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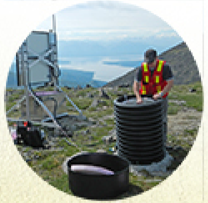


Geological Survey of Canada
Scientific Presentation 125

Public presentations May 11, 2021: Environmental Geoscience Program, current status of research projects for the 2019-2024 program cycle

N. Jacob, J. Jautzy, H. Kao, C. Rivard, J.M.E. Ahad, P.R. Gammon, P.M. Outridge, J.M. Galloway, A.J. Desbarats, M.J. Duchesne, M. Bringué, and D. White

2021

Canada

Public presentations May 11, 2021: Environmental Geoscience Program, current status of research projects for the 2019-2024 program cycle

Date presented: May 2021

Permanent link: https://doi.org/10.4095/328455

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Publications in this series have not been edited; they are released as submitted by the author.

Environmental Geoscience Program (EGP)
Presentation of research status for 5 out of 14 projects in 2020-2021

The goal of the EGP is to distinguish the environmental effects of natural resource development from those produced by natural processes, and to develop new approaches to support the sustainable use and development of Canada's natural resources through informed decision-making.

The ultimate outcome of EGP is to increase the effectiveness and efficiency of Canadian environmental regulation and oversight. In developing innovative geoscience for environmental stewardship, as well as increasing public and private sector access to research findings, decision-makers have a greater capacity to carry out and review environmental assessments.

Due to the pandemic, research advancement occasionally faced delay due to laboratory closure and lack of fieldwork access. Nevertheless, the advancement of projects are documented herein and via the EGP YouTube account. The presentations that were recorded during the public presentations via Zoom on May 11, 2021 are available via the following link: https://www.youtube.com/channel/UCWiCrKnTeF-j_La6_Wc5NMA

Key words: *Clumped isotope geothermometry, induced seismicity, aquifers impacts, diluted bitumen (Dilbit), oil sands modeling, marine oil spill, Mackenzie River Basin, climate change, global mercury budget, geological storage of carbon, cobalt, cumulative effects, permafrost degradation, permafrost geochemistry and regional assessment.*

Environmental Geoscience Program (EGP)

Due to time constraints only 5 projects were publicly presented on May 11, 2021.

The following decks are the advancement of all Geological Survey of Canada research projects under the Environmental Geoscience Program but were not presented to the public on May 11, 2021.

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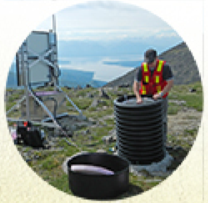



Development of automatized clumped isotope measurements on dolomite for improved characterization of paleofluids in sedimentary rocks

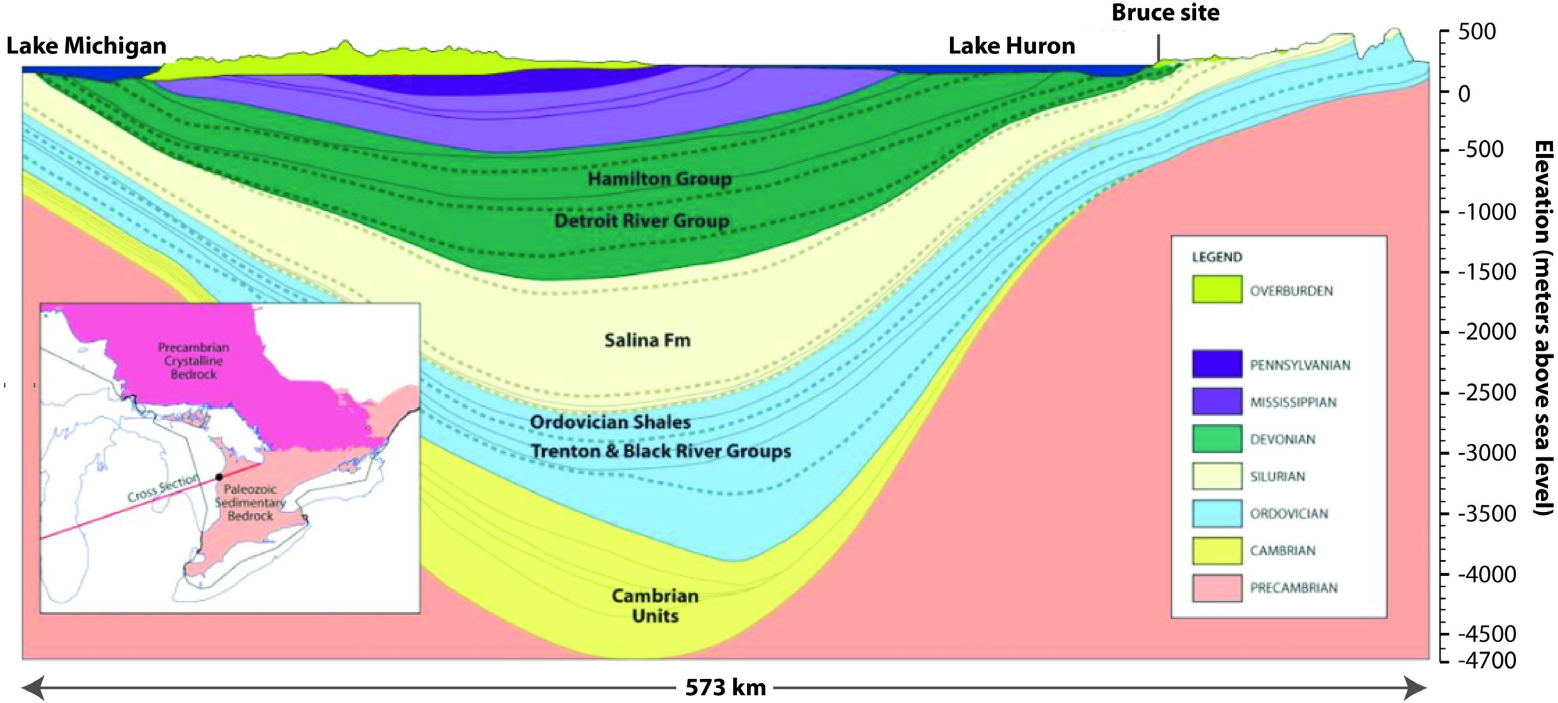
J.J. Jautzy, B. Fosu, T. Al[1], I. Clark[1]

[1] University of Ottawa

2021

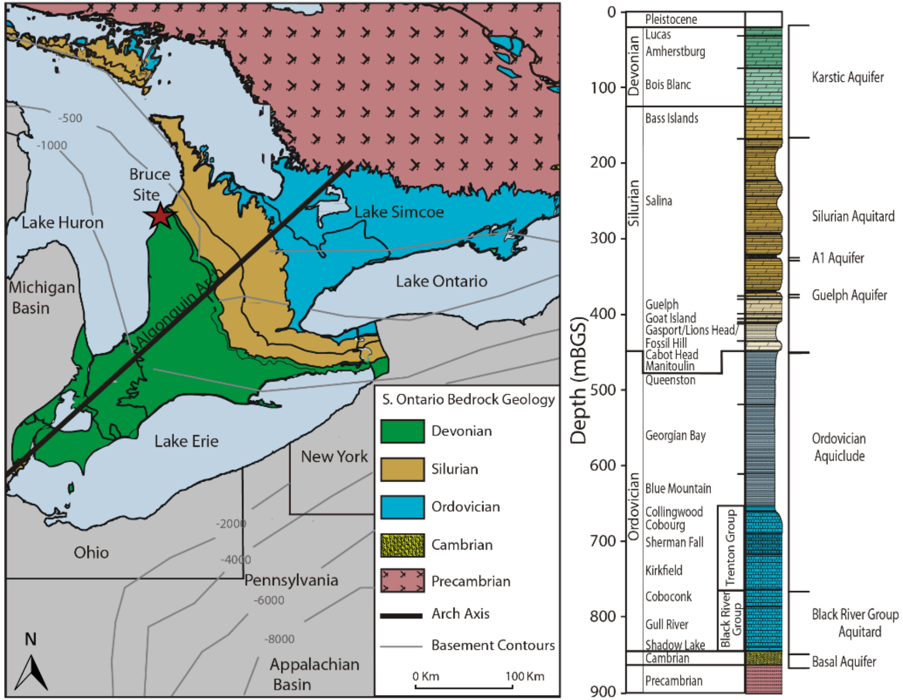
Canada

Context



(Intera Engineering Ltd. 2011)

Hydrostratigraphy



Ontario Geological Survey (1991); Armstrong and Carter (2010); Al *et al.* (2015)

$K_h 10^{-8}$-10^{-4} m s^{-1}

$K_h 10^{-14}$-10^{-8} m s^{-1}

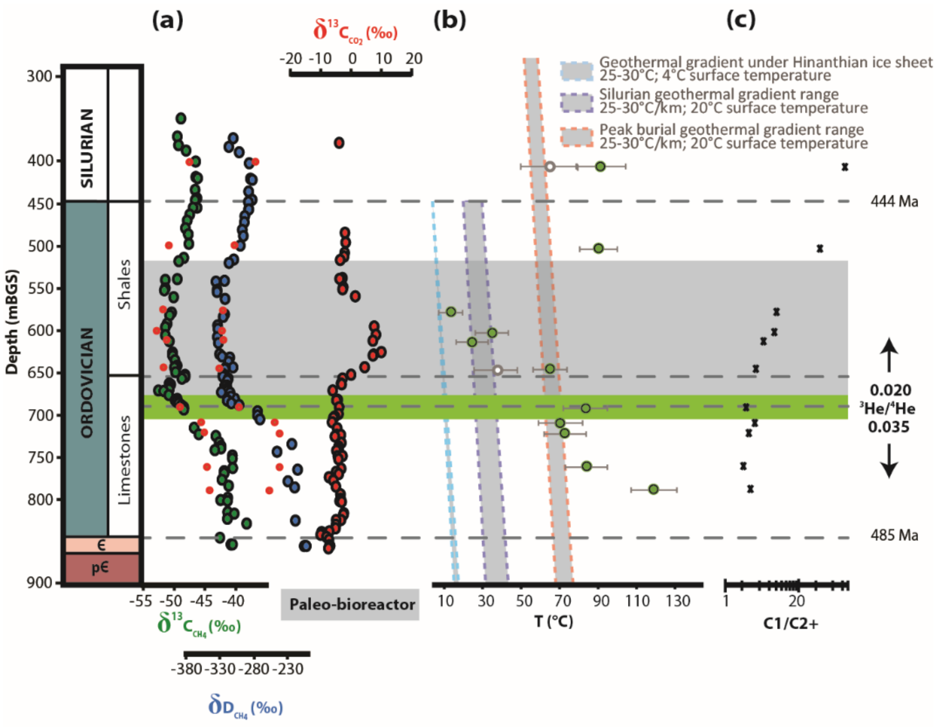
$K_h 10^{-16}$-10^{-14} m s^{-1}

$K_h 10^{-12}$-10^{-10} m s^{-1}

$K_h 10^{-6}$ m s^{-1}

Very low hydraulic conductivity aquiclude in Ordovician shale and limestone

Previous work

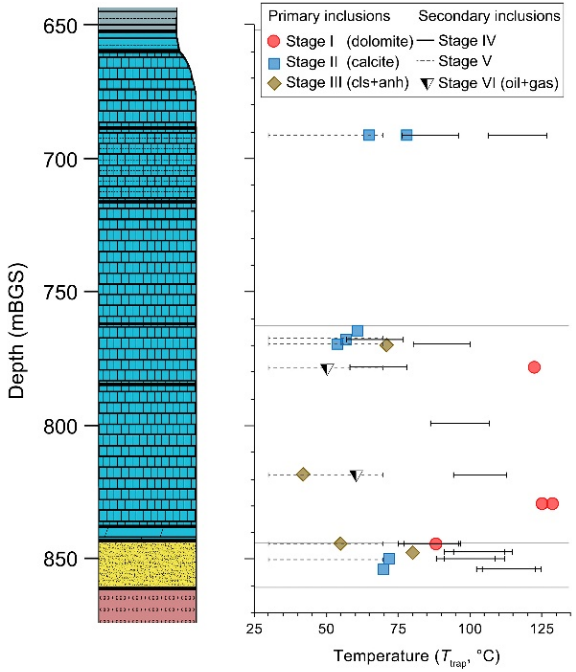


Clark *et al.* (2013, 2015) Jautzy *et al.* (2018, 2021)

Mainly 2 systems:

- Extremely tight aquiclude confined for at least 260 m.y.
- Lower system with a complex paleofluid history.

Previous work



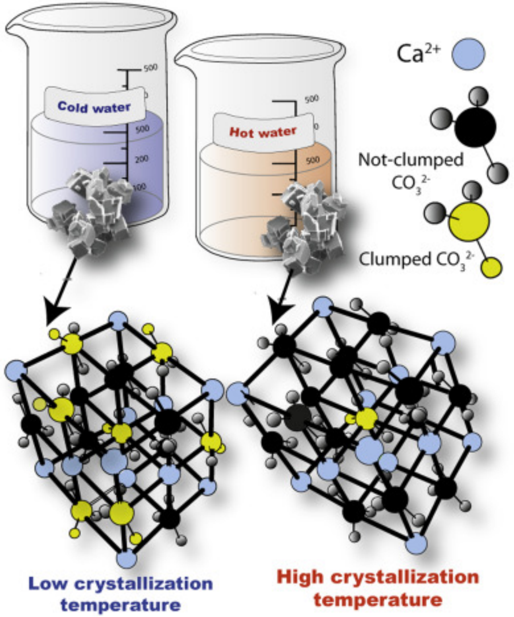
Petts *et al.* (*2017*)

Mainly 2 systems:

- Extremely tight aquiclude confined for at least 260 m.y.
- Lower system with a complex paleofluid history.

Isotopic Clumping on Carbonates: Δ_{47}

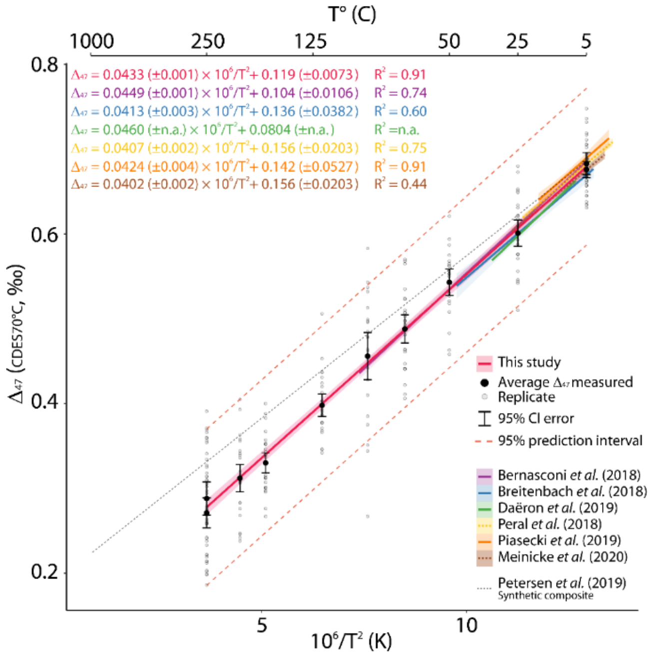
Performances	KIEL IV
Sample mass requirement	0.6-1.2mg (*n*=10-20)
Analytical throughput	138 replicates/week
Long term stability/precision	SD=35ppb SE=2.5ppb (*n*=200)
Temperature uncertainty	Low T (0°C) ±2°C High T (200°C) ±8°C

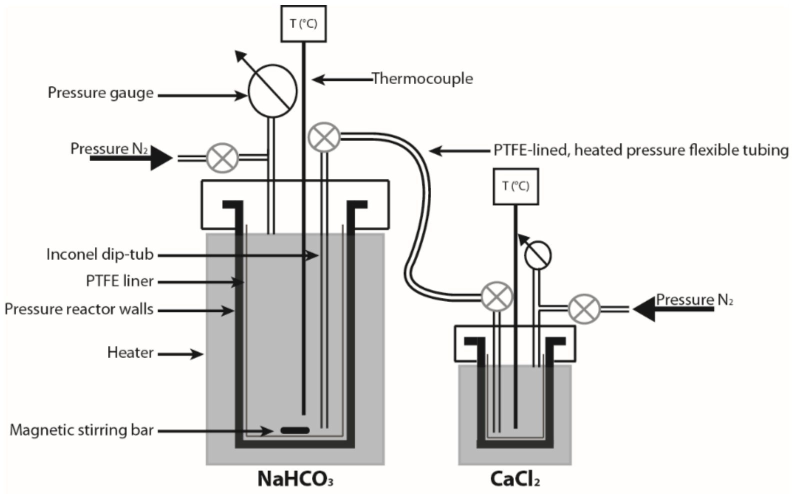


Mangenot *et al.* (2017)

A single phase geothermometer

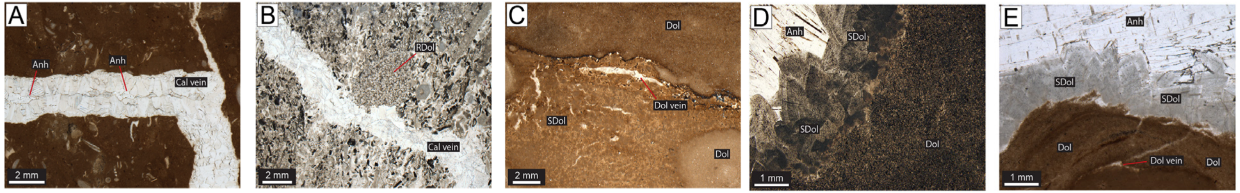
R&D: From Calcite to Dolomite





Jautzy *et al.* (2020b)

Application



Petts *et al.* (*2017*)

Δ_{47} on co-localized dolomite and calcite phases to provide:

1) additional information on the temperature history of the sedimentary package;

2) information on the paleo-temperature where fluid inclusions are absent;

3) further investigation of the effect and extent of the suggested conductive heating (i.e. attributed to the reactivation of the mid-continent rift) on the sedimentary rocks in southern Ontario.

Acknowledgments

- Laura Kennell-Morrison (NWMO)

Contact Information

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Thank you!

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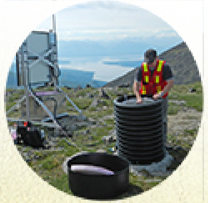



Geological Survey of Canada

Induced Seismicity Research Project:
Highlights of Accomplishments in 2020-2021

Projet de recherche sur la sismicité induite :
Faits saillants des réalisations en 2020-2021

H. Kao

2021

Canada

ABSTRACT

The Induced Seismicity Research (ISR) project has a national scope with team members from NRCan offices in Sidney, Ottawa, and Quebec City. The Project establishes close collaboration with both public and private sectors, including provincial and local governments, crown corporations, professional organizations, and academia, to address critical knowledge gaps in the source process of induced earthquakes and to provide observation-based science to improve regulations on the development of unconventional hydrocarbon resources.

Key accomplishments during 2020-2021 include:

- Adoption of research results into the regulatory framework of induced earthquakes in BC;
- Publications of research results on source characteristics of significant induced earthquakes in western Canada;
- Development of innovative methodologies for detection and location of repeating earthquakes and precise earthquake focal depths;
- Enhanced injection-induced earthquakes (IIE) monitoring for major shale gas basins in BC and AB.

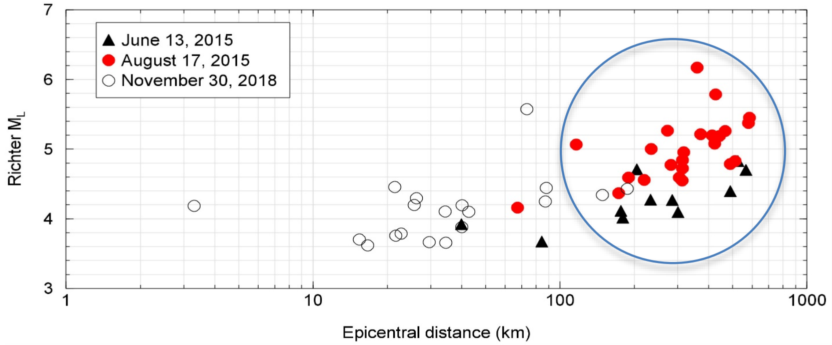
KEY PROJECT MEMBERS

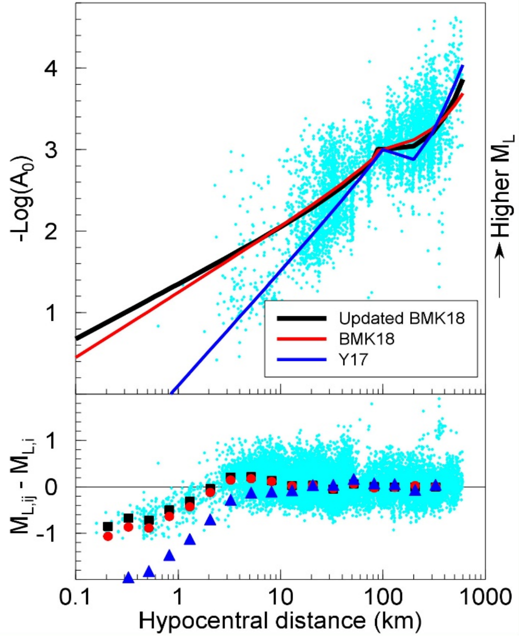
- GSC Research Scientists and Supporting Staff
  - Sidney: Honn Kao (Project Leader), John Cassidy, Ramin Dokht, Adebayo Ojo (NRCan PRP post-doc), Hongyu Yu (NRCan PRP post-doc)
  - Ottawa: Maurice Lamontagne, Don White
  - Quebec: Nathalie Jacob and Christine Laberge (admin support)
- GSC Research Associates and Supports
  - Alireza Babaie Mahani and Ryan Visser (scientists funded by Geoscience BC)
  - Bei Wang (PDF funded by Geoscience BC)
  - Dawei Gao, Ayodeji Kuponiyi, Jesse Hutchinson, Fengzhou Tan (UVic graduate students)
  - Chet Goerzen (UVic undergraduate student) and Jesse Acosta (co-op student)
  - Amir Farahbod (contractor and volunteer)

Recognition and Collaboration Highlights

- Publications Leading to Regulatory Changes
  - BC Oil and Gas Commission announced in Feb 2021 (Industry Bulletin 2021-05) that all regulatory decisions on induced earthquakes in BC will be made according to magnitude values calculated with the formula in *Mahani and Kao* (2018, 2020).
- External Research Resources
  - $154,800 from Geoscience BC in support of the routine operation of seismograph stations and injection-induced earthquake (IIE) research in NE BC.
  - $135K contributed by the BC Seismic Research Consortium in support of IIE monitoring in the WCSB.
- Densify Local and Regional Seismograph Coverage
  - McGill University, University of Victoria, University of Calgary, Ruhr University Bochum (Germany), Geoscience BC, BC Oil and Gas Commission (BCOGC) and Canadian Association of Petroleum Producers (CAPP)
- Joint IIE Research and Publications
  - McGill University, University of Victoria, University of Calgary, Ruhr University Bochum (Germany), Geoscience BC, and BC Oil and Gas Commission

New Magnitude Formula for Western Canada





- Original formula (Richter, 1935) systematically overestimates M_L when stations are >100 km away from the hypocenter.
- This discrepancy creates a confusing situation for the industry (whose private arrays are always close to the earthquake sources) and the regulators (who depends on NRCan's reported M_L values based mostly on distant stations).
- This study proposes a new formula specifically for western Canada to eliminate the discrepancy between M_L values derived from nearby and distant stations.

$$\begin{cases} 0.671 \times log\left(\frac{R_{hypo}}{100}\right) + 0.003 \times \left(R_{hypo} - 100\right) + 3.0 & R_{hypo} \leq 85 \text{ km} \\ -0.881 \times log\left(\frac{R_{hypo}}{100}\right) + 0.003 \times \left(R_{hyp} \;\; - 100\right) + 3.0 & R_{hypo} > 85 \text{ km} \end{cases}$$

Mahani and Kao (2018, 2020)

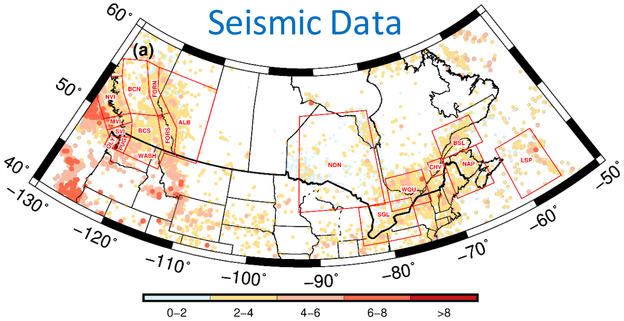
Reactivation of an Intraplate Fault by Mine-Blasting Events

- Regional seismicity is observed as far as 100 km from a mine-blasting site in central BC.
- We develop a multivariate decision tree to determine the causal relationship between these events and the local blasting activities.
- Many of the observed events align remarkably well with the Rocky Mountain Trench (RMT), suggesting a reactivated segment of an unmapped fault system.
- Seismic hazard can be significant if the entire 150-km segment ruptures during a major earthquake.

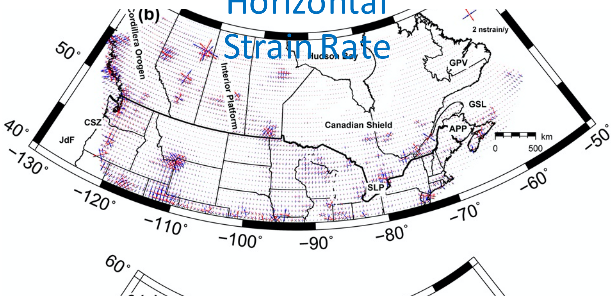
Dokht et al. (2020)

Strain Accumulation and Release Rate in Canada and Northern U.S.

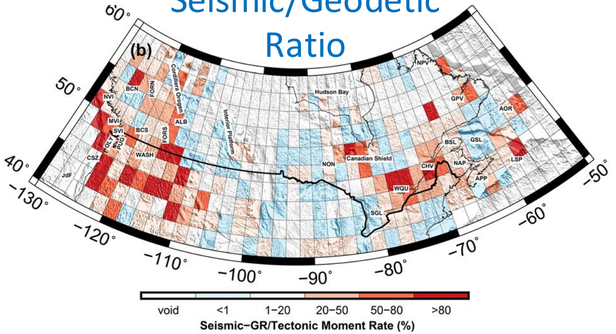
Seismic Data



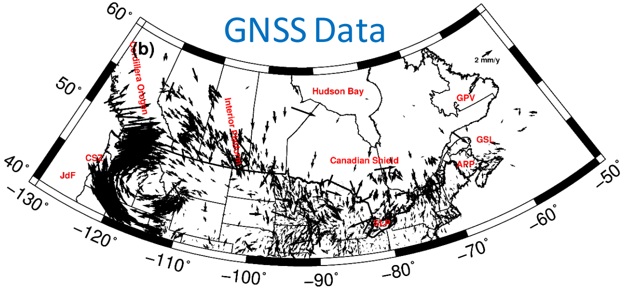
Horizontal Strain Rate



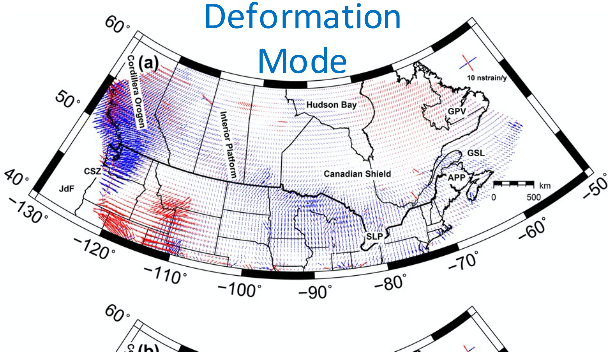
Seismic/Geodetic Ratio



GNSS Data



Deformation Mode

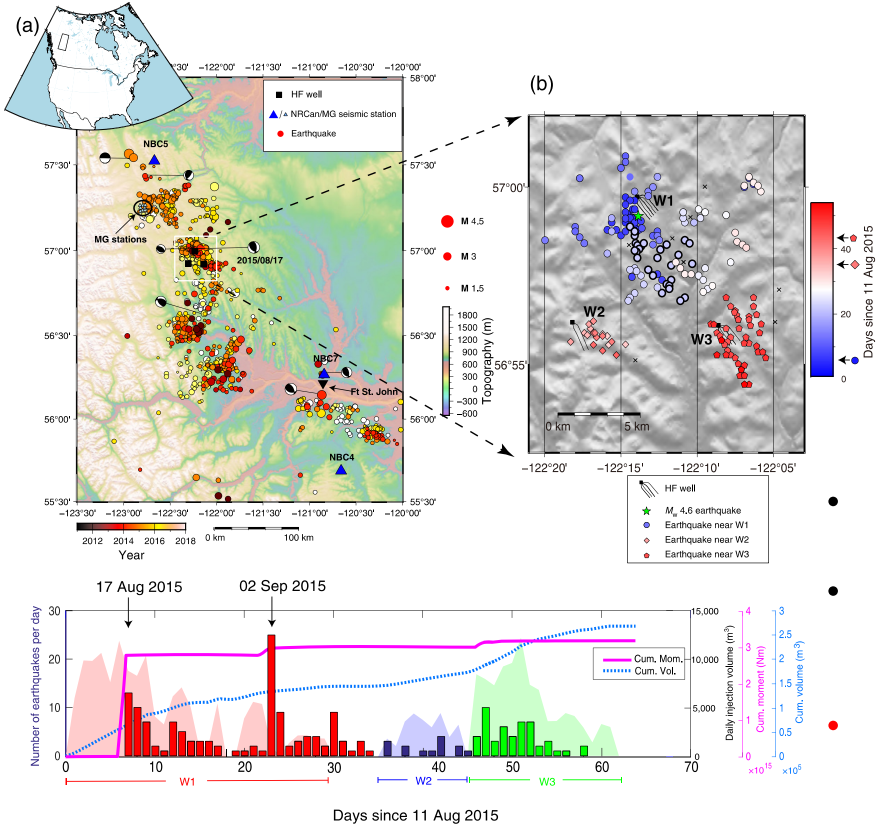


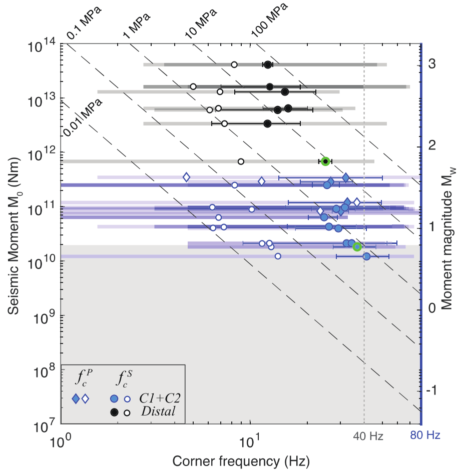
- <20% of tectonic energy is released seismically.
- Most of the difference can be explained by GIA* in east Canada.
- Recurrence interval of large earthquakes varies from decades near plate margins in the west to thousands of years in the stable continental interior.

* GIA = Glacial Isostatic Adjustment

Ojo et al. (2020)

Source Process of HF-induced Earthquakes in Western Canada





- The largest HF-induced event has a stress drop value comparable to that of tectonic events (1–35 MPa).
- It is most likely triggered by an increase of pore pressure associated with the migration of injected fluid, which also explains the ~5 day delay from the onset of HF.
- Events closer to HF site have smaller stress drop, probably due to higher fracture density and/or elevated pore pressure in the rock matrix.

