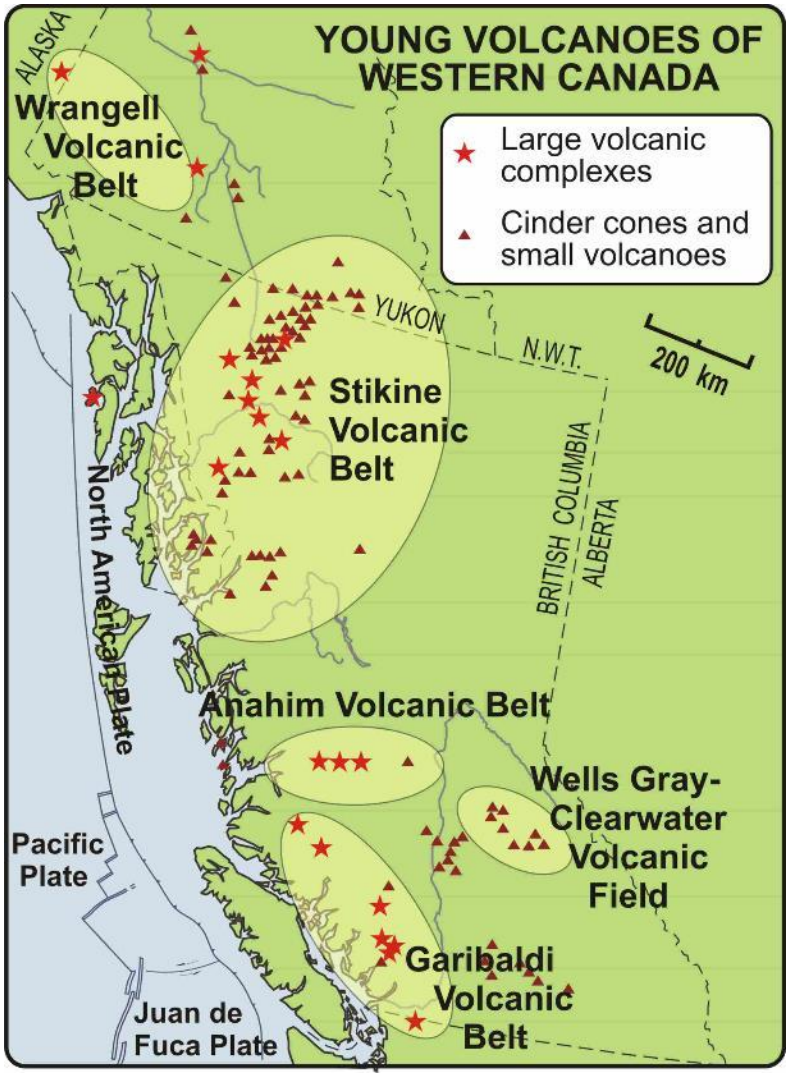
Geothermal Resources of the Garibaldi Belt

Mount Meager 2019 Field Campaign

Thank you!

- Squamish and Lil'wat First Nations
- Maxine Bruce, Tammie Jenkin
- Geoscience BC and NRCan Emerging Renewable Power Program
- Innergex Renewable Energy
- No Limits Helicopters
- The research team

