GEOTHERMAL TECHNOLOGY IN CANADA

FUTURE PATHWAYS

JANUARY 23 - 24, 2020

FEDERATION HALL | UNIVERSITY OF WATERLOO | CANADA

Professor Grant Wach
Basin and Reservoir Lab
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Dalhousie University

Basin & Reservoir Lab

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Rift and synrift sediment distribution in the Paleozoic and Mesozoic basins of the Atlantic Canadian Margin- CCUS, CAES and Geothermal Potential

Professor Grant Wach
Earth and Environmental Sciences
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KAUST Research Conference 2020

Maturing Geothermal Energy for Saudi Arabia

January 27 - 29, 2020

Auditorium between buildings 4 and 5

Basin & Reservoir Lab

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جامعة الملك عبدالله للعلوم والتقنية

King Abdullah University of Science and Technology

KAUST Conference Objectives

- Maturing Geothermal Energy in Saudi Arabia
- Amongst highest per capita power consumption
- Ambitious goals have been set by governments
- Expectations of increased renewable capacity (and jobs!)
- Entire cities are under development that will run on 100% renewables (NEOM and the Red Sea Development) Vision 2030 plan

KAUST Conference Challenges

- Can geothermal energy be matured economically to become a 3rd alternative for renewables (after solar and wind)
- Can life-sustaining water and desalination and air-conditioning be run on Geothermal power?
- Can Geothermal help to lower our environmental footprint?
- Is Geothermal Power a sleeping giant among renewable power sources?

Geothermal in Canada- What policy makers need to know

Proceedings World Geothermal Congress 2020
Reykjavik, Iceland, April 26 – May 2, 2020

Geothermal Energy in Canada – Kickstarting an Industry

Catherine J. Hickson[1], Fran Noone, Jasmin Raymond, Maurice Dusseault, Tiffani Fraser, Katie Huang, Kirsten Marcia, Mafalda Miranda, Bastien Poux, Kathryn Fiess, John Ebell, Grant Ferguson, Janis Dale, Leo Groenewoud, Jonathan Banks, Martyn Unsworth, Brian Brunskill, Steve Grasby and Jeff Witter

Paper submitted on behalf of Geothermal Canada, 1503-4194 Maywood Street, Burnaby, British Columbia,

Geothermal in Canada- What policy makers need to know- 25 points

- 21- What is the role of universities and provincial/ federal research centres in establishing and developing geothermal energy
- 22- Can geothermal help achieve sustainable development in Canada, especially in remote communities that are currently carbon-fuel dependent
- 23/24 How can the oil and gas and mining sectors expertise be harnessed to advance geothermal energy use.

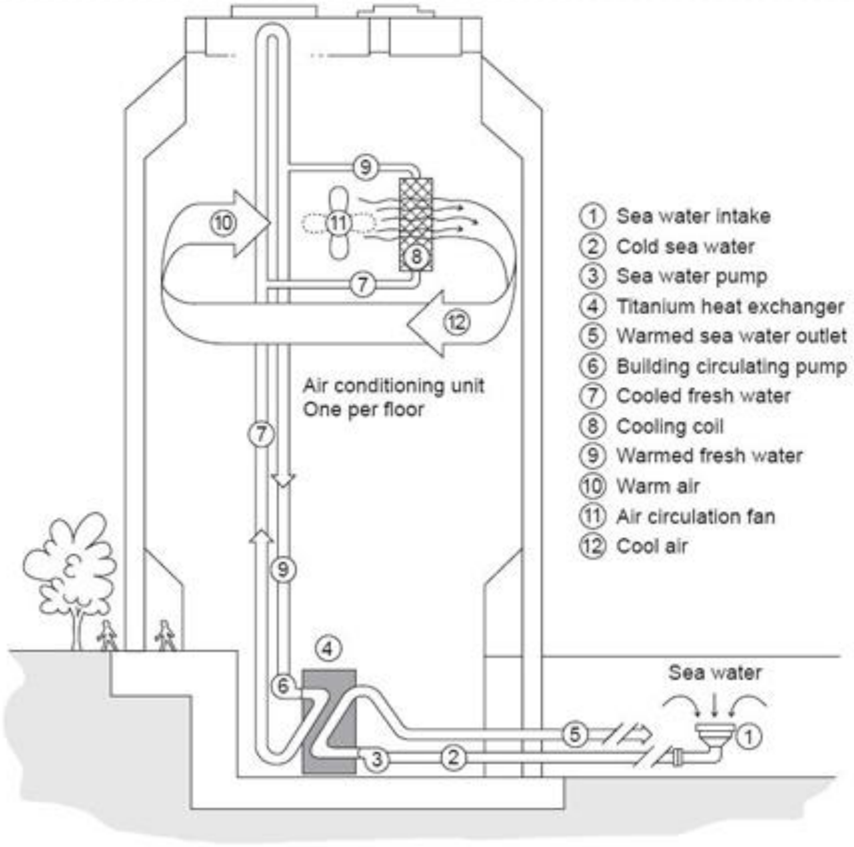
Outline

- Renewable opportunities in the Maritimes
- Tidal and Marine Geothermal
  - Bay of Fundy and Halifax Harbour
- Geothermal from Coal Mines
  - Springhill case study
- Compressed Air Storage (CAES)
  - Cumberland Basin and the Energy Corridor Case Study
- CCS in offshore Saline Aquifers
  - Case study of the Sable development
- Geothermal potential in the High Arctic

GEOTHERMAL IN THE MARITIMES

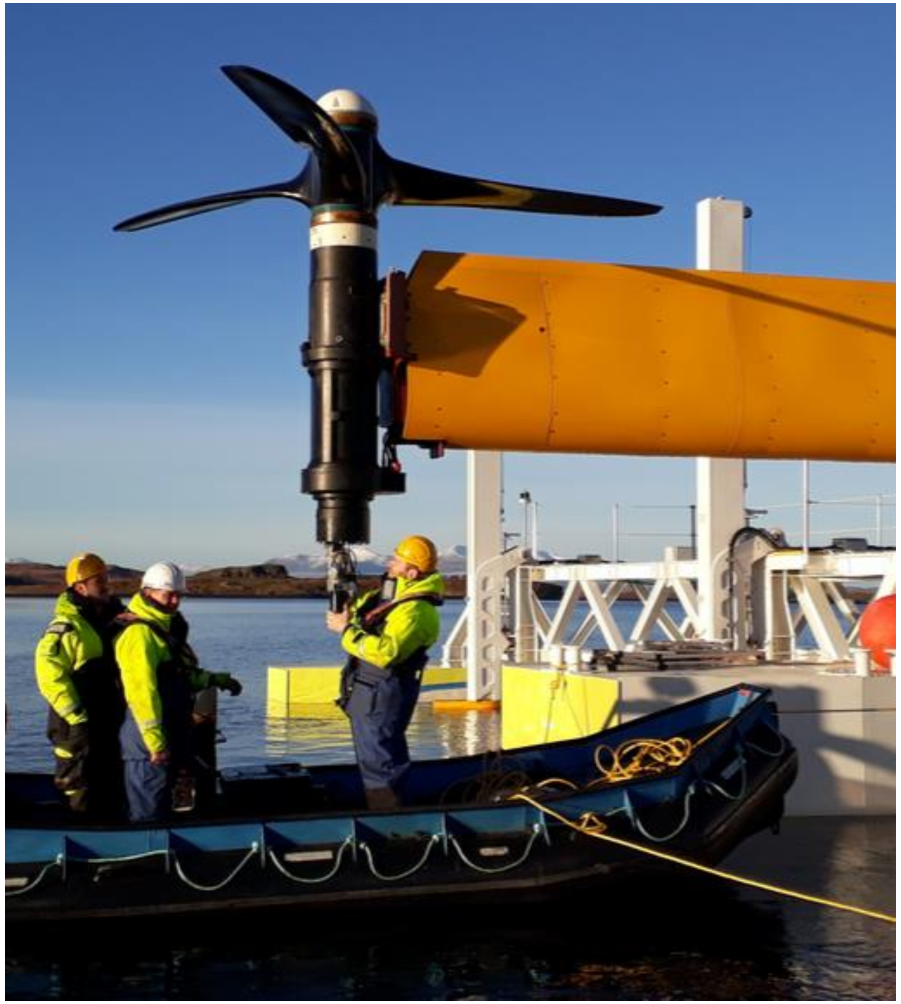
Sea Water Cooling System

Purdy's Wharf has a unique, energy-efficient cooling system that works by circulating sea water through a heat exchanger system with the building's cooling water. The colder sea water chills the building's cooling water, which is then circulated through the buildings.



Purdy's Wharf Project

Sustainable Marine Energy (SME) and Minas Tidal LP (MTLP) have agreed to co-develop their adjacent berths at the Fundy Ocean Research Center for Energy (FORCE) and will utilise SME's PLAT-I floating in-stream tidal energy technology to deliver up to 9MW of tidal energy to the Nova Scotia grid.



NEW TECHNOLOGY DOES HAVE GROWING PAINS

LINK

fundyforce.ca

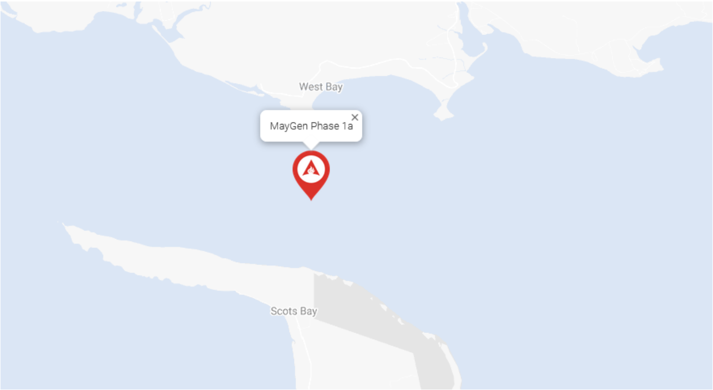
Status: in Development

capesharptidal.com

is a totally awesome idea still being worked on.

Check back later.

In October 2014, Atlantis signed a sublease agreement for a tidal turbine berth at the FORCE facility, together with a project agreement with the Nova Scotia Department of Energy. Subsea electrical cables were laid at the FORCE facility in October 2014. In December 2014, Atlantis was awarded a feed-in tariff for up to 4.5 megawatts of tidal generation to be deployed at FORCE. The Developmental Feed-In-Tariff award of C$530 (£292) per megawatt hour (MWh) provides revenue support for Atlantis to deploy and operate up to three state-of-the art AR-1500 turbines at FORCE.

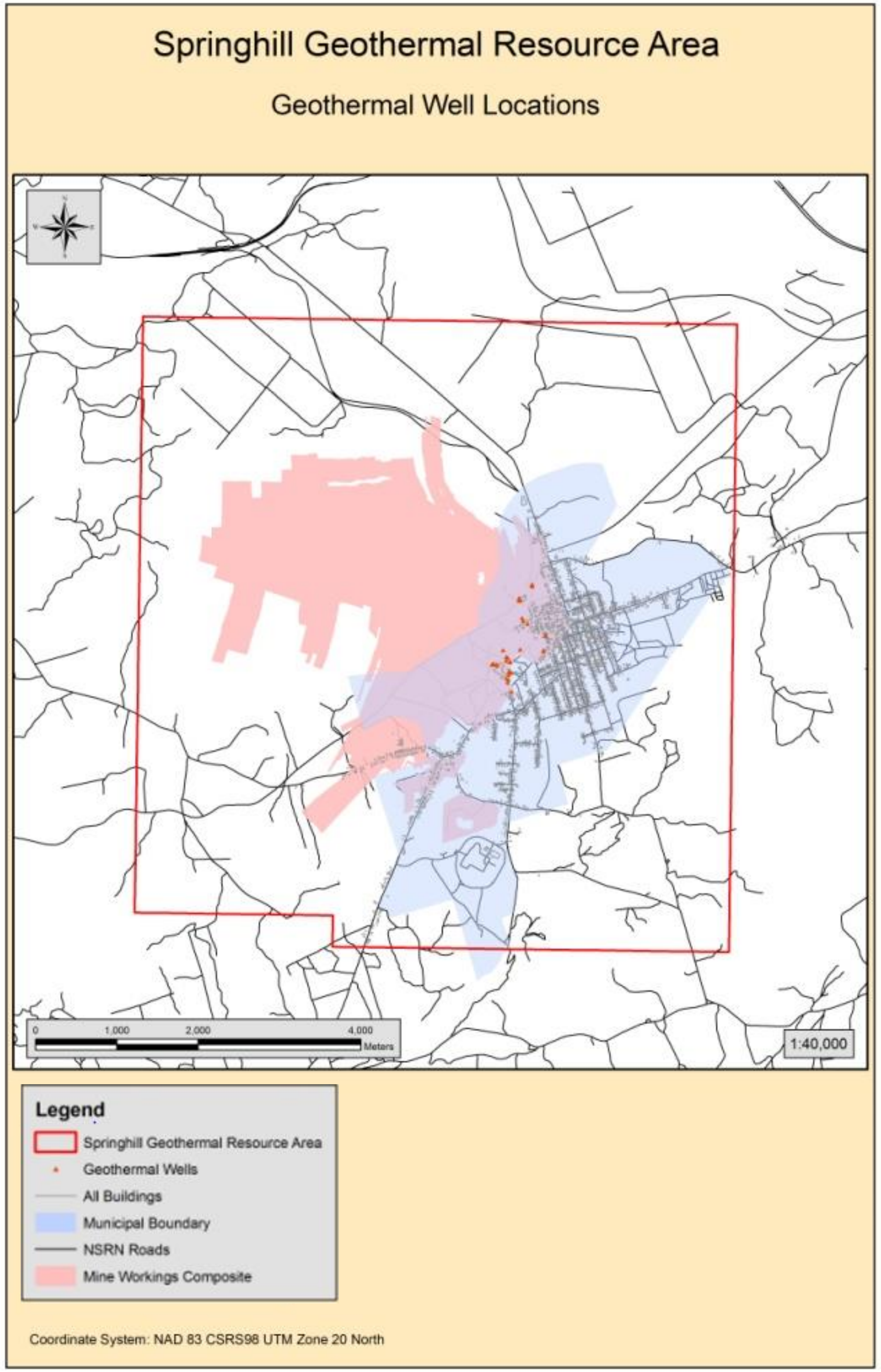


Springhill Mine Geothermal

-Mine openings flooded by groundwater inflow, and warmed below surface

-Warmed water offers a potential valuable geothermal energy source

-Since the early 1990's ~25 geothermal wells have been drilled, of which 17 are currently used by businesses/facilities. 6 wells maintained and operated by Town of Springhill, remaining 11 wells owned and maintained by private operators for heating, cooling and production purposes.



