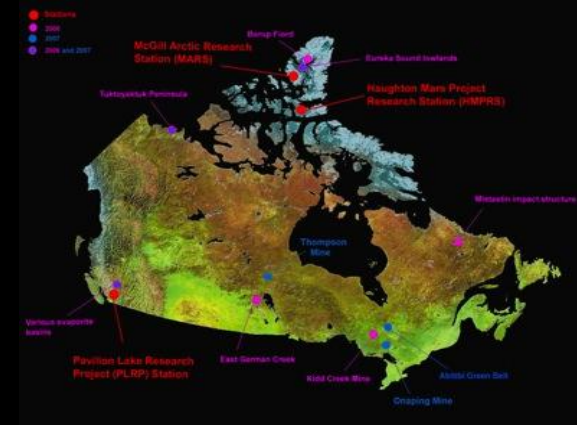
# Canadian Astrobiology Network

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4. Determining how early life on Earth interacted and evolved with its changing environment. University of Toronto (Sherwood Lollar) McMaster University (Slater): deep biosphere ecology. University of Western Ontario (Southam, Banerjee): life in hydrothermal systems.
5. Understanding the evolutionary mechanisms and environmental limits of life. McGill University (Whyte): extremophiles in the high Arctic/Antarctic Dry Valleys (permafrost, cold saline springs / methane seep cryoenvironments). Memorial University (Sylvester), University of Western Ontario (Osinski, Banerjee, Southam), University of New Brunswick (Spray): effects of impact cratering on habitability.
6. Determining the principles that will shape life in the future. This is an area that we see as an area of expansion through this *International Affiliate Membership initiative*.
7. Recognizing signatures of life on other worlds and on early Earth. McMaster University (Slater), McGill University (Wing), and University of Toronto (Sherwood Lollar), Memorial University of Newfoundland (Morrill): isotopic fractionation by biological and nonbiological processes. University of Alberta (Herd), McMaster (Slater) and University of Toronto (Sherwood Lollar): establishing nonbiological organic baselines.

# CAN Expertise and Collaborative Opportunities

- Analog research (ancient ultramafic settings, cryosphere, Hadean)
- Archean environments and biosphere
- Mineralogical and isotopic signatures
- Geochronology
- Low to moderate temperature reactions sustaining deep microbial communities
- Impact events (post-impact microbial colonization of subsurface)
- H<sub>2</sub>-rich environments in hydrogeologically isolated fractured rock
- Exoplanet detection/imaging, modeling



NSERC CREATE



# Canadian Astrobiology Training Program

<http://create-astrobiology.mcgill.ca/>



**PDF, PhD, MSc, Undergraduate positions available**





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# CREATE Astrobiology Program - Applicants

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## McGill University

Lyle Whyte      Cryomicrobiology

Wayne Pollard      Cryogeomorphology  
Jay Nadeau      Biophysics

Hojatollah Vali      Biosignatures

Boswell Wing      Biosignatures

## U. Toronto

Barbara Sherwood-Lollar      Methane Biosignatures

## U. Winnipeg

Ed Cloutis      Planetary Spectroscopy

## U. Western Ontario

Neil Banerjee      Biosignatures

Gordon Osinski      Mars Habitats

## McMaster University

Ralph Pudritz      Astrophysics

Greg Slater      Extremophiles

# CREATE Astrobiology Program - Collaborators & Partners

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## *Canadian Collaborators*

Warwick Vincent	Laval U.	Cryomicrobiology
Jonathan Stone	McMaster U.	Extreme Biology
Gordon Southam	UWO	Geomicrobiology
G. Dudek	McGill U.	Engineering
Greg Matlashewski	McGill U.	Microbiology
L. Matyas	GPS, McGill U.	Professional Skills
Mike Daley	York University	Instrument development
Alex Ellery	Carleton University	Instrument development

## *Partners*

Alain Berinstain, Victoria Hipkin, Richard Leveille	CSA
Nadeem Ghafoor	MDA Space Missions
Roman Kruzelecky	MPB Communications

# CREATE Astrobiology Program - Collaborators & Partners

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## *International Collaborators*

<b>Chris Mckay</b>	<b>NASA Ames</b>
<b>Lynn Rothschild</b>	<b>NASA Ames</b>
<b>Carol Stoker</b>	<b>NASA Ames</b>

<b>Henry Sun</b>	<b>Desert Research Institute</b>
<b>Charles Cockell</b>	<b>Open University, UK</b>
<b>Dale Andersen</b>	<b>SETI</b>
<b>J. Bell</b>	<b>Cornell University</b>
<b>T.C. Onstott</b>	<b>Princeton University</b>
<b>R. Mielke</b>	<b>NASA JPL</b>

**Spanish Astrobiology Center (CAB)**  
**Victor Parro**  
**Javier Gomez-Elvira**  
**David Fernández Remolar**

# CATP Science

## Extremophiles/Cryoenvironments

Slater\*, Whyte

*Cockell, Rothschild, Southam, Stone, Vincent*

## Biosignatures

Sherwood-Lollar

Vali, Wing

Banerjee\*, Onstott

## Planetary Analogues

Pollard\*, Pudritz

Osinski

*Bell, Berenstain, McKay*

## Astrobiology Instrument Development

Cloutis\*, Nadeau,

*Daly, Dudek, Ghafoor, Kruzelecky, Stoker, Sun*

Laboratory

Modern

Ancient

CATP Science Organization.

Expertise of key researchers and collaborators (*italics*) divided into four (4) primary research themes and three (3) different approaches: laboratory investigations, and modern and ancient environments. Initial leaders of each research theme are indicated by an asterix.

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# CREATE Astrobiology Program -

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Will provide Astrobiology training for ~70 HQP

~30 undergrads, ~14 MSc, ~12 PhD, ~14 PDFs

Actual enrolments 2009-2012

23 undergrads, 14 MSc & 10 PhD, 9 PDFs

**Budget ~ 1.7 M for 6 years  
2009-2015**

**Program recently renewed after third year review**

**Funding open to all applicants**

# CREATE Astrobiology Program - HQP Training

CATP Trainee #s / year

<b>Targets</b>			<b>as of 2012</b>	<b>Major Scholarships</b>
Undergrads (~ 30)			23	6
MSc (~ 14)			14	6
PhD (~ 12)			10	8
PDF (~ 14)			9	1
<b>Totals</b> (6 years)	70	<b>Actual</b> (3 years)	<b>56</b>	<b>21</b>

# **CATP – Research Rotations, Videoconferencing**

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**CATP funds students for research rotations between research groups to broaden their training/experience and facilitate development of new research initiatives**

**Funds support travel between research groups, as well as contributing to minor research expenses**

**Research rotations can also involve international partners and participation in field expeditions as well as participation in Astrobiology schools/field courses/AbGradCon**

# CATP - Implementation of Astrobiology Academic Programs/Specializations

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1. McMaster University & the Origins Institute :
  - Collaborative Graduate Program in Astrobiology
  - starting in Fall 2012, 1<sup>st</sup> in Canada
  - PhD and MSc students, led by the Origins Institute
2. McGill University :
  - Grad Course BMDE 501: Astrobiology in 2012 → Astrobiology Graduate Option ~2013 → Astrobiology Grad Program ~2014
3. Western University :
  - Graduate program in planetary science, 1<sup>st</sup> in Canada, contains a strong astrobiology component, presently with 35 grad students.
  - UWO Planetary Science Short Course



# CATP – Research Rotations, Videoconferencing

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**Bi-monthly Astrobiology seminar series available to all members. Presentations are given by CATP Co-Is, collaborators, recruits, and invitees and are videotaped and digitally archived for future viewing to build a strong library of lectures.**

Recent Examples .....

<http://create-astrobiology.mcgill.ca/seminars.html>

March 11, 2011      **Prof. Charles Cockell**      The Open University  
Habitats and vacant habitats for chemolithotrophs on Mars

April 8, 2011      **Dr. Darlene Lim**      NASA Ames Research Center  
Pavilion Lake Research Project: Using Underwater Field Science to Prepare Humans for Future Planetary Exploration

May 31, 2011      **Prof. Malcolm Walter**      University of New South Wales  
The first two billion years of life on Earth: the view from Australia

December 14 2011   **Dr. David J Des Marais**      NASA Ames Research Center  
Exploring Mars for evidence of habitable environments and life.



# CIFAR

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CANADIAN INSTITUTE  
for ADVANCED RESEARCH

Estd. 1982 by Dr. J.F. Mustard, CIFAR is a virtual institute to support advanced collaborative research relevant to Canada and the global community. Membership is by invitation and consists of researchers from universities and research agencies worldwide.

The institute is unique both for its pursuit of knowledge for knowledge's sake and its emphasis on long-term collaborative approach to research. (350 researchers in 12 groups).

