Geothermal Resource Potential of the Garibaldi Volcanic Belt, Southwestern British Columbia (Part of NTS 092J)

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Introduction

Geothermal energy holds promise to provide a source of clean and renewable energy that can support the transition to an economy with net-zero CO_2 emissions. Compared to other renewables, geothermal energy has the key advantage of providing dispatchable power supply, with one of the highest capacity factors of any energy resource. As such, geothermal can provide baseload power to the grid without need of storage solutions. In addition, geothermal energy can provide a source of low-cost heat to support the dominant energy demand in Canada.

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The benefits of geothermal energy are countered, however, by a much higher exploration risk. It is much easier to determine where it is windy and sunny than it is to find a permeable reservoir of hot fluids at a depth of several kilometres. The Garibaldi volcanic belt (GVB) of southwestern British Columbia (BC) is a case in point. The Geothermal Energy Program (1975–1985) of Natural Resources Canada (NRCan), along with BC Hydro, conducted geothermal exploration in the GVB, on the southern flank of Mount Meager. The results, along with subsequent industry drilling, defined high-temperature geothermal resources (Jessop, 2008; Witter, 2019). Although a world-class thermal resource was discovered, the technical success of the exploration program at Mount Meager was limited by the ability to define a high-permeability reservoir.

To address this issue, the Garibaldi Volcanic Belt geothermal energy project focused on reducing exploration risk in volcanic belts of western Canada, was launched in 2019 by NRCan's Geological Survey of Canada (GSC), in partnership with Simon Fraser University (SFU), The University of British Columbia (UBC), Douglas College (DC), University of Calgary (U of C) and University of Alberta (U of A). A multidisciplinary geoscience field program was initiated in 2019, with a focus on developing novel tools to image zones of high permeability in the subsurface (Grasby et al., 2020). Due to Covid-19 restrictions, a more limited field program was conducted in the summer of 2020, largely focused on the north flank of Mount Meager. This paper reports on the nature of the 2020 field program and the data collected.

Garibaldi Project

The Garibaldi volcanic belt is a chain of volcanoes less than 11 000 years old in southwestern BC. Historical drilling was focused on Mount Meager, as the area experienced the most recent volcanic activity, hosts numerous hot springs that suggest the presence active hydrothermal systems, and has a high heat flow. Drilling defined high-temperature geothermal resources (>250°C). While these temperatures were sufficient to produce electricity, the fluid-production rate was not sufficient to justify the cost of the 60 km of new transmission lines required to reach the site (power generation is a function of both temperature of the fluid and the rate at which the fluid can be produced to surface). Thus, although a world-class thermal resource was found, the geological conditions required to exploit it were not economical. The lack of geoscience information regarding the regional controls on permeability pose a significant drilling risk to subsequent industry exploration in the region (Witter, 2019).

The Garibaldi project seeks to develop a multidisciplinary approach to reduce exploration risk through an integrated geological and geophysical field campaign. Project funding was provided through NRCan (Renewable and Electrical Energy Division and GSC), together with Geoscience BC. The project incorporates a range of geoscience tools, including remote sensing, bedrock mapping, fracture measurements, geochemistry, and magnetotelluric (MT), gravity and passive-seismic surveys. The ultimate project goal is to extrapolate new knowledge gained from Mount Meager to the overall Garibaldi volcanic belt, thereby developing new predictive tools for finding permeable aquifers at depth. Results will also aid development of new geothermal-resource models, creating greater certainty in geothermal-resource assessments and supporting development of effective regulatory environments.

Mount Meager 2020 Field Program

Given issues related to Covid-19, a significantly revised field program was planned in order to limit potential exposure during fieldwork. To this end, no large field camp was established and, instead, daily helicopter flights from Whistler were conducted. Although less efficient, this allowed individual field crews to be placed in the field during the day, then return to town were they stayed in individual hotel rooms. This also allowed thorough cleaning of the helicopter between use by different research groups. The field program did include establishment of remote two-person field camps. The science focus of the 2020 field season was to fill in data gaps along the north flank of Mount Meager, including MT (U of A) and gravity (SFU) surveys (Figure 1). This work was supplemented with new geological mapping (UBC and SFU). An installed fibre-optic distributed-sensing cable deployed on the flank of Mount Meager in 2019 was also retrieved. A new network of temperature loggers was deployed along the south flank of Mount Meager to record variations in ground temperature during the winter. These instruments will be collected and data downloaded during the summer 2021 season.

The spatial gravity measurements, in conjunction with other geophysical methods, are being used to map the magmatic and hydrothermal subsurface features of volcanoes. During the summer of 2020, the gravity team from SFU surveyed 41 new gravity sites with a LaCoste & Romberg spring gravity meter along the north flank of the Mount Meager Volcanic Complex (Figure 1). Of these, 15 sites were located in the Upper Lillooet Regional Park (in the northwestern quadrant of Figure 1) and the remainder in adjacent areas in order to improve on the 2019 coverage of the spatial mapping of the Mount Meager Volcanic Complex. The gravity data will aid investigation of the deep magmatic structures (depth >10 km) by comparing data from distal stations with data from the proximal dense network of stations. The measured Bouguer gravity anomalies will be analyzed via an informed inverse-modelling approach, which combines information from geological and structural mapping, and MT and seismic measurements. This will restrict the number of possible solutions for the inversion and ensure that the results best reflect plausible subsurface geological features.

Collection of magnetotelluric (MT) data was also aimed at expanding the 2019 coverage around the north flank of Mount Meager. When combined with recently developed 3-D inversion techniques, a fully 3-D subsurface resistivity model will be developed from the combined data. In total, 12 new MT measurements were taken by the University of Alberta MT group, who are conducting a deeper focused MT survey designed to image pathways that carry fluids to the geothermal reservoir and the fumaroles on Job Glacier.