Overview of the Mine

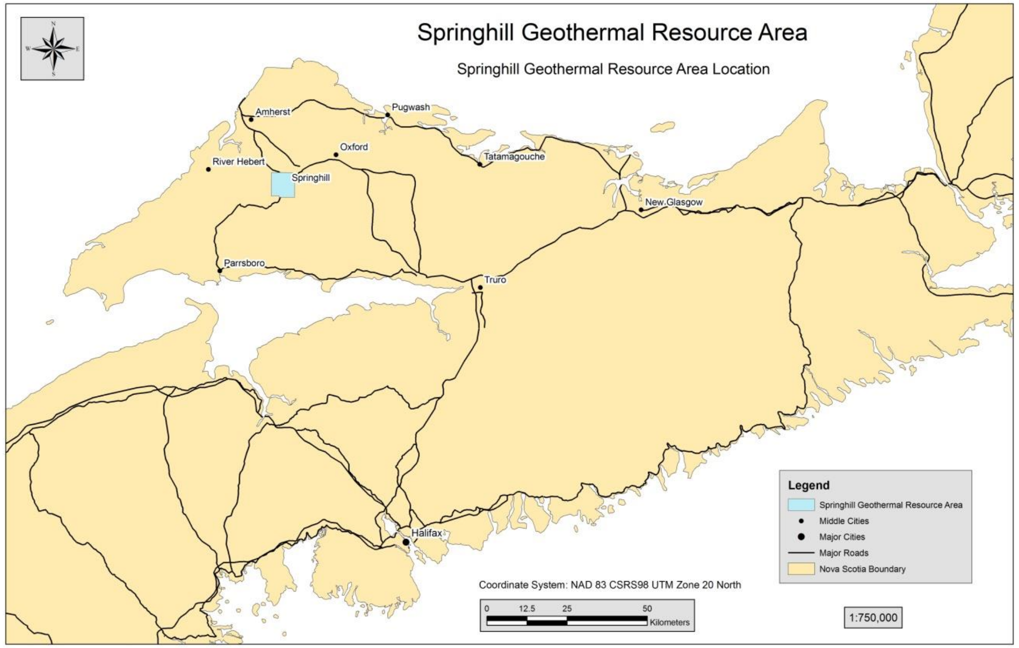
-Series of overlying coal seams that outcropped on surface

-Began large-scale mining activity in 1884

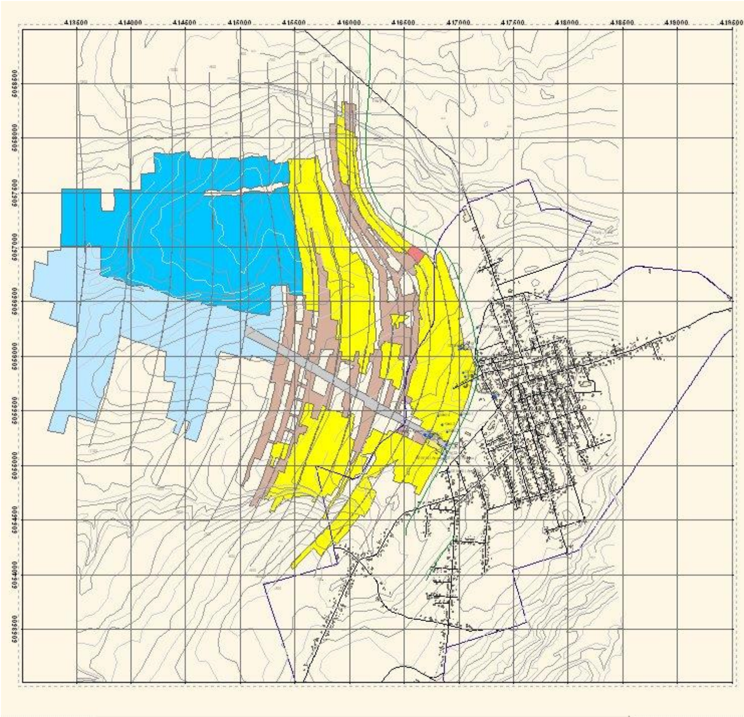
-Seams have a maintained thickness between 1.4-3m, dipping ~30deg at surface to ~11deg at depth

-Mined a distance of 4,400m to the west and reached vertical depth of 1,320m

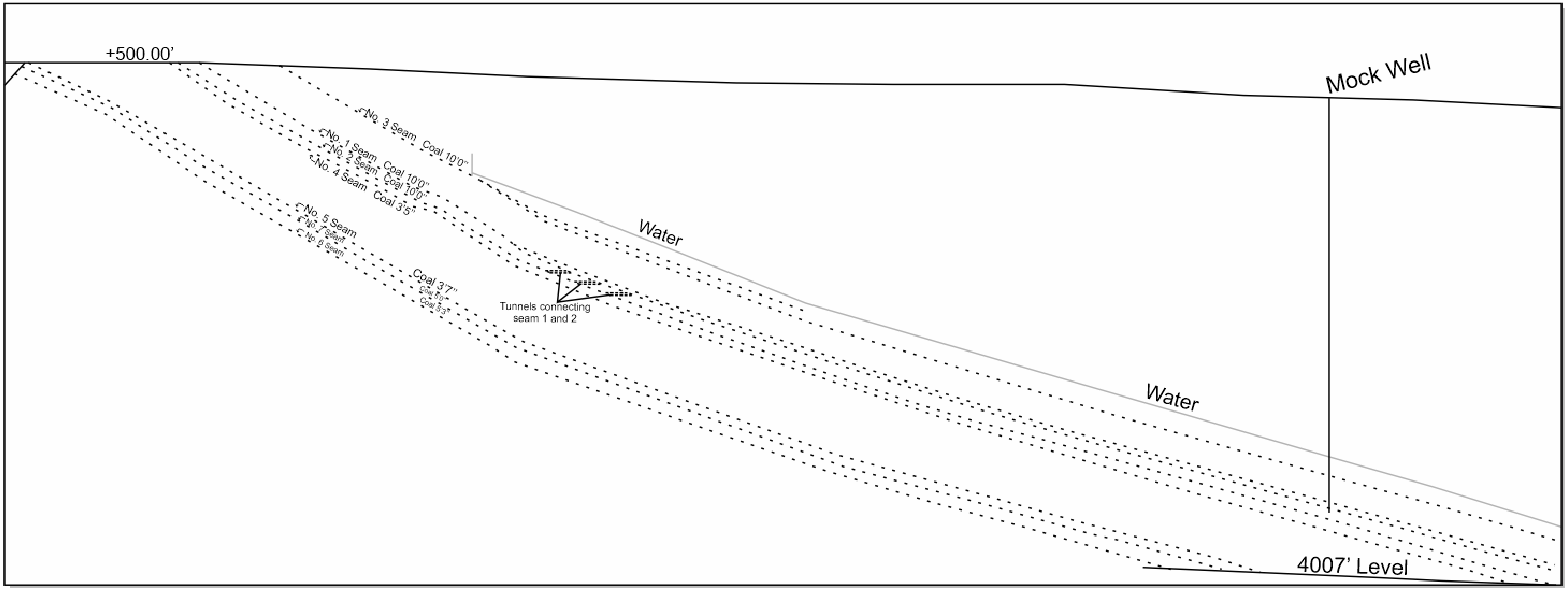
Continuous large-scale production until 1958 (Springhill Mine Disaster)



Springhill Mine Resource Area Location

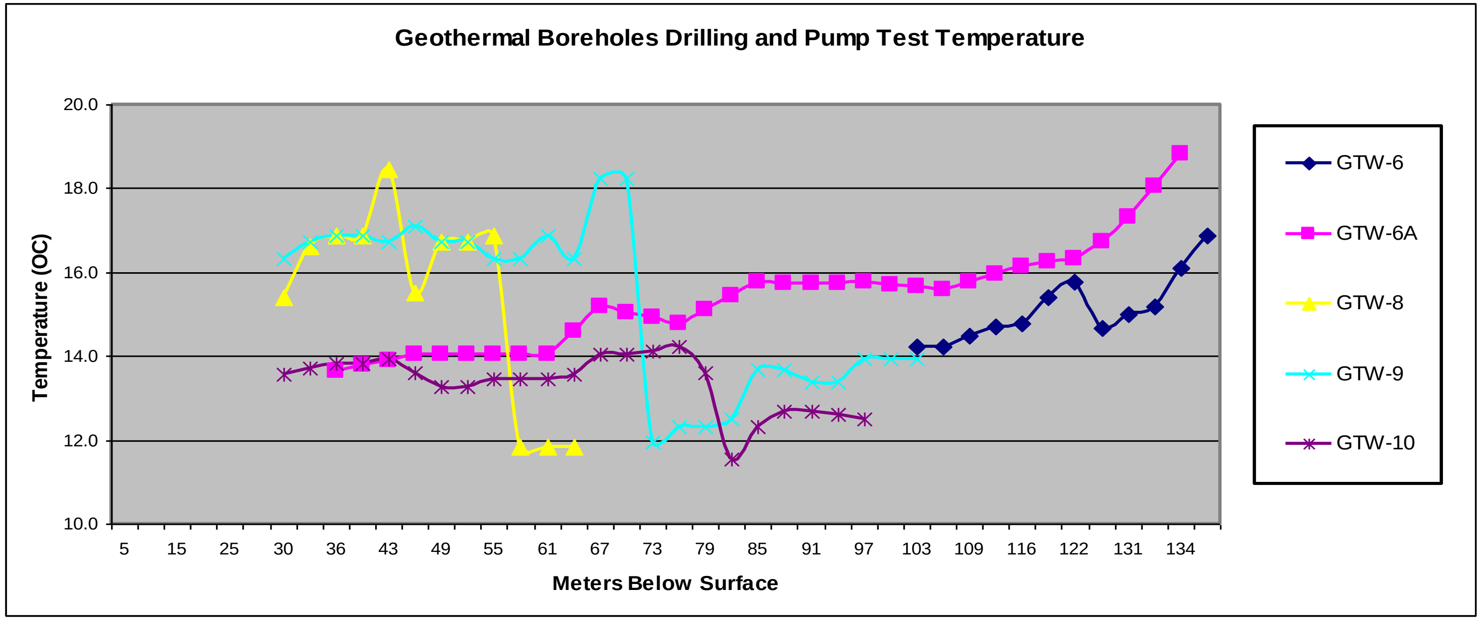


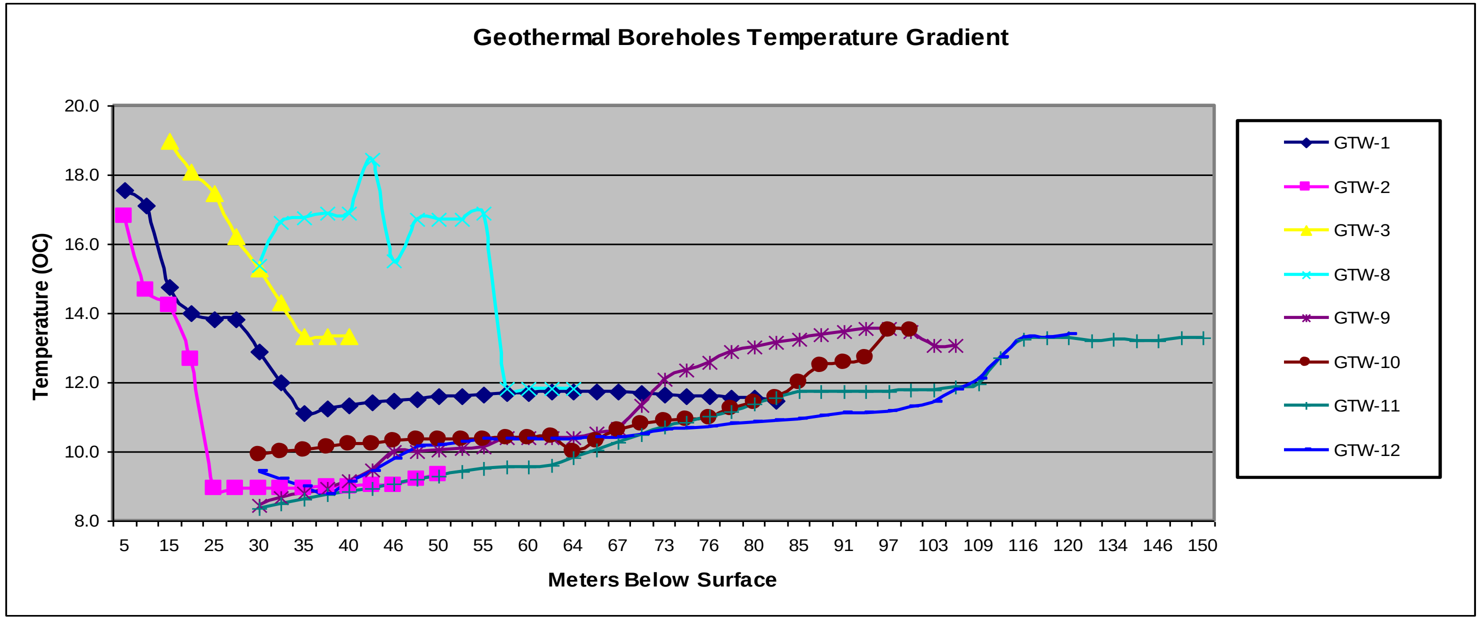
Abandoned underground mine workings for No. 2 Mine (No. 2 Seam) with Town of Springhill municipal area overlain



Cross section of coal seams looking South, seams dip to the West

Borehole Tests





Summary

Springhill Mine Water Geothermal has been used since early 1990’s.

- Numerous wells drilled and technical data reported however data and reporting lack
  - uniformity
  - completeness
  - quality control
  - compilation
- Mine Water Geothermal resource is currently accessed and used with no control.
- Generally users have experienced economic benefits and good reliability.

Moving Forward

- Working relationship with the NSCC - Springhill Campus (Refrigeration and Geothermal Program)
  - NSCC Springhill currently utilizes some of the geothermal technology to instruct students in their Refrigeration and Air Conditioning Program.
  - Sharing of technical data associated with well pump tests and analysis of mine water.
  - Some areas of the campus utilize the Springhill mine for heating.
- Special Mineral Lease for Springhill Geothermal Resource Area Acquired
  - Town of Springhill now has ownership of the Geothermal Mine Water Resource.
  - Allows Town to control the development and usage of the mine water geothermal resource.
  - Permit “Green Industrial Park” development and provide direct economic benefits to the Town.
- Concept design for Springhill Geothermal Business Park underway

ENERGY STORAGE IN THE MARITIMES

Energy Storage

The thing about renewable energy is that the sun doesn't always shine, the wind doesn't always blow, and tides don't always flow.

