Geoscience BC

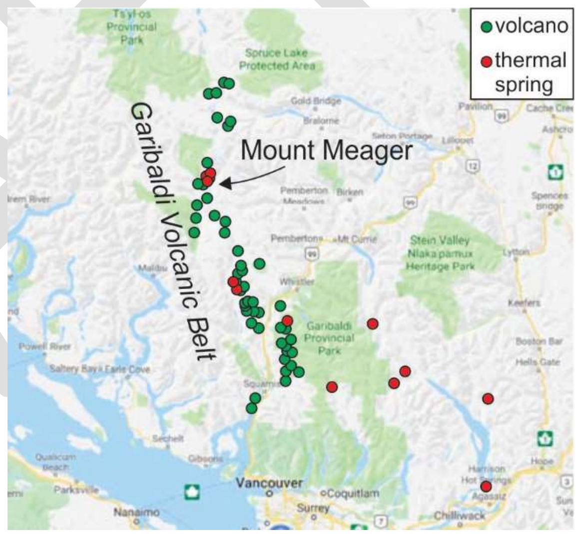
CANADA 1842 GEOLOGICAL SURVEY - COMMISSION GÉOLOGIQUE

Draft Project Outline – February 2019

Geothermal Resource Potential of the Garibaldi Volcanic Belt

Summary

There is growing policy demand to shift the Canadian economy to one supported by renewable energy resources. Geothermal energy has numerous advantages compared to other renewables, namely in its low environmental footprint and ability to provide a stable baseload-power supply without the need of energy storage solutions. However, these advantages are countered by much greater exploration risk related to finding hot aquifers in the deep subsurface. The previous NRCan Geothermal Energy Program (1975-85) provided essential insight into the thermal regime of Canada, including highlighting some of the highest temperature systems related to hot sedimentary basins (found in NWT, Yukon, BC, Alberta, Saskatchewan, Quebec) as well as volcanic belts (Yukon and BC). This work though lacked some of the essential geoscience required to find productive geothermal aquifers.



The Garibaldi Volcanic Belt represents a chain of young (less than 11,000 years old) volcanoes in southwestern British Columbia, in a region also known to have abundant thermal springs. In the 1980's NRCan, along with BC Hydro, conducted initial exploration drilling at one of the volcanoes, Mount Meager. These results defined geothermal fluids with temperatures greater than 250 °C, the highest temperature geothermal resources in the Canada. While this will produce electricity, the fluid production rate was not sufficient to justify the cost of the 60 km of new transition lines required to reach the site (power generation is a function of both temperature of the fluid and the rate that at which the fluid can be produced to surface). A key outcome of this research project was that while a world class thermal resource was found, the geologic conditions required to make it economical were not. Lack of knowledge of the regional controls on the rock property called permeability, a key controlling factor for the rate at which fluids can move through rock to the well bore, poses a significant exploration risk for industry exploration in the region despite the known world class thermal resource.

A new project will focus on reducing the exploration risk in one of the highest potential geothermal regions of Canada. With funding from NRCan (REED and GSC) along with *Geoscience BC* the project will work with academic partners to apply a range of geoscience tools, including remote sensing, geophysics, tectonics, volcanology, and geochemistry, to better understand the controls on rock permeability (putting the *geo* back into geothermal). The project will take knowledge from the Mount Meager research to apply to the overall Garibaldi belt, whilst developing new predictive tools for finding permeable aquifers at depth. Results will also be used to aid development of new resource models, creating greater certainty in national geothermal resource assessments. Consultation with local Indigenous groups will define final project boundaries and objectives.

Objectives

The overriding project objective is to reduce exploration risk by increasing our knowledge on what controls the occurrence of permeable zones at depth in the Garibaldi Belt. The project will build from the existing knowledge and history of exploration in the Mount Meager area and extrapolate those learnings over the broader region. The current funding profile includes funding from *Geoscience BC* for 2019/20 and then continuation funds from NRCan for three subsequent years. Given this, the first year of the project will focus on significant new data collection through a geophysical/geochemical program in the Mount Meager area supported by *Geoscience BC.* The remaining project years will then focus on data compilation and interpretation assuming no new funding will be available for additional field programs. If additional funding opportunities arise, then additional field programs will allow examination of a broader region of the Garibaldi Belt.

