Geothermal studies in Yukon– a collaborative effort to understand ground temperature in the Canadian North

Tiffani A. Fraser, Stephen E. Grasby, Jeffrey B. Witter, Maurice Colpron, Carolyn Relf
Outline

• Yukon Territory basics
• Geological setting
• Current project
  • 3 desktop studies
  • 2 temperature gradient wells
• Successes
Yukon Territory

Yukon River, Whitehorse

Area: 500,000 km²
Population: 36,000
Economy: government exploration/mining tourism
First Nations

Ta’an Kwäch’än Council

Ross River Dena Council
Energy mix

Old Crow, Yukon (photo from Protec Petroleum)

Dam on Yukon River, Whitehorse
Funding

“The Government of Canada is taking action to help reduce reliance on diesel fuel in rural and remote communities.”

Natural Resources Canada

Strategic Initiatives in Northern Economic Development (SINED) program
Geological setting

Western Canada post-terrane accretion ~ E. Mesozoic

Paleogeography by R. Blakey, 2015.
Faults, hotsprings, & young granites

Hot spring location
Paleogene granite
Cretaceous granite
2017-18 drill location
Permafrost

Permafrost Distribution
- 90-100%
- 50-90%
- 10-50%
- 2017-18 drill location
- Hot spring location

CONTINUOUS
- >200m
- 63 m
- 89 m

EXTENSIVE
- 20-60 m
- 135 m
- 16 m

SPORADIC
- 2 m

Hot spring location
- 16 m
- 89 m
- 20-60 m
- >200 m
The project...

• Phase 1: Desktop studies 2016-17
  
  *Curie Depth Point Mapping*
  *Radiogenic heat production*
  *Temp. profiles from historical wells*

• Phase 2: TG Well Drilling 2017-2018
  
  *Whitehorse trough – Takhini well*
  *Tintina trench – Ross River well*
Curie Point Depth (CPD) mapping

- data from public domain aeromagnetic data: NRCan and EMAG2 in Li et al., (2017)
- shallower CPD in southcentral and southwest Yukon associated with accreted terranes
- deeper CPD in north and southeast, associated with North American craton
- inferred high heat flow along Denali Fault

Depth to Curie Point (580° C) in kilometres (after Witter et al., 2018)
Radiogenic heat production

• focus on Cretaceous and Paleogene granitoids
• geochem from YGS databases
• Rybach (1981) calculation using U, Th, K
• many values higher than an average granite
• higher values associated with Cretaceous as opposed to younger plutons

Average granite: ~2.6 µW/m³

Temperature profiles from historical exploration wells

- collected from 108 wells from 23 former exploration programs
- data collected as part of Canada Geothermal Energy Program between 1976 and 1986*
- depth range from 9 – 793 m
- geothermal gradients range from 4 – 70°C/km, with the highest reliable near Faro and Burwash (40 and 44 °C/km)

* One data point from EBA Engineering (2013)
Temperature inversion

- commonly observe a thermal inversion (decreasing temperature with depth) 10-100 m from surface
- related to post-glacial warming
- presence of permafrost allows climate signal to penetrate deeper into ground \( ∴ \) more pronounced as you go north
- important to penetrate through this inversion to get true gradient
Takhini temperature well

- geology, road access, distance to power lines, & population used to delineate drill targets
- 1 chosen from ~ 32 potential spots in Whitehorse trough: Jurassic intermontane sedimentary basin intruded by younger granitoids
Takhini hot springs source = 46° C at surface.
Annual Hair Freezing Contest!

Hypothesis: radiogenic heating of meteoric water in permeable carbonate host rock?
Takhini well

• Fall 2017- Fall 2018: permitting, contracting etc.
• Fall 2018: 500 m RC and diamond drill well on Ta’an Kwach’an titled land
• target near hot springs (46°C surface water temperature), thermal anomalies in nearby well water, granitic intrusions (6µW/m³) and road accessible
• used local Yukon and First Nation contractors
• installed thermistor string with 16 nodes
• lithology dominantly sandstone, shale and tuff; logging and rock property in progress
Observations

- temps stabilized after 3 months
- no permafrost
- top <10 m influenced by seasonal temperature fluctuations
- temperature inversion to ~50 m
- steepening of gradient at ~300m
- vertical gradient 400 - 450m
- marked temperature increase from 13 to 25 °C between 450 and 500m
Interpretation

- 16.5°C/km gradient between 50-450 m; lower than the average upper crust and lower than the Curie Point model of 39°C/km
- possible aquifer between 450-500m
- fault and warm water at 500m?
- several possibilities below 500 m....
- detailed logging and rock property data still pending
- deeper drilling required!
Ross River temperature well

• testing a model of meteoric water circulation in Tintina Trench: a deep crustal fault zone

• drill target chosen from 10 identified by a 2014 technical study (Mira Geoscience, Univ. Nevada Reno, Univ. Alberta...) for the Kaska First Nation

• target at fault zone intersection; possible igneous body nearby

*Geological mapping by Nicholas Hinz, Seth Dee, and Jeff Witter, 2015.*
Ross River well

• Fall 2017 – winter 2018 permitting, gaining site access, contracting
• winter 2018 RC and diamond drilled to 500m (target was 600m)
• using Yukon and First Nation contractors
• thermistor string with nodes at 20 m intervals
• challenging drilling conditions – thick surficial and faulted rock; cold weather!
• encountered 207 m Cenozoic unconsolidated sediments, overlying 290 m ?Mesozoic/?Paleozoic sediments
Observations

- temps stabilized after 5 weeks; some fluctuation in the 50 – 140 m range
- permafrost 20 m to 40 m+
- temperature inversion to ~40 m
- below 140 m linear TG of 31°C/km; consistent with CPD mapping
- linear gradient suggesting consistent rock properties with no intervals of hot fluids
- detailed logging and rock property data pending
Program successes

- desktop studies were inexpensive yet instrumental in choosing TG drill sites
- publicly available data (e.g. aeromag, geochemistry, bedrock maps) are free and can provide regional information about ground temperature and heat flow
- Successful First Nation collaboration
- two new wells in Yukon drilled specifically to measure ground temperature and to advance geothermal research
- core data available for rock property and other studies
- encouraging drill results providing rationale to continue program
- publicly visible program that is gaining attention
Partners & Funding

Yukon Geological Survey (project lead & management; technical)
Geological Survey of Canada (technical)
Innovate Geothermal (technical consultant)
Ross River Dena Council & Dena Nezziddi Corp (local knowledge & expertise)
Ta’an Kwach’an First Nation & Dadaghay Dev. Corp (Cat A land access & contracting)
University of Alberta (rock property studies)
Canadian Northern Economic Development Agency (CANor)
Strategic Investments in Northern Economic Development (SINED)