

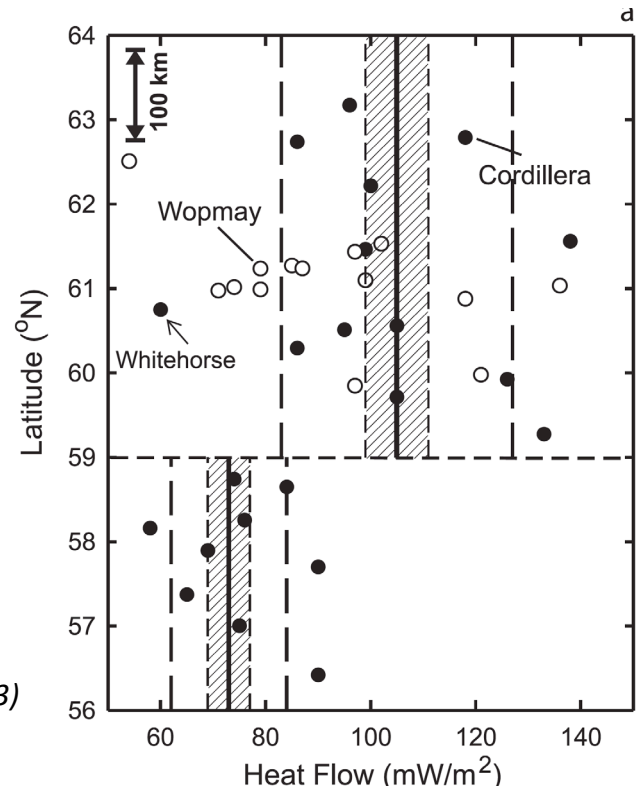
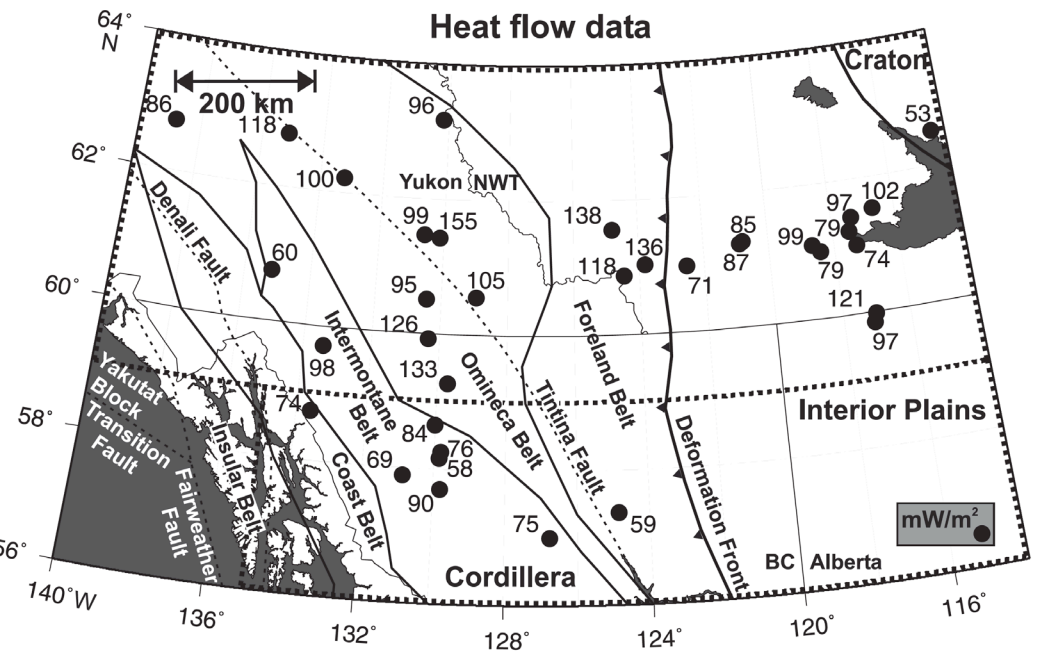
# Overview of geothermal research at the Yukon Geological Survey

*Maurice Colpron*  
*Yukon Geological Survey*

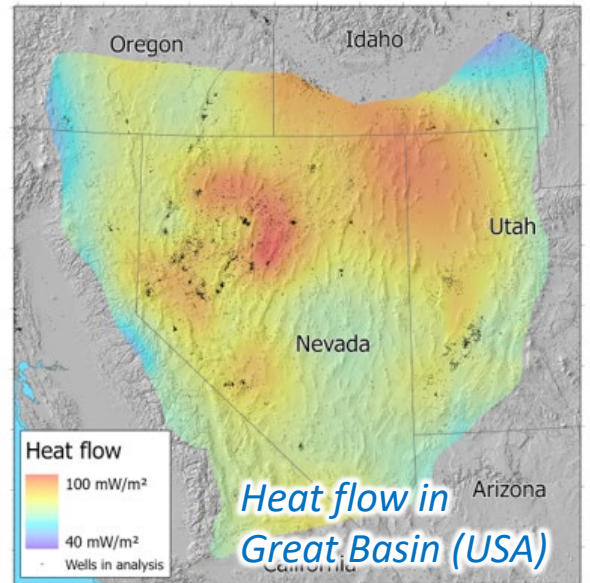


# The premise... Why geothermal in Yukon?

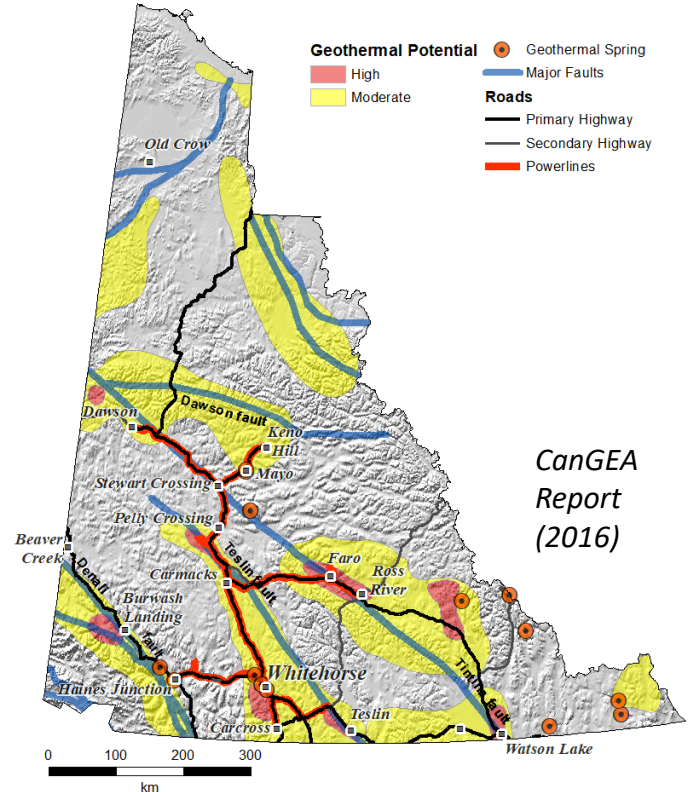
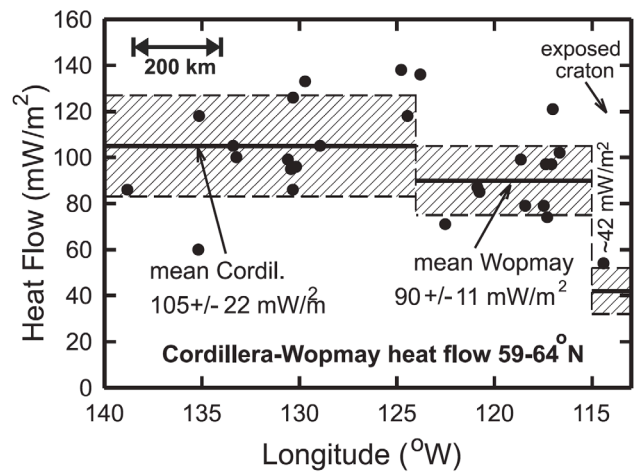
- How could YGS contribute to the “green energy transition”?
- Elevated heat flow in northern Cordillera
- Comparable to heat flow in SW US (Basin and Range)
- But based on few data points from mainly shallow exploration boreholes



Lewis et al. (2003)



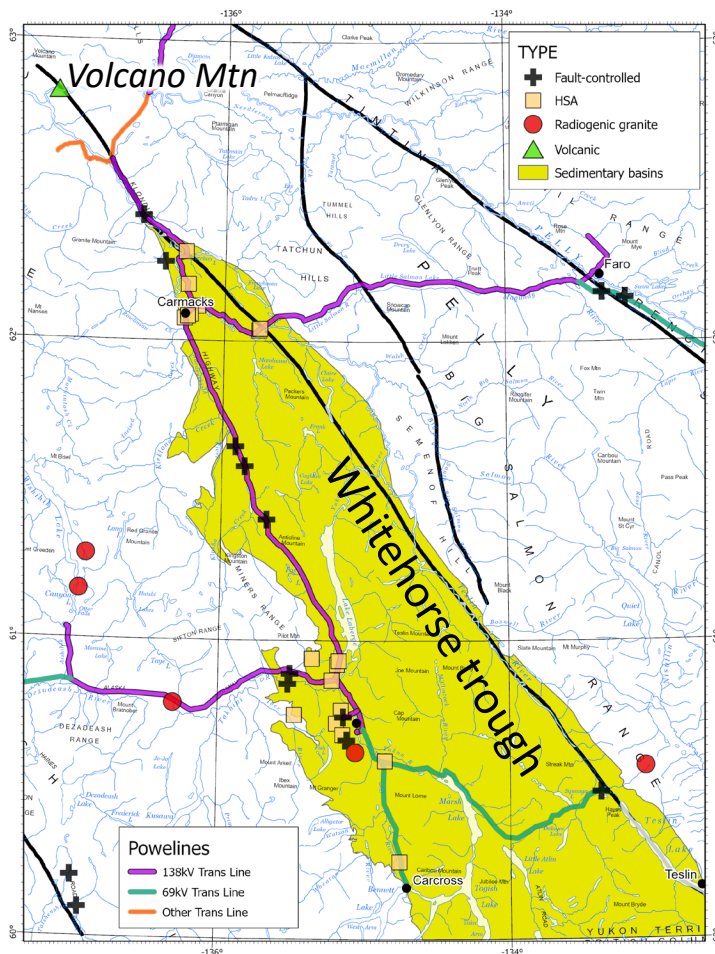
DeAngelo et al. (2022)  
USGS data release  
doi:10.5066/P9BZPVUC



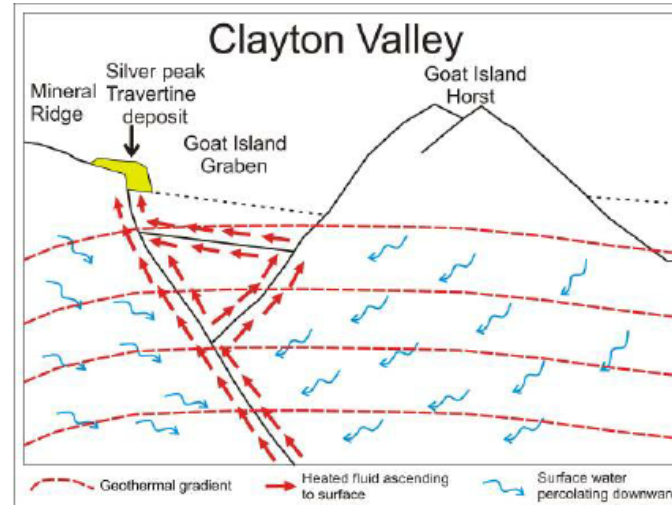
CanGEA Report (2016)

# First steps – 2016 & 2017

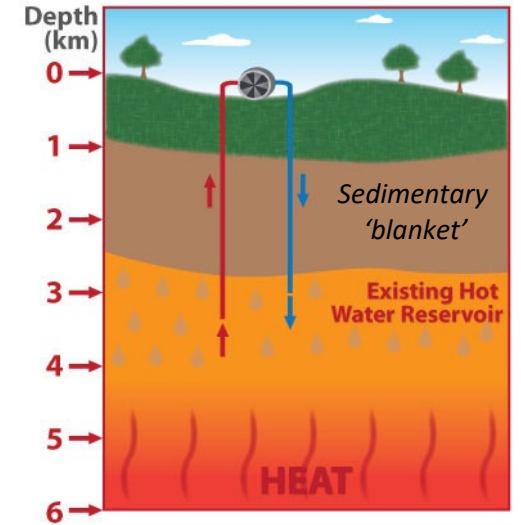
- Broad assessment of geothermal potential centered on Whitehorse trough
- Evaluating 4 types of geothermal systems, near communities – power grid
- Input from Steve Grasby (GSC) & Jeff Witter (Innovate Geothermal)



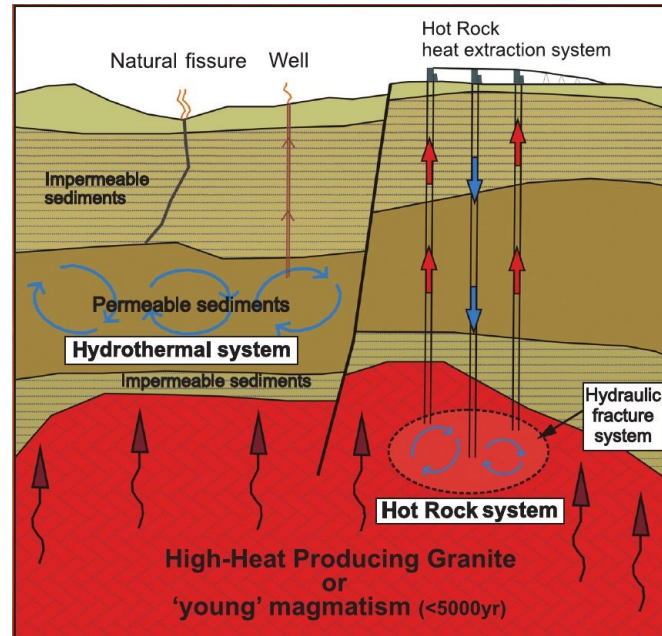
## Fault-controlled



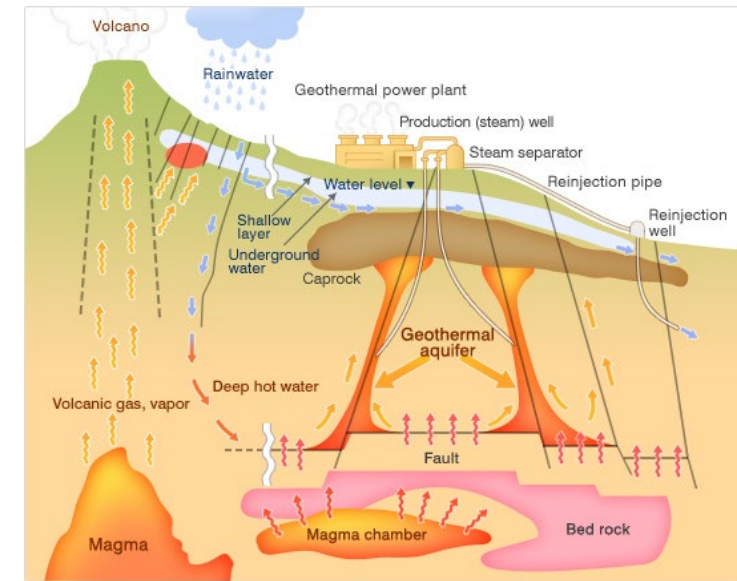
## Hot Sedimentary Aquifer (HSA)