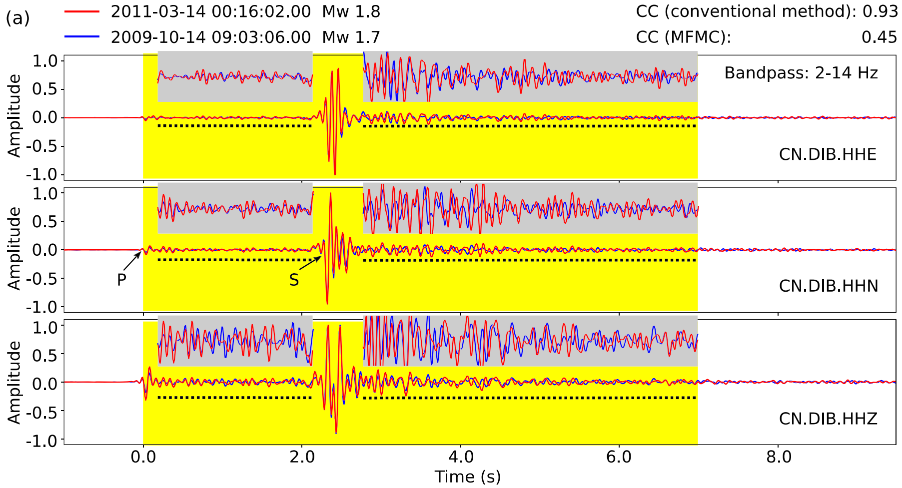
Wang et al. (2020, 2021); *Yu et al.* (2020)

Development of New Methodology to Identify Potential Repeating Events

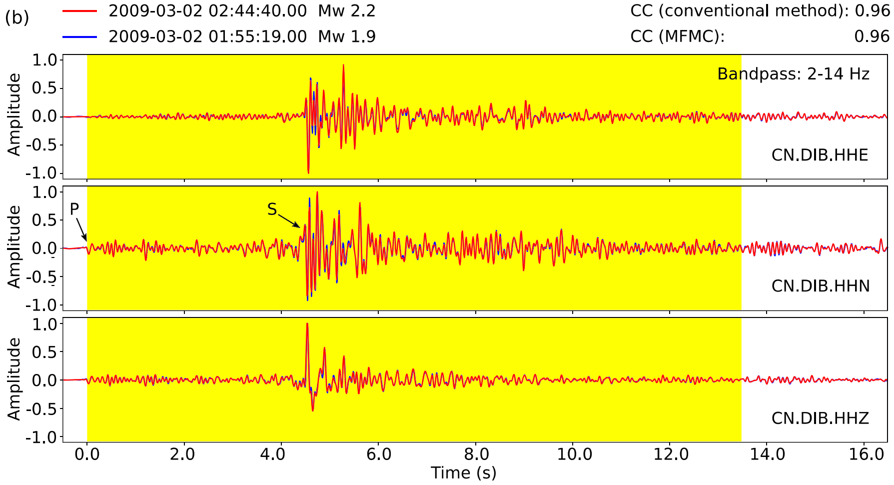
Match Filtering with Multi-segment Cross-correlation (MFMC)

$$cc_m = \frac{\sum_{i=(m-1)\times\frac{n}{N_{seg}}+1}^{m\times\frac{n}{N_{seg}}}\left[a_m(i)-\bar{a}_m\right]\left[b_m(i)-\bar{b}_m\right]}{\sqrt{\sum_{i=(m-1)\times\frac{n}{N_{seg}}+1}^{m\times\frac{n}{N_{seg}}}\left[a_m(i)-\bar{a}_m\right]^2\times\sum_{i=(m-1)\times\frac{n}{N_{seg}}+1}^{m\times\frac{n}{N_{seg}}}\left[b_m(i)-\bar{b}_m\right]^2}}$$

Fake Repeating Events



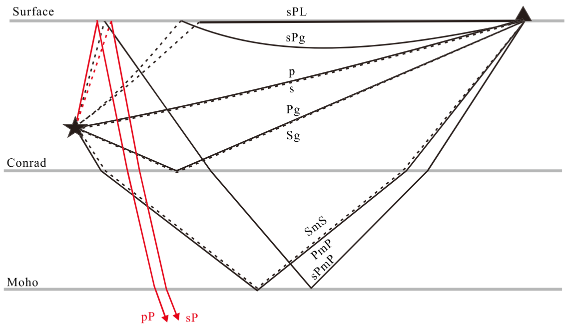
True Repeating Events



Gao and Kao (2020)

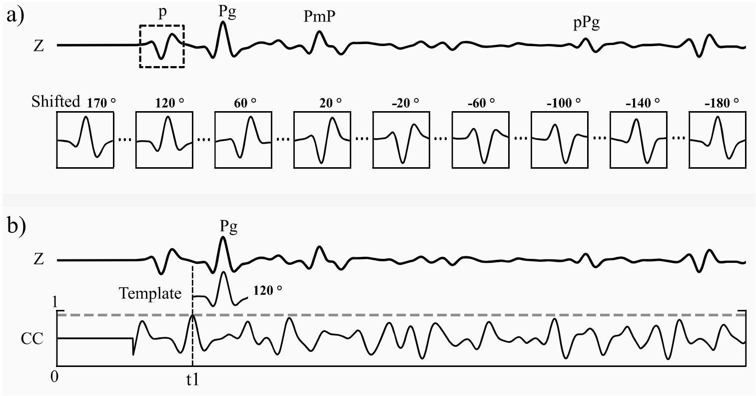
Development of New Methodology to Determine Precise Earthquake Focal Depths

Depth Phases

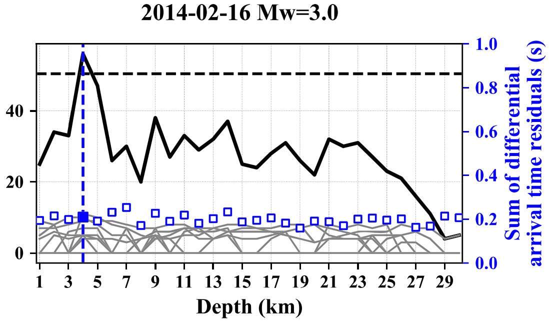


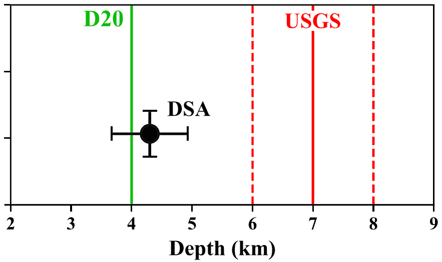
Seismic phases that are very sensitive to an event's focal depth.

Depth-Scanning Algorithm (DSC)



1. Produce waveform templates of depth phases.
2. Scan waveform segment after the P phase for depth phase matches.
3. The depth with the best matching result is the final solution.



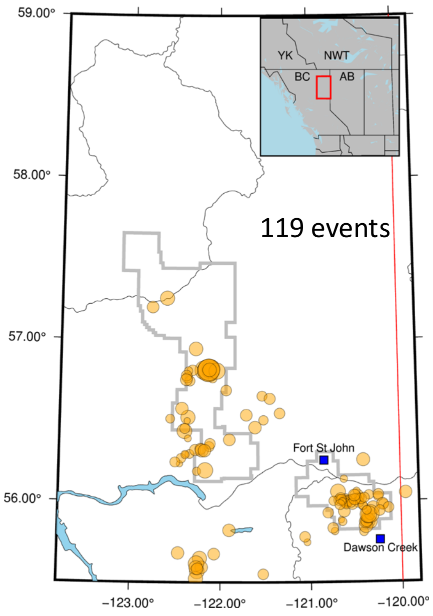


Application to a real induced earthquake in South Carolina, USA.

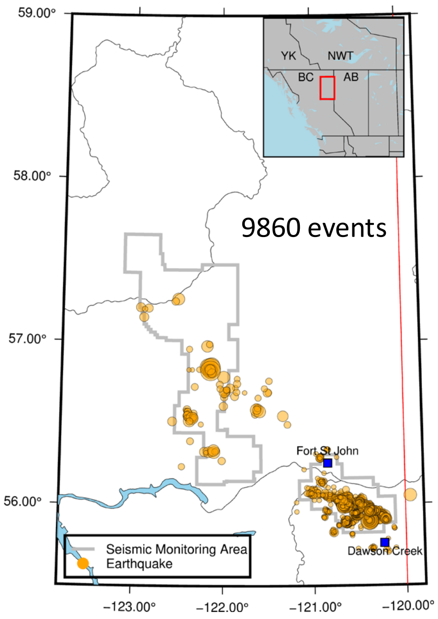
Yuan et al. (2020)

Enhanced Induced Seismicity Catalogues

2019

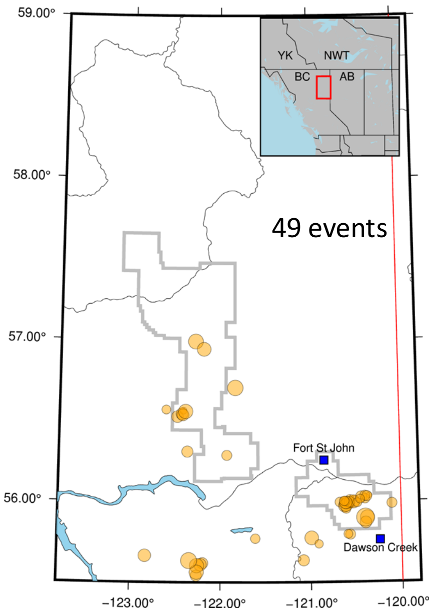


Canadian National Earthquake Database

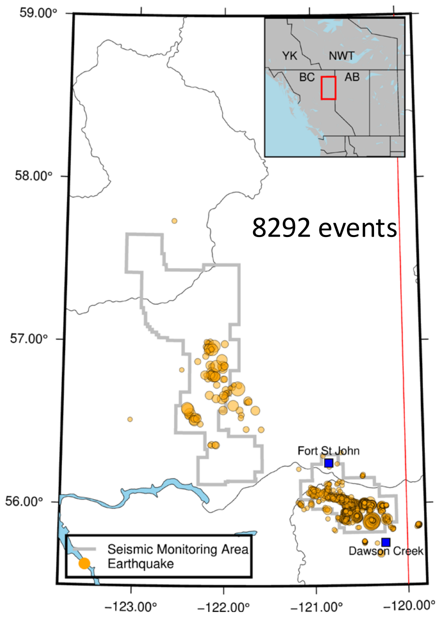


ISR Project

2020



Canadian National Earthquake Database



ISR Project

List of Key Publications

Dokht, R.M.H, H. Kao, A. Babaie Mahani, and R. Visser (2021). Spatiotemporal analysis of seismotectonic state of injection-induced seismicity clusters in the Western Canada Sedimentary Basin, *Journal of Geophysical Research: Solid Earth, 126*, e2020JB021362, doi:10.1029/2020JB021362.

Ojo, A.O., H. Kao, Y. Jiang, M. Craymer, and J. Henton (2021). Strain accumulation and release rate in Canada: Implications for long-term crustal deformation and earthquake hazards, *Journal of Geophysical Research: Solid Earth,* 126, e2020JB020529, doi:10.1029/2020JB020529.

Wang, B., A. Verdecchia, H. Kao, R.M. Harrington, Y. Liu, and H. Yu (2021). A study on the largest hydraulic fracturing induced earthquake in Canada: numerical modeling and triggering mechanism, *Bull. Seismol. Soc. Am.,* doi:10.1785/0120200251.

Babaie Mahani, A., D. Malytskyy, R. Visser, M. Hayes, M. Gaucher, and H. Kao (2020). Well-log-based velocity and density models for the Montney unconventional resource play in northeast British Columbia, Canada, applicable to induced seismicity monitoring and research, *Seismol. Res. Lett.,* doi:10.1785/0220200213.

Tan, F., H. Kao, E. Nissen, and Ryan Visser (2020). Tracking earthquake sequence in real time: Application of Seismicity-Scanning based on Navigated Automatic Phase-Picking (S-SNAP) to the 2019 Ridgecrest, California Sequence, *Geophysical Journal International, 223(3)*, 1511-1524, doi:10.1093/gji/ggaa387.

Gao, D., and H. Kao (2020). Optimization of the match-filtering method for robust repeating earthquake detection: The multi-segment cross-correlation approach, *Journal of Geophysical Research: Solid Earth, 125*, e2020JB19714, doi:10.1029/2020JB019714.

Yuan, J., H. Kao, and J. Yu (2020). Depth-Scanning Algorithm: Accurate, automatic and efficient determination of focal depth for local and regional earthquakes, *Journal of Geophysical Research: Solid Earth, 125*, doi:10.1029/2020JB019430.

Yu, H., R.M. Harrington, H. Kao, Y. Liu, R.E. Abercrombie, and B. Wang (2020). Well proximity governing stress drop variation and seismic attenuation associated with hydraulic fracturing induced earthquakes, *Journal of Geophysical Research: Solid Earth, 125*, doi:10.1029/2020JB020103.

Peña Castro, A. F., M. P. Roth, A. Verdecchia, J. Onwuemeka, Y. Liu, R.M Harrington, Y. Zhang, and H. Kao (2020). Stress chatter via fluid flow and fault slip in a hydraulic fracturing-induced earthquake sequence in the Montney formation, British Columbia, *Geophysical Research Letters, 47*, e2020GL087254. doi:10.1029/2020GL087254.

Wang, B., R.M. Harrington, Y. Liu, H. Kao, and H. Yu (2020). A study on the largest hydraulic-fracturing-induced earthquake in Canada: Observations and static stress drop estimation, *Bull. Seismol. Soc. Am.,* doi:10.1785/0120190261.

Babaie Mahani, A., & Kao, H. (2020). Determination of Local Magnitude for Induced Earthquakes in the Western Canada Sedimentary Basin: An Update. *Can. Soc. Explo. Gephys. Recorder, 45*(6), 1-12, https://csegrecorder.com/articles/view/determination-of-local-magnitude-for-induced-earthquakes-in-the-wcsb.

Dokht, R. M. H., Smith, B., Kao, H., Visser, R., & Hutchinson, J. (2020). Reactivation of an Intraplate Fault by Mine-Blasting Events: Implications to Regional Seismic Hazard in Western Canada. *Journal of Geophysical Research: Solid Earth, 125*(6), e2020JB019933. doi:10.1029/2020JB019933.

Babaie Mahani, A., F. Esfahani, H. Kao, M. Gaucher, M. Hayes, R. Visser, and S. Venables (2020). A systematic study of earthquake source mechanism and regional stress field in the southern Montney Unconventional Play of northeast British Columbia, Canada, *Seismol. Res. Lett., 91(1)*, 195-206, doi: 10.1785/0220190230.

CONTACT INFORMATION

- Project leader: Dr. Honn Kao
- Webpage on Science.gc.ca: https://profils-profiles.science.gc.ca/en/profile/honn-kao-phd
- Email address: Honn.Kao@canada.ca

THANK YOU!

Ressources naturelles Canada | Natural Resources Canada

Évaluation des impacts potentiels liés aux activités pétrolières et gazières sur les aquifères peu profonds dans la région de Fox Creek (AB) – Mise à jour de mai 2021

Assessment of potential impacts of oil and gas development activities on shallow aquifers in the Fox Creek area (AB) – May 2021 update

Christine Rivard

May 11, 2021

Canada

ABSTRACT

A multidisciplinary and multi-institutional project was initiated in the Fox Creek area (west-central Alberta) in April 2019 to study environmental impacts of hydrocarbon development activities. The initial objective was to specifically study potential impacts on shallow groundwater. However, different Sectors within NRCan later identified the Fox Creek area as a region of interest for developing regional cumulative effects evaluation methods in support of new impact assessment legislation. As a result, the scope is now much broader and the project includes studies of vegetation, forest, snow cover, wetlands, and contributes to a woodland caribou habitat study. The project involves many collaborators from the federal and provincial governments, as well as from the academic community.This project is supported by the GGP and EGP programs.

Project members
(including EGP, GGP and cumulative effects)

C. Rivard[1], C. Paniconi [2], E. Konstantinovskaya[3], O. Haeri Ardakani[1], H. Crow[1], G. Bordeleau[2], D., Lavoie[4], L.I. Guarin-Martinez[2,1], B.J. Meneses-Vega[1,2], A. Bahramiyarahmadi[3], B. Smerdon[6], J. Lovitt[5], W. Chen[5], R. Chalaturnyk[7], D. Alessi[3], B. Xu.[8], P. Leblanc-Rochette[1,9], R. Lavoie[9], A. Mort[1], H. Kao[1], S. Heckbert[6], B. Giroux[2], D. Degenhardt[10], I. Aubin[10], S. Grasby[1]

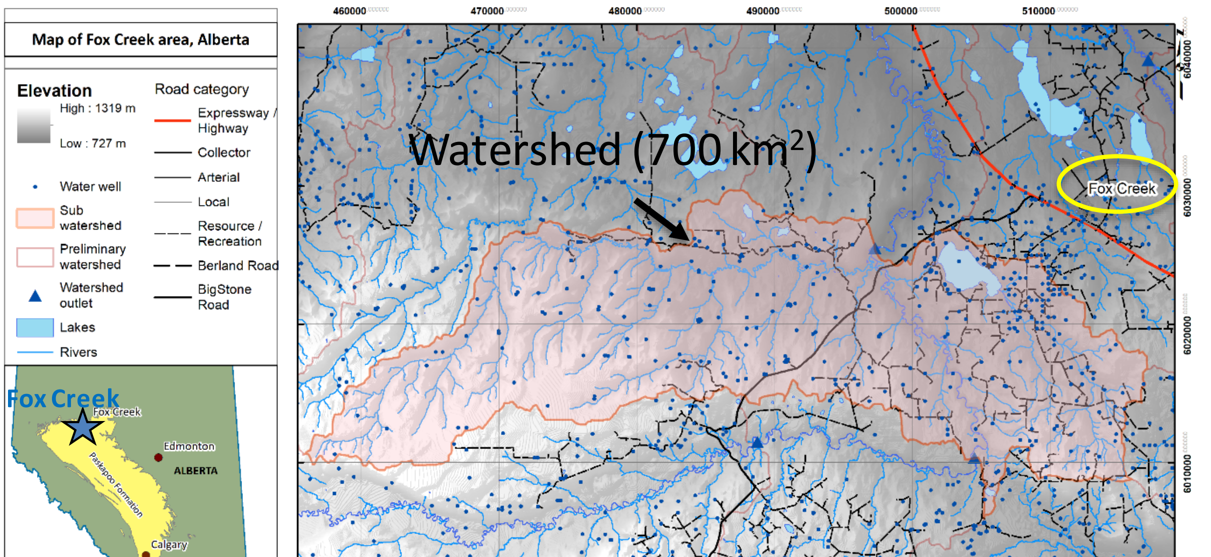
[1] *Geological Survey of Canada, Natural Resources Canada, Québec, QC; Ottawa, ON; Calgary, AB; and Victoria, BC;*
[2] *Institut national de la recherche scientifique – Eau Terre Environnement (INRS-ETE), Québec, QC*
[3] *University of Alberta, Department of Earth and Atmospheric Sciences, Edmonton, AB*
[4] *Consultant, geologist, Quebec, QC*
[5] *CCMEO, Natural Resources Canada, Ottawa, ON*
[6] *Alberta Energy Regulator, Edmonton, AB*
[7] *University of Alberta, Faculty of Engineering, Edmonton, AB*
[8] *Northern Alberta Institute of Technology (NAIT), Edmonton, AB*
[9] *Université Laval, École supérieure d'aménagement du territoire et de développement régional, Québec, QC*
[10] *Canadian Forest Service, Natural Resources Canada, Edmonton, AB and Sault-Sainte-Marie, ON*

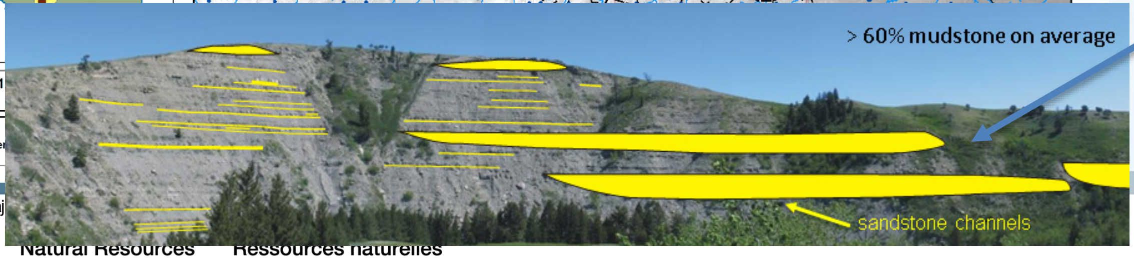
≈25 people

2 MSc students
2 PhD students

Description of the study area

Fox Creek, West-central Alberta: one of the most active regions for O&G production in the last 50 years





The study area is mainly forested and unpopulated

Elevations range from 785 to 1180 m

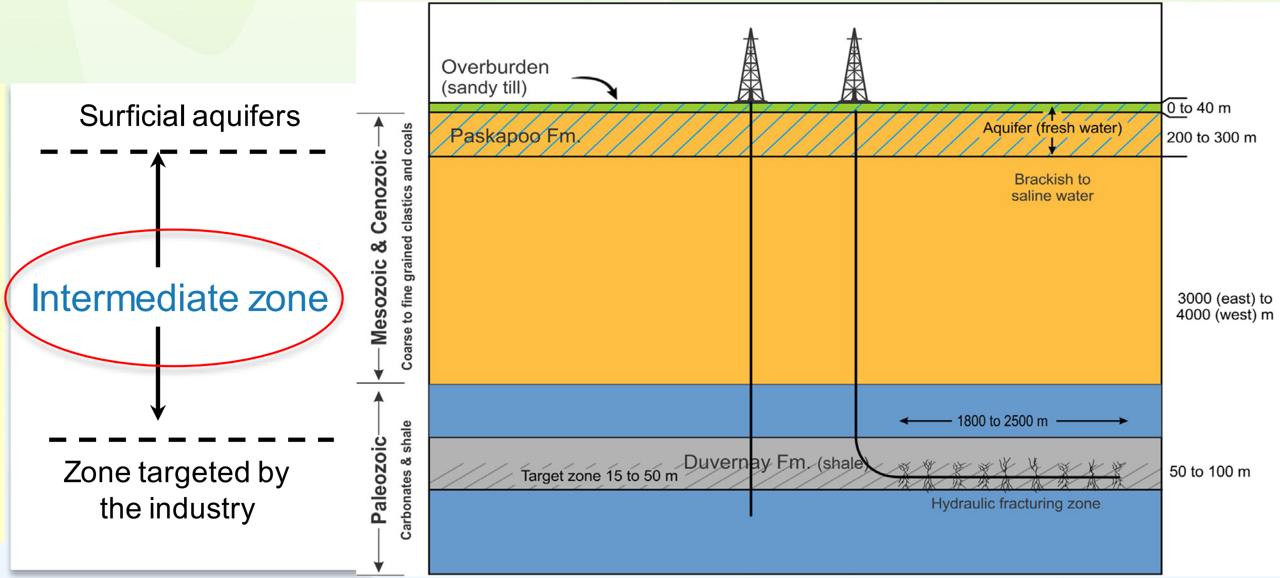
The regional aquifer is located in the Paskapoo Fm.: a complex succession of interbedded mudstone and siltstone with sandstone channels

Project objectives

1) Characterize the regional shallow aquifer (GGP)
2) Study the intermediate zone integrity (EGP)

Mean water-well depth in the Paskapoo Fm: ≈50 m

Mean O&G well depth: 3000-3500 m



3) Assess cumulative effects (CE)

Fieldwork in 2020

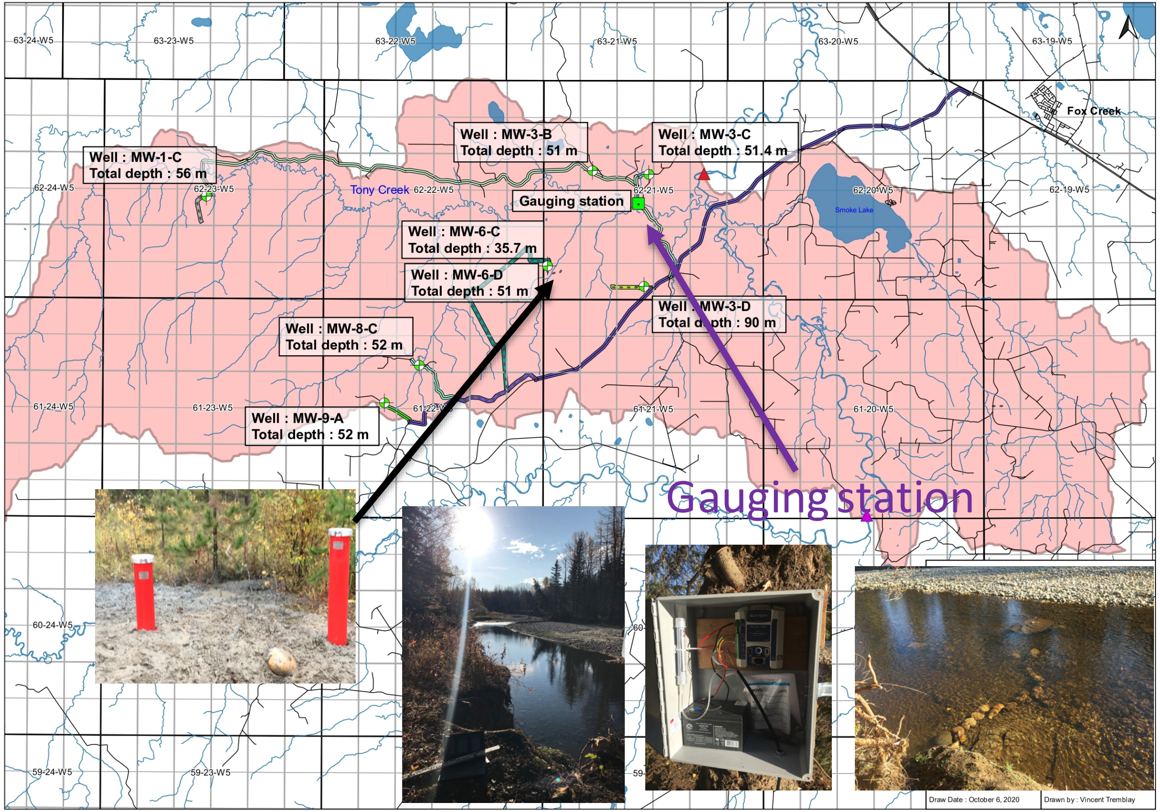
(September 12 – October 11)

- Drilling of 9 monitoring wells : depths from 35 to 90 m

- Rock (cuttings) sampling (with specific interests on rock heterogeneity and on eventual coal horizons for hydrocarbon source)

- Borehole geophysical logging
- Installation of pressure transducers
- Groundwater sampling

Fieldwork in 2020



8 wells drilled on Crown land, including a cluster well (MW-6)

+

1 well drilled on an active O&G well pad

Each well is very different!

- Depth to bedrock
- Water level
- % mudstone/silestone vs sandstone
- Number of fractured zones
- Number of flowing fractures
- Yield

Installation of a gauging station

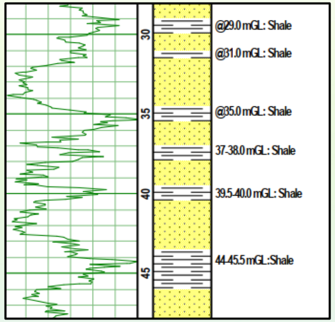
Borehole geophysical logging

Objectives :

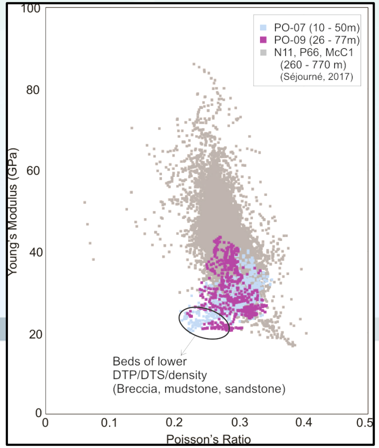
1) identify lithological, hydrogeological, and mechanical/structural conditions in the near surface bedrock

2) Support the shallow aquifer characterization by:
   - guiding depths for screen installations → GW sampling
   - identifying fluid pathways (hydraulic gradients)
   - providing near-surface datasets to examine continuity of shallow to deep geomechanical properties.

Lithological logs

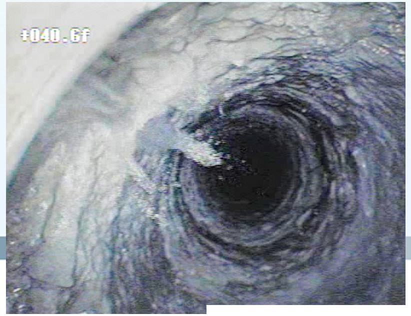


Geomechanical properties



Pipe and screen installation

Fluid flow

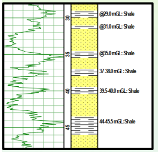


by Heather Crow

Borehole geophysical logging

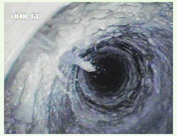
<u>Lithological logs</u>

- Natural gamma → stratigraphy based on changes in mineralogy
- Resistivity → stratigraphy based on changes in electrical properties



<u>Hydrogeophysical logs</u>

- Fluid temp/conductiv.
- Flow meters (2)
- Video camera



<u>Structural/Geomechanical logs</u>

- Acoustic Televiewer → identify frequency and orientation of structures
- Sonic tool → measure travel times P&S waves
- Gamma-gamma density

Logs collected:

	Lithologic		Hydrogeologic				Geomechanical		
Well	Gamma	Resist.	Fluid logs Temp/Cond	Camera	Flowmeter Impeller	Flowmeter HPFM	ATV	Density	Sonic
MW-1-C	✓		✓	✓		✓	✓	✓	✓
MW-3-B	✓	✓	✓	✓	✓	✓	✓	✓	✓
MW-3-C	✓	✓	✓	✓		✓	✓	✓	✓
MW-3-D	✓	✓	✓	✓	✓	✓	✓	✓	✓
MW-6-C	✓	✓	✓	✓		✓	✓	✓	✓
MW-8-C	✓	✓	✓	✓		✓	✓		✓
MW-9-A	✓	✓	✓	✓			✓		
MW-10-A	✓	✓	✓	✓	✓	✓	✓	✓	✓

Geochemistry

Only one well contained dissolved methane: MW-3-D (90 m)

$[CH_4]$ = 0.2 mg/L

$\delta^{13}C$ = -99 ‰

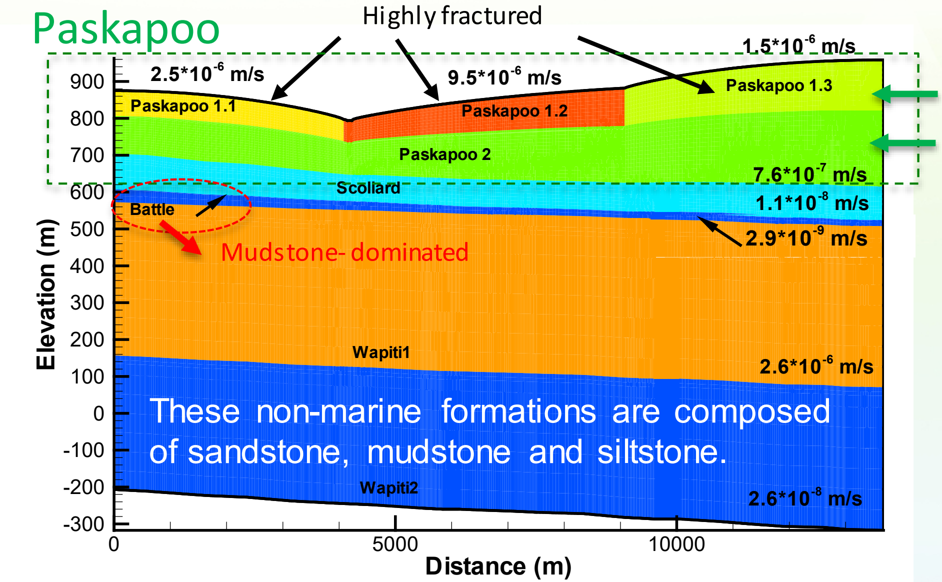
$\delta^{2}H$ = -390 ‰

→ **microbial origin**

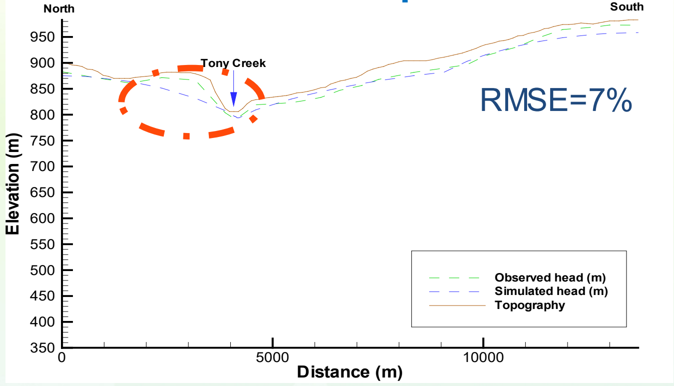
However, CO_2 values were very high (220-320 mg/L)

No Isojars contained methane

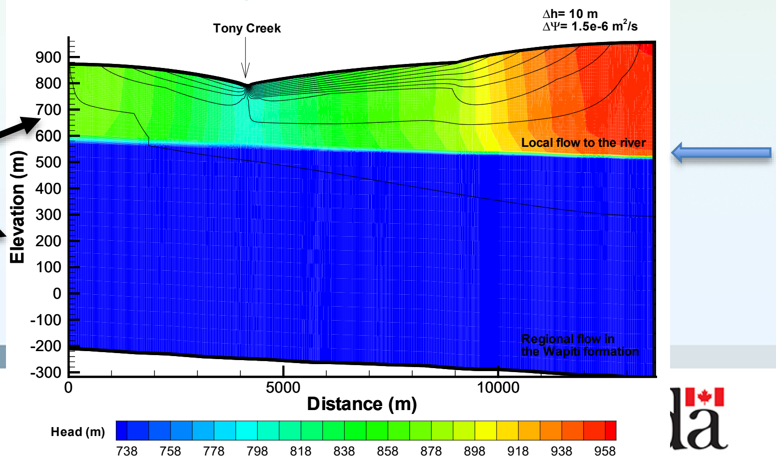
Hydrogeological modeling



Simulated versus interpolated water table



Hydraulic heads



Two hydrogeological systems separated by a nearly impermeable unit (Battle Fm.).

However, the Battle Fm. is not always present across the study area.

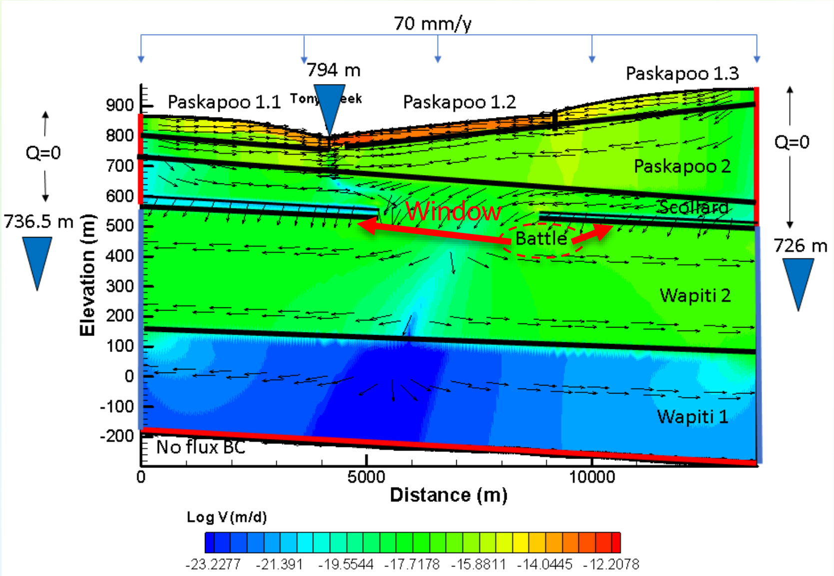
Natural Resources Canada Res: Can:

by Laura Isabel Guarin-Martinez, M.Sc. student

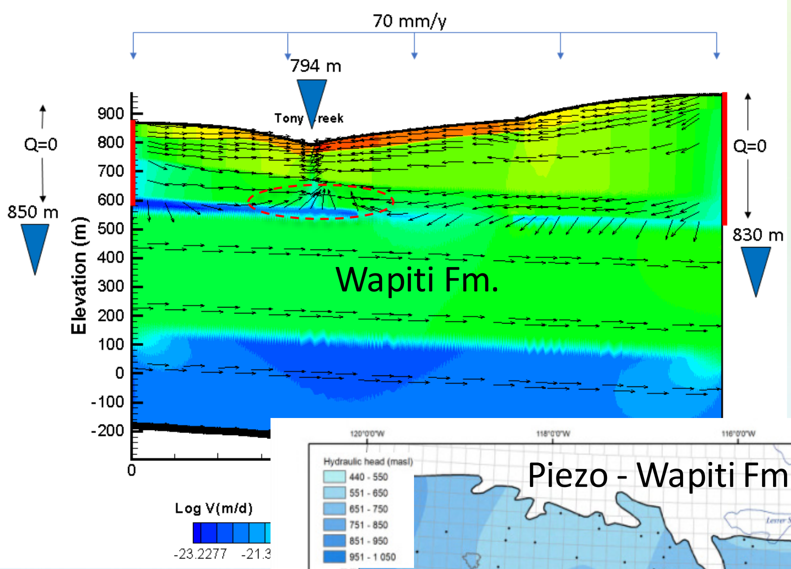
Hydrogeological modeling

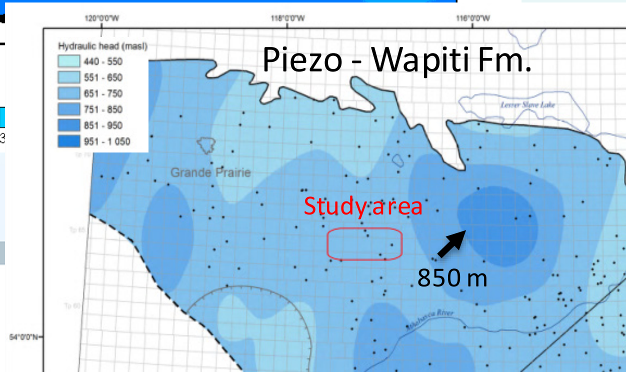
Scenarios with a discontinuous Battle Fm. – Upward flow?