Geothermal Potential of Volcanic belts

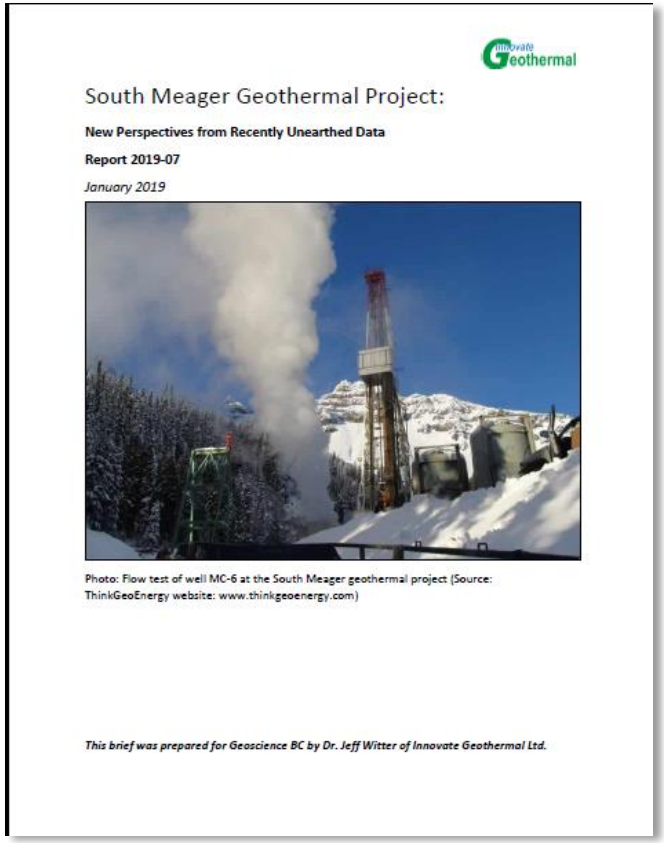


- **Canada has abundant, volcanoes**
- **Largely dormant since the Holocene (12,000 years ago)**
- **Mount Meager last erupted about 2400 years ago**

Mount Meager focus area

- **Fumaroles and hot springs suggest active geothermal system**
- **Location of early government research and industry exploration**
- **World class thermal resource discovered (>250 ºC)**
- **Economics limited by permeability**

(the ability of geothermal waters to move through the rock)



Innovate Geothermal

South Meager Geothermal Project:

New Perspectives from Recently Unearthed Data

Report 2019-07

January 2019

Photo: Flow test of well MC-6 at the South Meager geothermal project (Source: ThinkGeoEnergy website: www.thinkgeoenergy.com)

This brief was prepared for Geoscience BC by Dr. Jeff Witter of Innovate Geothermal Ltd.

The Mount Meager Team

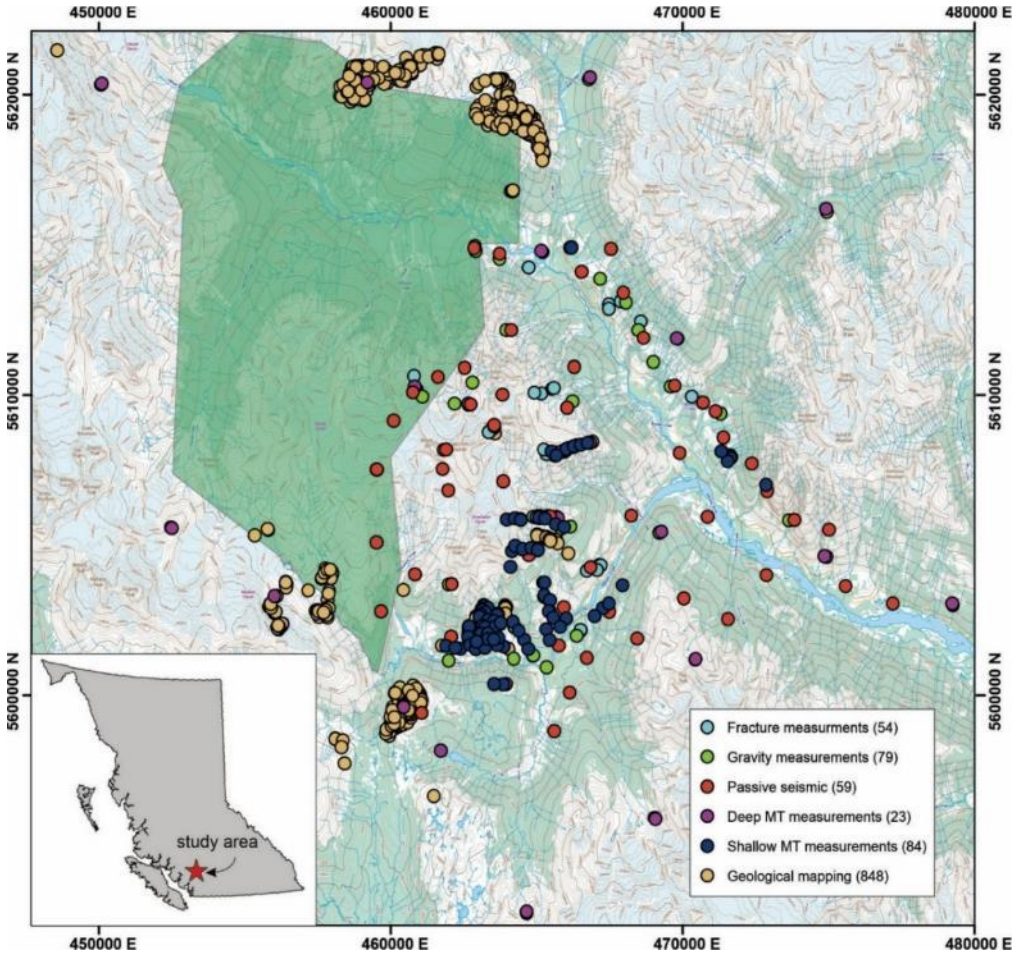
- Researchers from the Geological Survey of Canada plus 7 Universities (UBC, SFU, DC, UofA, UofC, ETH, Quest)
- 34 people in the field (375 person days)
- Training the next generation