## Radiogenic granites



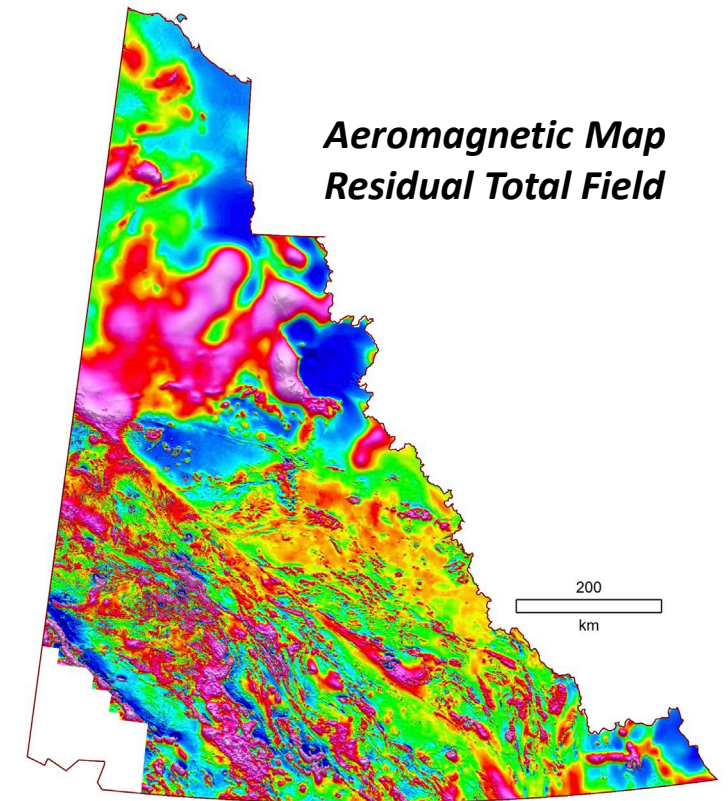
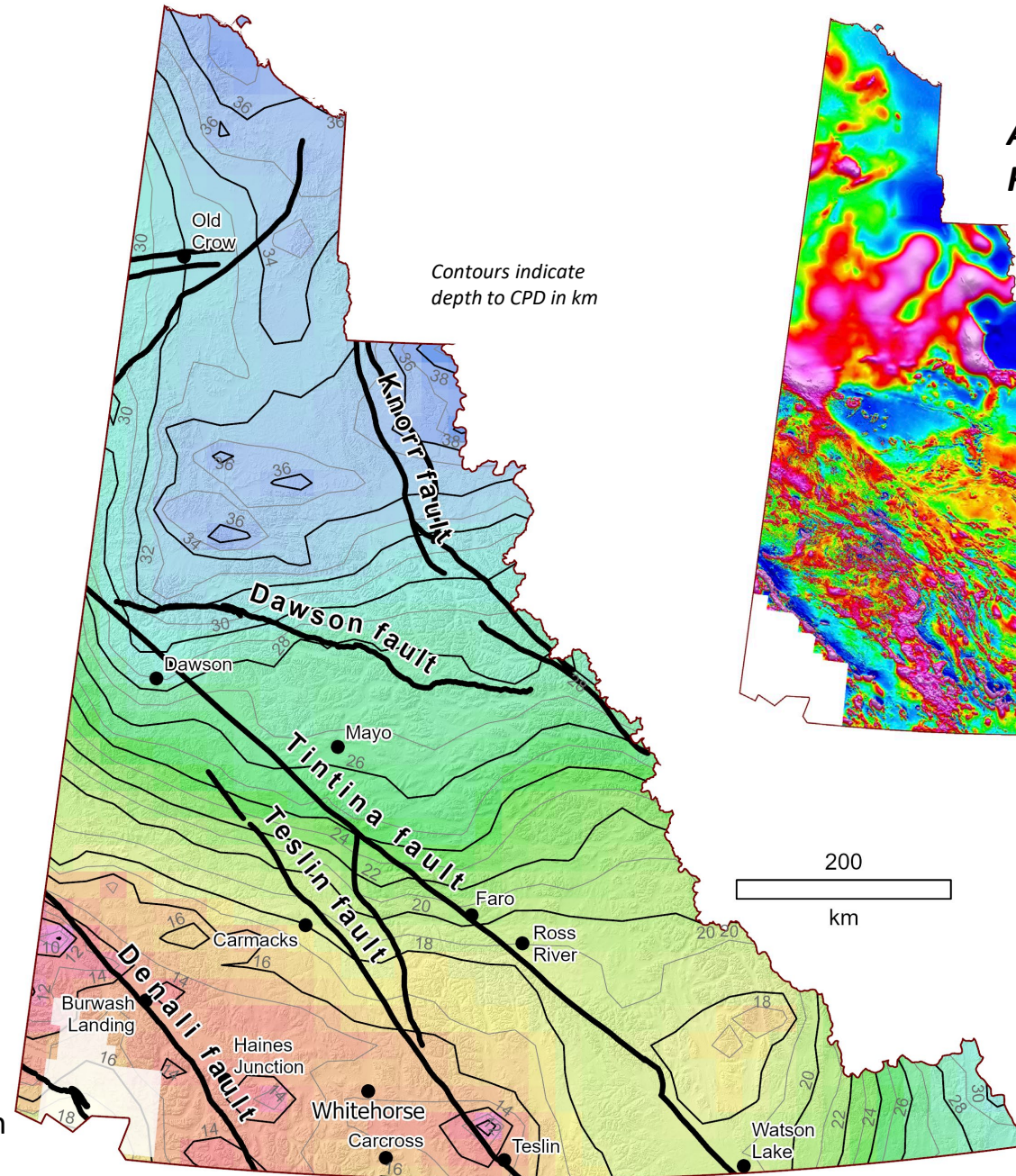
## Volcanic associated



# Curie Point Depth mapping

- Curie point is temperature of demagnetization (~580 °C)
- Calculated using regional aeromagnetic data
- Witter and Miller (2017) and Witter et al. (2018) for Yukon
- Li et al. (2017) – Global CPD map
- Highlights shallower CPD in southern Yukon
- Potentially higher geothermal gradient
- “Hot spots” along Denali and Teslin faults

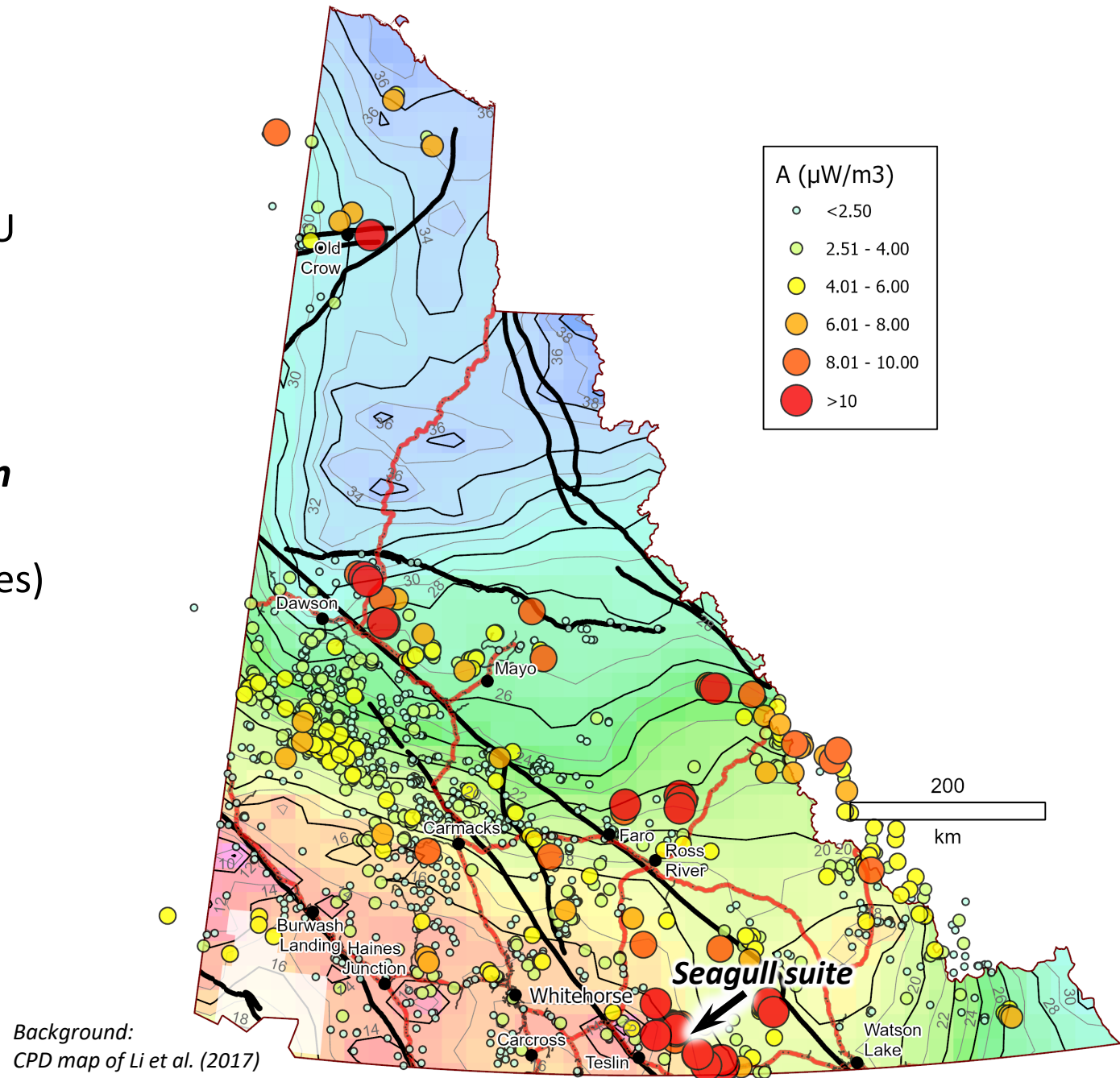
Curie Point Depth  
from Li et al. (2017)



Oneschuk et al. (2019)  
GSC OF 7862 v.2

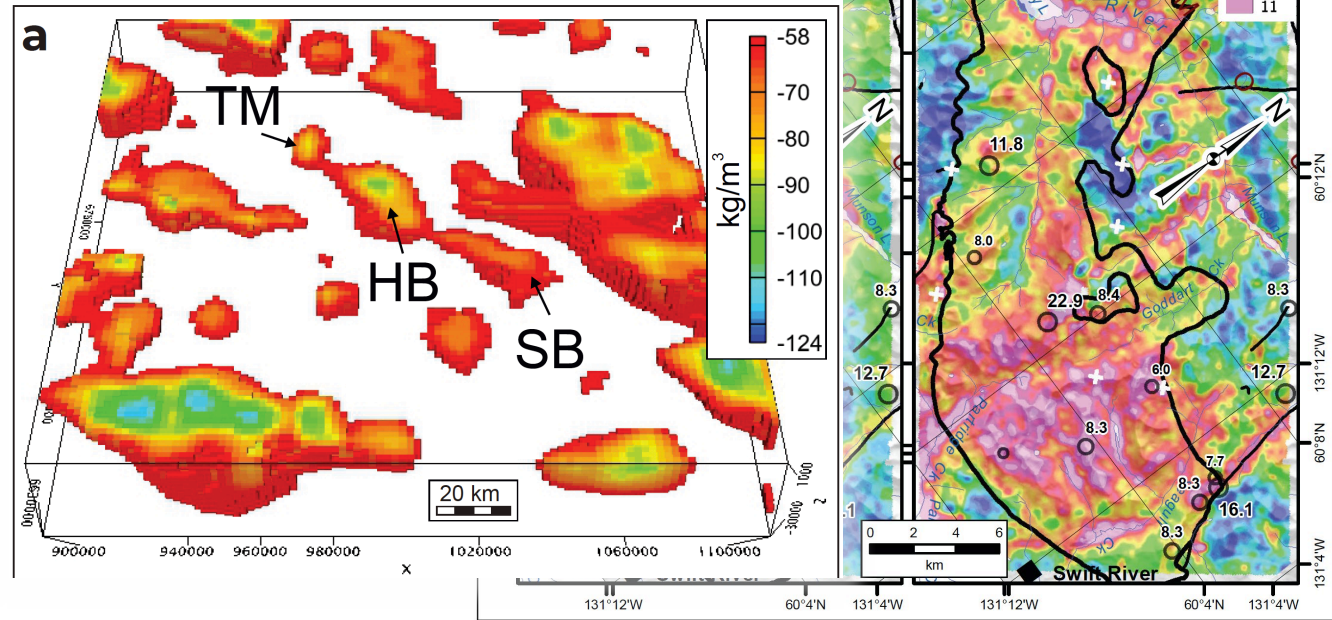
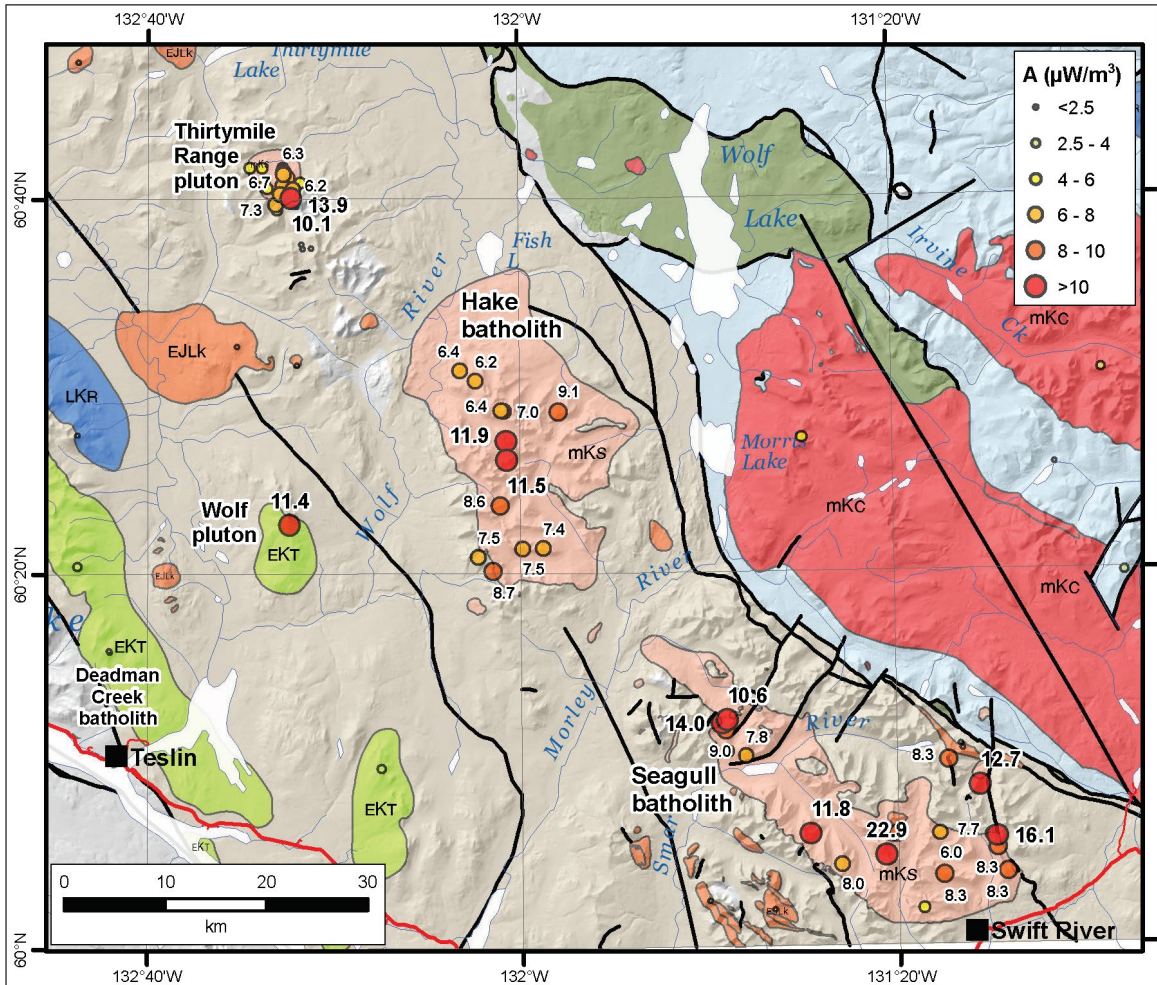
# Radiogenic Heat Production from granitoids

- Heat generated by radiogenic decay of K, Th, U
- First compilation by Melissa Friend (2017)  
***Open File 2017-60***
- Cretaceous and younger plutons
- Foundation for YGS ***lithogeochem compilation***  
<https://data.geology.gov.yk.ca/Compilation/35>
- Updated in 2019 for all plutons (>1760 analyses)  
***Open File 2019-16***
- Some really **HOT** Late Cretaceous plutons
  - Seagull suite
  - Tombstone suite
  - McQuesten suite



# Radiogenic Heat Production from granitoids

- Follow up study on Seagull suite (*YEG 2020*)
- Industry radiometric survey, Seagull batholith
- Gravity & volume modeling (N. Hayward, GSC)
- Potential thermal energy estimates



Range in Density Contrast (kg/m <sup>3</sup> )	Density Range adjusted for Bouguer density (2670 kg/m <sup>3</sup> )	Volume (km <sup>3</sup> )	Max Depth (km)	Average A (μW/m <sup>3</sup> )	Potential Heat Energy (MWt)
<b>Hake batholith</b>					
-124 to -58	2546 to 2612	4624	11	7.9	36.5
-134 to -48	2536 to 2622	6464	13	7.9	51.1
-144 to -38	2526 to 2632	11112	15	7.9	87.8
<b>Seagull batholith</b>					
-124 to -58	2546 to 2612	2744	9	9.9	27.2
-134 to -48	2536 to 2622	4928	13	9.9	48.8
-144 to -38	2526 to 2632	11612	18	9.9	115.0