Base case boundary conditions



Higher hydraulic heads in the Wapiti Fm.





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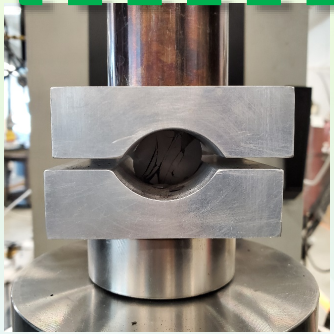
by Laura Isabel Guarin-Martinez, M.Sc. student

Geomechanical study

Goal: To better understand the behavior of the intermediate zone (which controls upward fluid flow).

Core testing (Duvernay Fm)

Brazilian Tests



UCS Tests

Triaxial Tests

Direct Shear Tests

Type of test	MURPHY SAXON 1-28-61-23	ROGCI HZ KAYBOBS 6-16-60-20
Brazilian	5	8
UCS	n/a	8
Mini-triaxial	11	n/a
Triaxial	1	4
Direct Shear	2	14

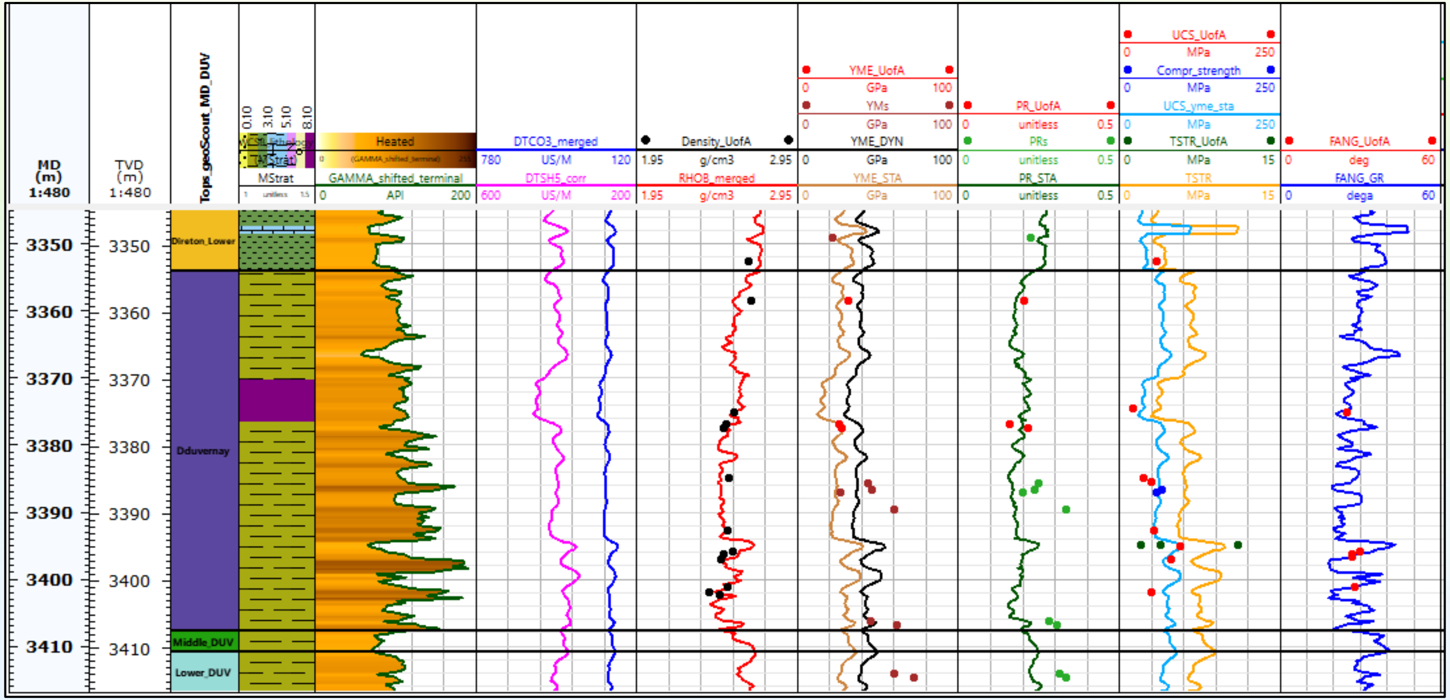
GeoREF

Cut, tested, computed by:
Atena Bahramiyarahmadi, PhD student

Checked by:
Nathan Deisman, PhD
Elena Konstantinovskaya, PhD

Geomechanical study

1D geomechanical modeling



The **profiles** of mechanical properties are estimated from well log data and calibrated using the results of the geomechanical tests.

Point data: (1) from the previous report AER R10735; (2) UofA – measured at GeoREF lab in this study

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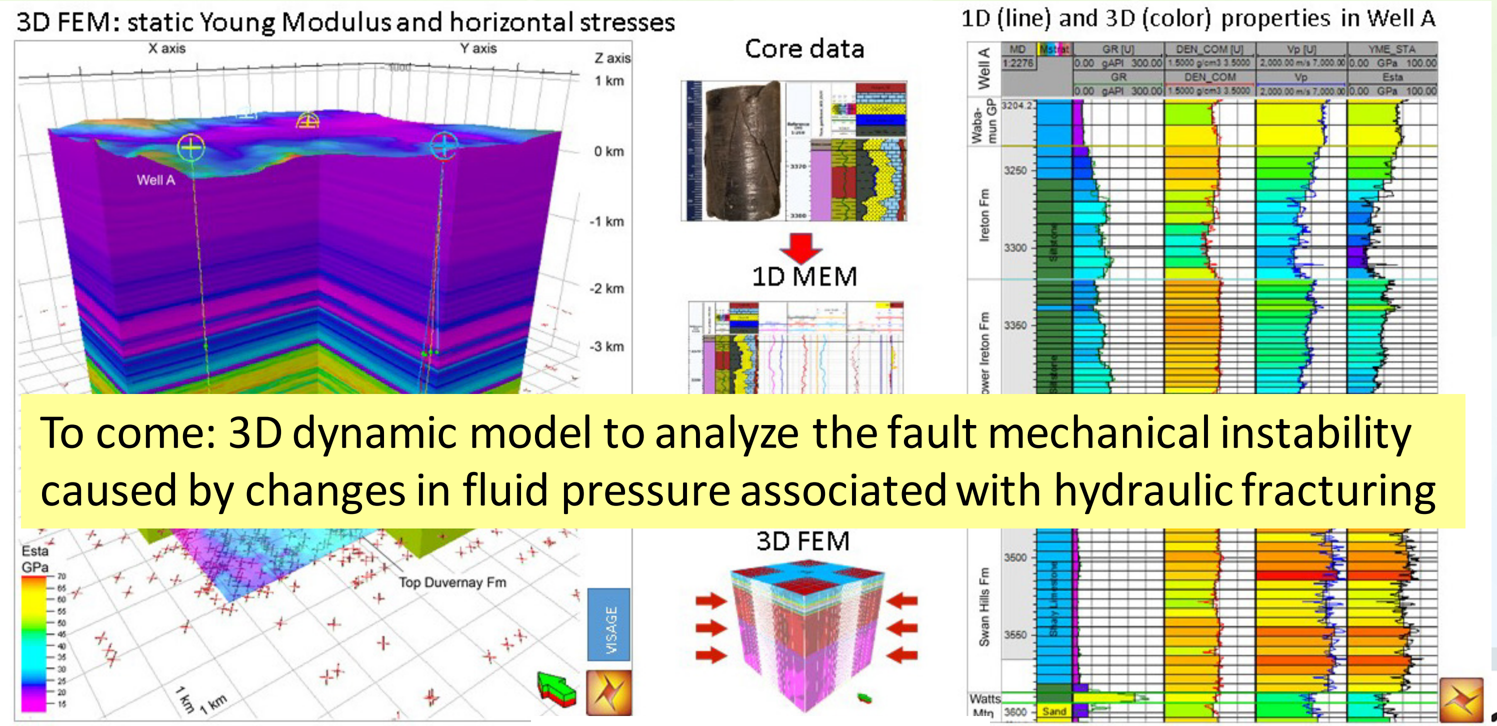
by Elena Konstantinovskaya

Canada

Geomechanical study

3D static geomechanical modeling:

- 3D structural modeling
- Properties modeling
- 3D Finite Element Modeling



To come: 3D dynamic model to analyze the fault mechanical instability caused by changes in fluid pressure associated with hydraulic fracturing

by Elena Konstantinovskaya

anada

Cumulative effects assessment (CEA)

Objectives:

1. Provide an overview of the state of scientific knowledge on CEAs through a literature review.

2. Learn about the opinions, views and concerns of Indigenous communities on CEAs and hear their recommendations on the CEA process and their involvement/participation in this process to improve the practice of CEA in general, via (virtual) focus groups.

3. Identify hindrances faced by consultants in the CEA process in Canada and hear their recommendations for improving the practice, via (virtual) interviews.

4. Based on the content analysis of the discussions, make concrete and realistic recommendations to address the difficulties and barriers currently encountered in the practice of CEAs in Canada, so that they can be conducted more effectively and respectfully.

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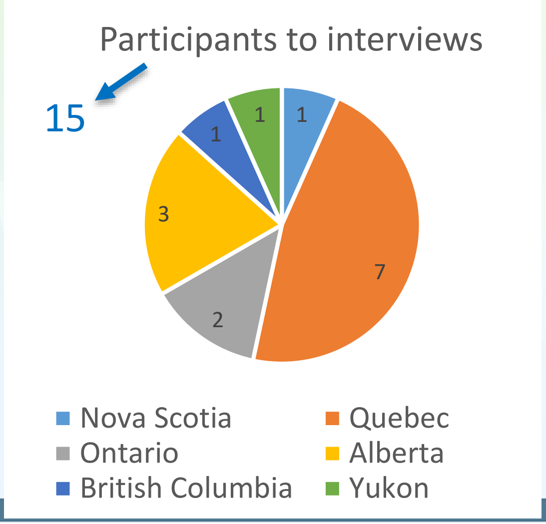
by Philippe Leblanc Rochette, M.Sc. student

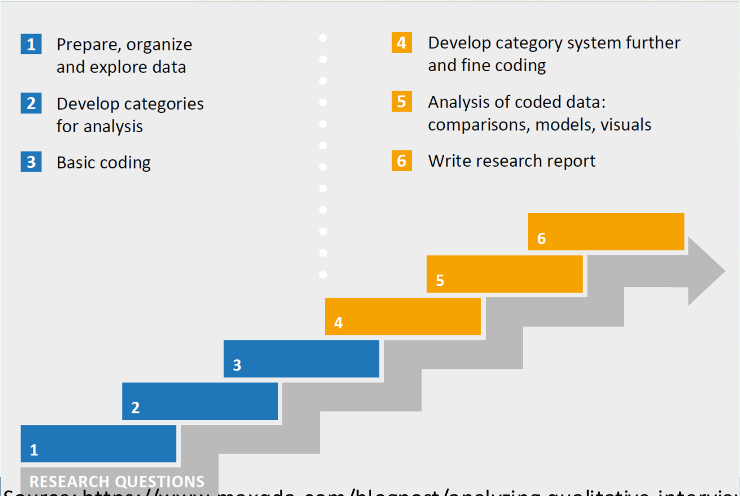
Canada

Cumulative effects assessment (CEA)

1) 15 semi-structured interviews with environmental assessment (EA) practitioners and federal government managers working in EAs
2) 5 focus groups with Indigenous communities and committees (QC, AB)
3) Data analysis of the interview/discussion transcriptions using the MAXQDA software



Analyzing Qualitative Interviews with MAXQDA in 6 Steps



Source: https://www.maxqda.com/blogpost/analyzing-qualitative-interviews-in-6-steps

by Philippe Leblanc Rochette, M.Sc. student

Cumulative effects assessment (CEA)

Indigenous people and committees, EA practitioners, and federal government employees across Canada share **similar views on many of the challenges and barriers** to the practice of CEA:

- CEs are better assessed when the federal government is involved (as part of environmental assessments, EAs) compared to work conducted exclusively under provincial jurisdiction.
- Lack of data availability and accessibility is the main barrier to the assessment of CE.
- Numerous public consultations for proposed projects can lead to consultation fatigue in Indigenous communities (due to a lack of resources) and decrease their level of engagement.
- The lack of consistency in the language used by governments in their requirements can confuse consultants in their work and the language used during consultations is often not well understood by Indigenous people, which is a barrier to effective consultation.

by Philippe Leblanc Rochette, M.Sc. student

Cumulative effects assessment (CEA)

Many consultants identified the lack of feasibility, clarity and realism in the requirements for CEAs as a fundamental barrier.

"... what happens [is that] I don't have the data and I don't have the knowledge. In fact, nobody has the science ultimately to do it. ... I've told this ... bluntly, in person, face to face across the table multiple times, with many parties, including those in government: do not ask us to assess something we can't assess. Unfortunately, that has not stopped the asking."

From George Hegmann, EA practitioner and main author of Cumulative effects assessment : practitioners' guide

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by Philippe Leblanc Rochette, M.Sc. student

Canada

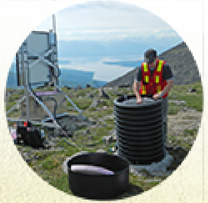
CONTACT INFORMATION

- Christine Rivard
- Work phone number: 418-654-3173 Christine.Rivard@canada.ca

THANK YOU!

NRCan's Environmental Geoscience Program 2021 meeting (virtual)
11 May 2021




Environmental impact of diluted bitumen
Impact environnemental du bitume dilué

Jason M. E. Ahad[1*], Scott L. Hepditch[2], Richard Martel[2], Valerie S. Langlois[2], Leah Mindorff[3] and Nagissa Mahmoudi[3]

[1] Geological Survey of Canada, Natural Resources Canada, Québec, QC, G1K 9A9, Canada,
[2] Eau Terre Environnement, Institut national de la recherche scientifique (INRS), Québec, QC, G1K 9A9, Canada
[3] Department of Earth and Planetary Sciences, McGill University, Montréal, QC, H3A 0E8, Canada

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Canada

Background

- In 2019, crude bitumen production from Alberta's oil sands region totalled ~ 3 million barrels per day, compared to ~ 0.5 million barrels per day for conventional crude[1]
- To transport bitumen via pipeline, it is blended with lighter hydrocarbons, yielding a less viscous, diluted bitumen ('**dilbit**')
- Dilbit is generally considered safer than other means of transport, although major pipeline ruptures have occurred (e.g., Kalamazoo R.)
- Dilbit spills may behave differently than conventional crude oil spills, yet our ***understanding of the environmental impact of dilbit in freshwater environments is limited…***

[1] *https://www.capp.ca*

Activities

To better understand the relationships between ***geochemistry*, *hydrology*, *microbiology*** and ***toxicology*** during natural attenuation of dilbit using controlled spill experiments (lab and field):

1. **Shallow groundwater systems:**
   i. *Large columns (INRS Labos Lourds)*
   ii. *Glass tanks (CanmetENERGY)*

2. **Riverine and lacustrine systems:**
   i. *Wave-action weathering (CanmetENERGY)*
   ii. *Microbial uptake of spilled dilbit in lake sediments (Experimental Lakes Area – ELA , Northwest Ontario)*

Large Column Experiments

- Gault Nature Reserve (Mont-Saint-Hilaire)
- Managed by McGill University
- 'Pristine' well-drained sandy loam soil

Soil Collection, McGill's Gault Nature Reserve (17 July 2019)

Sieving (2 cm mesh), homogenisation, weighing of soil (22-23 July 2019)

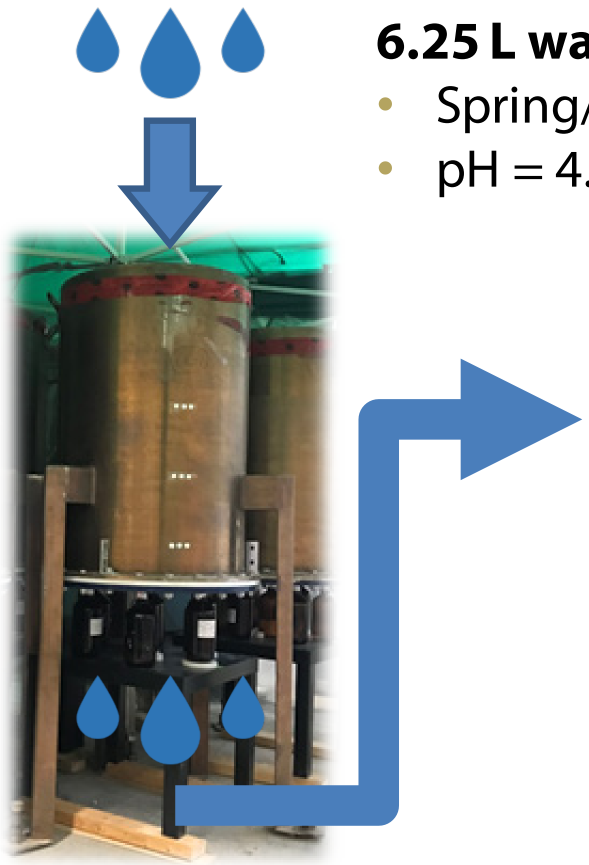
Soil compaction and ventilation tent installation (24 July 2019)

2 kg Diluted Bitumen

2 kg Heavy Conventional Crude

Control

DAY 0: Dilbit and conventional crude added (31 July 2019)



6.25 L water added each week (15 weeks)

- Spring/autumn recharge (9 ºC)
- pH = 4.80

Leachate (analyses carried out):

- ✓ Total organic/inorganic carbon (TOC/TIC)
- ✓ BTEX (benzene, toluene, ethylbenzene, xylenes)
- ✓ PAHs (polycyclic aromatic hydrocarbons)
- ✓ Acid extractable organics (naphthenic acids)
- ✓ Major elements & metals
- ✓ Fathead minnow (*Pimephales promelas*) toxicity assays

10 cores collected

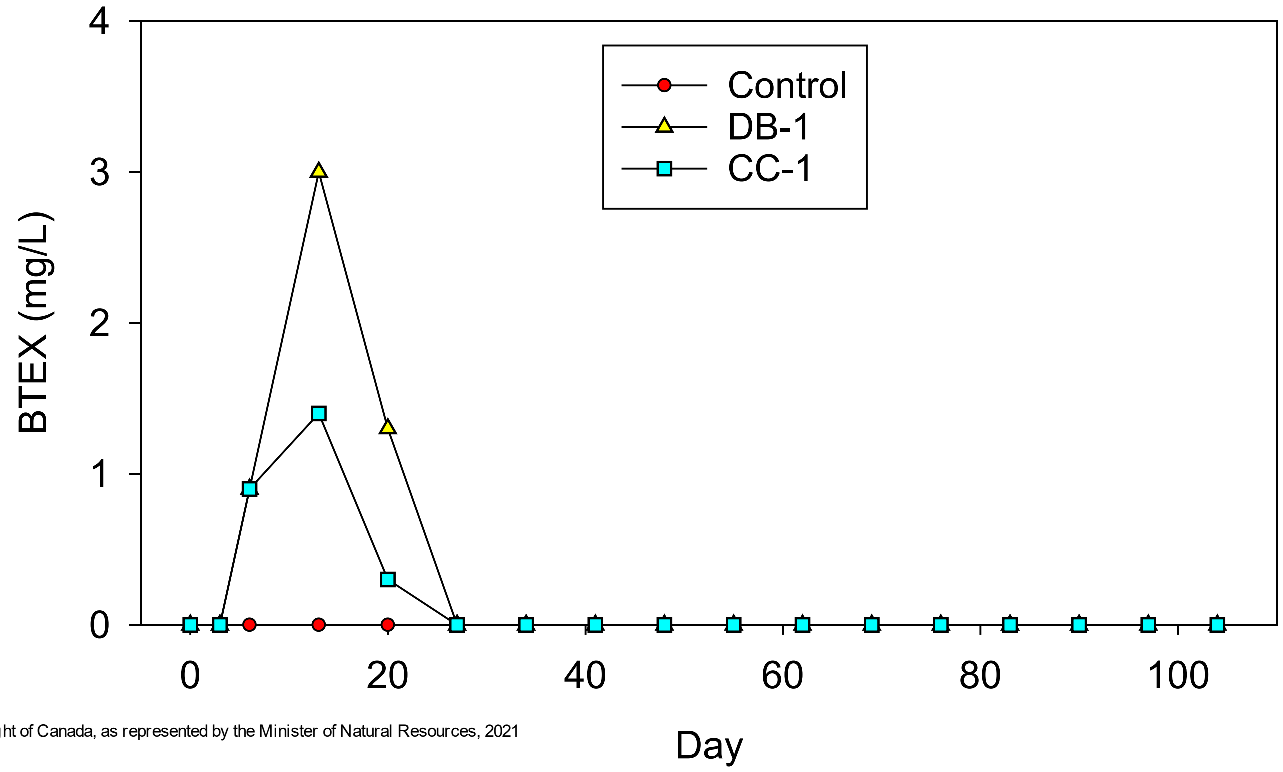
Soil cores (analyses carried out):

- ✓ Phospholipid fatty acids (PLFAs)
- ✓ Compound-specific $\delta^{13}C$ analysis of PLFAs
- ✓ Microbial community analyses (16S rRNA amplicon sequencing)

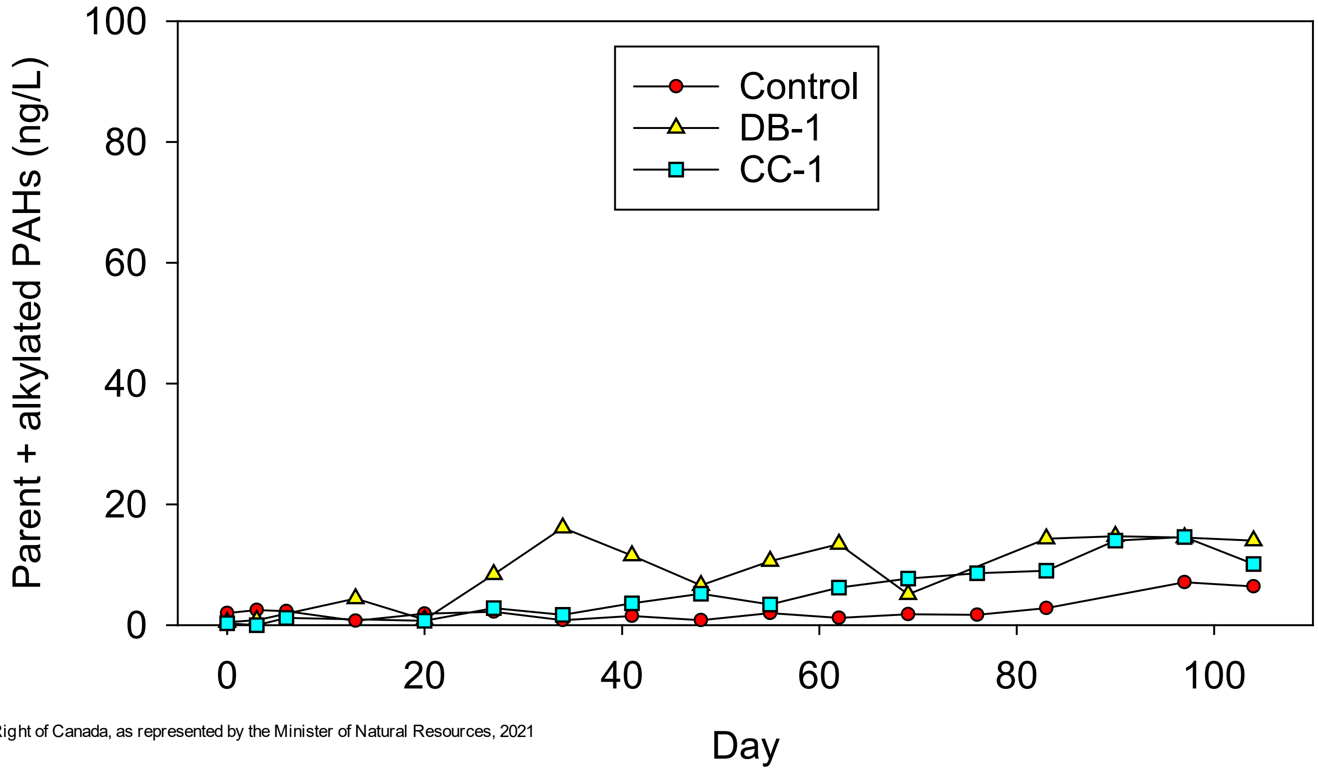
Soil cores (analyses ongoing):

- Compound-specific $\Delta^{14}C$ analysis of PLFAs
- Total petroleum hydrocarbons (concentrations)
- PAHs (concentrations)
- Compound-specific $\delta^{13}C$ & $\delta^{2}H$ analysis of PAHs

