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Accelerator Mass Spectrometry

AN ANALYTICAL TOOL WITH APPLICATIONS FOR A SUSTAINABLE SOCIETY

William E. Kieser

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André E. Lalonde AMS Laboratory and Department of Physics, University of Ottawa

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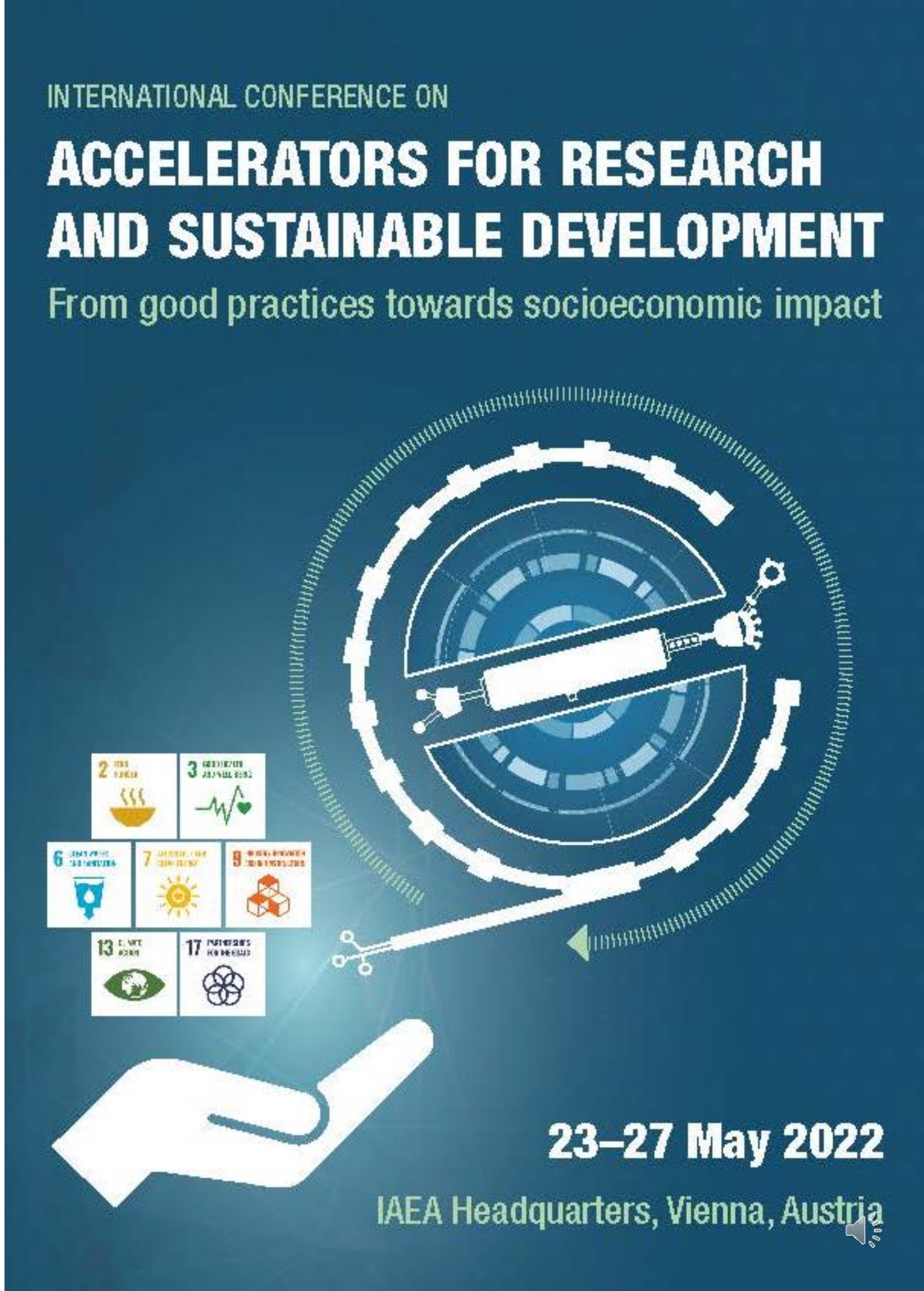
(contact-Liam.Kieser@uottawa.ca)



Accelerator Mass Spectrometry (AMS)

an Analytical Tool that Provides Applications
to Enable Sustainability in our Society

Overview

1. Why do we need AMS? – *requirements and some general applications*
2. How does AMS achieve its capability? – *principles and challenges*
3. Sustainability in AMS technology – *is smaller better? – specific design*
4. Application Example 1: *Carbon cycling in the ocean*
5. Application Example 2: *Monitoring of Remediation of Hydrocarbon Spills*

AMS – *Why was it developed?*

- Emerging need for greater sensitivity than in existing techniques, initially in the Earth and Environmental Sciences and Archaeometry, later in the bio-medical and materials sciences.