The proposed allocation of *Geoscience BC* funding is to support the 2019 field campaign carried out by the GSC along with collaborators from six academic institutions to address six main tasks as outlined below. Task 1 will be conducted in-house by the GSC and will not be supported by *Geoscience BC* funds.

Task 1 - Documentation of previous work

Significant results and data were collected over the initial research phase at Mount Meager and subsequent industry exploration. These results had been largely confidential, but have recently been made publically available through *Geoscience BC*. While some data has been digitized, data gaps are still identified by the Mount Meager Symposium Report. Retrieval, digitization, and analyses of the remaining pre-existing data will allow a comprehensive data set to set the foundation for which new research will be built on. This access to all available information allows a unique opportunity to synthesis previous work and findings to establish a solid foundation for the rest of the project to build upon. One caveat is that given plans for new geophysical data collection of higher quality than vintage work, there will be no resources expended on retrieval of previous geophysical data.

Task 2 – Magnetotelluric (MT) Geophysical Program (GSC/Carleton University/University of Alberta)

An array of 100 magnetotelluric (MT) stations will be deployed within the Mount Meager area to detect natural magnetic and electric field variations. MT data are sensitive to changes, both spatial and temporal, in subsurface electrical resistivity which itself is a function of key geothermal reservoir properties such as porosity, permeability and the salinity and temperature of the fluids within the pore spaces. Images, 3D volumes and maps arising from the MT data will be used at Mount Meager to delineate the subsurface variations of these parameters. The MT method is one of the few geophysical techniques able to investigate electrical resistivity a broad range of depths, and therefore it affords a unique opportunity to image permeable zones connecting deeper, hotter fluid sources to the surface.

The technique is also sensitive to lithology and faulting. The controls on the fluid systems and permeability exerted by these import factors can also be detected.

A few MT sites will also be collected outside the Mount Meager zone to fill in small gaps in legacy regional datasets to clarify the role of the modern tectonic environment in the nature and extent of the Mount Meager geothermal zone. Electrical conductivity is highly sensitive to the degree of partial melting, and therefore MT images and maps can also be used to identify crustal magma chambers driving heat and fluids into the local geothermal systems.

MT data will be collected with a combination of ground and helicopter access, and with each site recorded for one or two nights. The combined use of multiple recording systems by the multiple partners will ensure data collection in approximately two to three weeks. The data collected will be analyzed using state of the art 3D modelling techniques that can be constrained and built upon by the complementary geophysical or geological data collected by other tasks in the project. The maps and knowledge derived from the new models will be used in conjunction with these studies to help understand the permeable zones controlling the geothermal system in the Mount Meager area.

Task 3 – Passive Seismic Geophysical Program (University of Calgary)

A dense array of 50 nodal seismic stations will be deployed within a region of 25 by 25 km surrounding Mount Meager to detect natural Earth noise. This array will continuously monitor ground motion for four to six weeks during the summer of 2019. The signals recorded by the array would include seismic waves from local, regional and teleseismic earthquakes as well as the background ambient noise field that constantly propagates near the earth’s surface. Analyses will exploit information in the earthquake signals and ambient noise to investigate whether a magma chamber can be identified by measuring the velocities of seismic waves propagating through the volcanic system. Additionally, the locations of local seismicity will be used to assess the pattern, and depth extent, of faults across the region that may serve as conduits for hydrothermal circulation. Finally, there is significant potential in joint analysis of seismic and magneto telluric data also being collected at Mount Meager to exploit complementary aspects of data sensitivities. Sensors installed within the zone surrounding Mount Meager, will also allow examination of a portion of the broader Garibaldi Volcanic Belt to gain insight into which role Mount Meager has in the regional tectonic setting.

To complement the dense deployment, three longer-term seismic monitoring stations will also be installed within the study area that will record local, regional and teleseismic earthquakes over two to three years. Recording for this longer interval will help assess any changes in seismicity that accompany changes in the geothermal activity. The 50-station deployment will provide new images of Mount Meager’s structure with detail much beyond current knowledge of the area. While we expect these results to generate new insights into internal workings of an active geothermal system, we anticipate that these initial observations will also highlight where further investigation is warranted. Therefore, we plan to conduct subsequent seismic field studies designed to better resolve specific small-scale features or areas of interest within the volcanic belt.