There are many storage and reconversion options available for electricity. These include:

•electrochemical —conventional batteries (lead acid, lithium ion, and others), flow batteries

•chemical—hydrogen storage and fuel cell systems

•electrical—large capacitors

•mechanical

- Flywheel—energy is stored in rotating mass and released back to the grid when needed
- Compressed air energy systems—air is compressed and stored, then later released to turn a turbine that produces electricity
- Pumped-hydro storage—water is pumped to a higher elevation and stored in a hydro reservoir
- Hydroelectric systems that include large dams where water can be trapped and stored until it is needed

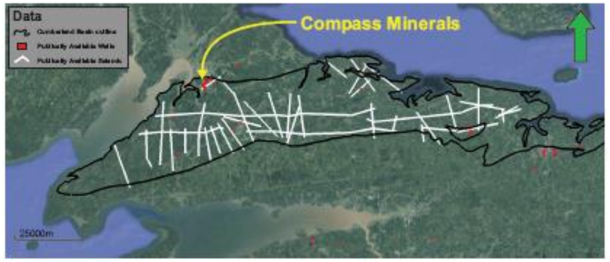
•thermal—electric thermal storage units, phase change materials, underground seasonal thermal storage systems, district heating, and hot water storage tanks

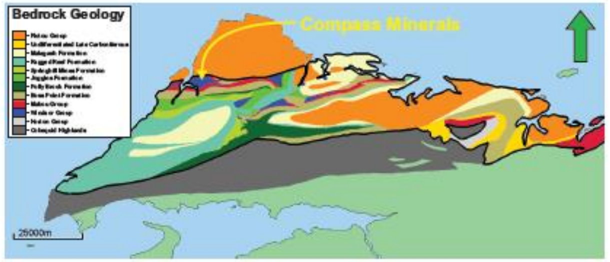
NOVA SCOTIA CANADA

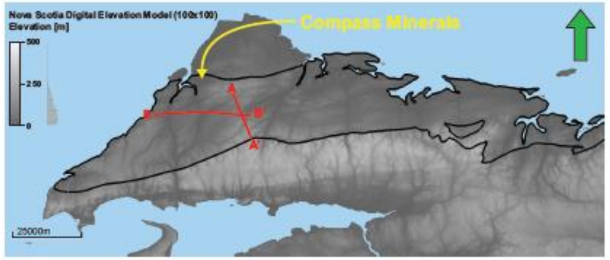
Energy and Mines

Geologic Setting of the Cumberland Basin, NS

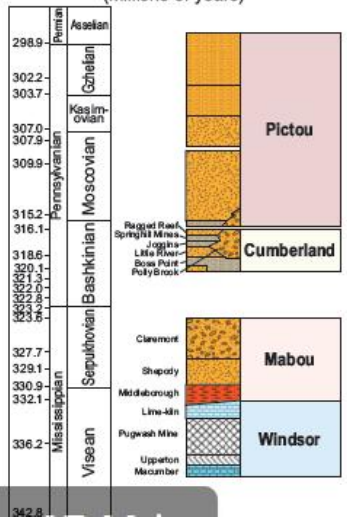
Grant Wach, Professor of Petroleum Geoscience, Basin and Reservoir Lab, Department of Earth and Environmental Sciences, Dalhousie University
Email: GRANT.WACH@DAL.CA

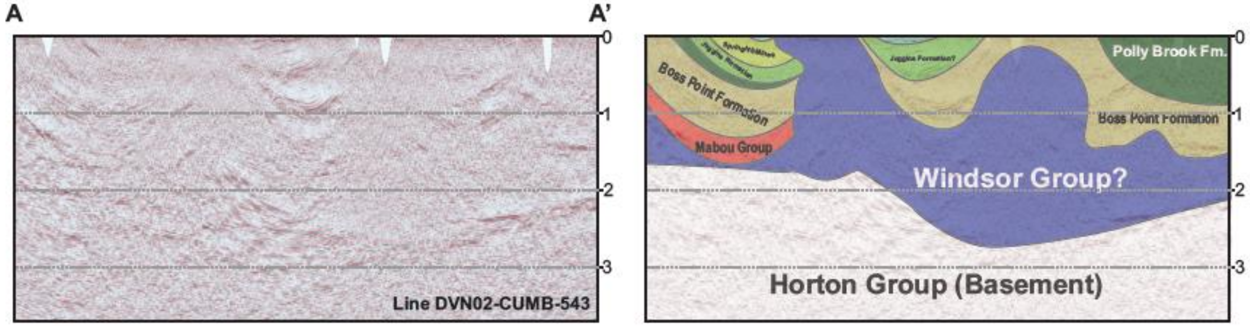


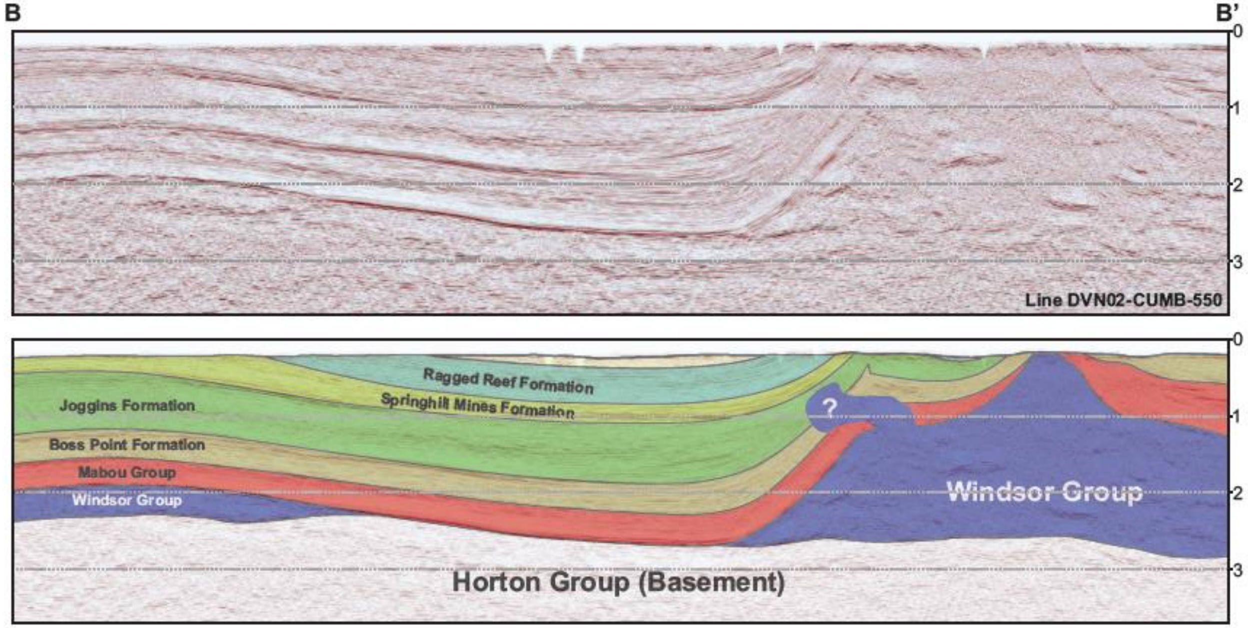




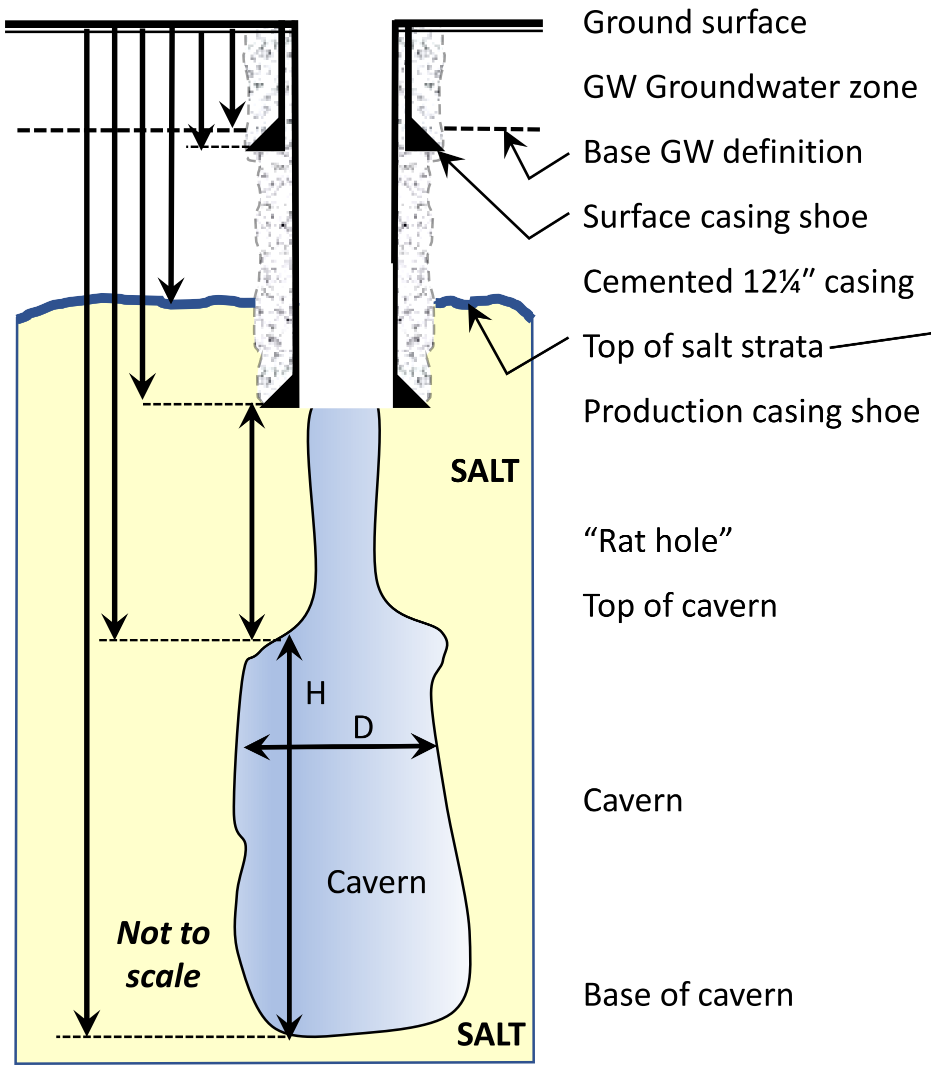
Chronostratigraphic Subdivisions Cumberland Basin
(Millions of years)

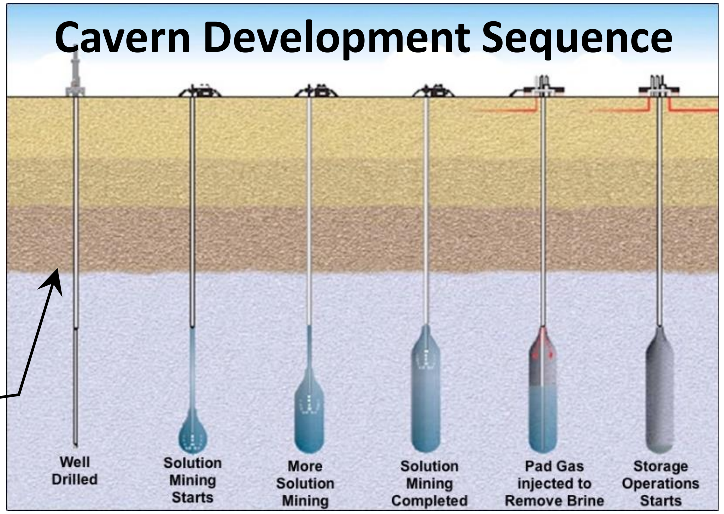






Caverns…





http://saltecintl.com/operations-test/operations-about-storage-in-salt-cavern-creation-test/ (Courtesy SalTec Int Inc)

Typical Dimensions**

GW base 50-70 m
Surface casing shoe 100-150 m
Prod casing shoe ~50 m below salt top
Rat hole length 20-30 m
Cavern height - H 150-250 m
Cavern diameter - D 35-50 m
Surface casing size 13⅜" in a 16" dia hole
Prod. casing size 10½" in a 12¼" dia hole

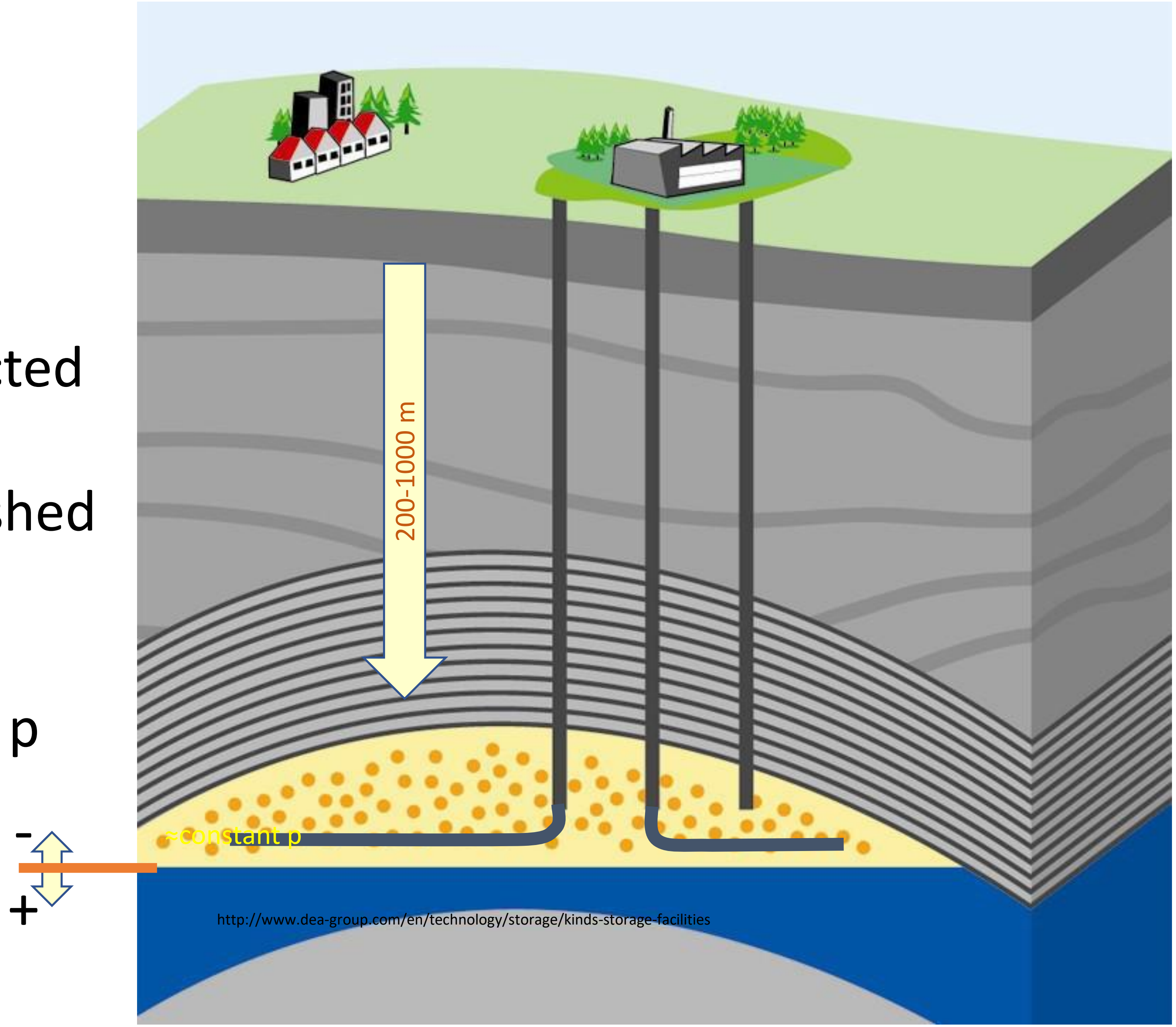
****Caveat: this is not a design, it is for conceptual purposes.**