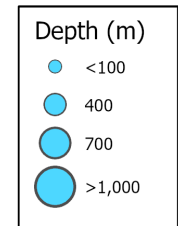
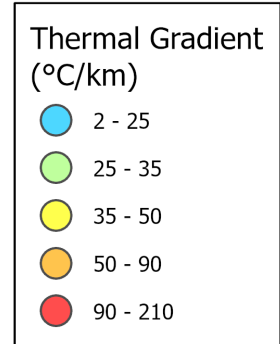
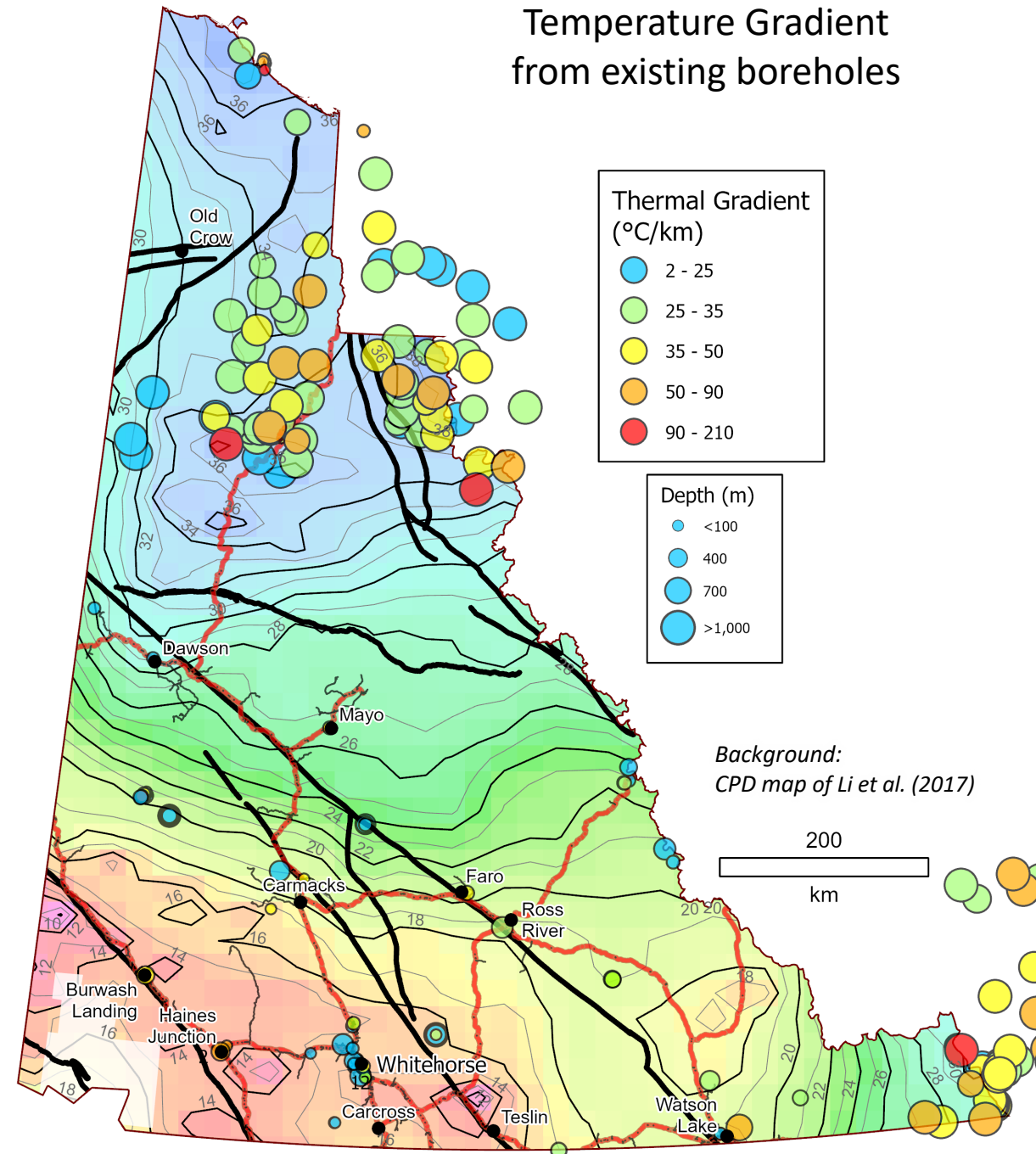
# Temperature Gradient (TG) wells

- Direct measurement of geothermal gradient
- Sparse data; deep wells in oil & gas basins (Eagle Plain, Peel, Liard)
- Mostly shallow, mineral exploration wells in other parts of Yukon
- Not all TG measured are reliable; only bottom hole T measured and commonly before re-equilibration

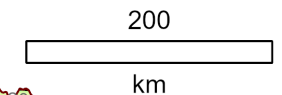


Photo: T. Fraser, YGS

Temperature Gradient  
from existing boreholes



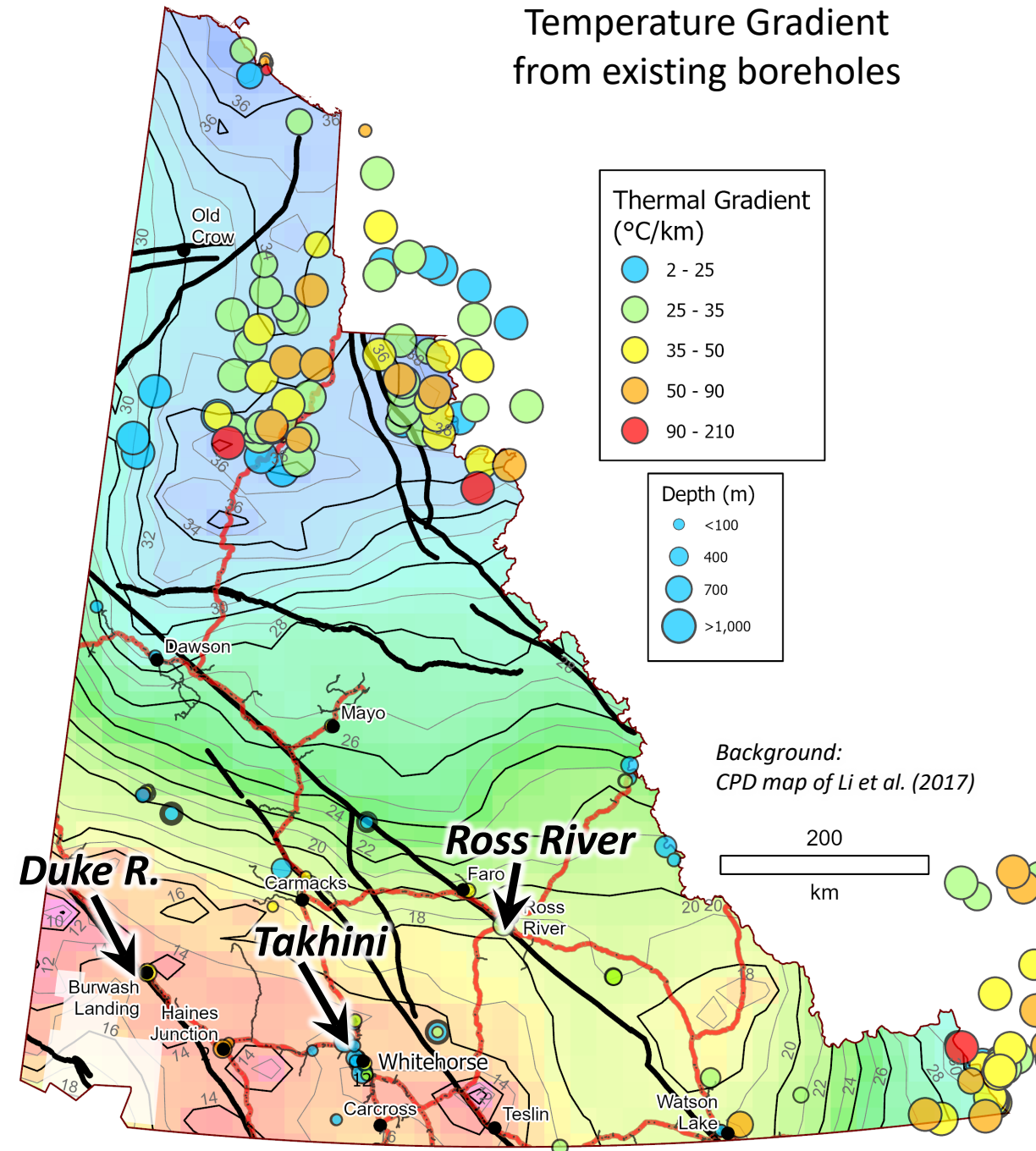
Background:  
CPD map of Li et al. (2017)



# Temperature Gradient (TG) wells

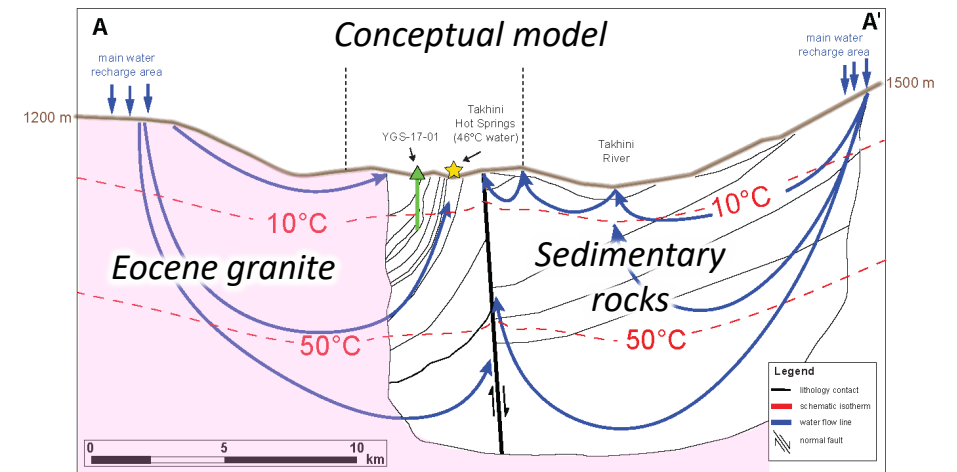
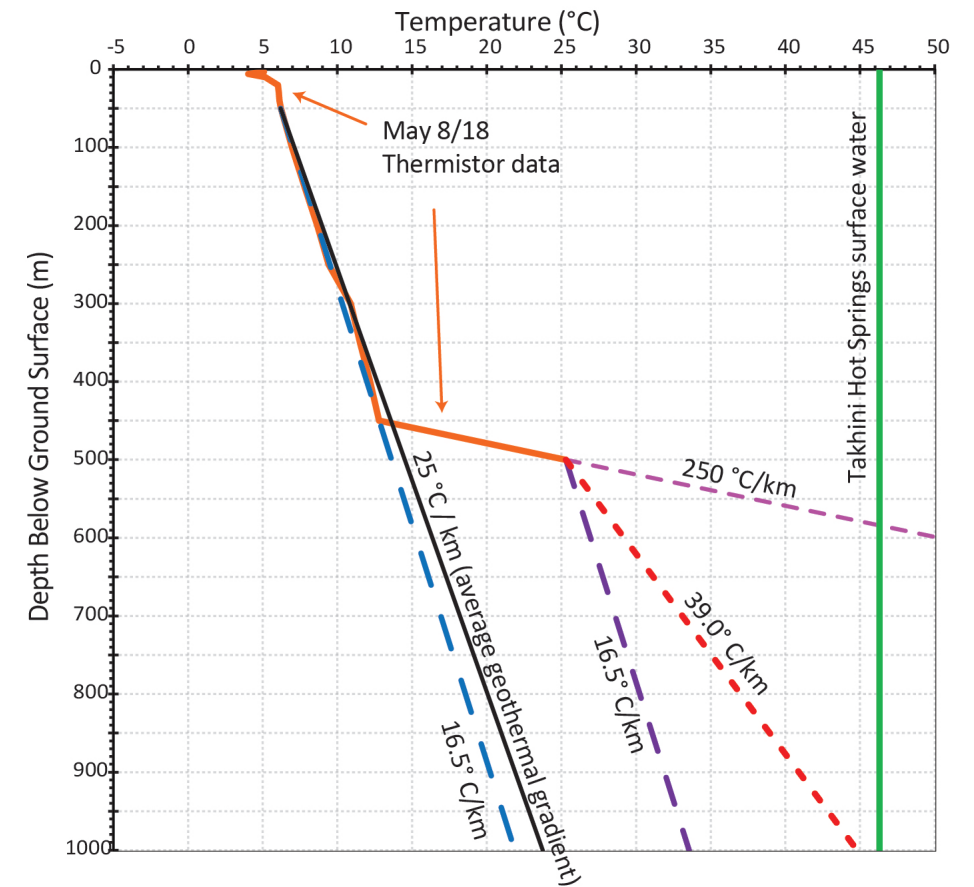
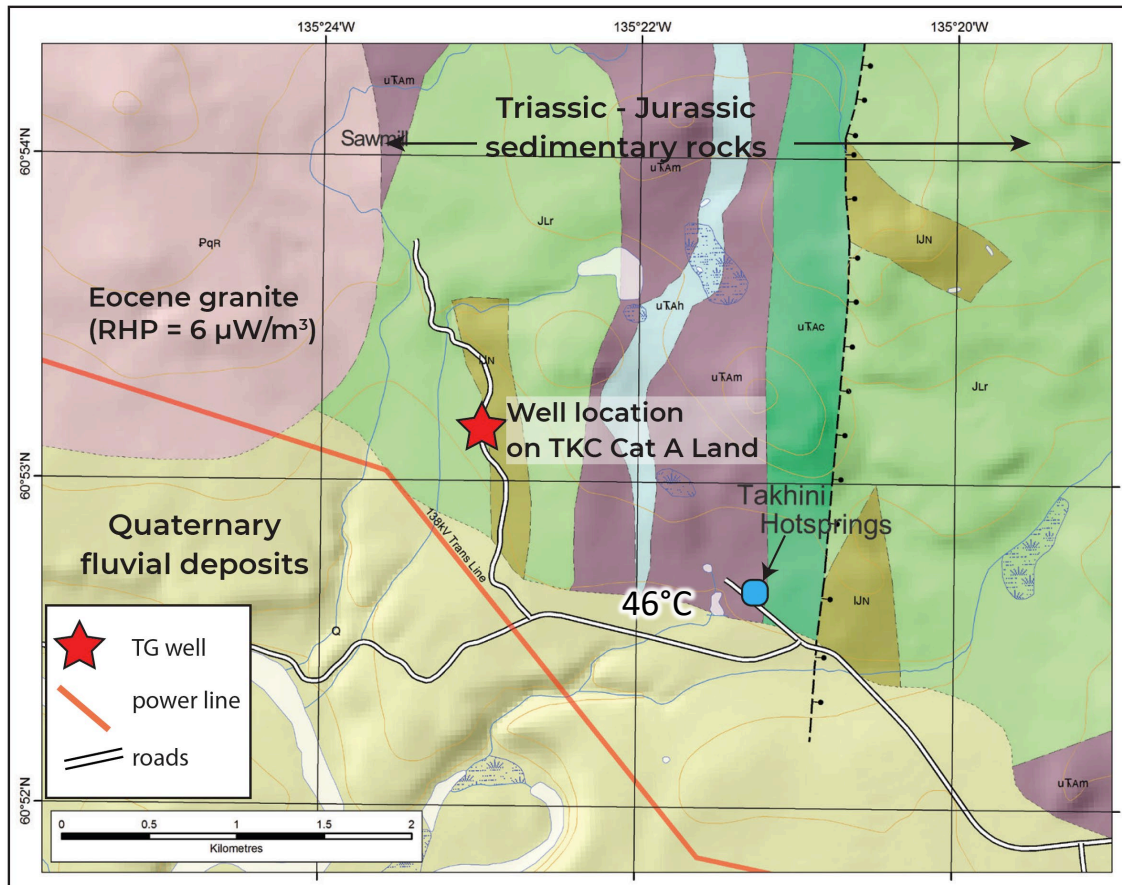
- Direct measurement of geothermal gradient
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- Mostly shallow, mineral exploration wells in other parts of Yukon
- Not all TG measured are reliable; only bottom hole T measured and commonly before re-equilibration
- YGS drilled two TG wells in 2017-18
  - Near Takhini Hot Springs
  - Near Ross River
- 2022 – Phase 1 drilling at Duke River near Burwash Landing
- Eavor Yukon TG well near Carmacks
- YGS is interested in measuring TG in any near-vertical, open well >300 m...

