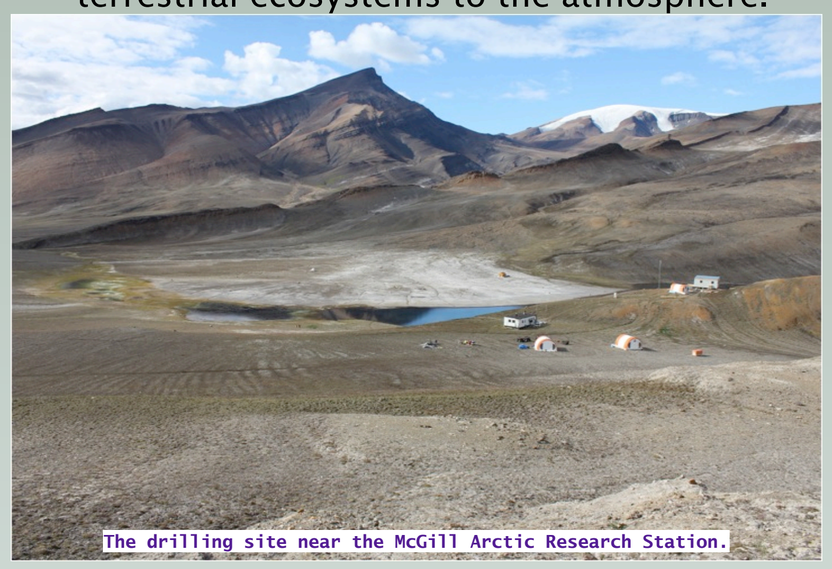
The Purpose

- Permafrost underlies about 22-24% of the Earth's surface.
- Global climate models project the strongest future warming in the Northern Hemisphere high latitudes.
- Thus, thawing permafrost and the resulting microbial decomposition of previously frozen organic carbon (C) is one of the most significant potential feedbacks from terrestrial ecosystems to the atmosphere.



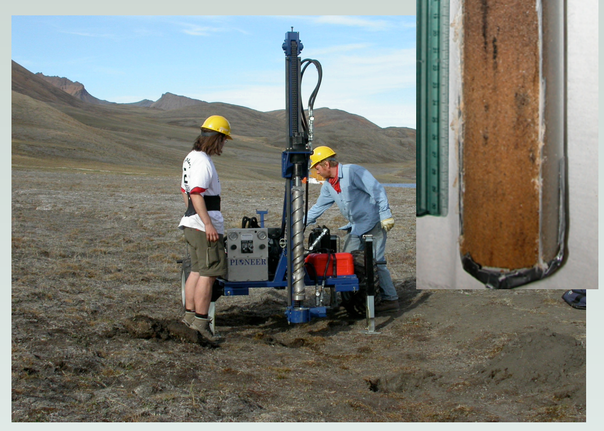
The drilling site near the McGill Arctic Research Station.

- There have been predictions that the decomposition of permafrost organic C will produce a significant feedback to global warming on a century timescale.
- These estimates are based upon experiments performed at 30°C, not performed on permafrost materials and based upon homogenized samples, not intact active-layer/ permafrost.

The location of the McGill Arctic Research Station where the core samples are taken.

- CH_4 has 25 times more greenhouse warming potential than CO_2 on a century timescale.
- Increases in factors leading to deglaciation were followed by a rise in atmospheric CH_4 originating from permafrost.
- The concentration of atmospheric CH_4 appears to have risen over the last two years after a decade of stability.
- This increase may be related to unusually warm summers in Siberia, which harbors the largest reservoirs of permafrost C.

- Part of this study relies upon understanding the rate at which individuals in the microbial community in the permafrost samples ingests the organic carbon.
- The community will be divided by type onto a RNA/DNA microarray. Each microbial type will be fluorescently tagged.
- The microbes will be fed a carbon substrate doped with ^{14}C.
- ^{14}C decays via beta decay.
- Our apparatus will detect the fluorescent light from the tags as well as the electrons emitted from the beta decay.
- **This has never been done in a single step process.**



(below) The drilling in action.
(above right) A core sample.

Our goal is to develop an apparatus that will read RNA/DNA microarrays and observe both the fluorescent tags from the samples and the electrons emitted from the ^{14}C beta decay. Each sample of RNA is distributed among wells that are 100×100×20 m^3. The samples are imaged with a cooled EMCCD camera and a wide-band fluorescence microscope. We propose altering a microscope configuration to include sensitivity to electrons from the beta decay .