Aquifer CAES

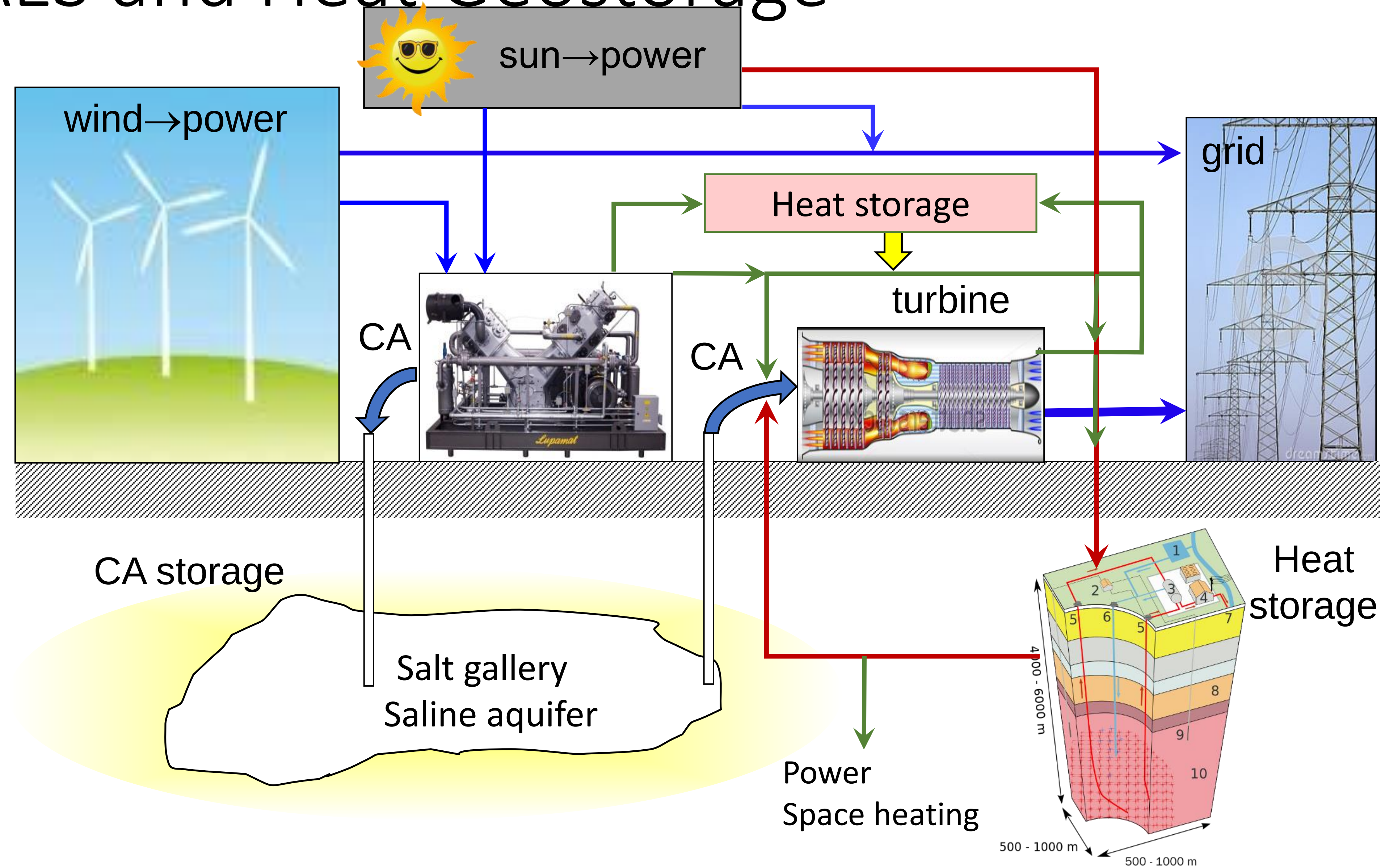
Air is injected

Water pushed down

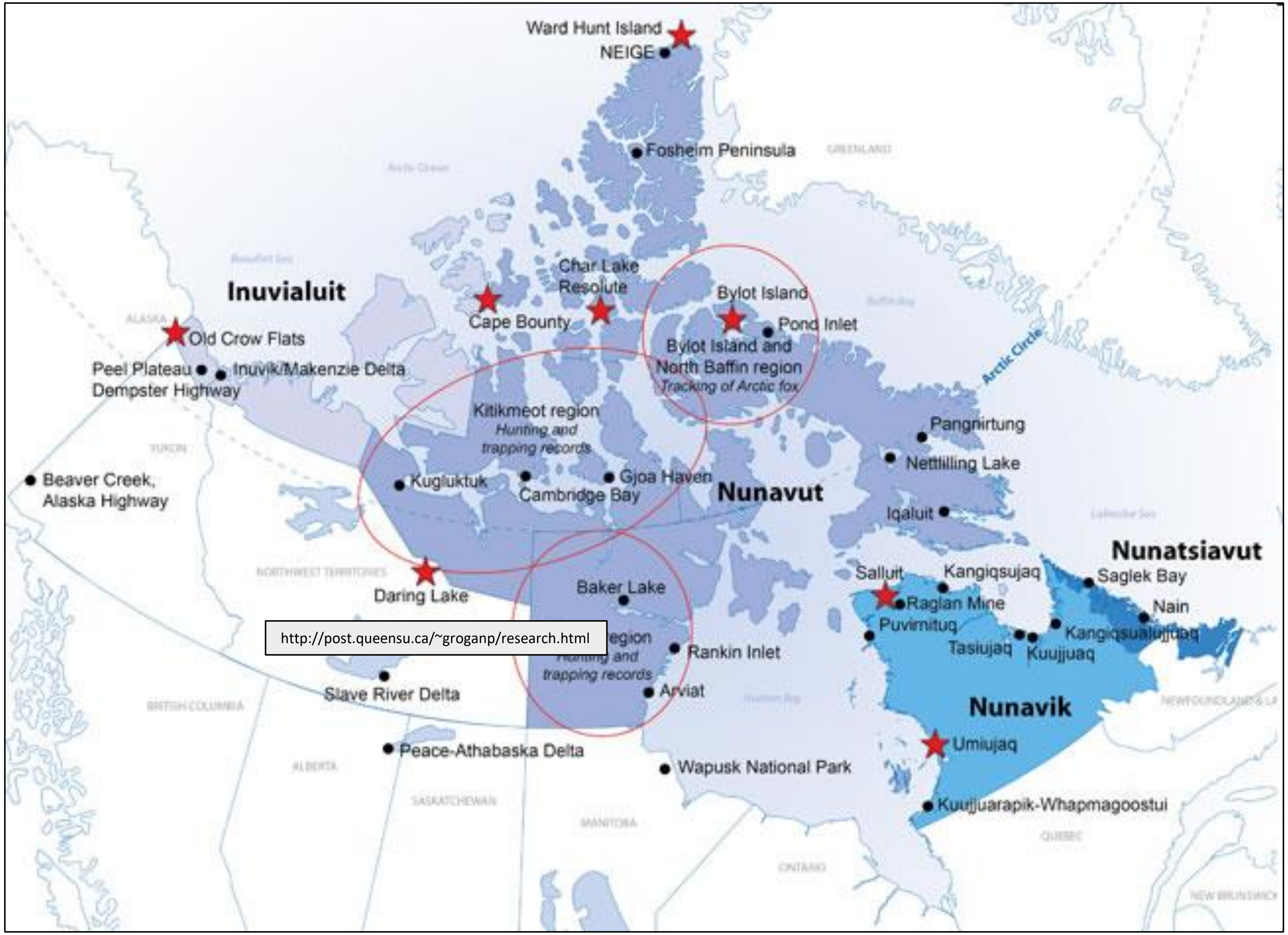
≈constant p



CAES and Heat Geostorage



Is CAES Part of Solution?



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Dynamic Modeling of Buoyant Fluids in the Sable Subbasin: What’s Next?

Presenter:
Darragh O’Connor
(darragh.oconnor@dal.ca)
Basin and Reservoir Lab
Dalhousie University

October 2019

Co-authors:

Bill Richards

Max Angel

Grant Wach

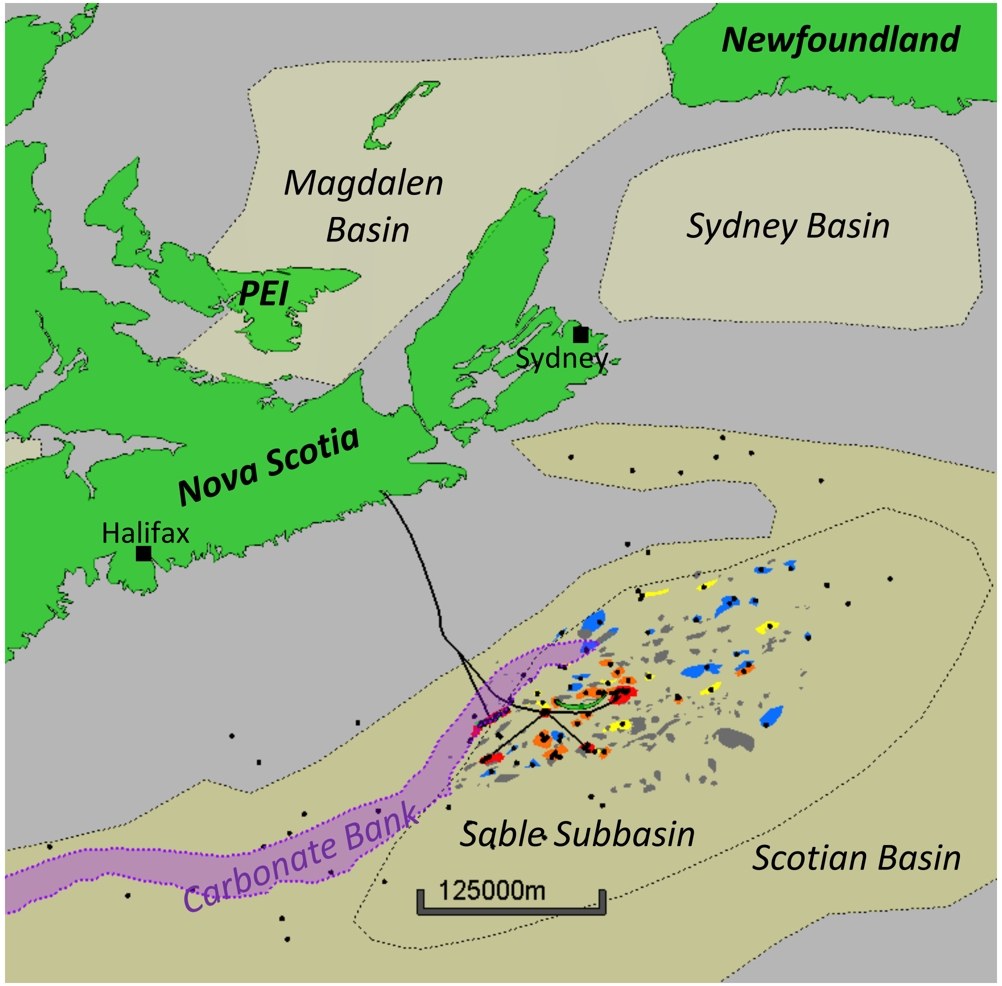
‘State-of-Play’ - Sable Subbasin

Only commercial hydrocarbon subbasin offshore Nova Scotia

- Exploration since 60’s, ~all shelf prospects mapped by NSPD in 1999
  - ~4 TCF proven resources (~150 TCF Southern N. Sea)
  - Undiscovered estimates as high as 120 TCF ignore well-known risks
  - 8 commercial fields now depleted (~2.3 TCF & ~45 MBO)
  - 15 undeveloped fields, ~33 wet structures, ~100 undrilled closures
- Extensive public data bases and interpretations: GSC, DOE, CNSOPB
- Geology is well understood - except source rocks

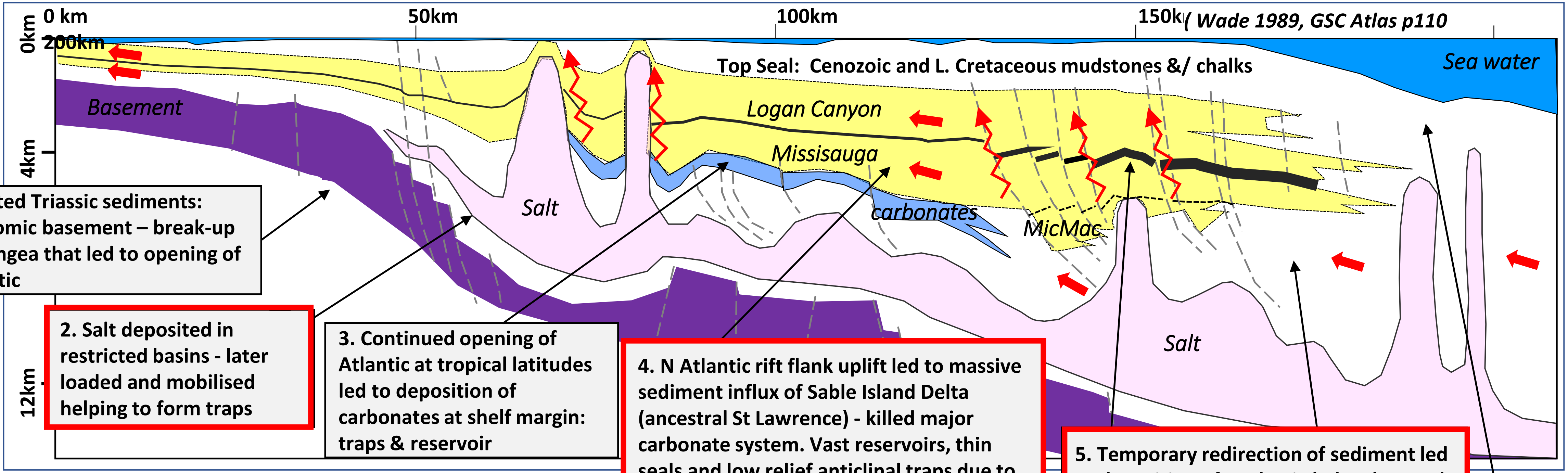
Why?