Temperature Gradient from existing boreholes



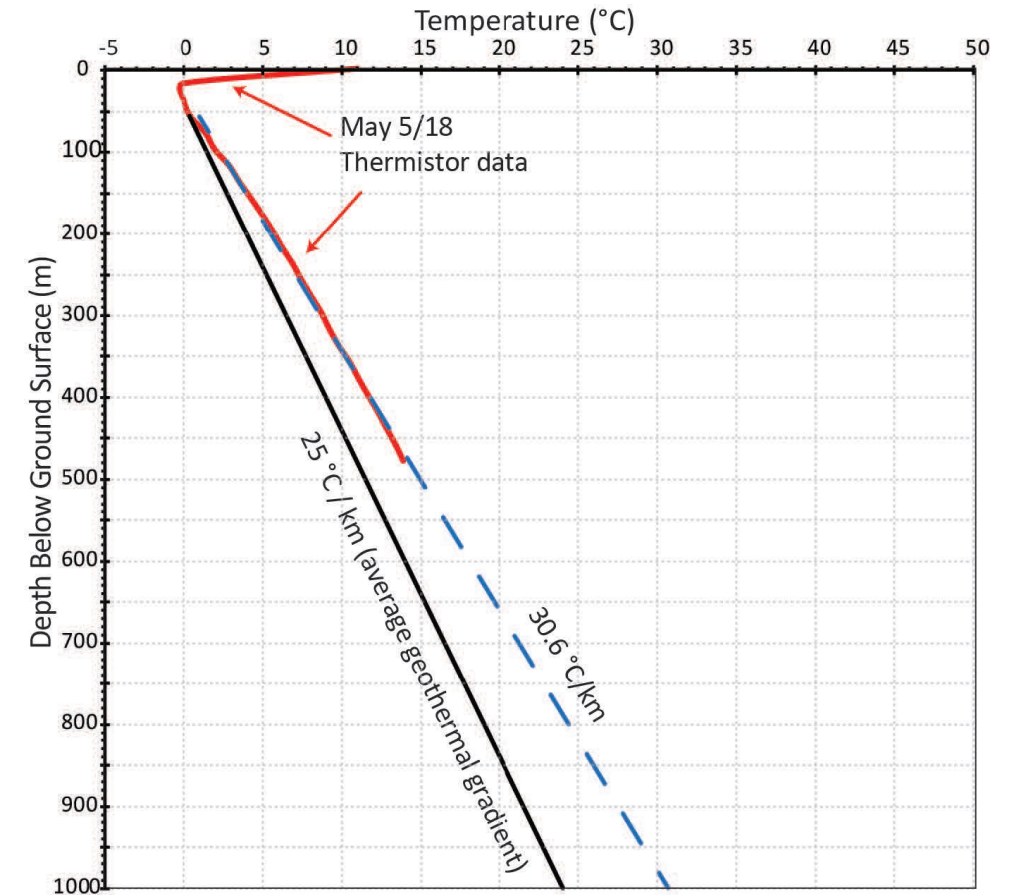
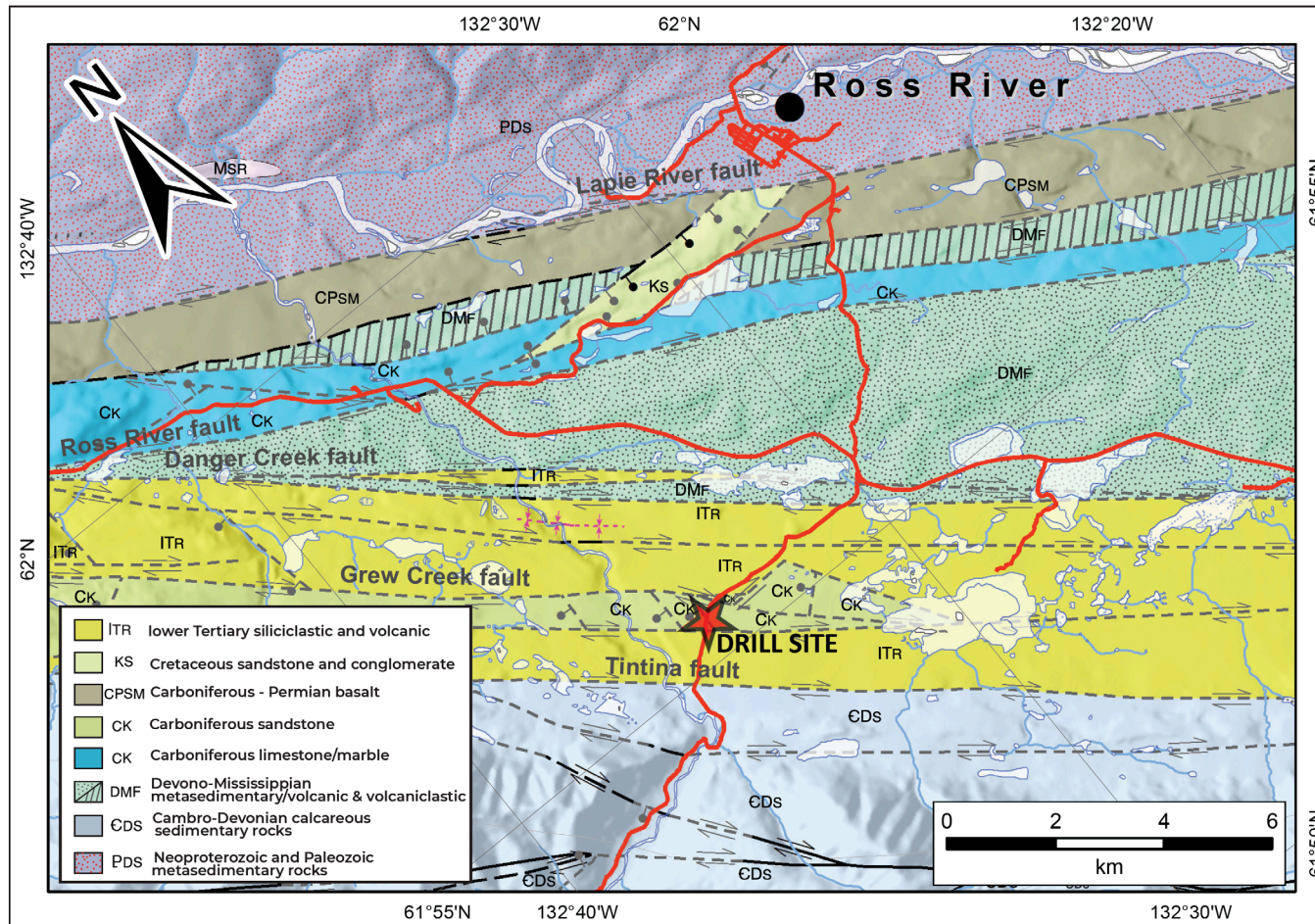
# Drilling TG wells – Takhini 2017

- Target – Hot Sedimentary Aquifer
- 500 m deep, relatively low T gradient to 450 m (~17°C/km)
- Spike to 25.3°C at bottom
- Current model – radiogenic heat + fault?
- **YEG 2018; YEG 2019; MR-19**



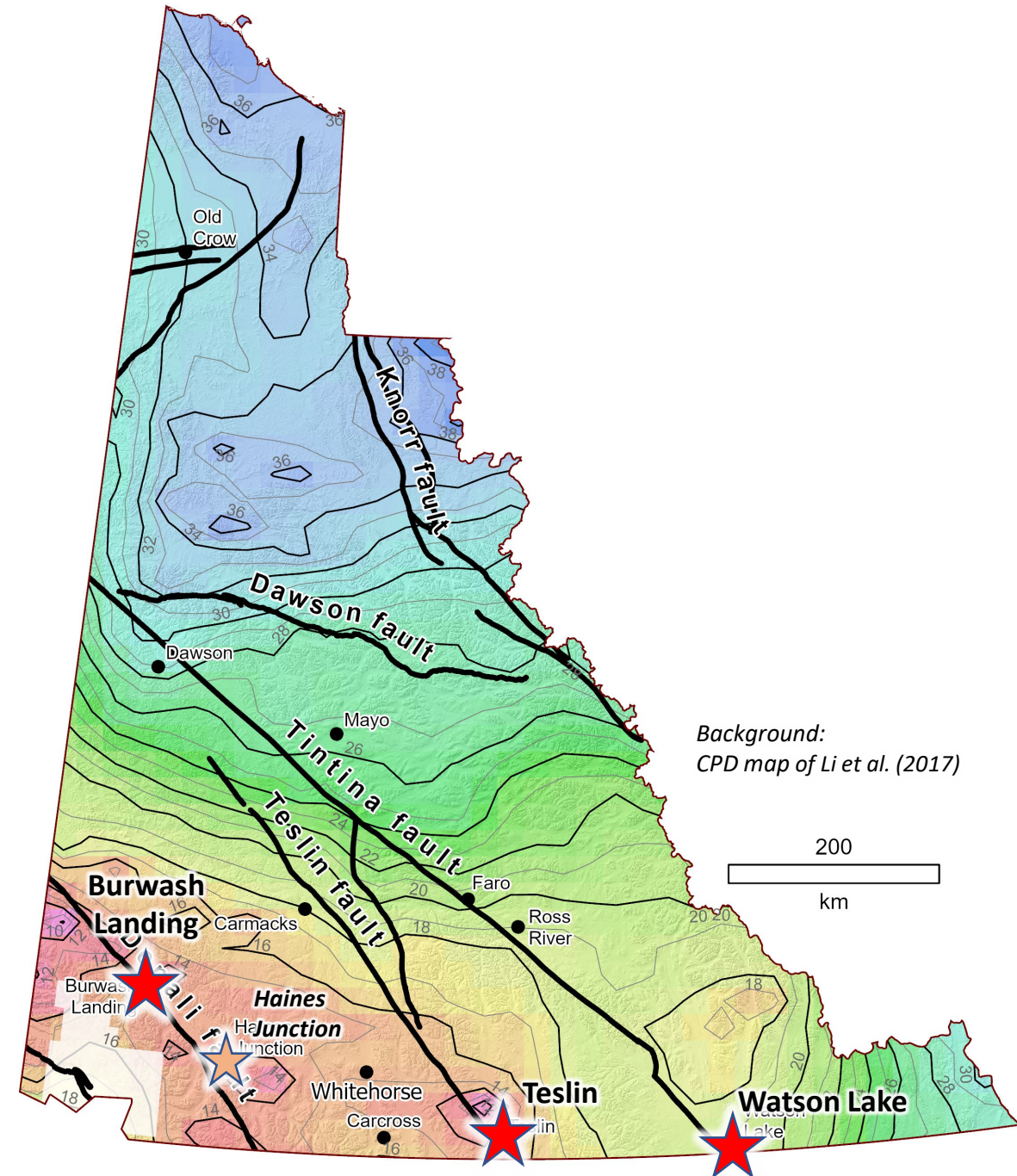
# Drilling TG wells – Ross River 2018

- Target selected from preliminary work by Mira Geoscience for RRDC (using mag, MT, mapping)
- Fault-controlled system; pull-apart in Tintina fault zone?
- 484 m deep; uniform thermal gradient  $\sim 30.6^\circ\text{C}/\text{km}$
- **YEG 2018; MR-19**



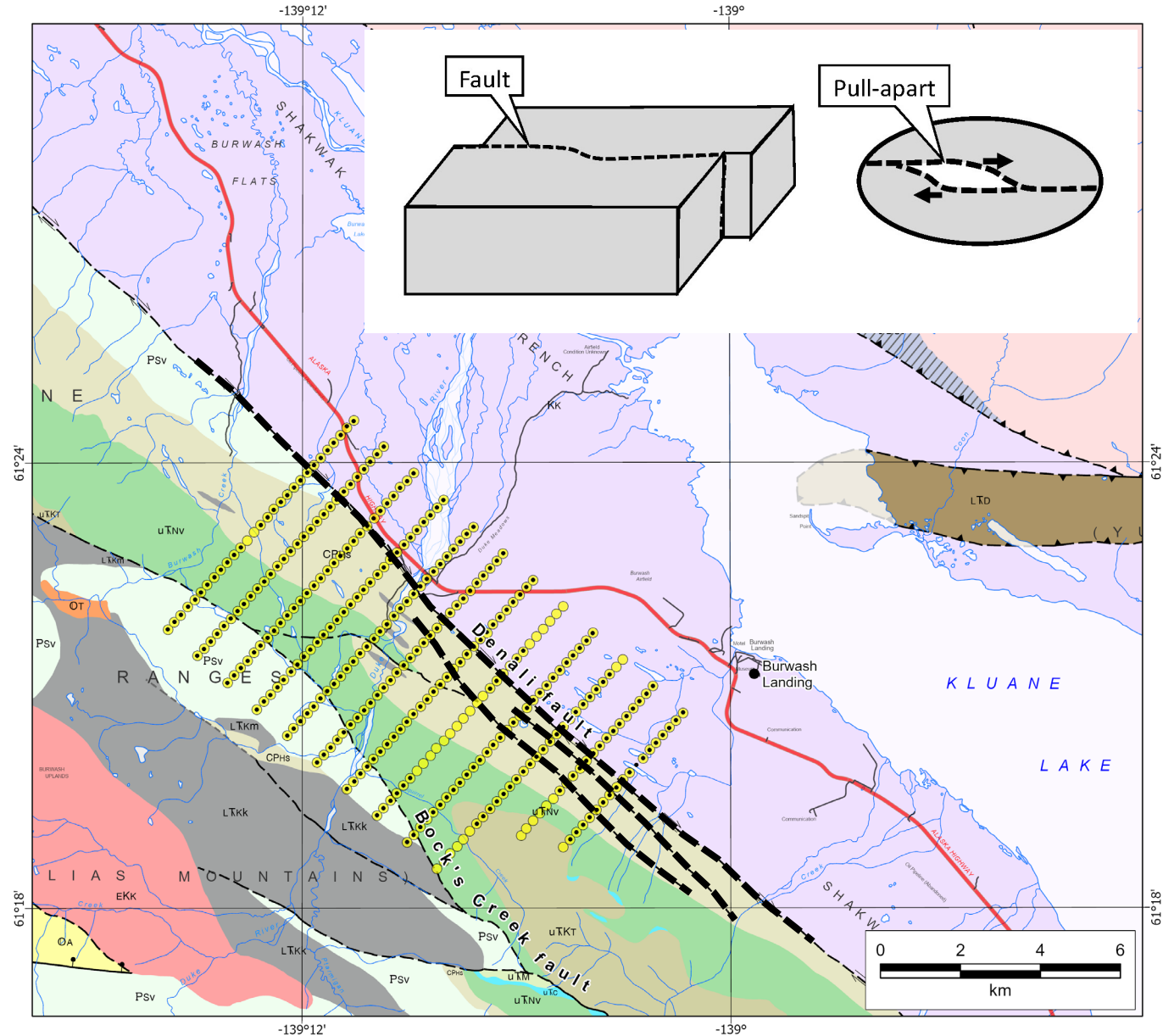
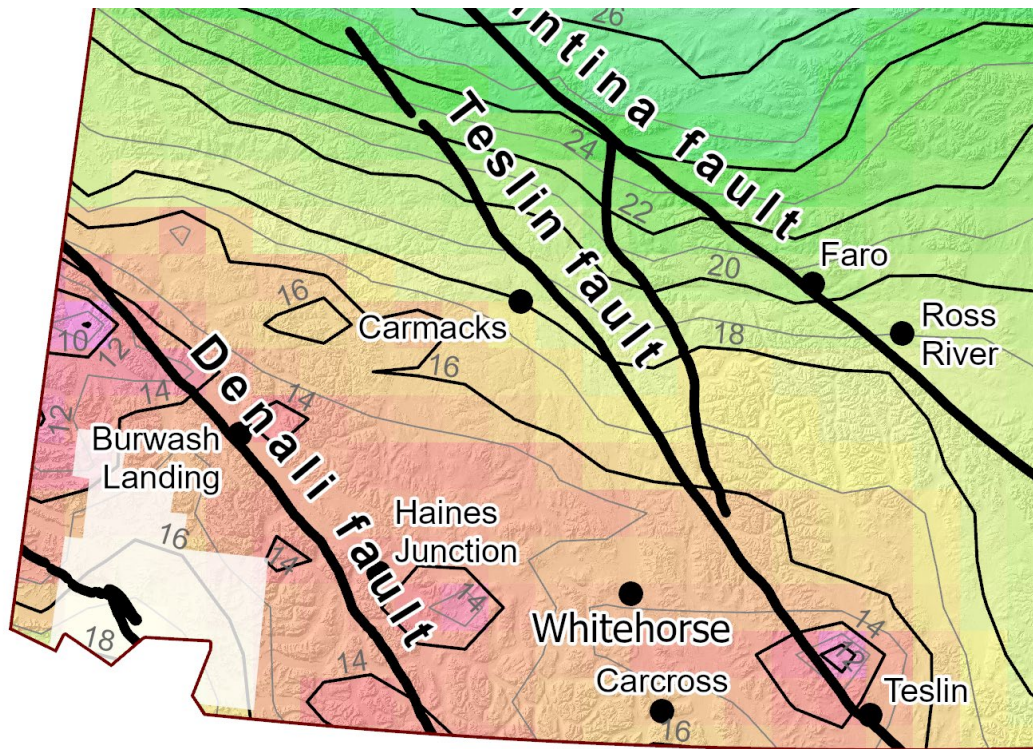
# Fault-controlled geothermal systems

- Funding from NRCAN – Emerging Renewable Power Program (\$2M; 2021-2023)
- YG ‘Our Clean Future’ (\$1M; 2021-24)
- Project focused on 3 major faults – Denali, Teslin and Tintina
- Multi-disciplinary team (~20) from YGS, GSC, USGS, Innovate, and universities (UofA, UofC, UVic, INRS)
- Collaboration with First Nations on these studies