  3 Post Docs, 6 PhDs,

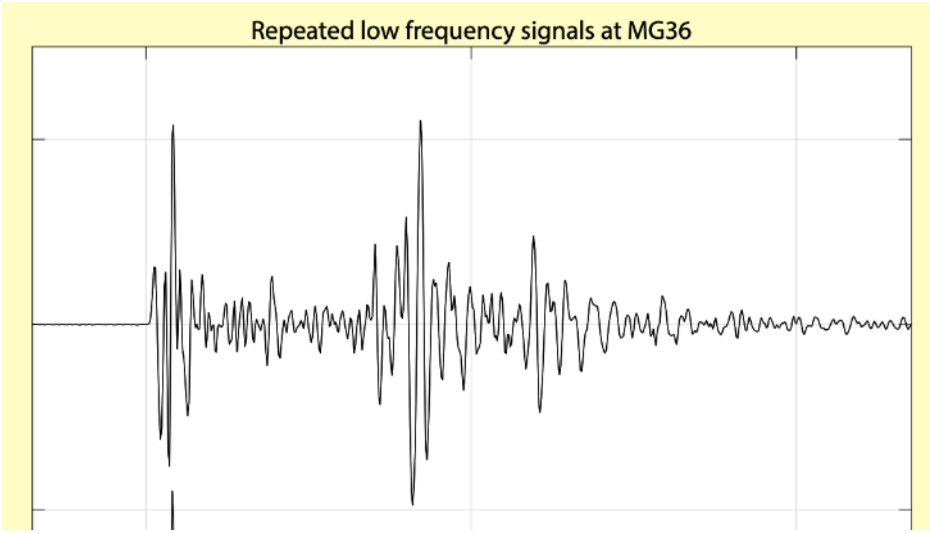
  1 MSc, 1 BSc

The field camp

Where we went

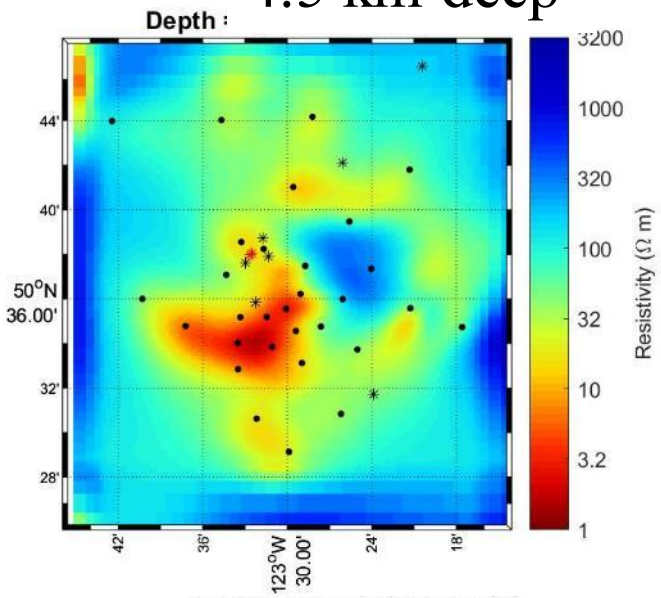


Passive Seismic (59 stations)