- **Only sub-basin with evidence of a significant source rock (ie: fields)**
  - Deltaic / marginal marine gas-prone source rocks inferred
  - No evidence of prolific restricted basin source rocks that generate world class oil reserves on other Atlantic margins – function of sediment influx, plate tectonics & oceanic circulation
- **‘Leaky system’: low-relief traps that leak updip towards Nova Scotia**
  - “Rollover anticline” traps in Jurassic- Cretaceous Sable Island Delta contain high-NTG reservoirs prone to cross-fault leak
  - “Drapes” and “reef margin” traps on downdip flank of Jurassic Abenaki Carbonate Bank have limited seals



Sedimentary Basins (after Williams & Keen, 1990)
Fields and Closures (after NSPD, 1999)
Scotian Basin Wells and Pipelines
Closures: red / orange=developed / undeveloped,
yellow / dark blue = wet with & without shows, gray = undrilled.

Sable Subbasin – Shelf-Slope Geology & Play Elements



1. Rifted Triassic sediments: economic basement – break-up of Pangea that led to opening of Atlantic

2. Salt deposited in restricted basins - later loaded and mobilised helping to form traps

3. Continued opening of Atlantic at tropical latitudes led to deposition of carbonates at shelf margin: traps & reservoir

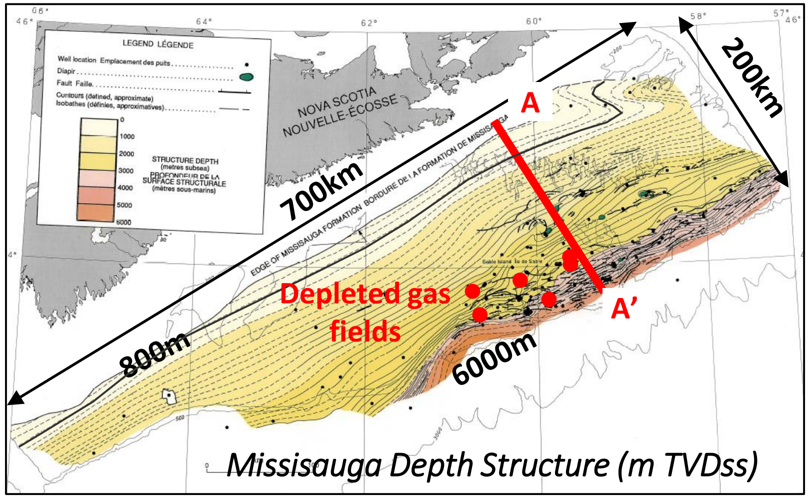
4. N Atlantic rift flank uplift led to massive sediment influx of Sable Island Delta (ancestral St Lawrence) - killed major carbonate system. Vast reservoirs, thin seals and low relief anticlinal traps due to loading, faulting and rotation.

5. Temporary redirection of sediment led to deposition of Naskapi Shale – key seal in the basin

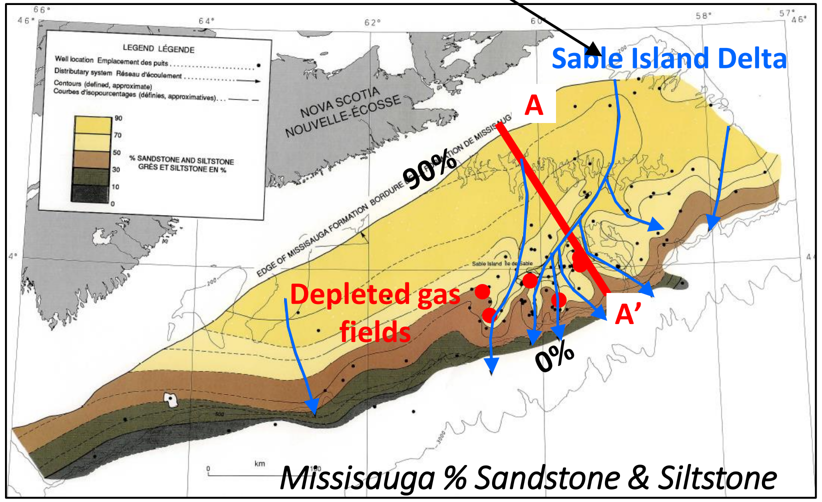
6. Lean deltaic and marginal marine source rocks are inferred, but no confirmation through biomarkers

7. Deltaic source wanes in Logan Canyon giving way to deep water mudstones and marls – & prograding Cenozoic mudstones. Topseal for system.
No further uplift at basin margins producing deep water fan systems similar to North Sea or Newfoundland

(GSC East Coast Basin Atlas Series: Cant, 1991)



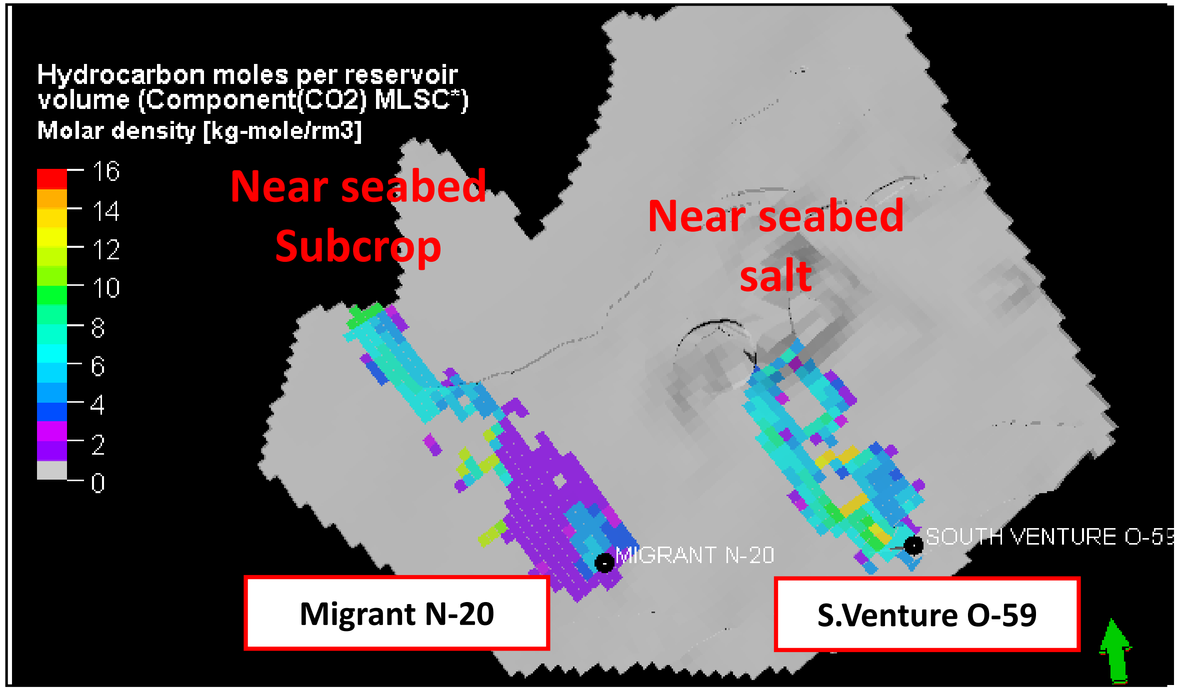
Missisauga Depth Structure (m TVDss)

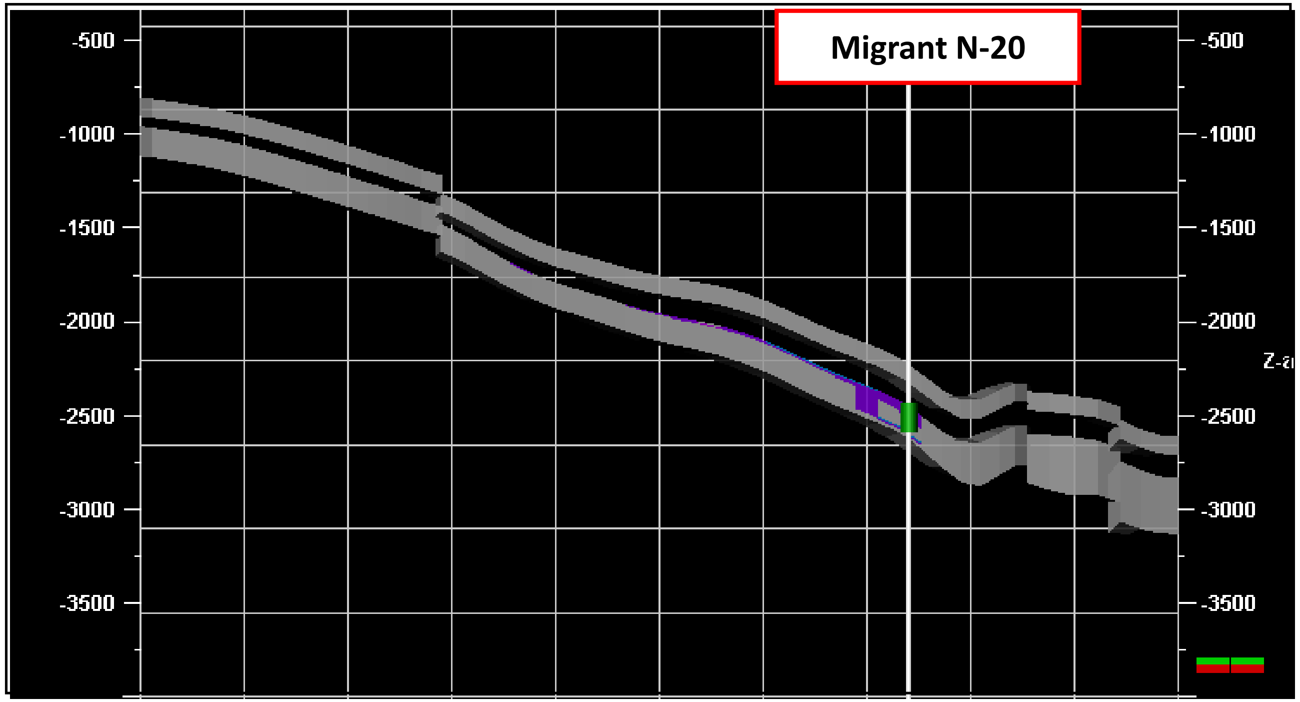


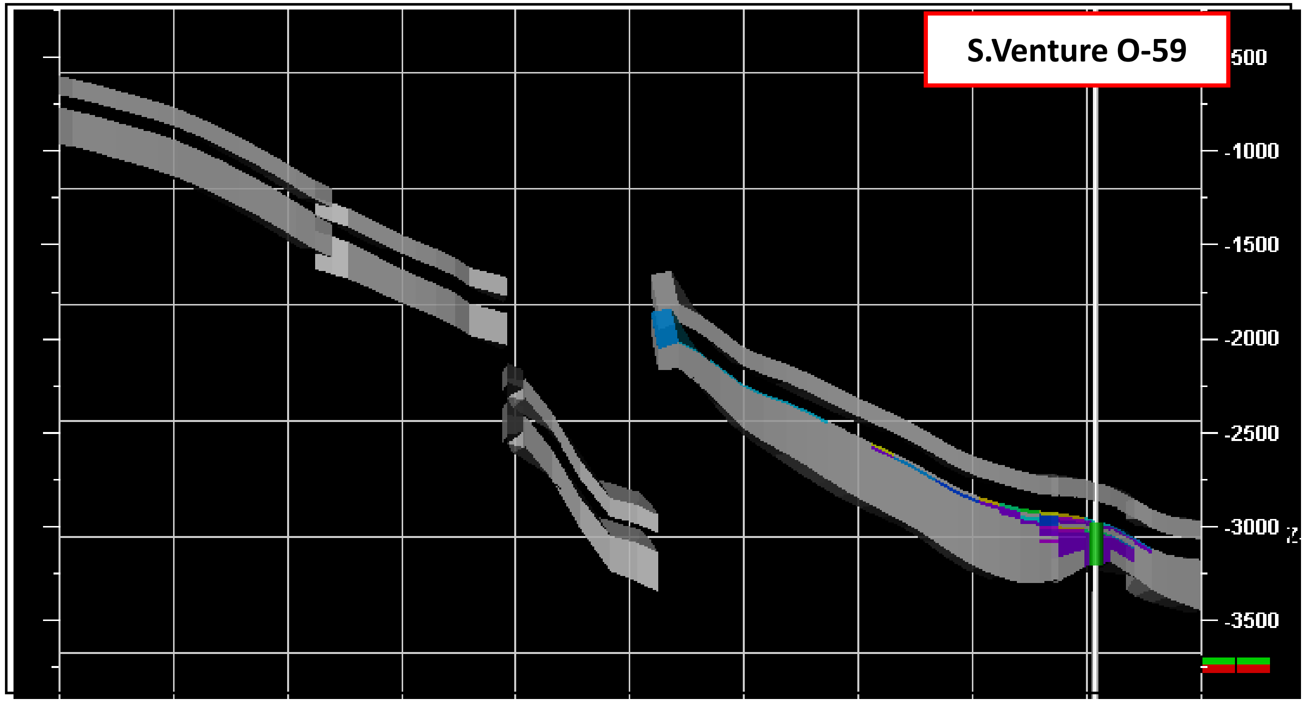
Missisauga % Sandstone & Siltstone

Regional Upper Missisauga Model
10Mt CO_2 per year per well – for 100 years

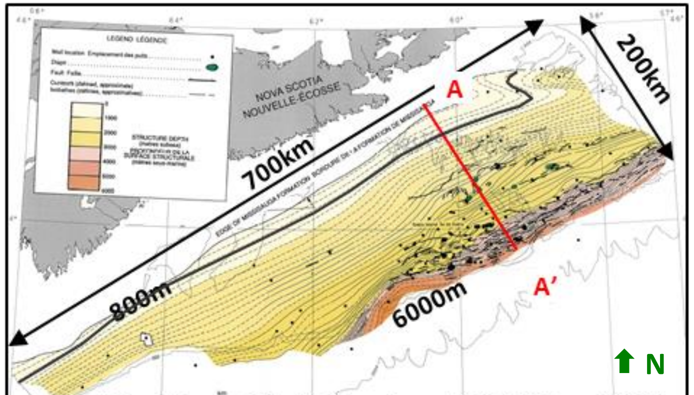
2600: 100 years injection – 500 years equilibration