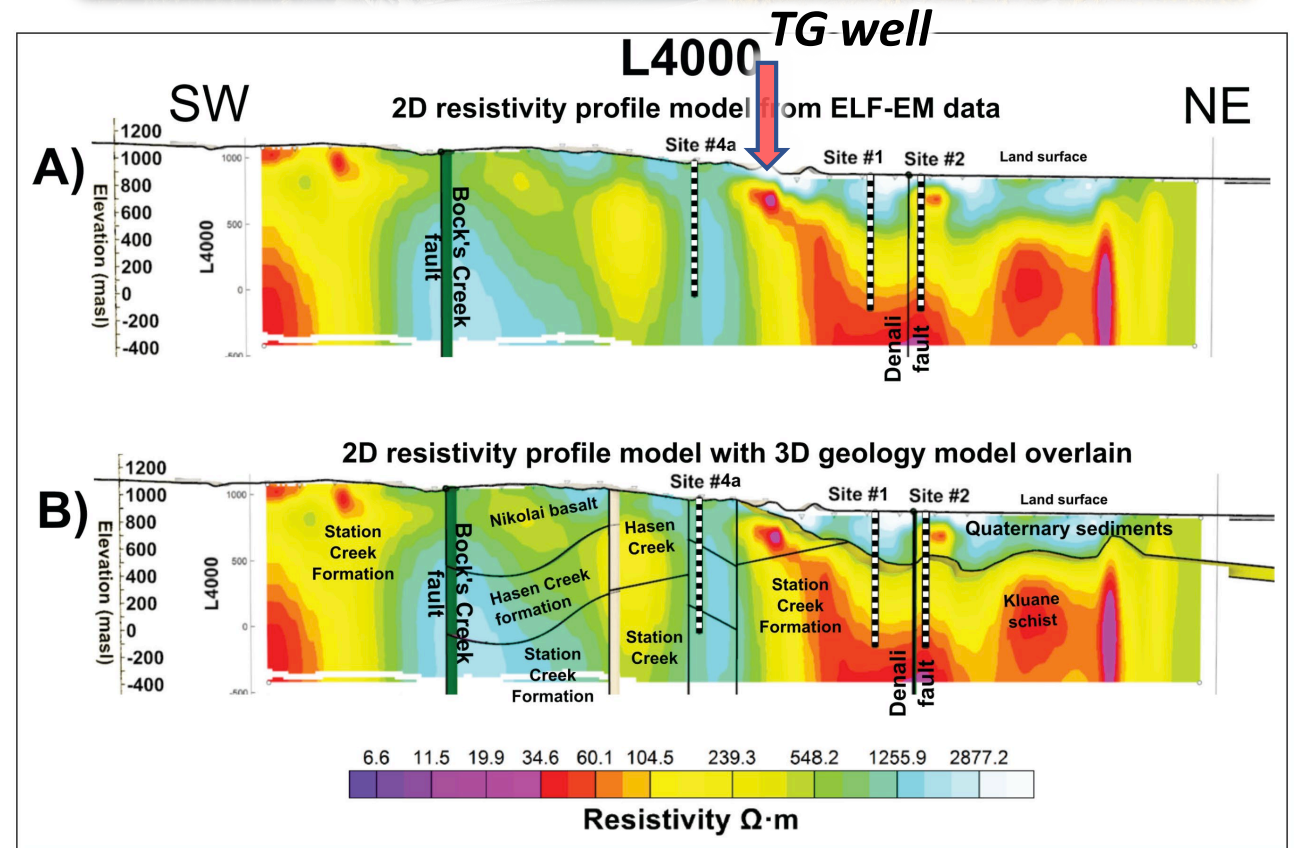
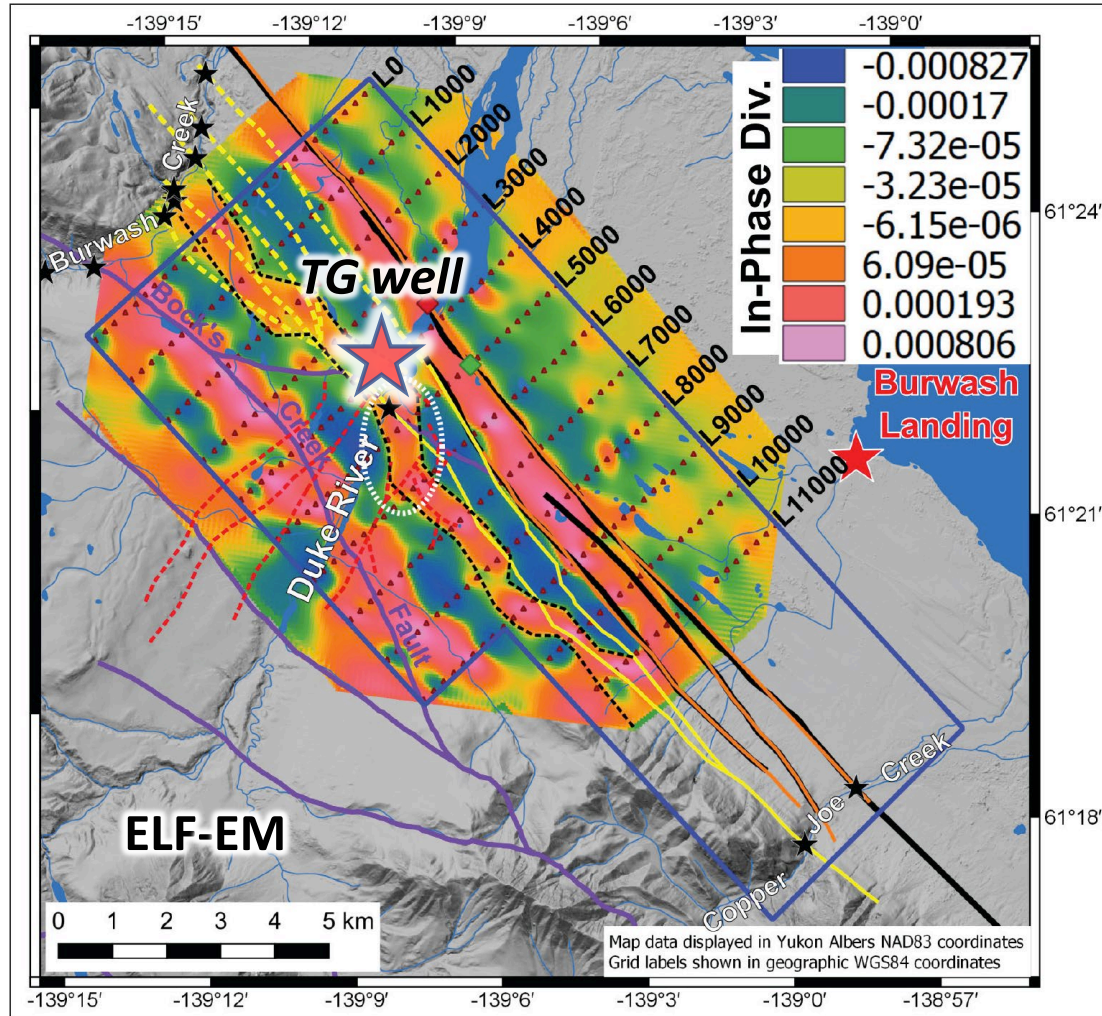
# Denali fault near Burwash Landing

- Shallow CPD along Denali fault
- 387 m well in Burwash Landing with TG of 49°C/km
- Apparent pull-apart in Denali fault
- Gravity and ELF surveys in 2018-19; InSAR analysis
- **Open File 2020-3**



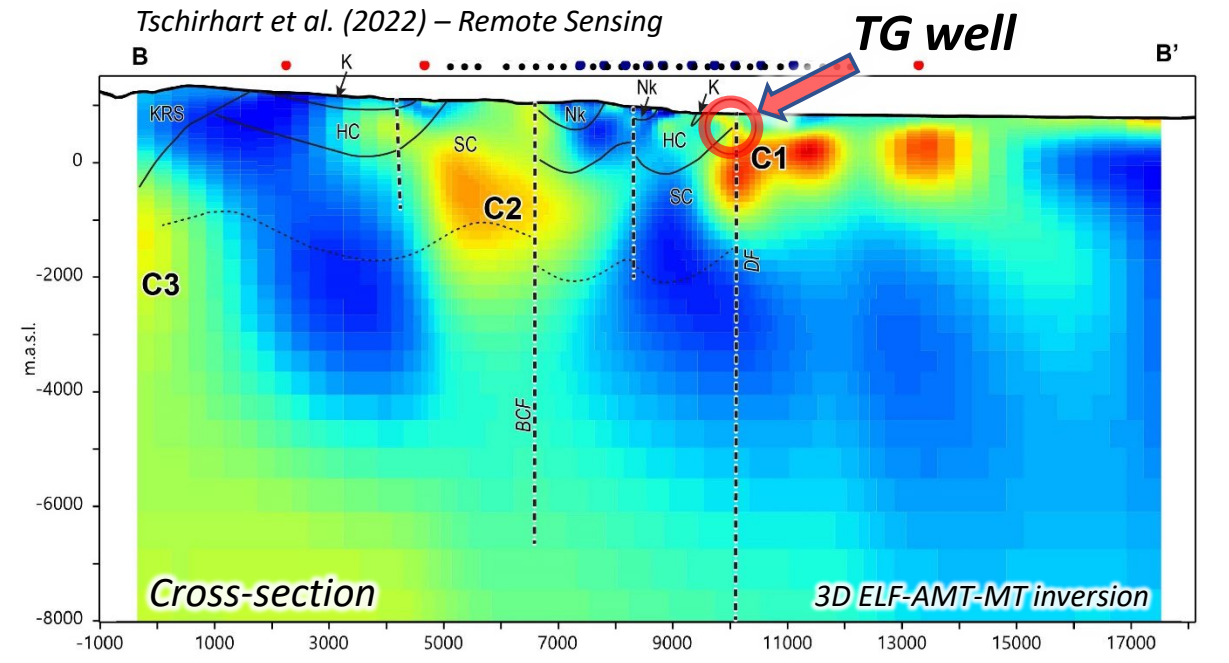
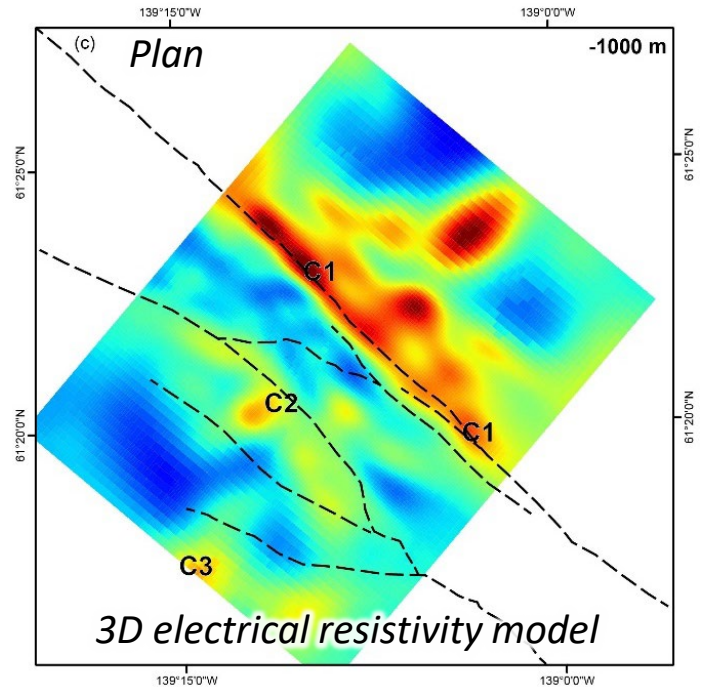
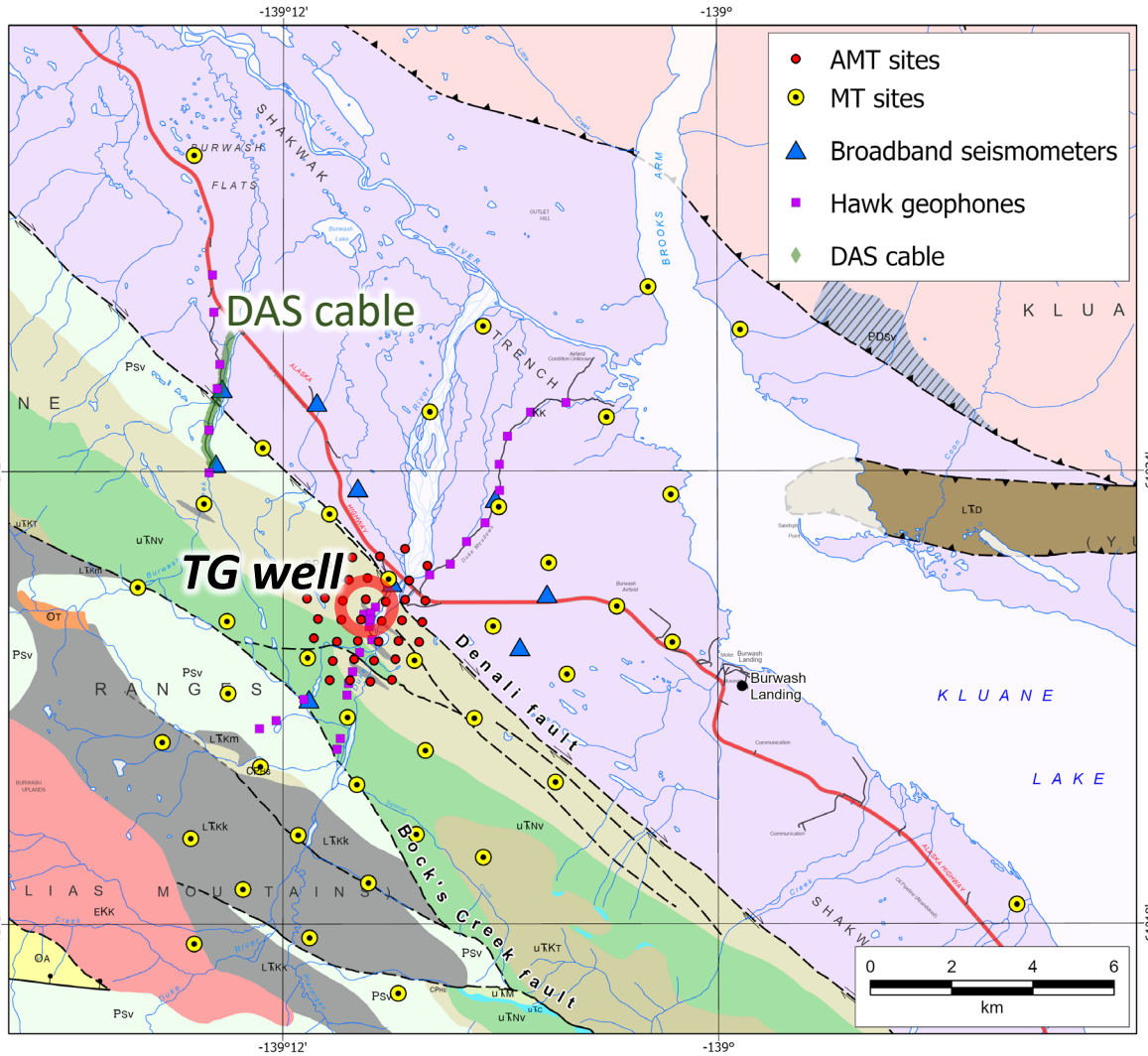
# Denali fault near Burwash Landing

- Geophysics supports presence of pull-apart zone
- Drilling TG well near Duke River



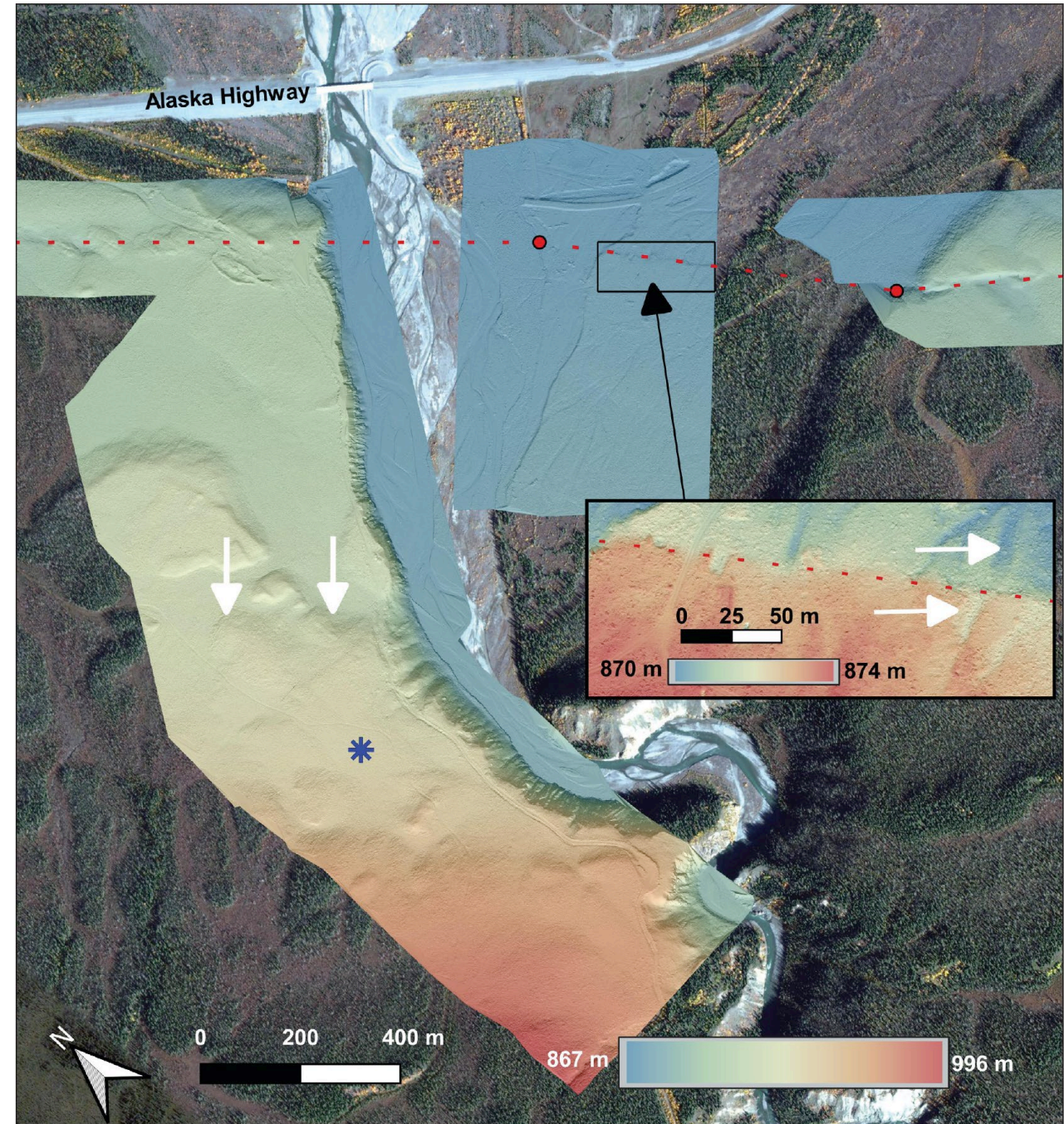
# Denali fault near Burwash Landing

- ELF-AMT-MT joint inversion highlights conductive zones (hot colours)
- Passive seismic deployment for tomography