- Requirement: to measure rare isotopes *(stable or radioactive)*
  - at very low concentrations *(typically 1 part in 10^{12} – 10^{15})*
  - in small samples *(0.01 to 1.0 mg) of* natural materials

- From its beginnings in 1977, the number of AMS labs has spread rapidly so that ~160 are operating across the world today

AMS – *Challenges*

- Very low concentrations *(typically 1 part in 10^{12} – 10^{15})*

- ***Challenge*: isobars.** At this level of sensitivity, other atoms or molecules which have the same mass can arrive at the detector.
- **Solutions: *work with negative ions (anions), use high energies to break up molecules*** *(or remove isobars with selective low-energy ion-gas or ion-photon reactions)*

- Small samples *(0.01 to 1.0 mg) of* natural materials

- ***Challenge:* ion beam current:** rare isotopes need to be measured at the same time as more abundant ones – up to or greater than 10^{14} times as many.
- **Solutions: use very powerful negative ion sources –** *10s to 100s of µA,* Use molecular anions *if atomic ones don't provide enough current.*

Some Typical Applications of AMS

- ***Chronology*: Measure radioactive isotopes - *match the half-life to the time range needed*** – *for example:*
  - *^{10}Be (1.5 x 10^6 y), ^{14}C (5730 y), ^{26}Al (7.4 x 10^5 y),*
  - *^{36}Cl (3 x 10^5 y), ^{129}I (1.6 x 10^7 y) . . .*
  - *^{236}U (2.3 x 10^7 y), ^{238}U (4.5 x 10^9 y)*

- **Tracing: following the paths of specific chemicals through complex systems:** *e.g. plant or human metabolism, ocean circulation, environmental carbon cycling*

Some Typical (and Some Less Usual) Applications of AMS

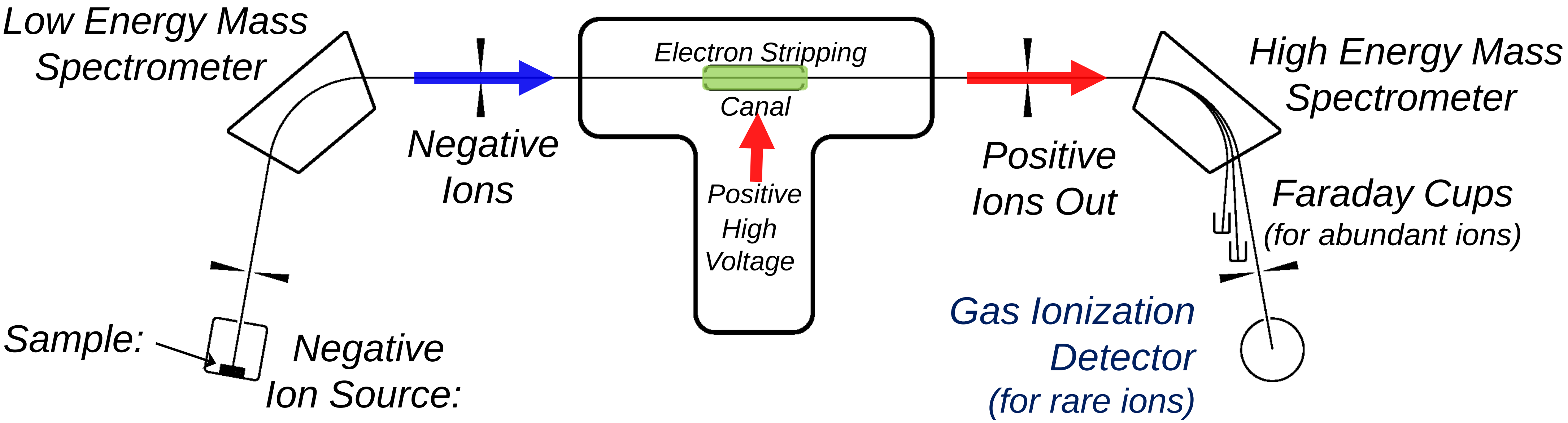
- **Earth Surface Evolution: Landslide frequency and probability, earthquake frequency** *(^{14}C, ^{10}Be, ^{26}Al, ^{36}C)* **, tectonic movement** *(^{129}I)*