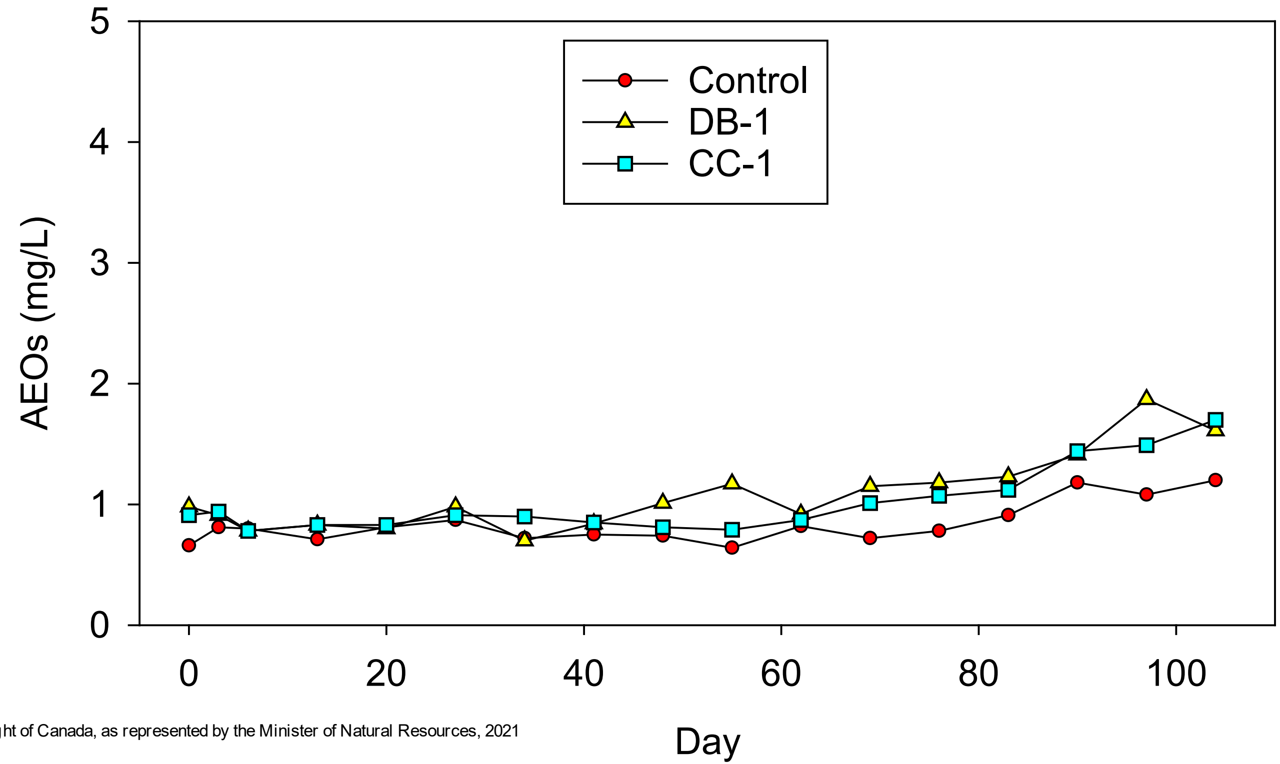
Leachate – BTEX

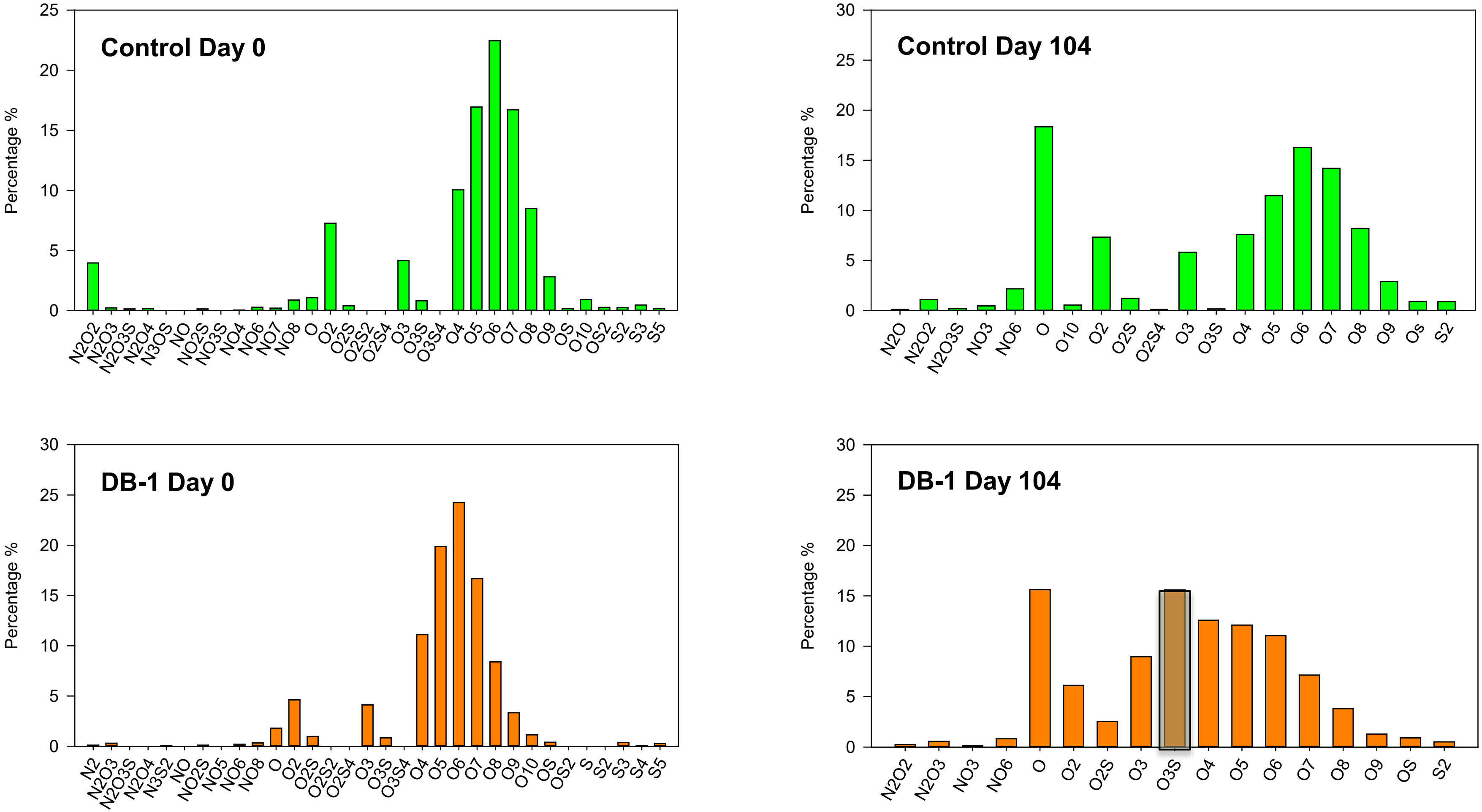


Leachate – PAHs



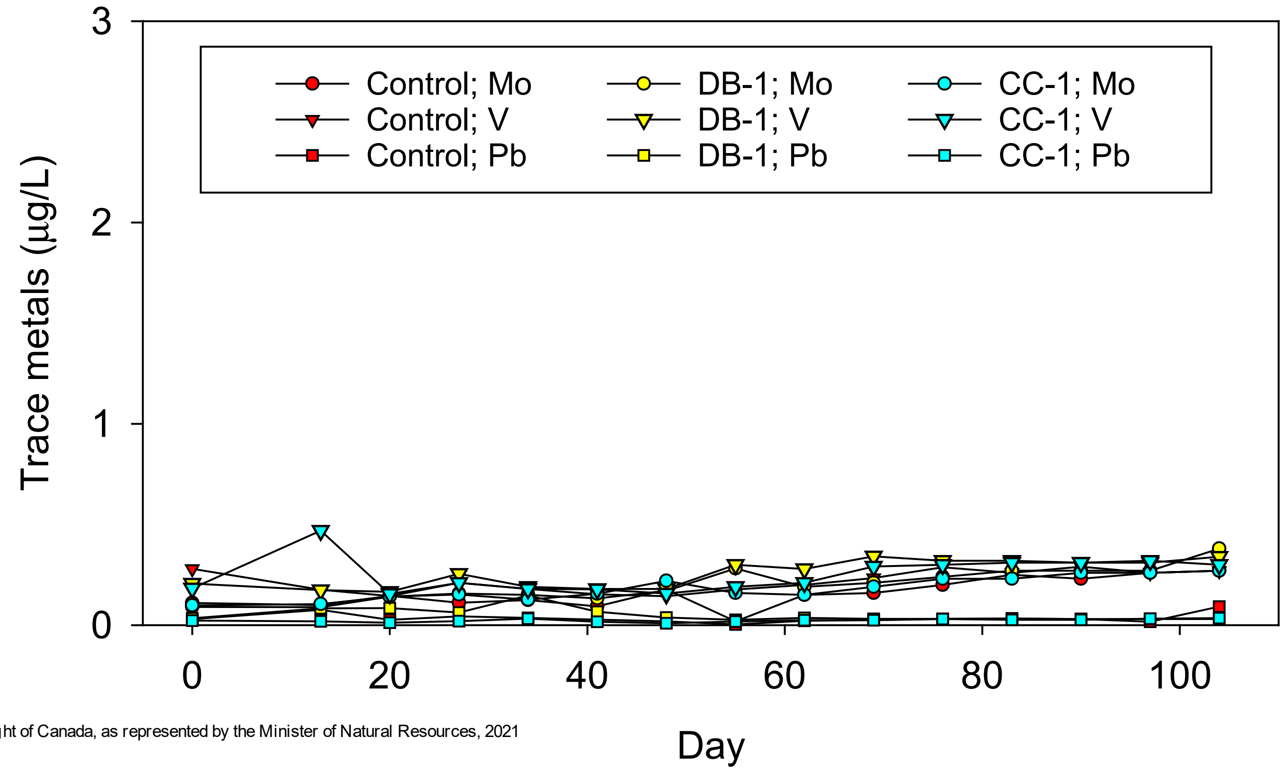
Leachate – AEOs



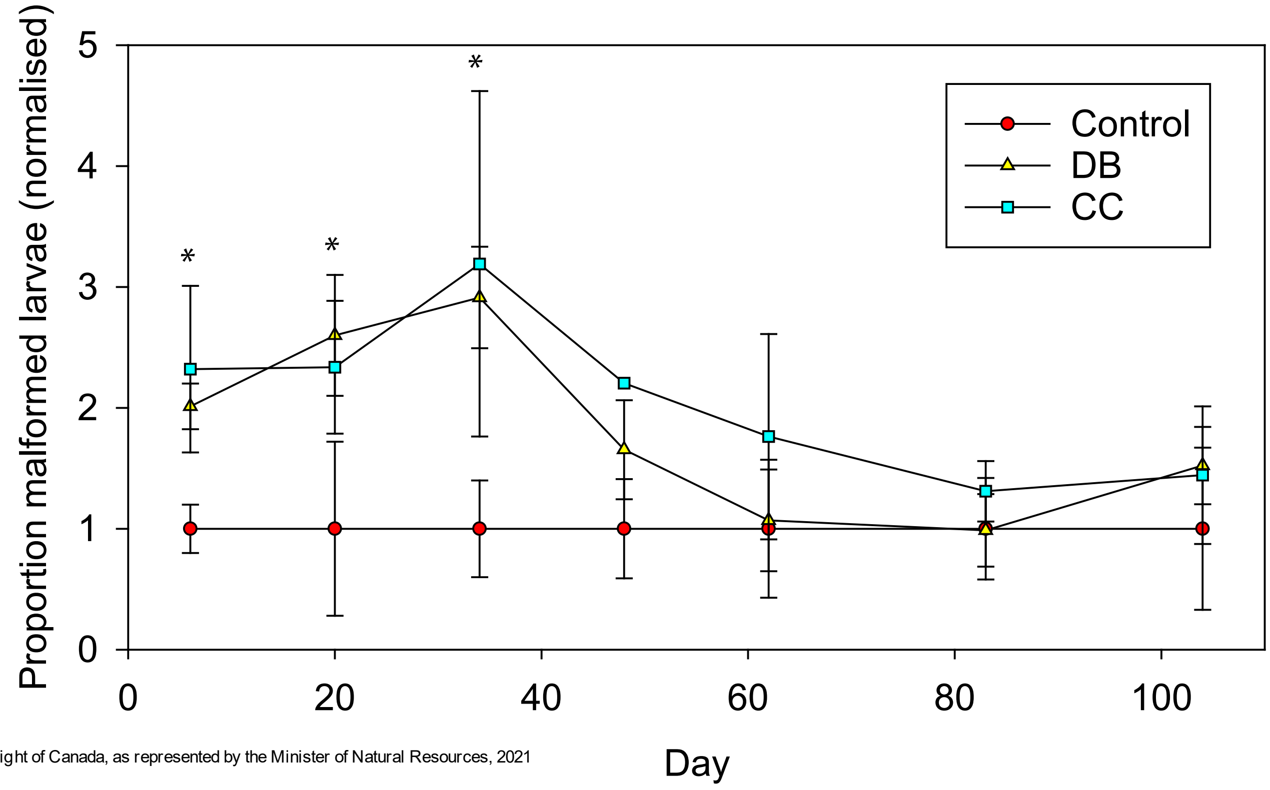


Control Day 0
Control Day 104
DB-1 Day 0
DB-1 Day 104
Percentage %

Leachate – Trace Metals

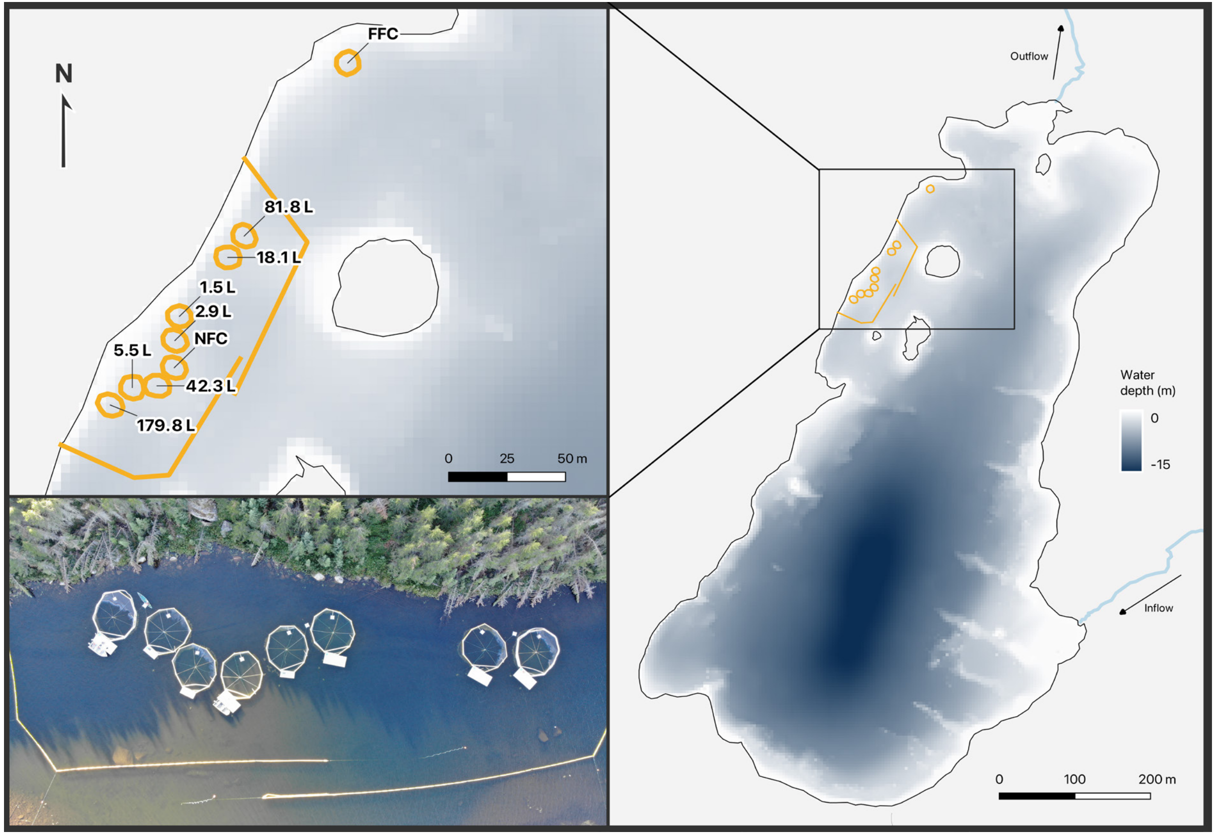


Malformations in Fathead Minnows



* *statistically different than the controls*

Controlled Dilbit Spill – ELA



- Between 1.5 to 180 L of dilbit was added to into ~100 m^3 "limnocorrals."
- The systems were monitored over 70 days (summer 2018)
- Sediments from various treatments collected at end of study

Rodriguez-Gil et al., In Review, "Simulating diluted bitumen spills in boreal lake limnocorrals - Part 1: Experimental design and responses of hydrocarbons, metals, and water quality parameters."

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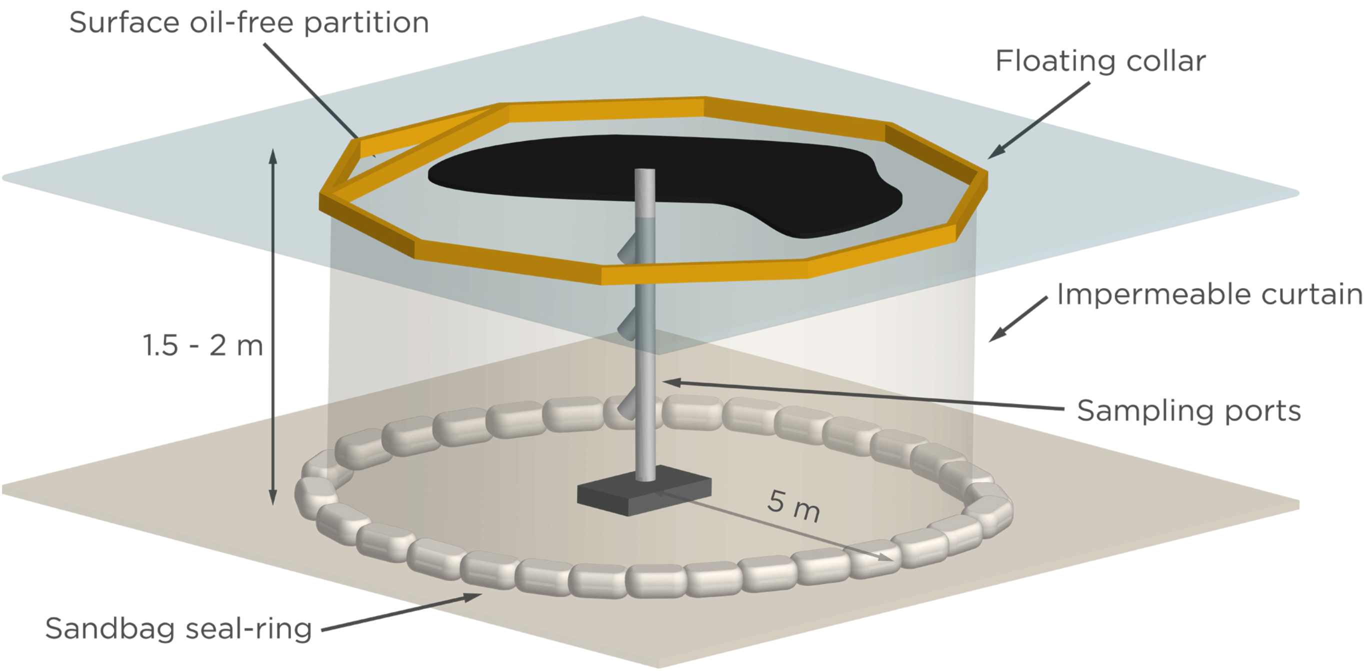
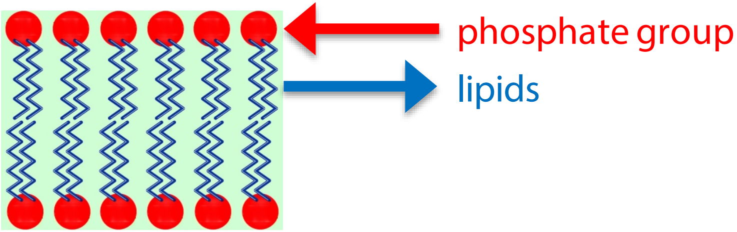
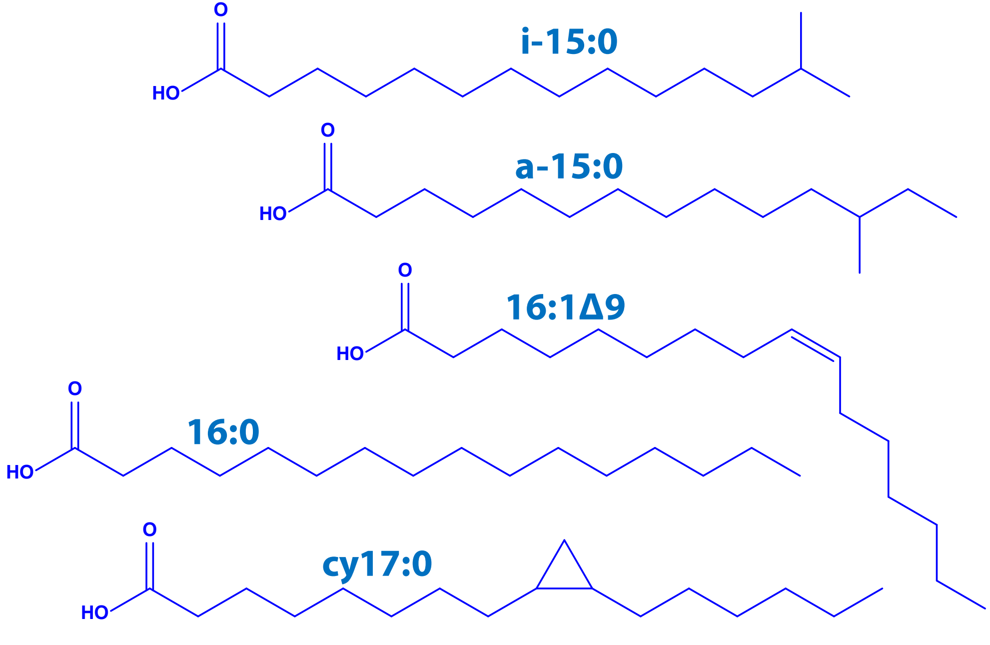
Limnocorral



Rodriguez-Gil et al., In Review.

$\delta^{13}C$ and $\Delta^{14}C$ Analysis of PLFAs

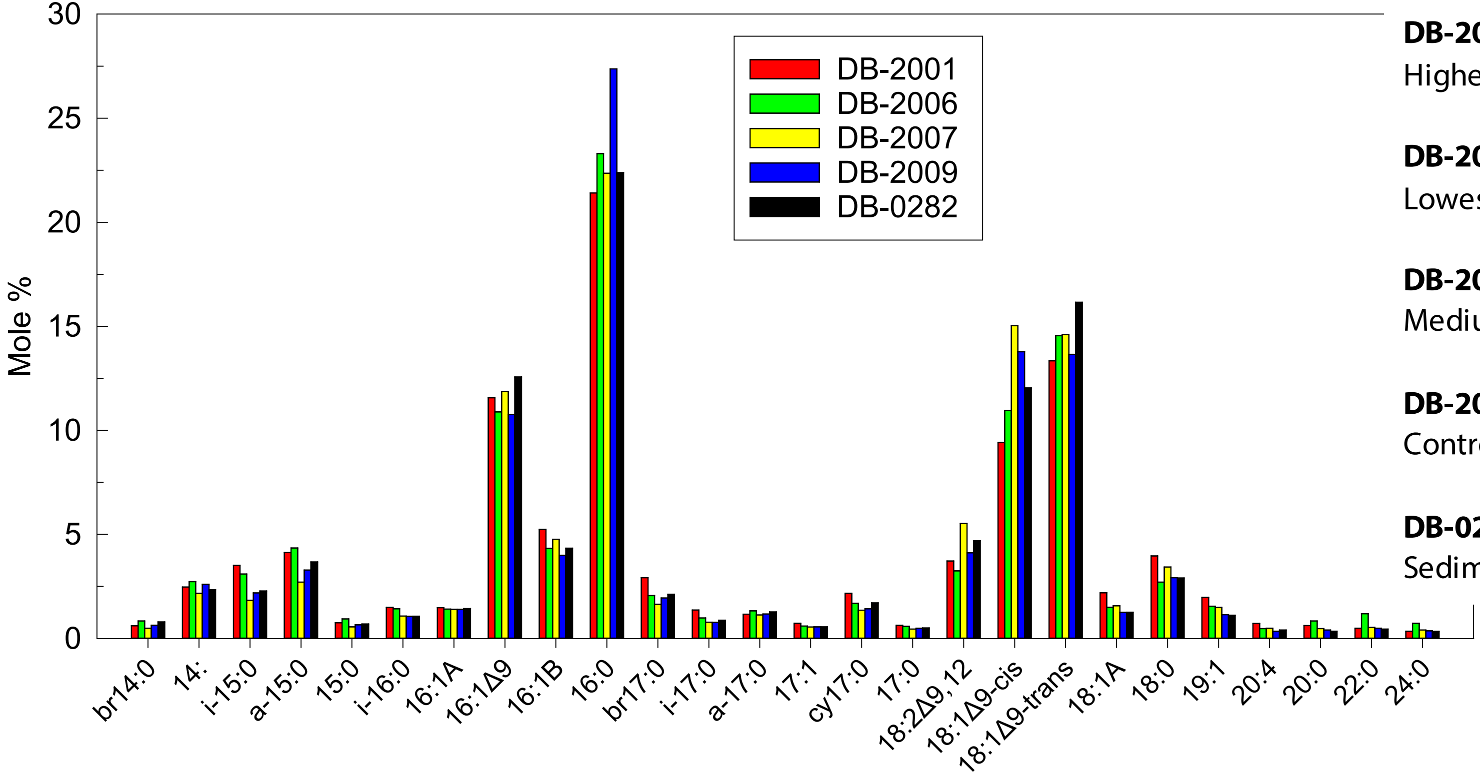




PLFAs: *Biomarkers for the **active** microbial community*

$\delta^{13}C/\Delta^{14}C$ analysis: provides insight into microbial ***carbon sources***

PLFA – distributions



DB-2001:
Highest treatment (179.8 L dilbit)

DB-2006:
Lowest treatment (1.5 L of dilbit)

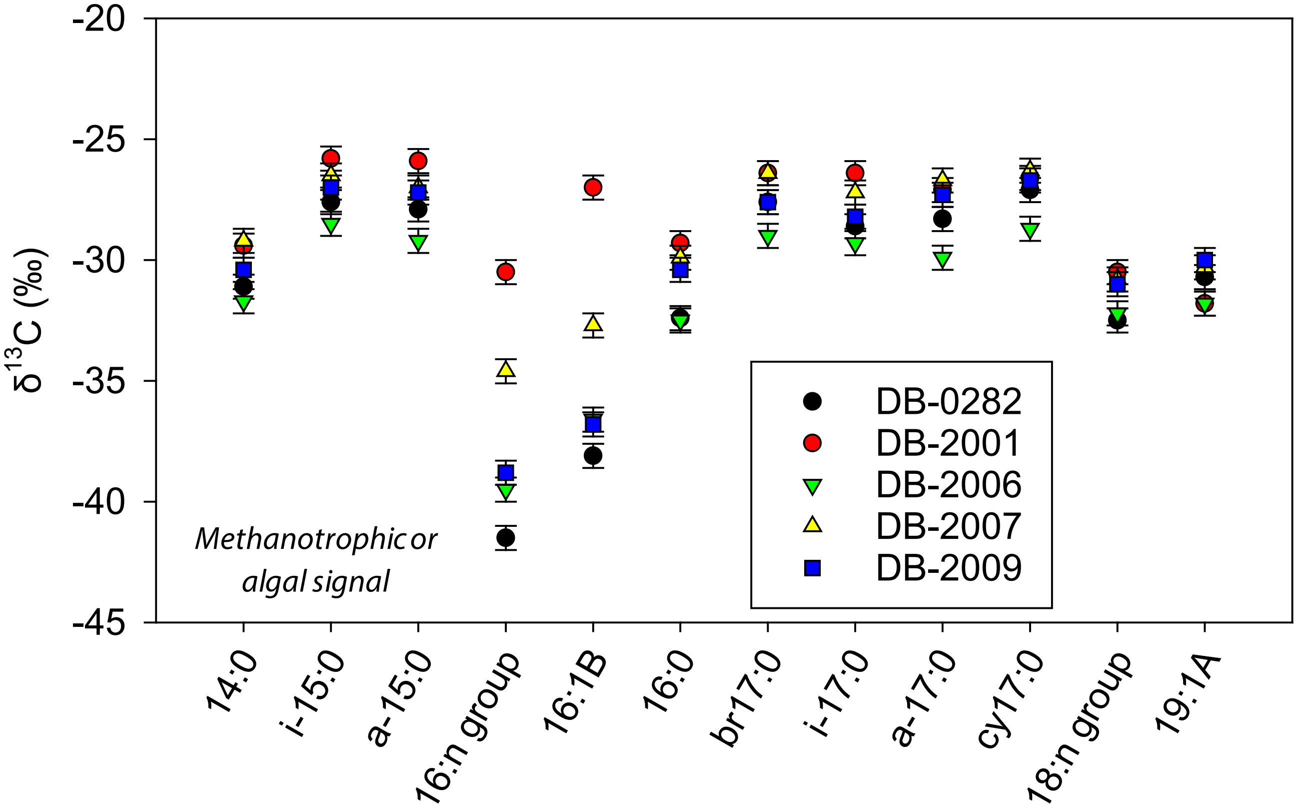
DB-2007:
Medium treatment (18.1 L dilbit)

DB-2009:
Control treatment (0 L dilbit)

DB-0282:
Sediment from lake prior to study

Canada

PLFAs – $\delta^{13}C$ values



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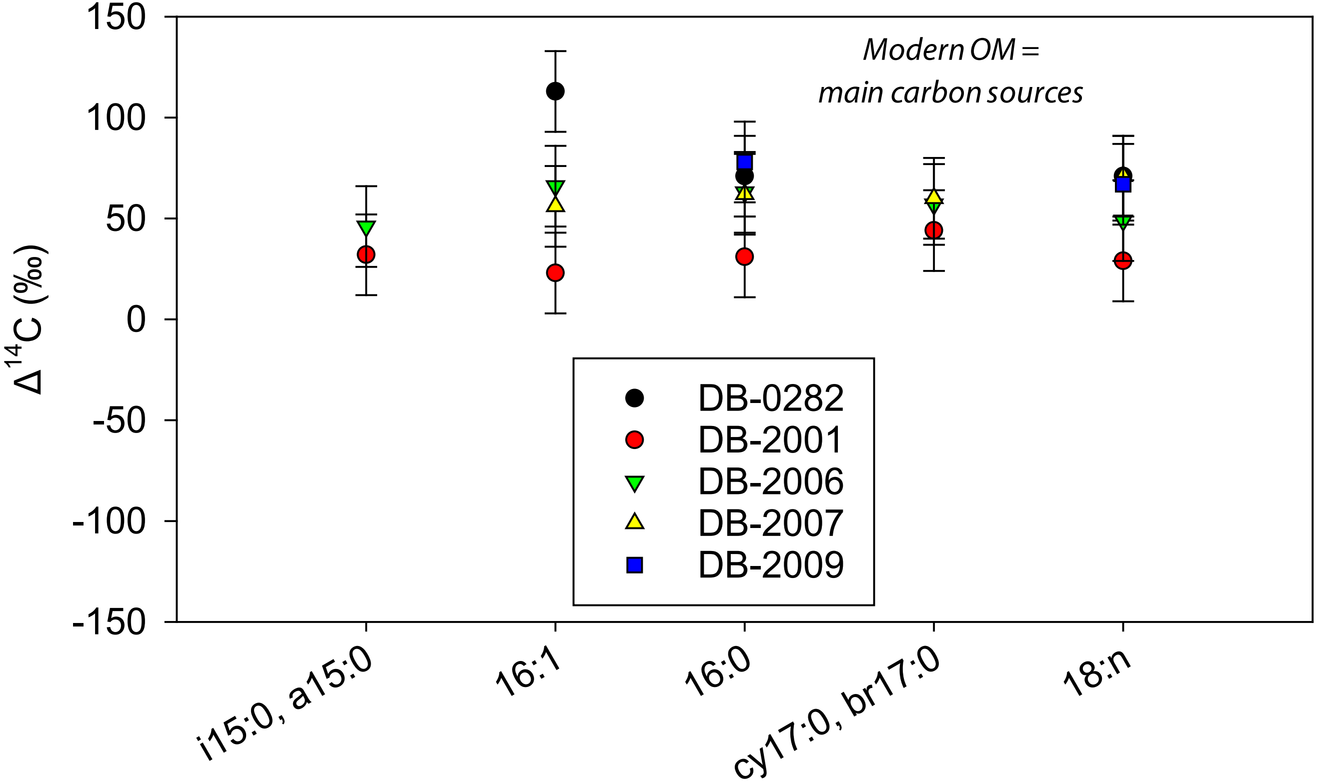
DB-0282:
Sediment from lake prior to study

PLFAs – Δ^{14}C values



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Control treatment (0 L dilbit)

DB-0282:
Sediment from lake prior to study

Merci!

- Delta-lab: Jade Bergeron, Marc Luzincourt & Anna Smirnoff
- John Headley & Kerry Peru (ECCC)
- In-kind Support:

CANADA 1842 GEOLOGICAL SURVEY - COMMISSION GÉOLOGIQUE

INRS Institut national de la recherche scientifique

uOttawa

IISD Experimental Lakes Area

McGill

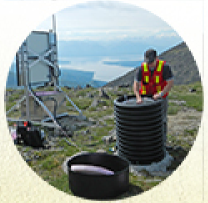
Environment and Climate Change Canada | Environnement et Changement climatique Canada

Dilbit – it’s what plants crave! ☺

Ressources naturelles Canada

Natural Resources Canada




Determining the processes responsible for plume attenuation in an oil sands wetland

Paul Gammon

May 11, 2021

Canada

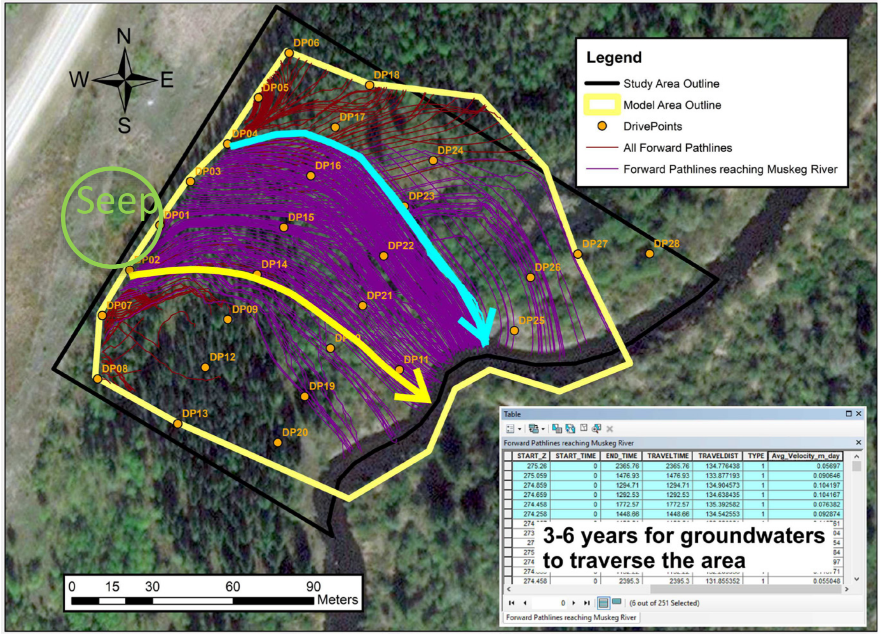
ABSTRACT

Data collection, whilst somewhat delayed by COVID-related lab shutdowns), continues to generate important new insights into the environmental processes and chemistry at the research site new Fort McMurray. Interpretation and modelling of inorganic geochemical data from the site demonstrates that the plumes' boron (B) distribution is consistent with an equilibrium sorption model. The model approximates the start of the OSPW seepage at 13 years ago, which suggests seepage probably started with the establishment of the tailings pond. Unlike B, modelling of the acid extractable organic (AEO) data indicates that the very rapid (<20 m) attenuation of the OSPW signature is unlikely to be due to sorption alone, but rather due to competitive ligand reactions that ultimately lead to carboxylic acid sequestration in the substrate. Data on microbially-mediated AEO decomposition and seep water toxicity and toxicity evolution within the plume are pending.

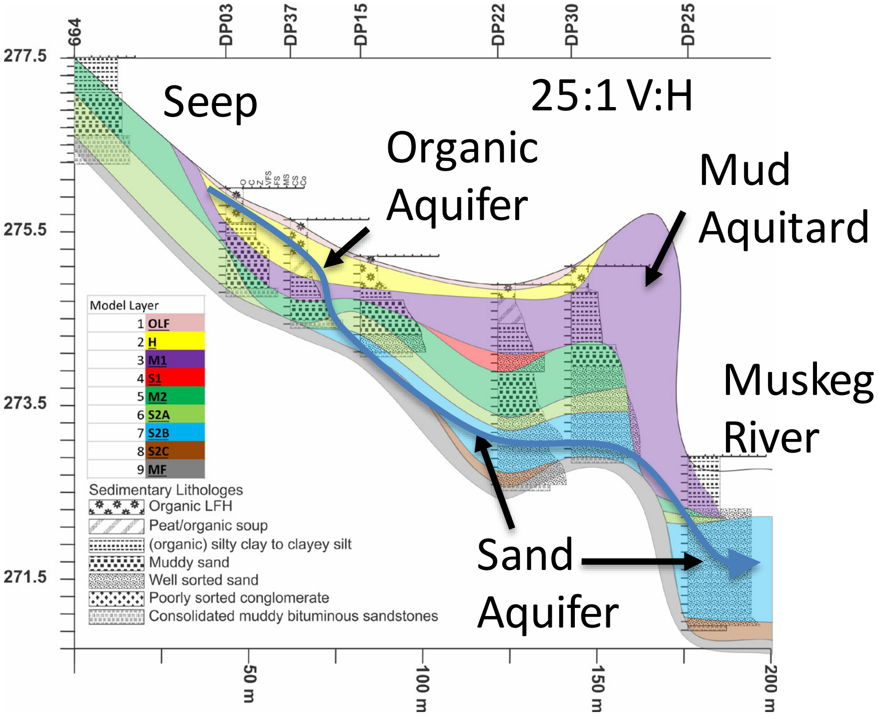
PROJECT MEMBERS

- Paul Gammon
- Jason Ahad
- Richard Amos
- James Zheng
- John Headley
- Samuel Morton
- Stephanie Roussel
- Martine Savard
- + AOS companies

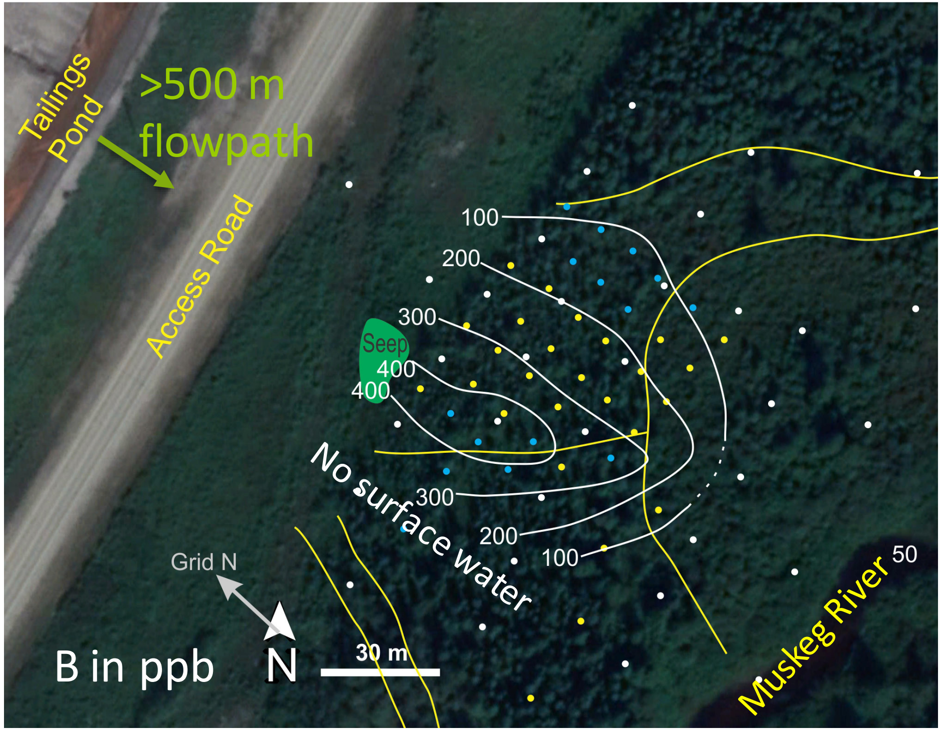
Site Physiography



Hydrostratigraphic Model



Surface waters B contours - bullseye



Detailed 10 m X 10 m grid fully captures surface water plume extent

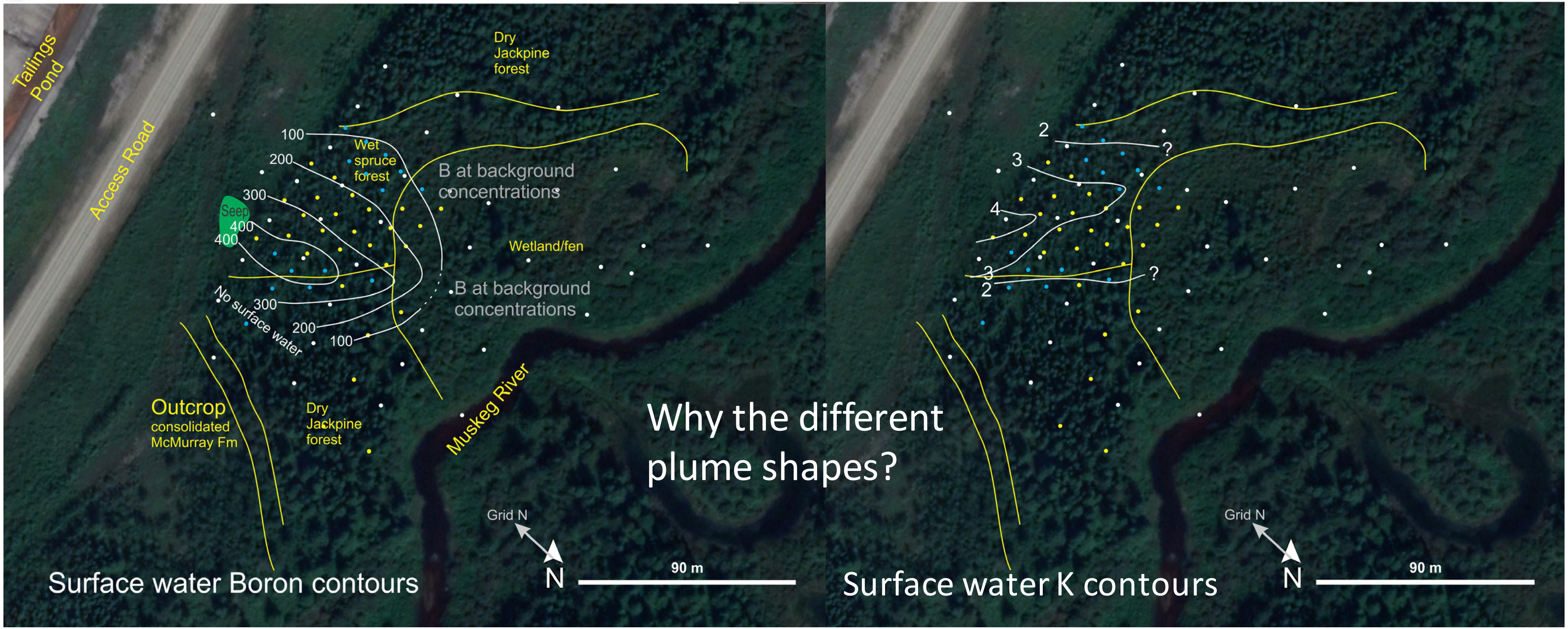
Plume defined by textbook bullseye contour pattern.

