Geothermal Resources of the Garibaldi Volcanic Belt – Phase 1

Stephen Grasby
and the Garibaldi Team

Thank you!

- Squamish and Lil’wat First Nations
- Maxine Bruce, Tammie Jenkins
- Geoscience BC and NRCan Emerging Renewable Power Program
- Innergex Renewable Energy
- No Limits Helicopters

The Garibaldi Team

- 34 researchers from the Geological Survey of Canada plus 7 Universities (UBC, SFU, DC, UofA, UofC, ETH, Quest)
- 34 people in the field (>400 person days)

Training the next generation

- 3 Post Docs, 6 PhDs, 1 MSc, 1 BSc

The Garibaldi Team

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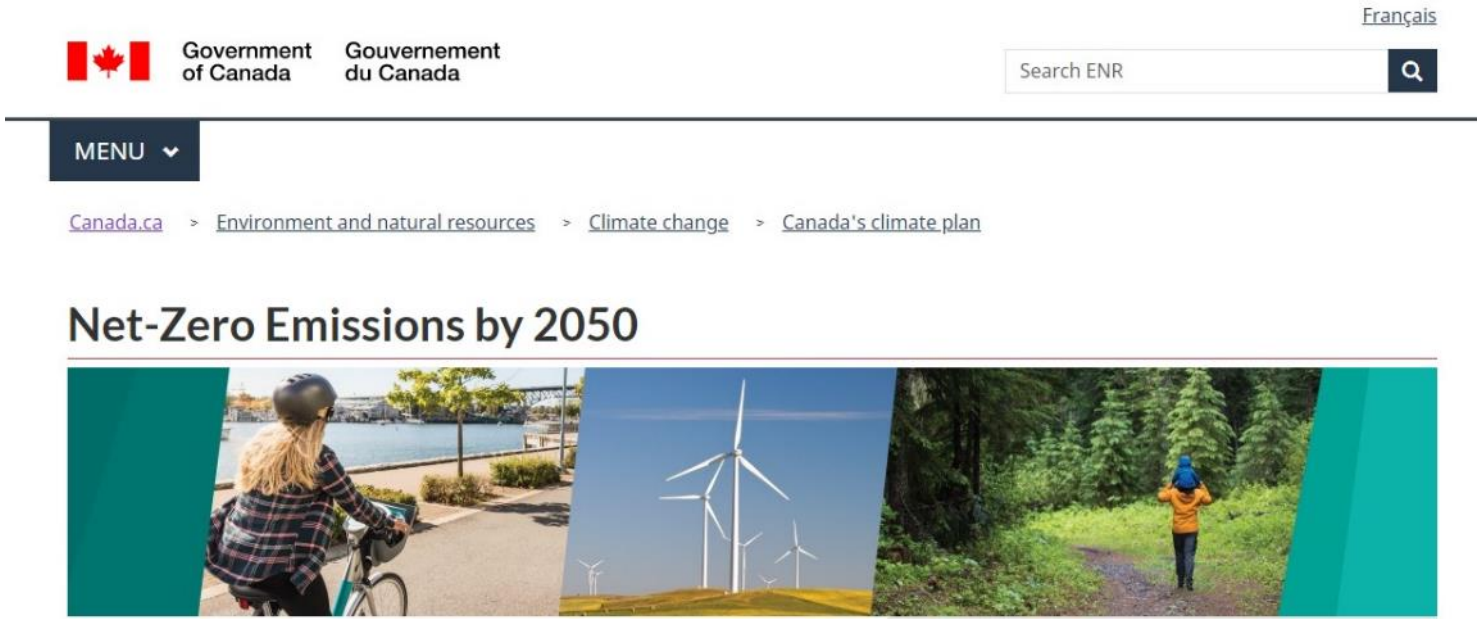
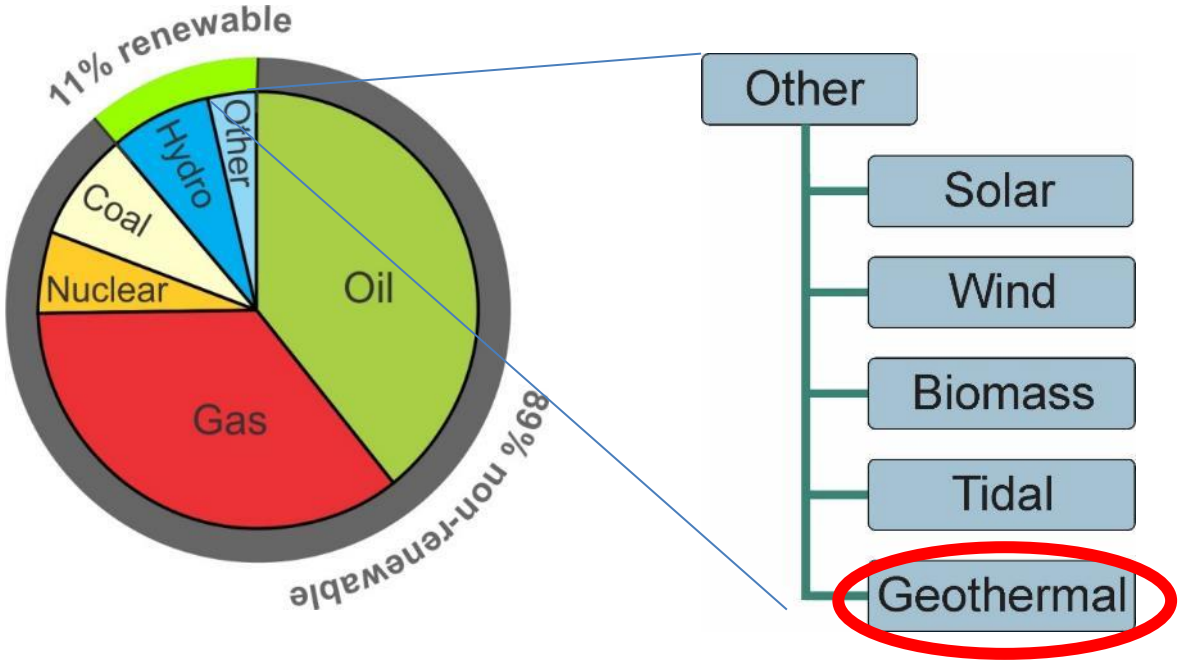
Supporting the transition to a low carbon economy