- **Hydrocarbon Spill Remediation: tests of effectiveness of bio-remediation techniques** *(^{14}C)*

- **Materials Characterization: analysis of radiopurity of materials for**
  - semi-conductors
  - ultra-sensitive detectors for AstroPhysical observations: e.g. Searches *for Dark Matter*

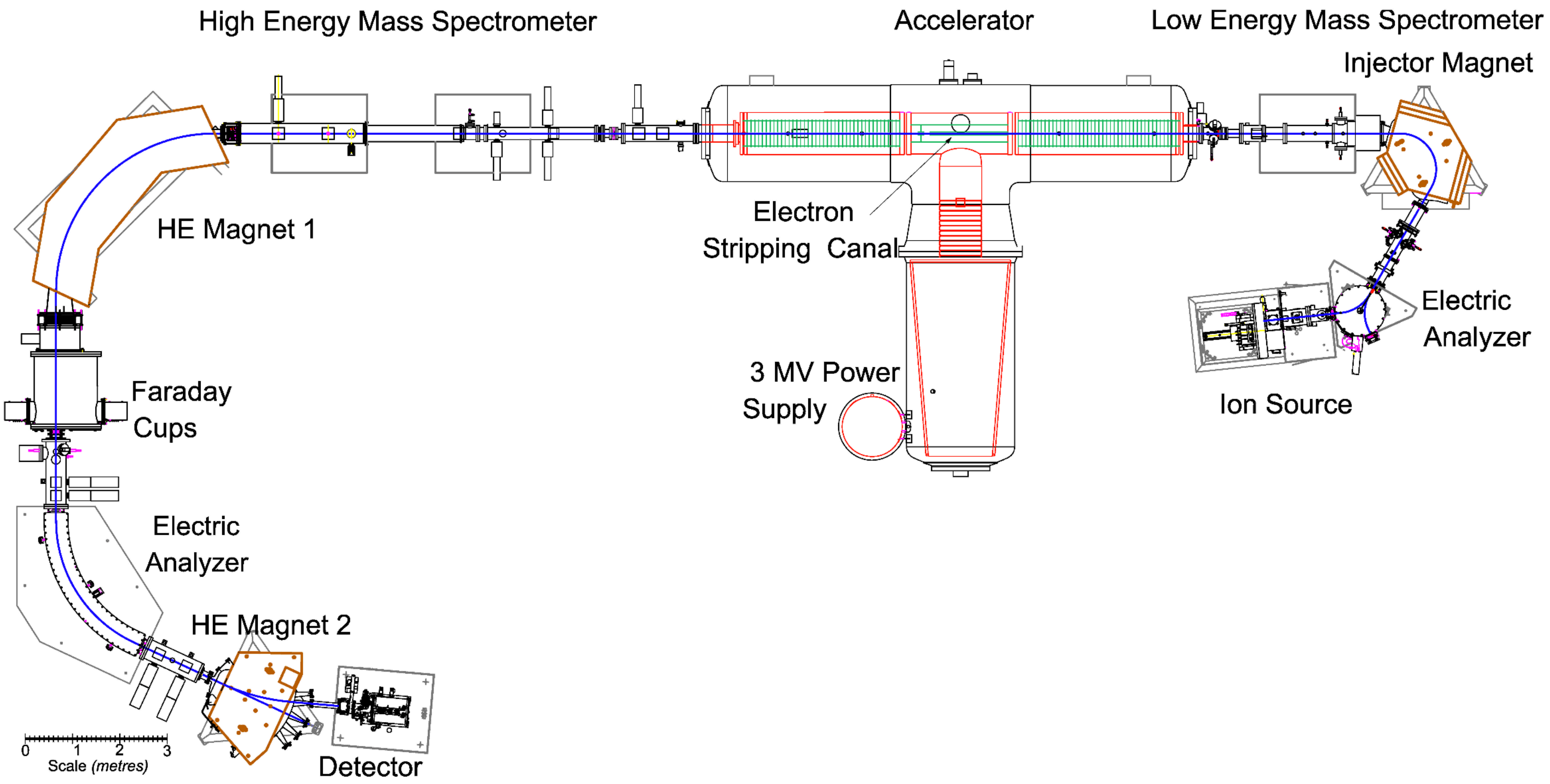
AMS Systems – Basic Parts

- Except for Radiocarbon analyses, most AMS systems use a tandem electrostatic accelerator.



- ***Electron Striping Canal –*** breaks up molecules by removing binding electrons.
- ***Gas Ionization Detector:*** Single atom counting ability with extremely low noise.

Of course, it's never all that simple . . . .