Attenuation is very rapid (~60 m).

Ongoing organic, isotopic, eDNA and toxicity analyses…

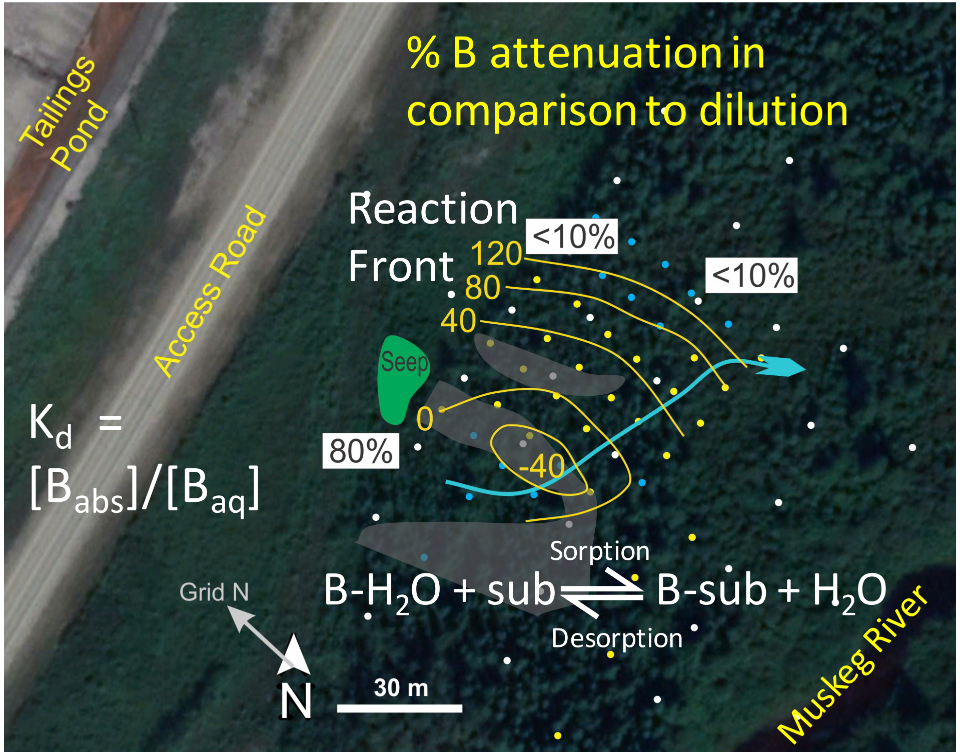
>500 m flowpath

Surface waters B vs K contours



Why the different plume shapes?

Surface B attenuation contours – reaction front



Rapid B attenuation >> dilution at edges of grid area. Suggests B controlled by sorption dynamics with a strong reaction front.

Area with negative contours are a B source:

- suggests B desorption due to max substrate B-sorption capacity
- B sorption equilibrium mediated by hydrology within plume.

K_d model

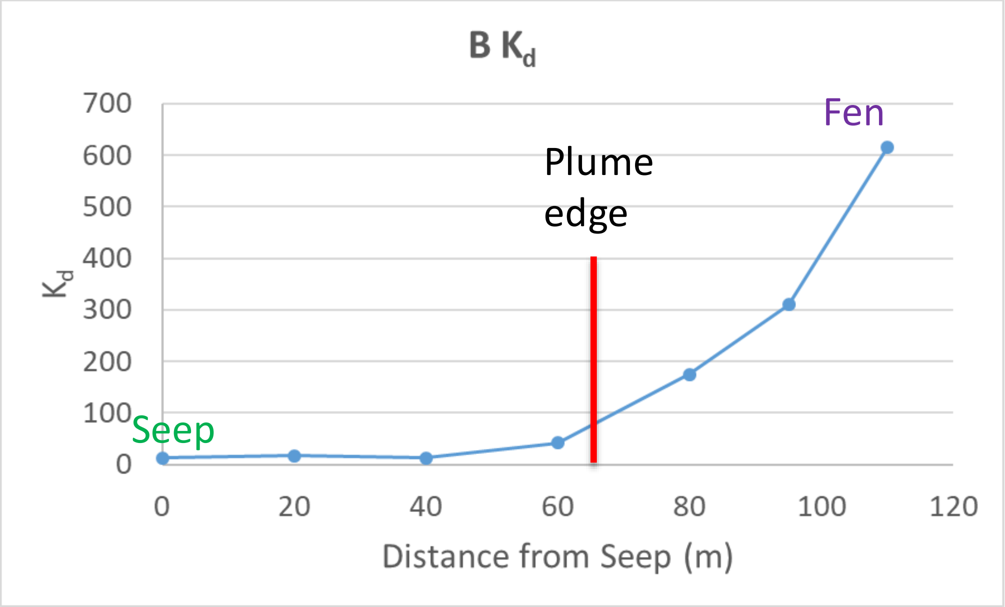
K_d in plume (12-17) is constant and consistent with experimental sorption isotherms

Implies:

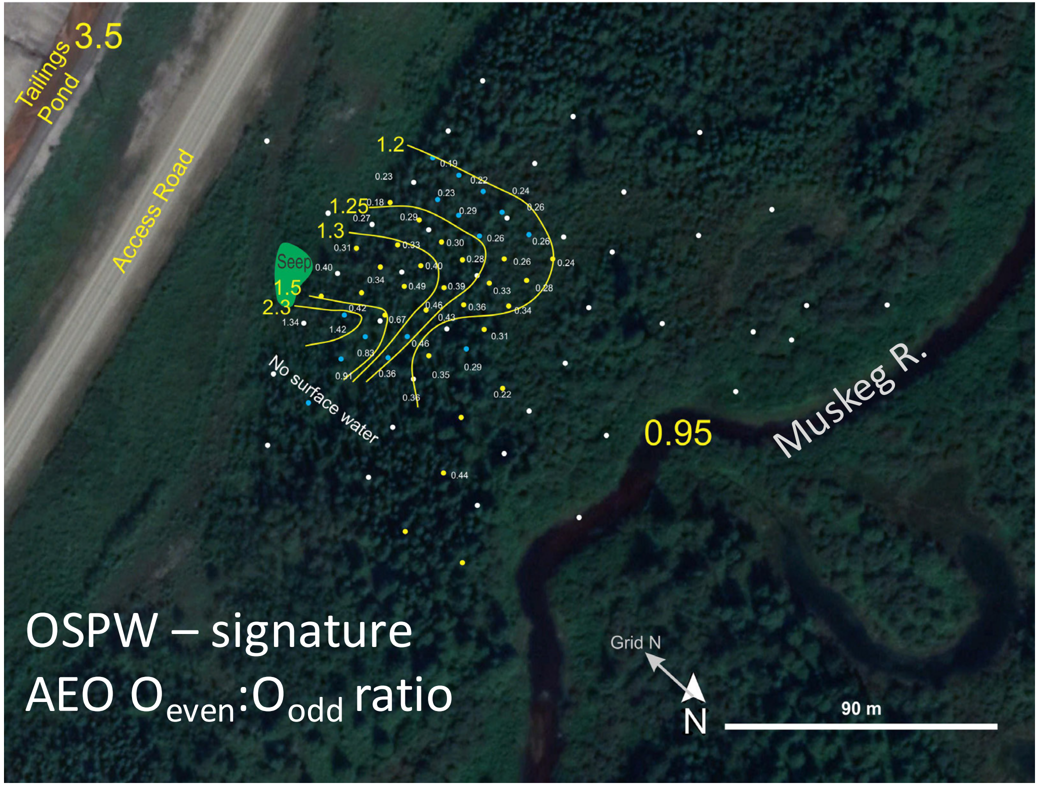
1) equilibrium B sorption inside plume,

2) Additional B sorption capacity remains outside plume

Assuming relatively constant B flux and homogeneity of humic soil layer, K_d modelling implies ~13 years of leakage – suggests seep likely active since tailings pond establishment



AEO attenuation



AEO tailings pond OSPW signature attenuates very rapidly

-consistent with limited isotopic data

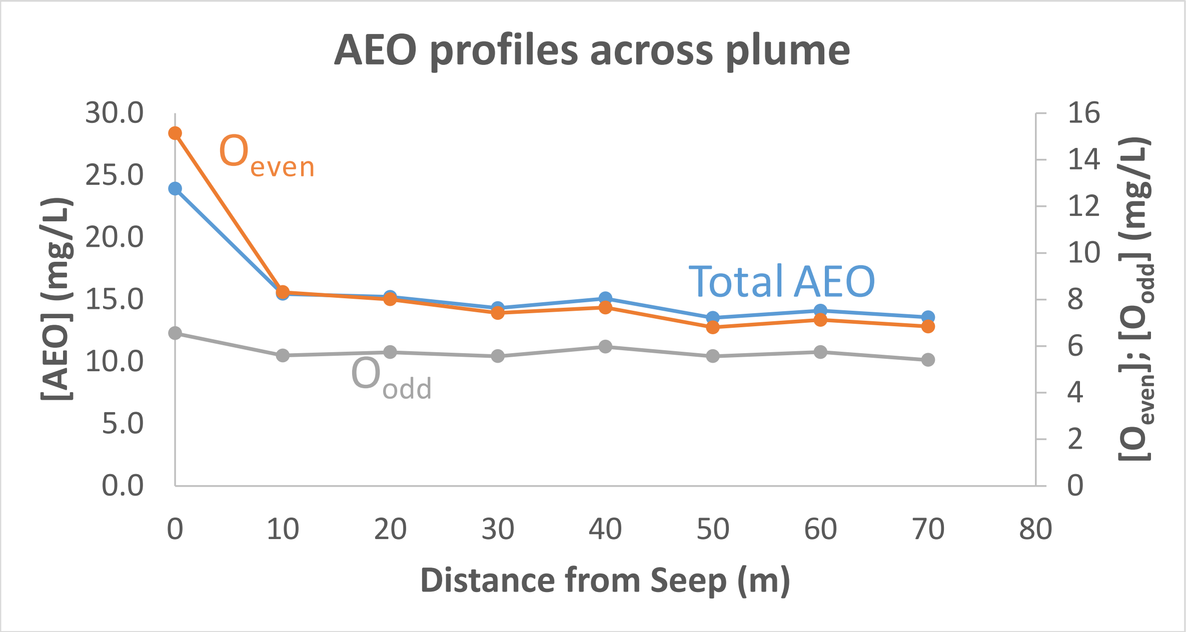
-generally consistent with plume as defined by K

-inconsistent with dilution & sorption processes for inorganics

Attenuation not uniformly distributed:

- suggests reaction front where seep surfaces
- reactions lessen the OSPW signature

Preferential sorption of AEOs



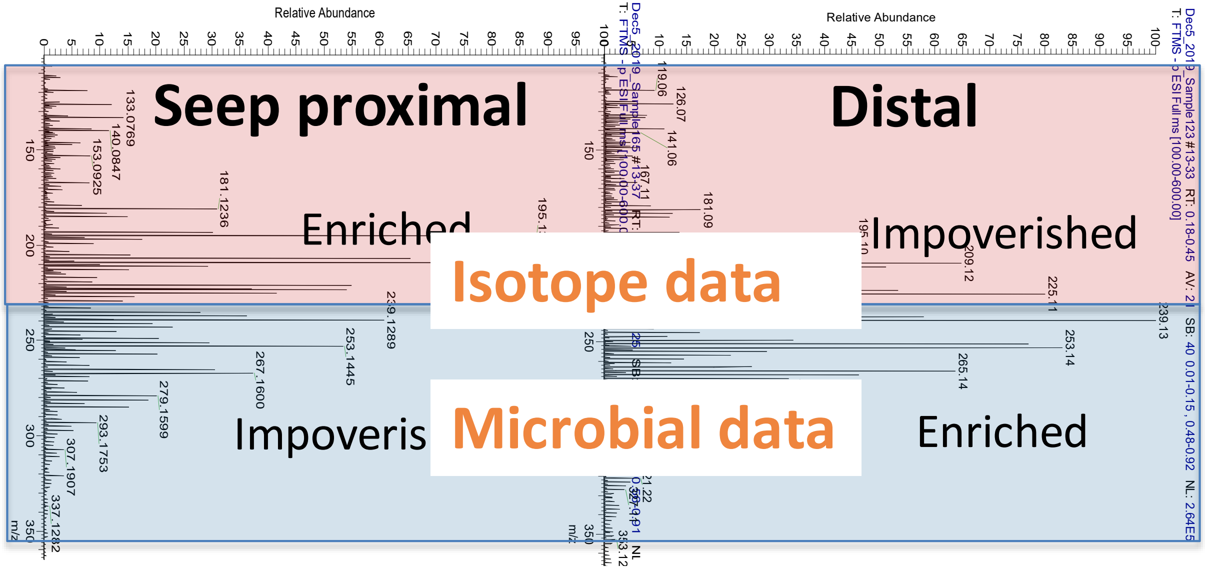
Strong (50%) preferential attenuation of O_{even} (carboxylic acid) compounds immediately upon entering the wetland.

Represents sorption K_d ~ 25 in in first 10 m
– >20X literature values

Other processes likely operating (exchange, decomposition).

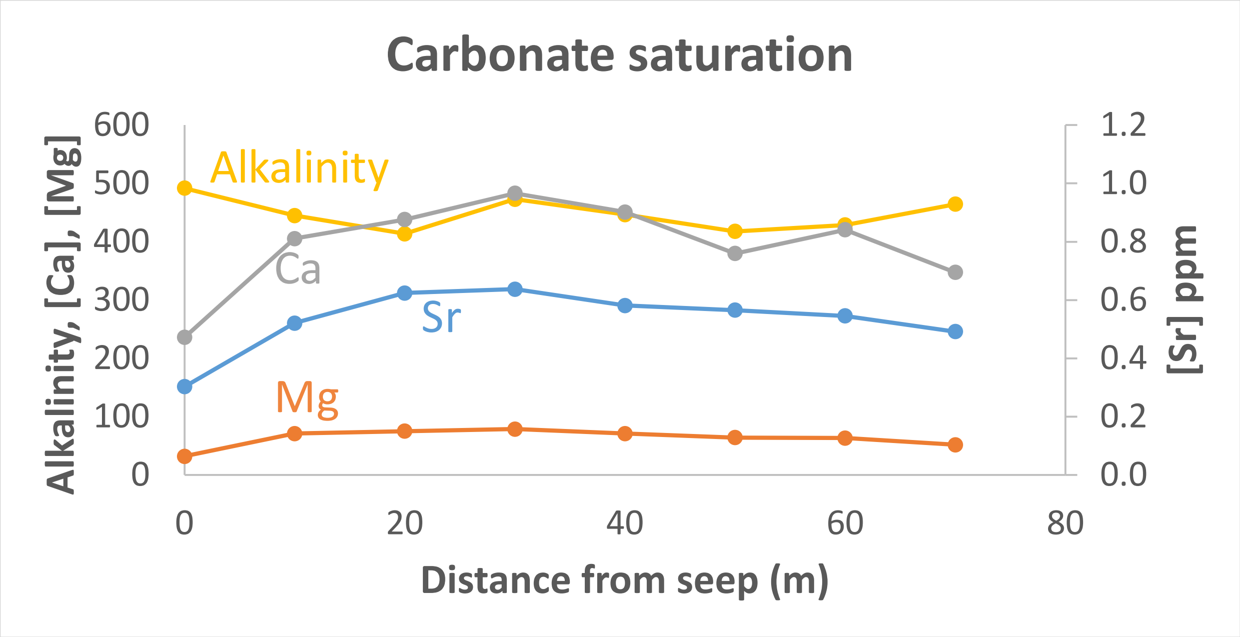
AEO exchange

OM chromatograms distinctly different between proximal and distal sites – implies AEO exchange



Does this impact (unknown) toxicity of seep waters?

Carbonate saturation



High alkalinity throughout the site

Modelling indicates multiple carbonate minerals are supersaturated

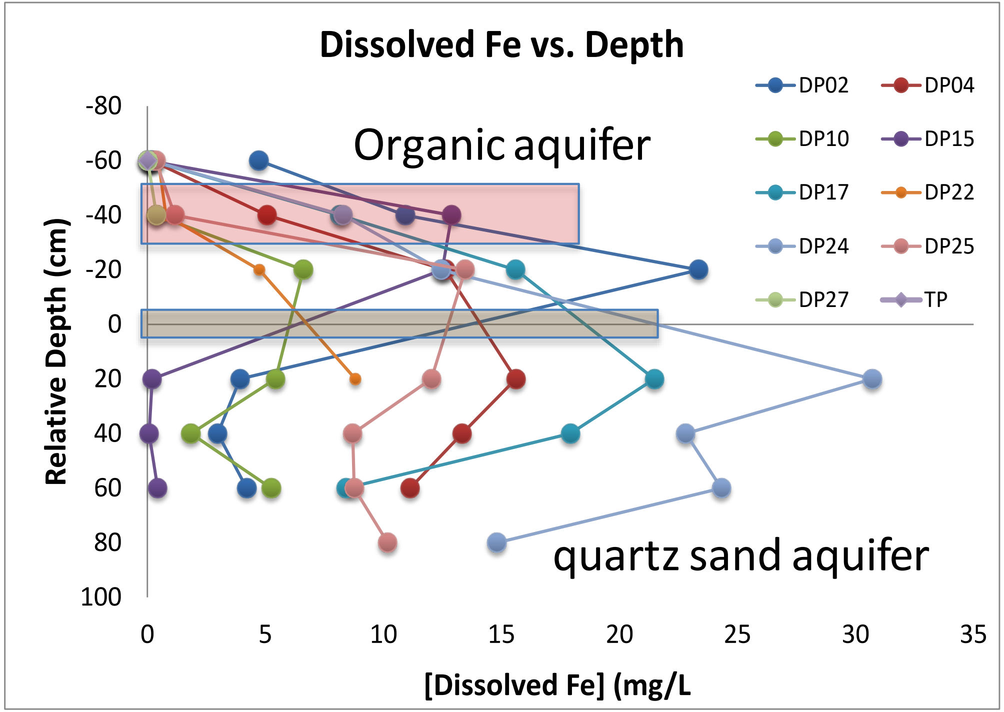
Carbonate saturation not related to OSPW seepage

Do carbonate dynamics impact AEO through organometallic complexes?

Oxyhydroxide saturation

Modelling indicates iron and manganese oxyhydroxide supersaturation in upper aquifer – redox zonation with vertical transfer of reduced ions.

Modelling indicates some sites may have aluminium oxyhydroxide supersaturation – unclear if significant.



Summary

Research site is now well characterised – some data still outstanding (COVID-related delays)

Hydrologic model enables 3D advective transport flux to be calculated

Plume environmental chemistry indicates:

- no definitive method for dilution calculation identified at present (?recalcitrant organics)
- B concentrations within the plume are controlled by equilibrium sorption dynamics
- equilibrium K_d model erected for B – seepage present since advent of TP
- AEO data indicates strong attenuation – likely not solely sorption controlled
  - exchange, decomposition likely processes
- carbonate, oxyhydroxide minerals likely precipitating - ?organometallics

CONTACT INFORMATION

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Thank you!

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Volcanic Mercury Emissions - Research in Support of the UNEP 2023 Global Mercury Assessment

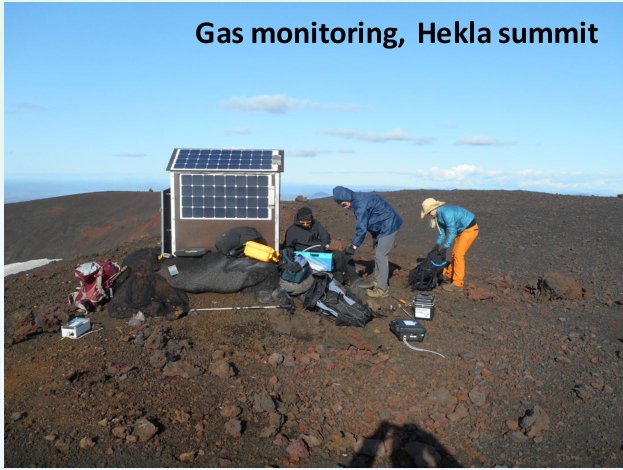
Émissions de mercure d'origine volcanique - Recherche à l'appui de l’évaluation mondiale du mercure du PNUE 2023

Peter Outridge. May 2021

Canada

ABSTRACT

- Goal: Help fill key knowledge gap in natural Hg cycle (volcanic systems' emissions), a weakness in global Hg budget supporting Minamata Convention on Mercury, 2017.
- Focus on Icelandic volcanic systems (possible high Hg emitters).
- Progress on schedule.



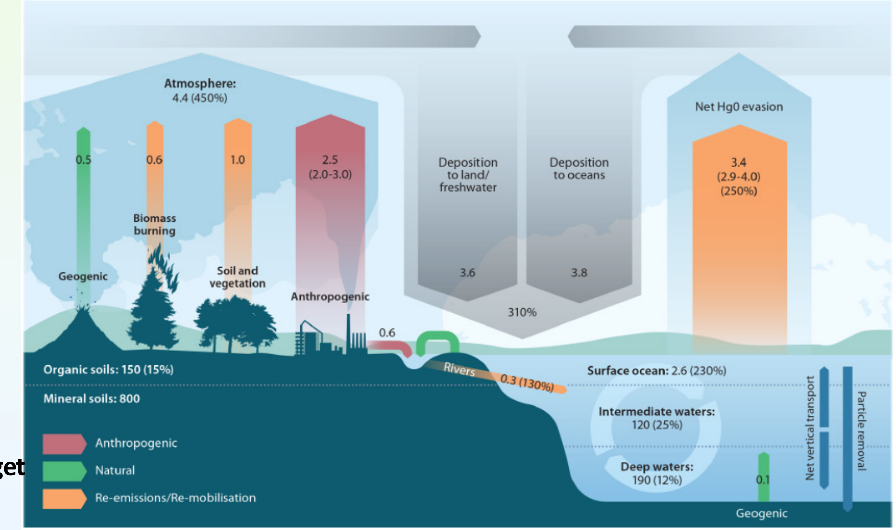
Gas monitoring, Hekla summit

PROJECT MEMBERS

- Peter Outridge, GSC P.L.
- Brock Edwards (NRCan RAP-PhD student)
- Feiyue Wang, U. Manitoba
- Melissa Pfeffer & Michelle Parks, Icelandic Met. Office
- Hamed Sanei, Aarhus U., Denmark
- Bruce Kjarsgaard, GSC

Project Context

- Total geogenic Hg emissions to air poorly constrained (<1 – ~30% of anthropogenic emissions, i.e. <10 – 900 tonnes/yr).
- Volcanic systems (erupting + degassing volcanoes, & geothermal/hydrothermal) ~90% of total natural.
- Iceland Hg studies 1970s support very high natural emission estimate
  - many 10,000s ng Hg/m^3 (background 1-2 ng/m^3)



AMAP/UNEP (2018) Global Mercury Budget

Progress (May 20 - May 21)

- Brock's PhD course work completed;
- Lit. review on global volcanic Hg published Mar 2021 (https://doi.org/10.1016/j.scitotenv.2020.143800);
- 2nd Iceland field trip, April 2021 (Brock) – passive & active sampling of mercury in effusion fumes from Geldingadalir erupting fissure. With Icelandic Met. Office and U. of Reykjavik collaborators.
- Drone sampling of Hg in volcanic plume (believed to be world 1st)


Photo copyright
Brock Edwards

Brock Edwards setting up a passive air sampler for mercury measurement down-wind from the erupting Geldingadalir fissure

CONTACT INFORMATION

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THANK YOU!

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Long-term hydrological dynamics of Canada's largest watershed: The Mackenzie River Basin

Dynamique hydrologique à long terme du plus grand basin versant du Canada: le bassin du fleuve Mackenzie

Jennifer Galloway

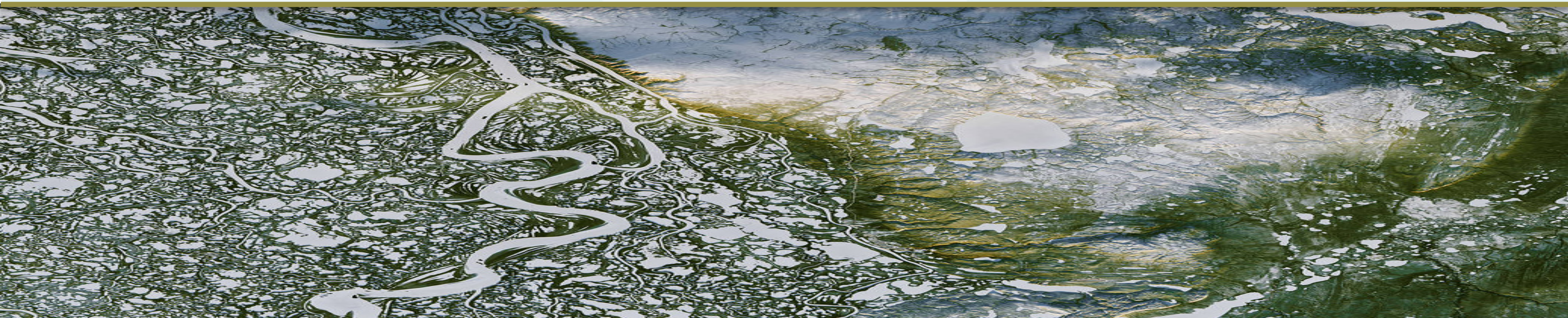
May 2021

Canada

ABSTRACT

- The Mackenzie River (*Deh-Cho, Kuukpak, Fleuve du Mackenzie*) Basin (MRB) is one of the World's largest (4200 km long) and most important freshwater ecosystems.
- Climate change is disproportionately affecting high northern latitudes, especially in NW Canada.
- How will climate change affect water quantity in the MRB?
- Ice jam flooding vs. low water levels
- Carbon storage vs. export
- This project will examine long-term trends and cycles to develop predictive ecohydrological models.

NASA Earth Observatory Joshua Stevens. LandSAT82 2016 data from USGS



PROJECT MEMBERS

Internal	Galloway, Jennifer (GSC-C)
	Hadlari, Thomas (GSC-C)
	Ardakani, Omid (GSC-C)
	Bringué, Manuel (GSC-C)
	Wolfe, Steve (GSC-N)
	Morse, Peter (GSC-N)
	Parsons, Michael (GSC-A)
	Whalen, Dustin (GSC-A)
	Dennis Jiang (GSC-C)
	Jaime Rafael Cesar Colmenares (GSC-C)
External	Falck, Hendrik and Kokelj, Steve (GNWT)
	Lantz, Trevor (University of Victoria)
	Shotyk, William (University of Alberta)
	Clark, Ian (University of Ottawa)
	Patterson, R. Tim (Carleton University)
	Chappaz, Anthony (Central Michigan University)
	Swindles, Graeme (Queen's University, Belfast)
	Baird, Andy and Morris, Paul (University of Leeds)
	Gałka, Mariusz (University of Lodz)
	Lord, Sarah (Gwich'in Renewable Resources Board)
	Snowshoe, Sharon (Gwich'in Tribal Council, Dept. of Cultural Heritage)
	Clarke, Leon (Manchester Metropolitan University)
HQP	Lukas Frost and Andrii Oleksandrenko (PhDs) (U of Alberta)
	Tait Overeem (MSc, U Vic)
	Naomi Weinberg (MSc) and Anne Nguyen (PhD, pending) (Carleton)



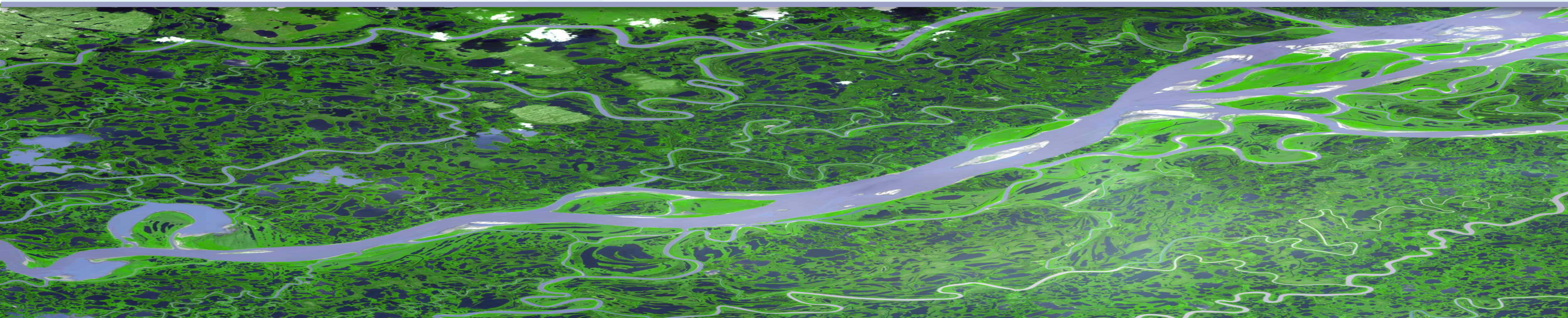



PROGRESS TO DATE

- ArcticNet (#51) funding (FY 19-20 to 21-22)
- Traditional Knowledge study (Sharon Snowshoe, Gwich'in Tribal Council, Dept. of Cultural Heritage, Trevor Lantz, U Vic & Tait Overeem, MSc candidate, et al.) initiated. Focuses on synthesis of previously documented TK related to water levels in the Gwich'in Settlement Area. This synthesis includes 40 interviews carried out as part of the Tracking Change Project (www.trackingchange.ca) . Based on the synthesis and identified knowledge gaps new activities will be planned to document knowledge recorded in interviews stored in the Dept. of Cultural Heritage's digital archive. This approach builds on an existing body of work to prevent interview fatigue

AND

ASTER, Aug. 4, 2005, 68.6°N, 134.7°W; NASA/GSFC/METI/ERSDAC/JAROS, and U.S./Japan ASTER Science Team



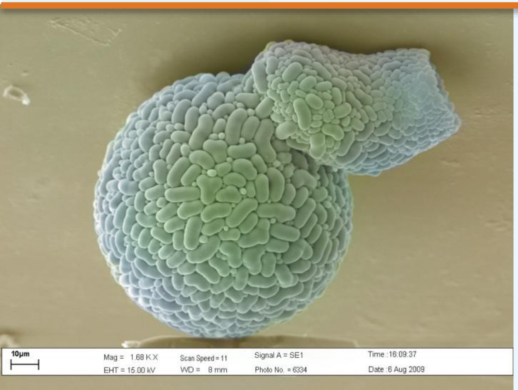
PROGRESS TO DATE

- Preparation and analysis of existing peatland monoliths and cores for pH, EC, ash content, HAWK pyrolysis, Hg analysis, organic contaminants, gamma spectrometry and AMS dating (^{210}Pb and ^{14}C), elemental analysis by ICP-MS, light stable isotopes, acid digestion (sequential, as needed), palynological analysis, plant macrofossils, and micropaleontological analysis (testate amoebae)

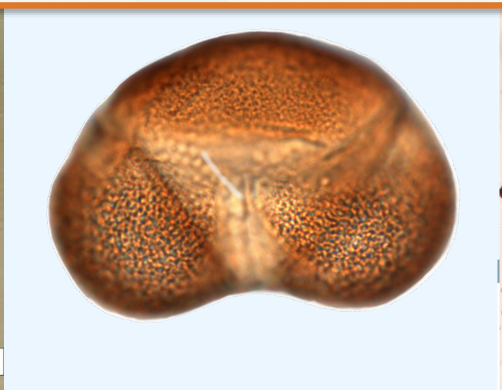
TO

- Reconstruct depth-to-water table (quantitative), fire and vegetation history, chemical change, hydrological change, and synoptic-scale climate patterns (e.g., Pacific Decadal Oscillation) that may drive water quantity change in the MRB

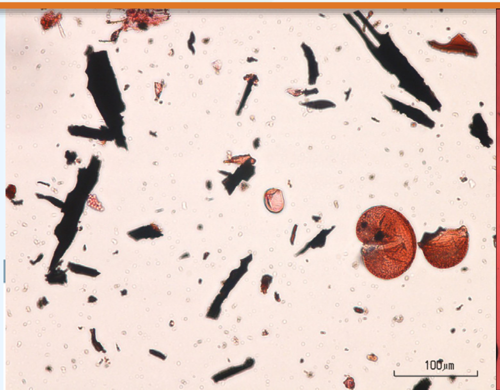
Lesquereusia epistomium survives peat fires (credit: Yuri Mazei)



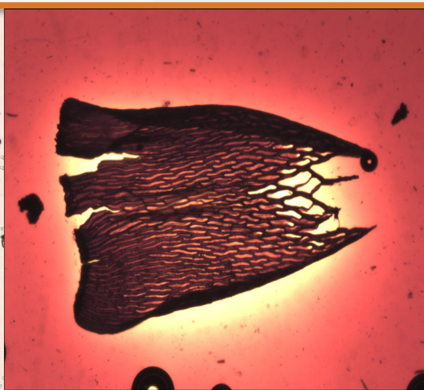
Picea (spruce) pollen (~125 µm) (credit: Neotoma database)



Microscopic charcoal (credit: Mathewes et al. 2019 Vegetation History and Archaeobotany)



Sphagnum riparium (credit: Mariusz Gałka)



HIGHLIGHTS

- Climate warming results in increased production in subarctic lakes. The increase in organic matter mediates redox conditions leading to release of elements previously stored in sediments to the surface waters (Miller et al., 2020; Chem. Geol.). Climate change needs to be considered in Environmental Assessment and remediation strategies (Miller et al., 2019; STOTEN).