SLIMER
Scintillator-Layered Imaging Microscope for Environmental Research

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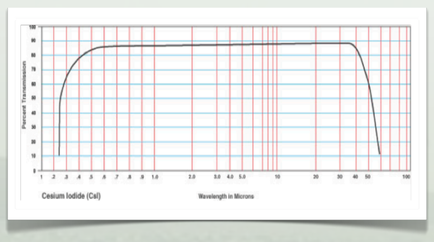
The Scintillator

- CsI(Tl) is a very commonly used scintillation material.
- It has a high light output of about 65 photons/keV.
- In ^{14}C beta decay, the end-point energy of the electron energy spectrum is 156.475 keV, and the mean energy of the emitted electrons is 49.47 keV.



(above) The CsI(Tl) transmission spectrum.
(below) SEM picture of columnar structure.

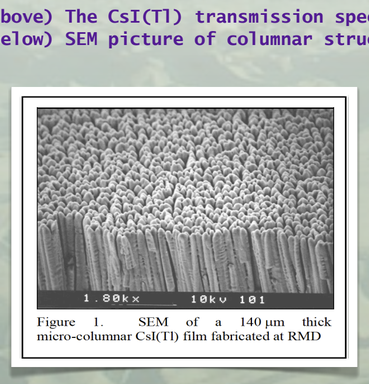
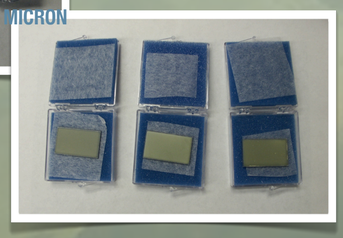
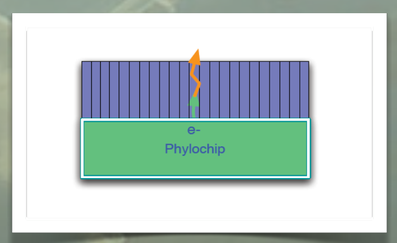


Figure 1. SEM of a 140 µm thick micro-columnar CsI(Tl) film fabricated at RMD

- The transmission spectrum for CsI(Tl) is broad and includes many common excitation and emission frequencies, so that the fluorescence should not be drastically affected.
- The emission spectrum is peaked around 550 nm, so the choice of fluorescent dye must take this into consideration.
- When grown on a substrate with a structure the CsI(Tl) forms columns which channel the light.
- The columnar CsI(Tl) is grown by vapor deposition; the columns are 3-5 µm in diameter.
- The advantage of columnar CsI(Tl) lies in the channeling of the scintillation light, resulting in better position determination.





(left) The CsI(Tl) samples in-hand in 3 thicknesses. (right) A drawing showing the channeling of the scintillation light from the beta-decay electron.

The System

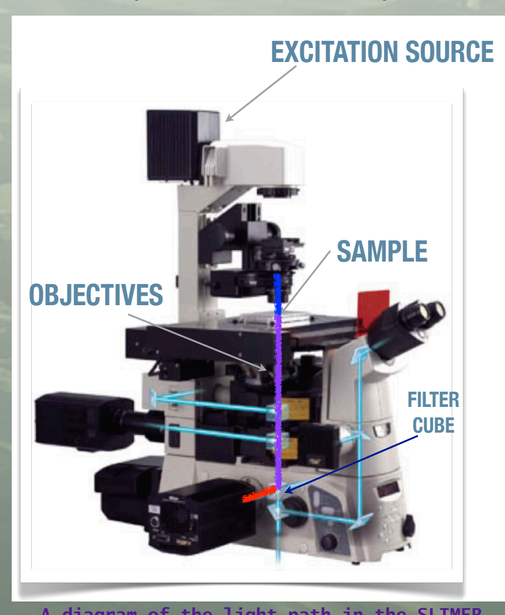
- We have purchased a Nikon Eclipse Ti Inverted Research Microscope.
- The objectives used in the camera have a high (>85%) transmission rate.
- The Semrock filter cube was also selected for its very high (>95%) transmission rate.
- We have also purchased a Photometrics Evolve- 512 EMCCD Camera.

The microscope and EMCCD camera (inset).

Component	Transmission (%)	Number of Photons (per 14C Decay)
Initial Production	N/A	3215
Solid Angle in CsI (Tl)	~50	1608
CsI(Tl)	88	1415
Objectives	85	1203
Filter Cube	95	1143
Vacuum Window	95	1086
Camera QE	~97	1053

A study of the light loss in components of the SLIMER system.

- The fluorescent tags will first be excited by the source in the microscope. This light will be detected by the EMCCD camera, revealing locations of different microbial types.
- A long period of collection will then be performed with no excitation light. This will reveal at what sites ^{14}C is present.
- Because the amount of ^{14}C ingested by the permafrost microbial community is unknown and probably small, a low rate of beta decay from the sample is expected.
- We are therefore especially concerned about the amount of light getting through to the EMCCD camera.



A diagram of the light path in the SLIMER system. The blue line represents the excitation light. The purple line is the combination of the excitation and emission light, and the red line represents the filtered emission light after passing through the filter cube.