Catalyst funding for: research, meetings, shared postdocs & grads

# CIFAR: Canadian Institute for Advanced Research



- Brings together leading researchers from across Canada and around the world to work collaboratively on complex advanced research projects.
- Currently more than 350 researchers are affiliated with CIFAR's 12 research programs.
- Initiated workshops in Astrobiology in April 2009, second workshop October 2010, third workshop February 2012

# CIFAR: Astrobiology workshops



- Small format workshops (~25 participants) with focused discussion on astrobiology research questions
- Broad participation from across Canada and internationally including the US, Japan and Germany
- Lead to CIFAR supporting Canadian student participation in the Santander summer school

# International Participants

- Ariel Anbar, School of Earth and Space Exploration, Arizona State University
- Steven B. Charnley, NASA Goddard Space Flight Center
- David Des Marais, NASA Ames Research Center
- Katherine H. Freeman, Department of Geosciences, Penn State University
- James F. Kasting, Department of Geosciences, Penn State University
- Christopher McKay, NASA Ames Research Center
- Michael J. Mumma, NASA Goddard Space Flight Center
- John F. Mustard, Department of Geological Sciences, Planetary Geosciences Group, Brown University
- Thomas Quinn, School of Aquatic and Fishery Sciences, University of Washington
- Dave Deamer: Department of Chemistry and Biochemistry, University of California Santa Cruz
- James G Ferry: Astrobiology Research Centre, Pennsylvania State University
- Raymond Pierrehumbert: Department of the Geophysical Sciences, University of Chicago
- Everett Shock: Department of the Geological Sciences, Arizona State University
- James (Jim) Cleaves, Georgia Institute of Technology
- Pascale Ehrenfreund, Space Policy Institute and George Washington University
- Ken Takai, JAMSTEC

# Evolution of Planetary Systems & Life

**Environments of Life**

**Capabilities of Life**

**Signatures of Life**

*Prebiotic  
Chemistry*

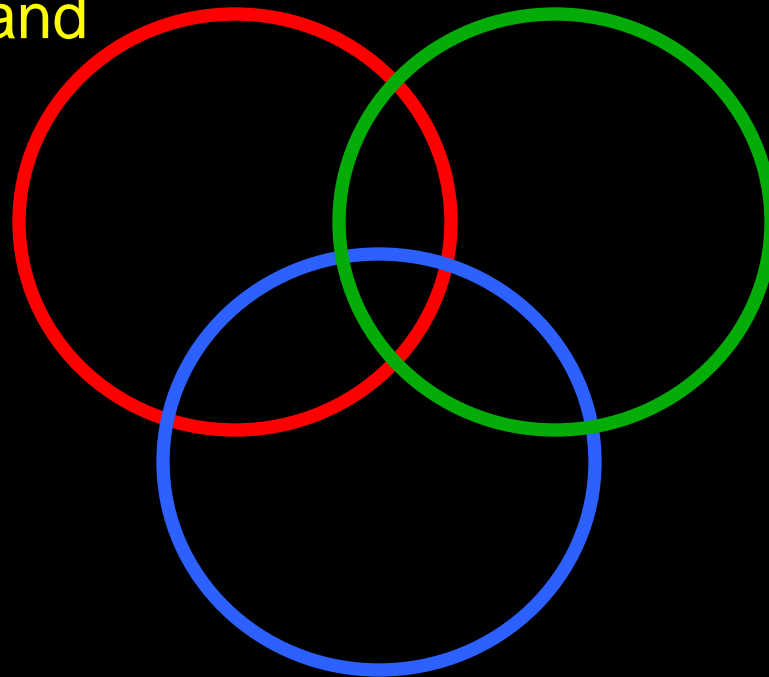
*Origins  
Of Life*

**Universal Concept of Life**

# Primary research theme: Crossing the Biotic Fringe

Prebiotic state and  
Abiosignatures

Biosignatures and the  
mechanisms of life



Transitions to Life

Courtesy. R. Jayawardhana, U of Toronto

1"



# Institutional Initiatives:

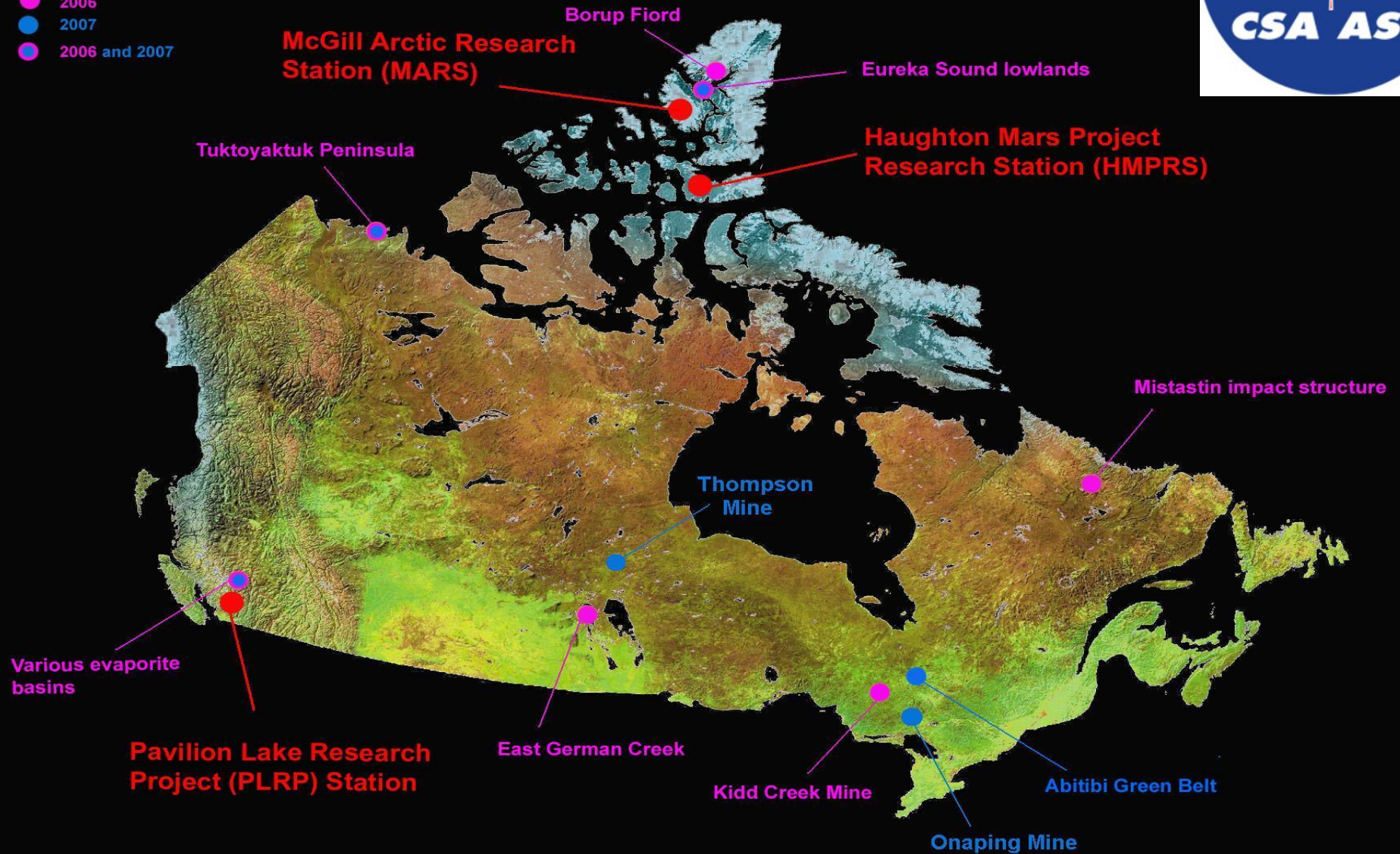
- Canadian Space Agency
  - CARN program
  - Analogue Missions program
- McMaster Origins Institute
  - Astrobiology key theme
  - Collaborative degree in astrobiology (first in Canada)
- University of Western Ontario
  - Planetary Sciences program : includes astrobiology
- McGill University



# Canadian Analogue Research Network:



- Stations
- 2006
- 2007
- 2006 and 2007





## CSA Programs:

- CARN Program: 2006-2010
  - Infrastructure and field access support for three primary sites as well as an increasing number of investigator proposed sites
  - 60% success rate for funding
- Analogue Missions RFP 2010
  - asked for analogue mission proposals to develop better science investigation and technology requirements from CSEW6 report
  - Focus on both science and operations aspects
- Exploration Core and Flights for the Advancement of Science and Technology (FAST) programs currently under review
  - instrument concepts and prototyping; field studies, nanosats, balloons; RFP's based on CSEW6 report objectives

# CSA Programs:



- Currently evolving a new community consultation structure following reorganisation of the CSA into Exploration, Utilisation, and Space Science and Technology thrusts in 2010. **Astrobiology goals are a priority for the Exploration thrust**, which includes planetary science mission and instrument development activities.
  - CSA is a partner in NSERC CREATE Canadian Astrobiology Training Program (CATP)
  - CSA Program Scientist, Planetary Exploration: [Victoria.Hipkin@asc-csa.gc.ca](mailto:Victoria.Hipkin@asc-csa.gc.ca) in frequent contact with NASA Astrobiology Senior Scientist, Mary Voytek: co-organisation of Analogue Sites for Mars Missions workshop, LPI, 2011
  - CSA Planetary Protection and Sample Curation Policy being developed, complying with COSPAR and international norms.

# McMaster Origins Institute – transdisciplinary research



Institute

People

Research

Colloquia

Undergraduate Research  
Specialization

Conferences-Workshops

Positions

Public Lecture Series

Space-Time



Structure in the Cosmos



Elements



Life



Species and Biodiversity



Humanity



[origins.mcmaster.ca](http://origins.mcmaster.ca)

Director, Prof. Ralph Pudritz;

Associate Director, Prof. Jonathon Stone

# Origins Institute – Goals

- Launched in 2004 - transdisciplinary research on some of the most fundamental questions in science – 6 basic themes:
  - Origin of spacetime (early universe, particle physics)
  - Origins of structure in the universe (galaxies, stars, & planets)
  - Origin of the elements (nuclear astrophysics)
  - Origin of life (astrobiology)
  - Origin of species (biodiversity, adaptation)
  - Origin of humanity

# Three pillars of the OI



## i) Research:

*Workshops/Conferences*

*Colloquia and Visitor's Program*

*Astrobiology research – NSERC CREATE*

*Origins Postdoctoral Program*

## ii) University education:

Undergrad: *Origins Research Specialization*

Graduate: *Collaborative Grad Program in  
Astrobiology - Canada's first*

## iii) Public Outreach:

*Origins Public Lectures (about 5 /yr)*

*(eg. Martin Rees, Brian Schmidt, Chris McKay,...)*

*3D Theatre*

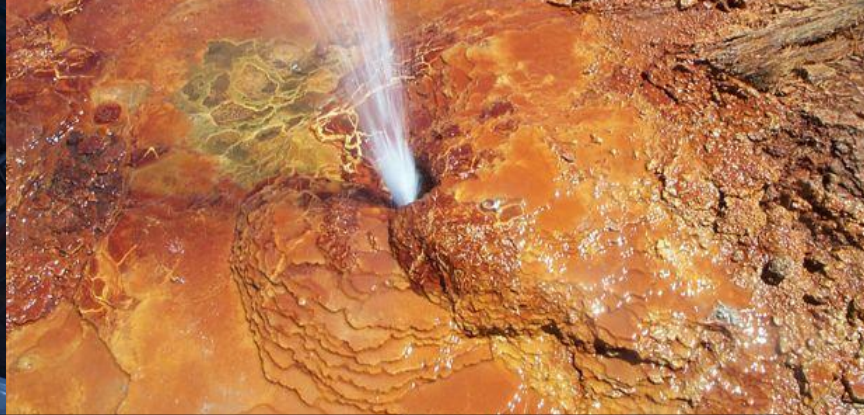
# Institutional Initiatives:

- University of Western Ontario
  - Graduate program in planetary science, 1<sup>st</sup> in Canada, contains a strong astrobiology component, presently with 35 grad students.
  - UWO Planetary Science Short Course
- McGill University
  - lead PI of CATP, co-chair of CAN Lyle Whyte
  - Grad Course BMDE 501: Astrobiology in 2012
    - Astrobiology Graduate Option ~2013 →
    - Astrobiology Grad Program ~2014

# Research into Biosignatures/abiosignatures:

- Deep terrestrial subsurface
  - B. Sherwood Lollar, G. Slater, B. Wing
- Ancient terrenes
  - N. Banerjee, B. Wing,
- Serpentinization
  - B. Sherwood Lollar, P. Morrill
- Pavilion Lake Research Project
- Endolithic communities
- Cryoenvironments





**Deep Subsurface:  
Sampling for CH<sub>4</sub> and H<sub>2</sub>:  
Abiotic and Biotic markers  
In deep subsurface sites  
undergoing WRI:  
including radiolysis and  
serpentinization**



# Direct microbial sampling

- Large format filtration of waters to collect microorganisms for molecular, organic and isotopic analysis to identify metabolic pathways present and being utilized



# Environmental Genomics Reveals a Single-Species Ecosystem Deep Within Earth

Dylan Chivian,<sup>1,2\*</sup> Eoin L. Brodie,<sup>2,3</sup> Eric J. Alm,<sup>2,4</sup> David E. Culley,<sup>5</sup> Paramvir S. Dehal,<sup>1,2</sup> Todd Z. DeSantis,<sup>2,3</sup> Thomas M. Gihring,<sup>6</sup> Alla Lapidus,<sup>7</sup> Li-Hung Lin,<sup>8</sup> Stephen R. Lowry,<sup>7</sup> Duane P. Moser,<sup>9</sup> Paul M. Richardson,<sup>7</sup> Gordon Southam,<sup>10</sup> Greg Wanger,<sup>10</sup> Lisa M. Pratt,<sup>11,12</sup> Gary L. Andersen,<sup>2,3</sup> Terry C. Hazen,<sup>2,3,12</sup> Fred J. Brockman,<sup>13</sup> Adam P. Arkin,<sup>1,2,14</sup> Tullis C. Onstott<sup>12,15</sup>

DNA from low-biodiversity fracture water collected at 2.8-kilometer depth in a South African gold mine was sequenced and assembled into a single, complete genome. This bacterium,

is a sulfate-reducing, fermenting, and iron-oxidizing bacterium inhabiting the deep crust, by using machinery from independent life-styles in the Earth's crust and offers an environment entirely enclosed.

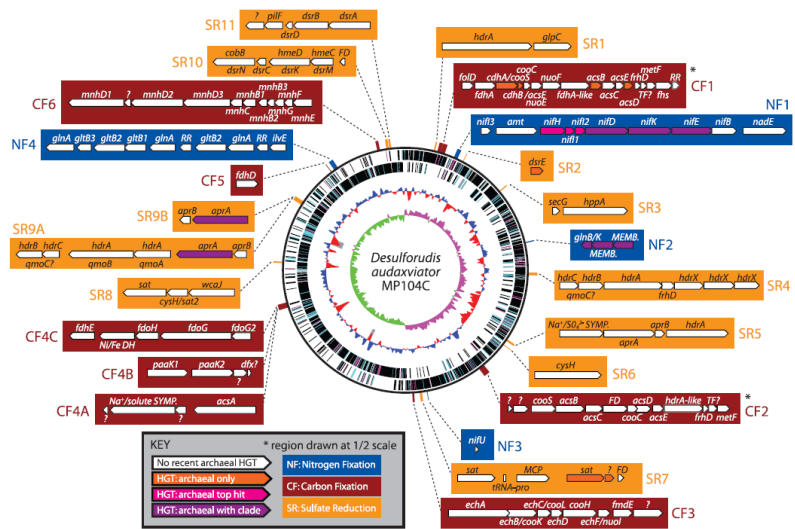
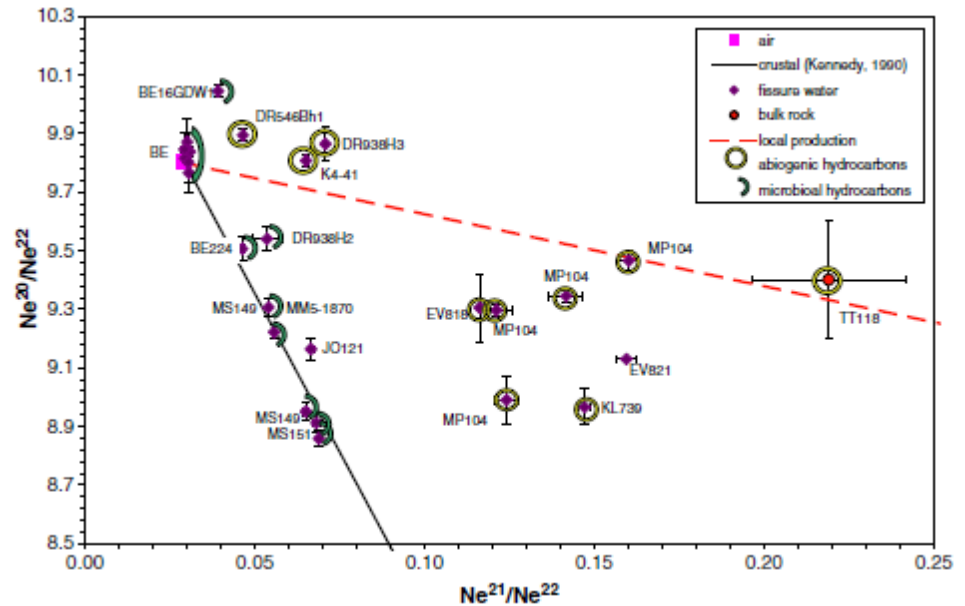


Fig. 2. Genome of *D. audaxviator*, with key genes highlighted. (Innermost) closest clade species (including open reading frame (ORF) genes) are in

# Lippmann-Pipke et al Chemical geology 2011



# Chivian et al. (2008) Science 322: 275-278

# Surface sites of active serpentinization:

- Develop, deploy, and validate biosignature identification at Mars analogue sites of present-day serpentinization
- Origin (biogenic and/or abiogenic) of hydrocarbons in springs
- Types of microbial life in these extreme ( $\text{pH} > 10$ ) environments
- Molecular biomarkers  
active and inactive  
sites of serpentinization
- Nutrients limitations
- C-Substrate utilization  
experiments



present-day serpentinization, NL  
Canada

# Cryomicrobiology/Cryosphere:

## McGill Arctic Research Station – Lyle Whyte

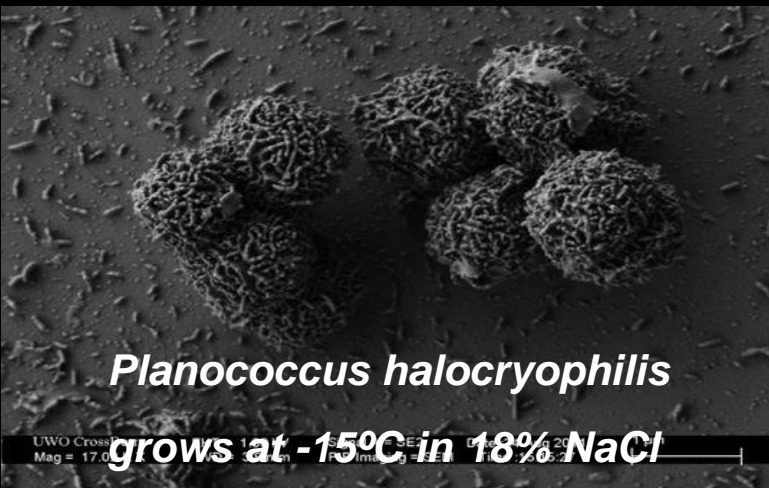
Cryomicrobiology, the exploration of the low-temperature limits of microbial life.