- Testate lobose amoebae respond to changes in the geochemistry of the sediments and are sensitive bioindicators of arsenic in subarctic lakes. They can be used to reconstruct quantities of this redox-sensitive element in sediment profiles (Nasser et al., 2020; PeerJ).

Photo: Paul Vecsei

OUTPUTS

- Galloway, J.M., Gałka, M., Swindles, G.T., Wolfe, S.A., Morse, P.D., Patterson, R.T., Falck, H., Kung, L. 2020. Ecohydrological dynamics of a degrading subarctic peatland: Implications for arsenic mobility. European Geosciences Union (EGU), virtual online meeting, May 3-8.
- Miller, C.M., Parsons, M.B., Jamieson, H.E., Ardakani, O.H., Patterson, R.T., **Galloway, J.M**. 2020. Solid phase organic matter control on arsenic mobility in mining-impacted sediment, Tundra Mine, Northwest Territories, Canada. Chemical Geology. *In review.*
- Nasser, N.A., Patterson, R.T., **Galloway, J.M.**, Falck, H. 2020. Intra-lake response of Arcellinida (testate lobose amoebae) to gold mining-induced arsenic contamination in northern Canada: Implications for environmental monitoring. *In press*. PeerJ.
- Nasser, N.A., Patterson, R.T., Roe, H.M., **Galloway, J.M**., Falck, H., Palmer, M.J., Sanei, H. 2020. Use of Arcellinida (testate lobose amoebae) arsenic tolerance limits as a novel tool for biomonitoring arsenic contamination in lakes. Ecological Indicators 113: 106277,
- Miller, C.B., Parsons, M.B., Jamieson, H.E., Swindles, G.T., Nasser, N.A., **Galloway, J.M**. 2019. Lake-specific controls on the long-term stability of mining-related, legacy arsenic contamination and geochemical baselines in a changing northern environment, Tundra Mine, Northwest Territories, Canada. Applied Geochemistry 109: 104403.
- Miller, C.B., Parsons, M.B., Jamieson, H.E., Arkanaki, O.H., Gregory, B.R., **Galloway, J.M.** 2019. Influence of late Holocene climate on solid-phase speciation and long-term stability of arsenic in sub-arctic lake sediments. Science of the Total Environment 709: 136115.
- Swindles, G.T., Morris, P.J., Mullan, D.J., Payne, R.J., Roland, T.P., Amesbury, M.J., Lamentowicz, M., Turner, T.E., Gallego-Sala, A., Sim, T., Barr, I.D., Blaauw, M., Blundell, A., Chambers, F.M., Charman, D.J., Freurdean, A., **Galloway, J.M.**, Gałka, M., Green, S., Kajukało, K., Karofeld, E., Korhola, A., Lamentowicz, Ł., Langdon, P., Marcisz, K., Mauquoy, D., Mazei, Y.A., McKeown, M., Mitchell, E.A.D., Novenko, E., Plunkett, G., Roe, H.M., Schoning, K., Sillasoo, Ü., Tsyganov, A.N., van der Linden, M., Väliranta, M., Warner, B. 2019. Widespread drying of European peatlands in recent centuries. Nature Geoscience 12: 922-928.
- Nasser, N.A., *Gregory, B.R.B., Steele, R.E., Patterson, R.T., Galloway, J.M. 2019. Behind the organic veil: assessing the impact of chemical deflocculation upon organic content reduction and lacustrine Arcellinida (testate amoebae) analysis. Microbial Ecology 79: 443-458.

Photo: Paul Vecsei

CONTACT INFORMATION

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https://scholar.google.ca/citations?user=x6SQcrsAAAAJ&hl=en

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Cumulative Effects of Resource Development on Mining-Impacted Watersheds

Effets Cumulatifs du Développement Minier dans les Bassins Versants Contaminés

Alexandre Desbarats

May 2021

Canada

ABSTRACT

Renewed exploration or development in historical mining districts, such as Cobalt, presents unique challenges for proponents and government regulators because of the cumulative nature of environmental impacts. To increase capacity to carry out or review environmental assessments, this project will develop geoscience methods for distinguishing environmental effects of new mining activity from complex existing background conditions in affected watersheds. Specifically, the project will develop means of unraveling the history of accumulated polymetallic contamination from multiple sources over multiple periods. This information and new data from mine wastes and mine drainage will be synthesized in the first geoenvironmental model for Ag-Ni-Co-As vein type deposits. Project results will be disseminated to key end users in order to improve the environmental assessment process and to ensure that decision makers have a better understanding of the cumulative nature of environmental impacts for sustainable mineral resource development.

PROJECT MEMBERS

- Alexandre Desbarats (GSC-NC, leader)
- Paul Gammon (GSC-NC)
- Michael Parsons (GSC-ATL)
- Jeanne Percival (GSC-NC)
- Katherine Venance (GSC-NC)
- Jennifer Galloway (GSC-Cal)
- Suzanne Beauchemin (Health Canada)
- Tom Al (University of Ottawa)
- Danielle Fortin (University of Ottawa)
- Heather Jamieson (Queen's University)
- Jennifer Cole (CANMET-CMIN)
- Richard Goulet (CANMET-CMIN)

Beaver-Temiskaming tailings

Cumulative Effects Assessment in a Historical Mining Camp undergoing a new Exploration Boom: Scientific Questions

- How to assess environmental impacts of new resource development against a brownfield legacy of pervasive contamination due to 90 years of un-regulated mining activity?
- What was the pre-mining (bio)geochemical baseline of the soils, sediments, vegetation, and waters of the mineralized watersheds?
- Has the existing environment reached a new geochemical equilibrium after historical resource development activities?
- Are there geochemical thresholds (tipping points) that need to be considered in assessing cumulative effects?
- Can lake sediment cores provide a reliable chronology of different phases of resource development in a mining-impacted watershed?
- With reference to climate change, what effects will the environment have on past, current, and future resource development projects?

Task 0: Partnership building with mining industry (Desbarats, lead)

FY 2020-2021 Achievements

- Partnership building with Agnico-Eagle Mines (AEM): Departure of original AEM representative (Chris Kennedy) required rebuilding partnership with new representative (Josée Brazeau).
- Partnership building with First Cobalt: Frank Santaguida (contact)
- Partnership building with local consultants Story Environmental Inc.: Contracting out fieldwork (discharge flow monitoring, core drilling) that could not be done due to pandemic travel restrictions.

Task 1: Metal(loid) loading in groundwater discharge to surface waters (Desbarats, lead)

Task 1.2: Discharge of metal(loid)-impacted groundwater from mine openings: Locating and characterizing anthropogenic seeps of mine-impacted groundwater

FY 2020-2021 Achievements:

- Planned fieldwork not possible due to pandemic travel restrictions
- Plan B! Fabrication, installation and instrumentation of a flow measuring system for monitoring discharge of contaminated mine waters from Shaft #98 in the Cobalt camp

H-Flume at Shaft #98

Task 2: Stability of legacy contaminants in wetlands and lake environments (Parsons, lead)

Task 2.1: Sample mine wastes, sediments, and surface waters upstream and downstream of mining-impacted areas to evaluate the concentration and speciation of Ag, As, Co, Hg, Ni, and Sb in pre-mining and near-surface sediments and pore water.

Task 2.3: Micro-paleontological analysis (arcellaceans, diatoms, pollen) of lake sediments to evaluate the ecological response to legacy contamination, and the cumulative effects of mining and other development activities on aquatic biota.

Tailings deposited in Crosswise Lake, Cobalt, ON, with mill foundations in the foreground

Task 2: Stability of legacy contaminants in wetlands and lake environments (continued)

FY 2020-2021 Achievements

- Planned sediment coring in Lake Temiskaming not possible due to pandemic. Plan B! Drilled two boreholes through mine tailings deposited in Crosswise Lake
- Collected continuous core samples in tailings and underlying organic and glaciolacustrine sediments (total 35 samples). Analyses next FY
- With Richard Goulet (CANMET-Mining) LOI to Genomics Canada on "Using sediment DNA and historical metal(loid) profiles in sediments to explain past ecological impacts from mining projects and predict future impacts under changing climate"

Task 3: Mineralogical characterization of mine wastes and other solid phases (Percival, lead)

Task 3.1: Review and re-analysis of selected archived samples from earlier studies as a platform to define the mineralogical signature for the geoenvironmental ore deposit model.

Task 3.3: Micro-mineralogy of primary and secondary As, Co, Ni and Sb phases in high-grade tailings and mill waste to evaluate the solid-phase speciation of these elements and their long-term stability under weathering conditions and remediation scenarios.

FY 2020-2021 Achievements

- Retrieval of archived material after move from Tunney's Pasture and preparation of heavy mineral separates; test of SEM analyses to ID heavy minerals in tailings samples
- Parsons with Heather Jamieson (Queen's) supervising M.Sc. Student (Melissa Turcotte) studying micro-mineralogy of mine wastes from archived samples

Task 4: Best management practices for cobalt-rich tailings (Beauchemin, Health Canada, lead)

Task 4.2: Laboratory experiments under controlled conditions to elucidate health risks from metal(loids) in airborne dust from tailings impoundments.

FY 2020-2021 Achievements

- Metals and Airborne Particulate Matter Laboratory (Health Canada) interested in airborne mobilization of Co, As, Ni, Pb from historical mine sites
- Preliminary sampling of road dust and dust from tailings impoundment in Cobalt was conducted under contract with Story Environmental
- Research proposal to be submitted under the 2022-2025 Chemicals Management Plan

Task 5: Weathering processes in Cobalt-type Ag-Ni-Co arsenide tailings (T. Al, University of Ottawa, lead)

Task 5.1: Field sampling of in-situ weathering products of primary Ag-Ni-Co arsenide and sulphide minerals in mine tailings

Task 5.2: Detailed mineralogical investigations of weathering products and laboratory studies of metal(loid) mobilization

FY 2020-2021 Achievements:

- M.Sc. student (Cole Fischer) fieldwork at Cart Lake tailings not possible in 2020 due to pandemic restrictions
- Plan B! Scope of thesis refocused on sample material collected in 2019 only

Cart Lake tailings

CONTACT INFORMATION

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THANK YOU!

Ressources naturelles Canada
Natural Resources Canada

Environmental impacts of permafrost degradation

Impacts environnementaux de la dégradation du pergélisol

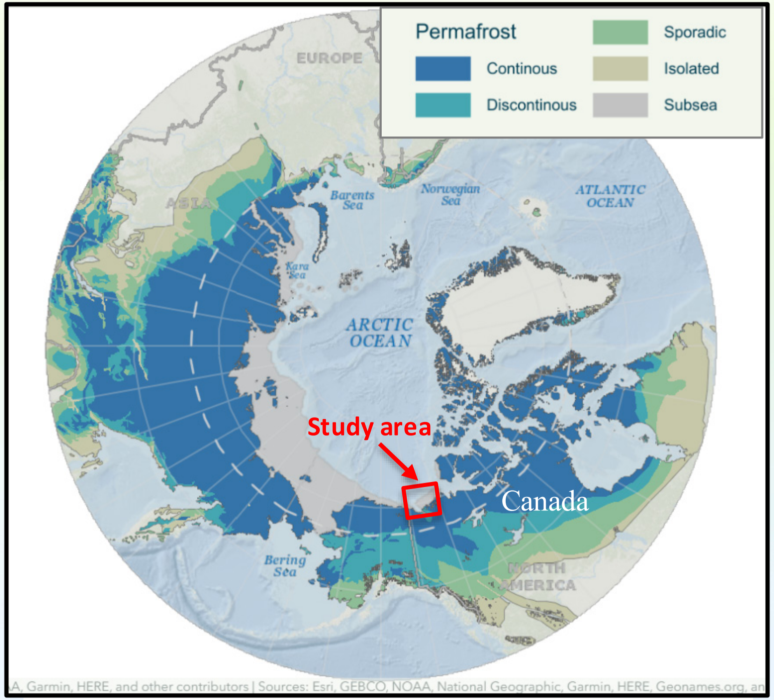
Mathieu J. Duchesne. May 2021

ABSTRACT

- Permafrost underlies ~50% of the Canadian landmass.

- Permafrost degradation: natural release of contaminants (e.g. heavy metals), trapped greenhouse gases and saline pore fluids into the environment.

- Project objectives:
  1. assess the environmental implications of permafrost degradation
  2. provide a baseline to better appraise the environmental consequences of resource development.

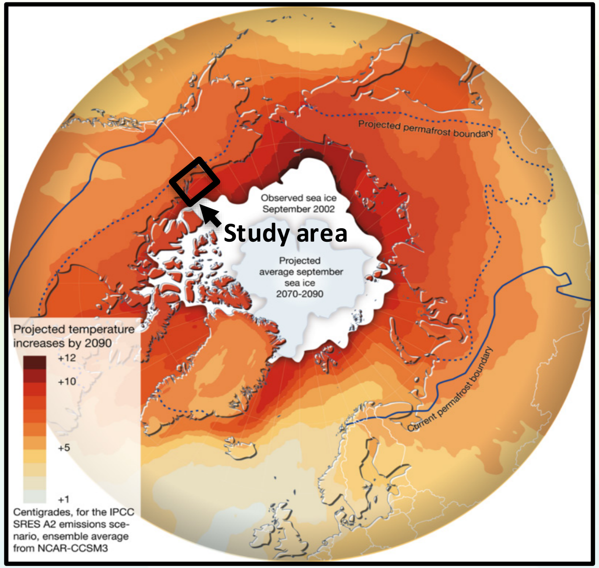


ESRI, GEBCO, NOAA, National Geographic, Garmin

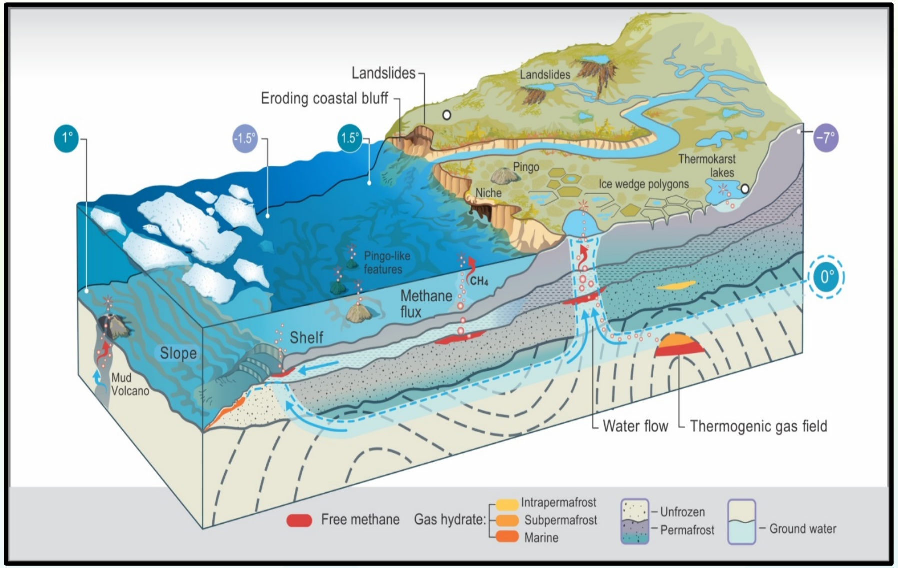
PROJECT MEMBERS

- GSC- Permafrost mapping and characterization: Brake, V. I., Duchesne, M.J., Hu, K., Pinet, N.
- GSC- Environmental and Geochemistry: Outridge, P., Zheng, J., Côté, M., Dallimore, S.R, King, E., MacLeod, R., Morse, P., Wolfe, S.,
- External collaborators: Fabien-Ouellet, G. (Polytechnique Montreal), Giroux, B. (INRS), Raymond, J. (INRS), Dupuis, J. Christian Dupuis (Laval University), Risk, D. (St. Francis Xavier University), Greinert, J. (GEOMAR), Gwiazda, R. (MBARI), Jin, Y. K. (KOPRI), Kang, S.-G. (KOPRI), Lapham, L. (U. of Maryland), Orcutt, B. (Bigelow Lab.), Overduin, P. (AWI), Paull, C.K. (MBARI), Rhee, T. S. (KOPRI), Riedel, M. (GEOMAR), Wheat, G. (U. of Alaska)

Project Context



National Center for Atmospheric Research, 2008



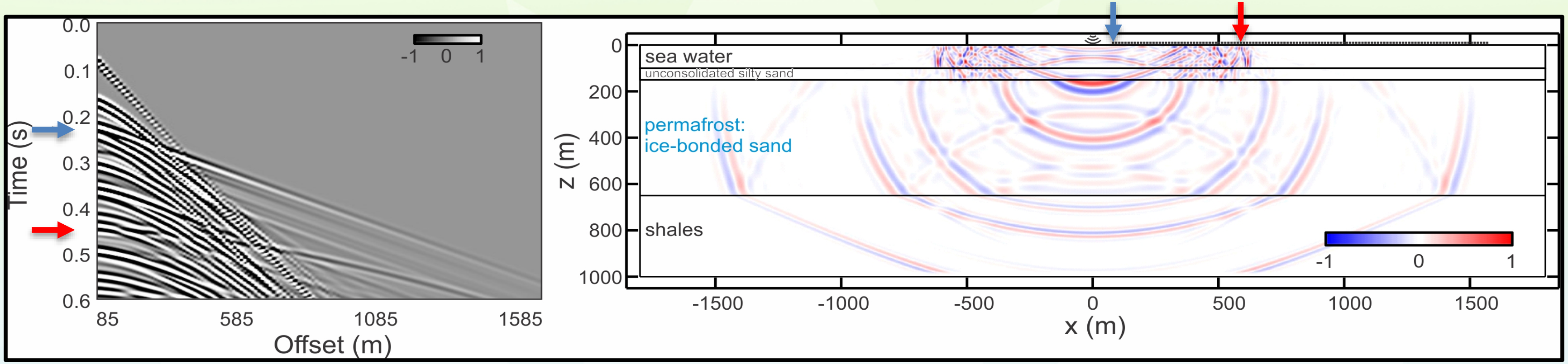
United Nations Environment Programme -Rapid Response Assessment-: Offshore and Coastal permafrost

The abrupt temperature increases across the Arctic circumpolar triggers a wide range of geological processes associated with permafrost degradation. Some of them, such as the release of greenhouse gases, have profound impacts on the environment

Progress (May 2020 - May 2021)

Seismic characterization of permafrost conditions: imaging the base of the permafrost

Duchesne, M.J. (GSC-Q), Fabien-Ouellet, G. (Polytechnique Mtl) & Bustamante Restrepo, J. (Polytechnique Mtl)

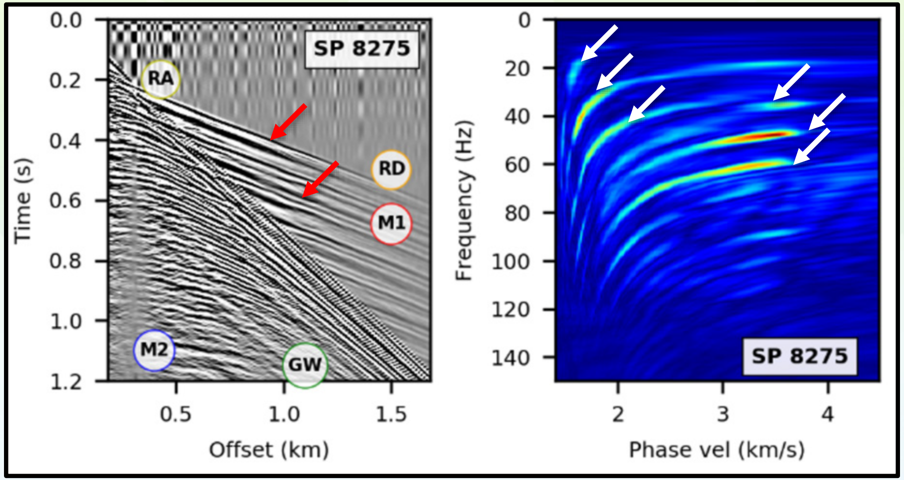


Imaging the base of subsea permafrost (red arrow on the shot gather on the left and on the snapshot of propagation wavefield on the right) from seismic methods is non-trivial task because of the occurrence data artifacts and the limit of the methods. Through numerical modeling, reflection imaging of the base of the permafrost is examined and the impact of specific characteristics of the subsurface and acquisition parameters are analyzed. Once the top and the base of the permafrost are identified on seismic data, they can be used to estimate permafrost thickness.

Progress (May 2020 - May 2021)

Seismic characterization of subsea permafrost conditions: what can we learn from guided waves?

Bustamante Restrepo, J. (Polytechnique Mtl), Fabien-Ouellet, G. (Polytechnique Mtl) & Duchesne, M.J. (GSC-Q)

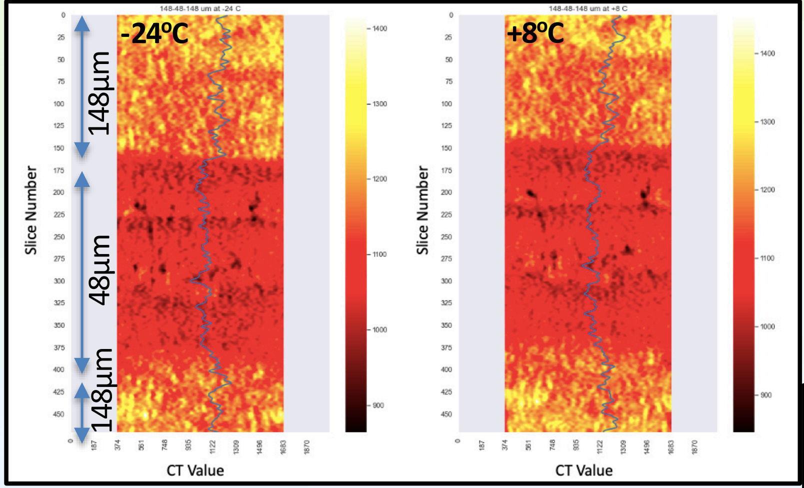


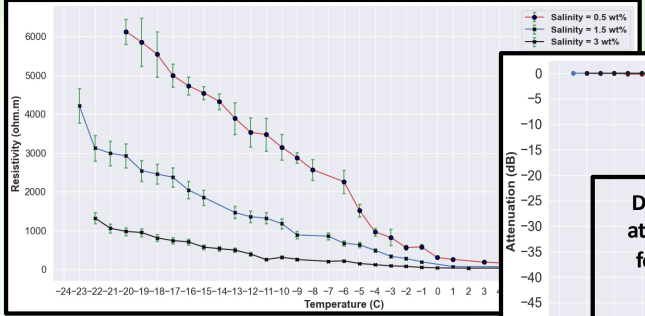
High impedance contrasts between sea water, unfrozen and frozen sediments give rise to important guided waves (red arrows on the shot gather on the left). The analysis of the different modes (white arrows) on the dispersion plot on the right allows to determine what part of the signal can be described as guided waves and use to characterize subsea permafrost conditions.

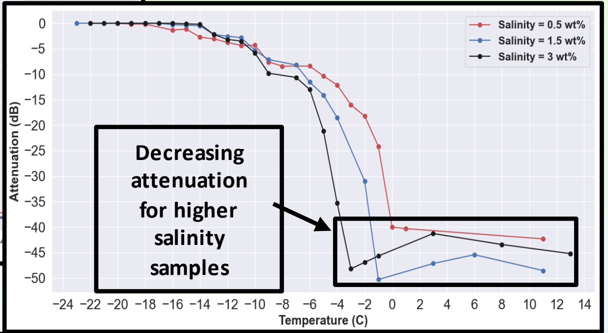
Progress (May 2020 - May 2021)

Simultaneous acoustic, electrical and X-ray computed tomography laboratory measurements of partially-saturated permafrost degradation

Vosoughi, E. (INRS), Giroux, B. (INRS), Duchesne, M.J. (GSC-Q) & Dupuis, J. C. (Laval U.)





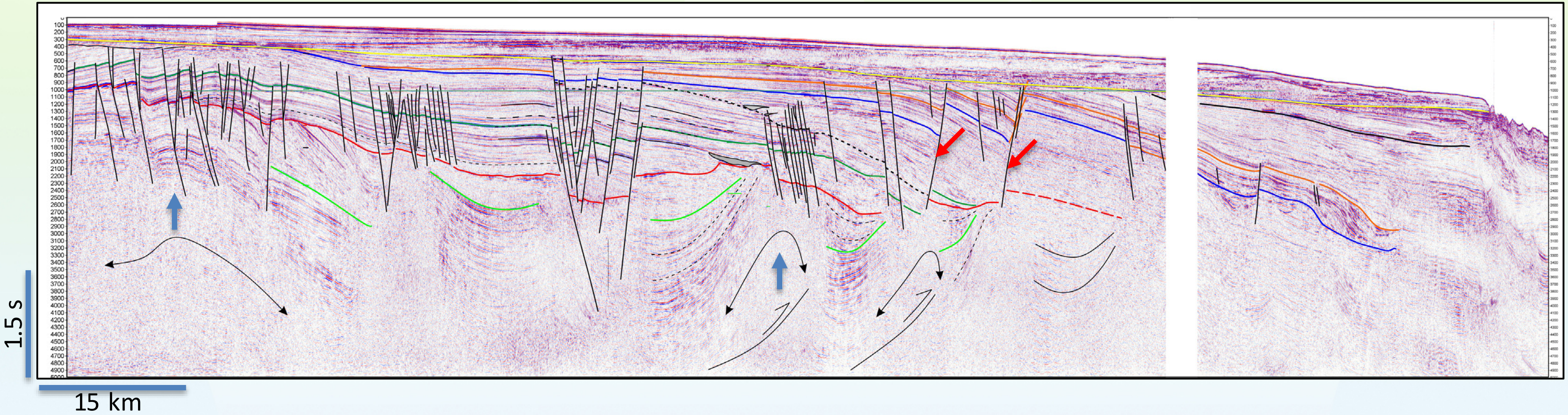


Simultaneous computed-tomography (left), electrical (center) and acoustic (right) measurements are made on synthetic permafrost samples to determine the impact of permafrost degradation on geophysical properties. This will provide a more accurate interpretation of geophysical data collected in regions experiencing permafrost degradation.

Progress (May 2020 - May 2021)

Structural interpretation of seismic reflection data

Pinet, N. (GSC-Q), Brake, V.I. (GSC-Q) & Duchesne, M.J. (GSC-Q)

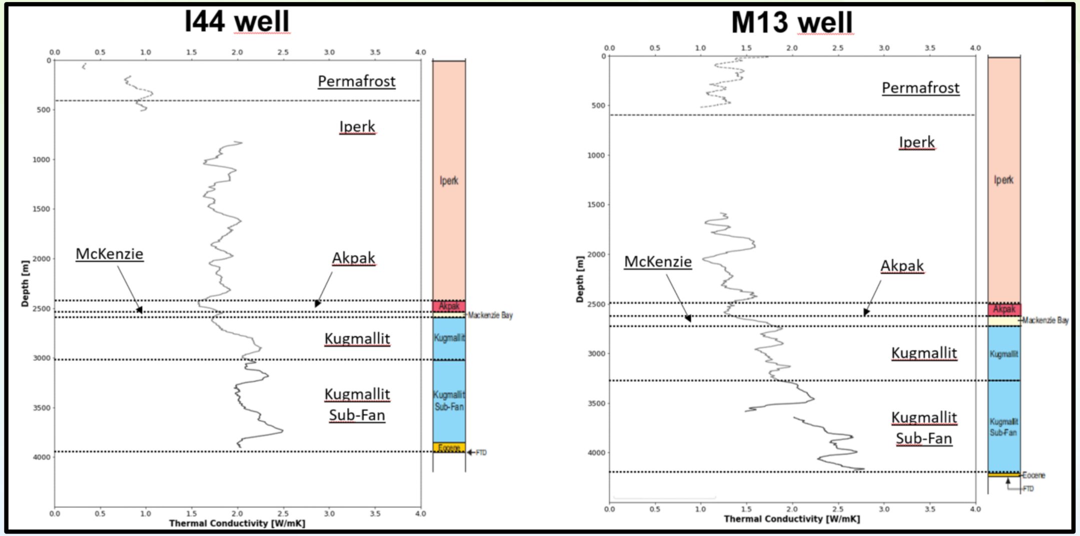


Interpretation of seismic reflection data allow to identify potential permeable geological structures (e.g. folds –blue arrows- & faults –red arrows-). This will help to understand the role fluid migration from depth as on permafrost degradation.

Progress (May 2020 - May 2021)

Geothermal characterization for numerical simulations of subsea permafrost degradation

Comeau, F-A. (INRS), Giordano, N. (INRS), Raymond, J. (INRS) & Duchesne, M.J. (GSC-Q)

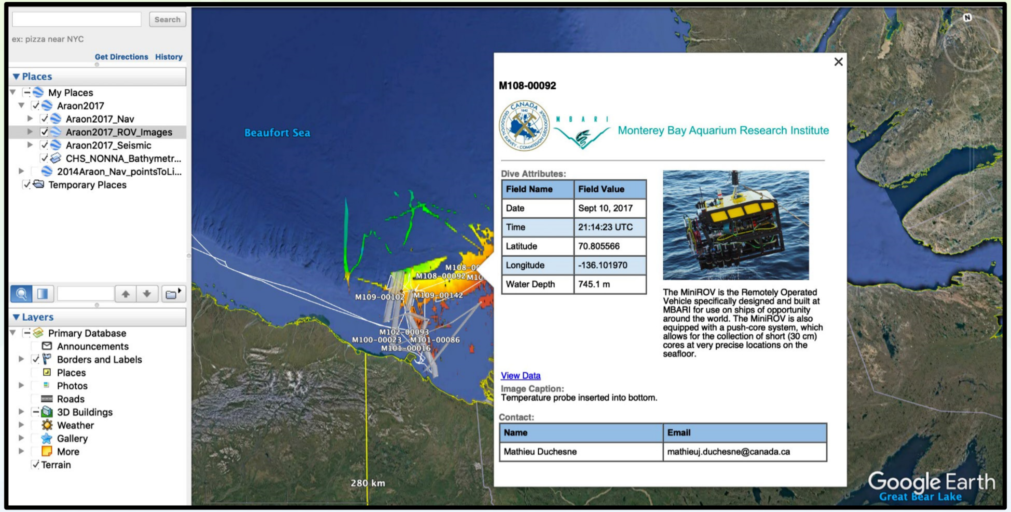


A geothermal characterization has been conducted on well-logs from 2 offshore wells separated by 4 km. For the same geological units, thermal conductivity profiles (left) and geothermal gradients show important variations. This will be used as input parameters for geothermal modeling to better understand the occurrence of discontinuous permafrost and the role intrinsic thermal properties of the subsurface have on permafrost degradation.

Progress (May 2020 - May 2021)

Data dissemination

Salmas, K. (GSC-P), Courtney, B. (GSC-A), Côté, M. (GSC-P) & Duchesne, M. J. (GSC-Q)

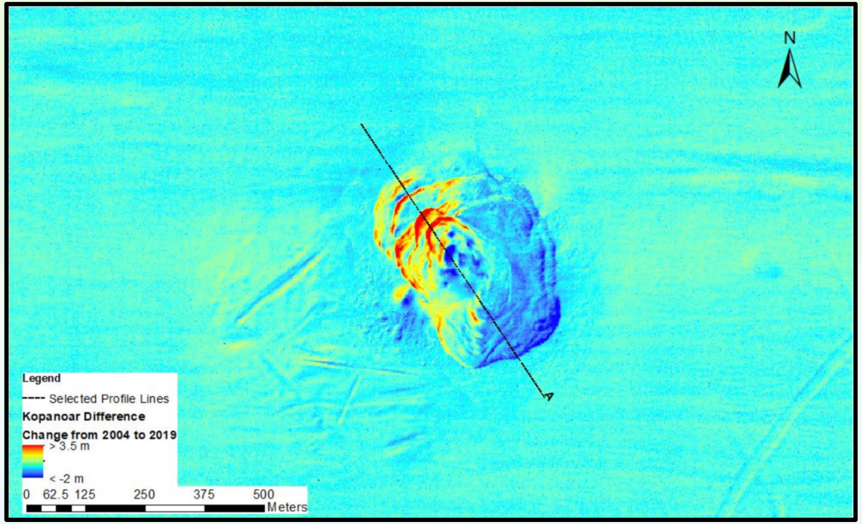


We built Google Earth projects summarizing geoscience data collected during various research expeditions in the Beaufort-Mackenzie area. Those projects will be hosted on the Federal Geospatial Platform.

Progress (May 2020 - May 2021)

Differential mapping of marine permafrost features

Dallimore, S.R. (GSC-P) & Podhorodeski, A. (GSC-P)

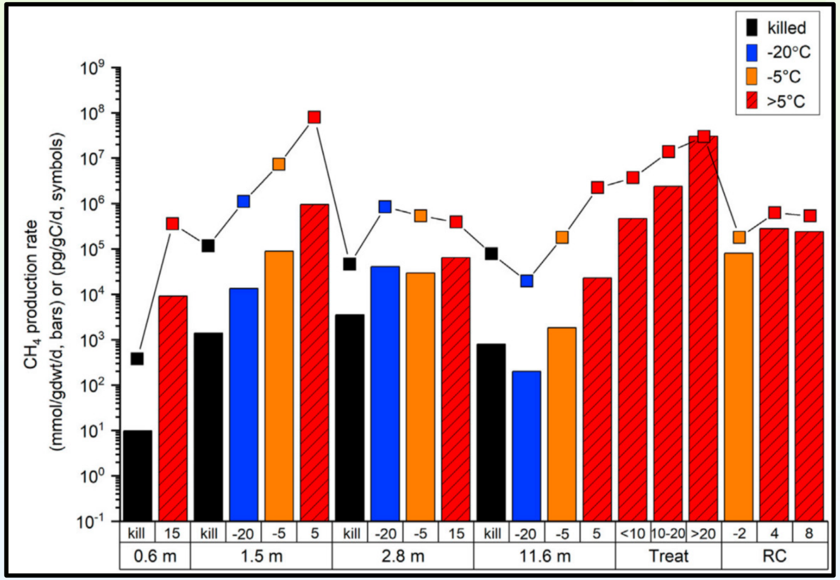


Differential multibeam bathymetry mapping (2004-2019) is used to document temporal changes of pingo-like features (circular ice mounds) observed on the seafloor and enhance the comprehension of the geological processes responsible of their formation.

Progress (May 2020 - May 2021)

Microbial greenhouse gas dynamics associated with warming coastal permafrost

Lapham L. L. (University of Maryland) & Dallimore, S. R. (GSC-P)



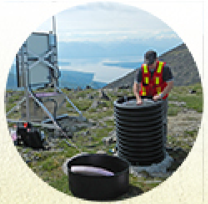
Controlled microbial incubations of sediment under thawed (5°C and 15°C) and under frozen (−20°C and −5°C) conditions showed that gross production rates of CH_4 and CO_2 increase upon thawing but also showed appreciable CH_4 and CO_2 production rates under frozen conditions (left). This indicates the potential for frozen sediments to produce greenhouse gases, even under frozen conditions, could be an additional important atmospheric source.