Sustainability in AMS Technology

- **Manufacturers are now building smaller AMS systems:**
  - tandem accelerators with lower terminal voltages e.g. 200 or 300 kV
  - single ended systems (either the low energy or the high energy spectrometer on a high voltage platform)

  These have much smaller space and power requirements

- **In larger systems, magnets typically consume the most power** *(more than the accelerator)*

  Systems built for specific isotope analysis (e.g. ^{14}C), can use permanent magnets with a small coil for minor adjustments

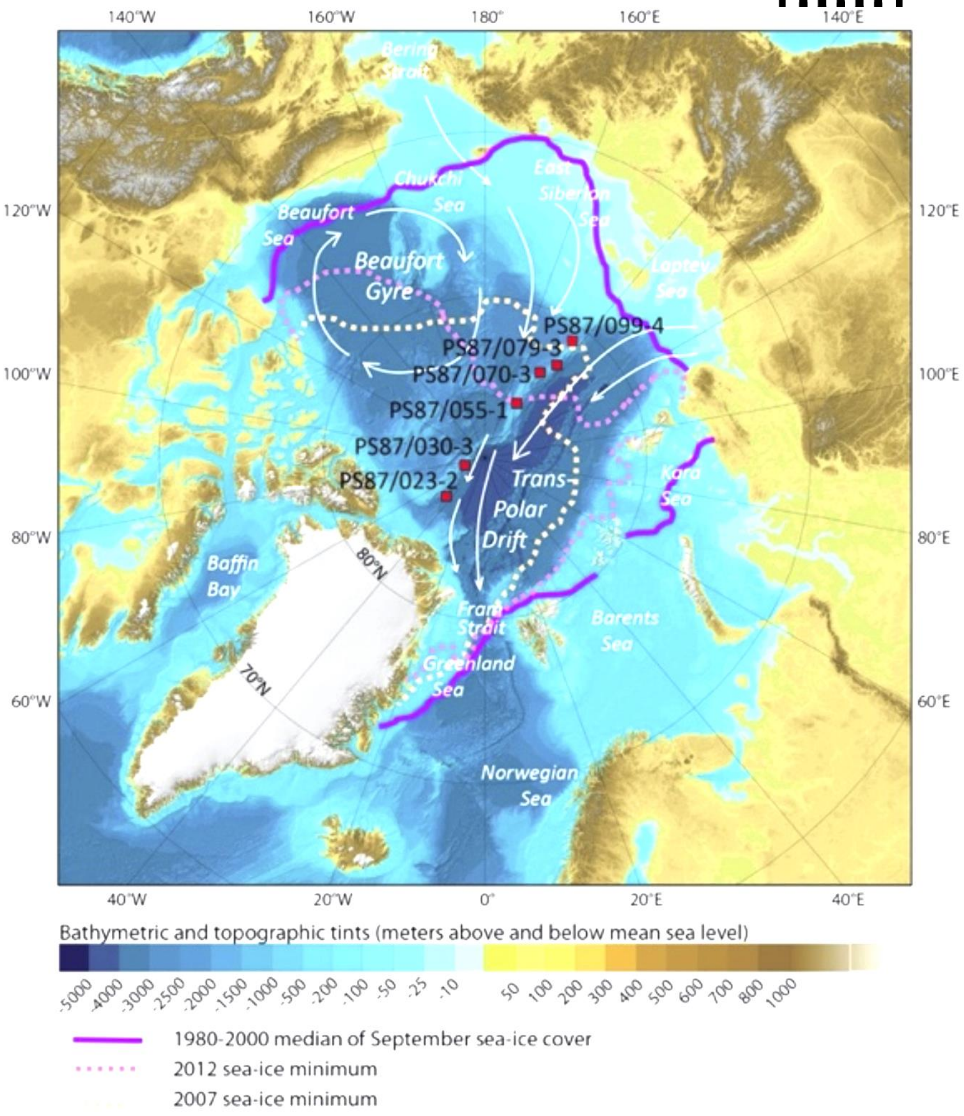
- **. . . an example of a ^{14}C system recently installed in our lab**