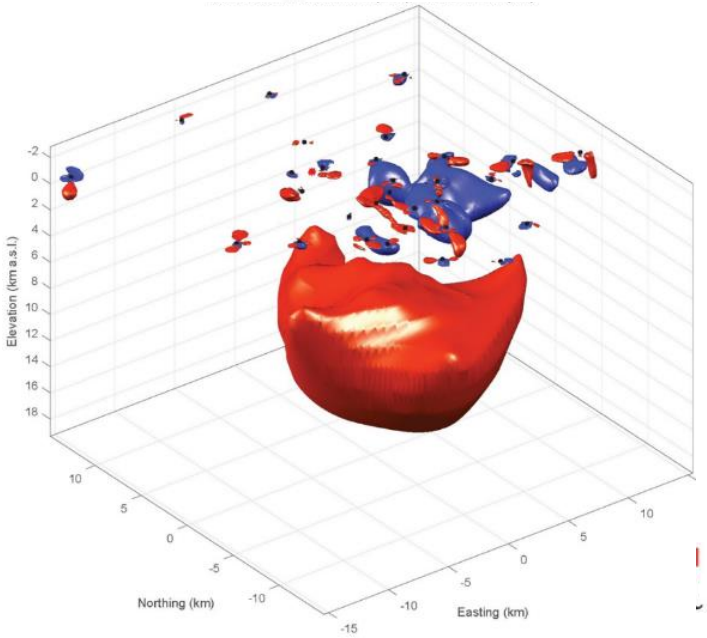


- Detects shaking from earthquakes (also rock fall, people jumping around sensor…)
- Potential to ‘see’ major faults and magma chamber because wave energy moves at different speeds through solids or liquids, or reflects from contrast in rock types

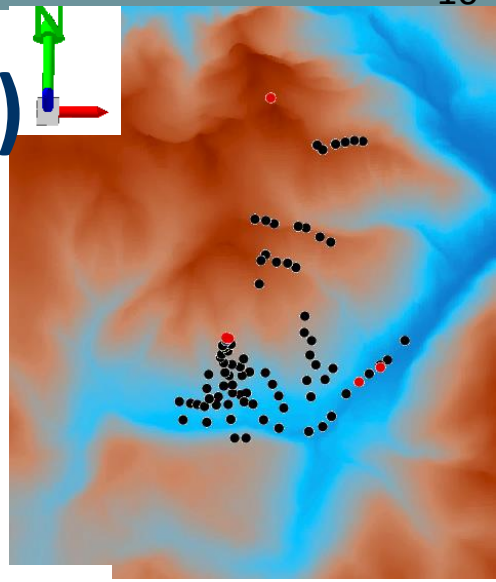
Deep magnetotellurics (23 sites)



- Measurement of natural magnetic and electric fields that move through the earth
- Contrast in conductivity allows us to produce a subsurface image



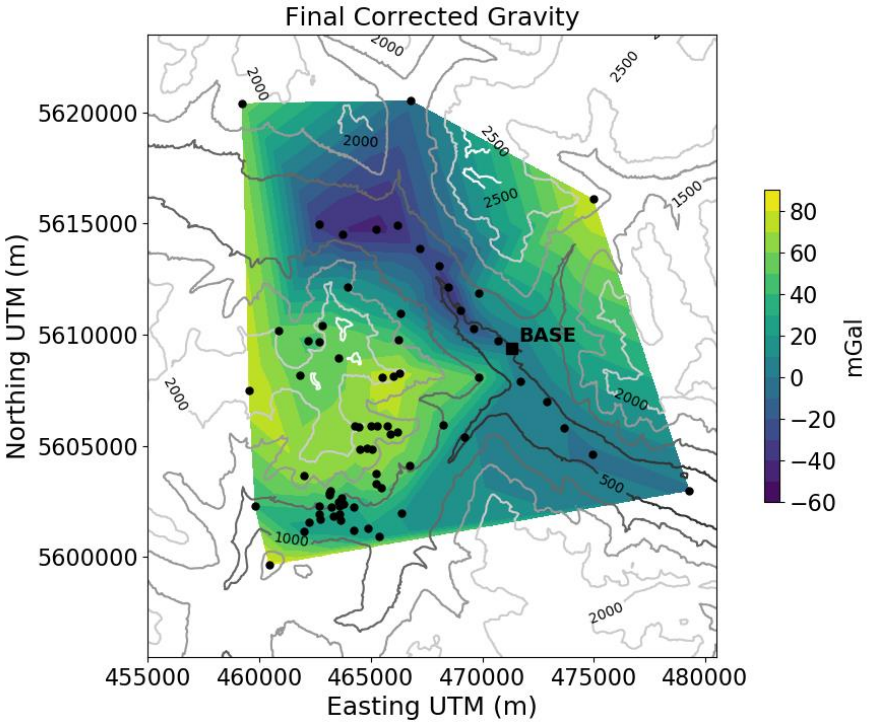
Shallow Magnetotellurics (84 sites)