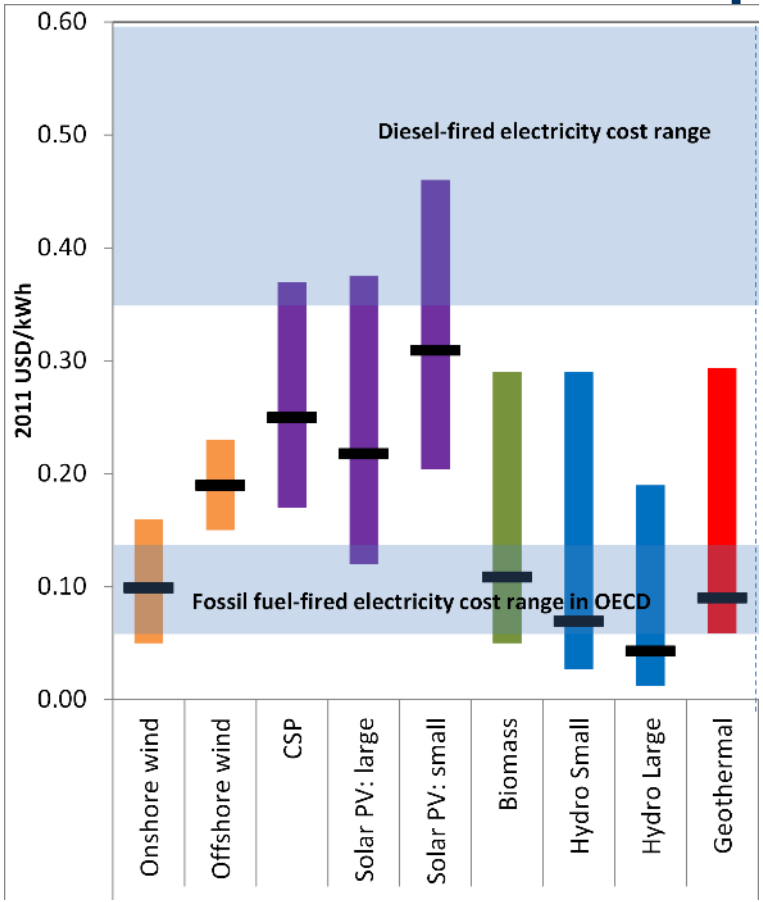


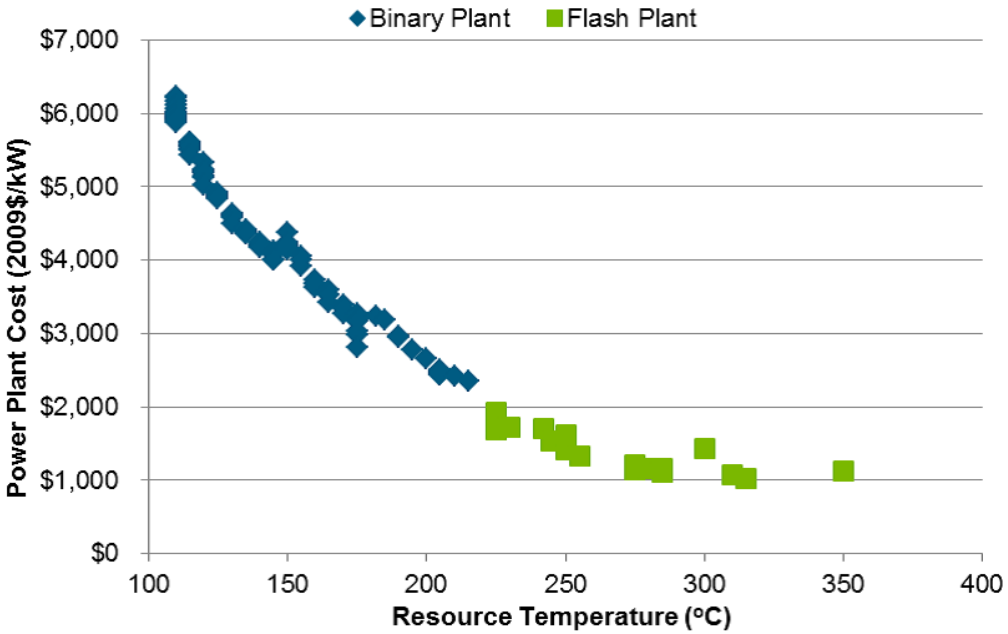
Expanding renewables

Canada's energy production is 89% non-renewable



Geothermal is cost competitive

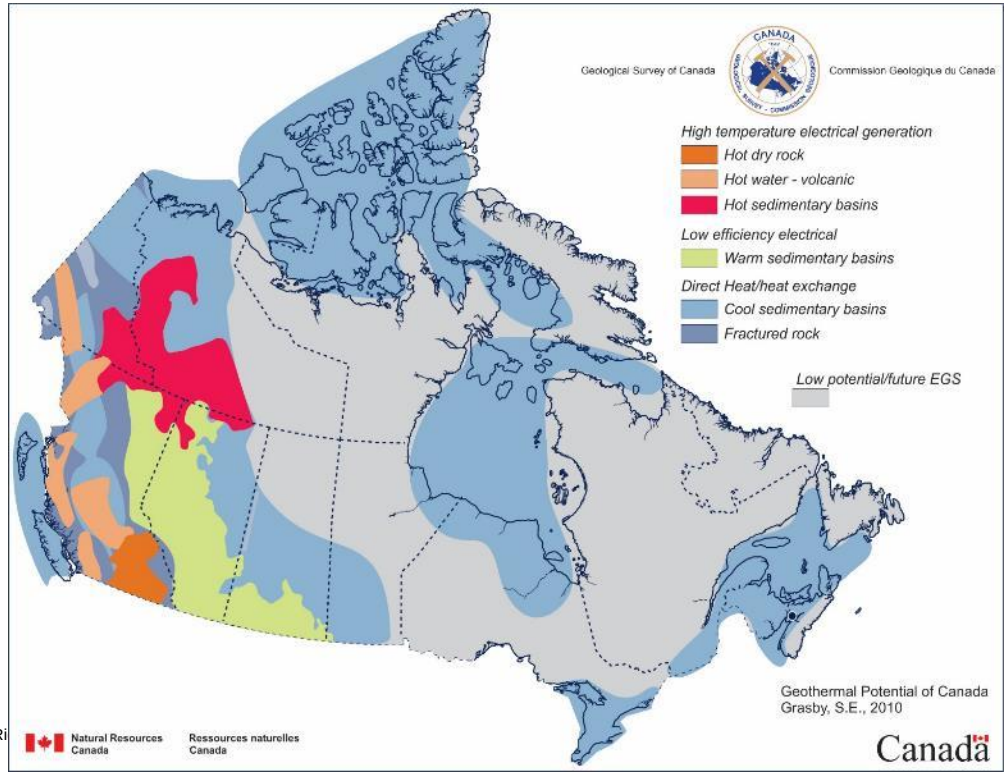


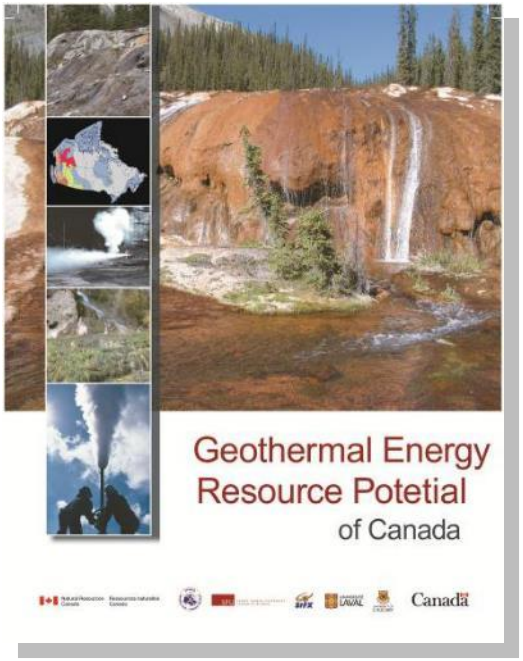


Source: IRENA 2020

Canada

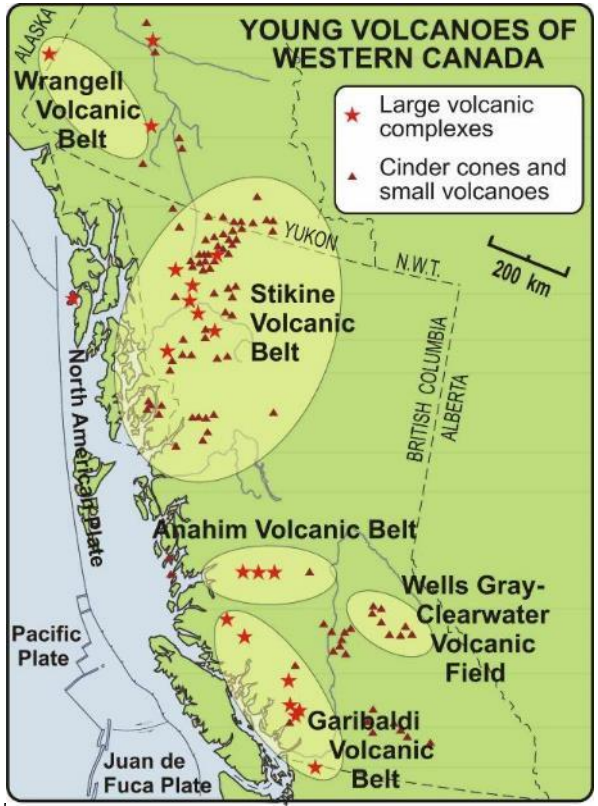
Geothermal potential of Canada





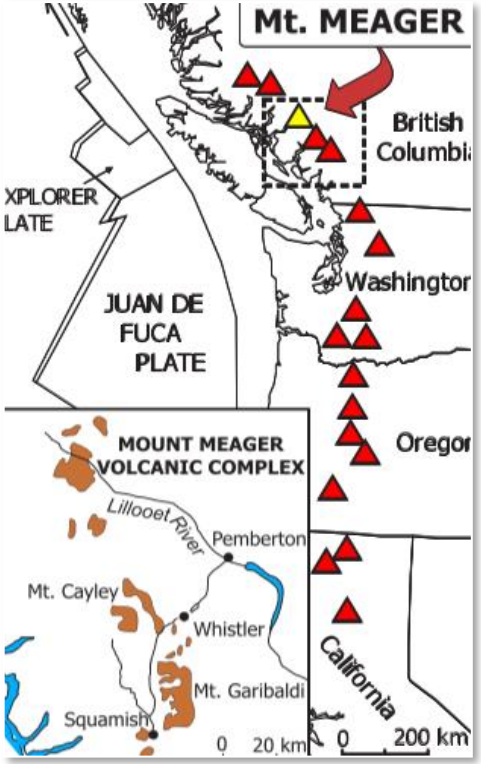
Grasby et al. 2012
doi.org/10.4095/292840

Volcanic belts of Canada



- **Canada has abundant, volcanoes**
- **Largely dormant since the Holocene (12,000 years ago)**