Permafrost

Cold Saline Springs

Unique Cryophilic Microbes

Biosignatures and biogeochemical cycling



*Planococcus halocryophilis*

grows at  $-15^{\circ}\text{C}$  in 18% NaCl



Lost Hammer  
Spring / subzero CH<sub>4</sub> Seep

# Deep Cryosphere *Nunavut mines*

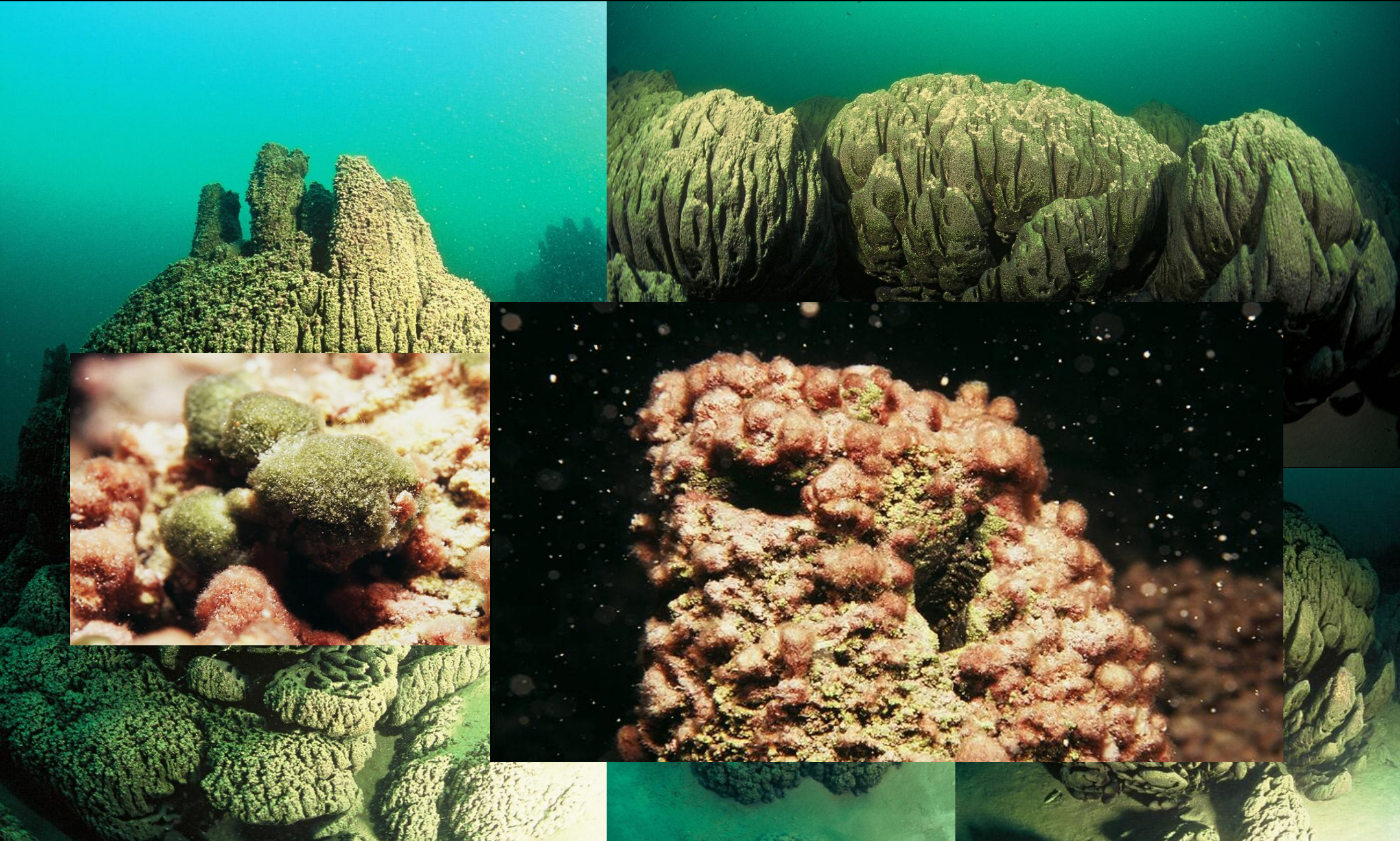
Lupin Mine (NAI – CSA)  
*IPTAI Team*



# High Lake Drilling Project *NAI DDF*



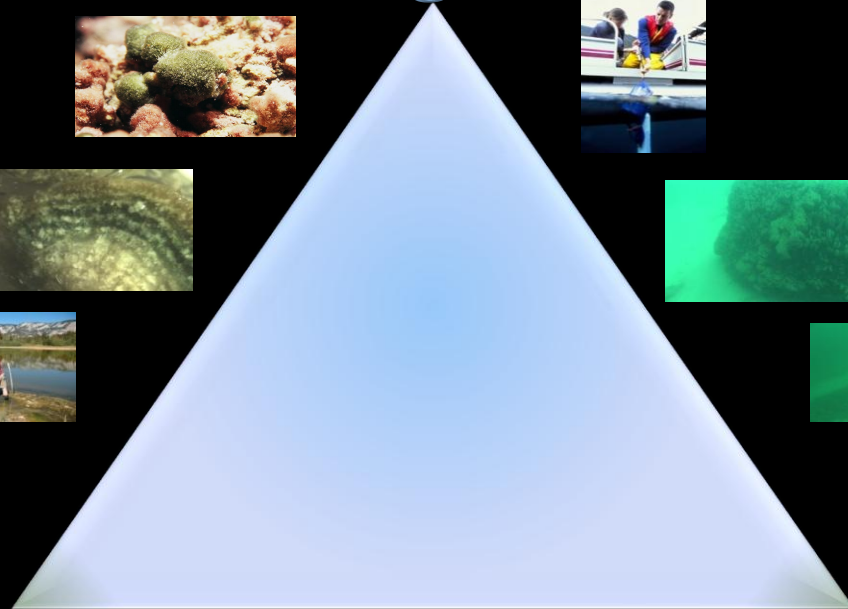
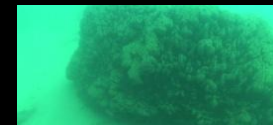
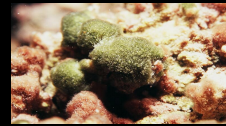
# Pavilion Lake Research Project: Microbialites



# PLRP/MARSLIFE Overview

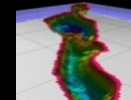
**What Mechanisms and Associated Interactions Control Microbialite Morphogenesis and biosignatures in Pavilion Lake?**

Biological



- **Multi-disciplinary Science and Exploration Initiative**
- **Multi-year program 2005-present**
- **Funding: NASA (MMAMA, DIO, ASTEP), CSA (CARN), Nuytco Research, NGS Science and Exploration Grant, NSERC, McMaster University**

Chemical



Physical



# PLRP/MARSLIFE DEEPWORKER SCIENTIFIC EXPLORATION OVERVIEW

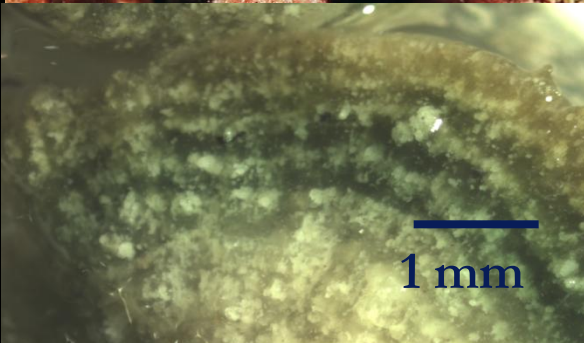
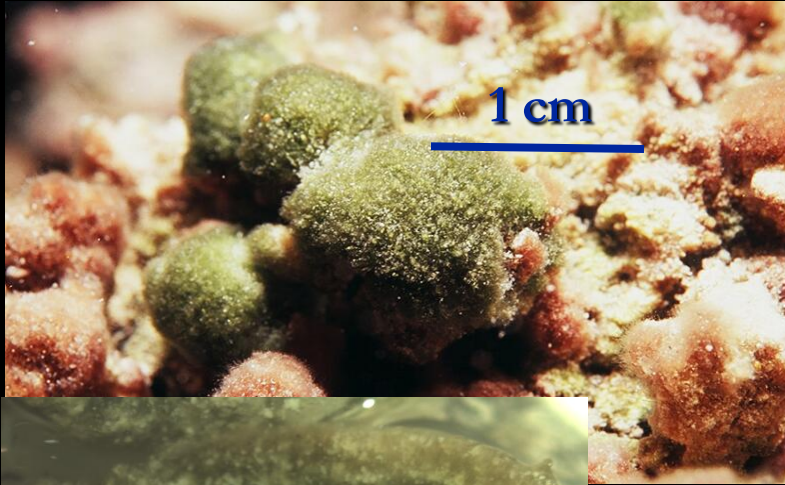


The need to constantly monitor LSS while performing other science duties such as sampling, photographing, etc and at the same time piloting the submersible provides a high fidelity analog to conducting science operations in hostile environments.

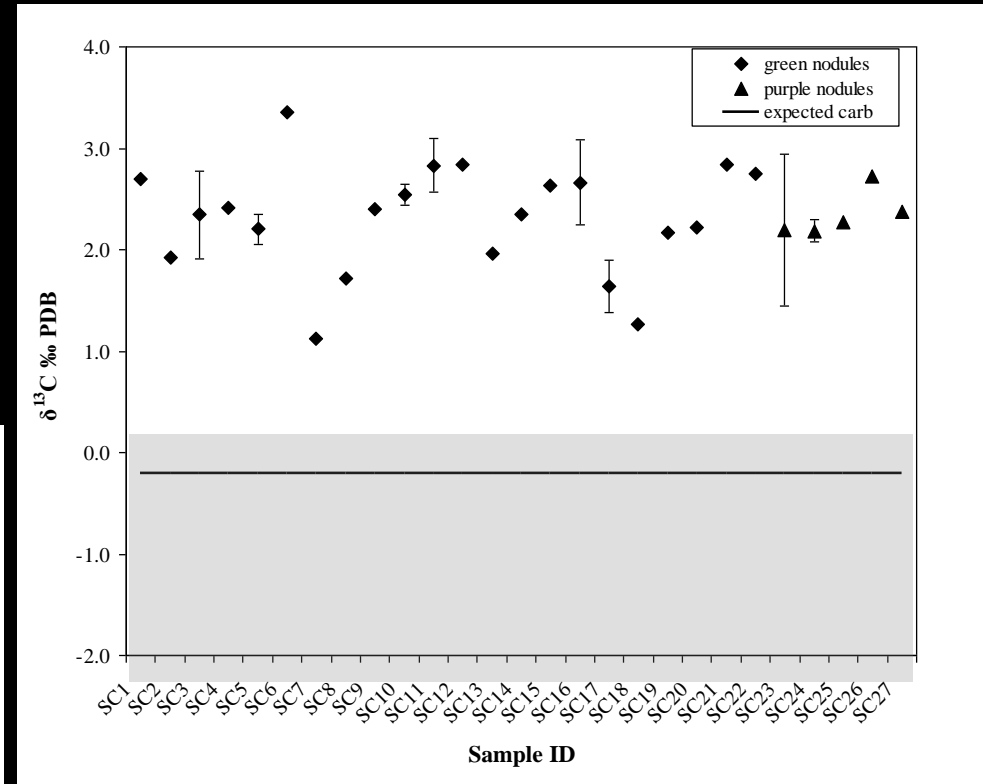
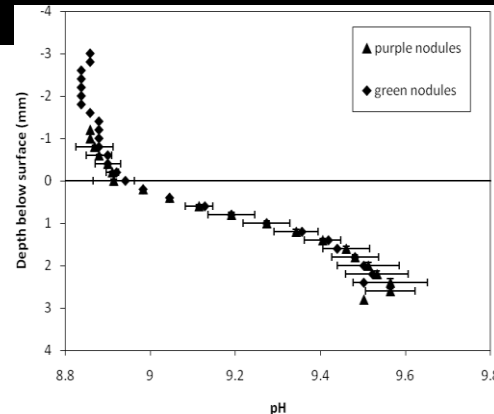
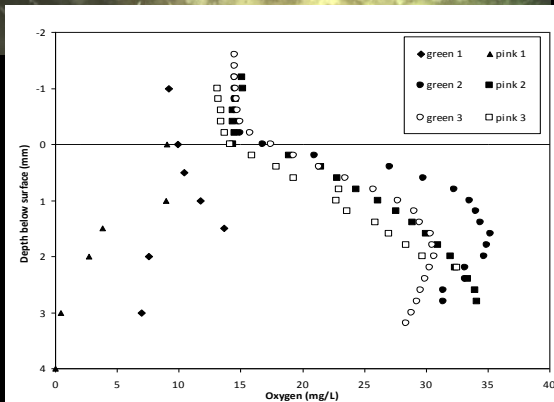
•To help enable the development, testing, and validation of new operational concepts associated with science driven EVAs PLRP has been:

- (a) developing training strategies for future human planetary exploration;
- (b) developing and field testing data management and synthesis tools for real-time contextual mapping;
- (c) detailing EVA science mission protocols;
- (d) designing science and data acquisition success metrics for application to Pavilion Lake and other field research activities (e.g. NEEMO, DRATS);
- (e) documenting traverse planning protocols
- (f) Testing communications protocols to maximize scientific return in a real science and exploration setting

# Biosignatures associated with surface microbial communities

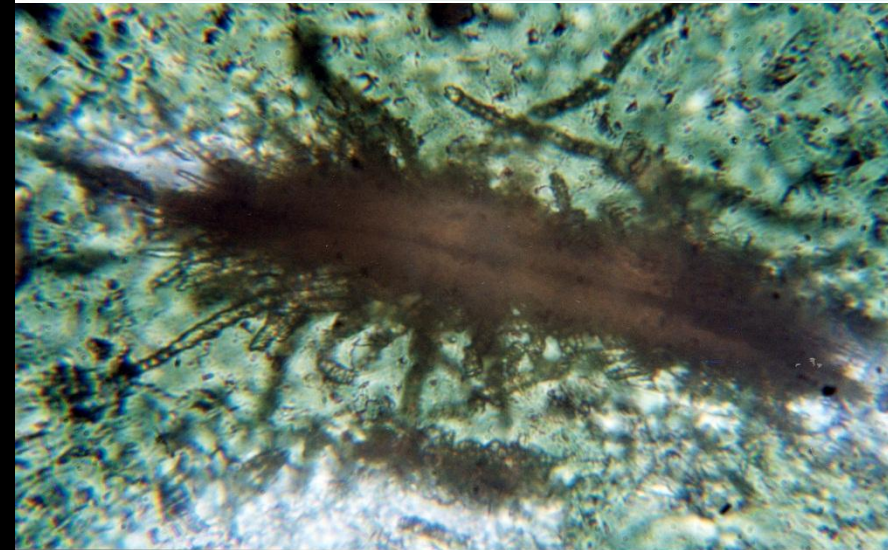
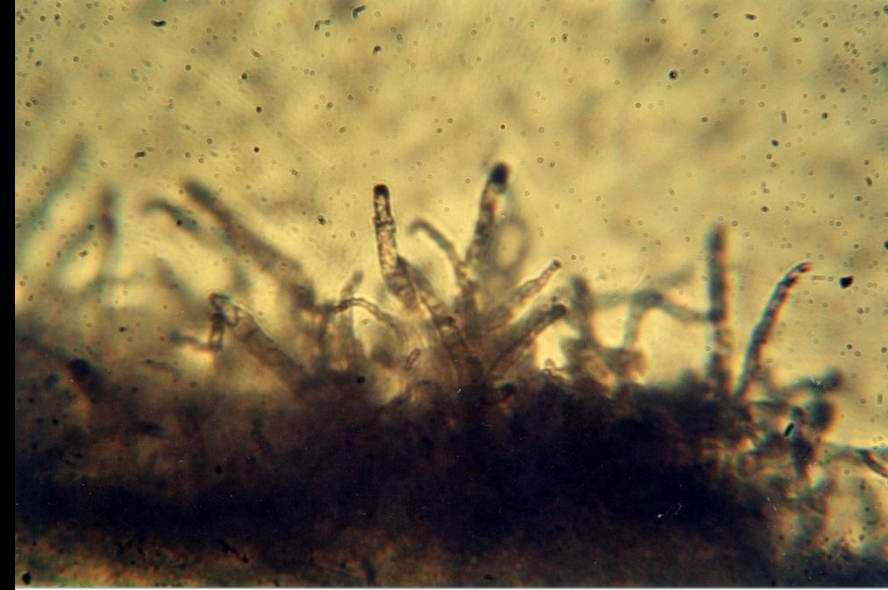


Carbonate enrichment biosignature associated with surface cyanobacterial communities

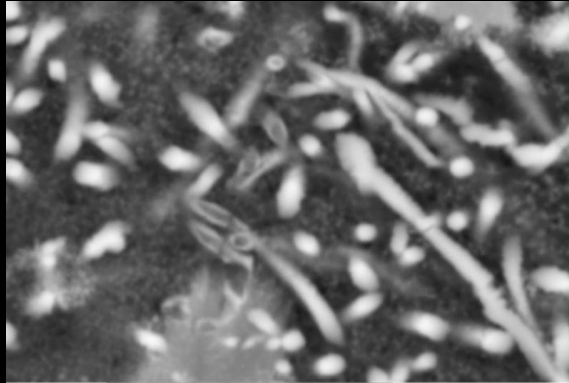


# Biosignatures in ancient terrenes and their modern analogues:

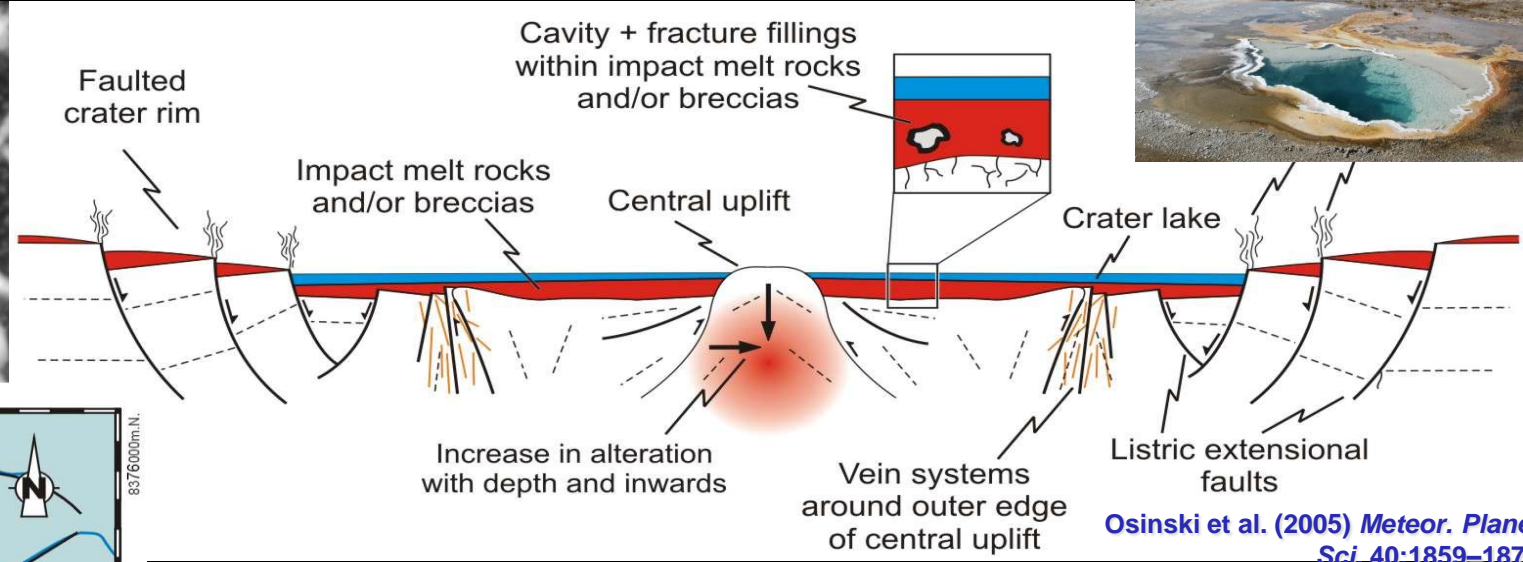
- Banerjee et al (Western) – formation of microtubules in basaltic glass as trace fossil of microbial activity
  - Observed in relatively recent (10 MY) seafloor volcanic glasses and in oldest pillow basalts sampled (Barberton)