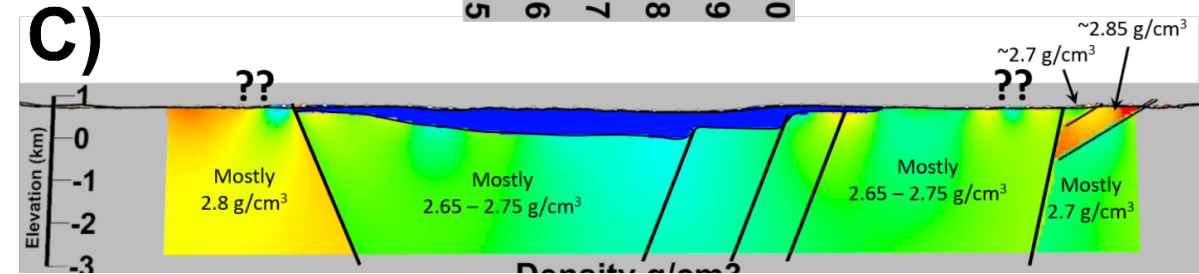
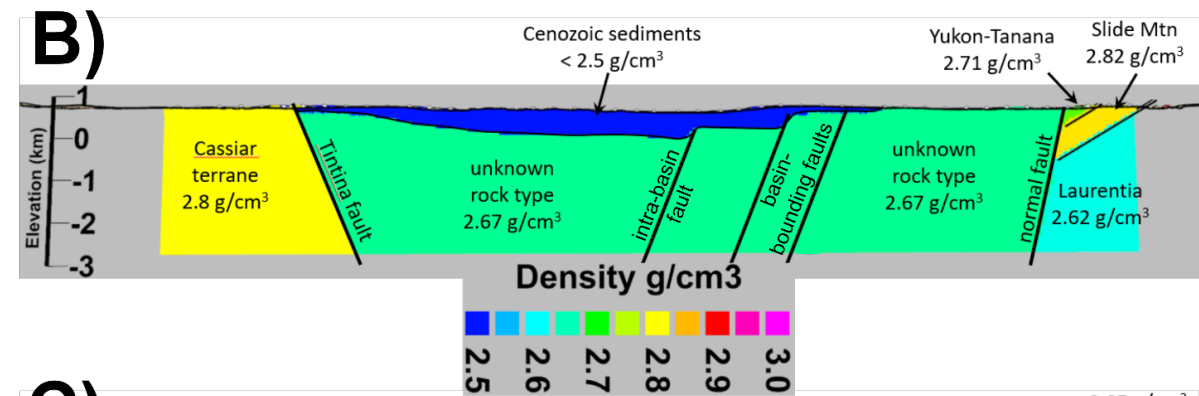
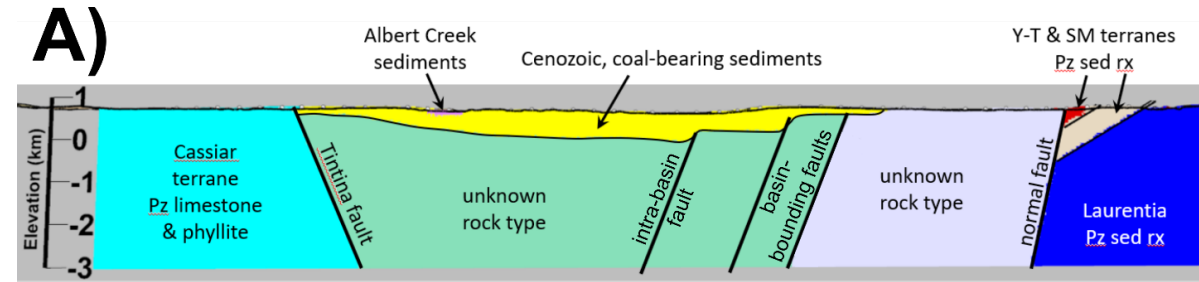
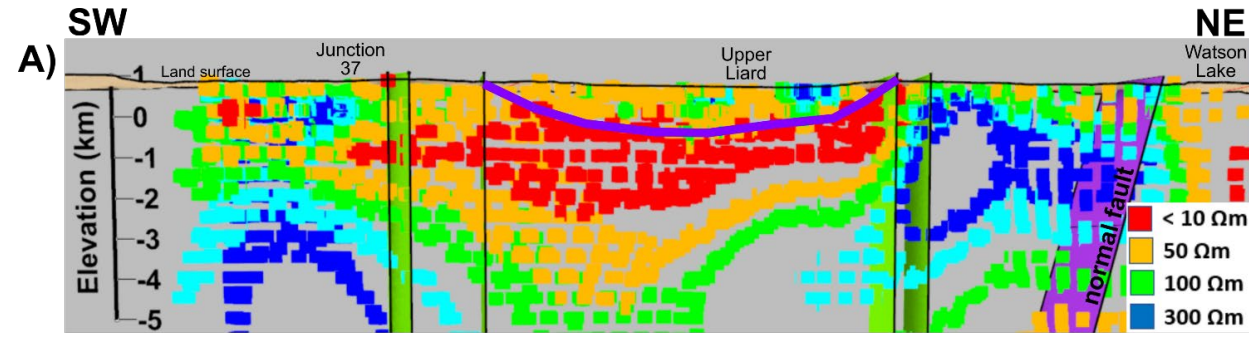
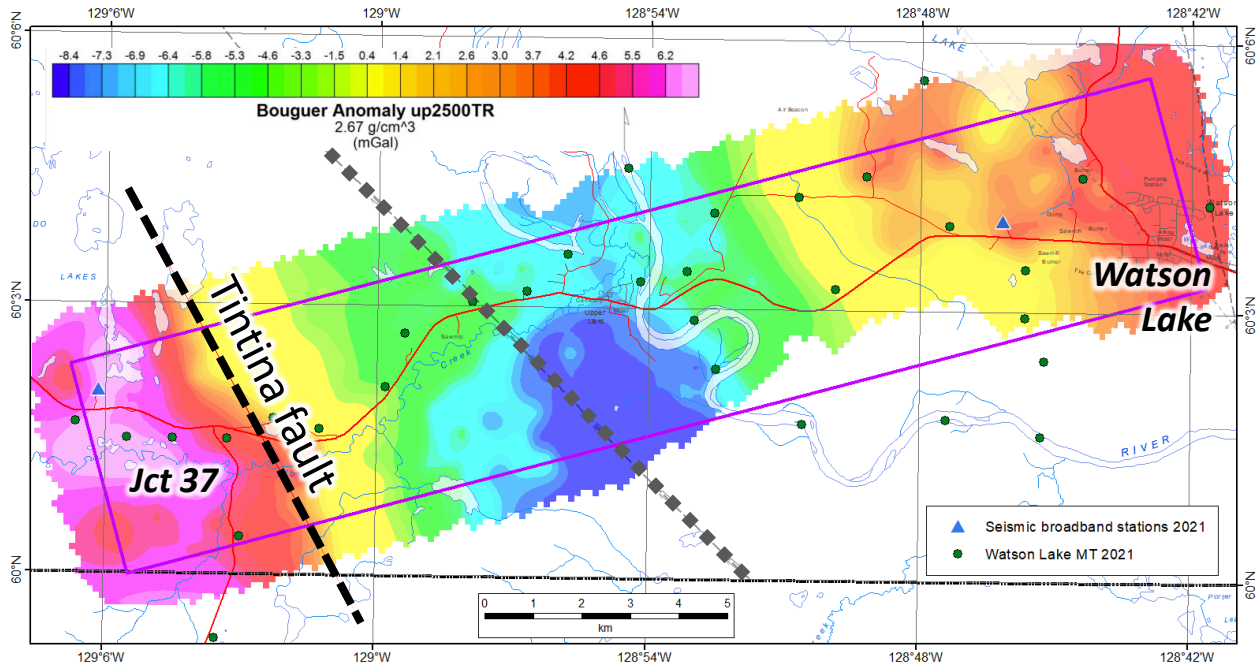
# Denali fault near Burwash Landing

- Neotectonic study – drone LiDAR acquired in 2021/2022 (T. Finley, PhD UVic; **YEG 2021**)
- Hydrothermal modeling study (F. Chapman, PhD INRS)
- Structural studies, mapping (J.S. Caine) [USGS, YGS]
- Deployment of ground temperature probes in Duke River area (S. Grasby, GSC)
- Water chemistry [GSC, YGS]
- TG drilling: Phase 1 – ~220 m RC (2022)
- Planning Phase 2 diamond drilling (to ~1000 m?) for 2023?
- Well to be instrumented with DTS (temperature) and DAS (downhole seismic) fiber optic cables



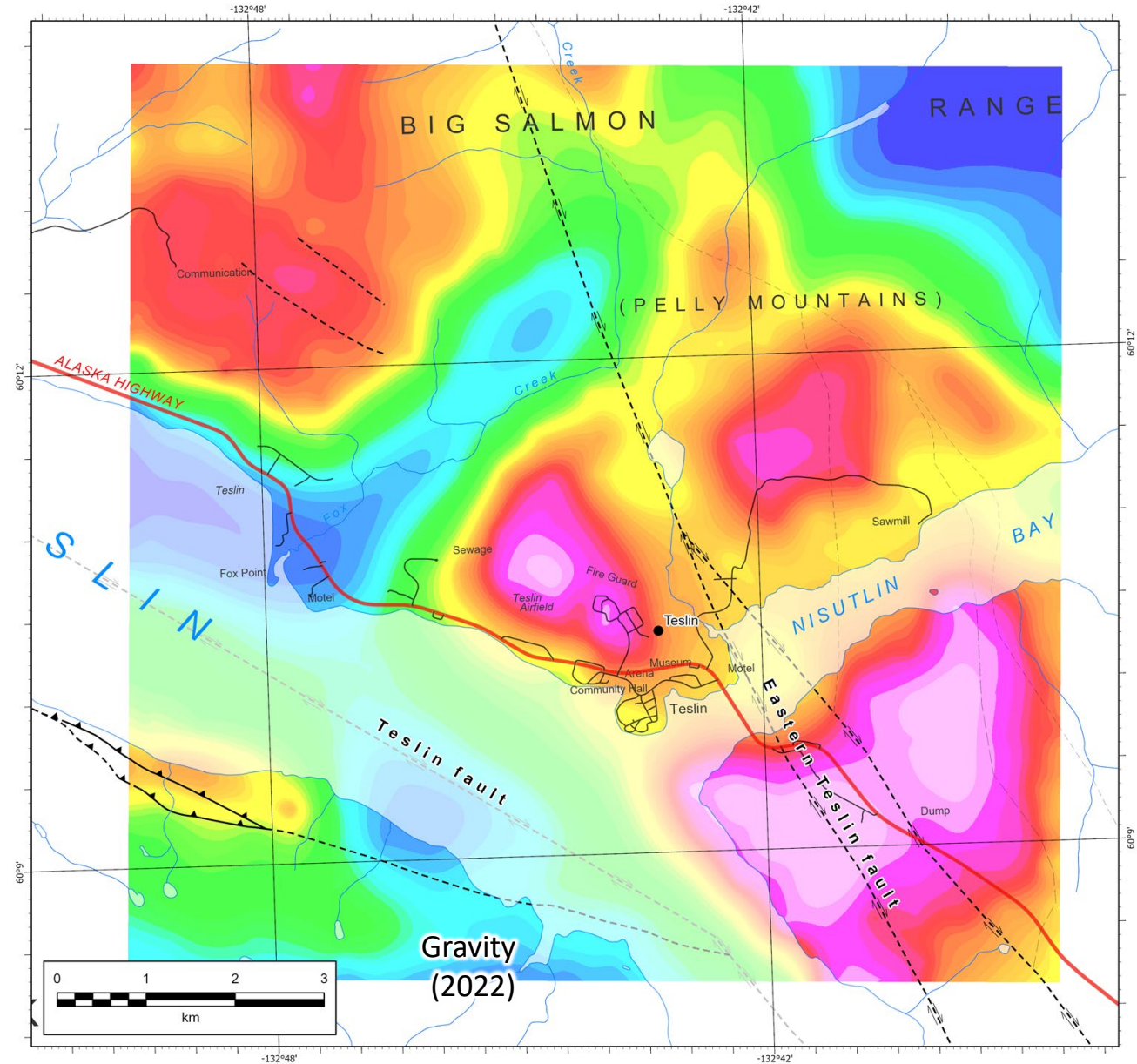
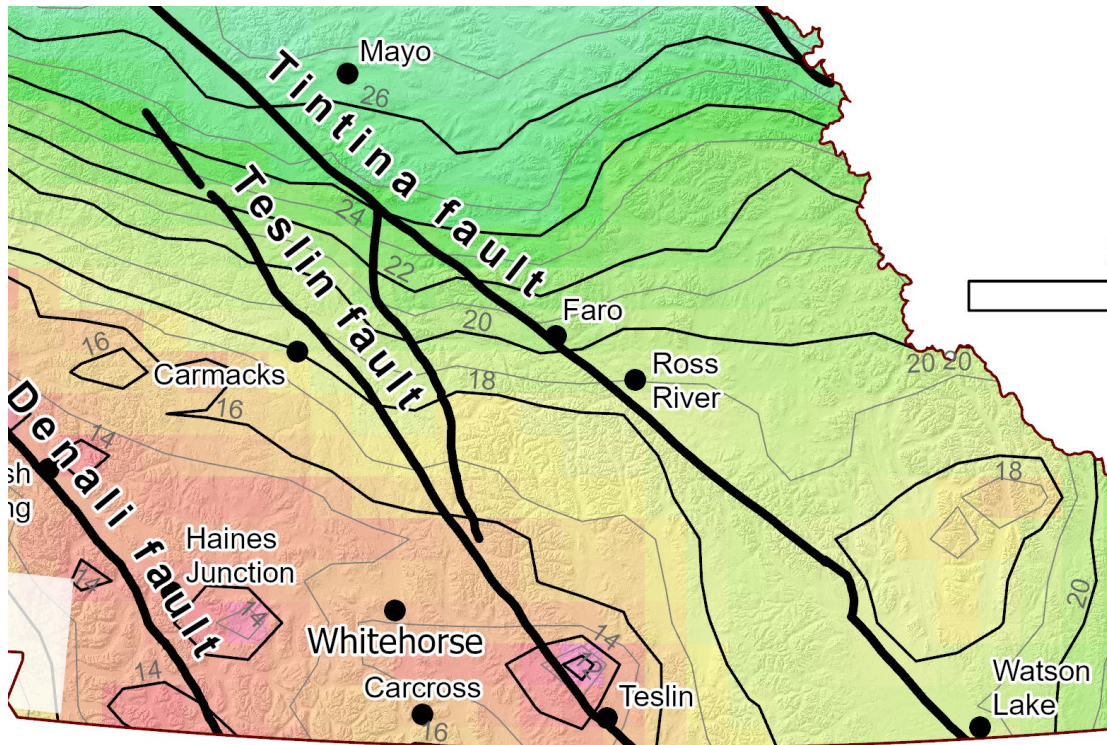
# Watson Lake – Tintina fault

- Possible elevated geothermal gradient (38-50°C/km)
- Gravity and MT modelling suggest up to 1 km of Cenozoic sediments
- Strong MT conductor across the Tintina fault zone
- Basement of sedimentary rocks, most likely containing graphite (shale, phyllite, ± chert?)
- Little indication of permeability in subsurface



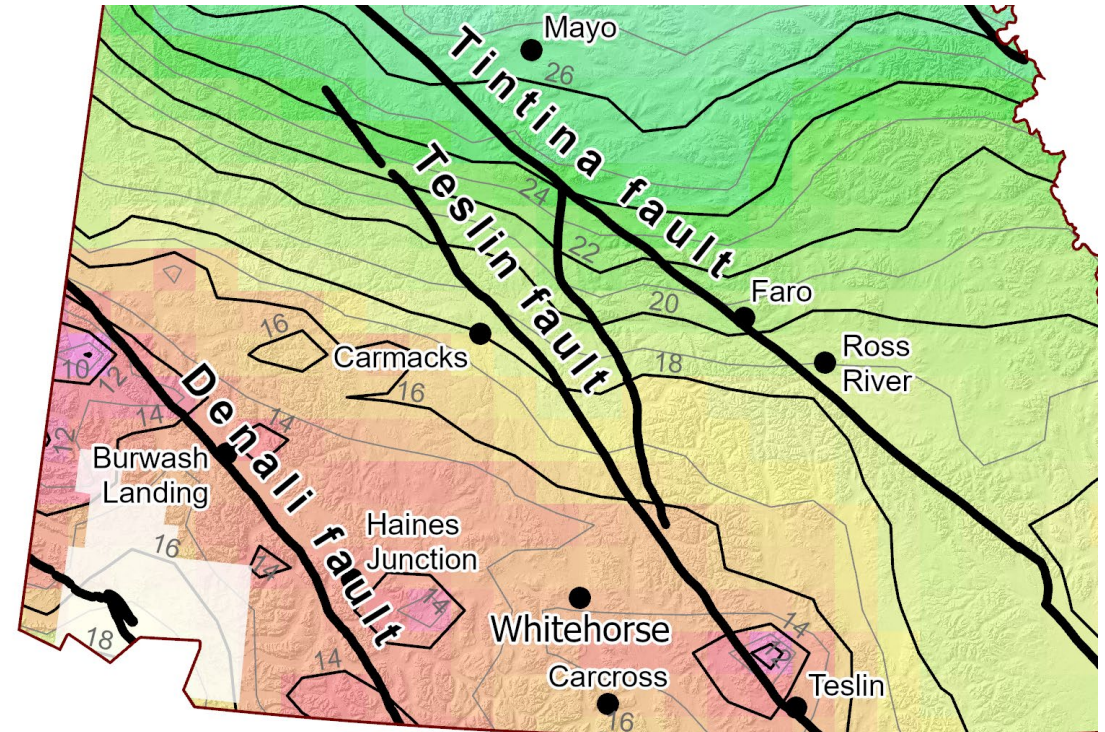
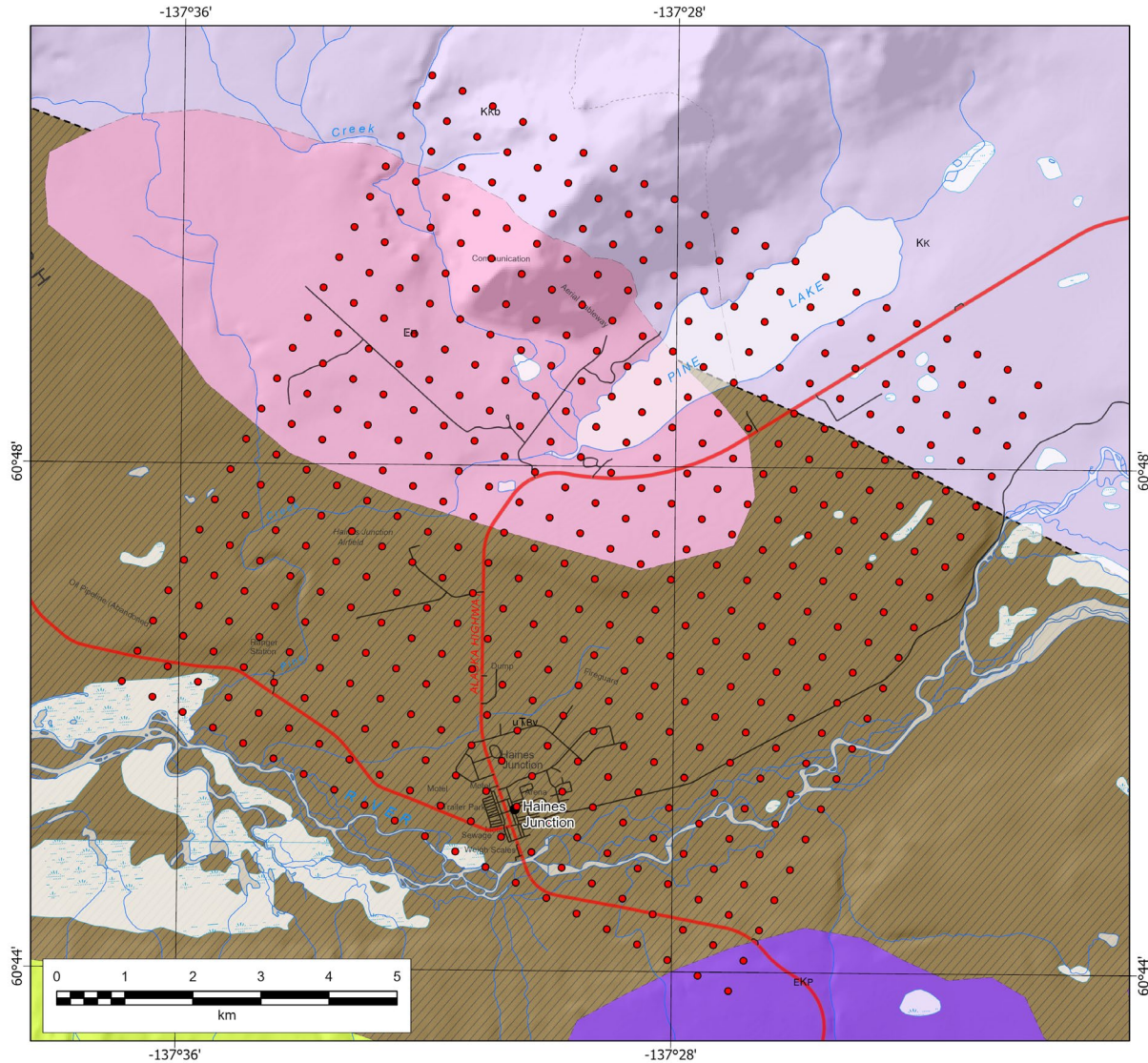
# Teslin