Garibaldi Volcanic Belt



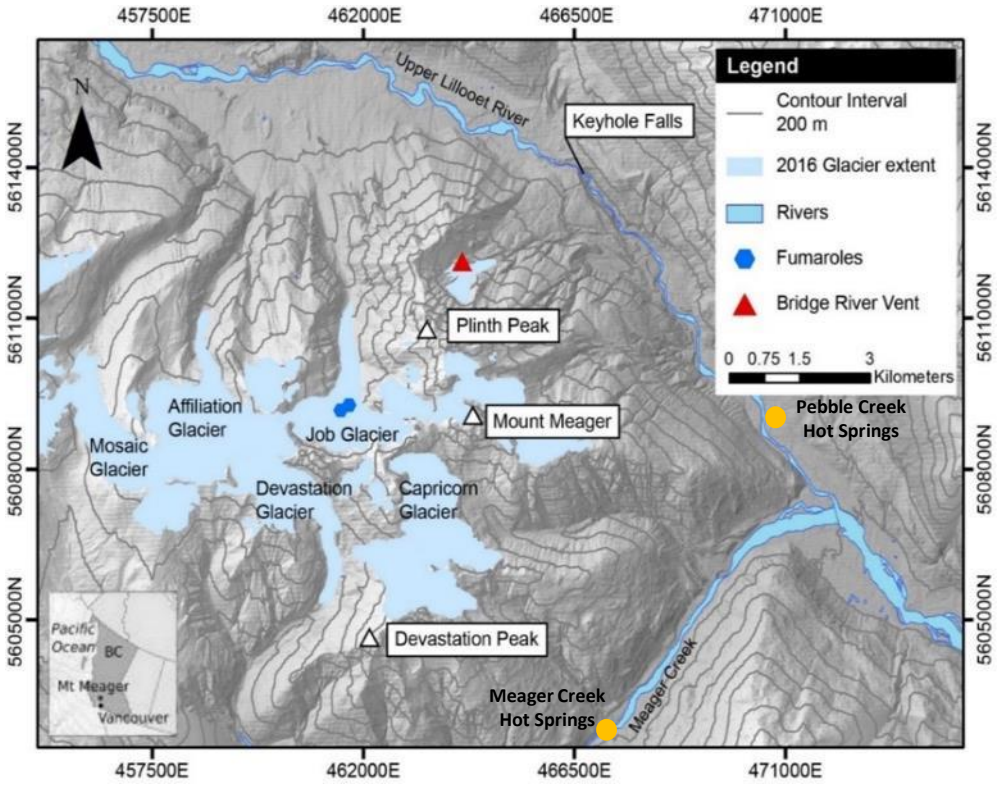
- Northern Termination of Cascades
- Related to Subduction of ocean crust under North America

- Focus on Mount Meager ~60 km from Pemberton, 140 km from Vancouver

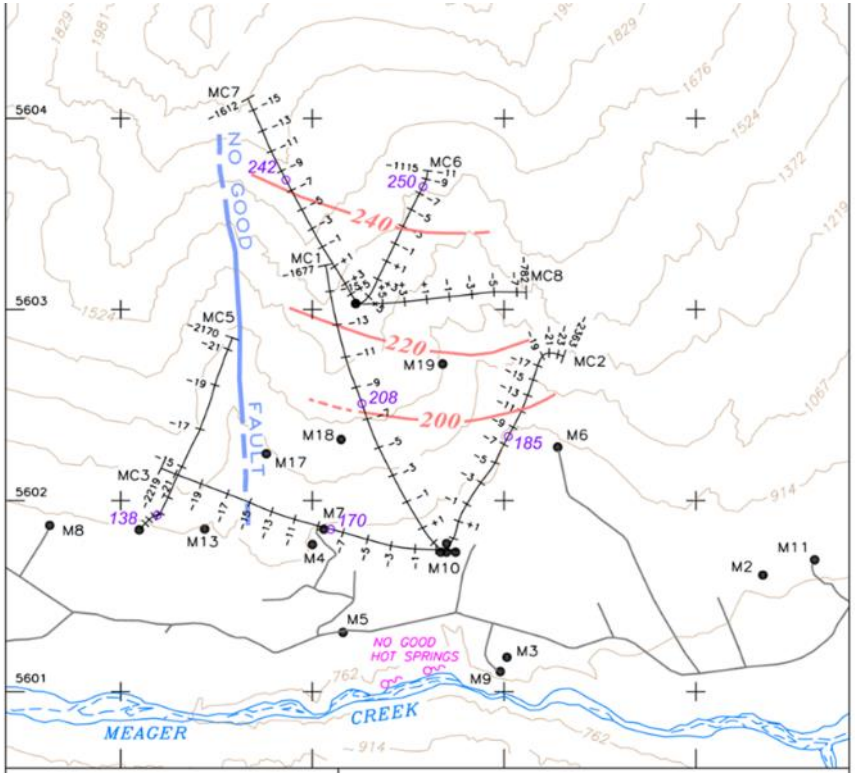
Hetherington (2014)

Mount Meager Volcanic Complex

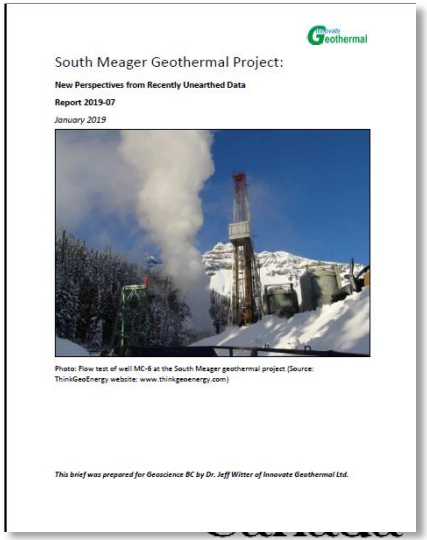
- Active 2.2 Ma to present
- Most recent eruption 2350 BP (Bridge River event)
- Extensive hydrothermal system (alteration, fumaroles, hot springs) suggest geothermal potential.