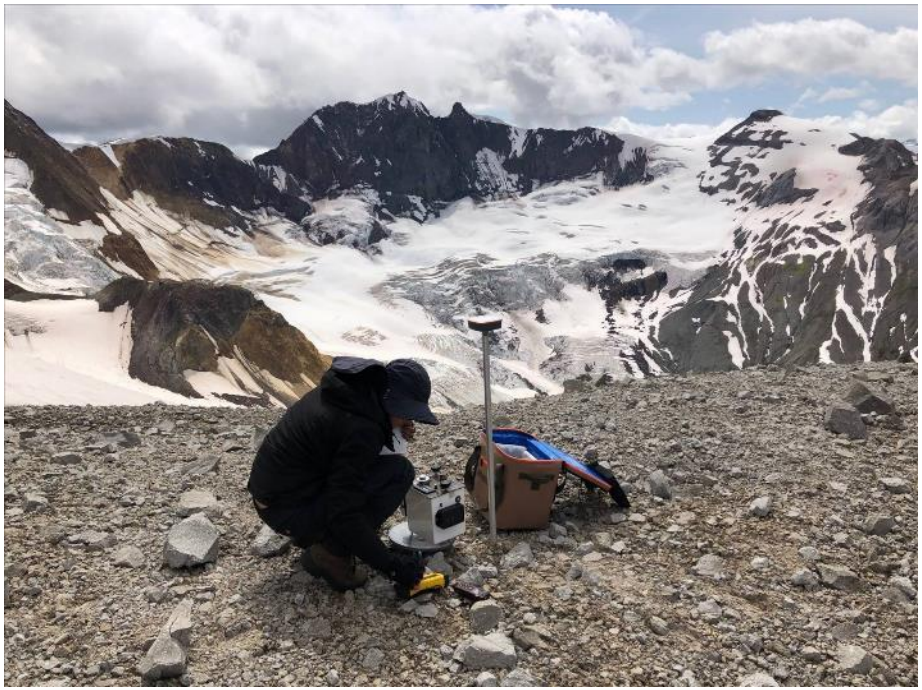


- Examining upper 2 km
- Looking for the geothermal reservoir

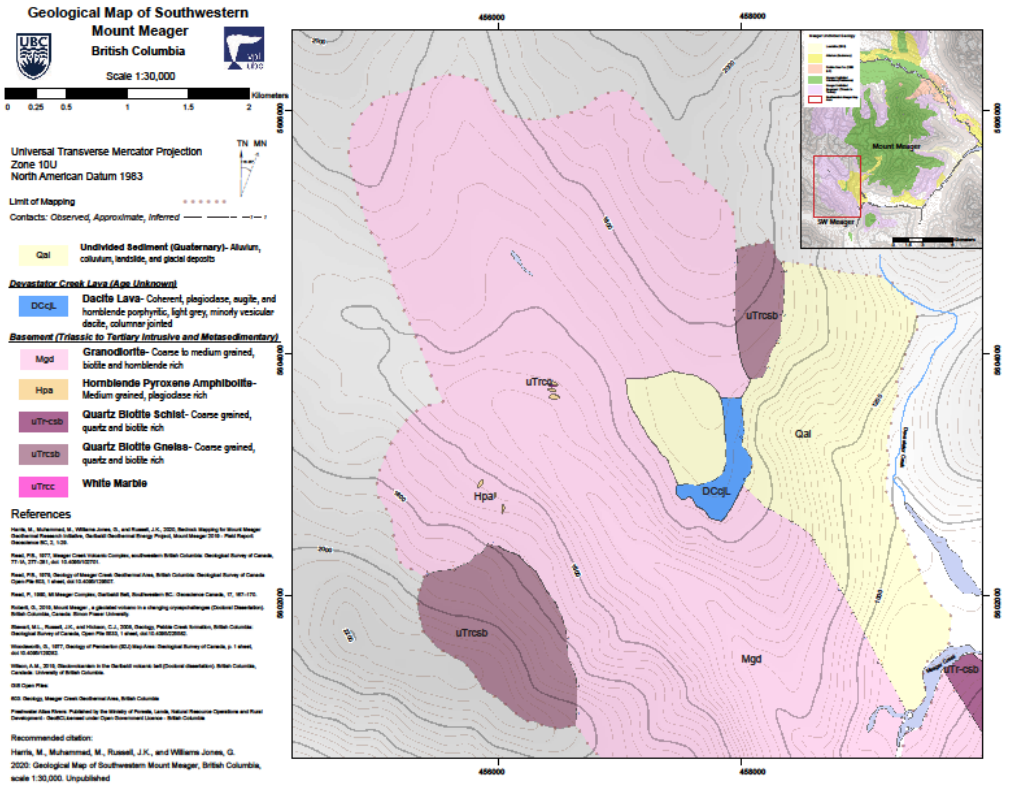
Gravity Survey (79 sites)

- Minute changes in Earth gravity due to density differences in rocks and fluids
- Defines both deep magmatic structures, and shallow hydrothermal sources