CONTACT INFORMATION

- Mathieu J. Duchesne
- Tel: 418.654.2647
- mathieuj.duchesne@Canada.ca

Ressources naturelles Canada | Natural Resources Canada




Infrastructure Impacts on Permafrost Geochemistry

Paul Gammon

May 11, 2021

Canada

ABSTRACT

The geochemistry resulting from permafrost freeze-thaw processes are poorly understood. This EGP activity aims to refine our current understanding of these processes, and how they are impacted by infrastructure development. This study will investigate the impacts on permafrost geochemistry associated with the construction of the Inuvik to Tuktoyaktuk Highway (ITH). It will investigate both the ITH development itself, and a gravel pit used as source material for ITH construction. However, COVID19-related restrictions meant that no fieldwork was possible in 2020-21. This situation means that there is no data to report for this fiscal year in terms of results and interpretations. This will continue until access to field sites is again permitted. Nonetheless, there were significant achievements for this project in the 2020-21 fiscal year, which include: 1) purchasing, through combined EGP – GEM-GeoNorth funding, arrays of sensors that will facilitate understanding of the geochemistry of permafrost active layer freeze-thaw processes; 2) development of a companion project within GEM-GeoNorth that aims to look at a wider array of permafrost processes; 3) continued engagement with Inuvialuit stakeholders to keep them up-to-date with respect to this project; 4) SLN capital purchase, in response to this projects request, of a cryogenic stage for laser ablation of ice – which will greatly advance the geochemical investigative arsenal.

PROJECT MEMBERS

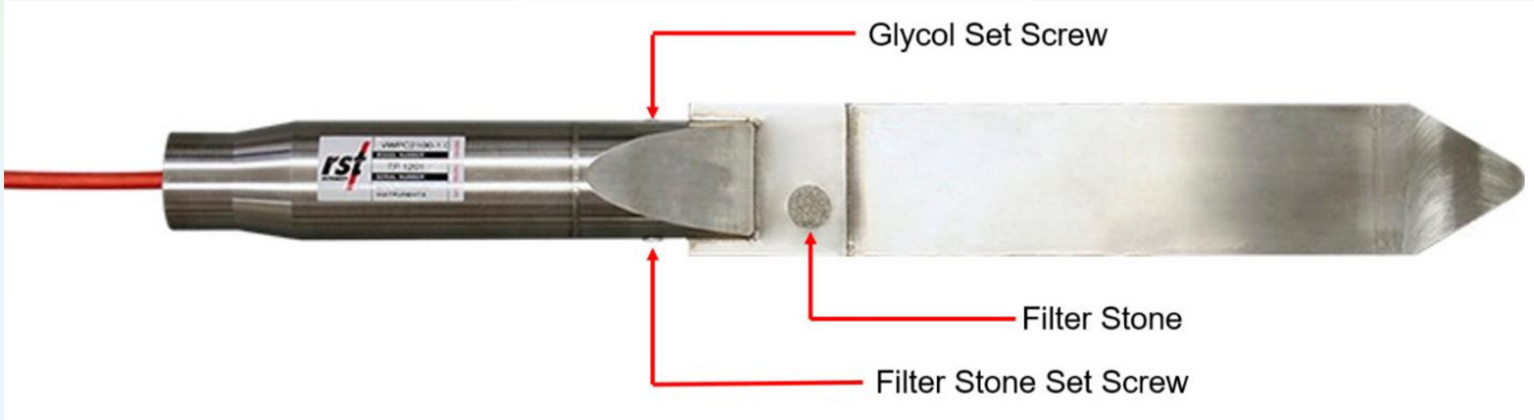
- Paul Gammon
- James Zheng
- Melissa Bunn
- Pierre Pelchat
- John Sekerka
- Richard Amos (Carleton U.)

Sensing of active layer groundwater during freeze-thaw

Sensor Arrays from RST and Hoskins:

1 Sensors for determining freeze-thaw pressure arrays

2 Water level and electrical conductivity sensors for understanding changes in active layer porewater parameters during freeze-thaw.



This project provided the template for a GEM-GeoNorth proposal

Companion project entitled: “Innovative geochemical methods for investigating permafrost and active layer processes in northern Canada”. The project:

1. Aims to develop better geochemical tools for permafrost and active layer investigations
2. Aims to generate data on a more diverse range of permafrost active layer types, primarily those associated with mineral mining and exploration.

CONTACT INFORMATION

- Paul Gammon
- 613-995-4909
- Paul.gammon@Canada.ca

Thank you!

Ressources naturelles Canada | Natural Resources Canada

Project MOSS:
Marine Oil Spill Studies

Projet EDPM:
Études sur les déversements pétroliers marins

MANUEL BRINGUÉ

May 2021

Canada

ABSTRACT

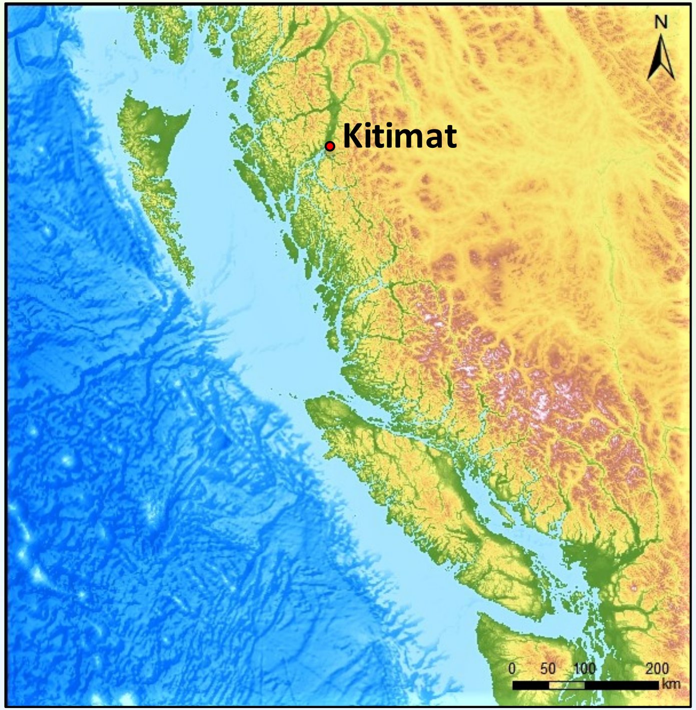
<u>Context</u>

Active port of **Kitimat** (BC's North Coast) is a gateway for the export of Canada's **energy** resources (LNG etc.) to international markets. Current and future projects translate into dramatically **increased tanker traffic** in Douglas Channel for decades to come.

<u>Objectives</u> are to determine:

- a baseline of **natural variability** in Douglas Channel (e.g., temperature, productivity) on seasonal to millennial time scales;

- the capacity of in-situ microbial communities to mitigate accidentally-released petroleum products **under reduced O_2 and lower pH conditions**.



PROJECT MEMBERS

- Manuel Bringué (PL), Jennifer Galloway, Omid Ardakani (GSC-Calgary)
- Jason Ahad (GSC-Québec)
- Michael Parsons (GSC-Atlantic)
- Paul Gammon (GSC-Ottawa)
- Gwyn Lintern, Cooper Stacey (GSC-Pacific)
- Heather Dettman (CanmetENERGY-Devon)

- Sophia Johannessen (DFO, IOS Sidney)
- Kenneth Lee (DFO, BIO Dartmouth)
- Charles Greer (NRC, Montréal)
- Vera Pospelova (U. of Minnesota)

PROJECT OVERVIEW

1. **Surface sediment** and **sediment trap** component – *CALIBRATION*

To assess **spatial distribution** and **seasonal variability** in phytoplankton communities and geochemical indicators.

2. **Sediment cores** component – *RECONSTRUCTIONS*

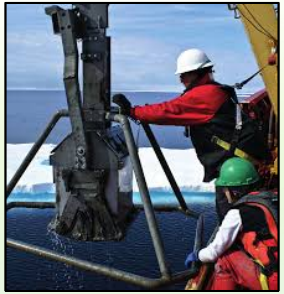
- Short (box) cores: to **reconstruct past environmental variability** and trace possible **human impacts** over the last ~ 120 yrs.
- Long (piston) cores: to reconstruct **natural variability** over the Holocene (last ~ 11,000 years), for context.

3. **Microcosm** experiments – *LAB TESTS*

Lab-based experiments testing the capacity of in-situ microbial communities (water + sediment) to degrade petroleum products **under a range of reconstructed and forecast O_2 and pH conditions**.

1.

2.

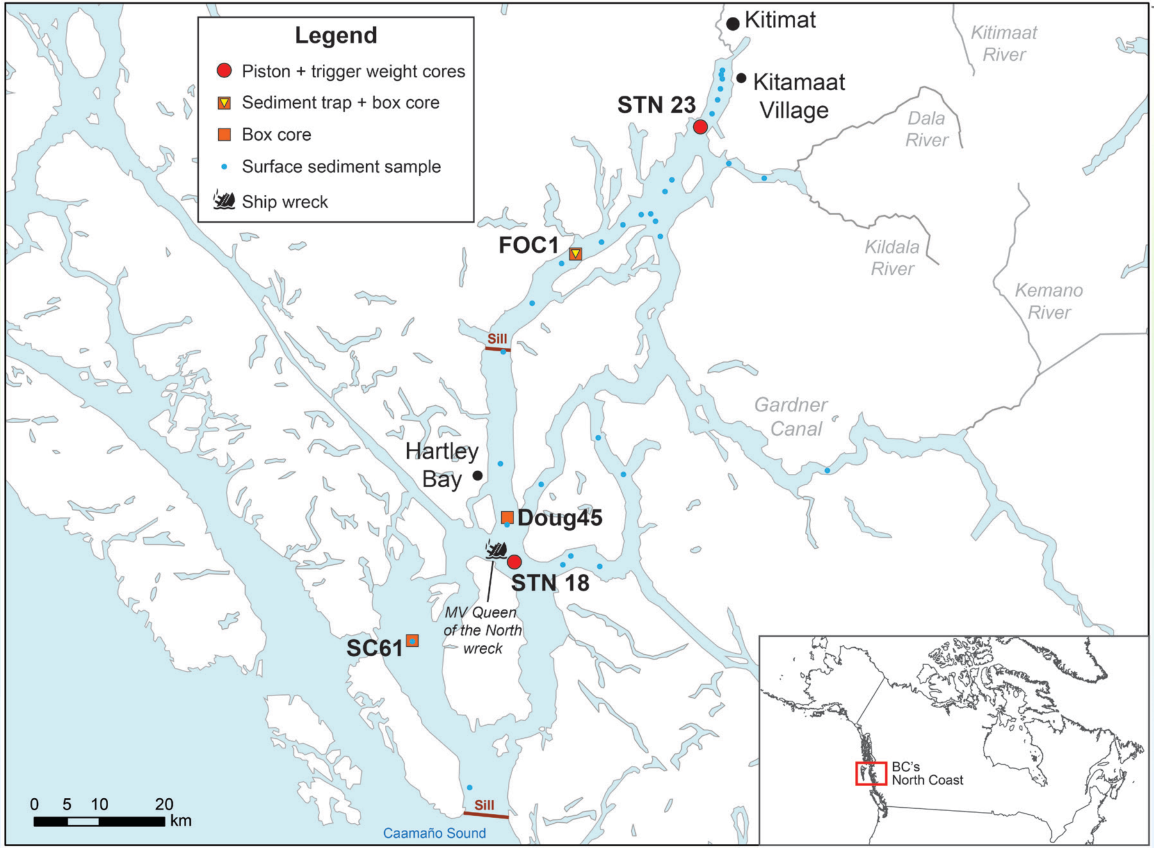


3.

Sediment samples

- Sediment trap
  - ~ 3 yrs of data
- 3 box cores
  - ~ 120 yrs
- 2 piston cores
  - Holocene (~ 11 kyr)

All material provided by PGC & DFO



Analyses (as of April 2021)

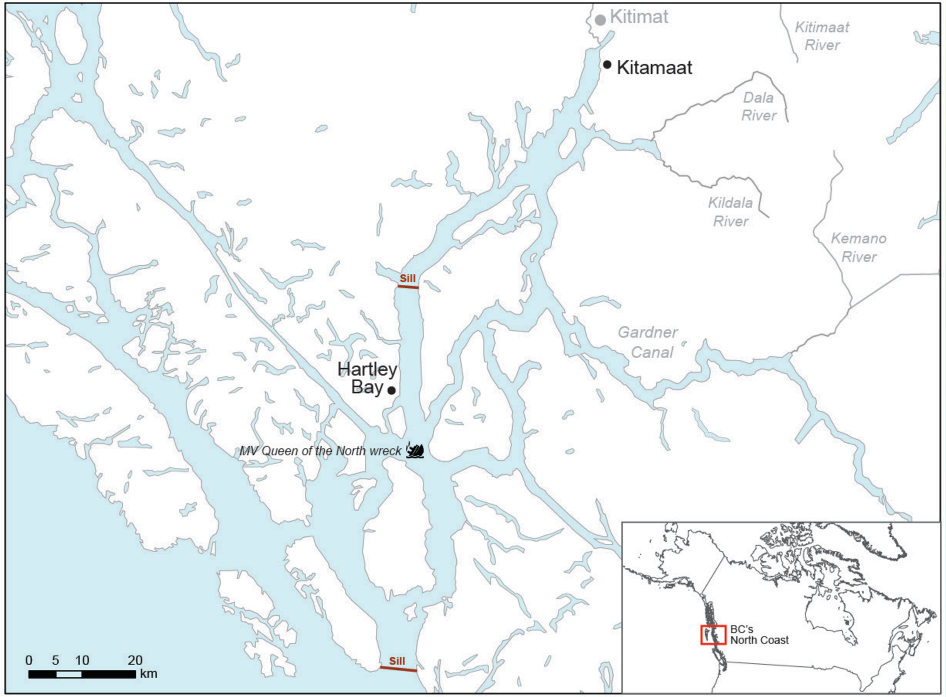
	Phase 1		Phase 2					Phase 3
	Sediment trap	**Surface samples**		**Box cores**		**Piston & trigger-weight cores**		Microcosm
Location	FOC1	Douglas Channel	FOC1	QotN wreck	Squally Channel	Whale Channel	Kitimat Arm	experiments
				(Doug-45)	(SC-61)	(Core 18)	(Core 23)	
# samples	88	32	21	~ 20	~ 20	65 (PC) + 24 (TWC)	79 (PC) + 16 (TWC)	(lab-based)
Time span	~ 3 yrs		~ 120 yrs	~ 120 yrs	~ 120 yrs	Holocene	Holocene	
Analyses								
Dating (^{14}C, ^{210}Pb)			✓	✓	✓	✓	✓	
Palynology	Lab	Lab	Lab	Lab	Lab	Lab	Lab	
Geochemistry								
Grain size						✓	Lab	
Biogenic silica	✓	Lab	✓	✓	✓	✓	✓	
Total C, N, C_{org}, C_{inorg}	✓	Lab	✓	✓	✓	Lab	Lab	FY4/5
$\delta^{13}C_{org}$, $\delta^{15}N$	✓	Lab	✓	✓	✓	Lab	Lab	
ICP-MS						Lab	Lab	
Focused								
PAHs		Lab				Lab	Lab	
Mo isotopes		Lab						

Progress was delayed because of the Covid-19 pandemic, but project is still on track.

Gitga'at and Haisla Nations

Dialogue with Gitga'at (Hartley Bay) and Haisla (Kitamaat Village) Nations initiated in 2018.

Fruitful conversations with Gitga'at Science Director Chris Picard already led to significant information sharing and networking, and helped to determine **which petroleum products to test** in microcosm experiments (phase 3).



CONTACT INFORMATION

- Manuel Bringué
- (403) 471-1727
- manuel.bringue@canada.ca

Also:

- Jason Ahad (PL of over-arching ‘oil spill’ project)
- (418) 654-2615
- Jason.ahad@canada.ca

THANK YOU!

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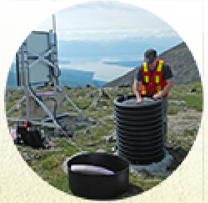



Ring of Fire: Reconstructing long-term environmental records to support regional assessment

Josué Jautzy

2021

Canada

Abstract

Ring of Fire (RoF) = large mineral deposits of Ni/Cu/Zn/Cr and PGM

- Located in one of the world's largest peatland system;
- Sensitive to climate change (Hadley et al., 2019) and anthropogenic stresses (Leclair et al., 2015)

Additional knowledge on environmental conditions required:

Pre-mining:

- Natural presence/behavior of metal(loid)s needs to be carefully assessed
- Baseline conditions response to climate change + remote anthropogenic stresses

Post-mining initiation:

- Changes to groundwater flow dynamic, geochemical fate of metal(loid)s in surface storage of tailings and waste rocks over time.
- Explore and develop environmental indicators adapted to the monitoring of RoF environment.

Project members

J. Jautzy[1], N. Benoit[1], J. Marion[1], M. Parsons[1], A. Desbarats[1], M. Bunn[1], J. Galloway[1], Paul Gammon[1], Pierre Pelchat[1], M. Nastev[1], J. Ahad[1], B. Fosu[1], C. Bégin[1], É. Girard[1], F. Letourneau[1], A. Dixit[1], P. Bergeron[1], E. Berryman[2], J. Girard[3], M. Garneau[3], N. Balliston[4], S. Finkelstein[5], Finn Viehberg[6]

[1]*Geological Survey of Canada, Natural Resources Canada (NRCan)*
[2]*CanmetMINING, Natural Resources Canada (NRCan)*
[3]*Environment Canada*
[3]*Université du Québec à Montréal*
[4]*University of Waterloo*
[5]*University of Toronto*
[6]*Greifswald Universität*

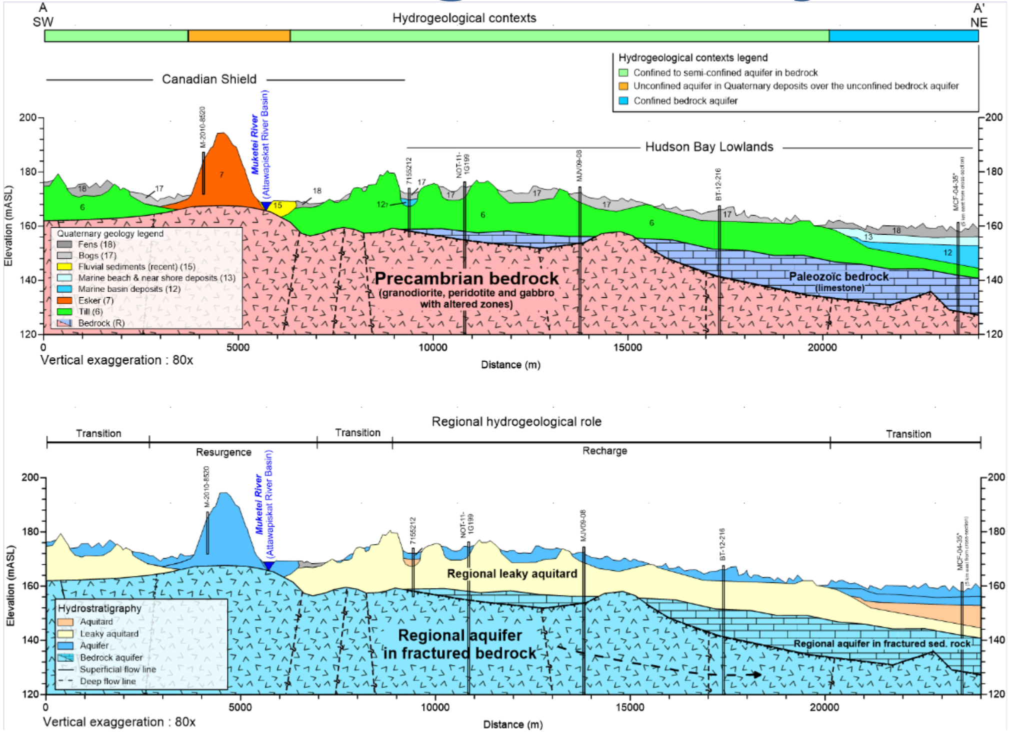
Main objective

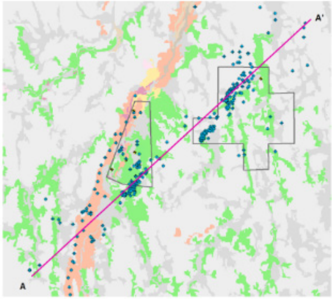
Improve knowledge on the evolution of the wetlands baseline conditions in response to climate and anthropogenic stresses and their effects on metal(loid)s mobility.

Activities

- Geoscience baseline conditions - Regional hydrostratigraphy.
- Machine Learning development for remote mapping - surficial geology.
- Environmental archives study on a pre-mining analog context of chromite deposit – Menarik lake (Qc).
- Hydrogeochemical study on a post-mining analog context of chromite deposits – Eastern Township (Qc).
- Analytical development of Chromium speciation analyses in water.

Geoscience baseline conditions
Regional hydrostratigraphy





Existing data:

Exploration boreholes: (MNDM)

Wells: Ontario Well Information System (MECP)

Outcrops: report by Metsaranta and Houlé (2017)

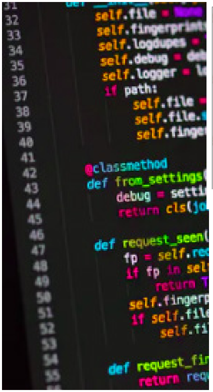
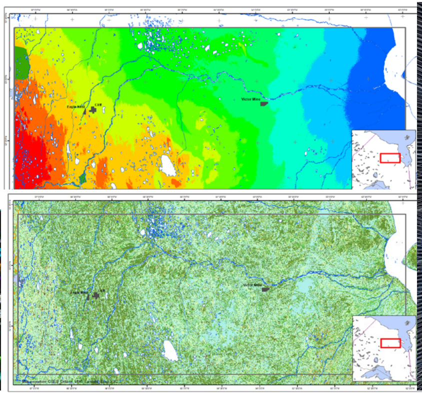
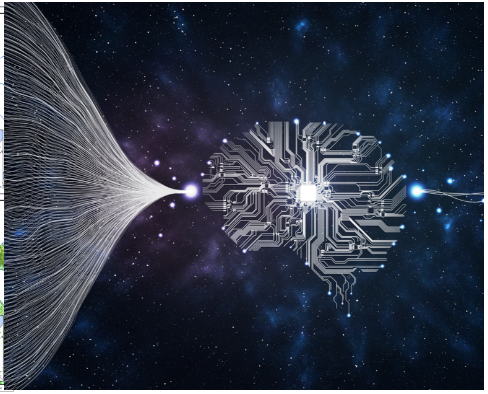
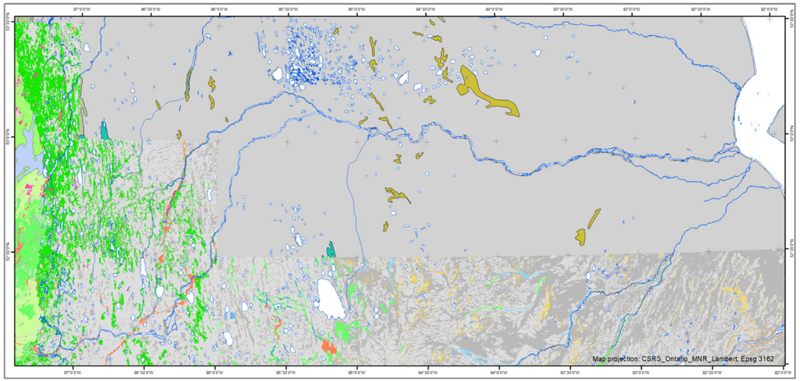
DEM: digital elevation model (OMNRF)

Sediment thickness estimation

Conceptual regional hydrostratigraphy

Machine Learning
Remote mapping - surficial geology

- Development of machine learning experiments pipeline (python, docker, AWS Cloud)
- Data processing: DEM, Landsat images, Wetlands map…
- Implementation of learning algorithm: convolution neural network (train, validation, test)
- Challenge: unbalanced data set

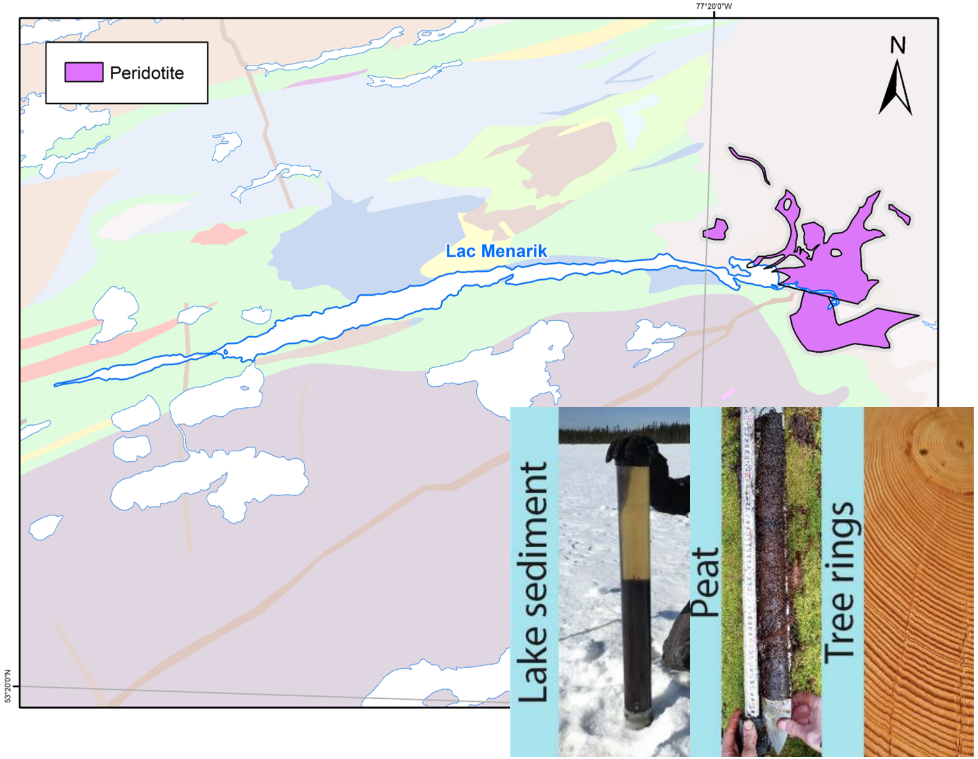
Machine learning (image from https://www.promptcloud.com/blog/machine-learning-vs-predictive-analysis-difference-and-usage/)

Study areas

- Ring of Fire: McFauld lake area
- Analog site 1: Menarik lake pre-mining context (580 km)
- Analog site 2: Eastern Township post-mining context (1300 km)

Pre-mining context

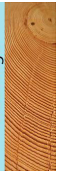
- Analog Cr-deposit context – Cr-mineralized outcrops in a boreal environment.
- Exploration of environmental archives for climatic reconstruction and potential record of natural Cr-background variation.
- Organic and inorganic geochemistry, development of indicator to serve the assessment of the mobility of Cr in the RoF environment.
- Field work: Summer 2021



Pictures modified from Cooke et *al.*, (2020)

Pre-mining context

Co-localized archives with ≠ complementary chronological scales.
Past climatic anomalies as analog to current climate change.

Peat  1000s yrs	Lake sediment  200-1000 yrs	Tree rings  50-200 yrs

Climate proxy

↕ *Link?*

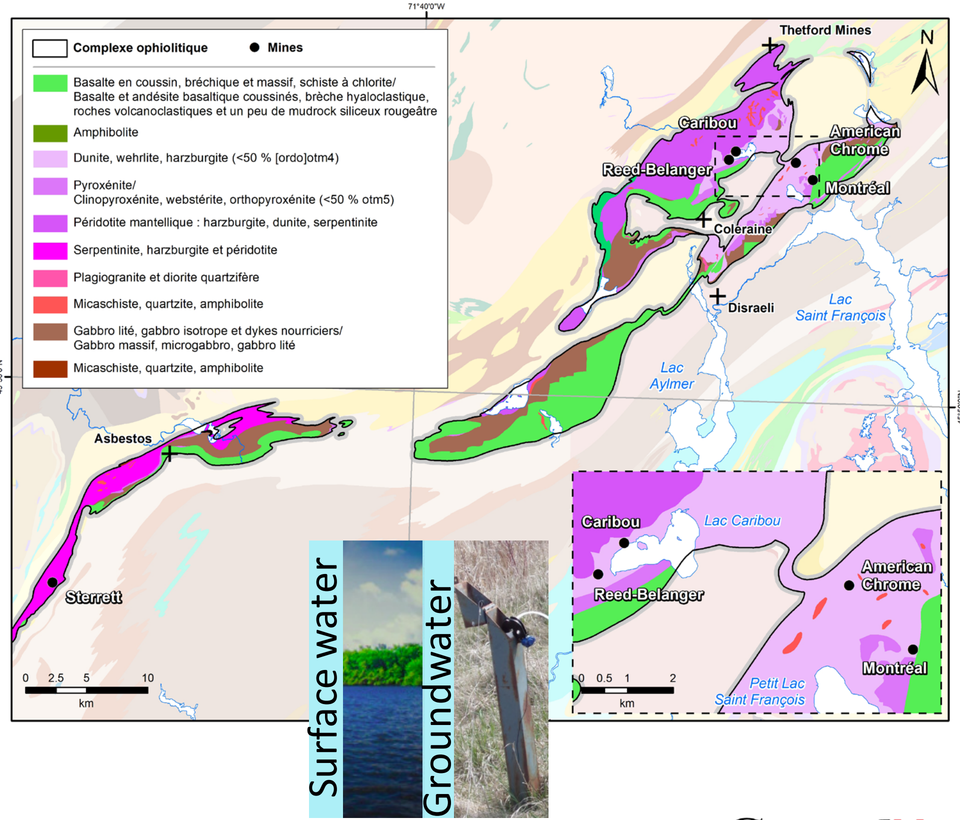
Record of Cr loading?

Test and development of new indicators:

- forest fire intensity
- natural level metallic loading

Post-mining context

- Analog chromite deposit context - Ophiolitic complex of Thetford
- 5 abandoned mines (American Chrome, Montreal, Reed-Belanger, Caribou, Sterrett)
- Sampling from: pit lakes, tailing, surface water and groundwater
- Cation/anion, alkalinity, DOC and Cr speciation
- Field work planned for summer 2021



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Analytical development of Cr speciation in water

- Analyses of Cr in the environment is complicated due to its possible interspecies conversion from the time of sampling to the time of analyses.
- Development of analytical methodologies at the GSC to mitigate this issue.
- Inter-laboratory comparison with different measurement techniques are anticipated to validate the developed methodology.

https://unsplash.com/photos/lQGJCMY5qcM

Conclusion

- Regional hydrostratigraphic conceptual model for the RoF.
- Machine Learning pipeline works well, the model is in the learning/validation phase.
- Fields works planned for this summer, preparation is done.
- Analog site studies and analytical development of Chromium speciation will provide geoscientific tools for future RoF studies.
- Insights on the long term evolution of metals in the environment.

Contact Information

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- nicolas.benoit@canada.ca

Thank you / Merci!