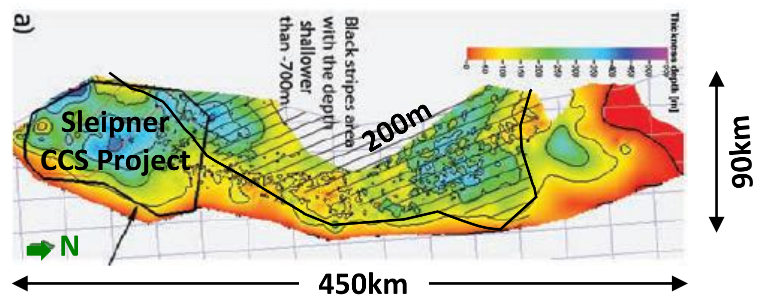




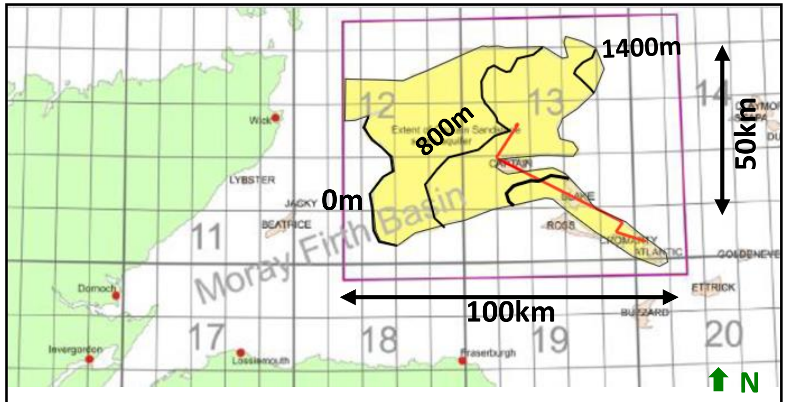
CCS Potential: Comparison Sable, Utsira, Captain



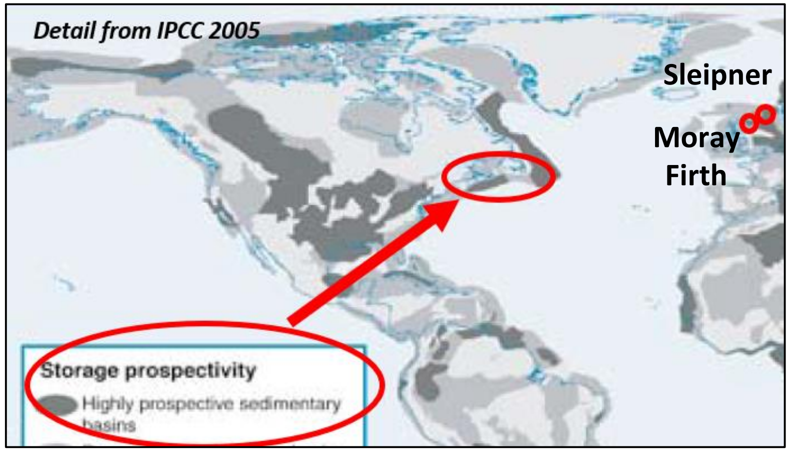
Missisauga Depth Structure (GSC Atlas, 1991)



Utsira isopach with depth contours
Pham, 2011 & Norwegian Petroleum Directorate CO2 Atlas



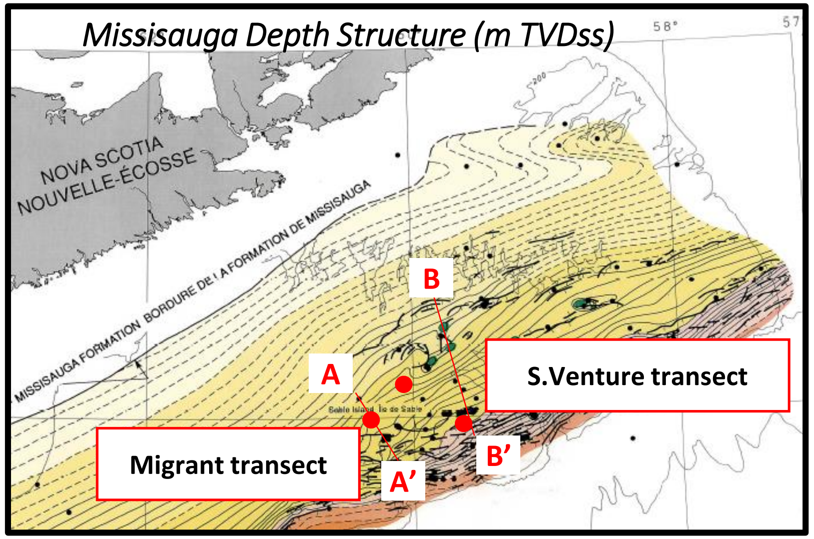
Captain Sandstone (Jin, 2012; depths Williams 2018)



	Thickness	Dimension	million tonnes		
	m	km	Low	High	
Captain	0-600	60 x 100	358	1668	2011 SCCS
Utsira & Skade	0-1000	90 x 450	500	1500	2011 NPD
Missisauga	0-5000	150 x 700	?	?	Calc here
Sable depleted hydrostatic reservoirs			~50		
NS Power annual emissions			~8		2012 NSP
Canada Fossil CO2 emissions 2017			~600		Wikipedia
Global Fossil CO2 emissions 2017			~37,000		Wikipedia

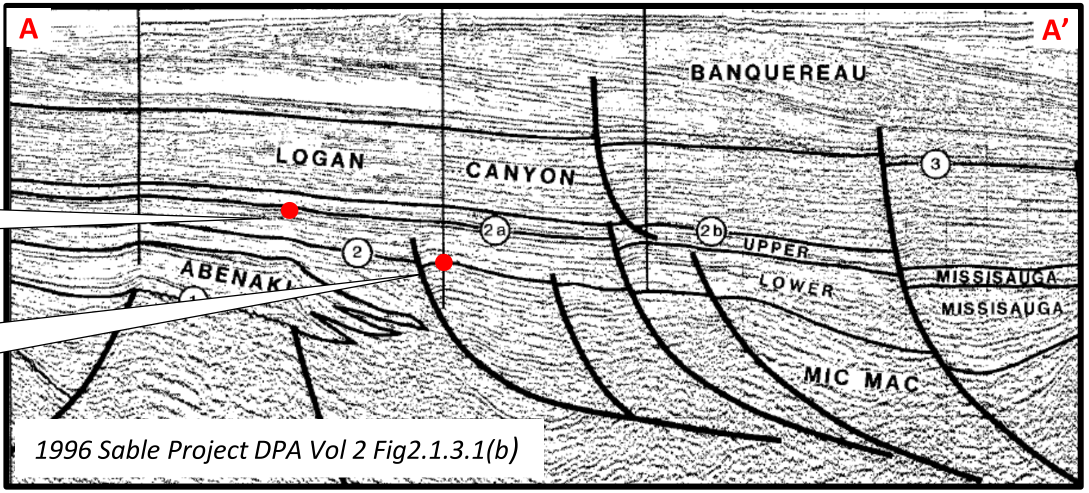
Summary of Dynamic Modeling

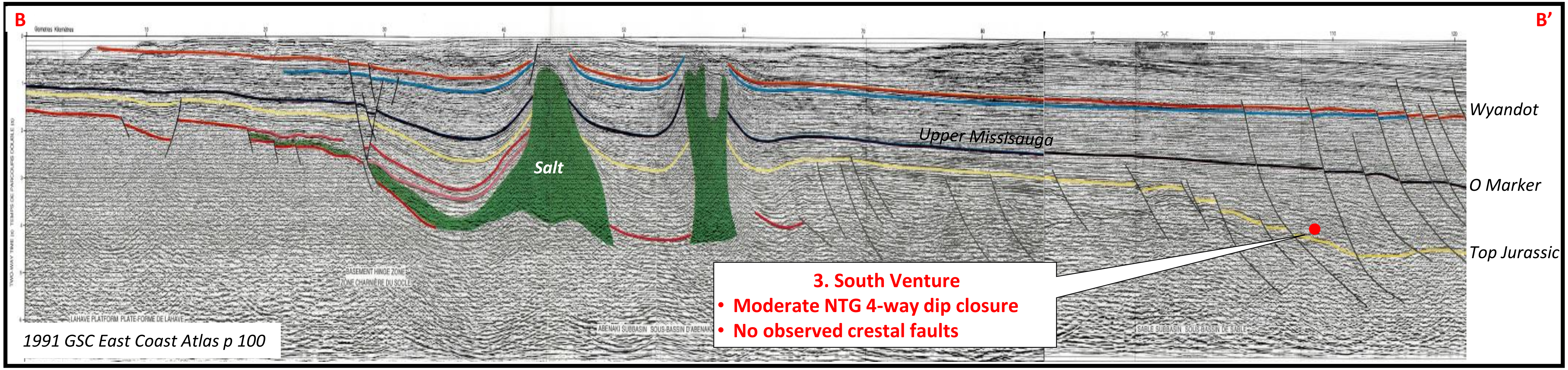
- Objective (1) to understand “fill & spill” fluid migration (leakage) in hydrocarbon traps



1. Penobscot (~25km NE)
- high NTG faulted structure

2. Migrant
- high NTG 4-way dip closure
- with crestal cross fault leak



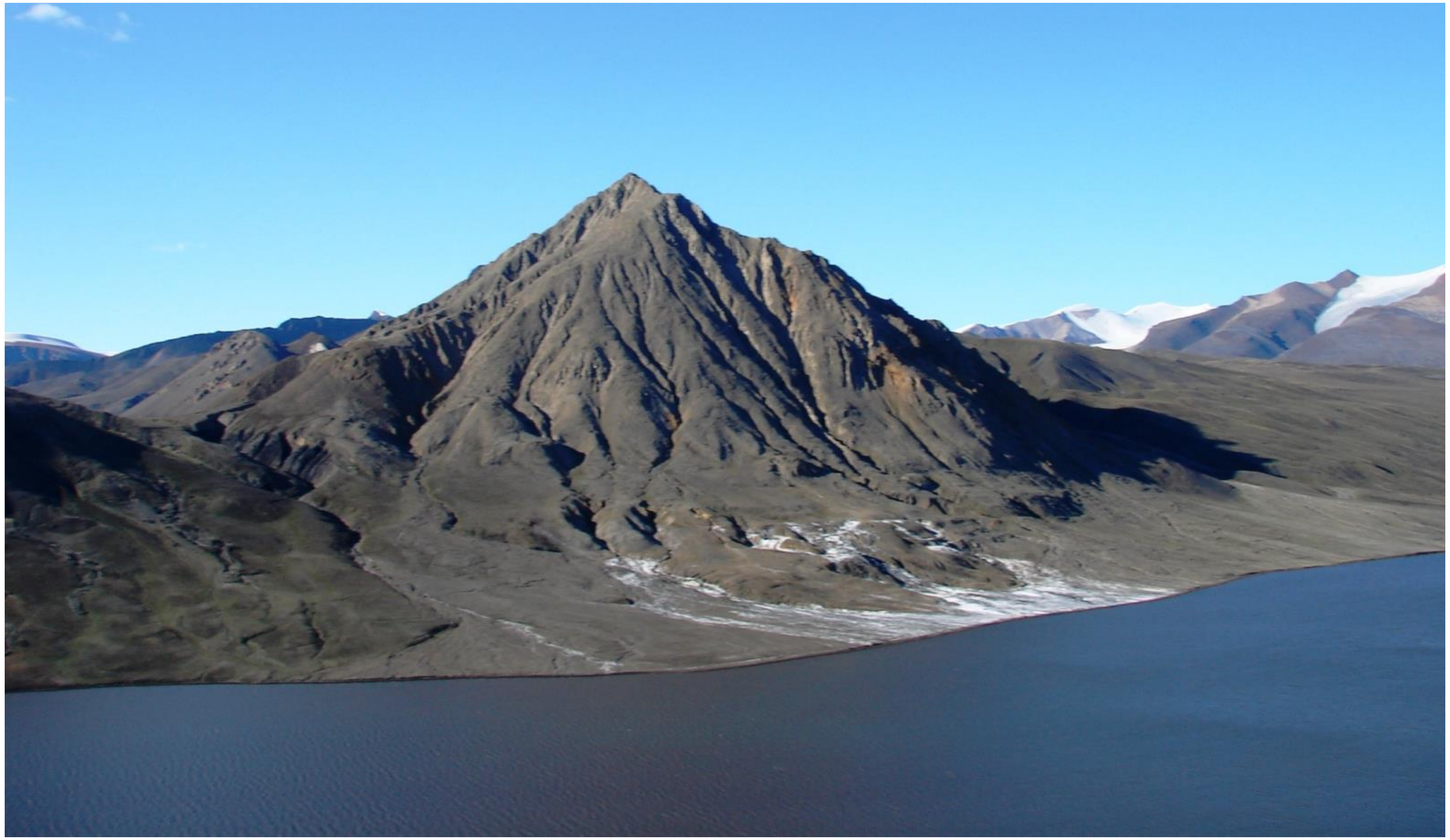


3. South Venture
- Moderate NTG 4-way dip closure
- No observed crestal faults

Geothermal Perennial Springs in Axel Heiberg

Zentilli et al 2019 Geofluids, Geofluids Article ID 9502904, 33 p

- Ground frozen to ~600 m (permafrost)
- Water coming out at ca. 5^{o}C year-round despite huge variations of air temperature