- Shallow CPD near Teslin
- Gravity survey completed in 2022
- AMT acquired in 2022
- Airborne EM planned by GSC (2023)
- Modelling of gravity/AMT in progress



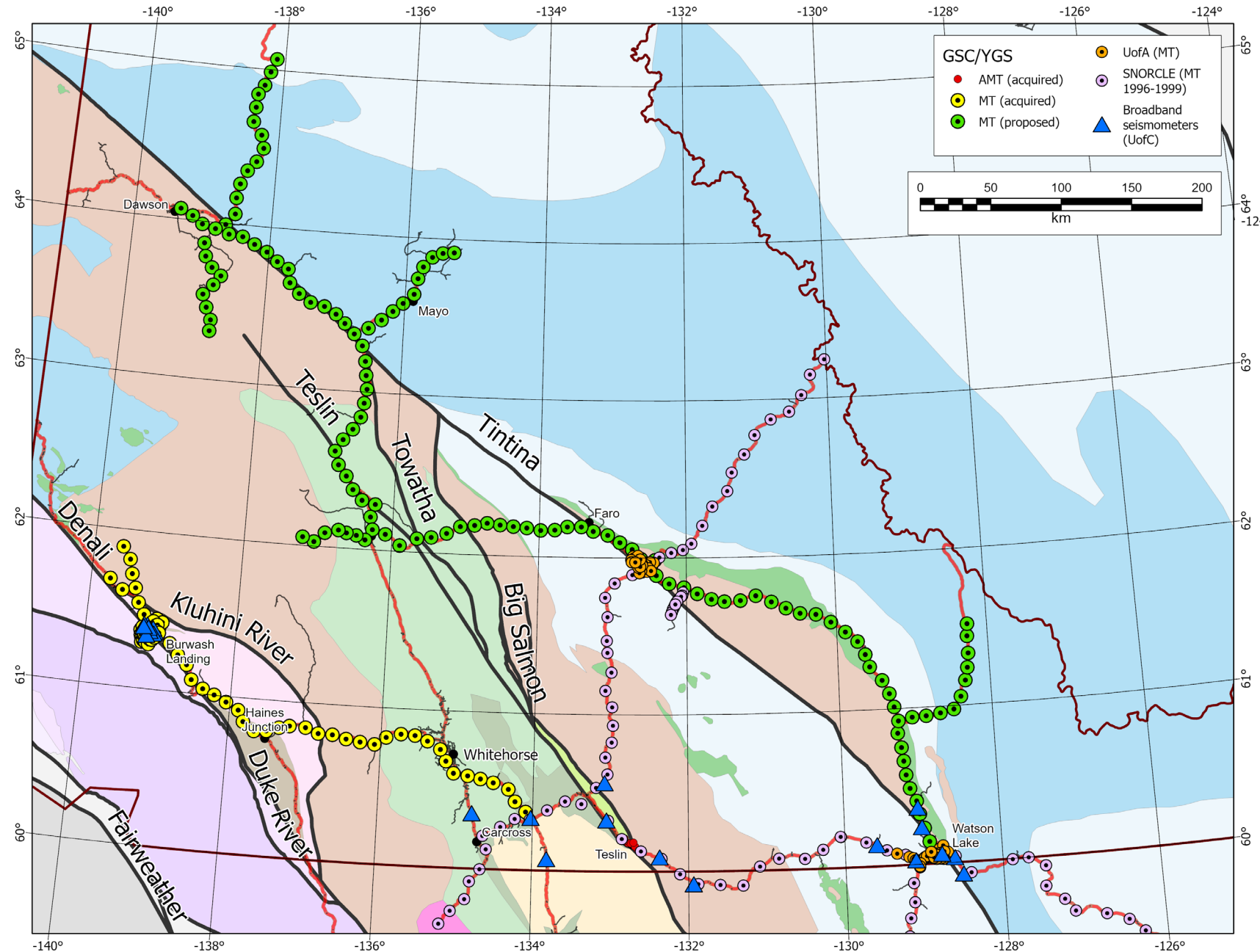
# Haines Junction

- Warm water in town wells (up to 20°C)
- Engaging with Champagne Aishihik First Nation and the Village of Haines Junction
- Gravity survey starting next week...



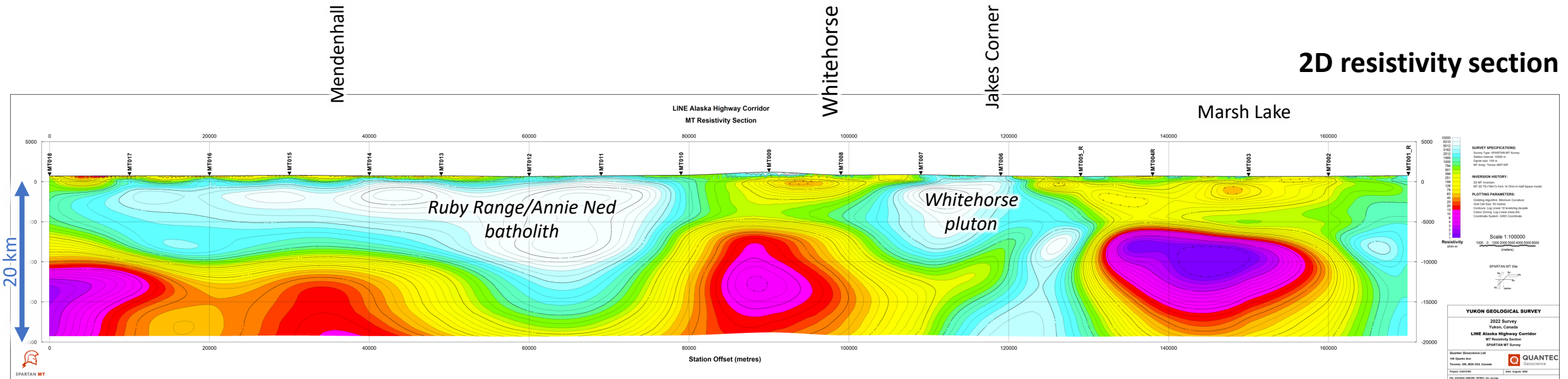
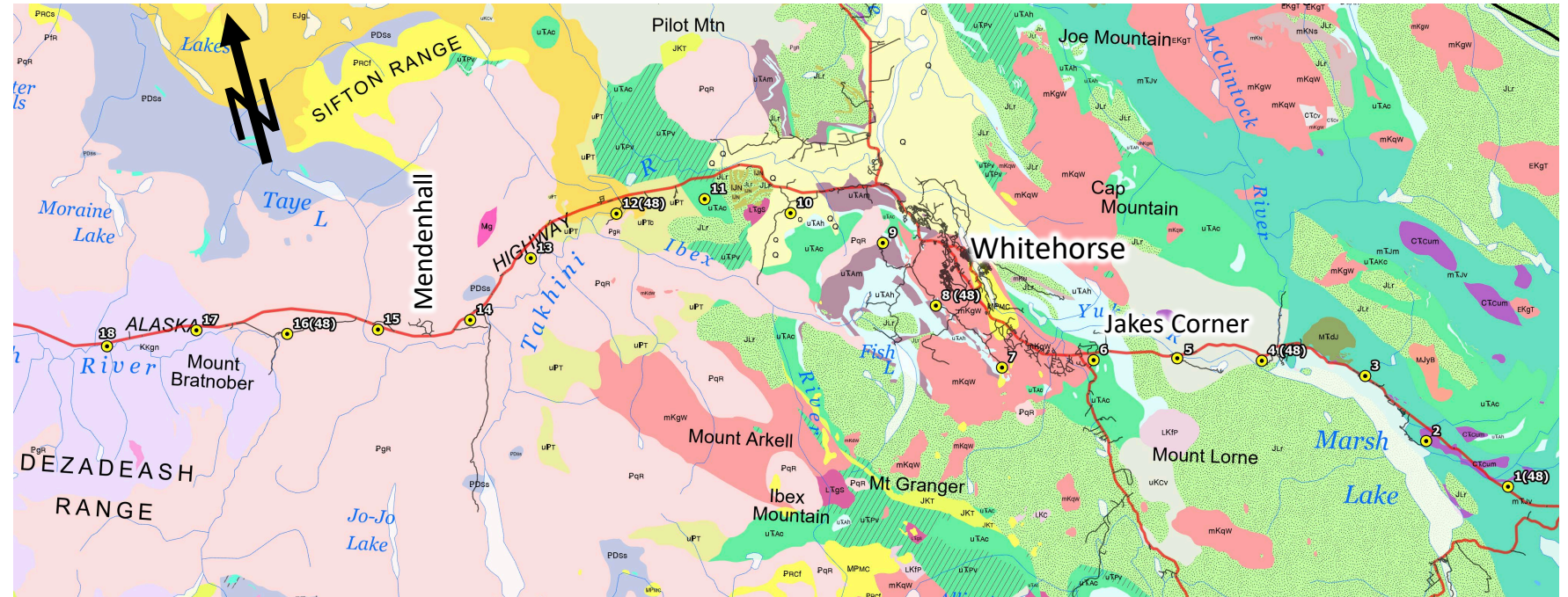
# Regional surveys

- Regional MT transects along highways (10 km spacing)
- Complement SNORCLE (or SNORE)
- Kluane Lake to Marsh Lake acquired in 2021-22
- GEM-GeoNorth funding (GSC)
  
- >20 broadband seismometers across southern Yukon over 3 years
- Denser deployment focused on drill site near Burwash Landing for 2021-22
- Jan Dettmer & Hersh Gilbert (U of C)



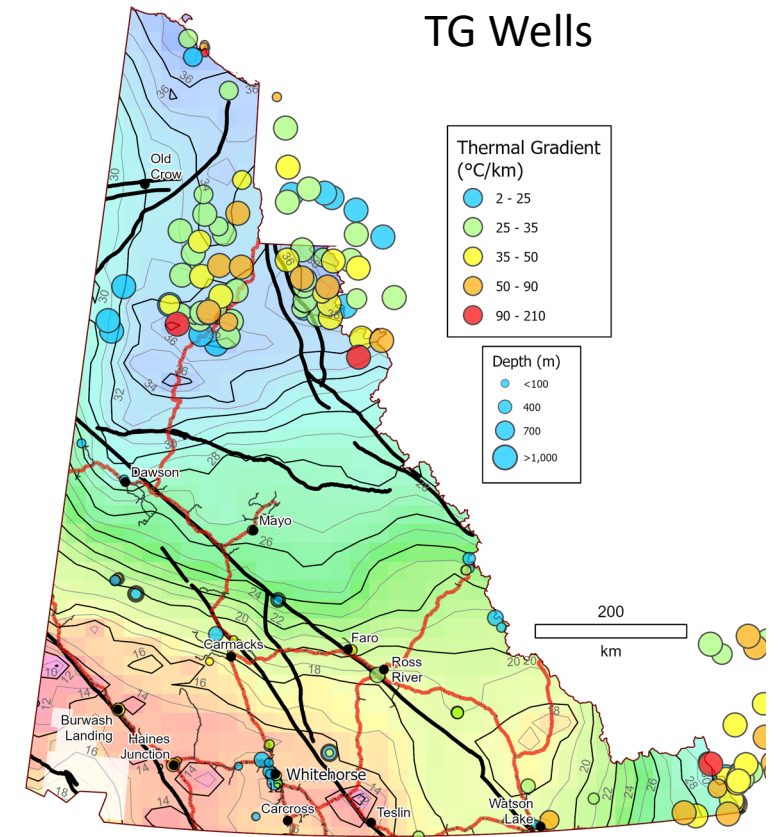
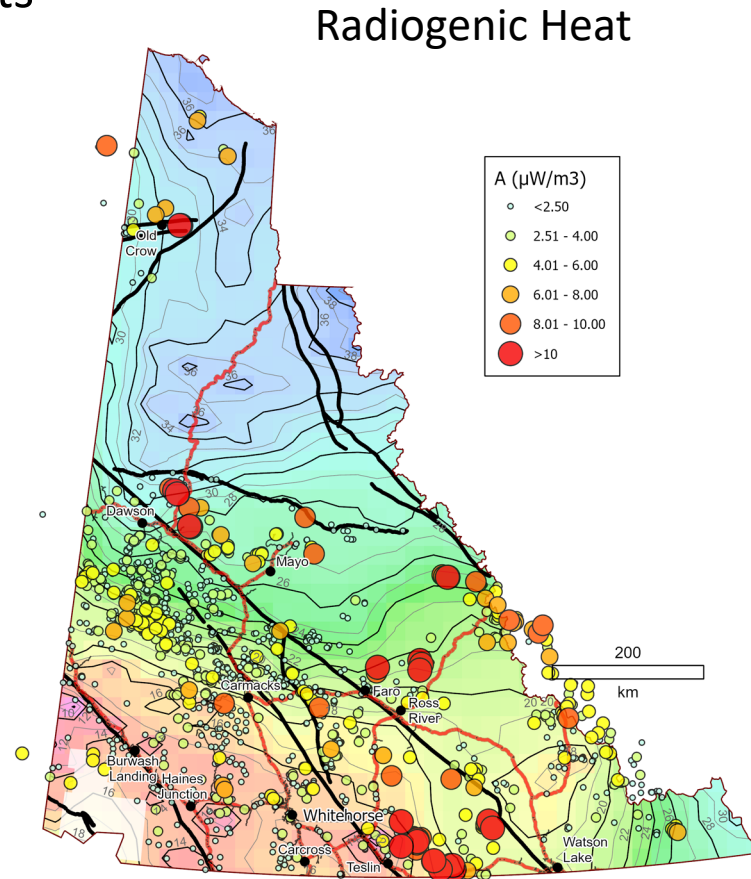
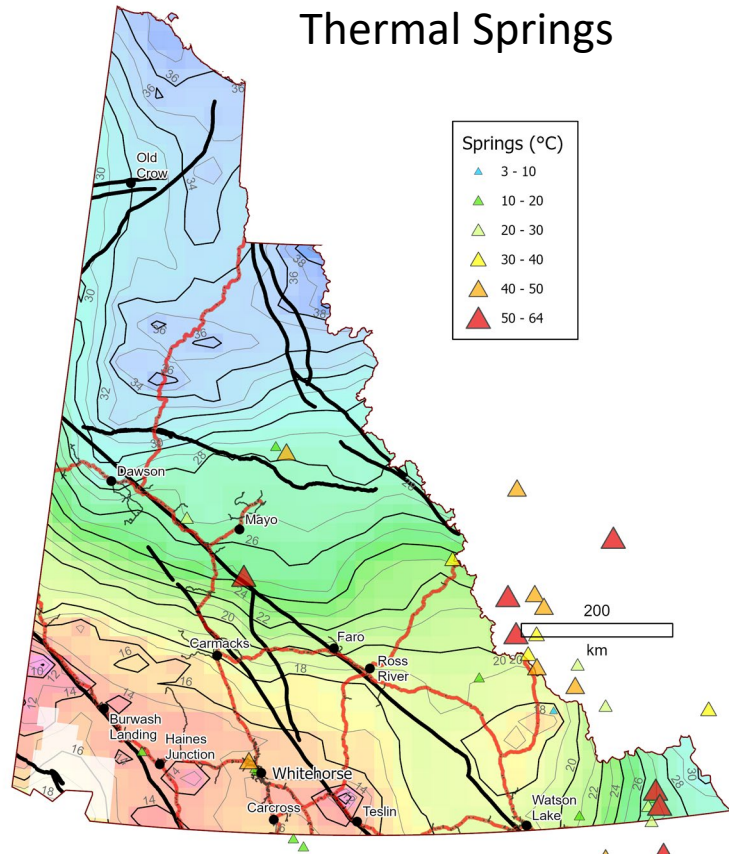
# Regional surveys