South Meager Geothermal Exploration



- **Early research and drilling by NRCan and BC Hydro**
- **Subsequent industry exploration and drilling**
- **Data public – available at Geoscience BC**

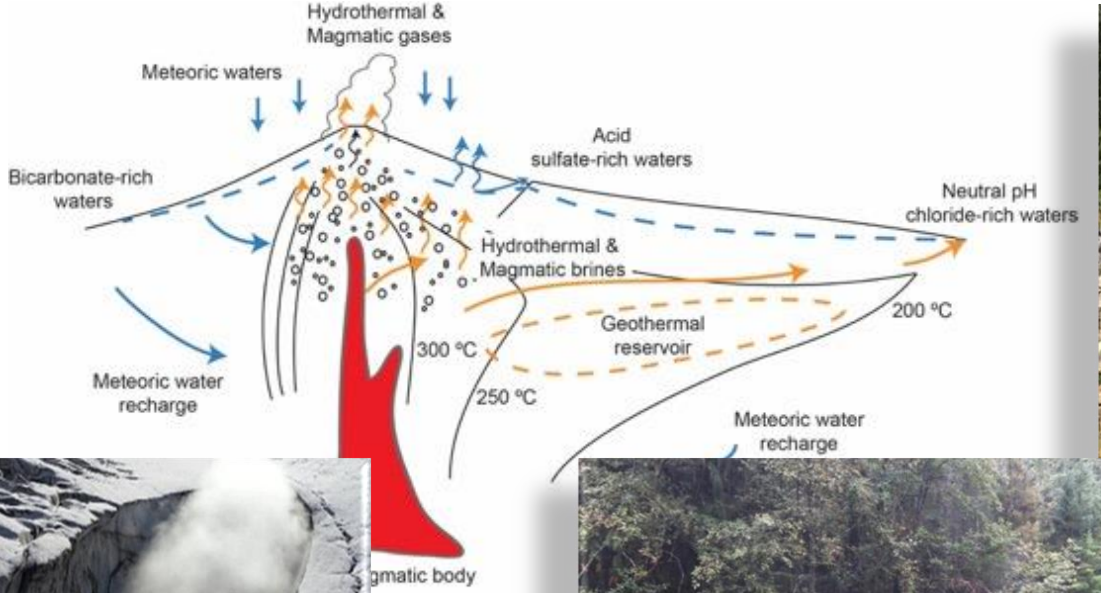


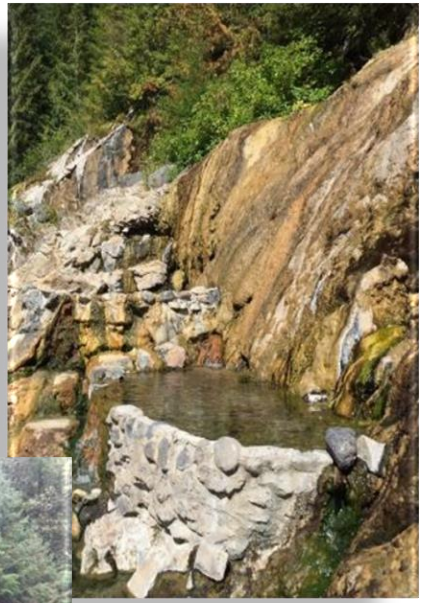
Witter, 2019

Mount Meager research well

- **NRCan/BC Hydro Collaboration**
- **World class thermal resource**
  > 250 °C
- **First geothermal power production in Canada (250 kw)**