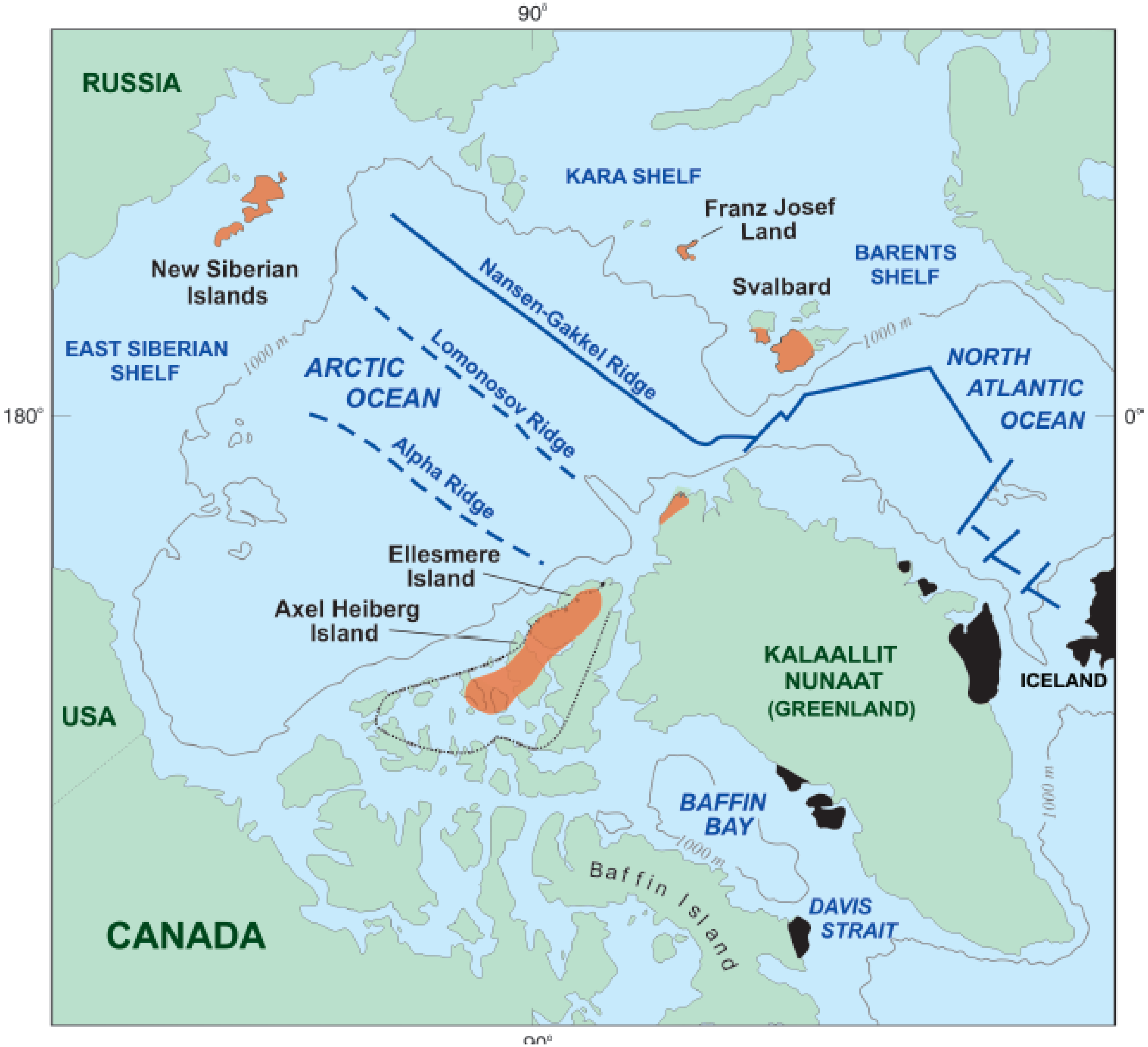


Fig. 1. Map of Circum-Arctic landmasses showing the location of the Canadian Arctic Islands in northern Nunavut. The outline of the Sverdrup Basin is shown by a dotted line. Volcanic and intrusive rocks of Cretaceous age belonging to the High Arctic Large Igneous Province are shown in red (HALIP; see text for explanation). Igneous rocks of Tertiary age are shown in black. Major structures in the Arctic Ocean are also shown: full line, active ridge; dashed line, aseismic ridge (modified from Srivastava, 1985).

What Next for Sable?

- Drill more leaky ‘rollover anticlines’ & ‘carbonate drapes’?

- Scotian Margin identified as having world class CCS potential in 2005 (IPCC)

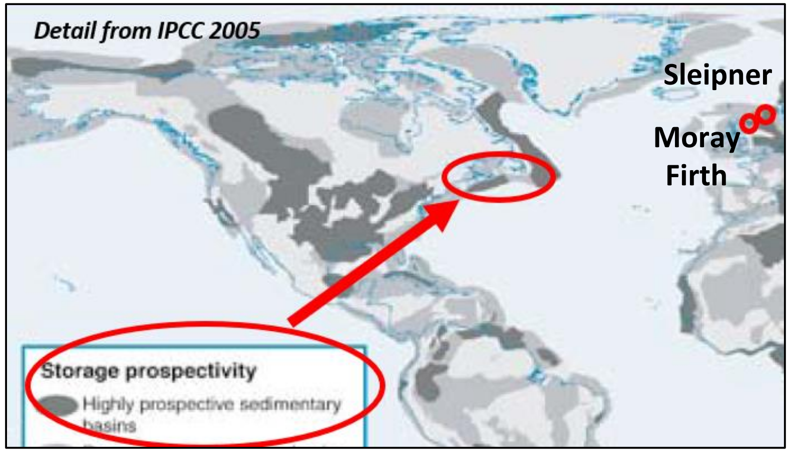
- CCS storage capacity could exceed estimates for Sleipner, Norway (ongoing 20 years) and the Captain Sandstone (planned project in the Moray Firth) which similarly rise to the seabed (or within a few hundred meters) .

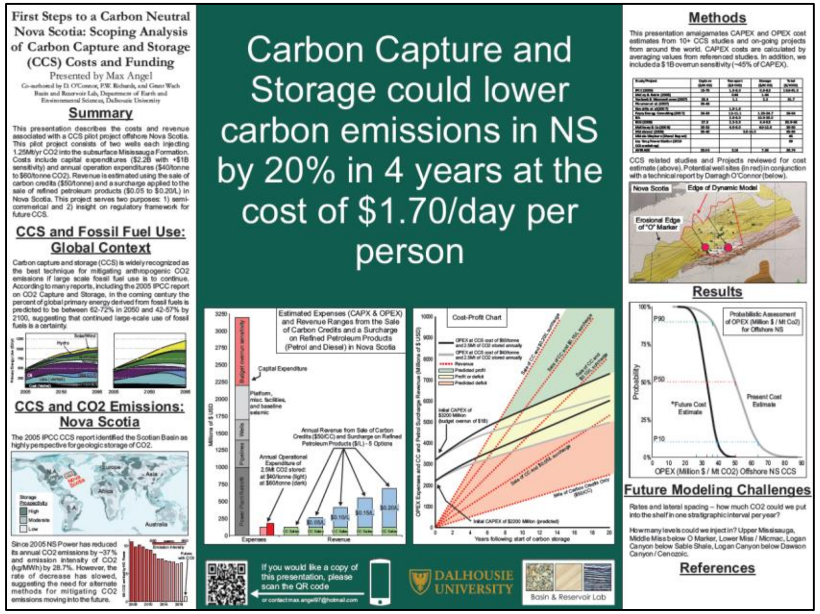
- What physical mechanisms prevent buoyant CO_2 from reaching seabed?
  - ➢ migrating CO_2 plume leaves about 30% residually trapped gas & over thousands of years migrating CO_2 dissolves in saline aquifers and sinks

- What injection rates and pressures enable safe storage? Of how much CO_2?
  - ➢ Addressed through dynamic modeling, here and in N. Sea (Eclipse 300)

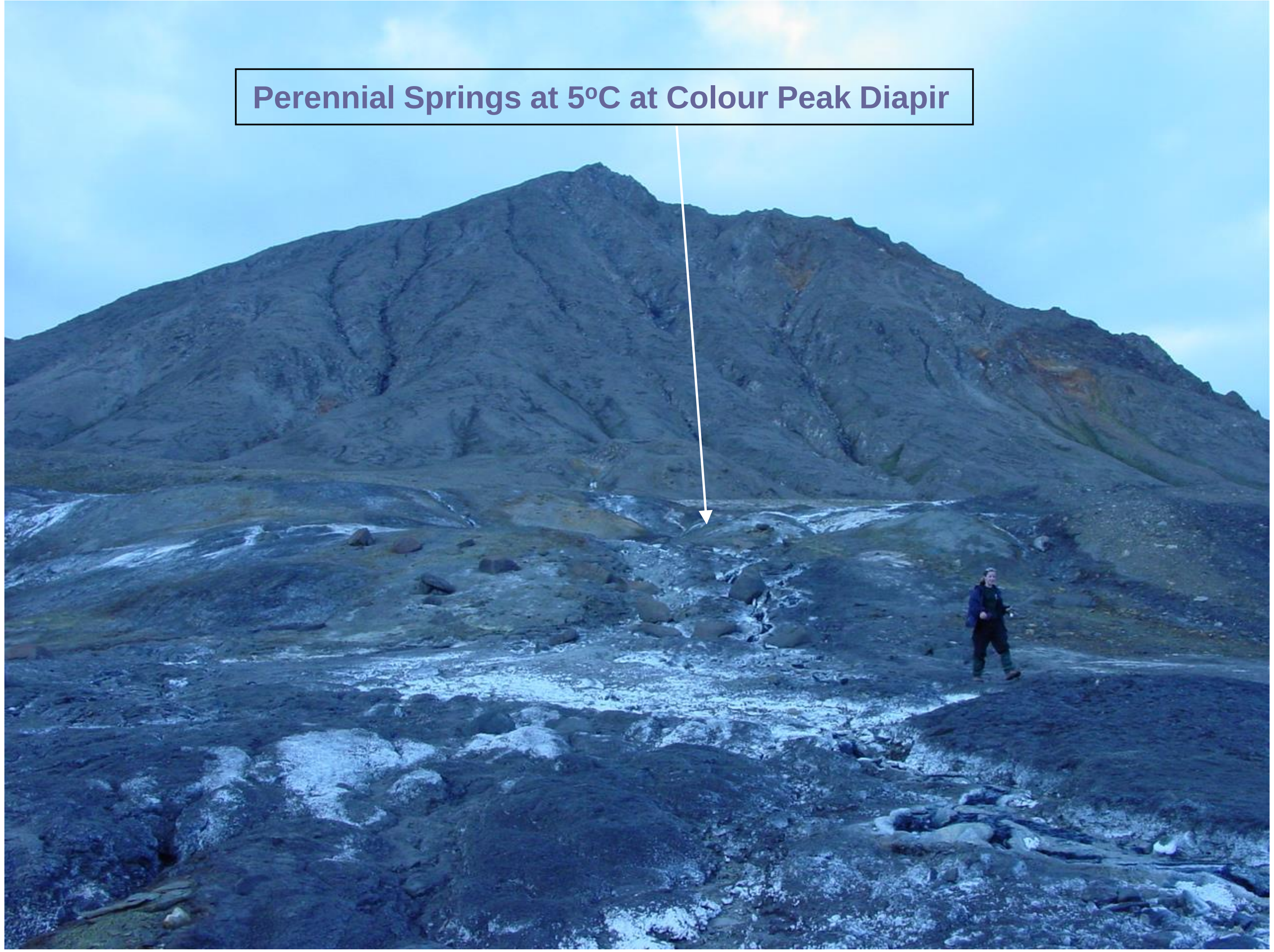
- CCS investigated onshore Nova Scotia – lacks suitable reservoirs