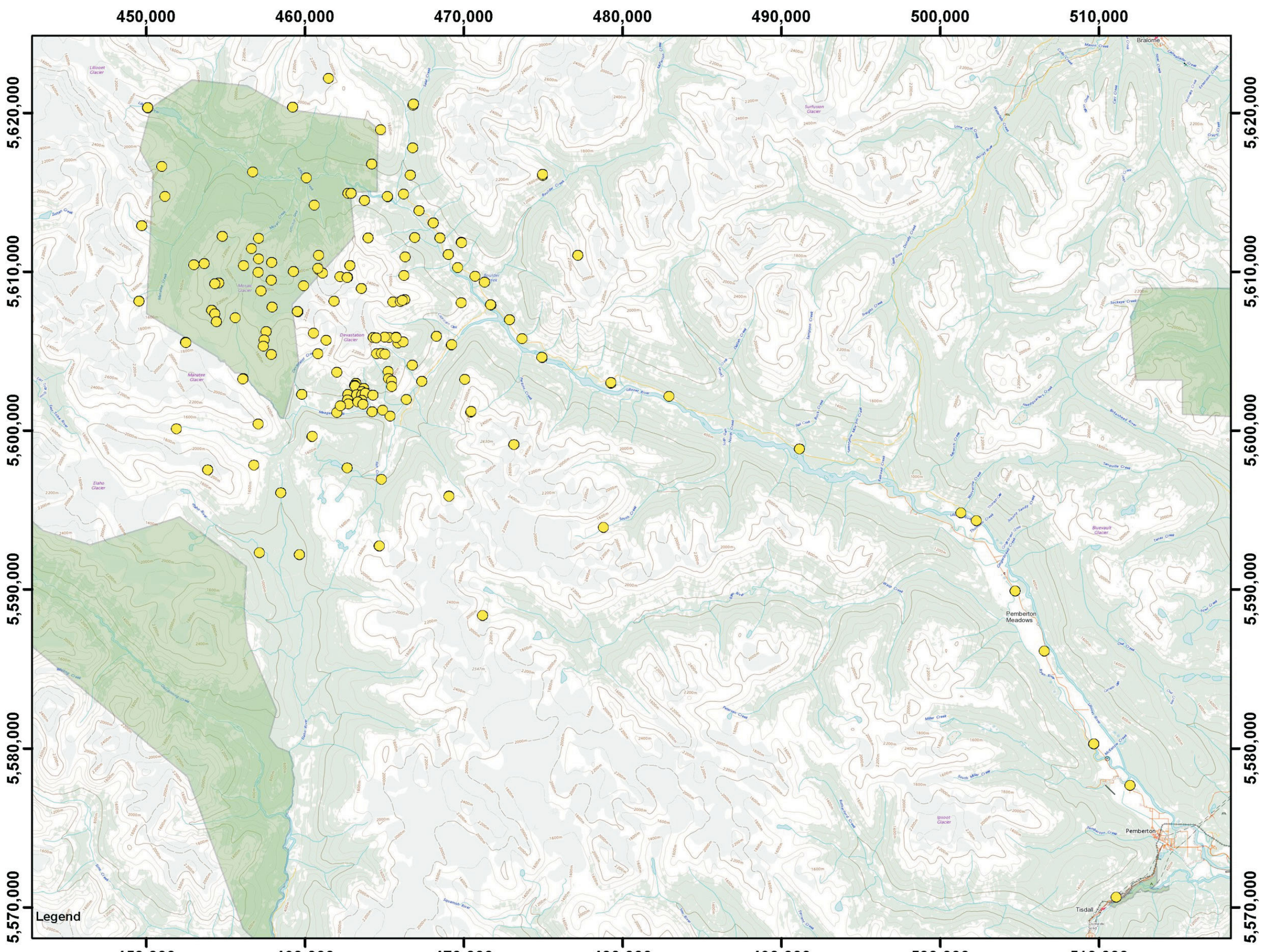

Figure 1. Location of geophysical measurements taken during the 2019 and 2020 field seasons of the Mount Meager field program. Base map from Natural Resources Canada.

These deep MT measurements will also define the size and content of any magma bodies beneath the volcano.

Detailed bedrock mapping was conducted to enhance understanding of the nature of the spatial distribution of volcanic rocks that form the Mount Meager Volcanic Complex. Field mapping included recording rock-property observations, with a particular focus on rock types with enhanced reservoir properties (Figure 2). The resultant geological maps and observations will support the development of hydrogeological models for bulk-rock permeability to better characterize potential fluid flow at depth.

In order to test potential preferential heat flow associated with fracture systems, a series of temperature-data recorders was also deployed in a grid along the south flank of Mount Meager. Each of these includes one sensor on the ground surface and one buried at a depth of ~15 cm. It is hoped that the data recorded through the winter beneath snow cover will reveal localized areas of higher heat flux.

Figure 2. Field researcher A. Calahorrano-Di Patre conducting gravity measurements on Mount Meager

Conclusions

Despite the challenges and limitations imposed by Covid-19, the summer 2020 field program was still a success. Key science goals of retrieving instruments deployed in 2019 and filling in data gaps along the north flank of Mount Meager were achieved. These data are still being processed and will be incorporated into projects of three postdoctoral fellows, six Ph.D. students and one M.Sc. student. Final results will be integrated into a new 3-D model of the geothermal and volcanic plumbing of the Mount Meager complex. Results will provide novel new methods to help predict the occurrence of permeability at depth and greatly reduce the risk associated with drilling for geothermal reservoirs in volcanic systems of British Columbia.

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