- Regional MT transects along Alaska Highway (2022)
- See Rob Gordon's talk



# Geothermal data compilation

- Compilation of thermal and water chemistry data from existing wells and springs
- Includes previously unpublished reports from studies commissioned by YEC

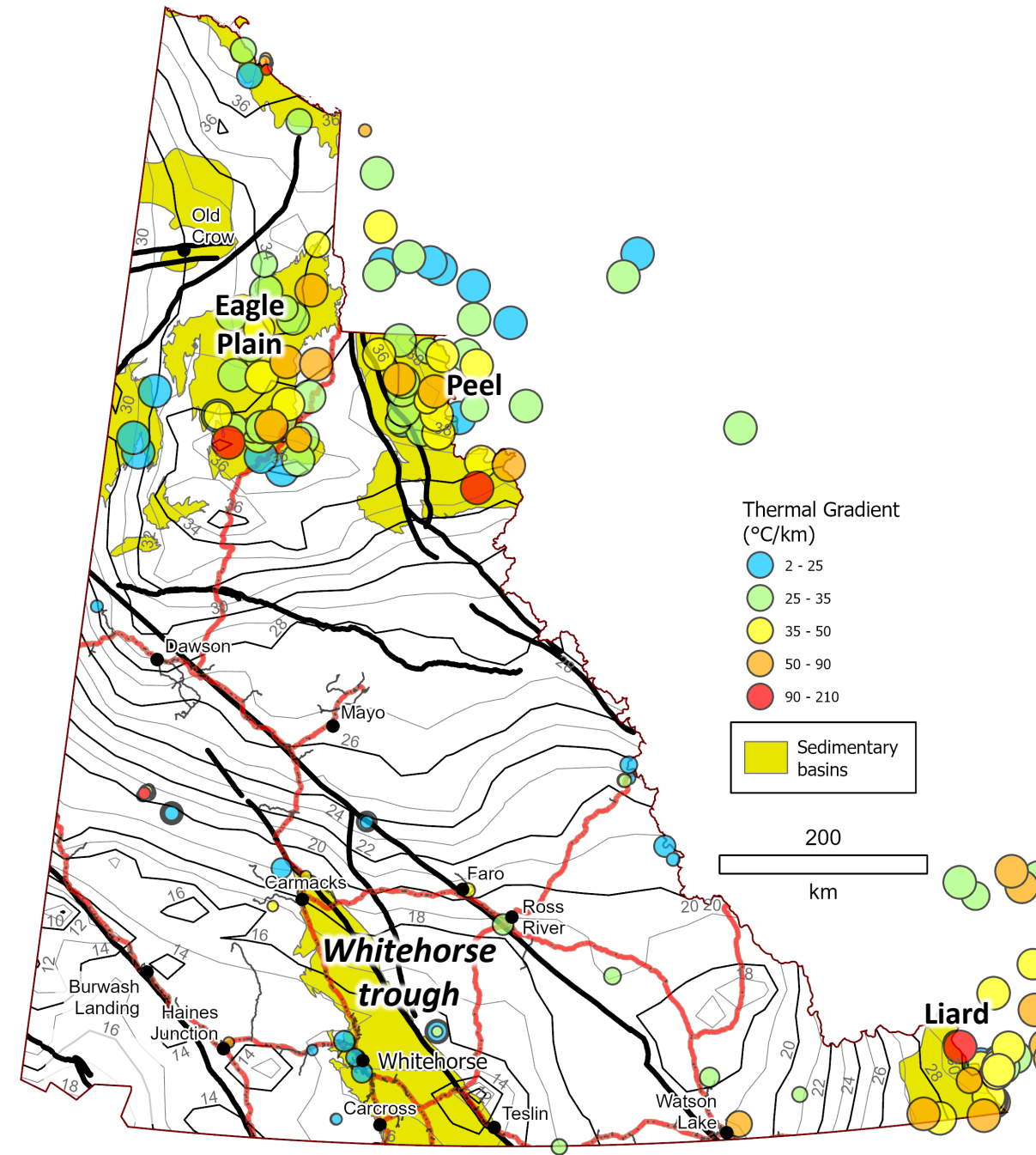
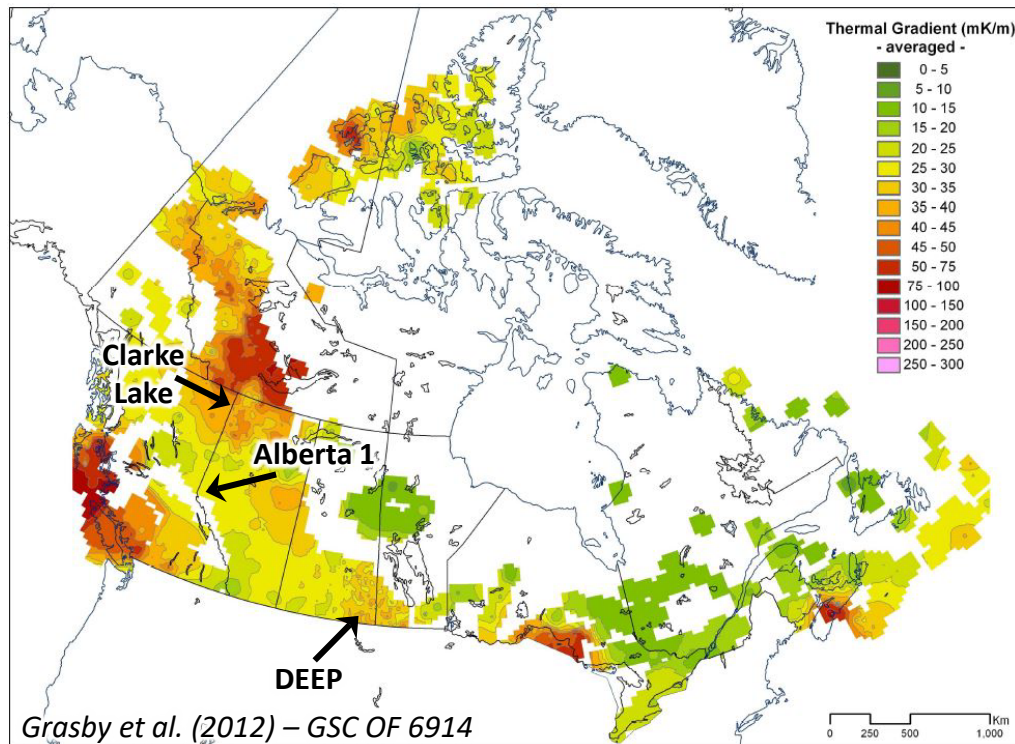


Background:  
CPD map of Li et al. (2017)

- Web Map under development

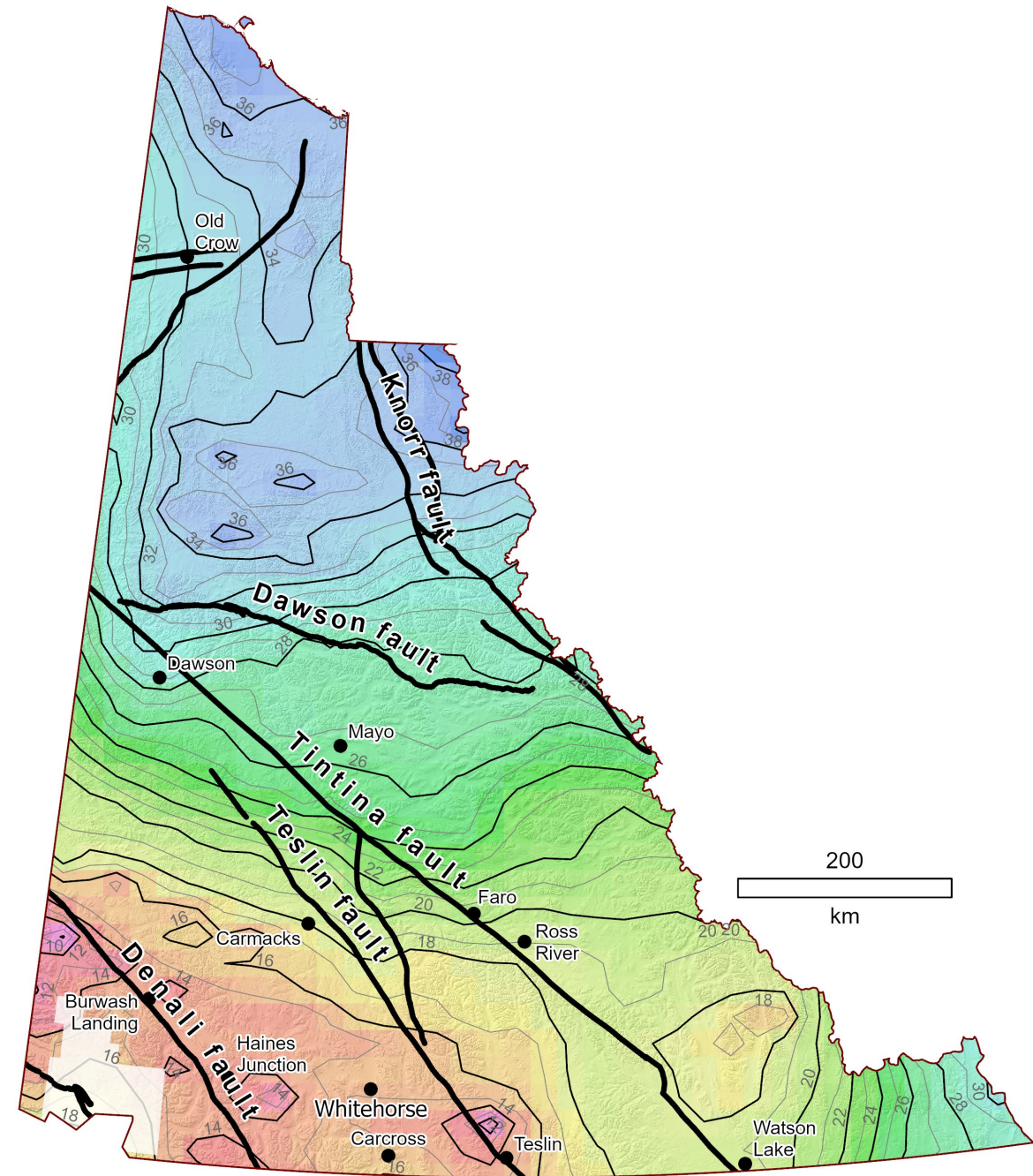
# Conclusions and Forward-looking statements

- Elevated thermal gradient in sedimentary basins (Eagle Plain, Peel, Liard) despite greater CPD
- Hot sedimentary aquifer systems (HSA)
- Most advanced geothermal projects in Canada are HSA
- Whitehorse trough remains untested



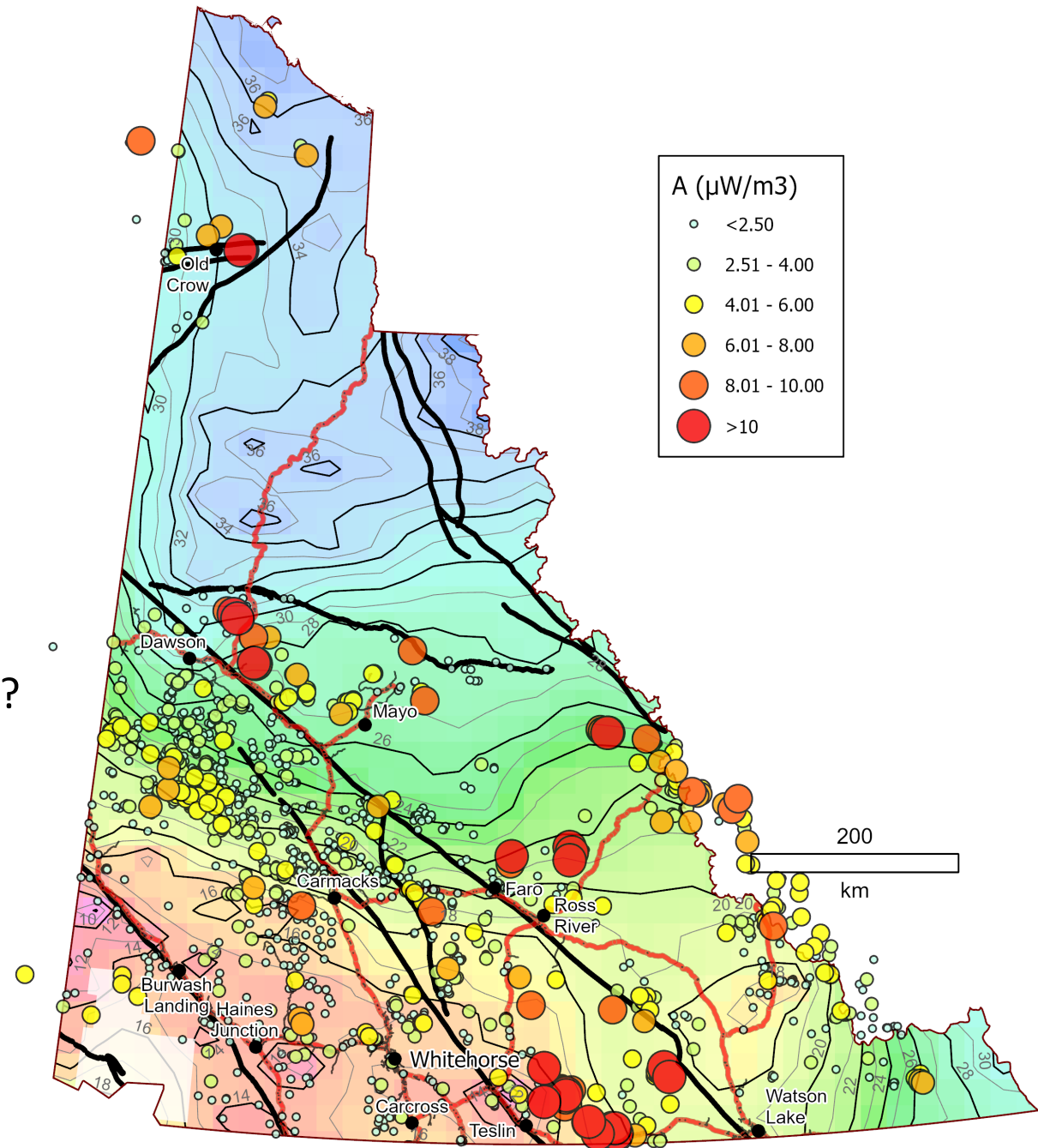
# Conclusions and Forward-looking statements

- Currently evaluating potential along major fault zones
- Studies on Denali fault are most advanced
- Interpretations of Tintina and Teslin faults in progress
- Final reporting planned for 2024



# Conclusions and Forward-looking statements

- Currently evaluating potential along major fault zones
- Studies on Denali fault are most advanced
- Interpretations of Tintina and Teslin faults in progress
- Final reporting planned for 2024
  
- Future research:
  - Continue evaluation of radiogenic heat potential
  - Potential of Late Cretaceous plutons in Mayo area?
  - Source of warm springs in Whitehorse area
  - Any potential in Carcross-Tagish region?
  
- **YGS objective:**
  - **Generate an improved heat flow map for Yukon**



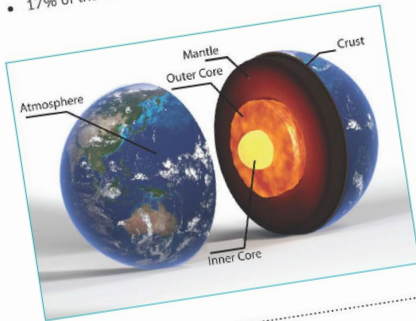
## Exploring Geothermal: What is geothermal energy?

Geothermal energy is the heat (thermal energy) that is generated and stored in the Earth.

### Where does the heat come from?

The Earth is composed of several layers, with each of these layers becoming hotter with depth, or as you move toward the centre of the Earth. They consist of the solid inner core, the liquid outer core, the mantle (includes partially melted rock known as magma) and the outer rigid crust. Heat is continuously produced in the earth by the slow decay of naturally occurring radioactive elements that are mainly found in rocks of the Earth's crust.

- 83% of the heat is generated by natural radioactive decay of uranium, thorium and potassium in the crust.
- 17% of the heat comes from mantle cooling.



FOR MORE INFORMATION, PLEASE CONTACT:  
Yukon Geological Survey at [geology@yukon.ca](mailto:geology@yukon.ca)

YGS Educational Series  
Published: May 2022



Image: Toronto Star

### Where on Earth do we find geothermal energy?

Because the temperature of the Earth increases with depth, geothermal energy is found everywhere deep in the ground. The rate of change of temperature with depth is known as the **geothermal gradient**. The average geothermal gradient is 25°C/km, but locally, can be much higher depending on the geological setting of an area. In areas with an unusually high geothermal gradient, geothermal energy development may be economical.

### How does geothermal heat get closer to the surface?

Most geothermal heat is generated several kilometres below the surface. The Earth's crust is actually broken into several large pieces known as tectonic plates. These plates are in constant motion – drifting apart or coming together at a very slow rate of just a few centimetres per year. The boundaries of major plates may be highly active with volcanoes and earthquakes. The most famous of these is known as the "Pacific Ring of Fire" which rims the Pacific Ocean. In these zones, heat is brought to the surface by volcanoes, or via large cracks in the Earth's crust (known as faults). When this near-surface heat is transferred to water, a usable form of geothermal energy is created.

# Geothermal Energy in Yukon

- Interest in geothermal development is strong among Yukoners
- Research to date suggests the potential for district heating is good; power generation may locally be possible
- Yukon government is developing legislation to regulate geothermal resources

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