A Single Isotope System for ^{14}C

High Energy Permanent Magnet during assembly

Application 1: *Carbon in the Arctic Environment.*

- **Arctic regions have experienced 2x the global increase in average temperatures –** *resulting in a "two-edged sword" for carbon storage / emission*
- **On-going studies of carbon in the water column** *(Walker, uOttawa)* **and sediments** *(de Vernal, UQAM)* **already providing information about the region's response to previous climate changes.**
- **The small sample AMS capability will enable Compound Specific Radiocarbon Analysis (CSRA) –** *provides information about the origin of the carbon in the sampling locations.*
- **CSRA also helps to understand and model carbon released from permafrost melting –** *in historical and current events.*



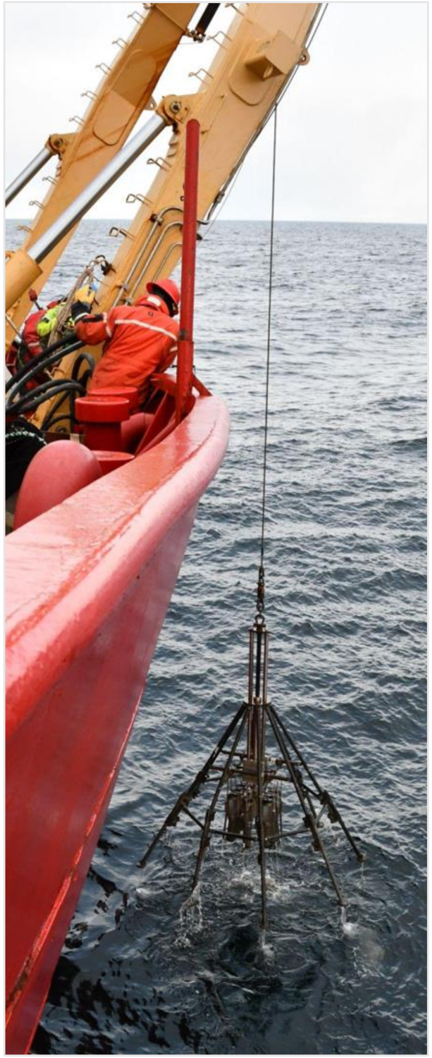
Recent Arctic Sampling Cruise *

* uOttawa *Graduate Student L. Jasperse*

Oceanographic Sampling Equipment *(used on recen cruise)*

Water Column Sampling – Rosette

Sediment Sampling – Corer



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Application 2 – *Bio-remediation of hydrocarbon spills* *

1. **Microbes are "designed" and used to break down toxic hydrocarbons into more benign components – and release some CO_2 in the process.**
   But are they "eating" the hydrocarbons of interest or a layer of forest fire debris?

2. **Soil gases can be sampled through a filter bed of $Ba(OH)_2$. CO_2 reacts with the $Ba(OH)_2$ and produces $BaCO_3$.**
   The quantity of ^{14}C in the CO_3 indicated the source of the "food" for the bacteria.

3. **Filter cartridges are loaded with $Ba(OH)_2$ in the lab and are use by commercial operators to test remediation sites.**

4. **Exposed filter cartridges are returned to the AMS lab and are analyzed using an automated Carbonate Handling System connected directly to the AMS ion source**

* Project by uOttawa M.Sc student Lindsay Shaw

Summary

- For almost 45 years, AMS has provided highly sensitive isotope analyses for Earth, environmental, archaeometric, bio-medical and materials sciences.
- New AMS systems and techniques are being developed which require less energy, space and sample preparation time.
- Applications continue to be developed which are making an impact on research that is important for the sustainability of our society.

Thank you

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