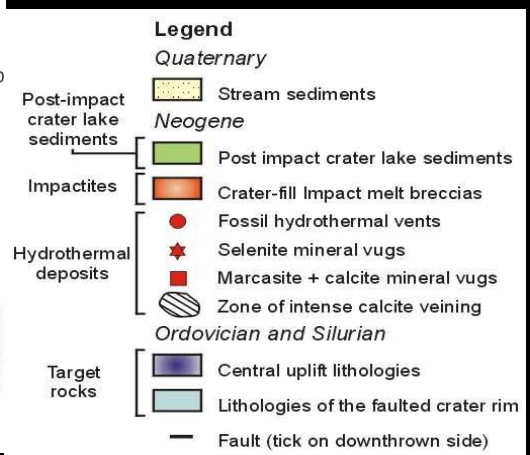
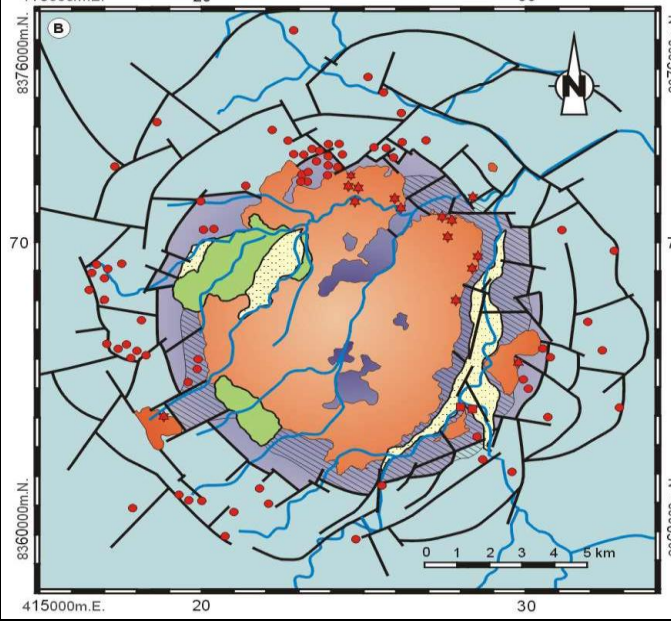
# The search for life on Mars: Impact craters as prime habitats and exploration targets



be 00-056 14 μm

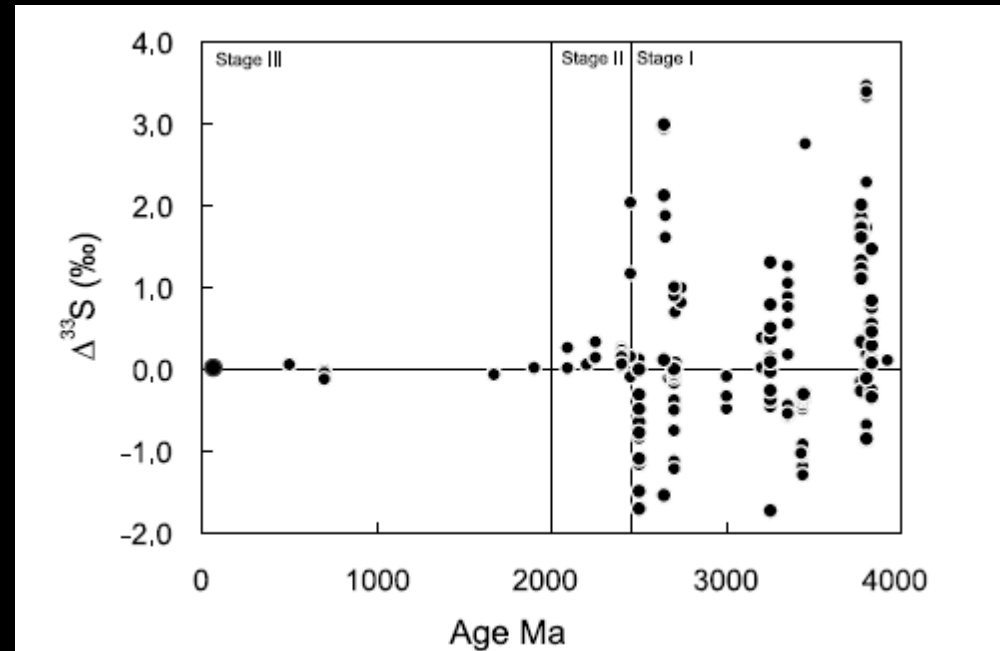


Osinski et al. (2005) *Meteor. Planet. Sci.* 40:1859–1873.



# Biosignatures in ancient terrains and their modern analogues:

- Wing et al (McGill)
- S isotopes and dynamics
  - Great Oxidation event
  - Ancient rocks
  - Experimental studies of S isotope fractionation



Farquhar and Wing EPSL 2003

# University of Alberta: Subzero Facility for Curation and Handling of Astromaterials

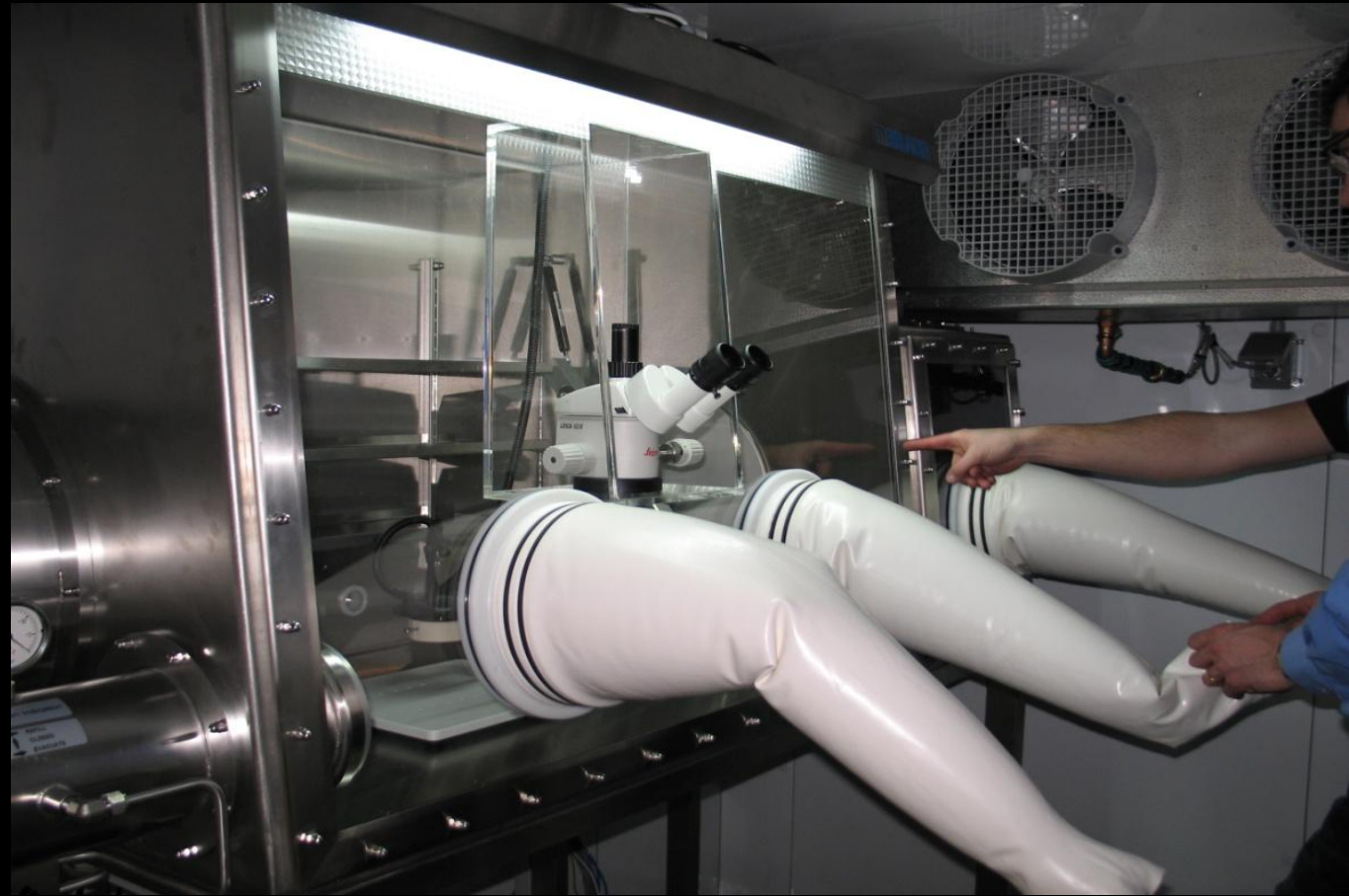
- C. Herd PI
- Unique facility
  - Ar glove box within a  $-20\text{ }^{\circ}\text{C}$  environmental chamber
- Enables astromaterials processing under cold, clean conditions



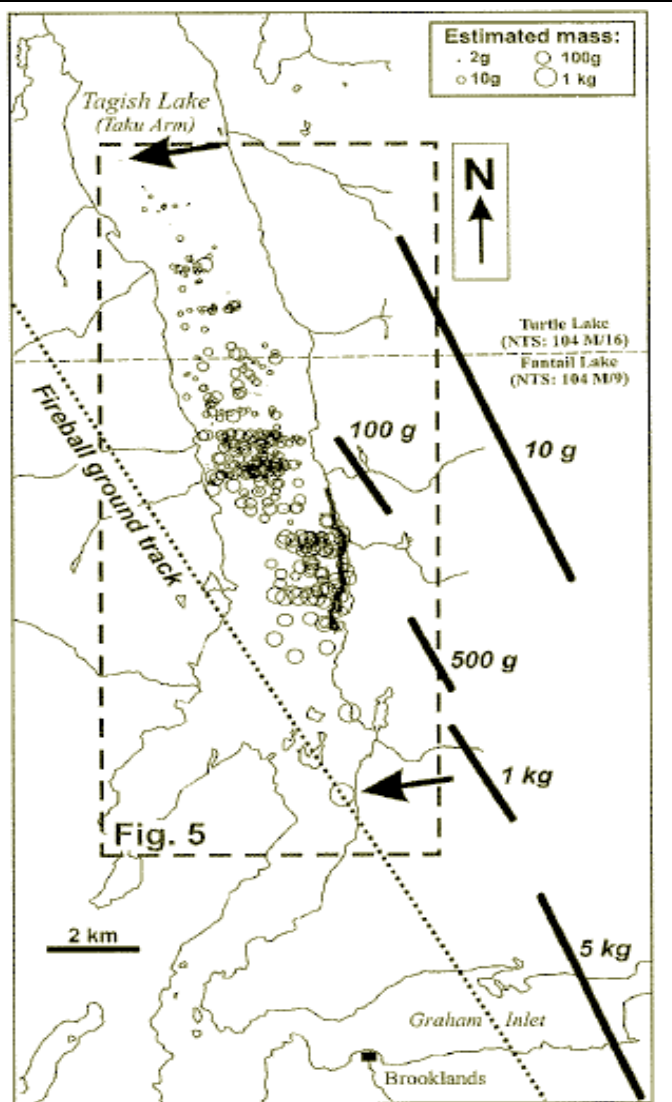
Class 1000 clean anteroom, with door to environmental chamber (at left); University of Alberta