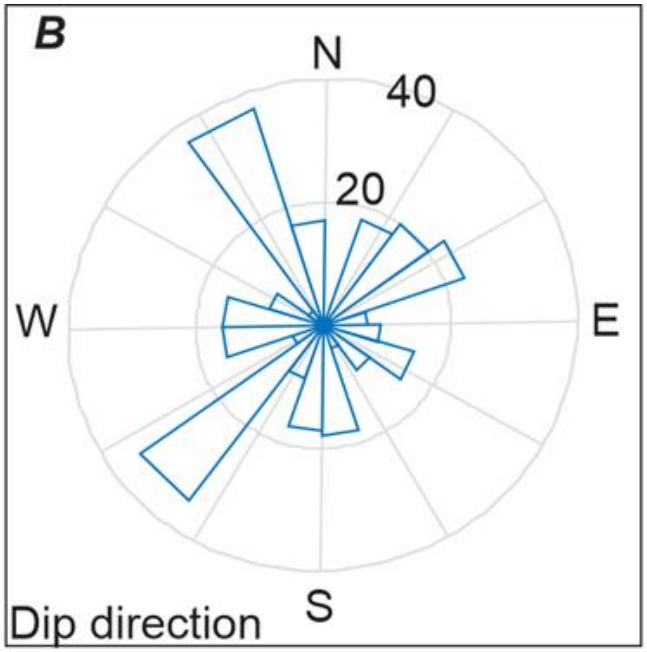
Geologic mapping (903 sites)



- Defining the geology of the region
- Studying faults and fractures that can conduct fluid flow

Fracture studies (55 sites)

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

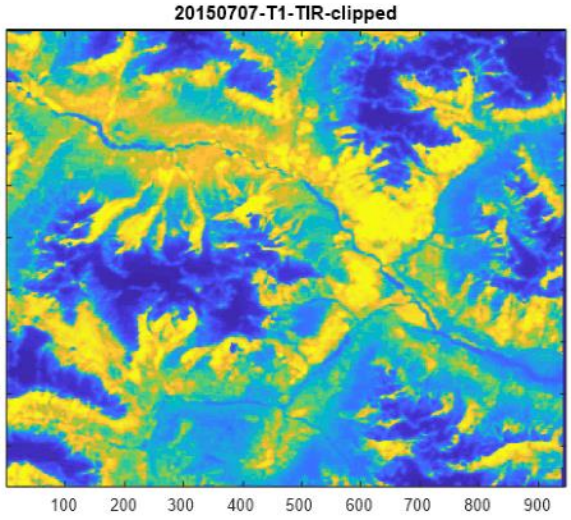


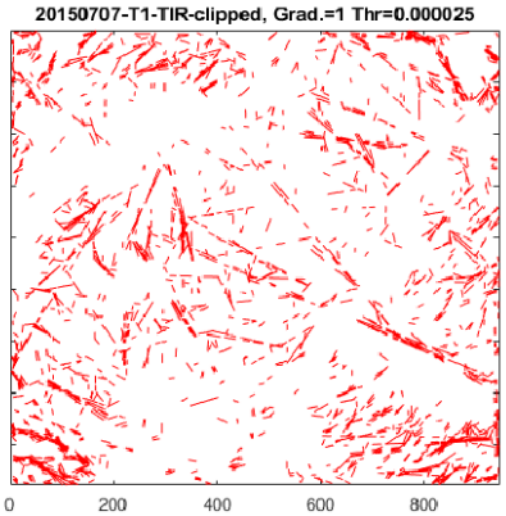
Hot Spring Geochemistry

- Periodic sampling of the hot springs to measure geochemistry
- Helps to assess the nature of the geothermal reservoir

Remote Sensing

- Satellite images show thermal anomalies
- Are they related to fracture systems?
- Can we predict geothermal paths ways?





Raw image → Thermal anomalies → Lineaments

Resource Modeling

Basic Physics and Equations for Modelling

$$\rho C_p \frac{\partial T}{\partial t} + \nabla \cdot q = Q$$

$$q = -k\nabla \cdot T$$

Heat flow: $q = k\nabla \cdot T = k\frac{\Delta T}{\Delta t}$ (W/m/k.k/m)

Heat capacity: $C_p = \frac{E}{\Delta T}$ J/K

Adding the host rock permeability (κ_ϕ), permeability κ_{fr} is an equation of fracture density ρ_f, length l and width w over of fracture area A_i.