Looking into the Heart of the Mountain





sources, 2019

Canada

Garibaldi Project - Reducing Exploration Risk

Predicting Permeability

- -fracture/stress system analyses
- -aquifer systems

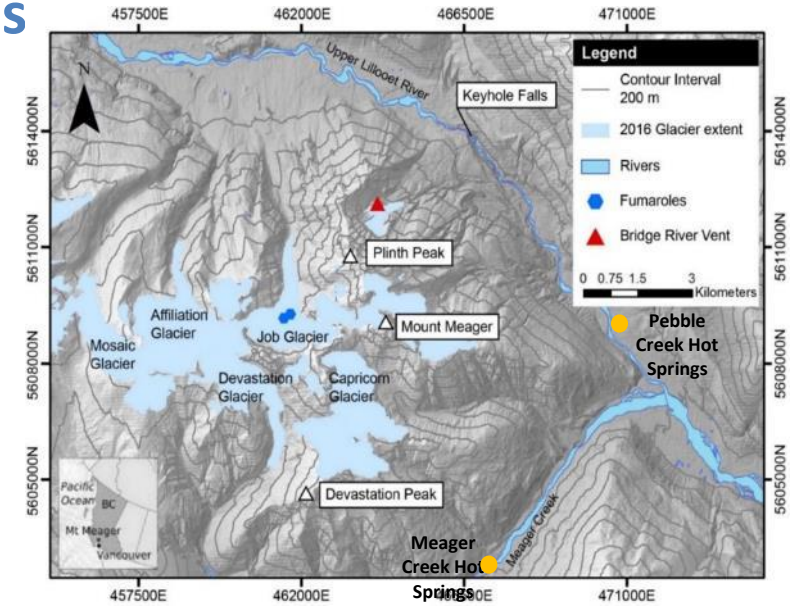
Heat Resources

- -regional thermal properties
- -volcanic history

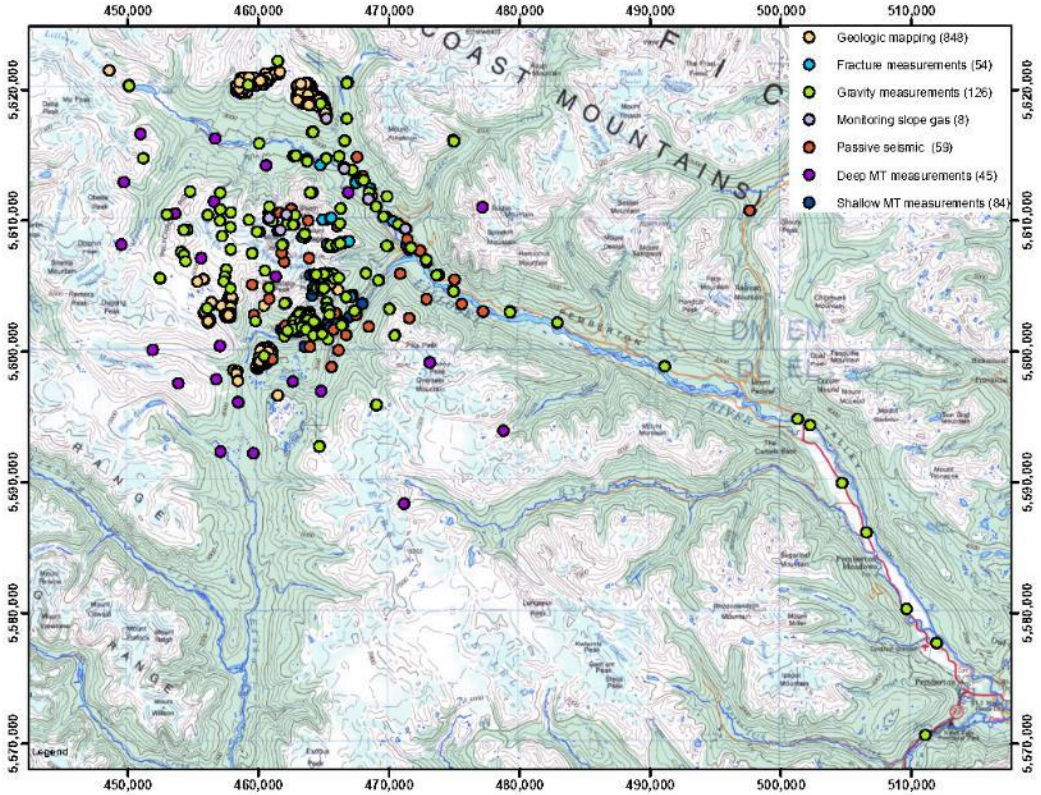
Resource Production

- -crustal-scale flow systems
- -thermal spring systems

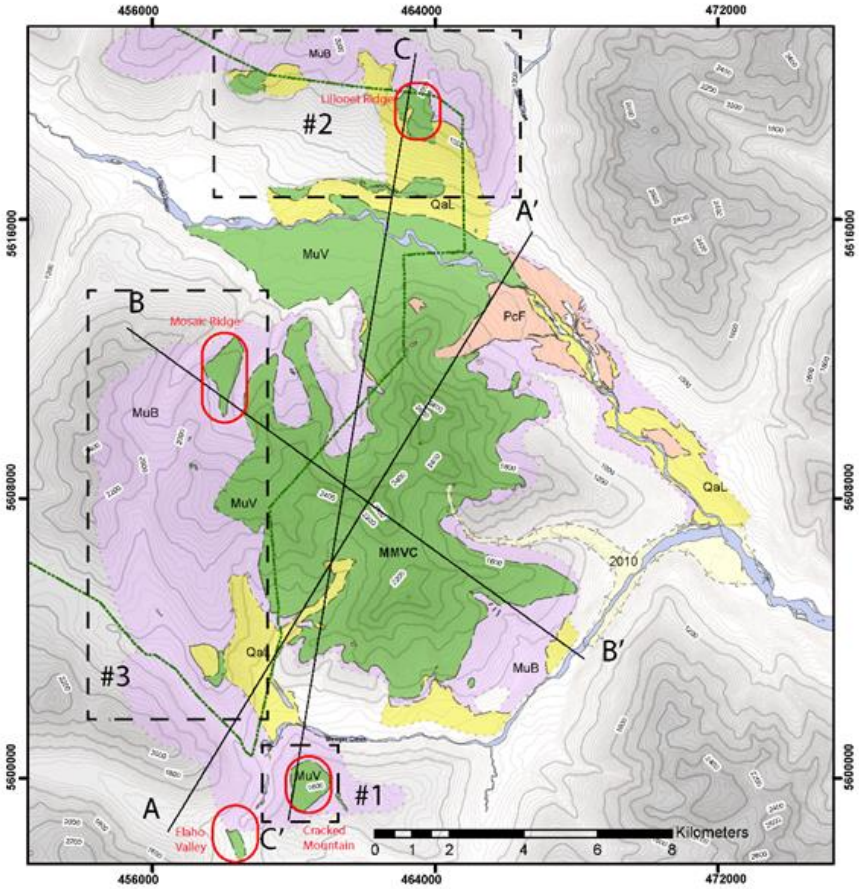
Resource Assessment Methodology



Where we went



Geologic mapping

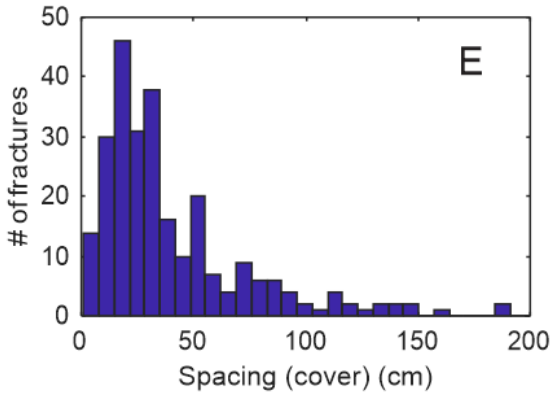


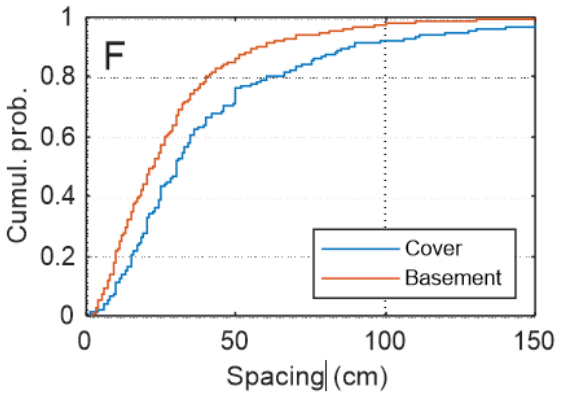
- Four new geologic maps
- Studies of faults and fractures that can control fluid flow
- New age dating to provide eruption history
- Underpins all work – informs rock type and characteristics

Canada

Fracture studies

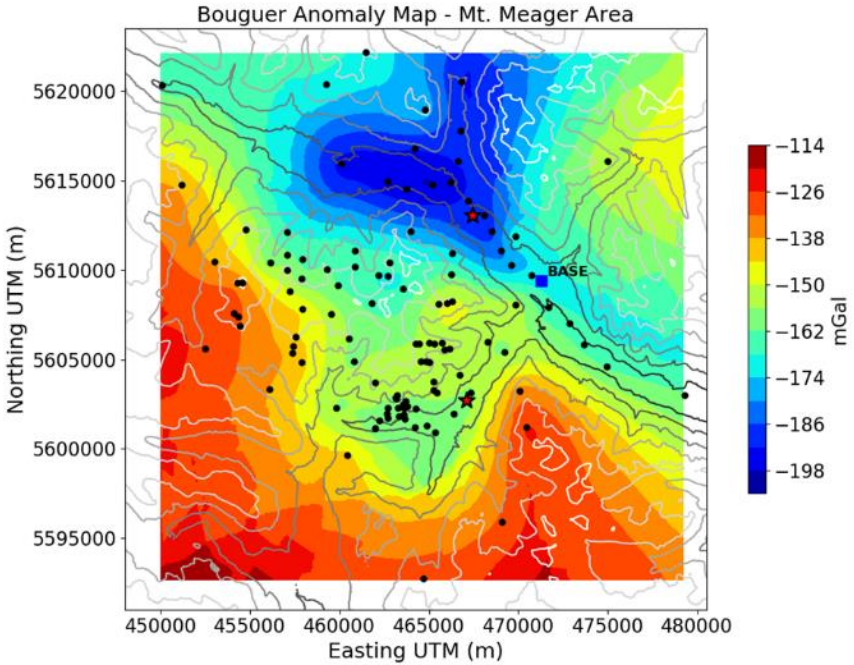
- Understanding dominant orientations and frequency of fractures that control fluid flow
- 1500 new measurements





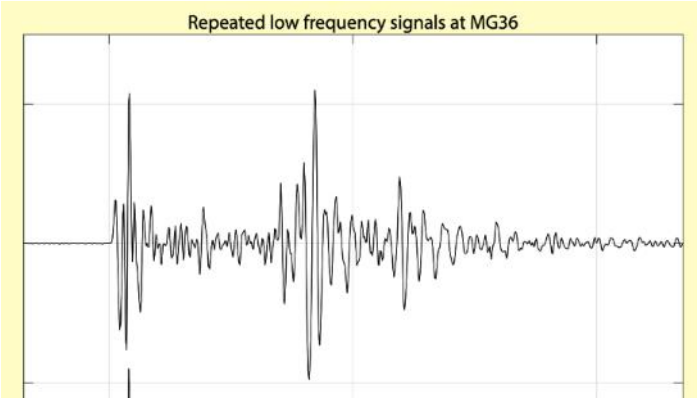
Gravity Survey

- Variations in Earth gravity show low gravity anomalies at the South Meager geothermal area and to the north under Plinth Peak
- Potential signatures of melt and geothermal system