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Measuring, monitoring and verification of geological carbon storage
Mesure, surveillance et vérification de la séquestration géologique du carbone

Don White

May 21th, 2021




Canada

ABSTRACT

Aquistore CO_2 storage site: 6 years of monitoring

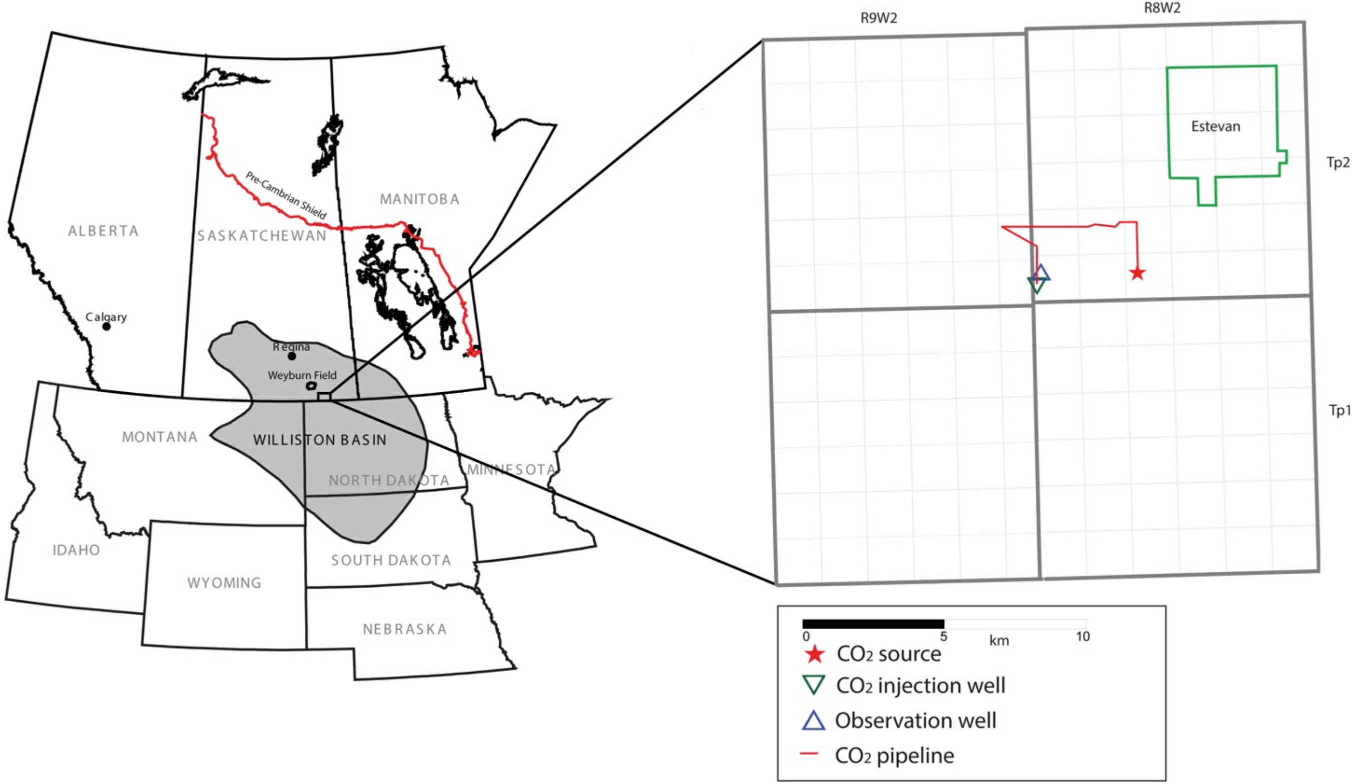
– Time-lapse seismic

– Induced seismicity

PROJECT MEMBERS

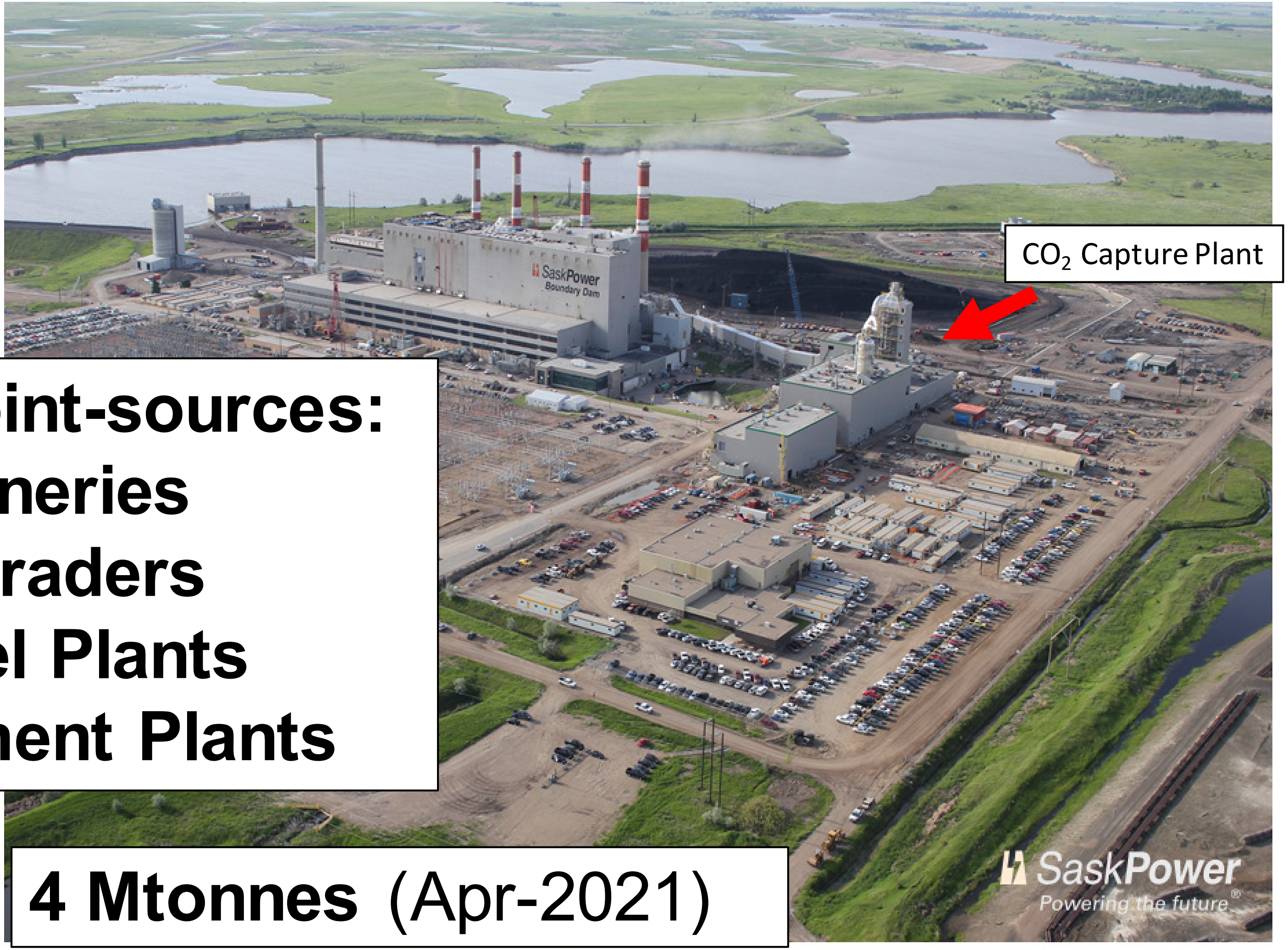
- Don White, Gilles Bellefleur (**GSC**)
- Mike Craymer, Jason Silliker (**CGS**)
- Sergey Samsonov (**CCRS**)
- Lisa Roach (**LAN Geophysics**)
- Darcy Holderness (**SaskPower**)
- Erik Nickel, Ivan Marsden, Zeinab Movahedzadeh (**Petroleum Technology Research Centre**)
- Ben Rostron (**University of Alberta**)
- Chris Hawkes (**University of Saskatchewan**)
- Anna Stork (**Bristol University**)
- Michelle Robertson (**Lawrence Berkeley National Lab**)
- Masashi Nakatsukasa, Mamoru Takanashi (**Japan Oil, Gas Metal NC**)
- Kevin Dodds (**Australian National Low Emissions Coal Research & Development**)

Aquistore CO_2 Storage Project



CO_2 point-sources:

- Refineries
- Upgraders
- Steel Plants
- Cement Plants



4 Mtonnes (Apr-2021)

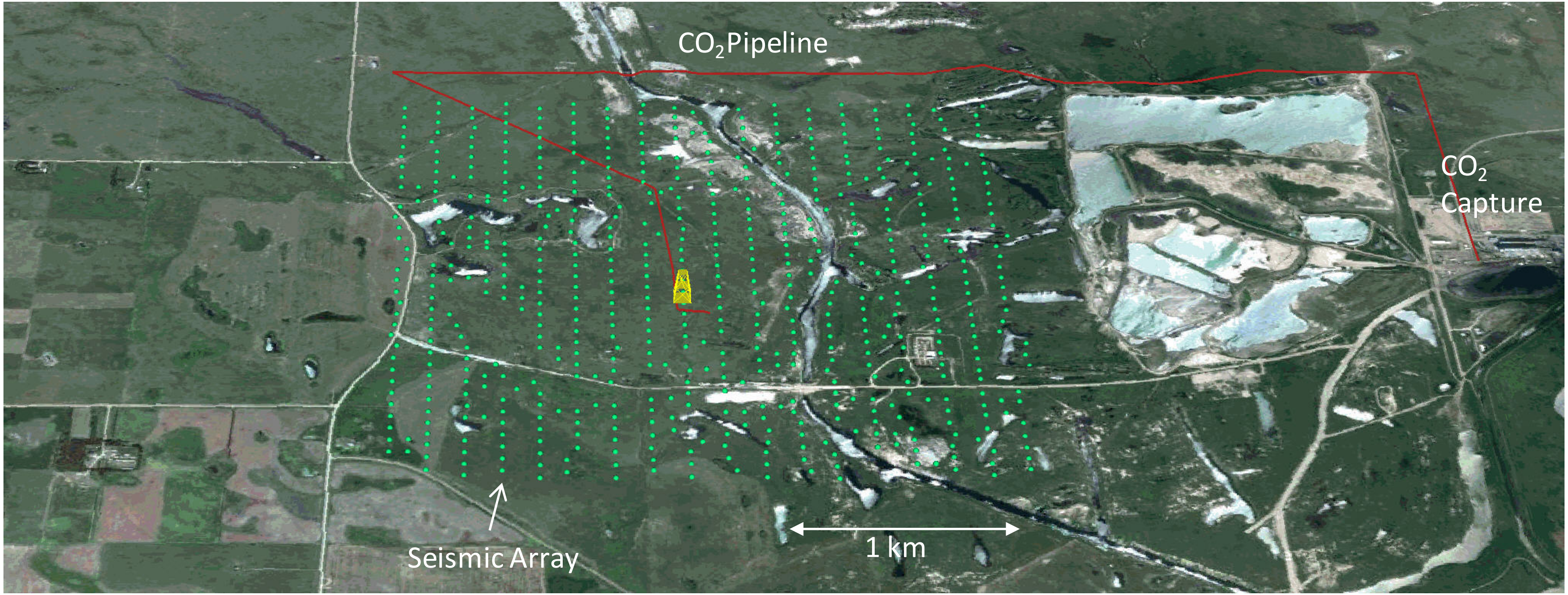
GSC Research Objectives

- Methods for monitoring CO_2 containment
- Induced seismicity

Outcomes

- Informs regulations and international standards under development
- Effective but efficient CO_2 monitoring

Aquistore CO_2 Storage Project

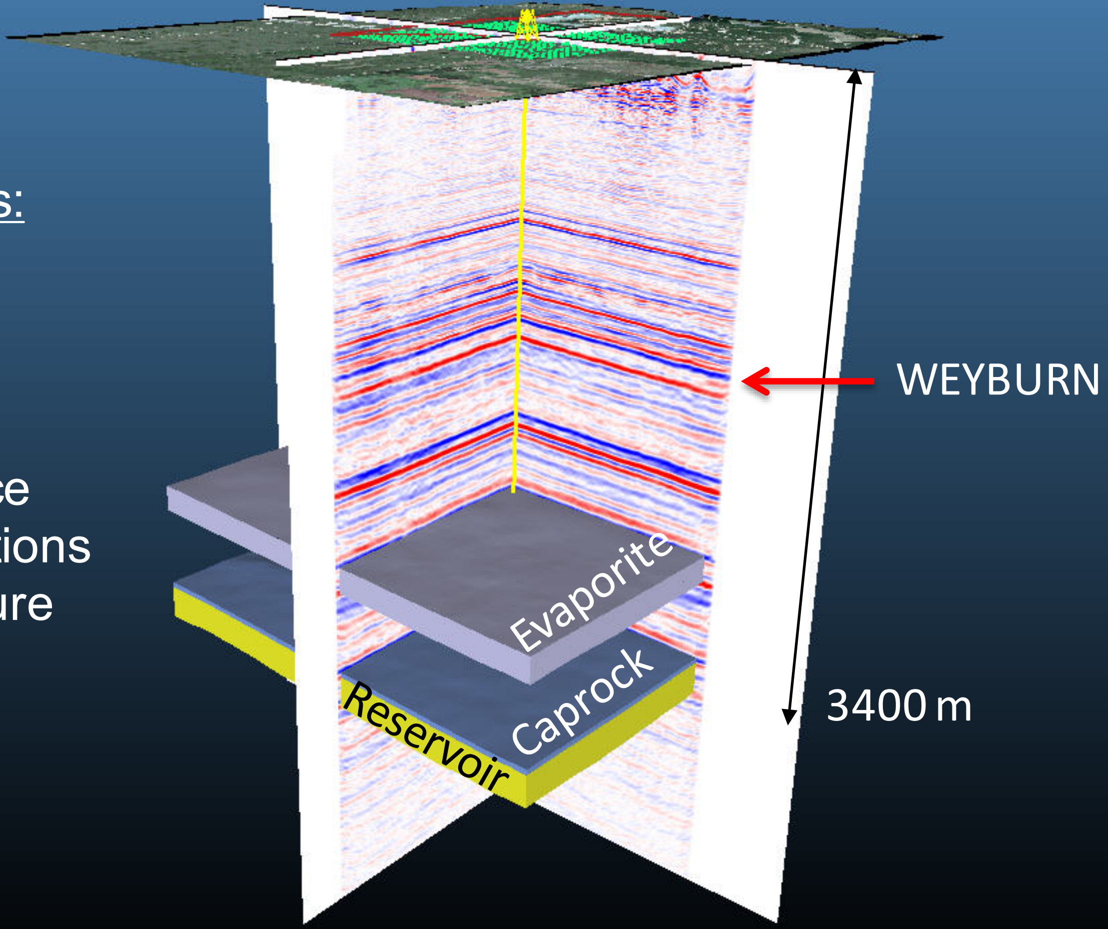


Monitoring Challenges:

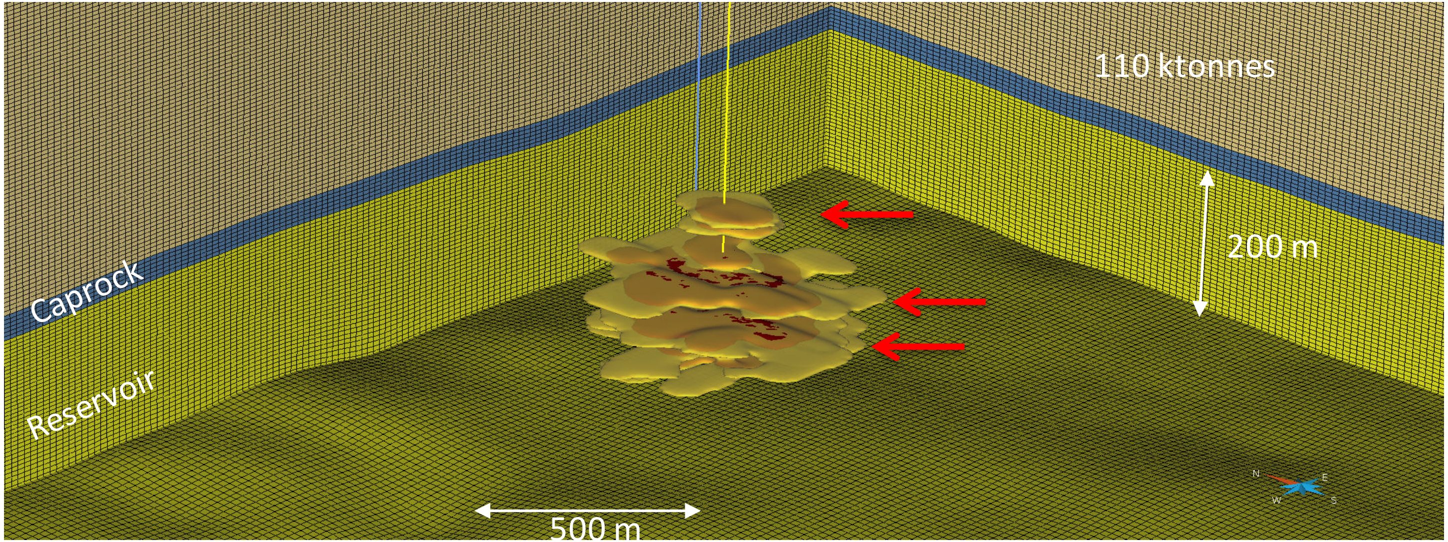
- Deep reservoir
- Low injection rate

Advantages:

- Weyburn experience
- Permanent installations
- Minimal infrastructure
- Limited land use

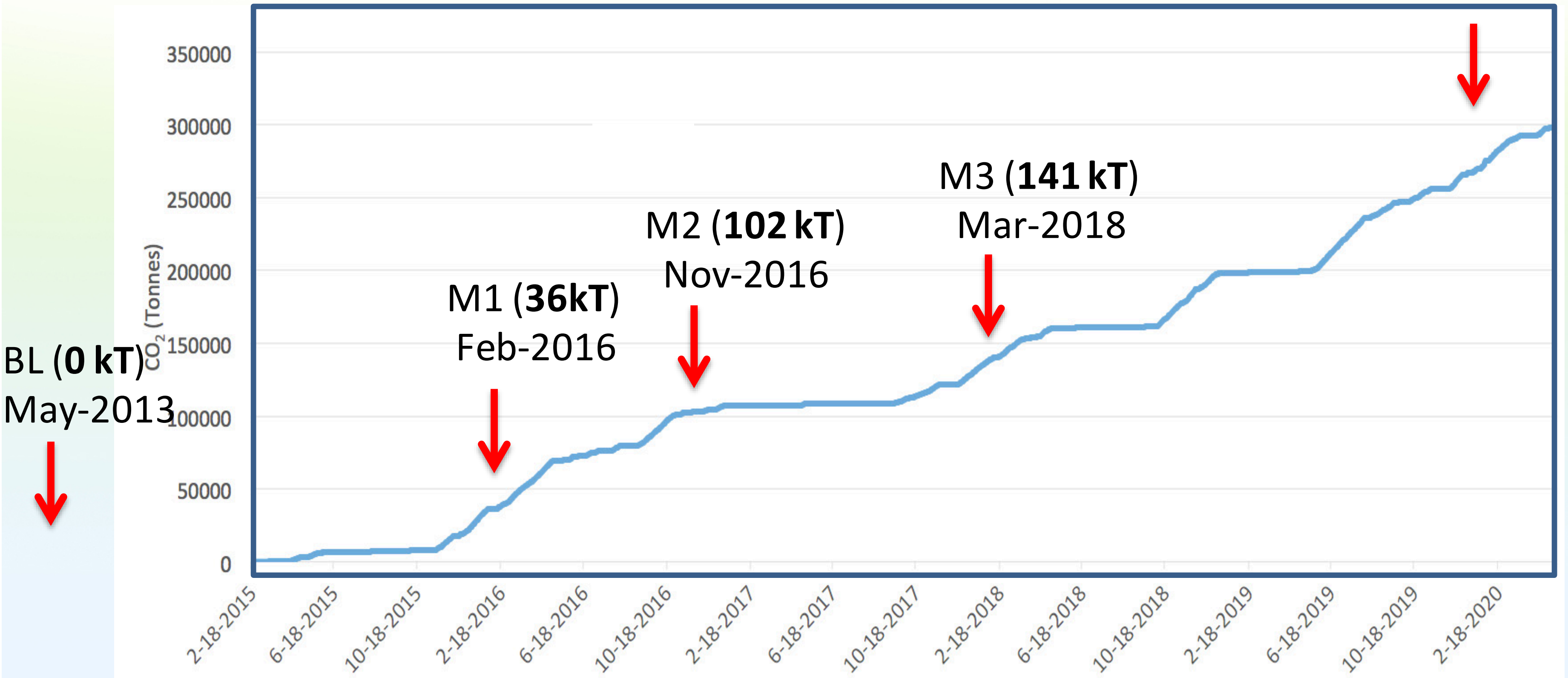


Model: 110 kT CO_2

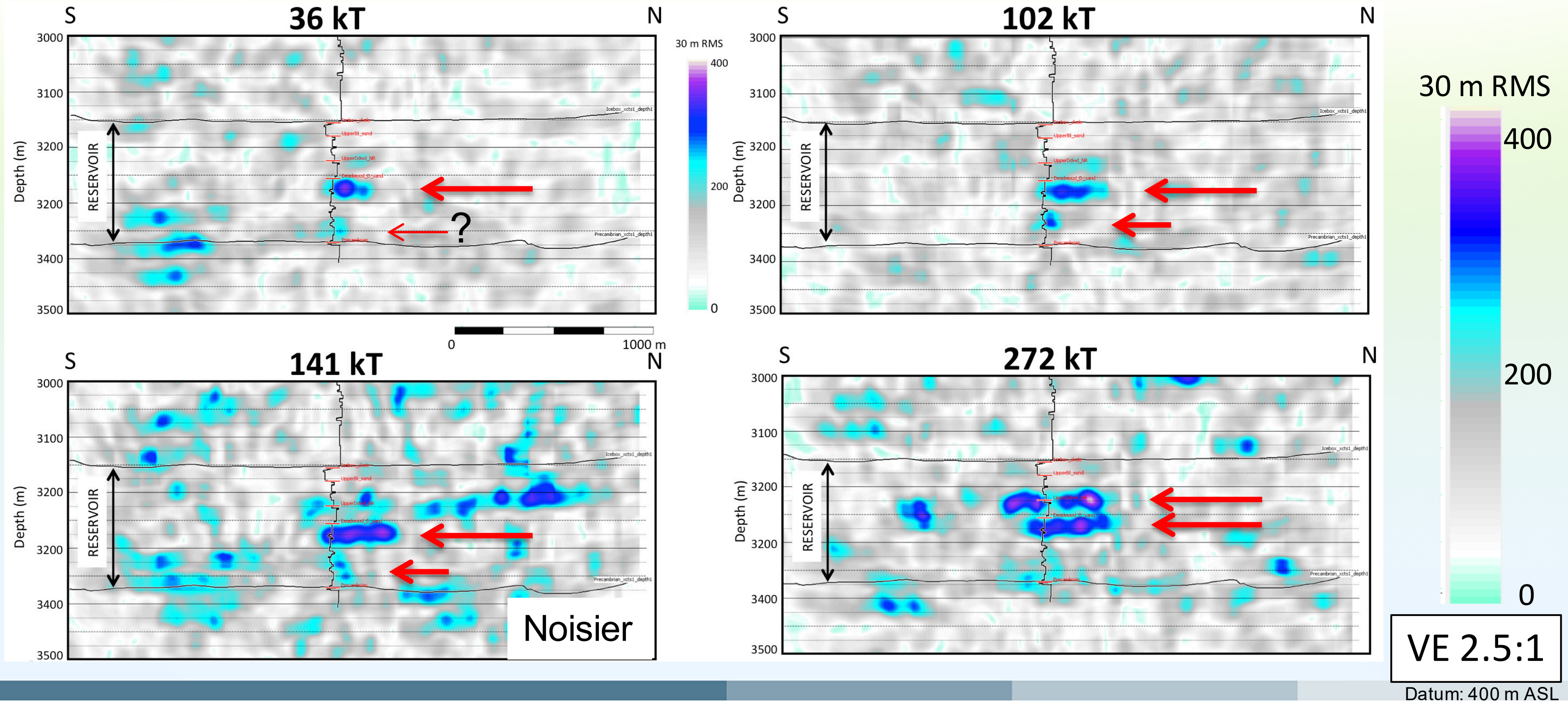


3400 m Depth

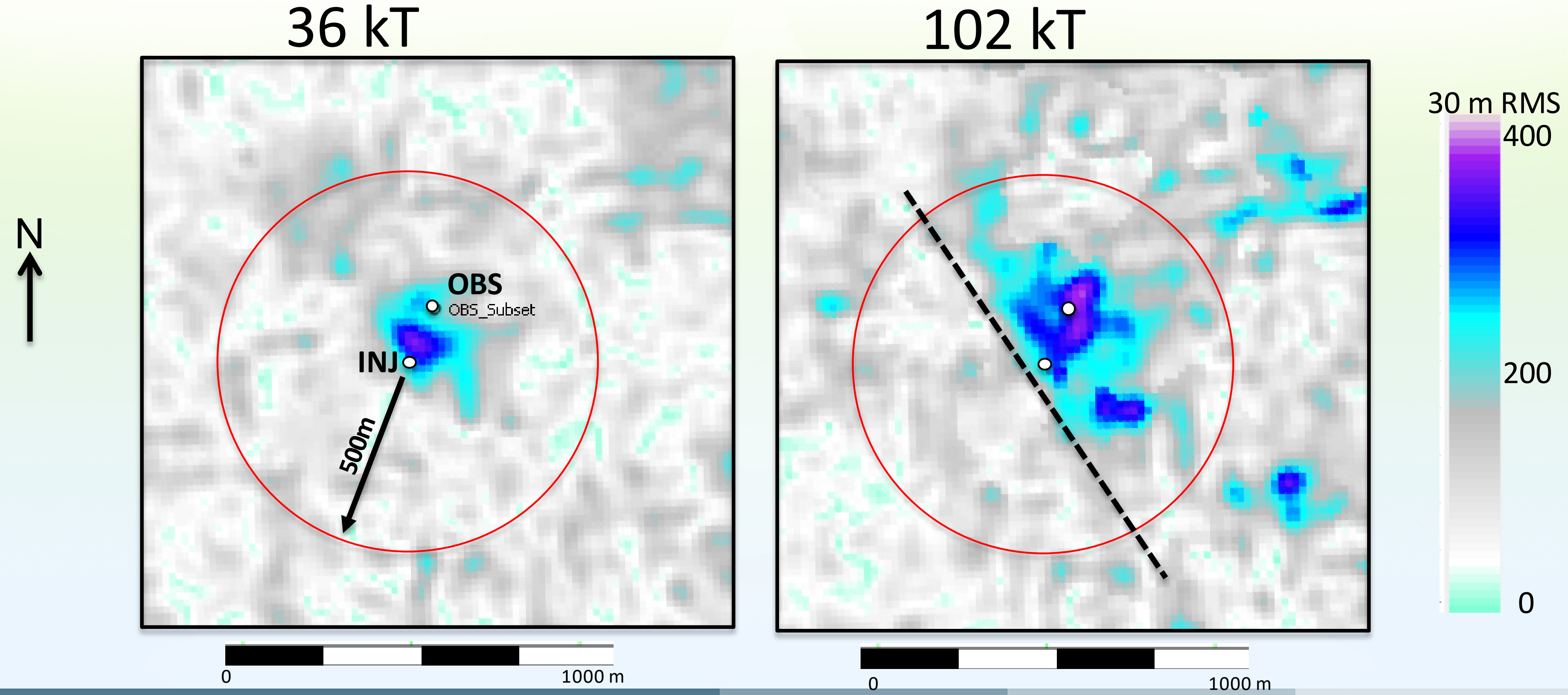
Monitoring CO_2 Injection



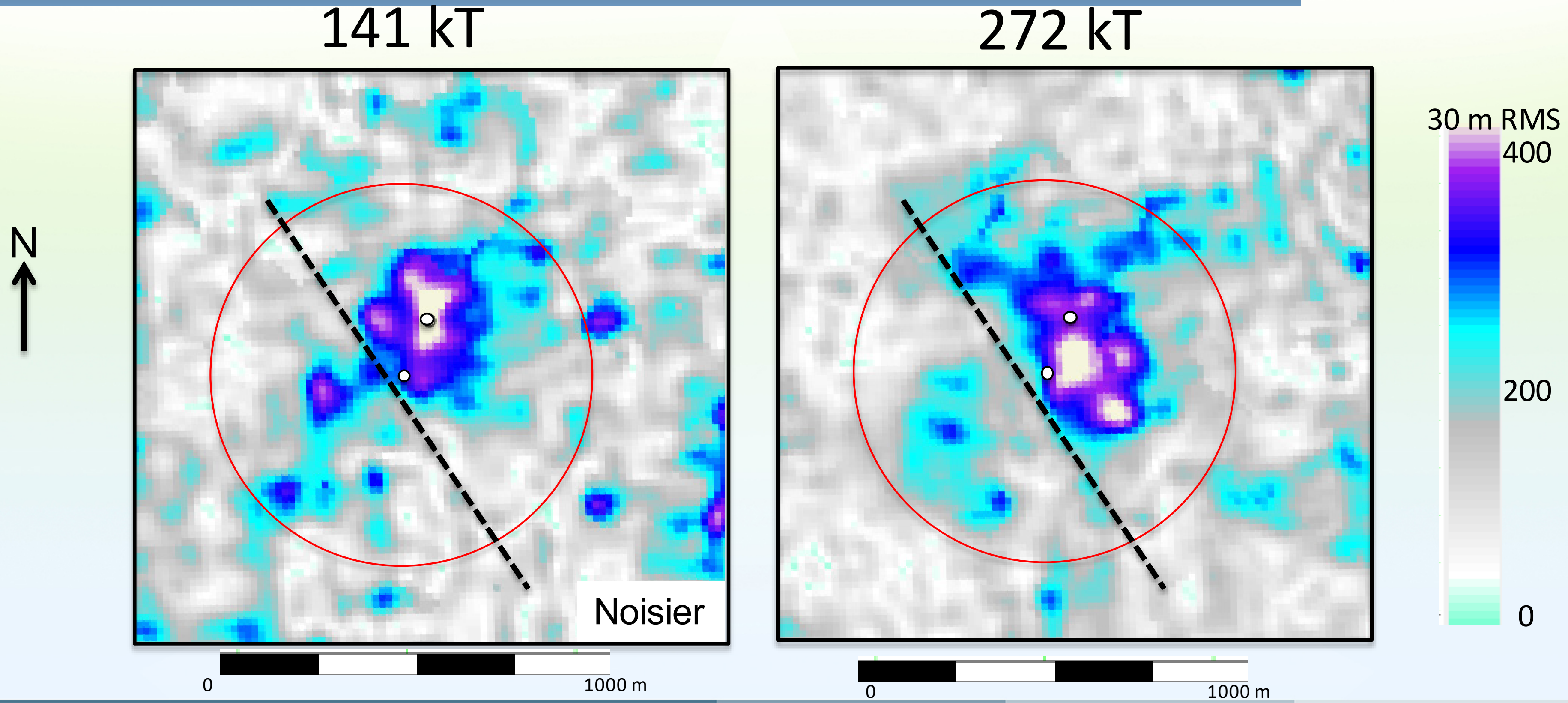
INJECTOR: 4D RMS AMPLITUDE DIFFERENCE



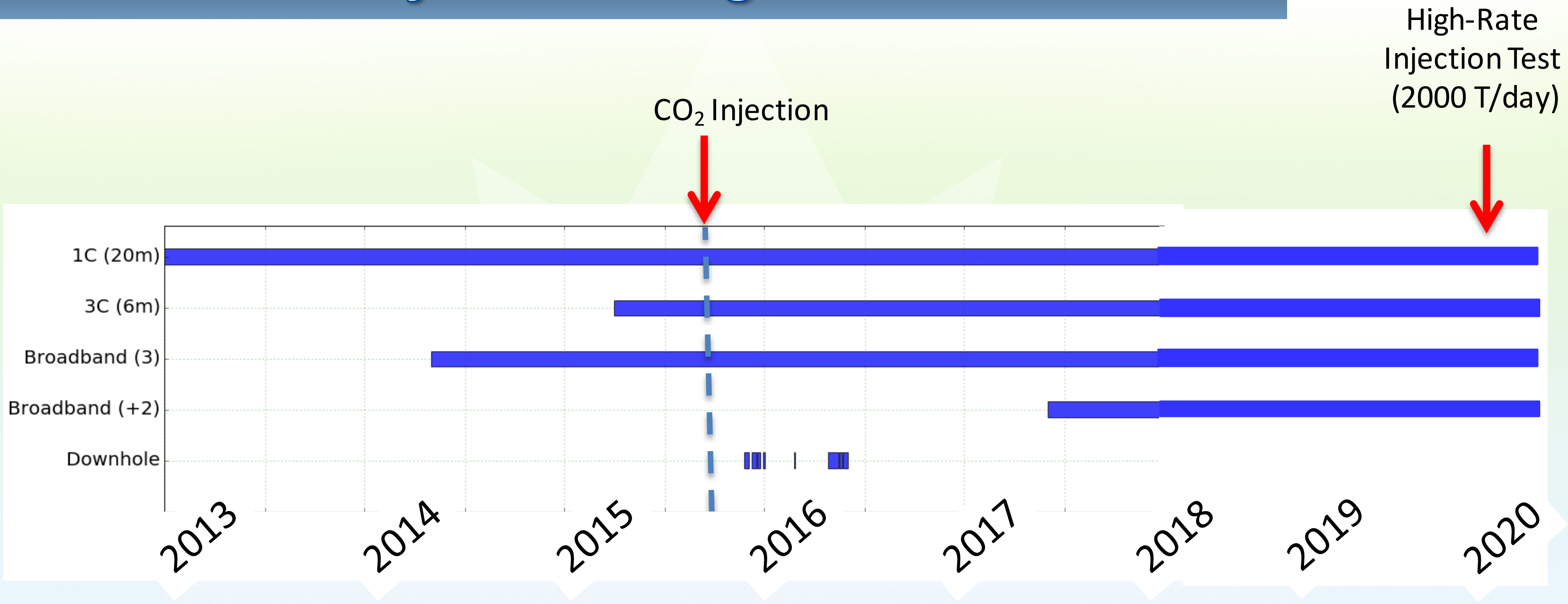
Upper Deadwood



Upper Deadwood



Induced Seismicity: Monitoring Period



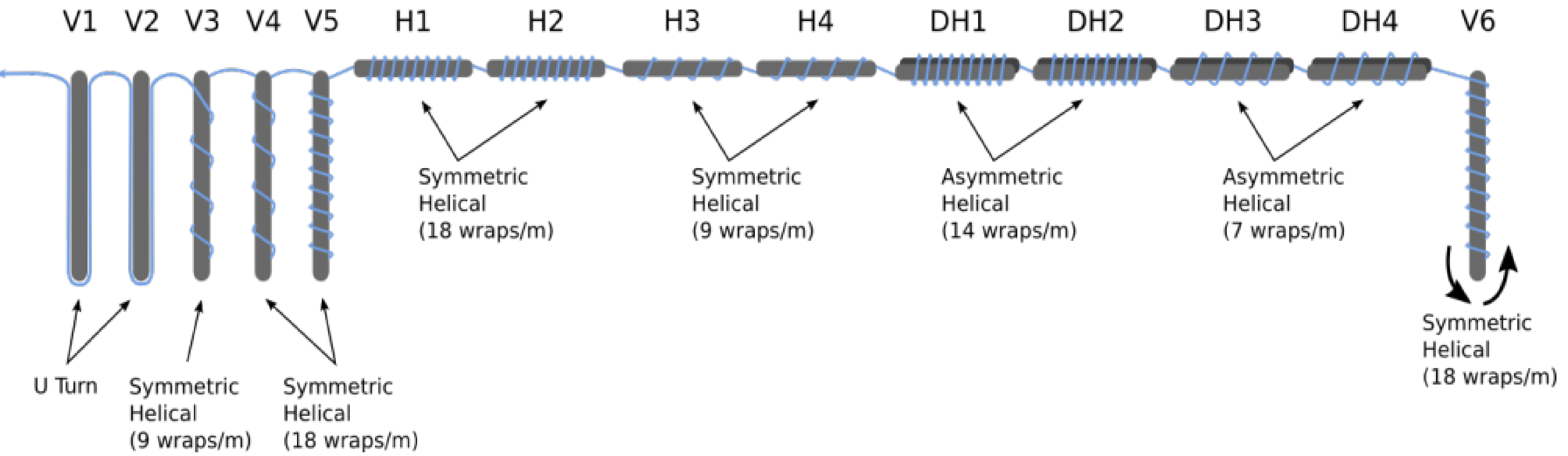
(Stork et al., 2018)

Induced Seismicity

- No induced seismicity during 6 years of injection
- Minimum detectable magnitude for 3.2 km depth:
  - BB: M_L= -0.8
  - Array: M_L= -1.6 to -0.6
- Magnitude of completeness (STA/LTA):
  - BB: M_W = 1.3
  - Array: M_W = 0.6

(Stork et al., 2018)

Experimental DAS Configurations (Fibre Optics)



Conclusions: Seismic Monitoring

- CO_2 plume contained within the reservoir.
- Vertical distribution of CO_2 in the reservoir illuminated.
- Lateral spread of CO_2 is generally consistent with direct detection of CO_2 in the observation well.
- Influence of reservoir structure is observed.
- 3D modelling confirms capability of 4D seismic to monitor deep CO_2 distribution.
- Ambient noise levels affect 4D sensitivity.
- No induced seismicity over first 6 years.

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THANK YOU!

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