Task 4 – Gravity Survey

Bouguer gravity is an important complimentary technique to magnetotellurics and seismic tomography, and can also be used to delineate subsurface geological structures through the determination of changes in subsurface material density. Since geothermal sources and paths are often marked by sharp density contrasts, even a simple Bouguer anomaly gravity map can help constrain the shape and size of these sources. Given the small size of relative gravity meters (~20 x 20 x 30 cm) and rapid measurement time (~10-15 min per site), gravity surveys can be easily made as part of a comprehensive field deployment. Importantly, recent advances in combined geologically-constrained 3D inversions of MT, seismic and gravity datasets, are enabling significantly more refined interpretations of the subsurface.

Task 5 – Remote sensing/fracture and stress field analysis (GSC/University of Calgary)

To develop predictive models for enhanced understanding of fluid flow at depth, regional characterisation of fracture systems is required along with definition of the regional continental stress fields within the Garibaldi belt. Remote sensing image analyses will be combined with AI to define trends and orientations and densities of lineaments through the study area. Identified lineaments will be ground truthed as part of the geologic and geophysical mapping program to assess if they represent higher permeability fracture systems.

Determination of the regional stress field can be more complex (e.g. Bell and Grasby, 2012), especially in areas of high topographic relief as the free surface cannot be assumed to be flat. Numerous methods exist that include well borehole breakout analyses, bedding slip etc. Collection of regional data will assist in the refinement of the tensile portion of the regional stress field, which would provide insight into preferred fluid flow directions. The current stress system will be studied using geoscience information (magnitude, location and sense of motion) from historical records of earthquakes in the study area and surrounding vicinities, and constrained by deformation patterns and additional geoscience information from previously drilled borehole data.

Task 6 – Geological Mapping (University of British Columbia)

In order to develop an understanding of the nature of fracture systems and their potential influence on bulk rock permeability, fieldwork is required to measure spatial distribution and variability in fracture orientation and fracture density. These results will support the development of hydrogeological models for bulk rock permeability to better characterise potential fluid flow at depth. High-density fracture zones appear to be associated with major fault and deformation belts. Identification and mapping of these zones using all available means (Landsat imagery and regional geophysical data, field observation, earthquake records) at a regional level provide the basis for construction of geothermal resource models. As well, regional mapping of faults and fracture systems will provide new predictive models of preferential orientation of fracture systems. As well, refined age dating will aid definition of the youngest (and hottest) flow units with the greatest heat generation potential; this is critical information for outlining potential "sweet-spots" of geothermal resources.

Mapping will be conducted through a series of helicopter supported fly camps over the summer of 2019 with particular attention to bedrock elements that would contribute to or relate to issues of permeability: such as, fracture sets, faults, lithologic contacts, and bedrock properties. These field results will be enhanced by inputs of other project teams working on remote sensing as well as the geophysical programs to create an integrated final product. The geological mapping will constrain, inform and contribute to our knowledge of porosity-permeability distribution in the bedrock geology and the lower levels of the volcanic system. The main product would be used collaboratively to create a preliminary map of permeability distribution.

Task 7 – Thermal Water/gas geochemistry

The occurrence of natural thermal anomalies in the form of thermal springs, and the chemistry of their water, are important exploration tools used by industry. Temperature records from hot springs coupled with water geochemistry provide physical data useful for better understanding heat energy in the deeper, hard-to-sample intervals and for critical physical properties of host rock. Thermal dynamic modelling can also help understand fluid flow paths as well as depths of steam separation to better constrain the geothermal system. Calculations of aqueous geothermometers also require detailed fluid geochemistry to allow estimation of maximum temperatures of fluids at depth. Gas geochemistry, including noble gases, can also provide insight into the geothermal system. Given this, new data will be collected through site visits of known thermal and mineral springs in the Meager area, along with geochemical sampling and analyses, and thermodynamic modelling of heat-flow in the thermal spring systems.