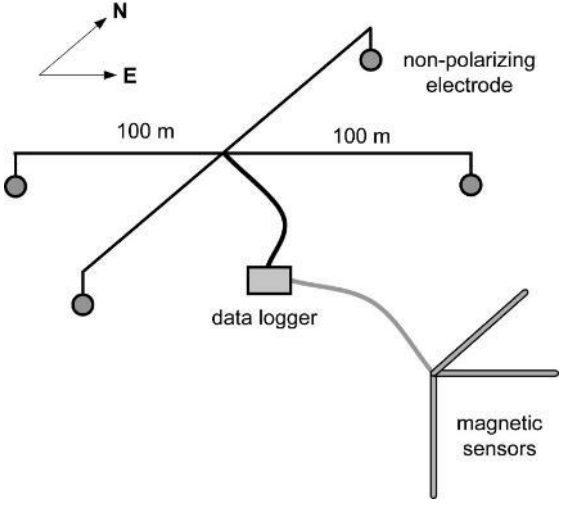
Canada

Passive Seismic

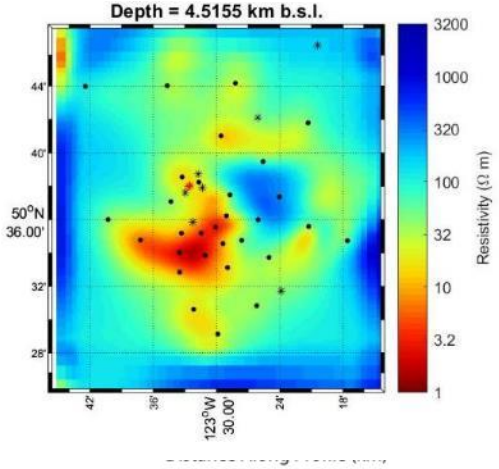


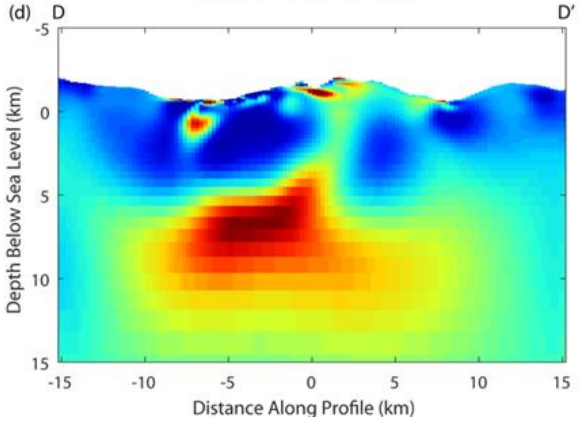
- Deployed 59 seismic stations
- Detects shaking from earthquakes (also rock fall, people jumping around sensor…)
- Provides baseline knowledge of natural seismicity in region

Magnetotellurics



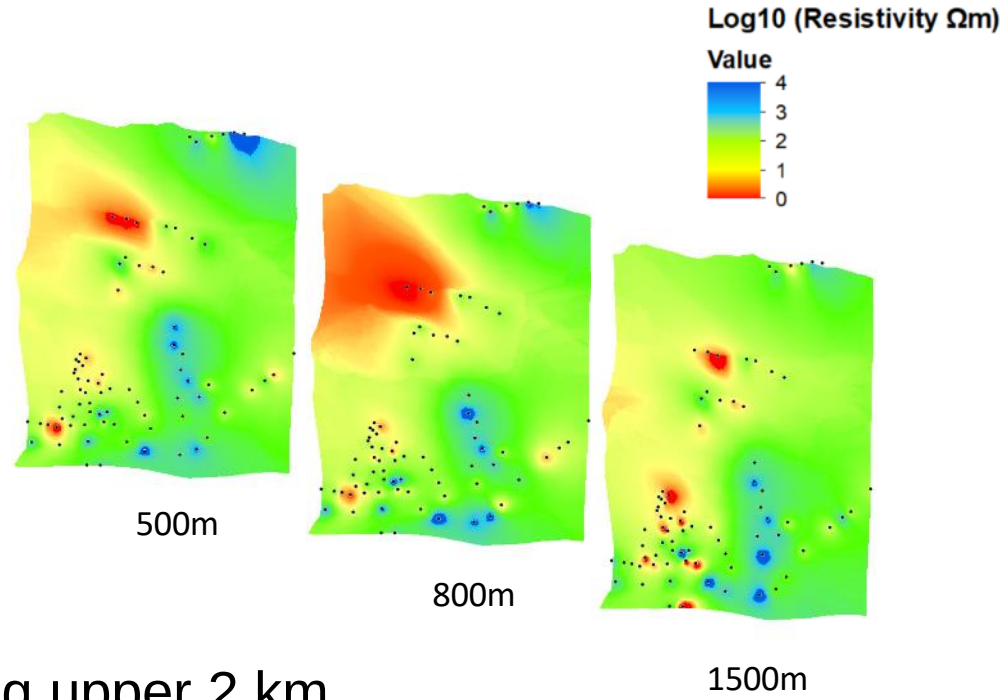
4.5 km deep





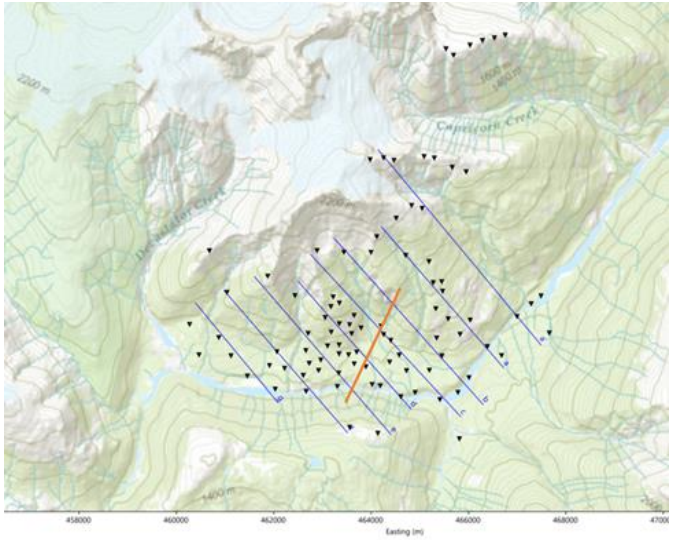
- Deep focus examining 2 to ~ 10 km depth
- Results show deep conductor and pathways to shallow level