- **Poster by Max Angel – scoping potential costs of CCS in the Sable Subbasin**





Zentilli et al 2019
Geofluids, Geofluids
Article ID 9502904, 33 p



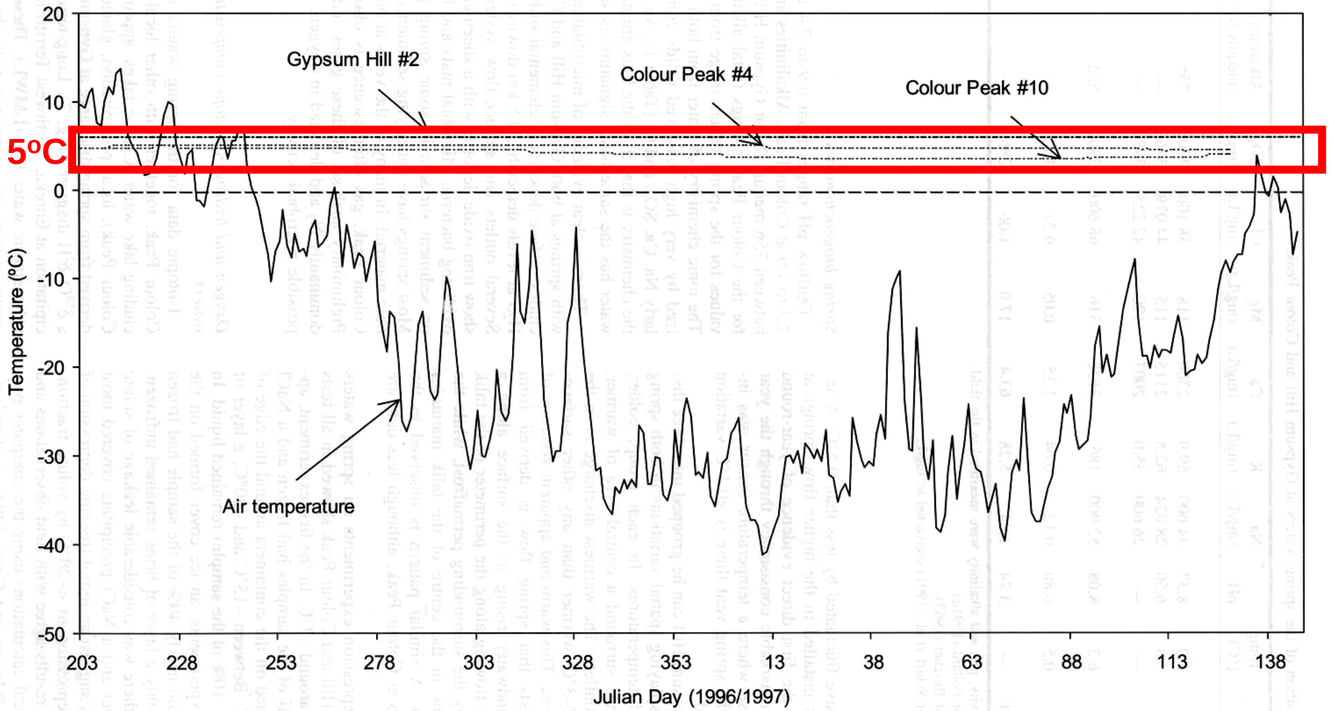
Rotten Eggs Smell: Bacterial Activity

Zentilli et al 2019
Geofluids, Geofluids
Article ID 9502904, 33 p

Andrea Mosher-Harrington 2003

Zentilli et al 2019
Geofluids, Geofluids
Article ID 9502904, 33 p

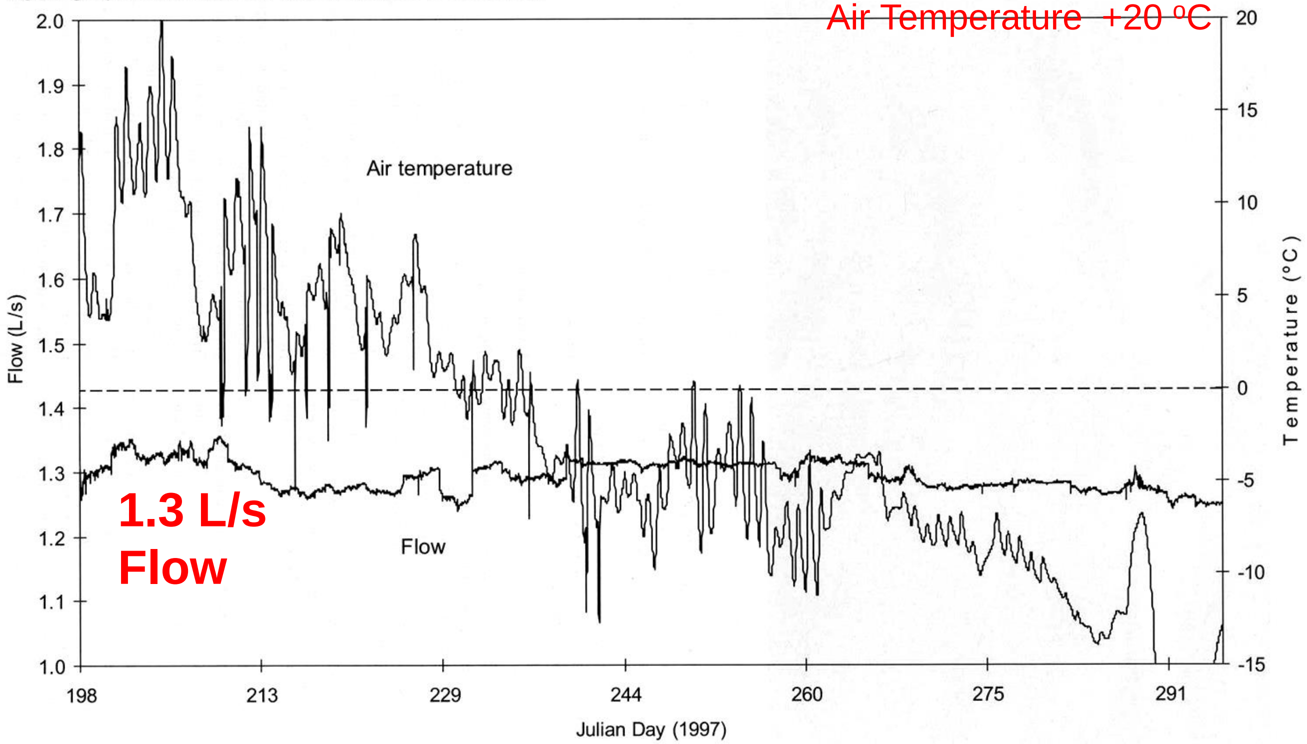
Fig. 6. Spring outlet discharge temperature data for springs at Gypsum Hill and Colour Peak compared with local air temperature. Note consistency of discharge temperatures throughout the year.



Pollard et al.

Zentilli et al 2019
Geofluids, Geofluids
Article ID 9502904, 33 p

Fig. 5. Spring outlet discharge rate vs. air temperature at Colour Peak.



Pollard et al. 1999

Springs NOT a new phenomenon, started >40 million years ago

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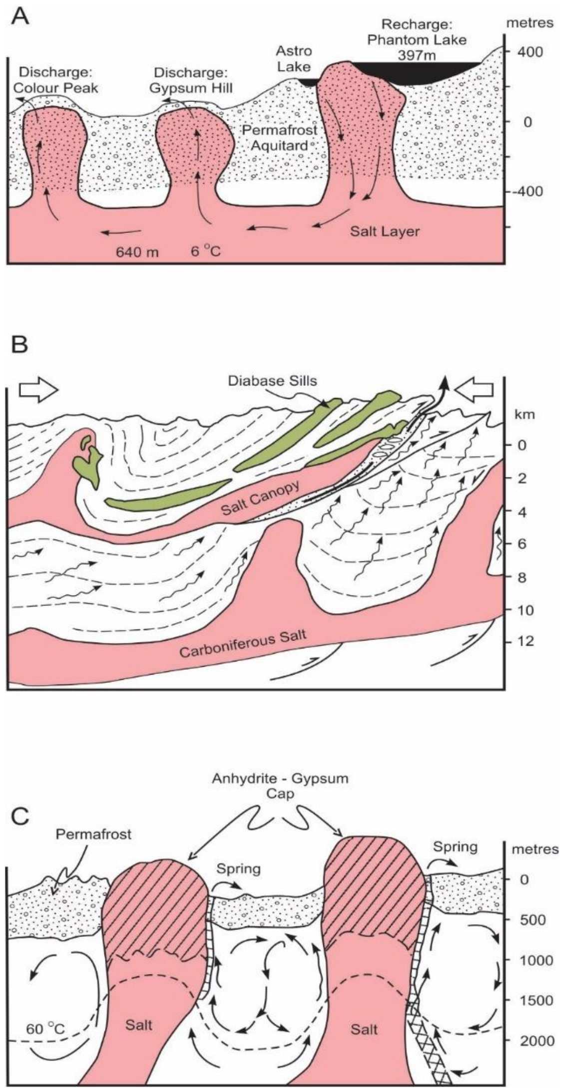

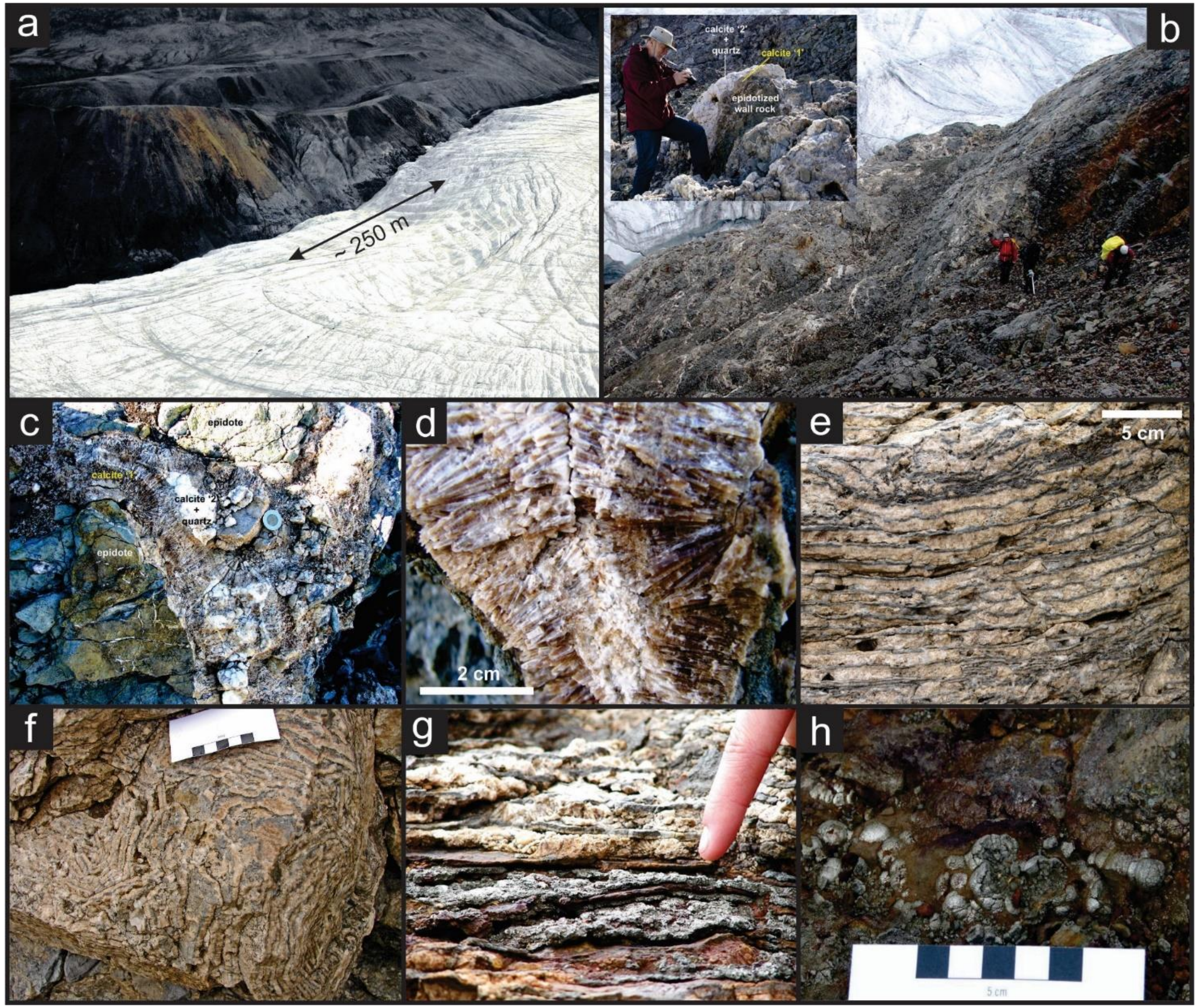

Zentilli, Omelon, Hanley.. (2019)

Zentilli et al 2019
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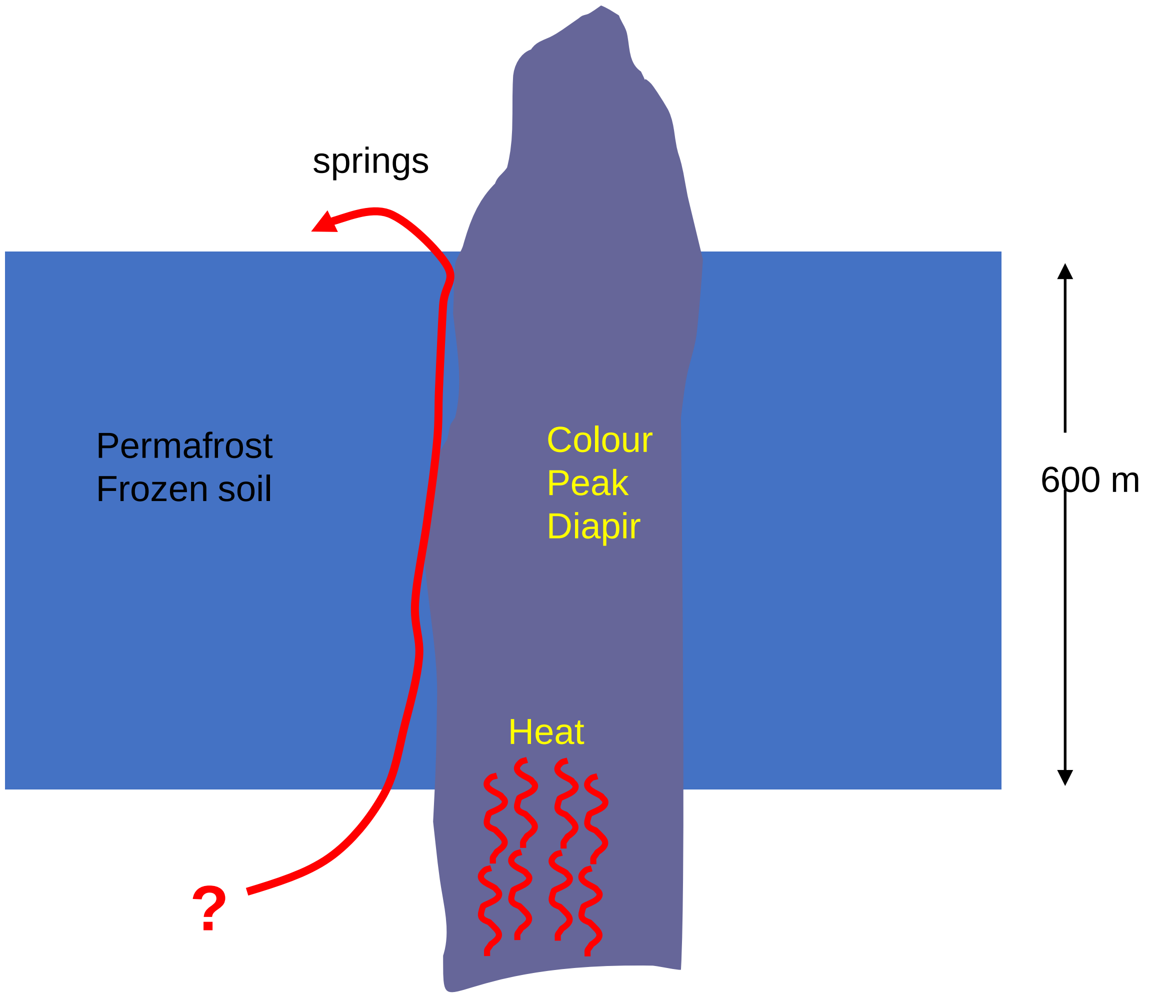

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Possible Geothermal Heating