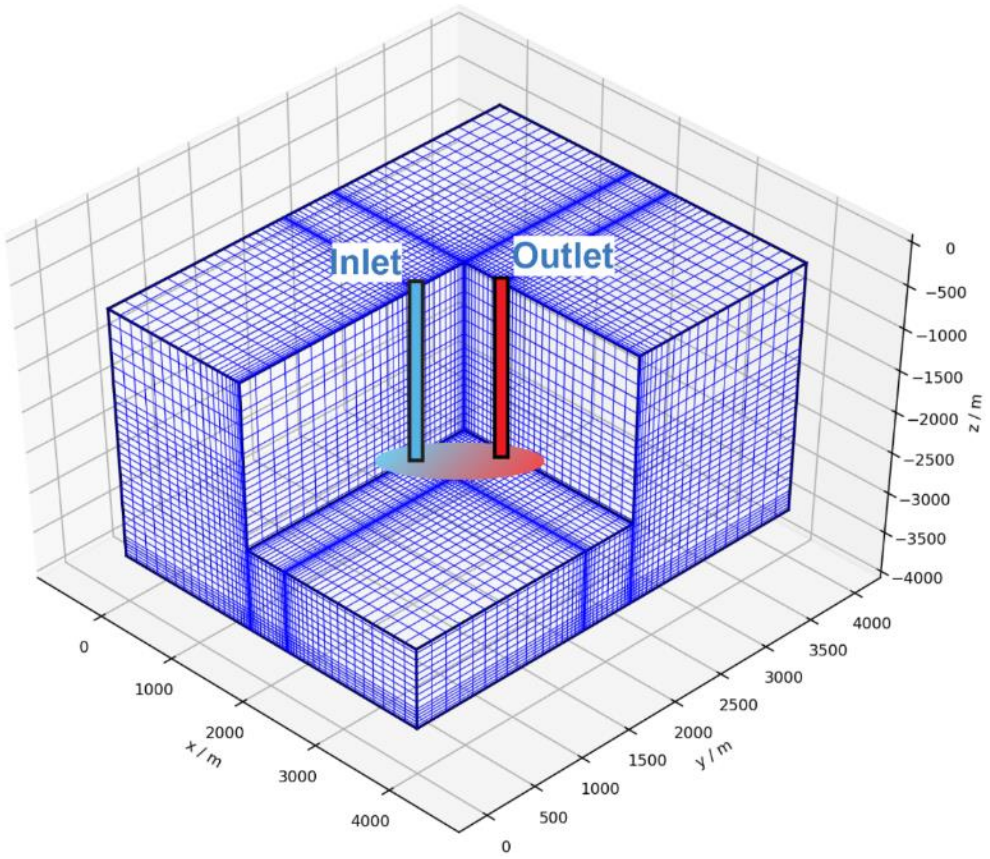
$$\kappa_{fr} = \kappa_\phi + \frac{\rho_f \cdot l \cdot w^3}{A_i}$$

Ex.: $k=(1e\text{-}16)+0.05*1*(0.5e\text{-}4)^3/1=6.35e\text{-}15 m^2$

Permeability of the fracture-bearing rocks (κ_{fr}) is a function of initial porosity ϕ:

$$\kappa_{fr} = 6 \times 10^{-13} \phi^{0.64}$$

Resource Modeling



<u>Preliminary</u> results suggest

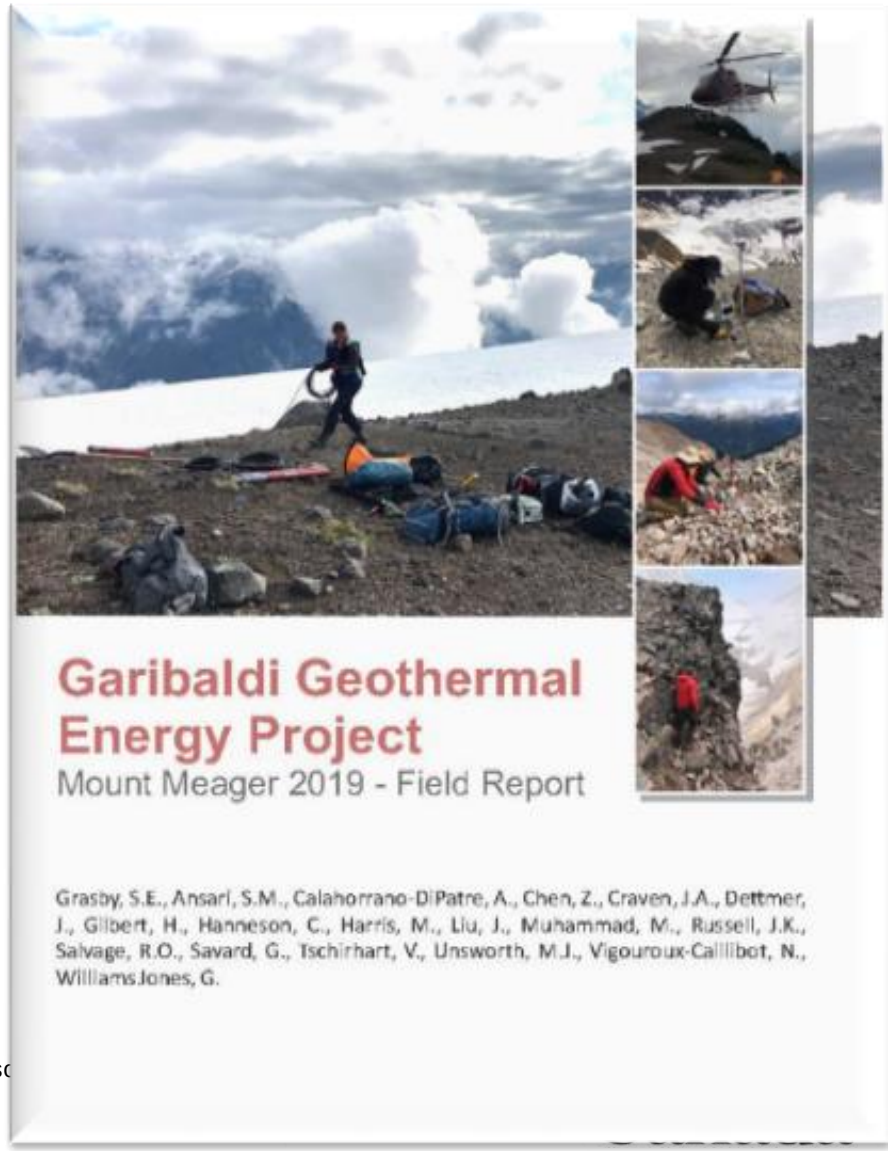
- 6-13 MW power for 1 well
- Production for > 30 years

Bonus science

- **Landslide hazard monitoring**
- **Volcanic hazard**
- **Ice Cave Fumaroles**

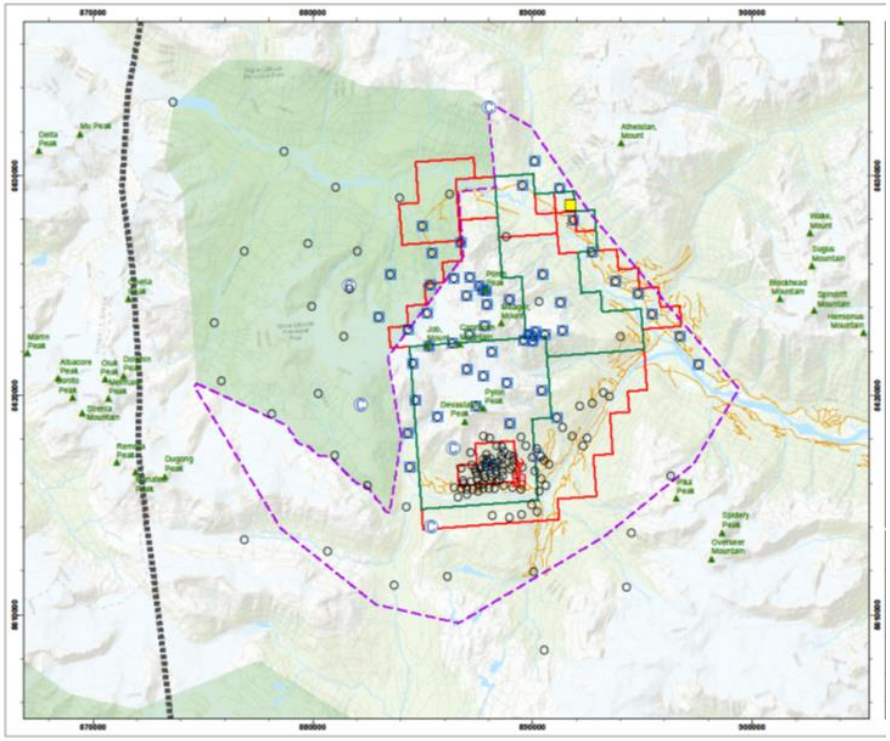
Results to date

- **Initial report online at *Geoscience BC***



What's next?

- **Data interpretation, thesis research, science papers in progress**
- **Public release of all data in 2021**
- **If possible and safe…. fill in holes from 2019**



Questions