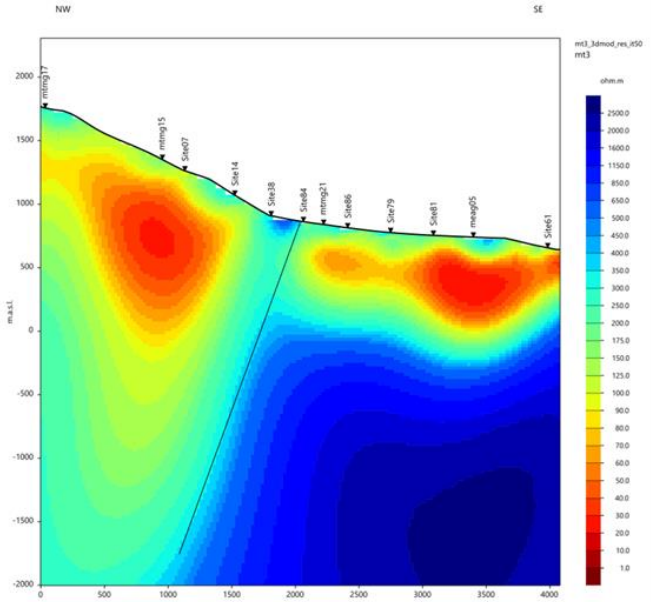
Shallow Magnetotellurics



- Shallow focus examining upper 2 km
- Looking for the geothermal reservoir

Shallow Magnetotellurics



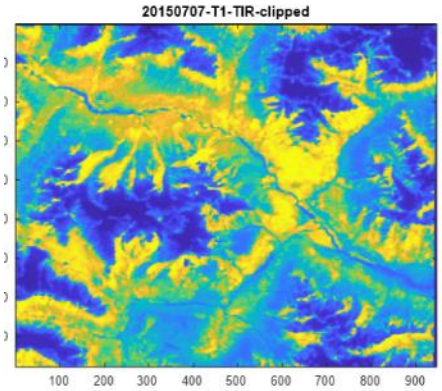


- Prominent conductive unit in subsurface
- Hydrothermal zone/fluid filled fractures?
- Need to model data in context of rock properties to resolve

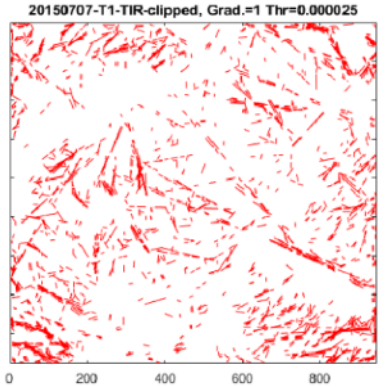
Remote Sensing

- Defined thermal anomalies in satellite images
- Defined lineaments assuming they represent fractures in rock

Raw image

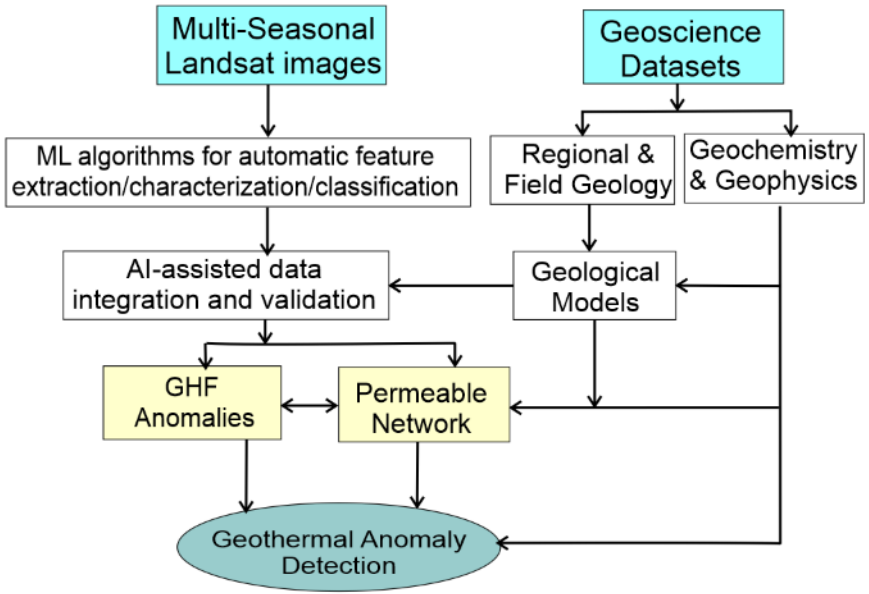


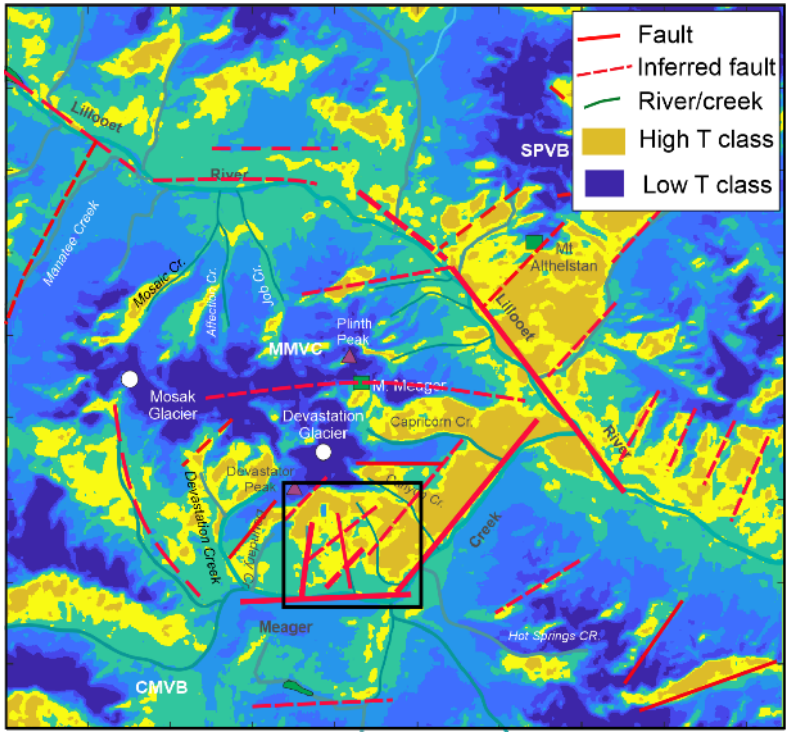
Thermal anomalies



Lineaments

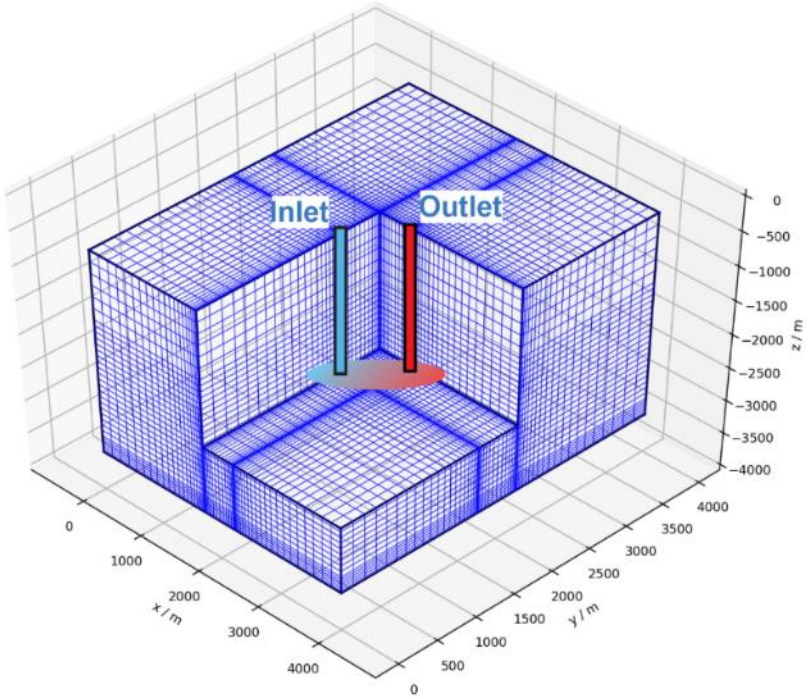
AI/ML-enabled geothermal resource evaluation