# Subzero Facility for Curation and Handling of Astromaterials

- Prevents against:
  - Loss of volatile compounds
  - Reaction with atmosphere
  - Terrestrial organisms
- Currently testing backgrounds, funding pending for further Tagish Lake work from CSA



# Investigating The Tagish Lake Meteorite



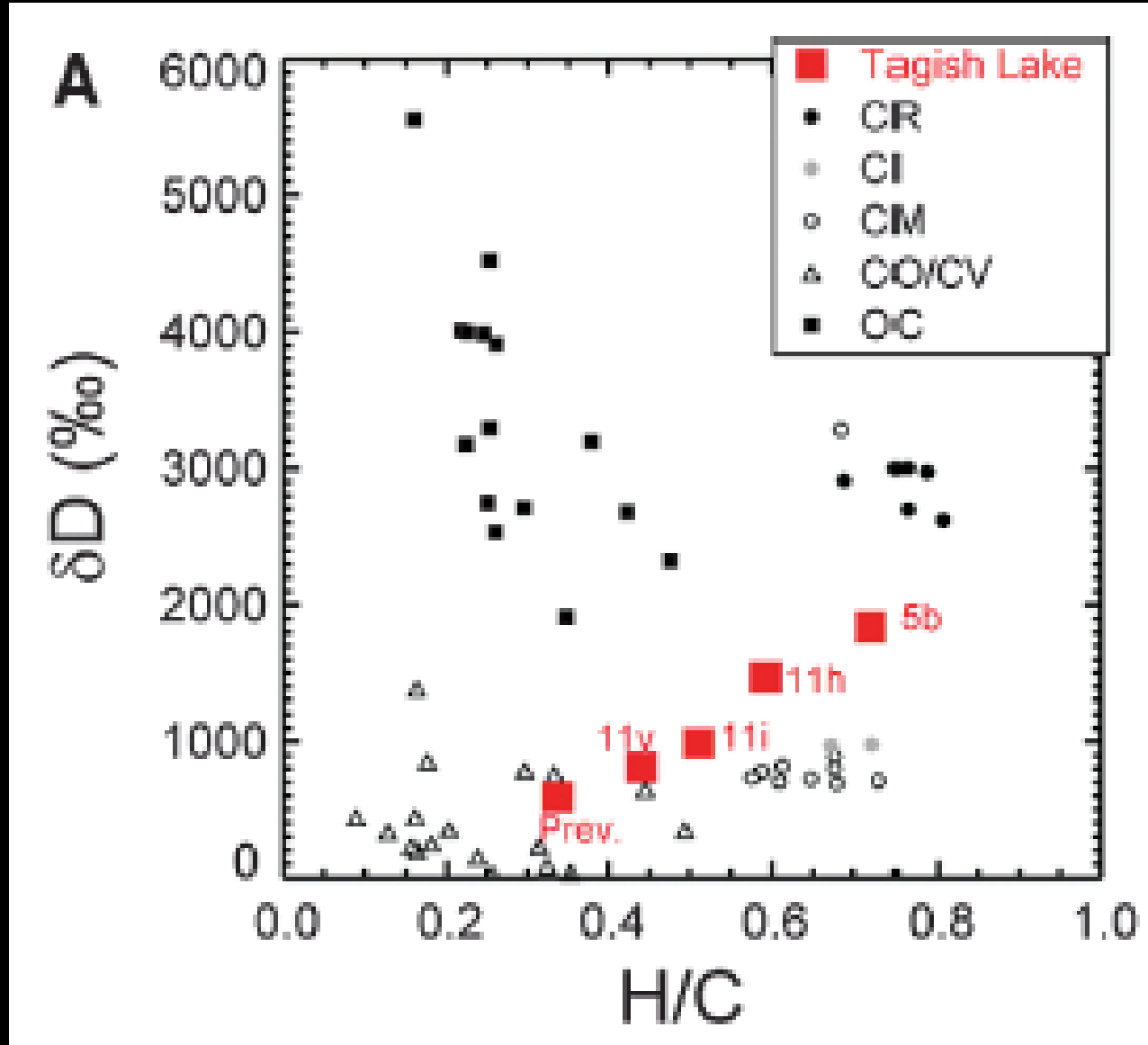
Sample 1; 159 g, ~10 cm in longest dimension

Michael Holly, Creative Services, University of Alberta

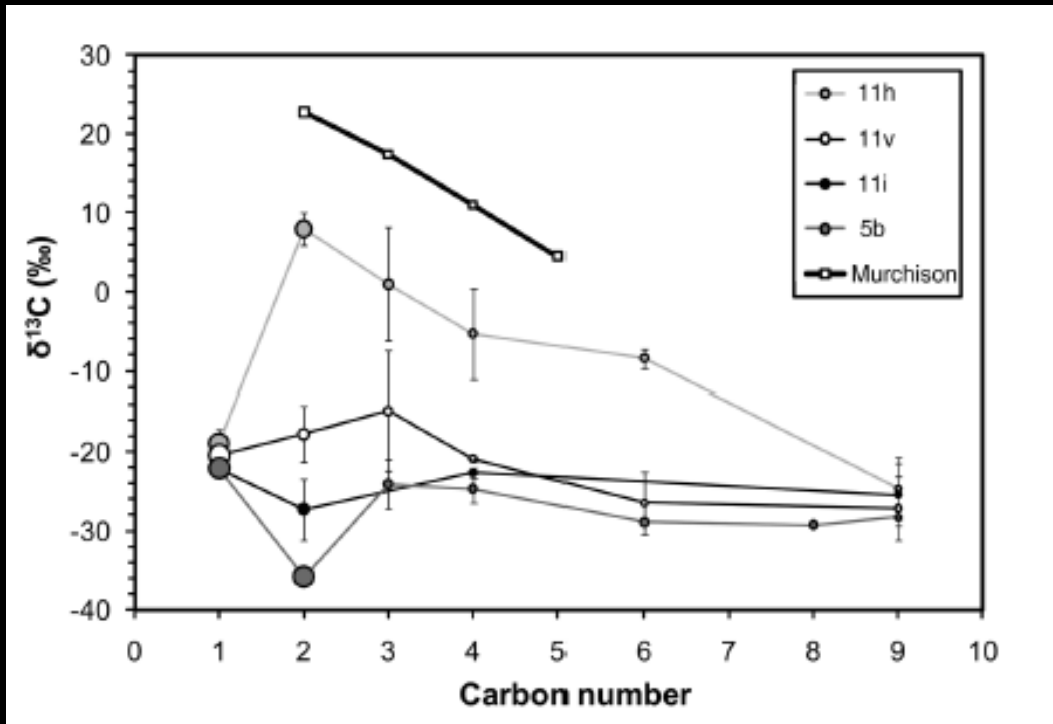
- Fell Jan. 18, 2000
- Specimens collected from frozen surface of lake on Jan 25 and 26
- Curated at U of Alberta, ROM
- Never thawed
- Ungrouped carbonaceous chondrite, rich in organic carbon
- Herd et al Science 2011



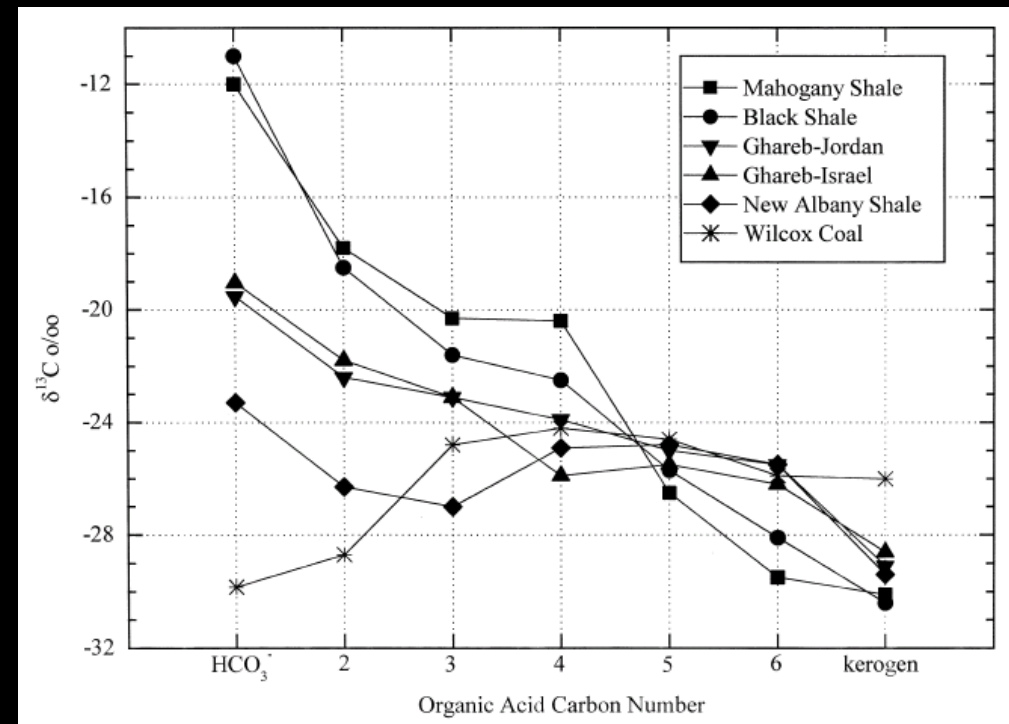
# Results – Bulk IOM



# Tagish Lake: Monocarboxylic Acid isotopes



Herd et al Science 2011



Franks et al GCA 2001

$\delta^{13}\text{C}$  MCA suggesting exchange of carboxyl carbon observed in some oil prone source rocks on earth

What does this tell us about parent body/planet formation, conditions and characteristics of organics delivered to planets?