Computer picked geothermal anomalies & AI-assisted interpretation

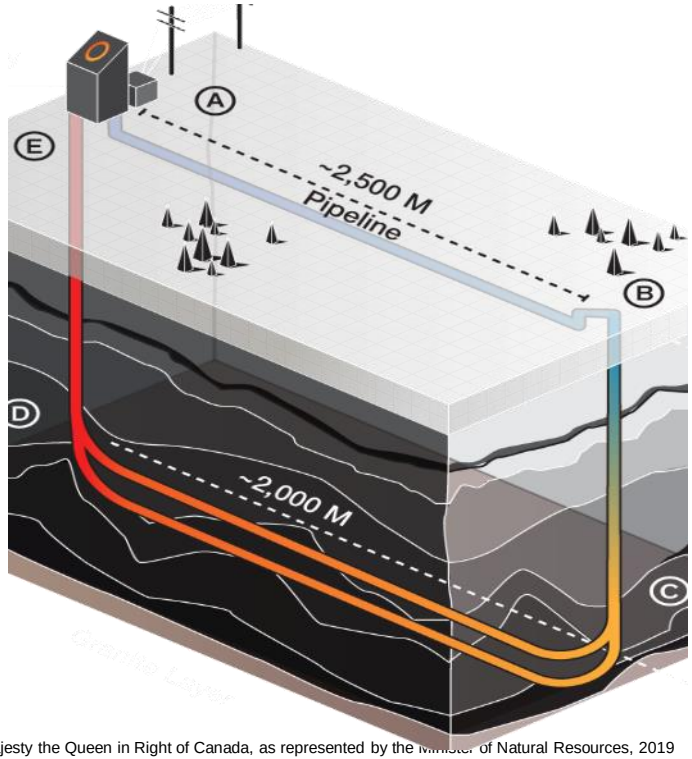
Resource Modeling



<u>Preliminary</u> results suggest

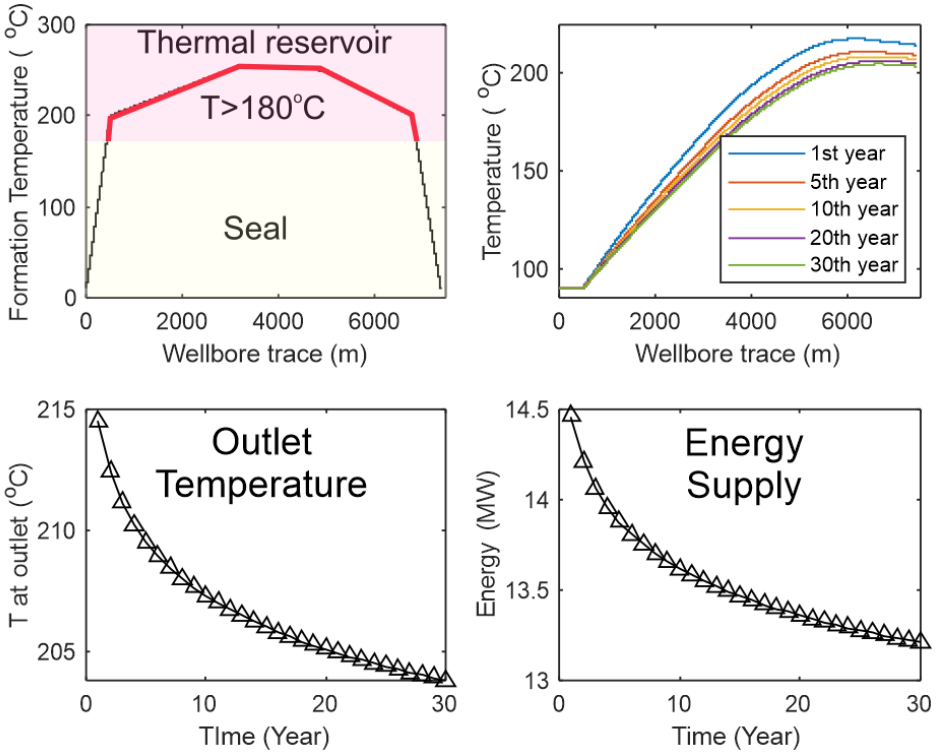
- 6-13 MW power for 1 well
- Production for > 30 years

Closed-loop type system



- Rock permeability and water availability are irrelevant to production
- Lower environmental footprint
- Untested in volcanic system but high thermal conductivity is favourable

Closed-loop - Preliminary model results

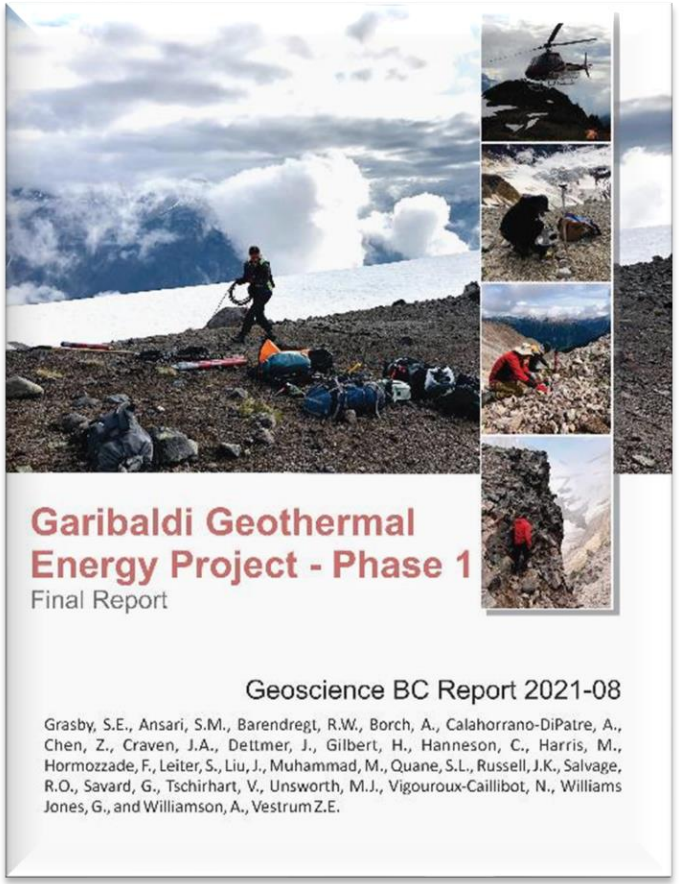


- **Outlet water >200 °C for over 30 years**
- **Energy production capacity >13 MW**

Summary

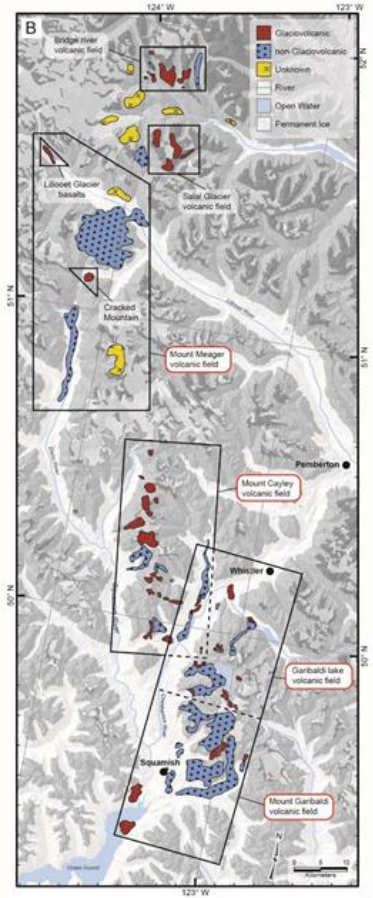
- Mount Meager is a world class thermal resource
- Potential for world class geothermal system

- All new data available online at GeoScience BC (thousands of measurements and terabytes of data).



Next steps

- Phase 2 – examine the Mount Cayley area to test methods in a less data rich environment
- Use results to extrapolate geothermal potential over broader Garibaldi Volcanic Belt
- Assess the total potential renewable clean energy supply from BC’s volcanoes and how it can contribute to achieving a Net Zero economy



Questions?