# Tagish Lake Collaborators

**Chris Herd, Sasha Blinova and Danielle Simkus**

Earth and Atmospheric Sciences

**Don Morgan**

Chemistry

University of Alberta

**Robert Hilts**

MacEwan University

**Larry Nittler, Conel Alexander, George Cody**

Carnegie Institution of Washington

**Greg Slater**

McMaster University

**Yongsong Huang**

Brown University

**Jason Dworkin and Danny Glavin**

NASA GSFC



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INSTITUTION FOR  
**SCIENCE**



**MACÉWAN**

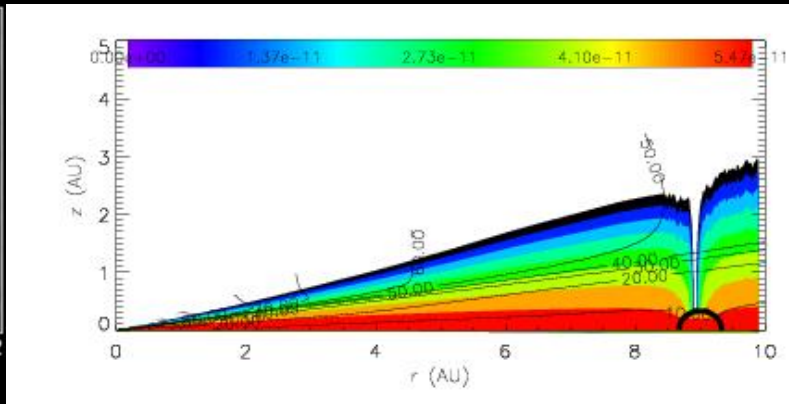


# Planetary Systems development & Life: Pudritz

- Constraints on planetary formation, formation of organics and relationships to host stars
- Implications for evolution of planetary atmospheres, physical and chemical properties, delivery of chemicals to planets and potential habitability
- How rare/common are Earth-like planets?



Edge-On Protoplanetary Disk  
Orion Nebula  
HST · WFPC2  
PRC95-45c · ST ScI OPO · November 20, 1995  
M. J. McCaughrean (MPIA), C. R. O'Dell (Rice University), NASA

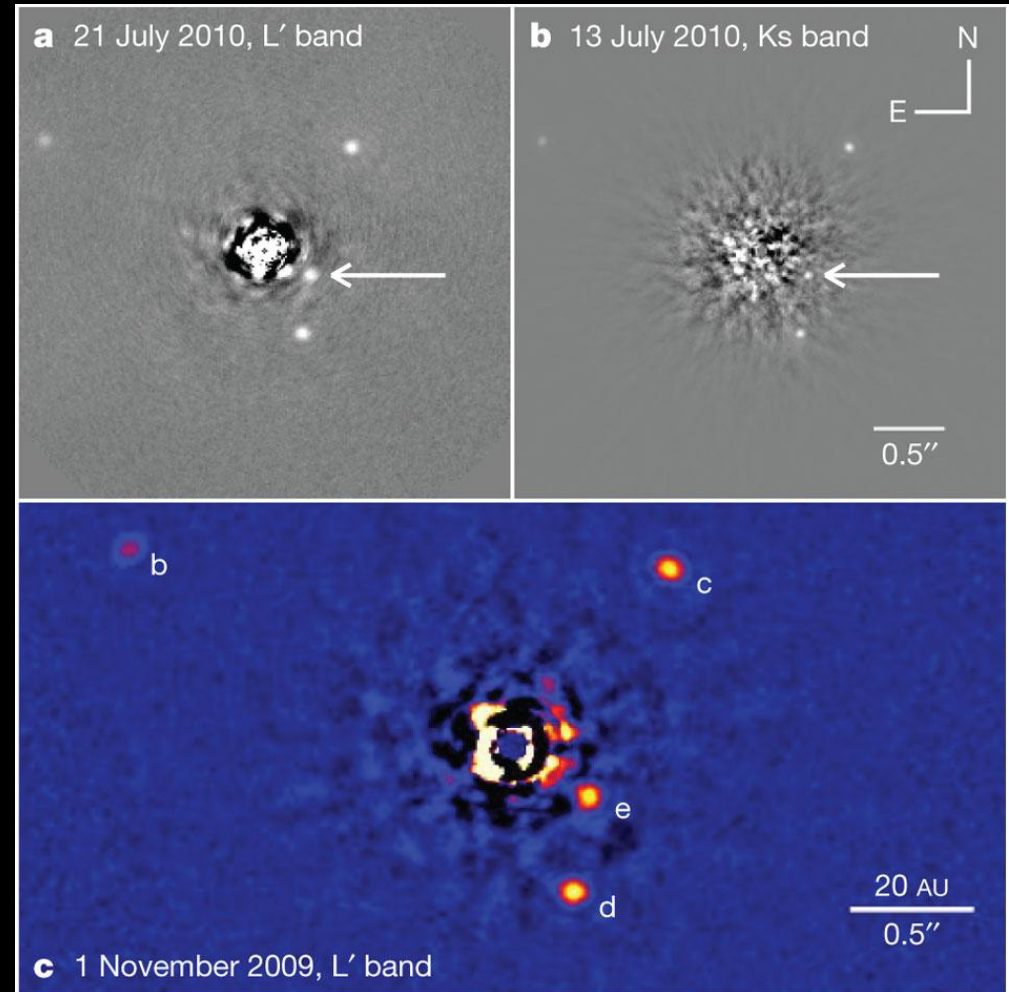


Courtesy. R. Pudritz, McMaster

Courtesy. R. Jayawardhana, U of Toronto

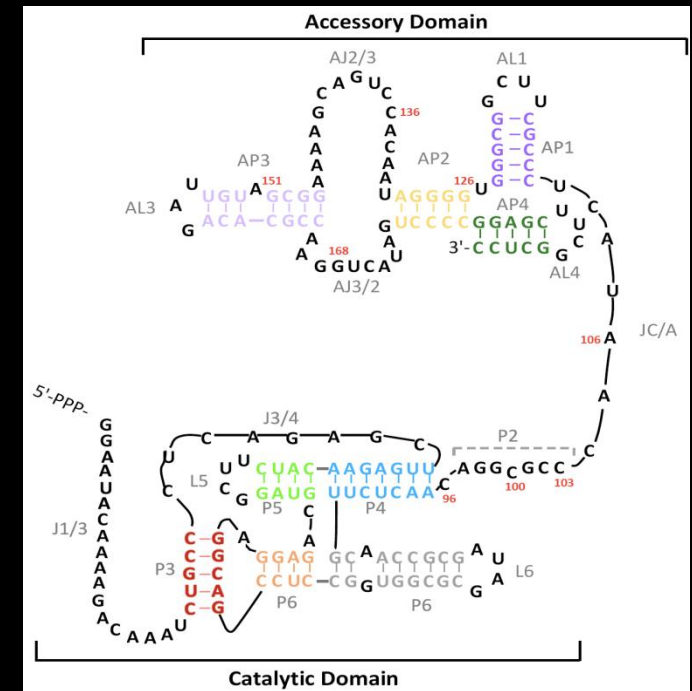
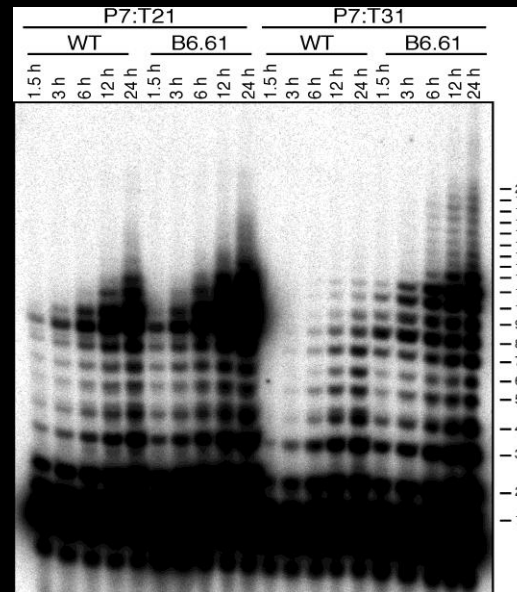
# Imaging of exoplanets

- C. Marois et al Science 2010 (Herzberg)
- R. Doyen (U. de Montreal)
- R. Jayawardhana (Toronto)
- J. Graham (Dunlap Institute)
- J. Matthews (UBC)



# Building an RNA replicator from scratch

- Act of creating life has to be a chemical event
- Achieving minimum level of complexity?
- Then mechanisms to preserve and replicate complexity?
- Building blocks of that intermediate step between prebiotic chemistry and RNA?



Selecting an RNA polymerase ribozyme with the potential to copy an RNA strand its own length. Current world record, 20 nt of extension (Zaher and Unrau, 2007), 1/10 of the way there!

# Summary and final thoughts

- Astrobiology in Canada is active across a wide range of topics from astrophysics and planet detection, through planetary science, earth science, to microbiology and instrument development and testing
- Research group topics include:
  - Analogue environment research
  - Biosignatures/geobiology
  - Abiotic hydrocarbons/serpentinization
  - Cryosphere research
  - Astromaterials
  - Exoplanets
  - Planetary science

# Summary and final thoughts

- Number of Canadian researchers involved in astrobiology research is increasing thanks to programs from CSA, CIFAR and NSERC funding
- Many researchers have close ties/involvement with US colleagues including NAI programs
- Identifying ways to take the next steps in building Canadian Astrobiology research activities